KERALA VETERINARY & ANIMAL SCIENCES UNIVERSITY

SECOND PROFESSIONAL YEAR

ANIMAL NUTRITION

(3+1)

TEACHING NOTES

COMPILED BY: ABHIJITH S P

KERALA VETERINARY AND ANIMAL SCIENCES UNIVERSITY
COLLEGE OF VETERINARY AND ANIMAL SCIENCES MANNUTHY
DEPARTMENT OF ANIMAL NUTRITION
CVAS, POOKODE

Title of Course : Principles of Animal Nutrition and Feed Technology
Unit No. : 1
Credit Hours : 3 + 1

Compiled by

Dr. Biju Chacko
Dr. S. Senthil Murugan
Dr. Surej Joseph Bunglavan
Dr. Jincy. V. S

Reference books

1. Animal Nutrition : Maynard L. A., Loosli, J. K., Hintz, H.F. and Warner, R. G (7th edi)

2. Animal Nutrition : McDonald P., Greenhalgh, J. F. D., Morgan, C. A., Edwards, R Liam Sinclair, L . and Wilkinson, R (7th edi)

3. Animal Nutrition : Banerjee G. C.

4. Principles of Animal Nutrition and Feed Technology : D.V. Reddy

Title of the course: **Principles of Animal Nutrition and Feed Technology**

Unit No.: 1 **Credit Hours: 3 + 1**

Sl no	Theory
1	History of Animal Nutrition, common terms and definitions, importance of nutrients in animal health and production
2	Composition of animal body & plants, Proximate analysis
3	Water- functions, source, estimation, importance of water balance in animal body, requirement
4	Carbohydrates- classification, functions, estimation
5	Digestion in non ruminants and ruminants
6	Protein: classification; Amino acids: classification, functions, estimation
7	Digestion in non ruminants and ruminants
8	Lipids: classification; Fatty acids: classifications, functions, estimation
9	Digestion in non ruminants and ruminants
10	Vitamins: classification; Vitamin A: functions, deficiency, source, requirements
11	Vitamin D, E and K: functions, deficiency, source, requirements
12	B complex vitamins and vitamin C: functions, deficiency, source
13	Minerals: classification; Calcium and Phosphorus: functions, deficiency conditions, source and supplements, requirements
14	Magnesium, Sodium, Potassium, Chlorine and Sulphur: functions, deficiency
15	Trace elements: functions, deficiency, sources
16	Toxic elements and organic minerals
17	Processing of inferior quality roughage: physical, chemical and biological methods
18	Methods of forage preservation: Silage making, characteristics of good quality silage, losses in silage making
19	Hay making: steps, losses during hay making
20	Harmful natural constituents and common adulterants of feeds and fodders
21	Feed additives
22	Measures of food energy: Gross Energy, Digestibe Energy, Total Digestible Nutrients, Nutritive Ratio
23	Metabolisable Energy: factors affecting metabolisable value of feed; Net energy
24	Heat increment, Starch Equivalent
25	Direct and Indirect Calorimetry
26	Protein evaluation of feeds: Crude Protein, True Protein, Digestible Crude Protein; Measures of protein quality for non ruminants: Protein efficiency ratio, Biological value, Net protein utilization, Chemical score, Microbiological and chemical methods
27	Measures of protein quality for ruminants: protein equivalents, Rumen degradable and undegradable dietary protein
	Practical
1	Identification of feed and fodders
2	Identification of starch granules
3	Preparation and processing of samples for chemical analysis
4	Estimation of moisture
5	Estimation of total ash
6	Estimation of acid insoluble ash
7	Estimation of calcium in feeds
8	Estimation of phosphorus in feeds
9	Estimation of crude protein, ether extract and crude fibre: -demonstration
10	Detergent method for forage analysis:- demonstration
11	Detection of HCN in fodders
12	Laboratory ensiling of green fodder:- demonstration

HISTORY OF ANIMAL NUTRITION

Hippocrates: Observed that children produce more heat and they require more food.

Sanctorius: He weighed himself on a balance before and after eating food, to find out what happened to the food.

Antoine Lavoisier: The great French chemist is referred to as the ***Father of the science of nutrition*.** He introduced balance and thermometer to nutrition studies. He discovered that during respiration the quantities of oxygen absorbed and carbon dioxide given off depends on the food intake and the work done. With Laplace he designed the first animal calorimeter and demonstrated that respiration is the essential source of body heat.

Bousingault: Observed that in villages where they used salt containing iodine, goiter was less.

Spallanzani: Swallowed linen bags containing food and retrieved them by strings attached to them periodically to study the chemical changes.

Mulder: Gave the name protein which means '*to take first place*'

Magendie: Recognized as the founder of the modern experimental methods in animal feeding experiments. He employed diets of pure carbohydrates and fats to prove that food nitrogen is essential. He published '*gelatin report*' which stated that all proteins were not of equal value.

Liebig: Founder of agricultural chemistry.

Lawes and Gilbert: Examined the body composition of animals by slaughtering them.

Babcock: Conceived the idea of trying out rations made up entirely from a single plant. It stimulated the use of purified diets which resulted in the discovery of first Vitamin. In 1913 Vitamin A was discovered by two independent teams of scientist *McCollum and Davis* & *Osborne and Mendel*.

Zuntz: Developed the first portable respiration apparatus for farm animals. He formulated the fermentation hypothesis to explain the mechanism of forage utilization by ruminants.

Atwater: Constructed the first human respiration calorimeter.

Henneberg and Stohmann: Devised a method called ***Proximate Analysis*** in 1865 at Weende experimental station, Germany which expressed the nutrients present in feeds in terms of 6 broad fundamental groups (Moisture, Ether extract, Crude fibre, Crude Protein, Total ash and Nitrogen free extract).

Kellner: Conducted respiration studies with farm animals and developed *Starch Equivalent* system of energy evaluation.

Armsby: Constructed the first animal respiration calorimeter and developed the *Net Energy* system of evaluating feeds.

Rubner: Showed that carbohydrate and fat were inter changeable in metabolism on the basis of energy equivalents.

Lind: Found that juice of citrus fruits could cure scurvy.

Eijkman: Observed that in birds consuming polished rice there was polyneuritis and the condition was cured by giving bran or rice polish.

Casimer Funk: Gave the name *Vitamin* to vital amines.

W C Ross: Classified amino acids as essential and non essential.

Mitchell: Wrote the book 'Comparative nutrition of man and domestic animals'

Morrison: Wrote the book 'Feeds and feeding'

Maynard: He was the chairman of the NRC committee on animal nutrition in 1942. He authored a book on Animal Nutrition.

Klieber: Constructed respiration apparatus for large animals and used $W^{0.75}$ instead of surface area to describe energy metabolism.

Underwood: His field of scientific research was trace element nutrition & physiology and authored the book 'The mineral nutrition of livestock'.

Van Soest: Developed procedures to estimate *fibre fractions* in feed stuffs (***Detergent method***).

Indian Scenario

Animal nutrition research started in India with the establishment of the laboratory at Imperial Agricultural Research Institute, Pusa, Bihar in 1921 which was later shifted to Imperial Institute of Animal Husbandry and Dairying at Bangalore in 1923 and later to Mukteswar in 1935 and finally to its present location in IVRI in 1939. A book on nutritive value of Indian cattle feeds and feeding of farm animals was published by K C Sen which was later revised by S N Ray and S K Ranjhan

COMMON TERMS IN ANIMAL NUTRITION

Nutrition: It is the branch of science that deals with ingestion, digestion and absorption of various nutrients, their transport to body cells and the removal of waste products of metabolism.

Nutrient: Any food constituent or group of food constituents of the same general chemical composition that aids in the support of animal life.

Food: Any edible material which nourish the body.

Feed: Single article of food eaten by animal.

Diet: A mixture of feed stuff that supplies nourishment to body.

Ration: Feed offered for a given animal during a day of 24 hrs.

In general the term diet is used for monogastric animals and human beings while the term ration is used for ruminants.

Balanced ration: A balanced ration is one that furnishes nutrients in such proportions and amounts that it will properly nourish a given animal for 24 hrs.

Malnutrition: Impairment of health resulting from a deficiency, excess or imbalance of nutrients.

Health: It is the state of complete physical, mental and social well being and not merely an absence of any disease.

Nutritive status: It is the condition of health as influenced by utilization of nutrients by the body.

Dietetics: It is the practical application of the science of nutrition to the feeding of people.

Maintenance: State in which there is neither gain nor loss of a nutrient by the body

Feeding standards: Tables which indicate the quantities of nutrients to be fed to the various classes of livestock for different physiological functions like maintenance, growth, lactation, egg production, wool production, work etc. Thaer developed the first feeding standard.

Energy: The driving force for maintenance of life, growth, reproduction, production and work.

COMPOSITION OF ANIMAL BODY AND PLANTS

Composition of animal body

Lawes and Gilbert analyzed the body of farm animals by slaughtering them and published it in 1859.

a) Fresh basis: Water- 60%, Protein - 16%, Fat-20% and Ash-4%.

b) Fat free basis: Water-75%, Protein-20% and Ash-5%

c) Fat free and water free basis: Protein-80% and Ash-20%

- The ratio of protein and ash is constant (4: 1) irrespective of nutritional status.
- Carbohydrate (glucose and glycogen) in animal body is negligible (less than 1%)
- Water content decreases with age (embryo has 95%, at birth it is 75-80%, for young animals it is 60-70% and for adult it is 50-65%).
- In body, water content is highest in plasma (92%), followed by muscles (72-78%), bone (45%) and least in enamel (5%)
- In body fat is localized in adipose tissue and around the internal organs. Fat content of body is inversely related with water content (fat content increases with nutritional status and age)
- 7 major minerals of animal body are Calcium, Phosphorus, Magnesium, Sulphur, Sodium, Chlorine and Potassium.

Composition of tissues

***Blood*:** Comprises 5-10% of adult body weight. Plasma has 90% water and 10% solids. Half of solid part is contributed by plasma proteins and the remaining by cholesterol, lipoproteins, NPN, sugar and inorganic salts. Pigments include hemoglobulin (has Fe), hemocyanin (has Cu) in shelled animals like crabs & lobsters and pinnaglobulin (has Mn) in shell fish.

***Skeletal muscle*:** Comprises 50% of adult body weight. It contains 75% water. Of the dry matter, about 75-80% is protein and the rest is fat and small amounts of carbohydrates & minerals.

Epithelial tissue: has the insoluble protein keratin.

Connective tissue (cartilage, tendons and ligaments): has collagen

Nervous tissue: mainly made of complex lipids.

Estimation of gross composition of animal body

I. Direct method: slaughtering the animal and analyzing the carcass

II. Indirect methods

a) Chemical methods:

Principle: lean body mass (empty body weight less the weight of fat) of an animal is constant in composition.

1. Weight of water is measured by dye dilution technique. Markers like antipyrene or water containing radioactive isotopes of hydrogen is injected into body, so that it goes into solution in body water. Quantitative determination of the dilution of the marker after the equilibrium has been reached gives idea about body water content. Once the weight of water is measured, the weight of protein, fat and ash is calculated by using the multiple regression equations.

2. Based on the concentration of potassium in the lean body mass

b) Densitometric method: carcass composition is estimated from its density.

c) Dual Energy X ray Absorptiometry

d) Ultrasonic Scanning

e) Computerised Tonography

f) Nuclear Magnetic Resonance Spectroscopy

Composition of plants

Plants contain the same substances present in the animal body but differ in the relative amounts present. Plants also show larger differences in composition among species compared to animals. The chief component of plant is water and it decreases with age. The main component of the dry matter of plant is carbohydrate. Cell wall of plants consists mainly of cellulose while the plants store energy in the form of starch. Lipid content of plants is relatively low (4-5% on DM basis) and it is highest in seeds followed by leaves and stem. In plants most of the protein is present as enzymes, the concentration is high in young growing plant and falls as the plant matures. Like proteins, nucleic acids also contain nitrogen and they play basic role in the synthesis of proteins in all living species. Organic acids which occur in plants as well as animals include citric, malic, fumaric, succinic and pyruvic acids. Plants can synthesize all the vitamins they require for metabolism. Potassium and silicon are the major inorganic elements in plants, while it is calcium and phosphorus for animals.

PROXIMATE ANALYSIS

Henneberg and Stohmann deviced at Weende experimental station in Germany a scheme in 1865 for routine description of animal feed stuffs commonly referred to as the proximate analysis or weende analysis. According to this method, the nutrients present in a sample or feed are analysed and expressed in terms of six broad fundamental groups or principles called the proximate principles. They are water, crude protein, ether extract, crude fibre,total ash, and nitrogen free extract. The proximate analysis or feed analysis forms the basis for description of feed composition tables , purchasing feeds , rations formulation and is the staring point for more detailed analysis for specific nutrients.

WATER

Water is the most important nutrient. Rubner stated that the body can lose almost all of its fat, half of its protein and yet live, but loss of $1/10^{th}$ of body water results in death.

Functions of water

1. Universal solvent: serves as the medium in which the intra and extracellular chemical reaction takes place.
2. Transport function: helps in the transport of nutrients, enzymes, hormones, end products of metabolism etc
3. Helps in maintenance of body temperature due to its high specific heat and latent heat.
4. Important in pH regulation.
5. Gives shape and structure to the cell.
6. It lubricates the joints in body.
7. Helps in hydrolytic reactions.
8. Act as a refractive medium in the aqueous humor of eye.

Requirement of water

Species	**Water intake (litre)**
Dairy cattle	80-90
Beef cattle	50-70
Lactating Horse	45-55
Horse doing medium work	35-45
Lactating swine	12-15 (14)
Growing swine	6-8
Lactating sheep	4-6
Growing sheep	3-4
Poultry	0.25-0.5

Sources of water

1. Drinking water
2. Water present in feeds: It includes free water and bound water. Free water can be removed by drying while the bound water cannot be separated easily from protoplasm by evaporation at high temperature or under dry conditions. Green succulent fodder has 70-80% moisture. Concentrate feeds and straws have nearly 10% moisture.
3. Metabolic water: Metabolic water is produced inside the body by metabolic processes taking place at the cellular level in different tissues and it comprises about 5-10 % of the total intake of water. One molecule of glucose on oxidation gives 6 molecules of water i.e. metabolism of glucose yield 60% of its weight as water. Similarly protein produces

40% and fat yields above 100% of its weight as water. Metabolic water is an important source of water supply for incubating chick and hibernating animals. Metabolic water is also produced by the dehydration synthesis of body proteins, fats and carbohydrates.

Significance of moisture estimation in feeds

1. To understand the characteristic of the feed (dry feed, succulent feed etc.)
2. To calculate the composition of feed on dry matter basis.
3. To know the bulk storage capacity of the feed. In general, feeds with more than 11% moisture gets mouldy and spoiled during storage.
4. Significant in calculating the cost per unit weight of feeds.
5. Useful in selecting the fodder for making silage. Fodder crops with 35% DM are ideal for making very good quality silage.

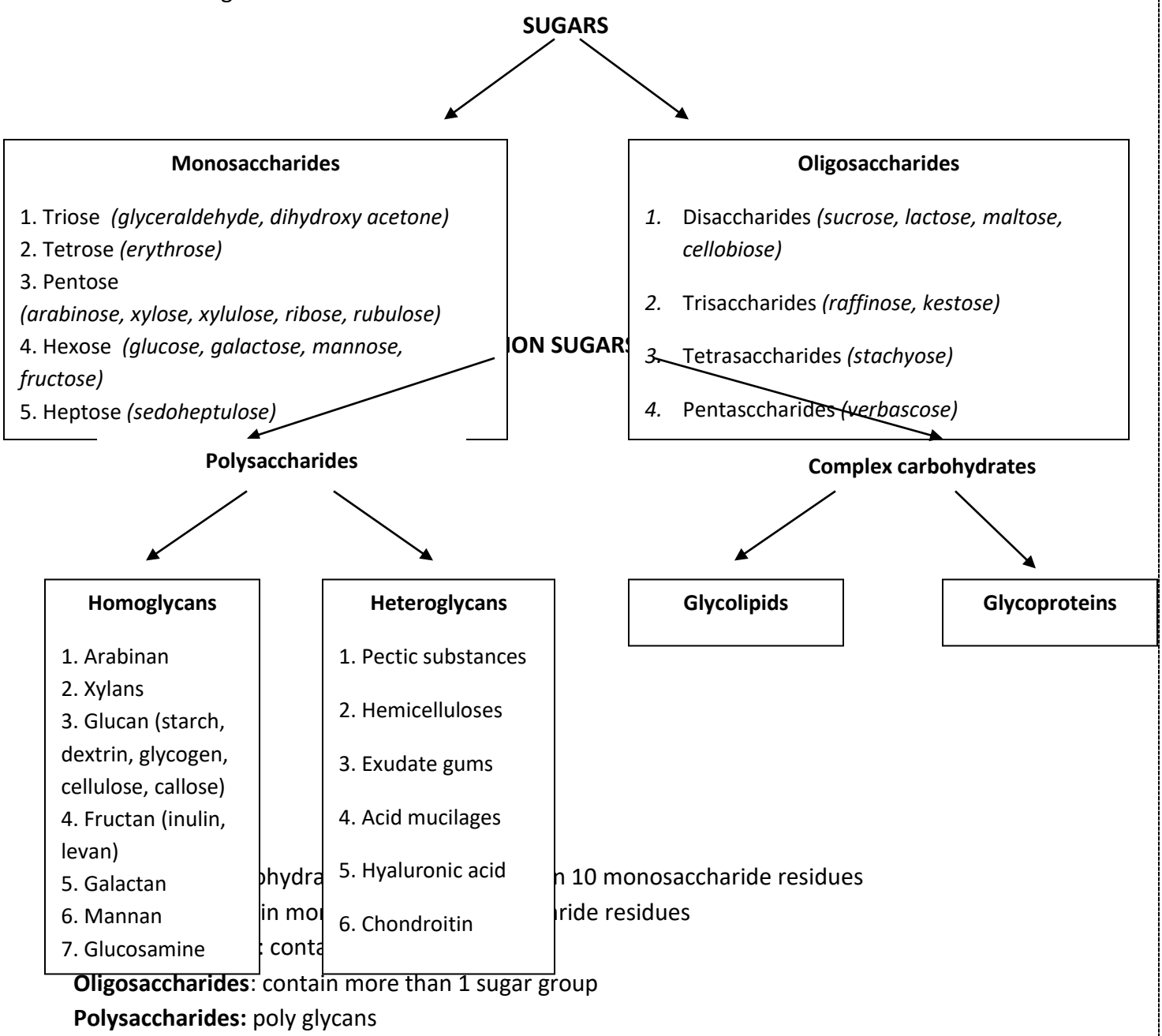
Effect of water deprivation

When water is deprived on a hot and dry environment, the animal exhibits thirst and when the deficit approaches 4-5% of body weight there will be discomfort and anorexia. When the loss increases to 6-10% of body weight there will be headache and in coordination of movements, indistinct speech, dyspnea and cyanosis. At a deficit of 12-14%, eyes will be shrunken, skin will be shriveled, inability to swallow and the animal shows nervous symptoms. When the deprivation exceeds 14%, heart pumps faster, blood becomes viscous and finally there will be hyperthermia and death.

CARBOHYDRATES

The name carbohydrate originates from the French word '*hydrate de carbone*'. Carbohydrates make up 75% of dry weight of plant world. Carbohydrates are polyhydroxy aldehydes, ketones, alcohols or acids or substances that yield one of these compounds on hydrolysis. These are broadly classified into

1. Sugars
2. Non sugars



...ohydra... ...n 10 monosaccharide residues
...in mo... ...aride residues
...: conta...

Oligosaccharides: contain more than 1 sugar group

Polysaccharides: poly glycans

Homoglycans: contain only a single type of monosaccharide units

Heteroglycans: on hydrolysis yields, mixture of monosaccharides and derived products.

MONOSACCHARIDES

***Triose and tetrose*:** do not exist in free forms. They are formed as intermediates in metabolic reactions. The tetrose, erythrose is a reactant in the phosphogluconate oxidative pathway.

Pentoses

Arabinose: It is present in the homoglycan arabinan. It is a component of hemicellulose and is also present in gumarabic. Free arabinose is found in heart wood of conifers.

Xylose: Occurs as pentosans in xylans. It forms the main chain in grass hemicellulose. Small amount of D xylose is present free in plums, cherries and grapes. Xylose is produced by hydrolysis of hay, straw, oat hulls, many woods and corn cobs. In the polymerized form in hemicellulose it constitutes a significant part of the energy supply for animals if fermented by gastrointestinal microbes.

Ribose: present in all living cells as component of RNA, several vitamins and co enzymes.

Xylulose & Ribulose: intermediates in the pentosephosphate metabolic path way.

Hexoses

Glucose (grape sugar): it is also called dextrose (dextrorotatory i.e. + 52.5). It is a white crystalline solid, soluble in water. It occurs as free form in fruits, honey, blood, lymph, CSF etc. 40% of sugar of honey is glucose. It is the major component of many oligosaccharides, polysaccharides and glucosides. Glucose is the end product of carbohydrate digestion in non ruminants. Commercially glucose is produced by the hydrolysis of corn starch.

Fructose (fruit sugar): it is the sweetest carbohydrate. It is also called levulose (levorotatory i.e. -92). In physiological conditions, fructose usually exists as furan ring. Glucose and fructose are the only two monosaccharides that occur to any extent in free form in nature.

Mannose: It doesn't occur free in nature but occur as polymerized form (mannan). It is a component of glycoprotein's. It is found in blood, serum globulins and in certain egg proteins. As mannans it is found in yeast, mould and bacteria.

Galactose: It doesnot occur free in nature except as a break down product of fermentation. Lactose, anthocyanin pigments, galactolipids, gums and mucilages has galactose. It is present in certain compounds of brain and nervous tissue as galactosides.

Compound	**Relative sweetness**
Sucrose	1
Fructose	1.35
Glucose	0.74
Xylose	0.67
Sorbitol	0.54
Maltose	0.45

Galactose	0.32
Lactose	0.16
Saccharin	200-700

Heptoses

Sedoheptulose: it is an intermediate compound in pentose phosphate metabolic pathway or HMP shunt.

Monosaccharide derivatives

1. *Sugar acids*: e.g. gluconic acid is produced from glucose by oxidation of aldehyde group (on C1) whereas glucuronic acid is formed when primary alcohol group (on C6) is oxidized. Glucuronic acid forms an ester or harmless glycoside (glucuronide) with a number of toxic materials such as phenols as well as with a number of hormones such as androgens and cortisone. The bile pigments bilirubin and biliverdin are glucuronides. When both the aldehyde and alcohol groups are oxidized, glucaric acid is obtained.
2. *Sugar phosphates*: e.g. glucose1 PO_4, glucose6 PO_4 fructose 1 PO_4
3. *Sugar alcohols*: produced by reduction of aldoses or ketoses e.g. sorbitol from glucose, mannitol from mannose/fructose and dulcitol from galactose. Sorbitol is an alcohol intermediate in the pathway for the formation of fructose from glucose which provides the large amount of fructose normally found in semen.
4. *Alditols*: polyhydroxy alcohols formed by reduction of monosaccharides e.g. ribitol (constituent of flavin coenzymes), glycerol, myoinositol, xylitol (sweetener used in sugarless gums and candies).
5. *Amino sugars*: produced when one or more hydroxyl groups of monosaccharides are replaced by amino groups. e.g. D glucosamine and D galactosamine.
6. *Deoxy sugars*: has one oxygen less than that present in the parent molecule e.g. Deoxyribose in RNA. Deoxy mannose is rhamnose and deoxy galactose is fucose.
7. *Glycosides*: hydrogen of hydroxyl group of anomeric carbon atom of glucose is replaced by esterification or condensation with an alcohol or phenol group. Similarly galactose form galactoside and fructose form fructoside e.g. cyanogenic glycosides in plants. Cyanogenic glycosides itself are non toxic but they are hydrolysed to HCN which is toxic. Common cyanogenic glycosides in animal feeds are given below:

a) Linamarin or phaseolunatin: found in linseed, java beans and cassava. Hydrolysis of linamarin yields glucose, HCN and acetone.

b) Vicianin: found in the seeds of the wild vetch (*Vicia angustifolia*). Hydrolysis of vicianin yields glucose, HCN, arabinose and benzaldehyde.

c) Amygdalin: found in bitter almonds, kernels of peach, cherries, plums, apples and fruits of Rosaceae. Hydrolysis of amygdalin yields glucose, HCN and benzaldehyde.

d) Dhurrin: found in the leaves of great millet sorghum vulgare. Hydrolysis of dhurrin yields glucose, HCN and p-hydroxy benzaldehyde.

e) Lotaustralin: found in the plants trefoil (*Lotus australis*) and white clover (*Trifolium repens*). Hydrolysis of lotaustralin yields glucose, HCN and methyl ethyl ketone.

Structural aspects of monosaccharides

1) *Stereoisomerism***:** stereoisomers are compounds having the same structural formula but differ in special configuration. Number of asymmetric carbon atoms determines the possible isomers of a given compound. A carbon is said to be asymmetric when it is attached to 4 different atoms or groups. Glucose has 4 assymmetric carbon atoms and hence 16 isomers. Glyceraldehyde is the simplest monosaccharide with one asymmetric carbon atom.

2) *D and L isomers*: D and L isomers are mirror images of each other. The spatial orientation of OH groups on the carbon atom that is adjacent to the terminal primary alcohol carbon determines whether the sugar is D (OH group is on right side) or L (OH group is on left side) isomer. Naturally occurring monosaccharides are mostly of D configuration.

3) *Optical activity of sugars:* it is the feature of compounds with asymmetric carbon atom. The term dextrorotatory (+) and levorotatory (-) are used to compounds that respectively rotate the plane polarized light to the right or to the left. Glucose has 4 assymmetric carbon atoms and hence 16 isomers (8 in '+' form and 8 in '-'form).

4) *Epimers:* monosaccharides that differ in their configuration around a single specific carbon atom. Glucose and galactose are epimers with regard to carbon 4 & glucose and mannose are epimers with regard to carbon 2.

5) *Anomers:* α and β cyclic forms of D glucose are known as anomers. They differ from each other in the configuration only around C1 known as anomeric or hemiacetal C atom. In case of α anomer, the OH group held by anomeric carbon is on the opposite side of the group CH2OH of sugar ring. The reverse is true for the β anomer.

6) *Chair and boat conformations:* Haworth projection formulae of monosaccharides are depicted by a 6 membered ring pyranose or a 5 membered ring furanose. The six membered pyranose ring might exist either as a boat or chair conformation. The chair configuration of glucose is free from any bond angle strain and is how it exists spatially in nature.

OLIGOSACCHARIDES

Disaccharides

1. *Sucrose* (maple sugar/table sugar): most ubiquitous and abundant disaccharide. α D glucose and β D fructose joined together by α 1-2 linkage (oxygen bridge between their anomeric carbon atoms i.e. C1 of glucose and C2 of fructose). Sucrose has no active reducing group. Sugarcane has 20% sucrose while in sugar beet it is 15-20%. It is also found in roots like

carrot and in fruits. Barley sugar is obtained by heating sucrose to 160^0C and caramel is obtained by heating it to 200^0C. Sucrose is dextrorotatory and on hydrolysis yeilds glucose and fructose (by sucrase or by acids) the plane of rotation changes from dextro to levo (invert sugar). It is the process by which honey bees convert the sucrose of plant nector to honey.

2. *Lactose* (milk sugar): it is not as soluble as sucrose and is less sweet ($1/6^{th}$). Chemically it is β D glucose and β D galactose joined together by β 1-4 linkage. It has one active reducing group. Lactose in milk is converted to lactic acid by microorganisms to form the curd. Lactose when heated to 150^0C turns yellow and becomes brown compound called lactocaramel when the temperature becomes 175^0C.

3. *Maltose* (malt sugar): it is produced during the hydrolysis of starch and glycogen by dilute acids or enzymes. It is produced from starch, during the germination of barley by enzyme amylase/diastase. Malt is prepared from barley after controlled germination and drying. It is water soluble but is not as sweet as sucrose. Chemically it has two α D glucose unit joined together by α 1-4 linkage. Maltose has one active reducing group and is dextrorotatory.

4. *Cellobiose*: it doesn't occur in nature as free sugar. It is the basic repeating unit of cellulose. Chemically it is two β D glucose units joined together by β 1-4 linkage. Only microorganisms can break this linkage. It has one active reducing group.

Trisaccharides

1. *Raffinose*: it is the commonest naturally occurring trisaccharide which is widely present in plants. Raffinose is found in small amounts in sugar beet. It accumulates in molasses during commercial preparation of sucrose. Cotton seed has 8% raffinose. Raffinose is composed of 1 unit each of glucose, fructose and galactose. On hydrolysis fructose is removed first leaving a disaccharide melibiose which consist of glucose and galactose. Melibiose is an isomer of lactose.

2. *Kestose*: occur in vegetative parts and seeds of grasses. It is composed of 1 glucose and 2 fructose units.

Tetrasaccharides

1. *Stachyose*: it is ubiquitous as raffinose and has been isolated from 165 species of plants. It is non reducing and has one unit each of glucose and fructose along with 2 units of galactose. It is seen in seeds of leguminous plants.

Pentasaccharides

1. *Verbascose*: it has one unit each of glucose and fructose along with 3 units of galactose. All the 3 galactose of verbascose is linked in α linkage. Verbascose is found in substantial quantities in leguminous seeds. Since there is no enzyme in the intestine of animals capable of splitting the α galactosidic linkage, stachyose and verbascose cannot be digested. In the large intestine they are fermented and large amount of gas, mainly hydrogen and carbon dioxide is liberated.

POLYSACCHARIDES

They are complex carbohydrates which are polymerized products of large number of simple sugars.

1. Homoglycans: these are very much different from sugars. Has high molecular weight and is made of pentoses or hexoses. They do not give the various sugar reactions characteristic of the aldoses and ketoses. They occur as reserve foods or structural material in plants.

a) *Arabinans*: homoglycan of arabinose

b) *Xylans:* homoglycan of xylose.

Pentosans (arabinans, xylans etc) are not degradable by mammalian enzymes, but rapidly hydrolyzed by microbial and fungal enzymes. When pentosans are boiled with HCl, an aldehyde furfural is produced. This reaction is the basis of the quantitative determination of pentosans and is used in the commercial production of furfural from oat hulls and corn cobs.

c) *Glucans*: starch, glycogen, dextrin, cellulose and callose

i) *Starch*: reserve food in plants. It occurs as granules (size and shape of starch granules varies with species). Granules are made in concentric layers and although glucan is the main component of granules they also contain minor constituents such as protein, fatty acids and phosphorus compounds which may influence their properties. Starch has two components i.e. amylose and amylopectin. Amylopectin is the main component of almost all the starches (70-80%). Proportion of amylose and amylopectin depends upon the source. While doing the qualitative test for starch, amylose gives deep blue colour with iodine while amylopectin gives blue violet or purple colour. Chemically amylose is long un branched chain consisting of 200-1000 D glucose units linked by α 1-4 linkages. Amylose is soluble in hot water. Amylopectin is insoluble in hot water and has bush like structure and is a branched chain with α 1-6 linkages at the branching points (side chain has 19-26 glucose units) and α 1-4 linkages everywhere else. The amount of amylose in starch is controlled genetically and increases with maturity. Starch granules are insoluble in cold water. When the starch suspension in water is heated the granules swell and eventually gelatinize. Gelatinization is the irreversible change in the crystalline structure of the molecule of starch granule when moist heat ruptures the starch granules. On gelatinization the potato starch granules swells and burst while the cereal starch granules swells but do not burst.

ii) *Glycogen* (animal starch): it is found in the liver, muscle, brain etc of animal body. It is analogous to amylopectin in structure. Glucose is the repeating unit in glycogen joined together by α 1-4 glycosidic bonds and α 1-6 linkages at the branching points (side chain has 12 D glucose units). Molecular weight of glycogen varies with animal species, type of tissue and physiological state of the animal.

iii) *Dextrins*: dextrins are the break down products of starch by the enzyme amylase or dilute acids. Starch is sequentially hydrolysed through different dextrins and finally to maltose and glucose in monogastric digestion. It is soluble in water and produces gum like solution. On reaction with iodine higher members gives red colour and lower members gives no color.

Presence of dextrins gives a characteristic flavor to bread crust, toast and partly charred cereal foods.

iv) *Cellulose*: it is the most abundant single polymer in plant kingdom. Pure form of cellulose is found in cotton. It has high molecular weight and has repeating units of cellobiose (two β D glucose units joined together by β 1-4 linkage). In plant cell wall cellulose is linked with hemicelluloses and lignin. Cellulose can be hydrolysed to glucose by strong acids and it can be degraded by fungi and bacteria.

v) *Callose*: consist of β 1-3 and frequently β 1-4 linked glucose residues. This β glucan occur in higher plants as components of special walls appearing at particular stages of development. A large part of the endosperm cell wall of cereal grains is composed of β glucans of this type. They are also deposited by higher plants in response to wound and infections.

vi) *Fructans*: reserve material in roots, stems, leaves and seeds of a variety of plants particularly in the compositae and gramineae. It is soluble in cold water and is composed of β D glucose units (2-6 or 2-1 linkages). Fructans on hydrolysis yields, in addition to D fructose, a small amount of D glucose, which is derived from the terminal sucrose unit in the fructan molecule. Inulin (2-1 linkage) is a fructan present in Jerusalem artichoke, burdock, dandelion and golden rod as reserve polysaccharide. Levan is a fructan with 2-6 linkage.

vii) *Mannans*: polymer of mannose found in plant cell wall. It is the main component of the cell walls of palm seeds, where it occurs as a reserve food and disappears during germination.

viii) *Galactans:* found in the seeds of many legumes, including clovers, trefoil and lucerne.

ix) *Glucosaminans*: chitin is the only known homoglycan containing glucosamine. It is a linear polymer of N acetyl D glucosamine held together by β 1-4 glycosidic bonds. It is the most abundant polysaccharide next to cellulose. It is found in the exoskeleton of insects and crustaceans.

2. Heteroglycans: when the polysaccharides are composed of different types of sugars or their derivatives, they are referred to as heteropolysaccharides or heteroglycans. Heteroglycans generally have 2-6 different types of monosaccharide units.

i) *Pectic substances*: includes a group of closely associated polysaccharides which are soluble in hot water. The main member is pectin. Occurs as constituent of primary cell walls and intercellular regions of higher plants (middle lamella). It is abundant in soft tissues of plants like peel of citrus fruits and sugar beet pulp. Pectin consist of linear chain of α 1-4 linked D galacturonic acid units in which varying proportions of the acid groups are present as methyl esters. Chains are interrupted at intervals by the insertion of L rhamnose residues. Sugars like D galactose, L arabinose and D xylose are attached as side chains. There is no mammalian enzyme capable of hydrolyzing pectin and their digestibility depends on microbial action. Pectins are α linked while hemicelluloses is β linked. Pectic substances are used in jam making due to their gel forming property. Pectic acid is a similar compound but is devoid of ester groups.

ii) *Hemicelluloses*: alkali soluble cell wall polysaccharides of plants those are closely associated with cellulose. Pentosans make up a significant amount of hemicelluloses. Hemicelluloses from grasses contain a main chain of xylan made up of β 1-4 linked D xylose units with side chains containing methyl glucuronic acid, galacturonic acid and frequently glucose, galactose and arabinose. In general, hemicellulose is composed of D glucose, D galactose, D mannose, D xylose, L arabinose and uronic acids, joined together in different combinations and in various glycosidic linkages. However, arabans and xylans make up a significant part of hemicelluloses. Hemicellulose is much resistant to chemical degradation than cellulose. It is the cell wall fraction most closely allied with lignin.

iii) *Exudate gums*: natural exudates from bark and leaves and often from wounds in plants. These are salts, especially of calcium and magnesium and in some cases a proportion of the hydroxyl groups in them are esterified usually as acetates.

iv) *Gum Arabic/Acacia gum*: consists of arabinose, galactose, rhamnose and glucuronic acid.

v) *Acid mucilages*: consist of arabinose, galactose, rhamnose and galacturonic acid. Usually obtained from bark, roots, leaves and seeds of plants e.g. linseed mucilage.

vi) *Hyaluronic acid*: consist of acetyl D glucosamine and D glucuronic acid. On hydrolysis it yields glucosamine, acetic acid and glucuronic acid. Found in skin, synovial fluid and umbilical cord. It is viscous and play important role in the lubrication of joint.

vii) *Heparin*: it is an anticoagulant and is composed of sulphates of D glucosamine and glucuronic acid. On hydrolysis it yields glucuronic acid, glucosamine and sulphuric acid.

viii) *Chondroitin*: similar to hyaluronic acid but has galactosamine instead of glucosamine. Sulphate esters of chondroitin are major structural components of cartilage, tendons and bones.

ix) *Mucopolysaccharides*: found in animal connective tissue. Synthesized from amino sugars, D glucosamine and D galactosamine together with uronic acids.

x) *Lignin*: lignin is not a carbohydrate and is not a well defined individual compound. It is a polymer which arises from 3 derivatives of phenyl propane namely coumaryl alcohol, coniferyl alcohol and sinapyl alcohol. Lignin molecule is made up of many phenyl propanoid units associated in a complex cross linked structure having ether linkages resistant to acid and 15alkali. Alkali treatment of highly lignified feeds such as straws breaks the hemicellulose lignin bond and improves the digestibility of hemicellulose. Lignin confers chemical and biological resistance to the cell wall and provides mechanical strength to the plant.

COMPLEX CARBOHYDRATES

1. *Glycoproteins*: these are proteins covalently bound to carbohydrates. Carbohydrate content varies from 1% to 90%. These are widely distributed in cells and perform a variety of functions (enzymes, hormones, transport proteins, structural proteins and receptors).

2. *Glycolipids*: glycosphingolipids are important constituents of cell membrane and nervous tissue. Cerebrosides are the simplest form of glycolipids. They contain a ceramide (sphingosine attached to a fatty acid) and one or more sugars. Gangliosides (found in ganglions) are the most complex form of glycosphingolipids. They are the derivatives of cerebrosides and contain one or more molecules of N-acetylneuraminic acid the most important sialic acid.

PROTEINS AND AMINO ACIDS

Proteins are constituted by 5 major elements in the following proportion

Element	Proportion (%)
Carbon	51-55
Hydrogen	6.5-7.3
Nitrogen	15.5-18.0
Oxygen	21.5-23.5
Sulfur	0.5-2.0

Besides the above, proteins may also contain other elements such as P, Fe, Cu, I, Mg, Mn, Zn etc. The content of ***Nitrogen***, an essential component of proteins is generally taken as ***16% (The factor 6.25 used while calculating the protein content from the estimated nitrogen is 100/16)*.**

Amino acids: Proteins are polymers of aminoacids. Nearly 300 amino acids occur in nature. 20-22 amino acids are found in the structure of proteins. Amino acids are derivatives of short chain fatty acids and has two functional groups (amino group and carboxyl group). Proteins on hydrolysis yields Lα amino acids. In nature amino acids exist as L form. Efficiency of utilization of L form of amino acids is greater than that of D form (exception is methionine). All amino acids except glycine are optically active. Amino acids are amphoteric in nature and they exist as cations in acidic pH and anions in alkaline pH

Iso electric point: pH at which net charge of the amino acid is 0.

Classification of amino acids

I. *Mono amino mono carboxylic*

a) Amino acids with aliphatic side chains: glycine, valine, alanine, leucine, isoleucine

b) Amino acids containing hydroxyl groups: serine, threonine

II. *Mono amino dicarboxylic/ acidic amino acids*: aspartic acid, glutamic acid

III. *Diamino monocarboxylic/ basic amino acids*: arginine, lysine, histidine

IV. *Sulfur containing amino acids*: cysteine, cystine, methionine

V. *Aromatic amino acids*: phenylalanine, tyrosine, tryptophan

VI. *Amides of acidic amino acids*: aspargine, glutamine

VII. *Imino acid* (it has NH group instead of NH_2 group): proline

In yet another classification the amino acids histidine, proline, hydroxy proline and tryptophan is classified as heterocyclic amino acids.

Based on the metabolic fate, amino acids are classified as

1. Glycogenic amino acids: these amino acids can serve as precursors for the formation of glucose or glycogen e.g. alanine, aspartic acid, glycine, methionine etc

2. Ketogenic amino acids: these amino acids can be used for the synthesis of fat. Leucine and lysine are exclusively ketogenic.

3. Glycogenic and ketogenic amino acids: the four amino acids isoleucine, phenyl alanine, tryptophan and tyrosine are precursors for synthesis of glucose as well as fat.

Peptide bond formation: formed when the amino group of an amino acid combines with carboxyl group of another amino acid.

Structure of proteins: Protein structure is rather complex which can be divided into 4 levels of organization.

1. *Primary structure*: the linear sequence of amino acids forming the back bone of proteins linked together by peptide linkage.

2. *Secondary structure*: special arrangement of protein by twisting of the polypeptide chain.

a) α helix: stabilized by extensive hydrogen bonding within the polypeptide chain

b) β pleated sheet: stabilized by hydrogen bonding between the polypeptide chains.

3. *Tertiary structure*: the three dimensional structure of a functional protein. It is a compact structure with hydrophobic side chains held interior while the hydrophilic groups are on the surface of the protein molecule. Besides hydrogen bonds, disulfide bonds, ionic interactions and hydrophobic interactions contribute to the tertiary structure of proteins.

4. *Quarternary structure*: Some of the proteins are composed of two or more polypeptide chains referred to as sub units. The monomeric sub units are held together by non covalent bonds namely hydrogen bonds, hydrophobic interactions and ionic bonds. The spatial arrangement of these sub units is referred to as quarternary structure. Eg Hemoglobin

Properties of proteins:

1. Solubility: in general, proteins form colloidal solutions with water. Solubility varies between different proteins. Keratin of hair is insoluble in water while the albumin is soluble. Proteins are least soluble and most precipitated in their isoelectric point. *Salting out* is a method to precipitate proteins from solution by neutral salts such as ammonium or sodium sulphate and *salting in* is the method to increase the solubility of less soluble proteins by adding certain salts. No protein is soluble in fat solvents.

2. Proteins undergo denaturation in the presence of heat, alcohol, acid, alkali and heavy metal salts.

Classification of proteins:

1. Simple proteins: they are composed of only amino acid residues

a) Globular proteins: these are soluble in water or other solvents and are digestible. Eg albumin, globulin, glutelins, prolamines, histones, globins, protamines etc. Albumin is water soluble and forms a significant part of serum protein and egg protein. Globulin is insoluble in water and is found in blood, milk and in seeds of plants.

b) Fibrous proteins: insoluble in water and resistant to digestion.

i) Collagen: it is the most abundant single protein in mammals. It is the principal component of cornea and connective tissue. Collagen makes the meat of old animals less tender. It is insoluble and indigestibe. On heating or on treating with acid it is converted to gelatin, which is digestible and soluble. Collagen is devoid of cysteine and tryptophan and lacks the disulphide linkage. Collagen is rich in amino acid hydroxyproline. Collagen is a poor quality protein and large amount of it in animal feeds is detected by identifying the presence of hydroxyproline.

ii) Elastin: it is found in tendons, arteries and elastic tissues. It stretches in two directions. It is very poor quality protein as it is poorly digested. Copper is required in elastin synthesis and aorta is ruptured in copper deficient fowl and guinea pigs.

iii) Keratin/reticulin: it occur in hair, horn, beak of birds and wool. Keratin is rich in cystine and has many disulphide linkage.

2. Conjugated proteins: they have a non protein moiety known as prosthetic group or conjugating group besides the amino acids e.g. nucleoproteins, glycoproteins, lipoproteins, phoshoproteins, chromoproteins, metalloproteins etc

3. Derived proteins: these are denatured or degraded products of simple and conjugated proteins e.g. coagulated proteins, proteans, metaproteins, proteoses, peptones, polypeptides etc.

Protien quality

Magendie published the gelatin report which states that gelatin in diet will not take the place of good quality meat protein i.e. proteins differ in their nutritional quality e.g. Zein (maize protein) is deficient in the amino acids lysine and tryptophan and is rich in leucine. In general, vegetable protein supplements are deficient in lysine (exception is soybean) and animal proteins (fish meal, milk protein, egg protein etc) are rich in lysine. W C Ross classified amino acids as essential and non essential. Harper used the term indispensible amino acids for essential amino acids and dispensible amino acids for non essential amino acids. Essential amino acids are those amino acids which cannot be synthesized in the body at a rate required for normal growth (cell is unable to synthesize the carbon skeleton of the amino acid to which amino nitrogen should be attached. Therefore, these amino acids are to be regularly supplied through diet. 8 amino acids are dietary required for all species and 13 or more required by one or more species. Ten amino acids are essential for rats and human beings (arginine, histidine, isoleucine, leucine, threonine, lysine, methionine, phenylalanine, tryptophan, valine). {the code ***a****ny* ***h****elp* ***i****n* ***l****earning* ***t****hese* ***l****ittle* ***m****olecules* ***p****roves* ***t****ruly* ***v****aluable* may be memorized to recall essential amino acids). Of the ten listed above, two amino acids namely arginine and histidine can be partly synthesized by adult humans, hence these are considered as semi essential amino acids for human beings. The rest of the amino acids can be synthesized by body and hence they need not be consumed in diet. Arginine requirement is high for chicks as they have no urea cycle for arginine production and the feathers are rich in arginine. Proper balance of essential

amino acids is required for proper nitrogen nutrition. Those proteins whose assortment of amino acids more nearly approximates the needs of the animal are of high quality and those which do not are of low quality.

Non protein nitrogenous (NPN) substances in animal feeds

It includes purines (adenine and guanine), pyrimidines (thymine, cytosine and uracil), amino acids, amides, amines, nitrogenous glucosides, alkaloids, ammonium salts, urea, biuret, nitrates etc. Ruminants natural feed contains 30% of the nitrogen as NPN substances. 1/3rd of the total nitrogen in pasture herbage/early cut hay and 1/2 of the nitrogen of silage is made of amides and amino acids. NPN compounds are absent/low in mature hay and concentrates. Mature seeds has below 5% of NPN.

LIPIDS

The term lipid originates from the Greek word 'lipos' which means fat. Lipids are heterogenous groups of compounds and therefore, it is difficult to define them precisely. They can be regarded as organic substances insoluble in water and soluble in organic solvents (alcohol, ether etc). Unlike the polysaccharides, proteins and nucleic acids, lipids are not polymers. They are mostly small molecules.

Classification of lipids

I. *Simple lipids*: esters of fatty acids with alcohols.

a) Fats and oils/ triacylglycerols: These are esters of fatty acids with glycerol. Physically, oil is liquid and fat is solid at room temperature.

b) Waxes: Esters of fatty acids with alcohols other than glycerol.

II. *Complex/Compound lipids*: Esters of fatty acids with alcohols containing additional groups such as phosphate, nitrogenous base, carbohydrate, protein etc.

a) Phospholipids: Additional group is phosphoric acid and frequently a nitrogenous base e.g. glycerophospholipids (lecithin, cephalin), sphingophospholipids e.g. sphingomyelin.

b) Glycolipids: Have fatty acid, carbohydrate and nitrogenous base.

c) Lipoproteins

d) Other complex lipids: e.g. sulfolipids, amino lipids, lipopolysaccharides.

III. *Derived lipids*: Obtained on the hydrolysis of group I and group II lipids.

IV. *Miscellaneous lipids*: compounds possessing characteristics of lipids e.g. carotenoids, hydrocarbons etc

V. *Neutral lipids*: Uncharged lipids e.g. mono-, di- and tri acyl glycerols, cholesterol and cholesteryl esters.

Fatty acids

Fatty acids are the simplest form of lipids. They are carboxylic acids with hydrocarbon side chain. Palmitic acid (16C) and stearic acid (18 C) are the most common. Saturated fatty acids (end with suffix-*anoic*) do not contain double bonds while unsaturated fatty acids (end with suffix-*enoic*) contain one or more double bonds. Melting point of fatty acids is proportional to the chain length. Saturated fatty acids includes acetic acid (2C), propionic acid (3C), butyric acid (4C), valeric acid (5C), caproic acid (6C), caprylic acid (8C), capric acid (10C), lauric acid (12C), myristic acid (14C), palmitic acid (16C) stearic acid (18C), arachidic acid (20C), behenic acid (22C) and lignoceric acid (24C). Unsaturated fatty acids includes palmitoleic acid (16C; 9), oleic acid (18C; 9), linoleic acid (18C; 9, 12), linolenic acid (18C; 9, 12, 15) and arachidonic acid (20C; 5, 8, 11, 14). Naturally occurring fatty acids generally have straight chain with even number of carbon atoms and occur in the cis form. Fatty acids in microbial lipids are branched with odd

number of carbon atoms. Chaulmoogric acid is a cyclic fatty acid, which is employed in the treatment of leprosy.

Essential fatty acids: Cannot be synthesized by body i.e. dietary essential e.g. linoleic and linolenic acid. Arachidonic acid becomes essential, if its precursor linoleic acid is not provided in diet in sufficient amounts. Prostaglandins are synthesized from arachidonic acid. Prostaglandins and the structurally related molecules prostacyclins, thromboxanes and leukotrienes are called eicosanoids because they contain 20 carbon atoms. The deficiency of essential fatty acids in human beings causes a condition called phrynoderma or toad skin characterized by horny eruptions on different parts of body, loss of hair and poor wound healing. The major feature of essential fatty acid deficiency in all the animals and birds is impairment of the exterior coat of the animal. Increase in the level of trienoic acid in tissues is a clear indicator of essential fatty acid deficiency. *Triene tetraene ratio is a measure of essential fatty acid deficiency* and for rats; optimum ratio should be below 0.4.

Triacylglycerols (fats and oils): Esters of glycerol with fatty acids. These are the most abundant group of lipids that primarly function as fuel reserves of animals. Adipocytes of adipose tissue are specialized for storing triacylglycerols. Triglycerides/triacylglycerols are the major lipid in seeds while in forage the major one is galactolipids.

Measures of purity of fats and oils

1. *Iodine number*: it is defined as the grams of iodine absorbed (2 moles of iodine/double bond) by 100 g of fat or oil. Iodine number is directly proportional to the content of unsaturated fatty acids.
2. *Saponification number*: it is defined as the mg of KOH required to saponify 1 g of fat or oil. Saponification number is inversely related to the chain length of the fatty acids present.
3. *Reichert Meissl number*: it is defined as the amount (ml) of 0.1 N KOH required to neutralize the soluble fatty acids distilled (steam volatile) from 5 g of fat. It is a measure of water soluble steam volatile fatty acids. RM number is useful in testing the purity of butter since it contains a good concentration of volatile fatty acids. Butter has RM number in the range 25-30, while it is less than 1 for most other edible oils.
4. *Acid number*: it is defined as the mg of KOH required to completely neutralize free fatty acids present in one gram fat or oil. Oils on decomposition (due to bacterial or chemical contamination) yield free fatty acids. Therefore, oils with increased acid number are unsafe for human consumption.

Rancidity of fats

Rancidity is the term used to represent the deterioration of fats and oils resulting in an unpleasant taste. Fats containing unsaturated fatty acids are more susceptible to rancidity.

a) *Hydrolytic rancidity*: Occurs due to partial hydrolysis of fat by the enzyme lipase which is present in molds, bacteria and in some fresh foods. There is hydrolytic splitting of the fatty acids from glycerol of the fat resulting in the production of mono- and di glycerides. Hydrolytic

rancidity will not alter the nutritive value of fat. Rancid odour is due to the fatty acids released during the hydrolysis.

b) *Oxidative rancidity*: Oxidation of unsaturated fatty acids results in the formation of peroxides. *Peroxide number* is a measure of oxidative rancidity. Presence of heavy metals like copper, iron etc enhances the chance of developing oxidative rancidity. Under certain conditions of temperature, moisture and often when catalytic amounts of heavy metals are present, a hydrogen atom is abstracted from the methylene carbon (CH_2 group) of unsaturated fatty acids leaving a free radical (H*). Free radical combines with oxygen to form peroxides and peroxides will react with hydrogen forming hydroperoxides. When saturated fatty acids are oxidized hydroperoxides are not formed but methyl ketones are formed. Such rancidity is known as *ketonic rancidity*. Oxidative rancidity alters the nutritive value of food by destroying vitamins like Vitamin A and carotene. The substances which can prevent the occurrence of oxidative rancidity are known as *antioxidants*. Naturally occurring antioxidant is Vitamin E (tocopherols). Hydroquinone, gallic acid, α naphthol, propyl gallate, butylated hydroxyl anisole (BHA) and butylated hydroxyl toluene (BHT) are the antioxidants commonly used in food preservation. Antioxidants supply hydrogen atom and replaces the hydrogen as soon as it is abstracted from methylene group.

Waxes: esters of fatty acids with alcohols other than glycerol (cetyl alcohol , carnaubyl alcohol and myricyl alcohol). Myricyl palmitate is the main ester of bee wax. Animal wax obtained from wool is lanolin and that from marine animals is spermaceti. Waxes are solid at room temperature, difficult to saponify and are not readily digested.

Phospholipids:

a) Glycerophospholipids: occur in biological membranes. It includes

i) Phosphatidic acid: This is the simplest phospholipid. It is intermediate product in the synthesis of triacylglycerols and other phospholipids.

ii) Lecithin (phosphatidyl choline): Most abundant group of phospholipids. It is found in cell membranes. Lecithin is prepared commercially from soybean seed. It is an excellent emulsifying agent and is used as smoothing agent in foods. It improves the utilization of fat in calves when incorporated in milk replacers.

iii) Cephalin (phosphatidyl ethanolamine): Cephalins play important role in blood clotting

iv) Phosphatidyl inositol: Important component of cell membranes. Action of certain hormones is mediated through it.

v) Phosphatidyl serine

vi) Plasmalogens: When a fatty acid is attached by an ether linkage at C_1 of glycerol in the glycerophospholipids, the resultant compound is plasmalogen. It forms nearly 10% of the phospholipids of brain and muscles.

vii) Cardiolipin: It is an important component of inner mitochondrial membrane. It is the only phosphoglyceride that possess antigenic properties.

b) Sphingophospholipids: e.g. sphingomyelin. Amino alcohol sphingosine is present. They do not contain glycerol. The alcohol group of sphingosine is bound to phosphoryl choline in sphingomyeilin. It is an important constituent of myelin sheath.

Glycolipids: Important component of cell membranes and nervous tissue. Glycolipids are derivatives of ceramide (sphingosine is attached to a fatty acid). Cerebrosides are the simplest form. They contain a ceramide and one or more sugars eg galactocerebroside and glucocerebroside. Gangliosides are the most complex form of glycosphingolipids. They are the derivatives of cerebrosides and contain one or more molecules of N-acetylneuraminic acid (sialic acid).

Lipoproteins: They are transport vehicles for lipids in the circulation. There are five types of lipoproteins (chylomicrons, very low density lipoproteins, low density lipoproteins, high density lipoproteins and free fatty acid albumin complexes).

Steroids: Compounds containing cyclic steroid nucleus (cyclopentanoperhydrophenanthrene) eg cholesterol, ergosterol, bile acids, vitamin D, sex hormones, adrenocortical hormones etc.

a) Cholesterol: Found only in animals and is the most abundant animal sterol. Widely distributed in all cells and is a major component of cell membranes and lipoproteins.

b) Ergosterol: Occurs in plants. Precursor for Vitamin D.

c) Bile acids (cholic, deoxycholic and chemodeoxycholic acid): Synthesized from cholesterol in liver.

Terpenes: e.g. carotenoids, xanthophyl etc. Terpenes yields isoprene moiety on degradation.

DIGESTION IN SIMPLE STOMACHED/MONOGASTRIC ANIMALS

PIG

***MOUTH*:** For pigs, the pointed lower lip is the chief prehensile organ. In pigs the lower incisor teeth are chiefly used for rooting, the inward curved upper incisors are used to grasp and shear the food while the premolars and molars aid to crush food. Digestive processes initiates in mouth. In mouth saliva is secreted by the salivary glands namely parotid (*secretion is rich in enzyme*), sublingual (*mucous secretion*) and sub maxillary (*mixed secretion*). The pH of pig saliva is 7.3. Saliva has 99% water. The remaining 1% is contributed by enzymes, inorganic salts and mucous. The *chief enzyme in saliva is ptyalin/ salivary amylase/α amylase*. α amylase is present in the saliva of pig, man, poultry, rat etc while it is absent in the case of dog, cat and horse. α amylase acts on amylose present in starch to glucose & maltose and the amylopectin is converted by its action to limit dextrin. α amylase acts only on α 1-4 glucosidic bonds. The lysozyme present in saliva kills the bacteria by hydrolyzing β 1-4 N acetyl glucasaminidic linkage. The functions of saliva includes

1. Lubrication
2. Initiates carbohydrate digestion
3. Kills pathogens in food.
4. Buffering action (due to bicarbonate and phosphate)
5. Temperature regulation

***STOMACH*:** Capacity of pig stomach is around 8 litres and that of total digestive tract is around 27 litres. The entrance to stomach is called oesophageal area which is followed by cardia, then comes the body of stomach/ fundus and the terminal part/ pylorus. Oesophageal area has no glands and the activity of salivary α amylase is continued. This area has microbes like lactobacilli and streptococci. The cardia secretes alkaline, enzyme free viscous mucous formed of a gel forming glycoprotein which protects the epithelium from acid attack. The gastric gland region in the body of the stomach has *parietal/oxyntic cells* which secrete HCl & the intrinsic factor (for the absorption of Vit B_{12}) and the *chief cells* which secrete pepsinogen. This area also secretes glycoprotein and mucus. Secretion of gastric juice from the gastric glands involves 3 phases.

1. Cephalic phase: occurs due to sight and smell of food
2. Gastric phase: occurs due to chemical sensors and distension of stomach
3. Duodenal phase: occurs by neural and hormonal messages

Acid concentration of the gastric juice varies with diet. Usually it is 0.1 M, pH 2. Pepsinogen secreted by the chief cells is converted to pepsin by the action of HCl. Pepsin attack those pepetide bonds adjacent to aromatic amino acids (phenylalanine, tryptophan and tyrosine) and linkages involving glutamic acid and cysteine. Rennin in young calves, lambs and kids resembles pepsin in activity. The products of protein digestion in the stomach are polypeptides of variable chain length & few amino acids and are alkaline in nature. Gastric

lipase produced in stomach initiates the lipid digestion. The pyloric region of stomach has mucous glands. The control of stomach emptying is by osmotic sensors in duodenum.

SMALL INTESTINE **(duodenum, jejunum, ileum)**: majority of digestion and absorption occurs here. Duodenum is the chief area of secretion of digestive enzymes while absorption occurs mainly in jejunum.

Brunners glands: It is found in duodenal area. The secretion of this gland is alkaline in nature and occurs through ducts between the villi.

Villi**:** found in small intestine. Aids in absorption. It has arteriole, venules (drain to hepatic portal system) and lacteal (drain to thoracic lymphatic duct). Enzymes produced by villi includes

Sucrase: breaks sucrose to glucose and fructose

Maltase: converts maltose to two molecules of glucose

Lactase: converts lactose to gluose and galactose. Mature animals of most species have a lower lactose tolerance than the young ones.

Oligo 1-6 glucosidase: attack α 1-6 links in limit dextrins

Amino peptidases: attack on the peptide bond adjacent to the free amino group of simple peptides.

Dipeptidases: complete the break down of dipeptides to amino acids.

Bile**:** Produced by liver. It has sodium and potassium salts of bile acids (*glycocholic acid and taurocholic acid*) i.e. **bile salts**, ***phospholipids*** and ***bile pigments*** (*biliverdin and bilirubin*, the end products of haeme catabolism). Bile salts are detergents or amphipaths. They have lipid soluble sterol nucleus and a water soluble portion (hydroxyl group and ionized conjugate of glycine or taurine). Bile salts activate the pancreatic lipase enzyme and emulsify fat. Bile salts also has a property to aggregate together to form micelles. The daily requirement of bile acid is greater than synthetic capacity of the liver and an enterohepatic circulation exists to maintain the supply.

Pancreatic juice**:** pancreas lies in the duodenal loop and has endocrine function (insulin production) and exocrine function (production of digestive enzymes by *acinar cells* & production of water and electrolytes by *duct cells*). Pancreatic juice is secreted into duodenum through pancreatic duct. The secretion of pancreatic juice is induced by the action of

a) *Secretin*: when acid enters duodenum the hormone secretin is liberated from the epithelium of small intestine into blood. When it reaches the pancreatic circulation it stimulates the pancreatic secretion to secrete a watery fluid containing high concentration of bicarbonate ions and very little enzyme.

b) *Cholecystokinin pancreozymin (CCK PZ)*: It is secreted when peptides and other digestive products reach the duodenum. It stimulates the secretion of trypsinogen, chymtrypsinogen, procarboxypeptidases A & B, proelastase, α amylase, lipase, lecithinases, cholesterol esterase, nucleases and phosphatases.

Enzymes

Trypsinogen: Trypsinogen is converted to trypsin by the action of *enterokinase* which is secreted from the duodenal mucosa. Once the conversion starts, it is further supported and stimulated by trypsin itself i.e. an autocatalytic reaction. Trypsin act only on peptide linkages involving the carboxyl group of lysine and arginine.

Chymotripsinogen: chymotrypsinogen is converted to chymotrypsin by the action of trypsin. Chymtrypsin act on peptide linkages involving the carboxyl group of tyrosine, tryptophan, phenylalanine and leucine. Trypsin and chymotrypsin are classified as endopeptidases as they attack peptide bonds in the interior of the molecule.

Procarboxypeptidase: it is an exopeptidase. It is converted to carboxypeptidase by trypsin. This enzyme attacks the peptides from the end of the chain, splitting off the terminal amino acid which has a free α carboxyl group.

Pancreatic α amylase: similar to salivary amylase. Attack α 1-4 glucan links in starch and glycogen.

Pancreatic lipase: Coverts triacyl glycerol to diacyl glycerol and then to monoacyl glycerol. Its action stops at monoacyl glycerol stage. Monoacyl glycerols and most fatty acids dissolve in the micelles formed by bile salts forming mixed micelles (triacyl glycerols are insoluble in these micelles).

Lecithinase A: hydrolyses the bond linking the fatty acid to the β hydroxyl group of lecithin. The product formed is lysolecithin.

Lecithinase B (lysolecithinase): converts lysolecithin to glycerol, phosphorylcholine and fatty acid.

Cholesterol esterase: catalyses the splitting of cholesterol esters.

Polynucleotidases: Hydrolyses the ester bond between sugar and phosphoric acid in the nucleic acids.

Deoxyribonuclease hydrolyse DNA and ribonuclease hydrolyse RNA.

Nucleosidases: Attack the linkage between the sugar and nitrogenous bases liberating the free purines and pyrimidines.

Phophatases: they complete the hydrolysis liberating the orthophosphoric acid from the ribose or deoxyribose.

- Small intestine is the chief site of absorption of vitamins and minerals.
- In pigs raw corn/maize starch is about as well utilized as the cooked product.
- *There is very little microbial digestion in the stomach and small intestine of pigs.*

***LARGE INTESTINE* (*caecum, colon, rectum*)**: Large intestine is the important site of sodium & chlorine absorption. Minerals like potassium, phosphorus and magnesium are also absorbed from large intestine. Pigs has short caecum and long colon compared with other monogastric omnivores. Large intestine has no villi but has small projections which increase surface area. Only mucous glands are present in large intestine. Digestion in large intestine is due to enzymes

carried from small intestine and due to microbial activity. There is extensive microbial activity in the caecum. End products of microbial digestion are volatile fatty acids, indole, skatole, phenol, hydrogen sulphide, amines and ammonia. Microbial fermentation in pigs accounts for 8-16% of the organic matter disappearing from the gastro intestinal tract. Volatile fatty acids are absorbed from large intestine and contribute to energy supply of the pig. Even though microbes synthesise some B vitamins, it is insufficient to meet the daily requirement of pigs and a dietary source is needed.

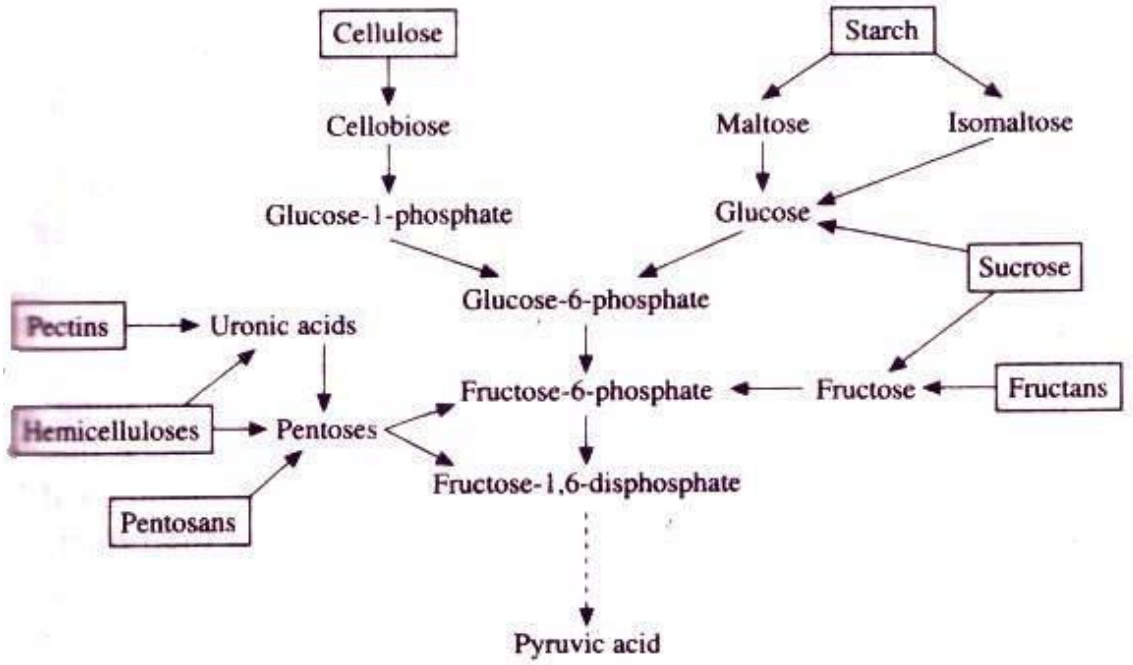
FOWL

Peculiarities

- The digestive and absorptive process in a chicken is rapid and takes less than 3 hours.
- In poultry the lips and cheek is replaced by beak.
- Teeth is absent for birds.
- Hard palate contains slit. Therefore, the bird scoops water and elevate its head and water runs down the esophagus by gravity.
- Soft palate is absent.
- Tongue is dagger shaped. Taste of sense is poor for birds. They have few taste buds on the back half of tongue adjacent to pharynx.
- 2/3 rd down the esophagus there is a pear shaped pouch called crop for holding the food. The crop is filled and emptied by peristalsis. Crops act as a storage place for food. Neither mucous nor enzymes are produced in the crop but the activity of salivary amylase continues in crop. Activity of microbes like Lactobacilli occurs in crop, producing acids like lactic acid and acetic acid.
- In poultry, proventriculus is the true stomach where pepsinogen and hydrochloric acid is produced. Gizzard is the muscular stomach where the digestion continues by the secretions of proventriculus.
- Gizzard exerts great force and food material undergoes mechanical grinding. Abrasive materials like grit, gravel, rock etc aid grinding of food in gizzard. Grit increases break down of whole grains by 10%. Koilin produced by gizzard wall is a protein polysaccharide complex having composition similar to keratin. It hardens in the presence of HCl.
- Duodenum forms a distinct loop while jejunum and ileum are not very distinct. 3 pancreatic ducts and 2 bile ducts opens into intestine at termination of duodenum.
- Caeca are two blind pouches lying between the small and large intestines. Caeca has little function in digestion. Some microbial digestion of fibre occurs here. From caeca by peristalsis food reaches colon.
- Cloaca is the bulbous end of the digestive tract. It is the common outlet of digestive, urinary and reproductive canals. Vent is the external opening of the cloaca.

DIGESTION IN RUMINANTS

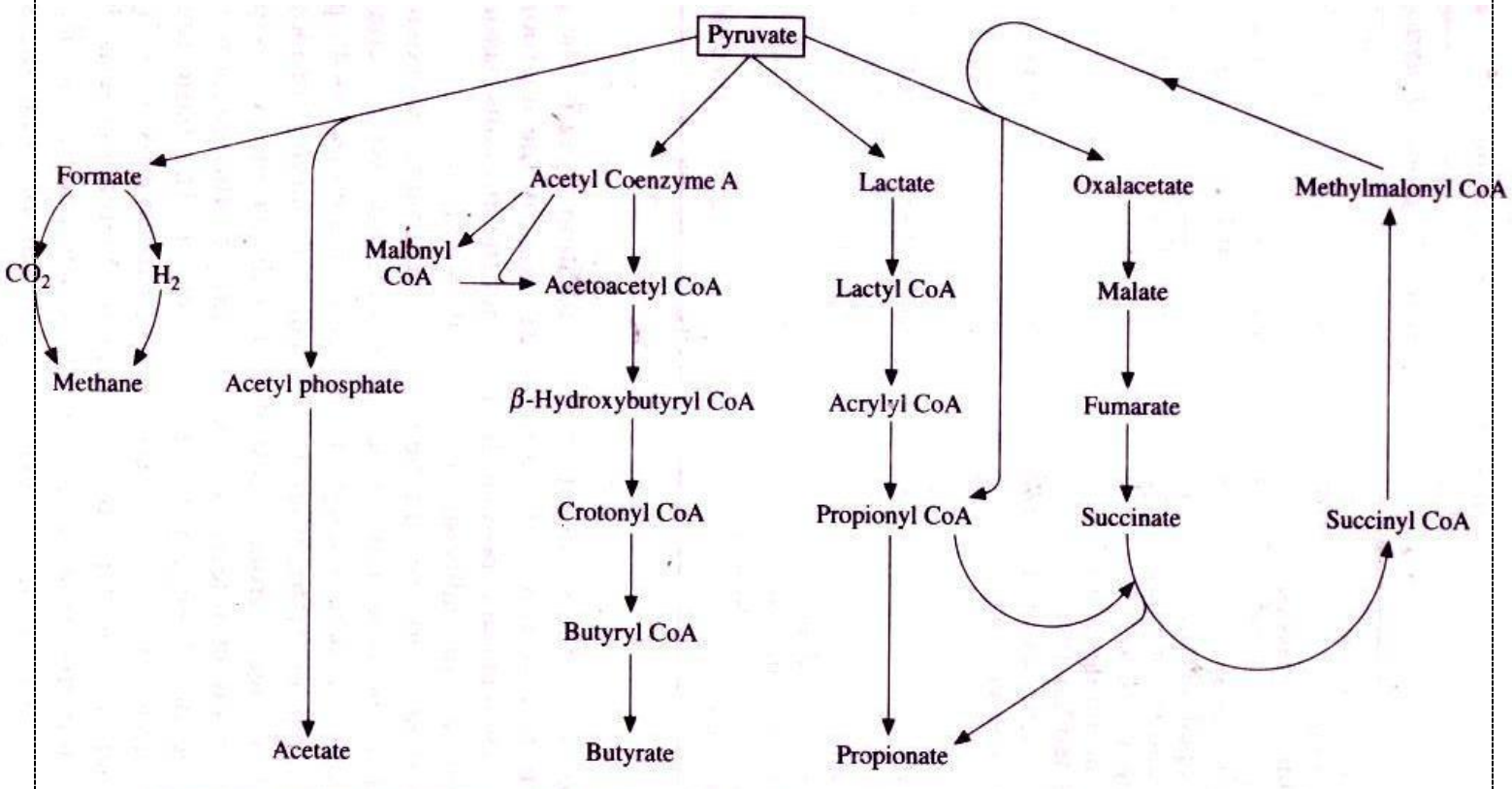
Carbohydrates: Microbial enzymes convert carbohydrates in feed (cellulose, starch, sugar, hemicelluloses, pentosans, fructans, pectins etc) to pyruvic acid in the rumen primarily by the EMP pathway (glycolysis) and the pentose phosphate pathway (HMP Shunt). Pyruvate is then converted into different end products (volatile fatty acids and gases like carbon dioxide, methane and hydrogen) depending upon the microorganisms involved and the diet.



Conversion of carbohydrates to pyruvate in the rumen. McDonald et al., 1995

Volatile fatty acids (VFA) are produced in the rumen from the pyruvate. On normal diet the volatile fatty acids produced are acetic acid (65%), propionic acid (20%) and butyric acid (9%). Other fatty acids (6%) formed in the rumen includes isobutyric acid, valeric acid, 2 methyl butyric acid and 3 methyl butyric acid. Concentration of VFA in the rumen depends on the diet of the animal and the time elapsed since the previous meal. If the animal is chiefly dependent on fibrous feeds like straws and hays then 70% of VFA will be acetic acid. Grinding and pelleting of forage has little effect on the VFA proportion when the diet consists of forage alone, but causes a switch from acetate to propionate if the diet also contains concentrates. If the grain/ concentrate level of the diet is increased the propionic acid content in rumen increases and the acetic acid content decreases. Similarly feeding of ionophore antibiotics like monensin favours the production of propionate and lowers the production of acetate. Proportion of butyric acid is

less affected by diet than other shorter chain volatile fatty acids. An adult cow produces 4 Kg volatile fatty acids a day. Normal VFA concentration in rumen is 70-150 mmol/L or 2-15 g/L. Majority of the VFA produced is absorbed by rumen, reticulum and omasum by simple diffusion and some may pass through the abomasum and absorbed in the intestine. In acid pH absorption is fastest for butyric acid, followed by propionic acid and acetic acid. Volatile fatty acids provide 60-80% of the metabolisable energy of ruminants on most diets. Portion of these VFA is used by bacteria and protozoa to synthesize their own polysaccharides or use as carbon skeleton for the synthesis of their body protein. The pathways involved in the production of VFA and gases by rumen microbes are given below:



Conversion of pyruvate to volatile fatty acids in the rumen. McDonald et al., 1995

Some other fatty acids are produced in small quantities in the rumen by de-amination of amino acids

Valine ⟶ ***Isobutyric acid***

Proline ⟶ ***Valeric acid***

Isoleucine ⟶ ***2 methyl butyric acid***

Leucine ⟶ ***3 methyl butyric acid***

Predominant pathway for propionate production in concentrate based diet is lactate acrylate pathway and in fibrous diets it is succinate pathway. Gases produced in rumen during carbohydrate digestion are carbondioxide, methane and hydrogen. Immediately after the meal, adult cattle produces gases at a rate of 30L/hr. 40% of the gases in the rumen is carbon dioxide, 30-40% methane, 5% hydrogen and the rest being contributed by oxygen and nitrogen. Carbon dioxide is produced partly as a by product of carbohydrate fermentation and partly by reactions of organic acids with bicarbonate coming from saliva in rumen.

7-8% of the gross energy of ruminant diet is lost as methane. 4.5 g methane is produced for each 100g of carbohydrate digested. Methane is formed by the reduction of carbon dioxide by methanogenic bacteria. Hydrogen, formate and succinate are the hydrogen donors for this reaction. Vitamins essential for methanogenesis are folic acid and vitamin B12.

Production of hydrogen in the rumen during the synthesis of volatile fatty acids from glucose is shown below

$C_6H_{12}O_6 + 2H_2O \longrightarrow$ 2CH3COOH + 2CO2 + 8H (*acetate synthesis*)

$C_6H_{12}O_6 \longrightarrow 2C_3H_6O_2 + 2O$ (*propionate synthesis via acrylate pathway*)

$C_6H_{12}O_6 \longrightarrow C_4H_8O_2 + 2CO_2 + 4H$ (*butyrate synthesis*)

So there is an excess of 8H per mole of acetate, 4H per mole butyrate and a deficiency of 4H for each mole of propionate formed via the acrylate pathway. To stay in balance, extra hydrogen must be removed. Methane is the hydrogen sink. From the above reactions it is evident that production of propionate will be accompanied by a reduction of methane level. Therefore, fermentation favouring propionate production usually results in improved feed efficiency in animals. However, depressed acetate production results in milk with a lowered percentage of fat.

Most of the gases formed in rumen is lost by eructation. In certain digestive disorders the gas is trapped in the rumen and the animal is unable to remove, a condition known as *bloat/ tympany* occurs. Excessive feeding of fresh leguminous fodders and a high grain ration causes *frothy bloat* in ruminants. Therefore, fresh legumes should be wilted or mixed with dry fodder and fed to stall fed animals. Feeding of dry roughages before turning the cattle to luxuriant pasture decreases the chances of bloat. The frothy bloat occurring due to feeding of much grain/concentrate and little roughage is termed as the *feed lot bloat*. Obstruction to normal expulsion of gases from the rumen by choking the esophageal passage by feeds like corn cob, turnip, sugar beet or jack fruit causes *free gas bloat*.

Proteins: In normal ruminant diet nearly 60% of the dietary protein undergo proteolysis in the rumen and are converted to peptides and amino acids. Enzymes for proteolysis are produced by rumen microorganisms. Peptides and amino acids thus formed are further fermented by deamination to carbondioxide, ammonia and short chain fatty acids. A part of the ammonia produced in rumen is utilized by rumen bacteria and along with carbon moiety of short chain

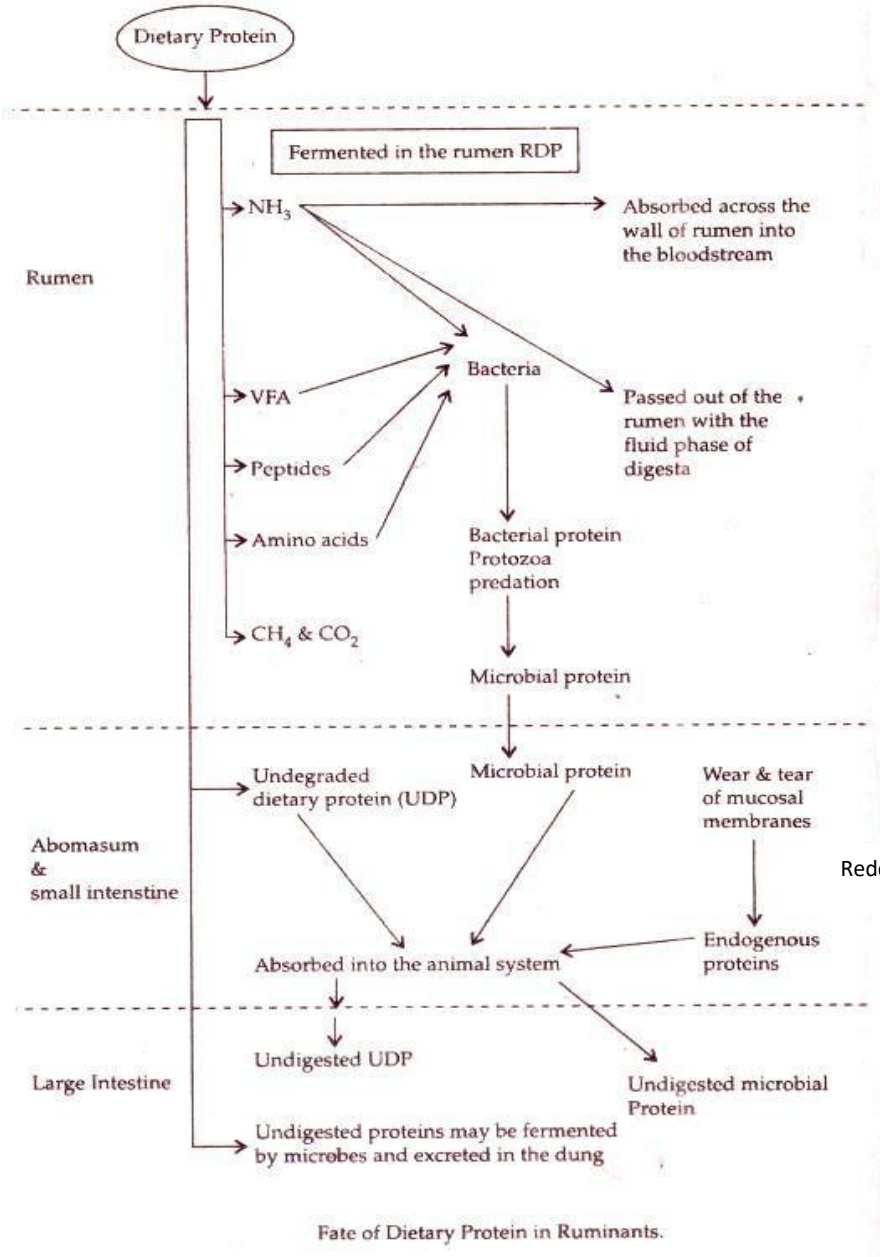
fatty acids the microbial proteins are synthesized by them. The ammonia in rumen liquour is the key intermediate in the microbial degradation of dietary protein and synthesis of microbial protein. Optimum ammonia concentration in rumen liquour is 5 to 30 mg/dL. Toxicity occurs if rumen ammonia level exceeds 80 mg/dL. Excess ammonia is absorbed into the blood, carried to the liver and converted to urea. Some of the urea may be returned to the rumen via the saliva, and also directly through the rumen wall, but the greater part is excreted in the urine. 80% of bacterial species existing in rumen can utilize ammonia as the sole source of nitrogen for growth while 26% bacteria requires it absolutely and 55% uses either ammonia or amino acids. Protozoa cannot use ammonia but derive their nitrogen by consuming bacteria and particulate matter. Rumen bacteria can also make use of NPN compounds and can upgrade the dietary protein of low biological values into microbial proteins of high biological values. The biological value of microbial protein is 80% (91% for protozoal protein and 74% for bacterial protein). The digestibility of protozoal protein is higher (88-90%) when compared to bacterial protein (66-75%). However, protozoal protein constitutes only 5-15% of total microbial protein flow from the rumen. The quality of microbial protein is inferior to animal proteins but is superior when compared to the protein of legumes (soybean, alfalfa leaf etc) and cereals. 200 g (90-230 g) of microbial protein is synthesized per kg of organic matter digested in the rumen or for each MJ of ME intake 7.8 g of microbial protein is synthesized if there is sufficient nitrogen in the diet. The rumen microbes continuously passes to the abomasum and small intestine, their cell proteins are then digested by the usual gastric enzymes of abomasum and pancreatic enzymes of the small intestine, and are absorbed as units of amino acids in the small intestine.

Metabolizable protein (NRC): That part of dietary protein un-degraded in the rumen and the microbial protein, which are absorbed by the host animal and is available for use at tissue level.

*Feeding of NPN compounds like urea to ruminants***:** The practice of feeding NPN compounds to ruminants originated in Germany. The common compound used is urea. Urea contains 46% N and the compound is 100% degradable in the rumen. 30% of the protein requirements of dairy cattle and buffaloes can be met by NPN compounds like urea. For efficient utilization of urea, simultaneous feeding of carbohydrate (1kg/every 100g urea) is a must for the sake of providing necessary energy requirement of the microbes. As rich source of carbohydrate, for urea feeding starch is the best when compared to molasses and cellulose. The rate of fermentation of molasses is too rapid, while that of starch is fairly rapid and for cellulose it is slow. Urea can be added at the rate of 3% in concentrate mixture (BIS specification is 1%), 0.5% in silage and at the rate of 1% in total ration. Urea has no benefits in diets containing over 13% protein as bacteria are unable to use ammonia effectively if rumen ammonia concentration exceeds 5-8 mg/dL, a level generated by 13% protein in diet.

Bypass protein**:** Bypass protein means rumen un degradable protein. In normal ruminant diet 60% of the dietary protein is degraded in the rumen and rest 40% is un degraded.

By protecting the good quality dietary protein from ruminal degradation it is possible to provide greater amounts of essential amino acids to the host ruminant. Methods employed for protein protection are heat treatment, treatment of proteins with tannins and treatment with formaldehyde.

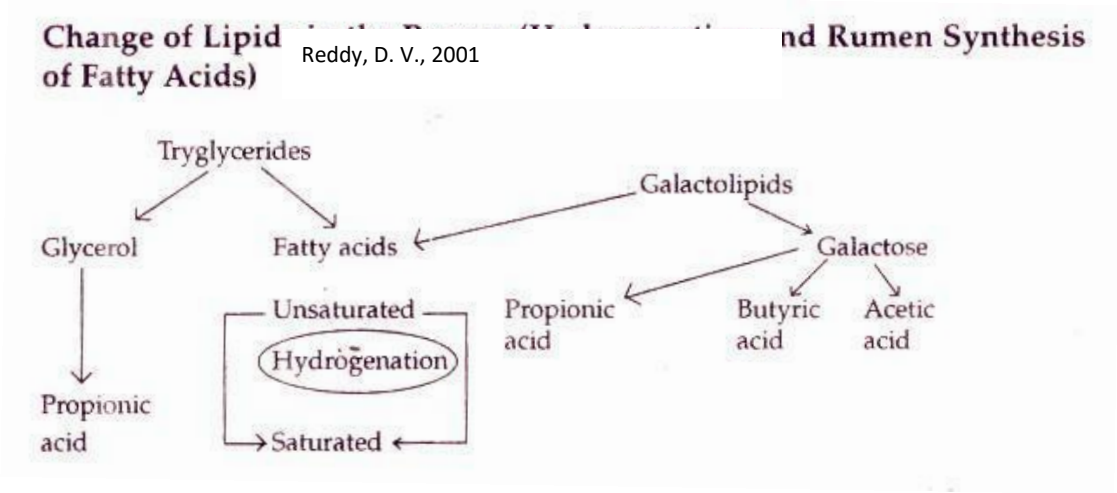


Fate of Dietary Protein in Ruminants.

Reddy, D. V., 2001

Lipids: young ruminants (calf, lamb, kid etc) have a lipid digesting enzyme named pre-gastric esterase, produced at the base of the tongue, which initiates the lipid digestion in the mouth itself. Later part of digestion of milk fat by young ruminants is similar to monogastric animals. The lipid content of an average adult ruminant diet is 3-5% on dry matter basis. Fat in the diet of adult ruminant chiefly consist of triglycerides (in cereal grains and oil seed cakes) and galactolipids (in forage). In rumen by the action of microbial lipases the dietary fat is

broken down to free fatty acids, glycerol and galactose. Glycerol and galactose are fermented in rumen to volatile fatty acids. The free fatty acids liberated are chiefly long chain unsaturated fatty acids like linoleic acid and linolenic acid. The short chain fatty acids are directly absorbed from rumen while the long chain unsaturated fatty acids undergo hydrogenation in the rumen and are converted to saturated fatty acids (chiefly stearic acid). Micelle formation by these fatty acids chiefly occurs in upper intestine, under the influence of bile salts, ingested phospholipids and biliary phospholipids. Absorption of micelle formed occurs in the jejunum. Re-synthesis of lipids takes place in the intestinal mucosal cells after their absorption. The newly synthesized lipids are usually different from those consumed in the diet. The re-synthesised lipids are put together as lipid droplets and surrounded by a thin layer consisting of mostly lipoproteins and phospholipids (75% as VLDL and 25% as chylomicrons -*vice versa in non ruminants*). Rumen microbes also synthesize considerable quantities of lipids which contain some unusual fatty acids (branched chain with odd number of carbon atoms) and these are absorbed and eventually incorporated in the milk and body fat of ruminants.



ABSORPTION OF NUTRIENTS

Carbohydrates: the principal monosaccharides produced by the digestion of carbohydrates are glucose, fructose and galactose. Of these, glucose accounts for nearly 80% of the total. Absorption of monosaccharides mostly takes place in the upper jejunum. Among monosaccharides galactose is most efficiently absorbed followed by glucose, fructose, mannose, xylose and arabinose. Glucose is transported into the intestinal mucosal cells by a carrier mediated and energy requiring process. Glucose and sodium share the same transport system i.e. when sodium diffuses into the cell it drags a glucose molecule along with it. However, the re-entry of sodium back into the intestinal lumen is an energy requiring active process. The enzyme Na^+- K^+ ATP ase is involved in the transport of sodium in exchange of

potassium against the concentration gradient. Once within the mucosal cell, glucose is transported into the capillaries by a facilitated passive diffusion. The mechanism of absorption of galactose is similar to glucose. Fructose absorption is relatively simple and doesn't require energy and is independent of sodium transport. Fructose is transported by facilitated diffusion mediated by a carrier and inside the epithelial cell it is converted to glucose. Pentoses are absorbed by simple diffusion.

Lactose intolerance: deficiency of the enzyme lactase or β galactosidase in human beings causes flatulence on consumption of milk or dairy products.

Proteins: free amino acids, dipeptides and to some extent tripeptides are absorbed by intestinal epithelial cells. The di- and tri peptides after absorption are hydrolysed into free amino acids in the cytosol of epithelial cells. L amino acids are more rapidly absorbed than D amino acids. The transport of L amino acids occurs by an active process against concentration gradient in contrast D amino acids are absorbed by simple diffusion (i.e. dependent on concentration gradient). At least 6 transport systems responsible for the absorption of amino acids have been identified. Amino acids are primarily absorbed by a similar mechanism, as described for the transport of D glucose (Na^+ dependent active process). A Na^+ independent system of amino acid absorption has also been identified. Another transport system is the *γ glutamyl cycle* or *meister cycle*. It involves a tripeptide namely glutathione or γ glutamylcysteinylglycine. In this system 3 ATP molecules are required for the absorption of an amino acid transferred to glutathione.

For a short period immediately after birth, the small intestine is capable of absorbing intact proteins by a process known as endocytosis or pinocytosis. This is very important for the transfer of maternal immunoglobulins to the offspring.

Lipids: in the small intestine by the action of pancreatic lipase, phospholipase and cholesteryl esterase the lipids are converted to monoacyl glycerols, free fatty acids, glycerol and cholesterol. Bile salts form mixed micelles with lipids (monoacyl glycerols, free fatty acids, glycerol and cholesterol) i.e. lipids at the interior and bile salts at the periphery. Lipid components of the micelle are absorbed through the plasma membrane of the intestinal mucosal cell by diffusion. Absorption is complete for slightly water soluble lipids like monoacyl glycerols and free fatty acids. However, for water insoluble lipids, the absorption is incomplete (less than 40% for dietary cholesterol). Among fatty acids, short and medium chain fatty acids are not dependent on micelle formation for the absorption. Micelle formation is essential for the absorption of fat soluble vitamins.

Re-synthesis of lipids takes place in the intestinal mucosal cells after their absorption. The short and medium chain fatty acids do not undergo any modification. They enter portal circulation, bind with albumin and are transported to the liver. The long chain fatty acids are activated by thiokinase (fatty acyl CoA synthetase) in the intestinal cells. The acyl CoA derivatives of fatty acids thus formed (Fatty acyl CoA) combines with monoacylglycerols to

produce triacylglycerols (reaction is catalysed by acyl transferases). Within the intestinal cells, cholesterol is converted to cholestrylester and phospholipids are regenerated from absorbed lysophospholipids. The newly synthesized lipids are usually different from those consumed in the diet. The re-synthesised lipids are put together as lipid droplets and surrounded by a thin layer consisting of mostly apolipoproteins and phospholipids. These particles are known as chylomicrons. They are released into lymphatic vessels by exocytosis. They enter the blood via the thoracic duct.

Nucleic acids: Digestion of nucleic acids takes place in small intestine, by the enzymes of pancreatic juice (ribonuclease and deoxyribonuclease). The enzymes hydrolyse DNA and RNA to oligonucleotides. Oligonucleotides are degraded to mononucleotides by phosphodiesterases. Nucleotidases act on nucleotides to liberate phosphate and nucleosides. Nucleosides may be either directly absorbed or degraded to free bases before absorption.

VITAMINS

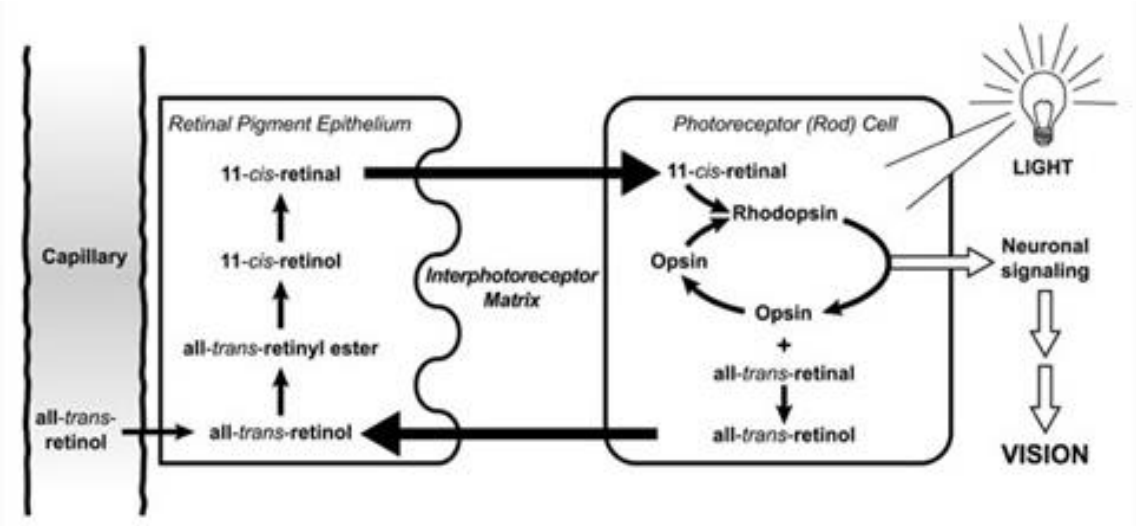
Vitamins are regarded as organic compounds required in the diet in small amounts to perform specific biological functions within the body. The term vitamin was coined by Casimir Funk. Vitamins can be classified into fat soluble vitamins and water soluble vitamins. Fat soluble vitamins include vitamin A, D, E and K. Their availability in the diet, absorption and transport are associated with fat. Water soluble vitamins include the B complex vitamins and vitamin C. Chemically fat soluble vitamins are made of carbon, hydrogen and oxygen while the water soluble vitamins, in addition to these elements contains either nitrogen, sulphur or cobalt. In feeds, fat soluble vitamins exist as pro vitamins while water soluble vitamins exist in pure forms. Water soluble vitamins are relatively non toxic while excess of fat soluble vitamins causes toxicity. The route of excretion of fat soluble vitamins is feces while the water soluble vitamins are chiefly excreted through urine.

FAT SOLUBLE VITAMINS

Vitamin A (Anti infective vitamin): in green plants it occurs as the precursor βcarotene or provitamin A. Among the carotenoid pigments (carotenes and xanthophylls) β carotene have the highest vitamin A activity. Conversion of β carotene to vitamin A can occur in the liver and in the intestinal mucosa. β carotene 15, 15 dioxygenase cleaves 1 molecule of β carotene to two molecules of retinaldehyde while the retinaldehyde reductase converts retinaldehyde to retinol. The cleavage enzyme β carotene 15, 15 dioxygenase is absent in cat and mink and hence these species cannot convert β carotene to vitamin A. Carotene present in feeds is cleaved completely to vitamin A in the intestine of pig, buffalo, goat, sheep, dog, rat, rabbit, donkey and zebra. However, cattle, man, horse and carp can also absorb carotene as such resulting in yellow coloured milk fat and body fat in these species. From the structure of β carotene, it would appear that 1 molecule of carotene would be split into 2 molecules of vitamin A. However, in physiological systems, this 2: 1 conversion ratio has not been demonstrated. Efficiency of conversion of carotene to vitamin A is low for ruminants when compared to poultry. Unlike carotene, vitamin A occurs only in animal kingdom and is a colourless compound. Fish oils like halibut liver oil and sword fish liver oil are concentrated sources of Vitamin A. Mc Collum and Davis & Osborne and Mendel independently proved the occurrence and specific physiological function of Vitamin A. Chemically vitamin A has a β ionone ring and an unsaturated side chain. Vitamin A can exist as alcohol (retinol) or aldehyde (retinal) or as acid (retinoic acid). Except for vision and reproduction, retinoic acid carries out all the functions of vitamin A. 1 International Unit of vitamin A is defined as the activity of 0.3µg of crystalline retinol or 0.6µg of β carotene. All animals need vitamin A or its precursor in the diet. Both carotene and vitamin A are destroyed by oxidation during storage especially at high

temperature. Large lose of carotene occurs while curing of roughages and in their later storage. The destruction is partly enzymatic and partly photochemical. However, cooking does not cause much harm to the potency of this vitamin.

Vitamin A is essential for normal vision. It is combined with a protein in visual purple. Visual purple/ rhodopsin is a compound that breaks down in the physiological process of sight as a result of photochemical reaction.



Rhodopsin cycle or Walds visual cycle

Vitamin A also plays important role in combating infection through maintenance of normal epithelia and it has been termed the *anti infective vitamin.* Vitamin A is essential for normal bone growth by controlling the activity of osteoblasts and osteoclasts. It also plays a role in the synthesis of mucopolysaccharides which are prosthetic groups in glycoproteins or mucoproteins present in cartilage and mucous epithelium. Chlorinated naphthalene, found in lubricating oils, interferes with the metabolism of Vitamin A.

Deficiency conditions of vitamin A includes

a) Nightblindness/ nyctalopia

b) Xeropthalmia/ dry eye: symptoms are dry cornea and conjunctiva, cloudiness and ulceration. It occurs in dog, fox, rat and children. In children, during this condition, white triangular plaques known as Bitot's spots are seen in certain areas of conjunctiva. If xerophthalmia persists for long time, corneal ulceration aggravates and degeneration occurs resulting in the destruction of cornea and the condition is termed *keratomalacia*. In poultry it is known as *nutritional roup* characterized by mucopurulent rhinitis and occlusion of respiratory tract, xeropthalmia and keratomalacia.

c) Copius lacrimation: most prominent symptom in cattle and horse

d) Sticking of eyelids: seen in chicken. Secretion of tear gland dry up, infection occurs and sticky discharge is produced.

e) Keratinisation of epithelium: during deficiency, normal epithelium is replaced by stratified keratinized epithelium. Differentiation of the epithelium for performing their normal function is hindered. Trouble encountered due to keratinization of epithelia are

1) Lowered resistance to the entrance of infective organisms
2) Diarrhea occurs when gastro intestinal epithelium are involved
3) Kidney and bladder stones occur when the epithelium of urinary tract is keratinized.
4) Reproductive disorders in male and female occurs when germinal epithelia are affected
5) Elevated CSF pressure occurs when there is decreased absorption of cerebrospinal fluid due to keratinization of epithelium

f) Bone abnormalities: In calves blindness occurs due to constriction of optic nerve caused by narrowing of the bone canal through which the nerves passes. In dogs deafness occurs due to such injury to auditory nerve. Muscle incoordination and nervous symptoms shown by vitamin A deficient cattle, sheep and swine is due to bone changes.

Vitamin D (Antirachitic factor/ Sunshine vitamin): this vitamin was named by Mc Collum. In plants it exists as ergocalciferol/ vitamin D_2 (formed from the exposure of ergosterol to sunlight) and in animals as cholicalceferol/ vitamin D_3 (formed from the exposure of 7 dehydrocholesterol to sunlinght). Both these forms have the same value in most of the species (cattle, sheep, goat, pigs etc), while D_3 is more effective for poultry. This is because of the fact that chick catabolizes vitamin D_2 much more rapidly than D_3. Thus vitamin D requirement for avian species are expressed as international chick units (1 ICU = 0.025µg of vitamin D_3). 7 dehydrocholesterol is formed as an intermediate in the body during cholesterol biosynthesis. Therefore, animals in pasture exposed to sunlight will not suffer from vitamin D deficiency in summer months. Dark pigmented and hairy skin adversely affects the synthesis of cholecalceferol. After absorption, vitamin D_3/ cholicalceferol is converted to 25 hydroxycholecalceferol in the liver. It is then converted to 1, 25 dihydroxycholecalciferol in the kidney by the enzyme 1α hydroxylase. This is the physiologically active form of this vitamin. It stimulates the synthesis of calcium binding protein involved in calcium absorption from the intestine. The action of 1, 25 dihydroxycholecalceferol resembles that of steroid hormones. Since it has 3 hydroxy group it is also called calcitriol. Hydroxylation reaction taking place in the kidney is the important control point in the activity of vitamin D. Actinomycin D inhibits the action of calcitriol. Hypocalcemia or vitamin D deficiency increases the activity of 1α hydroxylase in the kidney. Role of vitamin D is more pronounced when the amount of either calcium or phosphorus or the ratio between them is sub optimum in the diet. It regulates the plasma levels of calcium and phosphorus by regulating at three different levels (intestine, kidney and bone). Deficiency of vitamin D can cause demineralization of bones resulting in rickets in children and osteomalacia in adults because of interrelationship between calcium,

phosphorus and vitamin D. First symptom noted in fast growing animals and chicks during vitamin D deficiency is retarded growth and decreased feed consumption. In poultry, prolonged deficiency of vitamin D causes decreased egg production, decreased hatchability, production of thin shelled eggs and penguin like squat. Egg, milk, cod liver oil and other fish liver oils are good sources of vitamin D. Cured and well preserved hays has considerable amounts of vitamin D. Seeds and their byproducts are practically devoid of this vitamin. Vitamin D toxicity causes hypercalcemia, calcinosis (deposition of calcium in soft tissues and blood vessels) and bone abnormalities. Certain plants of family solanacea (*Cestrum diurnum, Solanum malacoxylon* etc) have 1, 25 dihydroxycholicalceferol activity leading to toxicity.

Vitamin E (Antisterility vitamin): this vitamin was named by Evans, who isolated it from wheat germ oil. In nature it exists as tocopherols and tocotrienols. Tocopherols are derivatives of 6 hydroxy chromane ring with isoprenoid side chain. Most biologically active and widely distributed form of vitamin E is α tocopherol. 1 IU of vitamin E is equal to 1 mg of α tocopheryl acetate. In body it functions as a chain breaking antioxidant, there by neutralizing free radicals and preventing peroxidation of polyunsaturated fatty acids (PUFA) within the membranes. If the PUFA in cell membranes undergo peroxidation, the structural integrity of the cells is lost and this results in metabolic derangements. In nature the synthesis of vitamin E is a function of plants. Commonly fed rations are able to meet the demand of this vitamin for farm animals. It is abundant in all cereal grains particularly in the germ and in byproducts containing germ. Most concentrated natural source of vitamin E is wheat germ oil. Forages and hay are good sources of this vitamin. Animal byproducts and milk are poor sources while egg yolk is a rich source. Vitamin E content of egg is proportional to its content in layer diet. Ground feeds has less vitamin E due to oxidative damage. Among fat soluble vitamins it is considered as relatively non toxic. Deficiency of this vitamin causes testicular degeneration in dogs, pigs, rabbits, rats, hamsters, roosters and fishes. During deficiency, birth of weak offspring's or fetal death is observed in rats, mice, guinea pigs and hamsters. Since it is essential for normal reproduction in many species, it is termed as *antisterility vitamin*. However, vitamin E has no role in the fertility of male mouse, cattle, sheep and goat. Deficiency of vitamin E causes dystrophy of skeletal muscles. The condition is common in lambs (*stiff lamb disease*) and calves (*white muscle disease*). Muscular dystrophy in lambs and calves can be prevented by administering either vitamin E or selenium. In chicks muscular dystrophy can be alleviated by supplementing vitamin E, selenium or sulphur containing amino acids. In turkey poults vitamin E or selenium deficiency causes *gizzard myopathy.* Chronic vitamin E deficiency causes injury to heart muscles of livestock, pig and poultry (e.g. *mulberry heart disease* in pigs). Vitamin E deficiency in chicks causes *nutritional encephalomalacia/ crazy chick disease*, characterized by uncoordinated gait, prostration and brain lesions. This condition cannot be cured by supplementing selenium and can be prevented only by vitamin E supplementation. Nutritional encephalomalacia is noticed in rabbits and guinea pigs without CNS changes and in rats with muscular and CNS changes.

Deficiency conditions like *exudative diathesis/ haemorrhagic disease* of chicks and *dietary liver necrosis* in rats and pigs can be prevented by either vitamin E or selenium. Haemolytic anemia is a basic effect of vitamin E deficiency. *Steatitis/ yellow fat disease* is a vitamin E deficiency disease observed in cats, minks and reptiles. This occurs when high levels of polyunsaturated fatty acids are fed with low level of vitamin E leading to deposition of ceroid pigment in adipose tissue with fat cell necrosis and subsequent inflammation.

Vitamin K: this vitamin was identified by Dam in 1935 as a factor present in green leaves which prevented haemorrhagic syndrome observed in chicks maintained on low fat diets. It is essential for normal coagulation as it is needed in the synthesis of clotting factors ii, vii, ix & x. Vitamin K converts prothrombin to thrombin by carboxylation of glutamic acid residues. Vitamin K is structurally related to ubiquinones, the components of mitochondrial electron transport chain and is believed to be involved in oxidative phosphorylation. In plants it exists as vitamin K_1 or phylloquinone and in animals/ intestinal bacteria as vitamin K_2 or menaquinone. Synthetic form of vitamin K is menadione. Warfarin and sulfaquinoxalene are synthetic analogues that can inhibit vitamin K action. Dicoumarol is the antimetabolite of vitamin K. Coumarin present in spoiled (mouldy) sweat clover gets metabolized to dicoumarol within the body. Therefore, feeding of spoiled sweat clover causes bleeding disease (haemorrhagic sweat clover disease) in ruminants. The deficiency of vitamin K is uncommon, since it is present in the diet in sufficient quantity and is adequately synthesized by the intestinal bacteria. There is no need for giving any special consideration to the vitamin K content of the ration of farm animals except in the case of poultry. The chicken does not have the type of microflora necessary to synthesize adequate amount of vitamin K. Vitamin K deficient chicken may bleed to death from a very slight bruise or injury. NRC recommends 0.53 mg vitamin K/kg feed for chicks. All leaves (fresh or dry) and animal protein sources like liver, egg, milk, fishmeal etc are good sources of vitamin K.

WATER SOLUBLE VITAMINS

Thiamine (Vitamin B_1/Antinueritic factor/ Aneurine/ vitamin F): Eijkmann proved the role of thiamine in preventing *polyneuritis* in birds. Chemically it is a molecule of pyridine linked by a methylene bridge to a molecule of thiazole. 1 IU of thiamine is considered as the biological activity of 3µg of pure thiamine hydrochloride. Richest source of thiamine is brewers yeast. Thiamine is present primarily in germ and seed coats of cereals. Wheat germ is considered as the 2nd richest source of thiamine. Animal sources like lean pork, liver, kidney and egg yolk are rich sources of thiamine. Milk is not a rich source and pasteurization destroys this vitamin. Thiamine in the diet is absorbed from the small intestine and it is taken to liver. In liver thiamine is phosphorylated to thiamine pyrophosphate (TPP). Excess intake of thiamine increases its blood level, but is not stored and is readily excreted in urine. However, as an exception, tissues of pigs contains several times as much thiamine than other animals and pigs

has a store that can meet body needs on a thiamine deficient diet for as long as two months.. This vitamin is needed in metabolism of both plants and animals. In cells thiamine function as coenzyme TPP or cocarboxylase which is needed for decarboxylation of α keto acids. In carbohydrate metabolism thiamine plays very important role in the decarboxylation of pyruvate to Acetyl CoA as a coenzyme for the enzyme pyruvate dehydrogenase. Therefore, during thiamine deficiency, pyruvic acid and lactic acid accumulate in the blood and tissues giving rise to deficiency symptoms. TPP plays an important role in the transmission of nerve impulse. It is believed that TPP is required for acetyl choline synthesis and in the ion translocation of neural tissue. Since thiamine has important role in energy metabolism, its requirement by the body bears direct relation to energy intake. There is large requirement of thiamine for lactation than for growth because of the increased metabolism involved. Beriberi and polyneuritis are later stages of thiamine deficiency which is due to accumulation of intermediates of carbohydrate metabolism (pyruvate and lactate) or due to lack of membrane permeability of nerves. Thiamine deficiency causes marked decrease in growth, mainly because of decreased appetite. During thiamine deficiency the transketolase activity in the erythrocytes is decreased. Transketolase reaction is a key reaction in the metabolism of pentose sugars in the pentose phosphate pathway. Measurement of RBC transketolase activity is a reliable diagnostic test to assess thiamine deficiency. In fox, thiamine deficiency causes a condition called *chastek paralysis*. Symptoms in animals termed *polyneuritis* are particularly characterized by unthriftiness, paralysis and convulsions and in birds there is a characteristic paralysis of the neck muscles which causes the head to be drawn back against the back of the bird so that the beak is pointed straight up in a star gazing attitude. In human beings thiamine deficiency conditions include *beri-beri* (seen in populations consuming exclusively polished rice as staple food) and *Wernicke-korsakoff syndrome* (disorder seen in chronic alcoholics). Like other B vitamins, thiamine is not dietary essential for ruminants, but thiamine deficiency can occur in lambs and calves without a functional rumen and also in adult ruminants under certain conditions. *Polioencephalomalacia* (PEM) or *cerbrocortical necrosis* is a thiamine deficiency condition seen in adult ruminants. The exact cause of the deficiency is unknown however; the disease generally occurs in animals fed diets high in soluble carbohydrates and low in fibre. Excess of sulphate (gypsum) in feed/ water induces PEM because sulphate gets converted to sulphite in rumen, which destroys thiamine. Normally, pyruvate does not cross the blood brain barrier and enter the brain. However, in thiamine deficiency, an alteration occurs in the blood brain barrier permitting the pyruvate to enter the brain directly. Diffuse encephalopathy occur characterized by brain oedema and swelling. Symptoms of PEM includes listlessness, circling, muscular incoordination, opisthotonous posture (drawing the head back over the shoulder), head pressing, progressing to blindness, convulsions and death. Experimentally this condition can be produced by giving large doses of anti thiamine compounds like amprolium.

Antimetabolites of thiamine include:

1. Amprolium: it is a coccidiostat used in poultry
2. Pyrithiamine: it has some structural relationship with thiamine.
3. Oxythiamine
4. Thiaminase: it is found in raw fish. This enzyme splits thiamine molecule into 2 components and makes it inactive. Thiamine deficiency has been reported in penguin, seals and dolphins fed diets primarily of fish in zoos. Wild aquatic animals do not suffer from thiamine deficiency because the fish must undergo some putrefaction to release this enzyme.
5. Bracken fern (*Pterydium aquilinium*) poisoning in horses is by causing thiamine deficiency. Fern has an anti thiamine substance of non enzymic nature similar to pyrithiamine
6. 3-5 dimethyl salicylic acid found in cotton seed and caffeic acid is a naturally occurring antithiamine factor.

Riboflavin (vitamin B_2/ vitamin G): Chemically it is 6,7-dimethyl iso alloxazine nucleus joined with alcohol of ribose (D ribitol). Riboflavin was the first B complex vitamin that was isolated in pure state. Occur as orange yellow crystals. It has a protein and a yellow pigment. When exposed to UV rays of sunlight it is converted to lumiflavin. All animals except ruminants depend on plants for this vitamin. Yeast is the richest natural source of this vitamin. Leaves are rich sources of riboflavin while cereals and their by products are poor sources. Oil seed cakes are fair sources of vitamin B_2. Commercially riboflavin is prepared from whey and distillers soluble. Like other B vitamins, ruminants depend on rumen microflora for this vitamin. During absorption, riboflavin is phosphorylated in the intestinal wall and carried by the blood to the cells of tissues where it occurs as the phosphate or as flavoprotein. Lactochrome/ lactoflavin is a greenish yellow fluorescent pigment found in milk and whey. In liver it occurs as hepatoflavin and in egg as ovoflavin. Riboflavin is essential for carbohydrate, protein, lipid and purine metabolism of all animals since it functions as coenzymes flavin mono nucleotide (FMN) and flavin adenine dinucleotide (FAD). FMN is a constituent of L amino acid oxidase, lactate dehydrogenase and Warburgs yellow enzyme. FAD is a constituent of succinate dehydrogenase, D amino acid oxidase, glycine oxidase, histaminases and xanthine oxidase. Decreased rate of growth and lowered feed efficiency are the common symptoms of riboflavin deficiency in all species. Riboflavin deficiency causes *curled toe paralysis* in chicks. Chicks walk on hocks with toe curled inward and paralysed legs. Paralysis occurs due to swelling and softening of sciatic and branchial nerves. In laying birds, deficiency of this vitamin causes lowered egg production and poor hatchability. *Clubbed down condition* of chick embryo occurs when there is deficiency of this vitamin in breeder diets. In swine the deficiency conditions include crooked and stiff legs, thickened skin, skin eruptions, exudates over back and sides and lens opacity/cataract. In human beings deficiency affects skin and eye functions. Cheilosis (with furrows and fissures around mouth), glossitis and dermatitis occur during deficiency. Galactoflavin is an antimetabolite of riboflavin.

Niacin (pellagra preventive factor of Gold berg/ Vitamin B_3): it is a derivative of pyridine (pyridine 3 carboxylic acid). Animal and fish byproducts, distiller's grain, yeast and oil meals are good sources of niacin. Green grass and leaves are fair sources while milk, fruits and egg are poor sources. Niacin is absorbed through intestine and a little is stored in liver. In monogastrics like dogs, pigs and rat the excretory products in urine are methylated metabolites (N methyl nicotinamide and N methyl 2 pyridone 5 carboxylamide). In herbivores, niacin is not metabolized by methylation and large amounts are excreted unchanged. In poultry the excretory product is dinicotinyl ornithine. Nicotinamide (amide form of niacin) is the active form of this vitamin. It functions as a component of two coenzymes namely nicotinamide adenine dinucleotide (NAD or coenzyme I) and nicotinamide adenine dinucleotide phosphate (NADP or coenzyme II). NAD and NADP resemble each other in structure but they are never interchangeable. A large number of enzymes belonging to the class oxidoreductases are dependent on NAD or NADP. NAD^+ plays important role in electron transport chain as the electron acceptor in three of the four dehydrogenation steps. NAD^+ is involved in the functioning of dehydrogenase enzyme involved in carbohydrate metabolism (glyceraldehydes 3 phosphate dehydrogenase, lactate dehydrogenase, pyruvate dehydrogenase complex and α ketoglutarate dehydrogenase complex), lipid metabolism (β hydroxyacyl CoA dehydrogenase, β hydroxybutyrate dehydrogenase and alcohol dehydrogenase) and protein metabolism (branched chain α ketoacid dehydrogenase and tyramine dehydrogenase). $NADP^+$ is specific for glucose 6 phosphate dehydrogenase and the malic enzyme (involved in the conversion of malate to pyruvate). Enzymes like glutamate dehydrogenase and isocitrate dehydrogenase are dependent either on NAD^+ or $NADP^+$. The reducing equivalents for fatty acid synthesis are provided by NADPH which come either from citrate transport (Acetyl CoA is converted to citrate for its transport from mitochondria to cytoplasm for fatty acid synthesis) or hexose monophosphate shunt. Some of the NADPH dependent enzymes are 3 ketoacyl reductase, HMG CoA reductase, squalene epoxidase, cholesterol 7α hydroxylase, phenylalanine hydroxylase and dihydrofolate reductase. Nicotinamide was first isolated from NADP. In body niacin can be synthesized from the amino acid tryptophan in all species except cats and mink. Cats and mink has increased activity of enzyme picolinic carboxylase the enzyme catalyzing the first step of the degradative pathway of tryptophan to Acetyl CoA and carbondioxide. On an average 1g of good quality protein containing about 60 mg of tryptophan is equivalent to 1mg of niacin for human beings. Thiamine, riboflavin and pyridoxine are involved in various steps for the synthesis of niacin from tryptophan.

Deficiency of this vitamin causes *pellagra* in human beings and *black tongue* in dogs. Elvehjem proved the role of niacin in curing black tongue. Pellagra is characterized by fiery red tongue, ulcers in mouth, dermatitis, loss of appetite, diarrhoea and nausea. The symptoms of pellagra are commonly referred to as three D's (dermatitis, diarrhea and dementia). A similar

condition also occurs in pigs (pig pellagra) and chicken (similar to black tongue). Pellagra may also be mediated through an amino acid imbalance. High corn diet increases the niacin needs for monogastric animals like rat, pig and poultry. The pellagrogenic effect of corn is due to its low content in tryptophan and the presence of niacin in bound form. Amino acid imbalance caused by excess leucine in feeds like jowar or corn can lead to niacin deficiency. Niacin deficiency causes hock disorders in ducks and turkey poults. The requirement of niacin for ducks is high when compared to chicken is probably due to relatively high picolinic carboxylase activity. Pyridine 3 sulfonic acid and N acetyl pyridine are the anti vitamins of niacin. Niacin is relatively non toxic, but massive doses causes' vascular dilatation or flushing with burning sensation.

Pyridoxine (vitamin B_6/ Adermin/ Factor I/ Antidermatitis factor/ Rat acrodynia factor/ Vitamin H/ Yeast eluate factor): name pyridoxine was proposed by Gyorgy. Vitamin B_6 represents three compounds namely pyridoxine, pyridoxal and pyridoxamine. The active form of this vitamin is pyridoxal phosphate (PLP). PLP is closely associated with the absorption and metabolism of amino acids (transamination, decarboxylation, deamination etc). The synthesis of certain specialized products such as serotonin, histamine, GABA, catacholamines and niacin coenzymes from the amino acids is dependent on pyridoxine. Synthesis of serine from glycine and the transulfuration reaction involved in the synthesis of cysteine is dependent on PLP. Enzyme glycogen phosphorylase involved in glycogenolysis needs PLP for its functioning. PLP is essential for the synthesis of sphingolipids, synthesis of δ aminolevulinic acid (haeme precursor) and in the formation of CoA from pantothenic acid. Pyridoxine intake is useful in preventing kidney stones and pyridoxine is believed to be involved in immune function and in the utilization of unsaturated fatty acids. Pyridoxine is involved in the complete metabolism of tryptophan, otherwise an abnormal metabolites xanthurenic acid and kynurenic acid is formed and excreted. Level of xanthurenic acid excretion has been used as an indicator of B_6 nutrition. Deficiency of pyridoxine causes *acrodynia* (dermatitis) and reproductive abnormalities in rats. Vitamin B_6 deficiency will not occur in farm animals in commonly fed rations. Pyridoxine deficiency if occurred causes slow growth, lowered production and convulsions in all species. In pigs and dogs pyridoxine deficiency causes slow growth, microcytic hypochromic anemia, convulsions nerve degeneration and haemosiderosis. In chicks pyridoxine deficiency causes abnormal excitability, aimless movements, convulsions followed by complete exhaustion and lowered growth and egg production. Pyridoxine antagonist/antimetabolites include desoxypyridoxine, methoxypyridoxine and isoniazid (a drug used in treatment of tuberculosis).

Biotin (coenzyme R/ anti egg white injury factor/ protective factor/ factor H/ vitamin B_7)**:** chemically it is a monocarboxylic acid (2 keto 3-4 imidazilido 2 tetra hydro thiophene-n-valeric acid). Biotin is widely distributed in plants and animals. There is substantial synthesis of biotin in the intestine of all species. Avidin/ avidalbumin/ egg white injury factor binds biotin and make it unavailable for absorption in the intestine. Avidin is a protein found in raw egg which is

a secretory product of the mucosa of the oviduct and thus found in the albuminous parts of egg. Certain *Streptomyces* species of bacteria present in soil produce streptavidin and starvidin which have avidin like activity. Biotin is involved in carbondioxide fixation/ carboxylation reactions. In biological system there are a few carboxylation reactions that do not require biotin (carbamoyl phosphate formation in urea cycle and carboxylation reaction in purine synthesis). Enzymes like propionyl CoA carboxylase (conversion of propionyl CoA to methyl malonyl CoA), pyruvate carboxylase (coversion of pyruvate to oxaloacetate in gluconeogenesis and citric acid cycle) and Acetyl CoA carboxylase (fatty acid synthesis) are biotin dependent. Biotin plays significant role in fatty acid synthesis as it is involved in the addition of carbondioxide to Acetyl CoA resulting in the formation of Malonyl CoA. A decrease in the enzyme propionyl CoA carboxylase is considered as the indicator for biotin deficiency. Biotin is also involved in the deamination of amino acids by bacteria. Biotin is covalently bound with ε-amino group of lysine to form biocytin in the enzymes. Destruction of intestinal flora due to prolonged use of drugs such as sulfonamides or high consumption of raw eggs can cause biotin deficiency. Symptoms of biotin deficiency are dermatitis, loss of hair/ feathers and poor growth. In rats, biotin deficiency causes *spectacle eye* (peculiar alopecia) and achromotrichia. In poultry, along with manganese, choline and folic acid, biotin is involved in preventing *perosis/ slipped tendon*. Biotin deficient diets to breeder poultry, lowers hatchability and causes malformations in late embryos. Malformations include shortening and twisting of legs, feets & wings and the beak becomes crooked (*parrot beak*). In pigs, biotin deficiency causes spasticity of hind legs, cracks in feet (*cracked feet*) and dermatitis characterized by dryness, roughness and brownish exudates. Biotin antagonists includes desthiobiotin and biotin sulphonic acid.

Pantothenic acid (filtrate factor, B_5): chemically it is β alanine joined by peptide linkage with pantoic acid (2, 4 dihydroxy 3-3 dimethyl butyric acid). The word pantothenic acid means universal/ from every where. Intestinal synthesis of this vitamin occurs in all species, especially in rabbits and horse it almost meet the body needs. It is present in almost all the feeds. Exceptionally rich sources of this vitamin are royal jelly of bees and ovaries of cod fish. Commercially available form of pantothenic acid is calcium pantothenate. Nearly 10% of the pantothenic acid is found in CoA (coenzyme for acetylation). CoA has pantothenic acid, adenosine 3 phosphate, pyrophosphate and β mercaptoethylamine (3 phospho adenosine 5 diphosphopantotheine). Combination of CoA with 2 carbon fractions (from fats, carbohydrates and certain amino acids) results in the formation of Acetyl CoA. Pantothenic acid is also a component of Acyl Carrier Protein (ACP) involved in fatty acid biosynthesis. Therefore, as a component of CoA and ACP, pantothenic acid is involved in various steps in the metabolism of nutrients (e.g. conversion of pyruvate to acetyl CoA, conversion of α ketoglutarate to Succinyl CoA, conversion of fatty acid to Acyl CoA etc). In some of the metabolic reactions, group transfer is important which occurs in a coenzyme A bound form (e.g. formation of acetyl choline from acetyl CoA and choline, formation of citrate from Acetyl CoA and oxaloacetate, formation

of acetoacetyl CoA from succinyl CoA and aceto acetate etc). Coenzyme A may be regarded as a coenzyme of metabolic integration, since acetyl CoA is a central molecule for wide variety of biochemical reactions as mentioned above and succinyl CoA is involved in many reactions including the synthesis of porphyrins of haeme. Deficiency of pantothenic acid causes growth and reproductive failure, skin and hair lesions, gastrointestinal symptoms and lesions of the nervous system. In chicken at initial stages of deficiency there is retardation of growth and feather development. It is followed by dermatitis characterized by granular eyelids which stick together. Scabs appear on mouth, vent and on feet. Deficiency causes pathological changes in spinal cord and liver. Prolonged deficiency in poultry results in low hatchability. In pigs the characteristic symptom of pantothenic acid deficiency is *goose stepping*. There is dermatitis with scurvy skin and thin hairs. Slow growth, brownish secretion around eyes and gastrointestinal troubles are also noticed. In foxes, dogs and rats, premature graying of hair occurs during deficiency of this vitamin. Bloody whiskers (accumulation of porphyrin from harderian gland on the whiskers) is noticed in rats during deficiency. In human beings, the deficiency symptoms include depression, reduced glucose tolerance, intestinal disorders and dermatitis with burning sensation of feet (*burning feet syndrome*).

Folic acid/ folacin (Antianaemia factor/ factor U/ vitamin M/ vitamin Bc/ Bc conjugate/ *Lactobacillus casei* factor/ SLR factor/ B_9): chemically folic acid is pteroyl glutamic acid (pteridine nucleus, glutamic acid and para aminobenzoic acid). It is yellow crystalline solid. Green leaves, cereals, legumes and animal products like meat are good sources of folic acid. However, milk is a poor source. Dietary folic acid exists as polyglutamate with 3-7 glutamate residues. It cannot be absorbed from intestine. The enzyme folate conjugase present in duodenum and jejunum splits the glutamate residues and the monoglutamate of folic acid is absorbed from the intestine. Folic acid has large number of biologically active forms when compared to other vitamins. The most common one is the coenzyme form namely tetra hydorofolic acid (THFA) which is synthesized from folic acid by the enzyme dihydrofolate reductase. The storage form is 5 methyl THFA. Folic acid is involved in the transfer of single carbon units. THFA serves as an acceptor or donor of one carbon units (formyl, formimino, methylene, methyl etc) in a variety of reactions involving amino acids and in nucleotide metabolism. The attachment of formyl group at position 5 of THFA give N^5 formyltetrahydrofolate which is commonly known as folinic acid or citrovorum factor. Folic acid is involved in the inter conversion of serine and glycine, purine synthesis, pyrimidine nucleotide-deoxythymidilic acid (dTMP) synthesis (involved in DNA synthesis), histidine degradation, synthesis of ethanolamine & choline and in the synthesis of N-Formyl methionine, the initiator of protein biosynthesis. THFA is mostly trapped as N^5 methyl THFA, the form in which it is present in the circulation. Vitamin B_{12} is needed in the conversion of N^5 methyl THFA to THFA, in a reaction wherein homocysteine is converted to methionine. Therefore, deficiency of folic acid affects purine biosynthesis resulting in deficiency of nucleoprotein formation for

blood cell maturation leading to anaemia. Enzymes which require folic acid for functioning are dihydrofolate reductase, thymidilate synthetase, glycine cleavage enzyme and many reductases and transferases. In rats and pigs, intestinal synthesis of folic acid is adequate to meet their needs but other species shows deficiency conditions like megaloblastic anemia (macrocytic hypochromic), bone marrow abnormalities and leucopenia. In chicks, folacin deficiency causes retarded growth, poor feathering and depigmentation of feathers. Poultry is the only farm animal that need a dietary source of folic acid and chick is the preferred animal for assaying feeds for folic acid. In human beings, folate deficiency is the most common type of hypovitaminosis observed primarily in the pregnant women. Lactating women, women on oral contraceptives and alcoholics are also susceptible to folate deficiency. Treatment with anticancer drugs like methotrexate (inhibits dihydrofolate reductase) will cause folic acid deficiency. In folic acid deficiency, there is decreased production of purines and dTMP thus impairing DNA synthesis. Due to block in DNA synthesis, the maturation of erythrocytes is slowed leading to macrocytic RBC. The macrocytic anemia with megaloblastic changes in bone marrow is a characteristic feature of folate deficiency. Folic acid is involved in the metabolism of histidine. In folic acid deficiency, formiminoglutamate (FIGLU) formed in histidine metabolism accumulates and is excreted in urine. Folic acid has interrelationships between other vitamins. Folic acid and vitamin B_{12} is involved in nucleic acid formation. Folic acid has sparing effect on choline requirement of rats and chicks due to increased synthesis of methyl groups. Vitamin C cures folic acid deficiency in rats. Folic acid also has relationship with riboflavin. Antivitamin of folacin is aminopterin (4 amino pteroyl glutamic acid) and amethopterin (methotrexate). They inhibit dihydrofolatereductase enzyme and is used in the treatment of many cancers including leukemia. Bacteria synthesizes folic acid from pteridine, PABA and glutamate. Antibiotics belonging to the group sulfonamides act by inhibiting the folic acid synthesis in bacteria. Sulfonamides are structural analogue of PABA. They competitively inhibit the enzyme dihydropteroate synthase which is responsible for the incorporation of PABA into pteridine nucleus to produce folic acid.

Vitamin B_{12} (cyanocobalamin/ antipernicious anemia factor/. Animal protein factor or APF/ chick growth factor/ cow manure factor/ zoopherin/ factor X/ lactobacillus lactis dorner): it is a unique vitamin, synthesized only by microorganisms and not by animals and plants. Vitamin B_{12} is never found in plants. Animals obtain cayanocobalamin/vitamin B_{12} either by eating foods derived from other animals or from the intestinal bacterial synthesis. Two similar compounds are hydroxocobalamin and nitrocobalamin. Vitamin B_{12} is not lost in cooking and is stable up to 250^0C. It was the last vitamin to be discovered. The structure of this vitamin consists of a corrin ring with a central cobalt atom. The corrin ring has four pyrrole units, just like a porphyrin. The dietary source of the vitamin (bound to proteins) is called as the extrinsic factor of Castle. The stomach secretes a special glycoprotein called intrinsic factor (IF). IF has been isolated from pigs, rats, guinea pigs and hamsters and not from ruminants and dog intestine. Binding of

vitamin B_{12} with intrinsic factor protects the vitamin against its uptake and use by bacteria. The cobalamin-IF complex is absorbed through ileal mucosal cells mediated by Ca^{2+} ions. In the mucosal cells B_{12} is converted to methylcobalamin. It is then transported in the circulation in a bound form to proteins namely transcobalamins. Methylcobalamin which is in excess is taken up by the liver, converted to deoxyadenosyl B_{12} and stored in this form. The two coenzyme forms of vitaminB_{12} are methyl cobalamin and 5 deoxyadenosyl cobalamin. In mammals two important reactions are dependent on vitamin B_{12}.

1. Methycobalamin is involved in the synthesis of methionine from homocysteine. Tetrahydrofolate is liberated during this step. Therefore, B_{12} deficiency results in decreased folate coenzymes that lead to reduced nucleotide and DNA synthesis. The outcome is the development of megaloblastic anaemia.
2. Methyl malonyl CoA is formed in the body during metabolism of odd chain fatty acids (e.g. propionic acid), metabolism of certain amino acids and in the degradation of pyrimidines. In the conversion of methylmalonyl CoA to succinyl CoA, B_{12} coenzyme deoxyadenosyl cobalamin is involved. Therefore, in B_{12} deficiency, methylmalonyl CoA accumulates and is excreted in urine as methyl malonic acid.

Deficiency of B_{12} causes pernicious anaemia (megaloblastic) in human beings and is also associated with neuronal degeneration and demyelination of nervous system. However, B_{12} deficiency causes normocytic or microcytic anaemia in animals. Deficiency of IF also may be a cause for pernicious anemia in human beings. Lowered growth, posterior incoordination and unsteadiness of gait is seen in animals during deficiency of this vitamin. In hen the deficiency conditions includes poor hatchability and bone abnormalities. B_{12} deficiency in rats causes hydrocephalus, eye defects and bone defects in the new born. In pigs B_{12} is essential for normal reproduction. In ruminants rumen micro flora is capable of synthesizing adequate amount of B_{12} if sufficient cobalt is provided in the ration. In ruminants, lack of synthesis of vitamin B_{12} by microbes results in impaired utilization of propionate resulting in increased excretion of methyl malonic acid in urine.

Vitamin C (ascorbic acid/ water soluble C/ antiscorbutic factor)**:** citrus fruits (lemon, gooseberry, guava etc), tomatoes and potatoes are rich in vitamin C. Vitamin C was first isolated by Szent Gyorgyi from citrus fruits and he named it hexuronic acid. Vitamin C in milk is lost during pasteurization. Vitamin C is dietary essential for human beings, guinea pigs, sub human primates, certain birds, certain fishes, bats and some insects. These species lack the enzyme L gulonolactone oxidase necessary for vitamin C synthesis from six carbon sugars. BIS recommends a minimum of 200 mg/kg of vitamin C in the compounded feeds for guinea pigs. 1 IU of vitamin C is the activity of 0.05 mg L ascorbic acid. Vitamin C is a strong reducing agent. L ascorbic acid undergo oxidation to form dehydroascorbic acid and this reaction is reversible. Both L ascorbic acid and dehydroascorbic acid are biologically active. However, D ascorbic acid is inactive. Most of the functions of vitamin C are related to its property to undergo reversible

oxidation reduction i.e. inter conversion of ascorbic acid and dehydroascorbic acid. Heating destroys vitamin C. vitamin C activity is absent in dried foods and it is destroyed by alkali. The major functions includes

1. Formation of collagen: vitamin C plays as coenzyme in the hydroxylation of proline and lysine while protocollagen is converted to collagen. The hydroxylation reaction is catalysed by lysyl hydroxylase and prolyl hydroxylase.
2. Bone formation
3. Iron and haemoglobin metabolism
4. Synthesis of seratonin from tryptophan
5. Tyrosine metabolism
6. Needed in the formation of tetrahydrofolate from folate
7. Cholesterol metabolism
8. Synthesis of corticosteroid hormones
9. As a strong antioxidant it can spare vitamin A, vitamin E and some B complex vitamins
10. Involved in the function of electron transport chain
11. Involved in the synthesis of immunoglobulins

Deficiency of vitamin C causes scurvy in human beings. The disease is characterized by spongy gums, loose teeth, anaemia, swollen joints, fragile blood vessels, decreased immunocompetence, delayed wound healing, sluggish hormonal function (of adrenal cortex and gonads), haemorrhage, osteoporosis etc. Antimetabolite of vitamin C is glycoascorbic acid.

Vitamin like compounds

Choline: chemically choline is trimethylhydroxy ethyl ammonium hydroxide. Due to the presence of three methyl groups, choline is actively involved in one carbon metabolism. It is found in all feeds rich in fat. Metabolic need for choline can be met in part by body synthesis (transmethylation). Methionine can furnish methyl groups which combine with ethanolamine to form choline. Similary methyl group from choline can be combined with homocysteine to form methionine. Therefore, methionine can partially replace choline and both choline and homcysteine together can replace methionine. Therefore, dietary requirement of choline depends on the level of methionine in the ration. Methyl groups can also arise *de novo* in the body, from a formate carbon under the action of folic acid with the involvement of vitamin B_{12}. Choline plays significant role in maintaining cell structure (as a component of phospholipids), fat metabolism in the liver, nerve impulse transmission (formation of acetyl choline) and in prevention of perosis in poultry. In liver, choline act as lipotropic factor and prevent abnormal accumulation of fat (*fatty liver*) by promoting its transport as phospholipids (e.g. lecithin) and lipoproteins or by increasing the utilization of the fatty acids in liver itself. Symptoms of choline deficiency include slow growth and *fatty liver*. In rats, deficiency causes haemorrhagic kidney and such rats later develop moderate to severe hypertension. In chicks, choline deficiency

causes *perosis* and in pigs the deficiency symptoms include slow growth, unthriftness, incoordination and fatty liver.

Inositol: it is hexahydroxy cyclohexane. Found in phytin of plants and in animal body it is a constituent of certain cephalins. Inositol is abundant in common feeds and shark muscle is a rich source. Inositol is required for the synthesis of phosphatidyl inositol which is a constituent of cell membrane. It act as lipotrophic factor along with choline and prevents the accumulation of fat in liver. For some hormones inositol acts as the second messenger at the membrane level for the release of Ca^{2+} ions. Inositol deficiency causes alopecia in rats. Inositol is able to perform some functions of other vitamins (e.g. pyridoxine & biotin).

Para aminobenzoic acid: microbes need PABA for folic acid synthesis. Therefore, during PABA deficiency microbial growth is hindered leading to deficiency of folic acid.

Polyphenol/ bioflavanoids/ vitamin P: isolated from lemon peel. Bioflavanoids acts as antioxidant and protect ascorbic acid from being destroyed. Believed to be involved in preventing fragility of capillaries and are used to correct the vascular abnormalities in human beings.

Lipoic acid: it is a sulphur containing fatty acid. Needed for microbial growth and in the oxidative decarboxylation of α keto acids in carbohydrate metabolism (along with other vitamins like thiamine, niacin, riboflavin and pantothenic acid). The conversion of pyruvate to Acetyl CoA and α ketoglutarate to succinyl CoA require lipoic acid.

Coenzyme Q/ Ubiquinones: involved in electron transport chain

Vitamin B_{13}: obtained from distillers soluble and has orotic acid.

Vitamin B_t: carnitine

Vitamin B_{17} (nitrilosides, amygdalin or laetrile): these substances are found in a number of seeds, sprouts, beans, tubers, and grains. While toxic in large quantities, proponents claim that it is effective in cancer treatment and prevention despite a lack of accepted scientific evidence.

MINERALS

Ash constitutes 3-5% of animal body. Nearly 60 minerals are found in animal body. Bones contain 25% ash on fresh basis. Minerals in body can be classified as follows:

1. Classification based on tropicity

a) Osteotropic: e.g. calcium, phosphorus, magnesium etc

b) Reticuloendotheliotropic: e.g. iron, copper, cobalt, nickel etc

c) Distributed throughout the body: e.g. sodium, potassium, chlorine, sulphur etc

2. Classification based on concentration in body

a) Major/macro minerals: calcium, phosphorus, sodium, potassium, chlorine, sulphur, magnesium

b) Micro/minor minerals: iron, zinc, fluorine, molybdenum, copper, manganese, iodine, silicon etc

c) Trace minerals: selenium, cobalt, chromium, nickel etc

3. Classification based on biological function

a) Essential minerals: calcium, phosphorus, magnesium, sodium, potassium, chlorine, sulphur, copper, iron, cobalt, zinc, selenium, molybdenum, manganese, iodine, fluorine, silicon, vanadium, tin, chromium, nickel and arsenic

b) Probably essential minerals: titanium, bromium, cadmium, strontium etc

c) Functions uncertain: lithium, lead, silver, aluminium, rubidium etc

CALCIUM AND PHOSPHORUS

70% of total minerals in body are constituted by calcium and phosphorus. 99% of body calcium and 80% of phosphorus is concentrated in bones. On fat free and dry basis, bone has 36% calcium, 17-18% phosphorus and 0.8% magnesium. In bones, calcium and phosphorus exist in two forms namely amorphous form (hydrated tricalcium phosphate) and crystalline form (resembles hydroxyapatite). The ratio between calcium and phosphorus in bone is 2:1. Blood cells are almost devoid of calcium but the blood plasma has calcium in two forms namely soluble/ ionized form and bound form (bound with protein). Normal plasma concentration of calcium is 9-12 mg/dL. The hormones parathormone (causes decalcification of bones, a process carried out by osteoclasts), calcitonin (calcification of bones, carried out by osteoblasts) and calcitriol maintain the plasma concentration of calcium within this range. The concentration of plasma calcium is 3-4 times the normal value in laying hens (30-40 mg/dL). Since the mobilization of calcium from blood to bone and vice versa is a continuous process, the level of calcium in blood is not easily influenced by dietary intake. The total phosphorus concentration

in blood is 35-45 mg/dL and that of inorganic phosphorus is 4-9 mg/dL. It is evident that an interchange of phosphate between organic and inorganic forms continually occurs. Unlike calcium, the dietary level of phosphorus has significant effect on blood phosphorus level. Dietary calcium and phosphorus ratio considered most suitable for farm animals other than poultry is generally within the range 1: 1 to 2: 1. This ratio is more important for non ruminants than for ruminants. An excess of either one of the mineral adversely affects the absorption of other. The proportion of calcium in the feed for laying hens is much larger since they require great amount of this element for egg shell production.

Absorption and excretion: calcium binding protein is required for the absorption of calcium in the small intestine. Vitamin D (through its active form calcitriol or 1, 25 dihydroxycholecalciferol) favours the production of calcium binding protein in the intestinal epithelial cells and promotes calcium and phosphate absorption. Absorption of calcium and phosphorus is dependent upon their solubility at the point of contact with the absorbing membranes. Form in which they are ingested, have no effect i.e. the factors which operate to hold them in solution help in their absorption. Lactose promotes calcium absorption by interacting with the absorptive cells of the intestine by increasing its permeability to calcium ions. Phytates and oxalates lowers the absorption of calcium forming insoluble salts. In general, alkaline condition is unfavorable for calcium absorption while acidity favors the absorption of calcium. Fatty acids forms insoluble calcium soaps and lowers the availability of calcium. Iron, aluminium and magnesium interfere with the absorption of phosphorus by forming insoluble phosphates. Phosphorus in phytate form is less available for monogastric animals.

In general faeces are a path of excretion of minerals which have been absorbed and metabolized and thus served the body, as well as those which have escaped absorption. Therefore, determination of apparent digestibility of ash is of no value. By using isotopes, distinction can be made between the endogenous fraction and the fraction which is not absorbed and the true digestibility of mineral thus calculated is referred to as the ***availability*** (instead of digestibility) of the mineral. Primary route of calcium excretion is faeces. Major portion of calcium found in faeces is endogenous. In herbivores the primary route of phosphorus excretion is feces while it is urine incase of carnivores.

Functions of calcium

1. Bone and teeth formation
2. Blood clotting (conversion of prothrombin to thrombin)
3. Regulation of heart beat and muscle contraction
4. Nerve impulse transmission
5. Maintenance of acid base equilibrium

Functions of phosphorus

1. Bone and teeth formation
2. Constituent of ATP, GTP, UTP, creatine phosphate etc

3. Required for the formation of phospholipids, phosphoproteins and nucleic acids
4. Maintenance of acid base equilibrium
5. Needed for the activation of certain proteins and enzymes

Deficiency diseases

1. Rickets in young ones and osteomalacia in adults: It is a disorder of defective calcification of bones. This may be due to dietary deficiency of calcium/ phosphorus or both. In calcium deficient calves and lambs rickets is characterized by enlarged and painful joints, decreased growth, bone deformities and arching of back. In severe and prolonged deficiency beading of ribs also takes place. In adult animals, osteomalacia is caused as a result of resorption of calcium and phosphorus from bones. Bones become brittle, weak and prone to fracture. Most acute cases of osteomalacia occur during gestation and lactation in mammals and during egg laying in birds.
2. Nutritional secondary hyperparathyroidism (NSH)/ osteodystropha fibrosa/ big head disease/ bran disease/ periodontal disease: occurs when diets contain low levels of calcium and excess of phosphorus (e.g. feeding of bran's alone). Excess phosphorus lowers the intestinal absorption of calcium resulting in hypocalcemia. Hypocalcemia causes release of parathormone and mobilization of bone calcium. Now fibrous connective tissue invades the bone and causes enlargement of bones. In horses and monkeys, this occurs in the facial bone (big head disease). Cases of NSH have been reported in horses, rabbits, birds, primates and carnivores.
3. Milk fever/ parturient paresis/ hypocalcemia: occurs in early lactation in high producing dairy animals. Calcium level of blood plasma of affected animals declines (3-7 mg/dL). In the beginning, the cow may show staggering gait during walking and later she lies down on her sternum with her head directed towards one side over the chest. Body temperature falls below the normal. The affected animals are treated with intravenous administration of calcium borogluconate for speedy recovery.

Feeding of diets high in calcium during the pre-partem period can result in a high incidence of parturient paresis in dairy cattle. A 500kg cow requires only about 30g of calcium to meet the maintenance and fetal demands in late gestation. Low calcium diets (<20 g Ca/d) fed during the last two weeks before parturition is effective in preventing parturient paresis. Maintaining a Calcium: Phoshorus ratio 1: 3.3, two weeks prior to parturition will prevent the occurrence of milk fever. But, feeding of Phosphorus above 80 g/d increase the incidence of milk fever, because it will reduce the intestinal Ca absorption. If the ration is low in Ca, the resulting negative balance of Ca can stimulate the activity of parathyroid gland. Low Ca intake will make the cow in negative Ca balance and in a state of withdrawal of Ca from bone thus maintaining the normal blood Ca level of 9-12 mg/dL.

A method of controlling parturient paresis in dairy cows when the Ca intake exceeds the requirement is to manipulate the anion cation balance of the diet. Diets high in cations especially sodium and potassium tend to induce milk fever compared with those high in anions,

primarily chloride and sulfur (reduces the incidence of milk fever). Analyzing the feed stuffs for sodium, potassium, chlorine and sulfur and determining the value of (Na + K) – (Cl + S) to produce a significantly negative total will effectively prevent parturient paresis (**-ve DCAB concept**). To prevent the occurrence of milk fever when high Ca diets are fed to dry cows, dietary cation anion balance must be reduced below -3 mEq/100g of dietary DM.

4. Osteoporosis: it is the failure of normal bone metabolism in adult. It differs from osteomalacia in that the mineral content of bone is normal but the absolute amount of bone is decreased. It occurs due to bone resorption being greater than bone formation. Osteomalacia and osteoporosis are sometimes used interchangeably in referring to bone troubles in the adult.

5. Osteopenia: it is often used to describe bone pathology and simply means too little bone.

6. Pica: deprived appetite noted in cattle due to phosphorus deficiency. The affected animals have abnormal appetite and chew wood, bones, plastics etc

7. Lowered fertility and milk yeild: low dietary intake of phosphorus is associated with low fertility and low milk yield in cows.

8. Thin shelled eggs: In laying hens calcium deficiency results in improper development of egg shell which is either not fully formed or easily breakable (thin shells). In poultry, calcium is stored as reserve in the medullary bone which occupies almost all the marrow cavity of long bones like femur. This reserve of labile calcium is utilized during time of egg shell formation. If adequate dietary calcium is not supplied, the reserve gets depleted, the egg shells become thin and fragile and gradually the hen develops osteomalacia.

Sources:

Animal byproducts like bone meal, fish meal, meat cum bone meal are rich sources of calcium and phosphorus. All seeds other than legume seeds (e.g. soy beans and their oil meals) are low in available calcium. Milk and green leafy crops are good sources of calcium. Leguminous fodders like berseem and lucerne are good source of calcium but poor in phosphorus. Legume hays are rich in calcium, straws in general are poor sources. Cereal grains and mill by products (especially bran's) are good sources of phosphorus though poor source of calcium. Dicalcium phosphate and calcium phosphate are very good sources of calcium and phosphorus while calcium carbonate is a rich source of calcium.

Phosphorus is found naturally mainly as phytate in all vegetable feed ingredients particularly in bran's. About, half the quantity of phosphorus in cereals is in the form of phytate phosphorus, which is hexaphosphoric acid ester of inositol. Six phosphate molecules are bound in one phytic acid molecule. Calcium, magnesium salts of phytic acid is phytate. Trace minerals like manganese and zinc are also bound to phytate. Monogastric animals cannot utilize effectively the phytate phosphorus from which the availability is poor. In ruminants, microbial phytase hydrolyses phytate and releases phosphorus, calcium and trace minerals. Certain cereals (e.g.

wheat) contains phytase but it get destroyed by acids of stomach. In poultry feeds the enzyme phytase (produced by certain bacteria and fungi) is added to increase the availability of phytate phosphorus. Efficiency of utilization of phytate phosphorus is highest in ruminants followed by horses, pigs and poultry.

Content of calcium and phosphorus in common supplements

Supplement	**Calcium (%)**	**Phosphorus (%)**
Bone meal	29	14
Dicalcium phosphate (DCP)	26	21
Deflourinated rock phosphate	29-36	12-18
Limestone	34	
$Ca(PO_4)_3$	17	21
$NaPO_4$		22
$(NH_4)_2PO_4$		20
Oyster shell	35	

Effect of feeding excess calcium/ phosphorus

1. High calcium diet well above requirements without concurrently increasing the zinc results in severe parakeratosis in pigs due to zinc deficiency.
2. High levels of calcium and phosphorus in the ration of swine and poultry intensify the effect of manganese deficiency.
3. Hyper secretion of calcitonin as a result of prolonged high dietary intake of calcium results in osteopetrosis/ dense bone.
4. High calcium intakes are reported to cause kidney stones.

MAGNESIUM

Magnesium is closely related to calcium and phosphorus in its distribution and metabolism. 70% of the body magnesium is located in the skeleton. Nearly $1/3^{rd}$ of bone magnesium can be mobilized for use in soft tissue. The level of magnesium in blood serum is 2-5 mg/dL. Even for growing animals there is only a need of 0.06% magnesium in ration. Most of the feeds have minimum 0.1% magnesium and hence the chances for deficiency are less. If deficiency occurs, urine magnesium concentration is a better indicator than serum magnesium. High calcium and phosphorus in diet can cause magnesium deficiency. On a low phosphorus diet magnesium interferes with calcium absorption. In ruminants, potassium depresses the absorption of magnesium from rumen, which is the primary site of magnesium absorption. In non ruminants magnesium is absorbed mainly by the intestinal cells. Major route of magnesium excretion is faeces.

Functions

1. Required in the formation of bones and teeth.
2. Activates many enzymes (especially those enzymes transferring phosphate from ATP to ADP)
3. Needed in energy metabolism
4. Cofactor for decarboxylation (for peptidases, acid & alkaline phosphatases)
5. Required for proper neuromuscular function
6. Photosynthesis in plants (component of chlorophyll

Deficiency conditions

1. Causes calcium deposition in kidneys (renal calculi can occur also when excess magnesium is consumed)

2. Grass tetany/ grass staggers/ lactation tetany in adult animals and hypomagnesemic tetany in calves: occurs in calves reared for long periods on milk alone and cows fed on lush green pasture (generally during spring). Tetany is usually preceded by a fall in serum magnesium to 0.5 mg/dL. The signs include nervousness, muscle twitching, labored breathing, convulsions and death. Sometimes the animal become extremely excited and violent convulsions develop, with animal lying on its side, the fore legs pedaling, and jaws working, making the teeth grate. The causes for magnesium deficiency are low dietary intake of magnesium, cation anion imbalance, consuming heavily fertilized pasture (using ammonium sulphate) and high content of potassium in pasture.

3. Magnesium deficiency in chicks causes slow growth, lethargy and death.

Sources: green fodders, wheat bran, dried yeast and oil cakes (cotton seed cake, linseed cake etc) are rich in magnesium

Supplements: In diet magnesium can be supplemented in the form of calcined magnesite (magnesium oxide) or magnesium acetate.

Sulphur: body has 0.15% sulphur and proteins generally contain about 1% sulphur by weight. Keratin, the protein of hair, hoof, wool etc is rich in sulphur. Sulphur content of wool is 4%. Sulphur containing amino acids are methionine, cysteine and cystine. They are involved in the synthesis of glutathione, insulin, taurine, CoA, heparin etc. Sulphur containing vitamins are thiamin, biotin, lipoic acid and CoA of panthothenic acid. Phosphoadenosine phosphosulphate (PAPS) is the active form of sulfate utilized in several reactions within the body e.g. synthesis of glycosaminoglycans, detoxification etc. N: S ratio in tissue protein and milk is 15: 1, while it is 5: 1 in wool. Sulphur of the body is mostly present in the organic form and the content of inorganic sulphur is very less in the body e.g. chondroitin sulphate of cartilage. Blood has small amount of sulphates and thiocyanates. Body needs mainly sulphur in organic form as sulphur containing amino acids. Elemental sulphur is not known to be utilized even by ruminants. There is evidence that sodium sulphate can be used by the rumen microorganisms more efficiently than elemental sulphur. Similarly in poultry, inorganic sulphur in diet can be utilized to

synthesize cysteine in egg albumin. Optimum N: S ratio in ruminant diet is 10: 1. Sulphur deficiency in ruminants causes reduced feed intake and reduced fibre digestion. Sulphate ion is of importance in causing toxicity and deficiency of the mineral molybdenum. Increasing the sulphate intake enhances molybdenum excretion. Moreover, excess intake of sulphur causes increased formation of hydrogen sulphide in rumen leading to reduced rumen motility, nervous signs and respiratory distress. Excretion of sulphur occurs through both faeces and urine. Sulphur excreted through urine is from catabolism of protieins. Majority of sulphur excreted in urine is inorganic in nature (80%). Rest exists as organic/ conjugated/ ethereal sulphate (10%) and unoxidized/ neutral sulphur (sulphur containing amino acids, taurine, thiocyanates etc). Excretion of neutral sulphur through urine is proportional to basal metabolism.

Sodium, potassium and chlorine: these elements are found in body fluids and soft tissues. They need regular dietary supply as they are not stored in the body. Major functions of them are to maintain osmotic pressure and acid base equilibrium. Sodium content of body is 0.2% and it is the chief cation of the extra cellular fluids. A very small amount of sodium is found in skeleton as insoluble inert form. Sodium is almost absent in blood cells. Sodium makes 93% of bases of blood serum i.e. it is the predominant basic element concerned in neutrality regulation (in association with chloride and bicarbonate). Sodium is needed in the absorption of sugars and amino acids from the digestive tract. Sodium is essential for normal muscle irritability and for initiating and maintaining heart beat. Sodium requirement for growing animals is 0.1 to 0.2% of diet. Vegetable feeds are deficient is sodium while feeds of animal origin contains high concentration of sodium. Sodium deficiency causes growth failure, dehydration, vascular disturbances, corneal keratinization, nervous disorders, reproductive abnormalities etc.

Potassium content of body is 0.2%. It is found mainly in blood cells. Potassium is the chief cation of the intra cellular fluid and plays very important part along with sodium chloride in the osmotic regulation. Nerve and muscle cells are rich in potassium. Potassium content of blood cells is 20 times that of plasma. In muscles the content of potassium is 6 times that of sodium. Potassium is the most abundant element present in cows milk. The content of potassium is very high in plants. Consequently it is extremely unlikely that potassium deficiency could occur in farm animals under natural conditions. Experimentally produced potassium deficiency causes decreased growth rate, general weakness, tetany and even death in acute cases. High intake of potassium interferes with the absorption and metabolism of magnesium (hypomagnesemic tetany). Dietary requirement of potassium is higher than that of sodium (0.2 to 0.6% of diet). Adrenal hormones (aldosterone) cause the kidneys to conserve sodium but increase the excretion of potassium. Chief route of potassium excretion is urine (90%).

Chlorine is found both within and outside the cells. Blood cells have one half as much as the chlorine in plasma. Nearly 15-20% of chlorine in body exist in organic form. Chlorides comprises 2/3rd of acidic ions in blood. Chloride deficiency causes alkalosis because they play a

key role in regulating pH of body fluids (chloride shift: movement of chlorine from body fluids to erythrocytes). Chloride is a component of HCl in the gastric juice. Body can store chlorides in skin and subcutaneous tissue. The requirement of chlorine is 50% as that of sodium. Most vegetable feeds are low in chloride. Feeds of animal origin like meat meal and fish meal are rich sources of chlorine.

An adult lactating cow needs 30 gm sodium chloride/day. Salt is added at the level of 0.5% in swine and poultry rations and up to 1% in the diet of herbivores. Excess intake causes salt toxicity if water is not provided adlibitum. Poultry and pigs are more prone to salt toxicity. Primary mode of action of salt poisoning is through disturbance in water balance. More than 3% salt in the diet of chicks causes oedema. In salt deficiency, sodium is the chief limiting factor (not chloride). Salt deficiency causes loss of appetite, lowered production, loss of body weight and cannibalism in poultry. Miners lose large quantiy of sodium chloride through sweat loss during their work. If they drink large quantity of water, they develop cramps. The occurrence of cramps can be prevented by drinking salt water.

Iron: body has 0.004% iron. Iron is a component of haemoglobin, cytochromes and myoglobin. Certain enzymes contain iron and some of the enzymes are activated by iron (e.g. catalase, peroxidase, xanthine oxidase, tryptophan pyrrolase, phenylalanine hydoxylase, enzymes of TCA cycle etc). 50% of iron in body exists as hemoglobin in RBC. Haemoglobin has 0.34% iron. Average lifespan of RBC is 127 days and there is recycling of iron after the death of RBC. Transport form of iron is transferrin and is found in blood serum. Storage forms of iron in organs like liver, spleen, bone marrow and kidney include ferrittin (20% iron) and hemosiderin (35% iron). Roughages have 100-200 mg iron/kg DM. Chief site of iron absorption is small intestine. Iron absorption is explained by mucosal block theory i.e. the mucosal cells of gastrointestinal tract absorb iron and gets physiologically saturated with iron as ferritin so that further absorption is impeded until the iron is released and transferred to plasma. Therefore, iron entry into the body is controlled at the absorption level depending on the body needs. Ferrous salts are more efficiently absorbed than ferric salts. In general, iron in tissues exists as ferrous form while in feed it exists mainly as ferric form. In the acid medium of stomach in presence of reducing substances like ascorbic acid and cysteine ferric form is converted to ferrous form which is soluble and is readily absorbed. After absorption, for transport the ferrous iron is further converted to ferric form. The requirement of iron in feeds for pigs (80 mg/kg) is higher when compared to chicks (40 mg/kg) and ruminants (25-40 mg/kg). Excess of iron in ration lowers the availability of phosphorus, creates alimentary disturbances and lowers growth. Iron deficiency causes anemia. Iron deficiency anemia in pigs and chicken is microcytic hypochromic while in calves it is microcytic normochromic. Iron deficiency anemia is common in suckling pigs (nutritional anemia/ thumps). In piglets the condition occurs when they are reared in concrete floors without any access to soil or other feeds. Piglets need about 15 mg iron/day. However, it gets on an average 1mg iron/day through sows milk. Anemic piglets are

weak with pale mucous membrane and unhealthy appearance. In severe cases there will be labored and spasmodic breathing (thumps) because of the deficiency of haemoglobin and the animal will have swollen appearance around the head and shoulders. The condition can be prevented either by drenching the piglets with a saturated solution of ferrous sulphate (1/3rd teaspoon for animals below 1 week and gradually increased to 1 teaspoon for animals above 4 weeks age) or by swabbing the udder of mother with saturated solution of ferrous sulphate. Another method is to inject 100mg of iron dextran compound when piglets are 3 days old and then repeat the same dose at 21 days. Iron deficiency in mink causes *cotton fur*.

Copper: copper is needed for haemoglobin formation (it is a constituent of ALA synthase). Copper deficiency affects iron absorption, iron mobilization from tissues and utilization of iron for haemoglobin synthesis. Conversion of ferrous iron to ferric iron after absorption is by the action of copper containing plasma protein, ceruloplasmin which acts as ferroxidase. Therefore, copper deficiency indirectly causes a functional iron deficiency. Copper occurs as haemocuprein/ erythrocuprein in vertebrate blood cells, haemocyanin in invertebrate blood cells, hepatocuprein in liver and cerebrocuprein in brain. Anemia due to copper deficiency is commonly microcytic hypochromic, but may be normocytic hypochromic or even macrocytic hypochromic in ruminants. Copper is important for normal bone formation as it is essential for osteoblastic activity and for normal collagen and elastin formation. Bone defects in grazing cattle and sheep on copper deficient pastures are characterized by spontaneous fracture and a condition very similar to rickets in young calves and osteoporosis in older animals. 50% of body copper is found in muscles. Copper containing enzymes are cytochrome oxidase, catalase, uricase, tyrosinase, superoxide dismutase, lysyl oxidase, ALA synthase, phenol oxidase and amine oxidase. Turacin a pigment found in feathers of turaco bird contains copper. Requirement of copper in the diet of farm animals ranges between 4-6 ppm. Metallothionein is a transport protein that facilitates copper absorption in the duodenum. Excess molybdenum, zinc, cadmium, sulphate and phytate in diet cause copper deficiency by decreasing its uptake. Plasma ceruloplasmin activity and plasma level of copper are indicators of proper copper nutrition. Wasting disease of cattle and sheep due to copper deficiency is referred to as *salt sick* or *lechsucht. Enzootic ataxia*/ *swayback/ gingin rickets/ swing back* occurs in lambs, kids and calves as a result of feeding copper deficient ration to the mother during pregnancy. Symptoms include uncoordinated movements of the hind legs, a stiff and staggering gait with swaying of the hind quarters after few weeks following birth. Nervous symptoms are due to demyelination of the spinal cord. Copper is involved in crimp formation in wool fibre. Wool produced due to copper deficiency (loss of crimp or waviness in wool accompanied by a general deterioration in quality, losing its elasticity and affinity for dyes thus resembling hair rather than wool) is called *steely wool* or *stringy wool*. Deficiency of copper also affects the process of pigmentation in the wool due to inhibition of tyrosinase required in the conversion of tyrosine to melanin. *Falling disease* is a copper deficiency condition observed in adult cattle of Australia. The condition

occurs due to degeneration of myocardium. Unthriftness and scouring encountered in cattle as a result of copper deficiency due to molybdenum toxicity is referred to as *teart* in England, *scouring disease* in Holland and *peat scour* in Newzealand. Molybdenum makes copper unavailable in presence of sulphur forming copper thiomolybdate. Copper deficiency in chicken causes *dissecting aneurysm* of the aorta. *Menke's disease* in human beings is due to defect in the intestinal absorption of copper and *Wilsons disease* occurs in human beings due to abnormal copper metabolism resulting in hepatolenticular degeneration. Copper when consumed in excess acts as a cumulative poison in liver. Sheep has been reported to be more susceptible to copper toxicity than any other farm animal. Tolerance for copper is more for pigs compared to cattle. Copper is used as growth promoter for pigs.

Cobalt: cobalt deficiency in ruminants causes loss of apetite, emaciation, anemia, listenessness and even death in severe cases. The condition is called *pining/ salt sick/ bush sickness/ wasting disease/ enzootic marasmus/ vinquish/ coast disease/ nakuruitis* i.e. in different names in different parts of the world. Fatty degeneration of the liver and deposits of hemosiderin in spleen are the postmortem lesions found in cobalt deficiency. The deficiency occurs when cobalt level in herbage is below 0.1 mg/kg. Vitamin B_{12}/ antianemic growth factor have 4% cobalt and is involved in propionic acid metabolism in ruminants. Ruminants need cobalt in ration and the rumen microorganisms synthesize Vitamin B_{12} utilizing the cobalt ingested in the feed. Non ruminants need Vitamin B_{12}, as such due to low level of vitamin B_{12} synthesis by intestinal microbes. The only known biological role for cobalt is as a constituent of vitamin B_{12}, which has two major coenzyme functions in the body. Methylcobalamin promotes methionine synthesis. Deoxyadenosylcobalamin performs a key role in the energy metabolism of ruminants by facilitating the metabolism of propionate (Methylmalonyl CoA to Succinyl CoA), which is an important precursor of glucose in ruminants. Cobalt deficiency has not been shown in monogastric animals. Cattle are less susceptible to lack of cobalt than sheep, but when they succumb the clinical picture of a 'pining' or 'wasting' disease is the same. There is anorexia, loss of body condition, muscular wasting and an anaemia that is normochromic and normocytic. Cobalt is supplemented in ration of ruminants as cobalt sulphate. Cobalt toxicity usually never occurs due to wide margin of safety. Compared to cattle, sheep are less susceptible to cobalt toxicosis.

Manganese: deficiency of manganese causes abnormalities in skeletal and reproductive system. Manganese through its activation of glycosyltransferases is required in the formation of mucopolysaccharides (which forms the organic matrix of bone) and glycoproteins. Manganese is involved in the biosynthesis of haemoglobin, fatty acids and cholesterol. Manganese activates the enzymes hydrolases and kinases and is a constituent of arginase, pyruvate carboxylase and mitochondrial superoxide dismutase. Pinnaglobin is a manganese-based porphyrin protein found in the mollusc *Pinna squamosa*. Manganese in the serum is bound to a specific carrier protein named transmagnanin. High levels of calcium and phosphorus in diet interferes with

manganese absorption. Deficiency of manganese can cause perosis/ slipped tendon in poultry. Perosis occurs in growing chicks and in this condition, the hock joint swells and achilles tendon slips from condyle. Deficiency of choline or biotin can also cause perosis. Fatty infiltration of liver is caused by deficiency of manganese and choline. In chicks, manganese deficiency causes head retraction. In pigs, manganese deficiency causes lameness (crooked legs & enlarged hocks), impaired glucose utilization and reduced vitamin K induced blood clotting response. In rabbits manganese deficiency causes crooked front legs. Mice born to dam with manganese deficient diet have congenital ataxia because of defective development of otoliths. Maize, animal origin foods and yeast are deficient in manganese. Rich sources of manganese are green fodders and cereal by products like rice bran and wheat bran. Requirement of manganese for poultry is 55 mg/kg DM of feed.

Zinc: body has 0.003% zinc. It is involved in the functioning of many enzymes either as a component or as activator (carbonic anhydrase, pancreatic carboxypeptidase, lactate dehydrogenase, alcohol dehydrogenase, alkaline phosphatase, cytosolic superoxide dismutase and thymidine kinase). Carbonic anhydrase has 0.3% zinc. Zinc activates alkaline phosphatase which have important role in keratinization and calcification. Zinc is essential for maintaining the normal serum Vitamin A level. Zinc being a component of alcohol dehydrogenase, plays important role in the conversion of β carotene to Vitamin A in the intestinal wall. Zinc is also involved in the synthesis of retinol binding protein. Zinc is needed in nucleic acid metabolism, functioning of certain hormones, immune regulation and electrolyte balance. The storage and secretion of insulin from the β cells of pancreas requires zinc. Zinc being a component of thymidine kinase, is important for DNA synthesis and hence for normal reproduction. Gusten, a zinc containing protein found in human saliva plays major role in taste sensation. Zinc absorption from the intestine is dependent upon the transport protein metallothionein. Zinc deficiency causes parakeratosis in swine especially when high calcium low phosphorus diet is fed. The disease is characterized by specific skin lesions with sore and itchiness resembling mange, anorexia, diarrhea and retarded growth. In poultry, the deficiency causes leg abnormality (swollen hock syndrome), parakeratosis and frizzled feathers. Excess calcium aggravates zinc deficiency in layers. Phytic acid reduces the absorption of zinc at intestinal level. In calves the deficiency of this mineral results in inflammation of the skin of nose and mouth, alopecia, stiffness of joints, swollen feet and parakeratosis. Animal proteins, bran and germ are rich sources of zinc. Zinc supplementation of swine and poultry diets is usually necessary on corn soybean based rations having high amounts of calcium. Zinc toxicity causes copper deficiency and vice versa. The requirement of zinc in the diet of farm animals ranges from 20-30 ppm in ruminants to 50 ppm for swine. Zinc is primarily excreted from the body in faeces.

Iodine: body has 0.00004% iodine of which, above 50% is concentrated in thyroid gland as iodothyroglobulin (a glycoprotein). The only known function of iodine is its requirement for the synthesis of thyroid hormones. The hormone thyroxine, which is synthesized by iodination of

the amino acid tyrosine, has about 65% iodine. Critical period for iodine deficiency in farm animals is the first few weeks after birth. Deficiency of iodine causes goiter/ big neck in human beings. Cretinism and myxedema are conditions of hypothyroidism in human beings. Hairlessness is the outstanding symptom of iodine deficiency in piglets and calves which is characterized by thick skin and puffy neck. In foals iodine deficiency causes navel ill resulting in extreme weakness so that the foal is not able to stand and suck. In birds, the molting process and pigmentation of feathers can be affected by iodine deficiency. Feeds obtained from the plants of genus Brassica (kale, cabbage, rape etc), soybean, linseed, peas and groundnut contains goitrogens which inhibits the iodination of tyrosine. Iodised salt has 0.0076% iodine in the form of sodium iodide, potassium iodide or sodium iodate. Iodised salt in mixed feeds is subject to less detioration because dietary proteins and unsaturated fats tend to stabilize iodine. Good sources of iodine are fishmeal, dried kelp, cod liver oil etc. Administration of thyroxine and iodine containing proteins (e.g. iodinated casein) stimulates milk production in cattle and egg production in poultry. Certain compounds such as thiourea and thiouracil suppress the functioning of thyroid gland and promote fattening. Prolonged consumption of large amounts of iodine (200-500 ppm) can cause markedly reduced thyroidal iodine uptake, causing iodide goiter.

Selenium: as selenocysteine it is a component of enzyme glutathione peroxidase (has 4 Se atom) which catalyses the removal of hydrogen peroxide and protects the cell membranes from oxidative damage. It forms a second line of defense after Vitamin E which reduces the production of hydroperoxides and thus the amount of glutathione peroxidase needed to protect cells. Therefore, there is mutual substitution of selenium and Vitamin E. In poultry the selenium deficiency condition is exudative diathesis (characterized by oozing of fluid and other materials from cells and tissues as a result of severe edema of the subcutaneous tissues), which can be prevented by supplementation of 0.1 ppm of selenium. In lambs, calves and chicks selenium deficiency causes muscular dystrophy and the condition is termed white muscle disease. Selenium deficiency causes liver necrosis in pigs & rats, gizzard myopathy in turkeys and sometimes even heart necrosis in calves and lambs. Selenium supplementation improves the reproductive efficiency and reduces the incidence of RFM (retention of fetal membranes) and mastitis in cattle. Requirement of selenium is 0.1 ppm in feed. Selenium toxicity occurs due to consumption of plants with high levels of selenium (seleniferous plants like *Astragalus*). Acute selenium poisoning causes respiratory failure. Acute and chronic selenium toxicity in livestock is referred to as blind staggers and alkali disease respectively. Chronic selenium toxicity causes loss of hair from mane and tail in horses. In cattle and buffalo chronic toxicity results in loss of hair from tail and hoof abnormalities (degnala disease found in Haryana and Punjab). During selenium toxicity a compound with garlic odour (dimethyl selenide) is excreted via the lungs. The mechanism by which selenium exerts its toxic effects in animals appears to be through its competition with sulphur compounds or because of its strong affinity for sulphur.

Selenium can replace the sulphur because of its chemical similarities to sulphur. Linseed meal, sulphates and organic arsenicals has some role in protecting from selenium toxicity.

Flourine: fluoride is mostly found in bones and teeth. Flourine deficiency causes dental caries. 0.5 to 1 ppm of fluorine is essential in water to prevent dental caries. It forms a protective layer of acid resistant fluoroapatite with hydroxyapatite of the enamel and prevents the tooth decay by bacteria. Toxicity due to fluorine is termed fluorosis and the occurrence is more common in ruminants than in non ruminants. Water, high in fluorides, feeds containing rock phosphate as mineral supplement and forages contaminated with fluorine fumes are the sources of toxicity. Fluorine toxicity causes bone and joint abnormality due to deposition of calcium fluoride on bones. Bones lose their normal colour and lusture gets thickened and softened. In severe cases there is exostosis. In teeth there are enamel defects and in children there is mottled enamel and discoloration of teeth (dental fluorosis). Chicken is more tolerable to fluorine than other farm animals.

Molybdenum: it is a component of enzyme xanthine oxidase, aldehyde oxidase, nitrate reductase and sulphite oxidase. Tungstate is the antagonist of molybdenum. Molybdenum deficiency has not been observed under natural conditions in any species. Supplementation of molybdeunum improves the growth of lambs by stimulating the activity of rumen microbes. Molybdenum toxicity causes teartness and it occurs when forage has more than 0.002% molybdenum. Symptoms of teartness include loss of weight, diarrhea, lowered production, anemia, stiffness and emaciation. Molybdenum toxicity usually occurs in copper deficient areas and can be cured by giving copper sulphate. However, feeding of excess molybdenum causes copper deficiency. Sulphate administration also results in an increased excretion of molybdenum in the faeces, suggesting a reduction in the rate of molybdenum absorption from the gut. Tolerance for molybdenum is higher for horses and pigs when compared to ruminants. Rats, rabbits, guinea pigs and poultry are intermediate in their tolerance.

NEWLY DISCOVERED TRACE ELEMENTS, METAL BINDING SUBSTANCES AND CHELATED MINERALS

Aluminium: it is the 3rd most abundant element in earth crust. Aluminium is found only in trace amounts in biological organisms. Kaolin and bentonite clays (used as pellet binders), sewage grown algae, mineral supplements, plants which accumulate aluminium and forages contaminated with dust are sources of aluminium to animal diets. There is some connection between aluminum concentration in the brain and Alzheimer's disease.

Chromium: in association with insulin, chromium promotes glucose utilization. Chromium lowers the total serum cholesterol level and is involved in lipoprotein metabolism. It decreases the serum LDL and increases the serum HDL and thus promotes health. Chromium participates in the transport of amino acids into the cells of heart and liver. Glucose tolerance factor (GTF) is the most active form of chromium organic complex. In addition to chromium, GTF contains

organic components of nicotinic acid, glycine, glutamic acid and cystine. In pigs, chromium when supplemented as chromium picolinate has carcass modifying effect by increasing the muscle mass and lowering the lipid content. Studies conducted in cattle proved that chromium plays important role in lowering stress, modulating the immune system, thus making the dairy cows to improve production and lowers the susceptibility to diseases. Chromic oxide is used as an external indicator in digestibility studies conducted in ruminants. Deficiency of chromium causes impaired glucose tolerance and decreases the sensitivity of peripheral tissues to insulin. Deficiency of chromium causes disturbances in the metabolism of carbohydrates, lipids, protein and nucleic acids. Chromium toxicity causes damage to liver and kidney.

Boron: It is involved in the regulation of parathormone and therefore, indirectly influences metabolism of calcium, phosphorus, magnesium and Vitamin D_3. Boron deficiency seems to affect calcium, phosphorus and magnesium metabolism, and affects the composition, structure and strength of bone, leading to changes similar to those seen in osteoporosis.

Lithium: it is used in therapy of manic-depressive psychosis. It has been shown to be an effective agent in the recovery of animals with bovine spastic paresis.

Nickel: it is found in the body in highest concentrations in the nucleic acids, particularly RNA, and is thought to be somehow involved in protein structure or function. Nickel is essential for urease activity of rumen microbes, nucleic acid metabolism and zinc metabolism. When chicks were fed diets low in nickel (less than 14 ppb), they showed impaired liver metabolism, dermatitis and change in pigmentation of skin.

Tin: it function as an oxidation reduction catalyst and function at the active site of metalloenzymes. It plays important role in the tertiary structure of proteins.

Vanadium: it seems to be essential for the chick and rat. Herringmeal (produced from an Atlantic fish named herring) is a rich source of vanadium. Vanadium regulates the activity of sodium potassium ATP-ase, phosphoryl transferase, adenyl cyclase and protein kinase. Vanadium is present in human enamel and dentin. Vanadium decreases the incidence of caries in rats, hamsters and guinea pigs. A deficiency causes reduced body weight, lowered feather growth and impaired reproduction in chicken. A level of 25 to 30 ppm in the diet is toxic to most animals. EDTA appears to act as antidote in vanadium toxicosis.

Silcon: next to oxygen, it is the second most abundant element on earth. It has role in mucopolysaccharide synthesis and may function as a biological cross linking agent contributing to the structural integrity of connective tissue. It is needed for the functioning of the enzyme prolyl hydroxylase involved in collagen synthesis. Deficiency of silicon causes growth depression in rats and chicks. In rats, silicon deficiency causes impaired incisor pigmentation while silicon deficient chicks have very small combs and have no wattles. High levels of silicon are detrimental to farm animals. Excess silicon content of plants lowers the digestibility of organic matter. During high intake, the mineral gets deposited in the urinary system causing calculi (silica urolithiasis). In miners, inhalation of silica into lungs causes silicosis.

Lead: common sources of lead poisoning (plumbism) in man and domestic animals are paints, motor oils, battery and industrial fumes. During poisoning the most important organ affected is the brain. Moreover, lead inhibits several enzymes, particularly, δ-aminolevulinate (ALA) synthase, ALA dehydratase and ferrochelatase of haeme synthesis. Diets rich in calcium, lowers the toxicity commonly.

Arsenic: found in skin, hair and nails. It is needed to form metabolites of methionine including cystine. Arsenic poisoning is caused by certain insecticides and fungicides. Arsenic binds with SH groups of several enzymes (e.g. pyruvate dehydrogenase) and inhibits many biochemical reactions. Further, arsenic causes coagulation of proteins and blockage of ATP generation.

Naturally occurring metal binding substances

Oxalates: paddy straw, pusa giant napier grass, some other green fodders and tree leaves are rich in oxalates. Excess oxalate in diet causes precipitation of dietary calcium in gastrointestinal tract as calcium oxalate. Therefore, oxalate containing feed stuffs causes calcium deficiency in livestock. Insoluble calcium oxalate after its absorption may crystallize in kidneys and bladder where calculi formation may occur.

Phytate: found naturally in all vegetable feed ingredients particularly in bran's. About half the quantity of phosphorus in cereals is in the form of phytin phosphorus which is hexaphosphoric acid ester of inositol. Six phosphate molecules are bound in one phytic acid molecule. Calcium, magnesium salts of phytic acid is phytate. Trace minerals like manganese and zinc are also bound to phytate. Phosphorus present in phytate is less available to monogastric animals. In ruminants, microbial phytase hydrolyses phytate and releases phosphorus, calcium and trace minerals. In poultry feeds the enzyme phytase (produced by certain bacteria and fungi) is added to increase the availability of phytate phosphorus.

Organic minerals/ Chelated minerals: organo metallic complexes are called chelates. In chelated minerals, the mineral is bound to organic compounds like amino acids or partially hydrolysed proteins e.g. copper lysine complex, zinc methionine complex etc. Organic minerals have higher bioavailability as they are absorbed into the system along with the organic compound.

FEEDS

International feed classes: National Research Council of USA (NRC), classified animal feeds into 8 classes on the basis of their physical and chemical characteristics, each of which is designated by a number (which is given in parenthesis). This classification utilized by the NRC was proposed by Crampton and Harris in 1969.

(1) *Dry forages and roughages*: all dry forages and roughages with more than 18% crude fibre (CF) or more than 35% cell wall constituents. The group includes the carbonaceous roughages like straws, grass hays, stalks etc and proteinaceous roughages like legume hays.

(2) *Pasture, range plants and forages fed fresh*: includes pasture grass, cultivated grasses, cereal fodders and legume fodders.

(3) *Silages*: includes ensiled forages e.g. grass silage, corn silage, alfalfa silage etc

(4) *Energy feeds*: products with less than 20% CP and 18% CF e.g. cereal grains like maize, rice, wheat etc and cereal byproducts like rice bran, wheat bran, rice polish etc

(5) *Protein supplements*: includes products with 20% or more protein. Protein supplements of vegetable origin includes soybean meal, ground nut cake, gingili oil cake, cotton seed cake, coconut cake etc. Protein supplements of animal origin includes animal tissue products (tankage, bone meal, meat cum bone meal, blood meal etc), fish products (fish meal) and milk products (dried milk, dried whey etc)

(6) *Mineral supplements*: bone meal, limestone, shell grit, dicalcium phosphate etc

(7) *Vitamin supplements*: fish oil, wheat germ oil, ensiled yeast etc.

(8) *Additives*: antibiotics, coloring material, flavours, toxin binders, hormones, preservatives etc

International feed number (IFN): Each feed is assigned a six digit International feed number (IFN) for its identification. The feed class number is the first digit of the IFN. E.g. for alfalfa hay the number is IFN 1-00-054 and for alfalfa fresh the number is IFN 2-10-196.

International feed vocabulary (IFV): IFV is designed to give a comprehensive name to each feed as concisely as possible. Each international feed name is coined by using descriptions from one or more of six facets.

1. Original material: i.e. the origin of parent material, may be specific (maize, wheat etc) and may be represented by scientific name or non specific (cereals, legume etc)
2. Part: represents the actual part of the parent material used as feed e.g. bran, seed, stem, leaf etc
3. Processes and treatments: e.g. grinding, pelleting, solvent extraction, sun curing etc
4. Stage of maturity: for forages the nutritive value depends on the maturity. e.g. early vegetative, late vegetative, early bloom, mid bloom, full bloom, late bloom, milk stage, dough stage, mature, past ripe etc.

5. Cutting: Many types of forage are cut and harvested a number of times and hence need description.

6. Grades: official grade given on the basis of composition. E.g. Bureau of Indian Standards (BIS) has given specifications in which 'minimum' and 'maximum' per cent of feed nutrients have been described.

Examples of International Feed Names:

Original material - Part - Process - Maturity - Cut - Grade

1. *Medicago sativa* - Stems - Sun cured - Early Bloom - Cut 1 - ----------
2. *Glycine max* - Seeds - Meal solvent extracted – ---------- - ---------- - 43 % Protein

General classification of feeds

Feeds are classified into roughages and concentrates based on the crude fibre content which is primarily responsible for bulk density of the feeds.

I.Roughages: The term roughage is used to designate feeds that are high in fibre and low in energy. Feeds with more than 18% crude fibre (or more than 35% cell wall constituents) in their dried state are classified as roughages. They can be further classified into succulent (moisture above 80%) and non succulent (moisture below 80%); leguminous and non leguminous; green and dry. Roughages can also be grouped based on their nutritive value (DM basis) as follows:

1. Maintenance type: have 3-5 % digestible crude protein (DCP) e.g. non legumes like cereal fodders, grasses and their hays
2. Productive type: have above 5% DCP e.g. legume fodders and their hay.
3. Non maintenance type: below 3% DCP e.g. straws and stovers.

II. Concentrates: classified into 3 groups based on energy and digestible protein

1. *Carbonaceous*: rich in energy and low in DCP e.g. cereal grains
2. *Proteinaceous*: rich in DCP e.g. oil seed cakes and animal protein supplements
3. *Products with energy and protein in intermediary position*: e.g. bran's, polish etc

In yet another classification concentrates are classified as

1. *Energy feeds*: Feed stuff with less than 20% CP and less than 18% CF on DM basis e.g. cereal grains, mill by products, fruits, nuts, roots, molasses etc. The main component of the DM of cereal grains is starch. The CP content of cereal grains varies between 8-12% and the cereal protein is generally deficient in the amino acids lysine and methionine. The oil content of cereals is concentrated in the embryo and among the common cereals; it is highest in oats (4-6%) and lowest in wheat (1-2%). Mill by products is the term used to describe the various cereal byproducts like bran. Bran is the outer coarse coat of grain separated during processing. Protein content of bran is 8-18%. Bran provides bulk to concentrate mixture and has laxative action. In general the bran's are rich in the mineral phosphorus.
2. *Protein supplements*: Contains more than 20% CP

a) Cakes and meals: They are the left over products after extraction of oils from seeds. Oil seedcakes and meals are rich sources of protein; about 95% of the nitrogen is present as true protein. Certainly they are of poorer quality than good quality animal protein supplements like fish meal. In general the vegetable protein supplements are deficient in the essential amino acid lysine. An exception to this is soybean meal.

Methods of oil extraction from oil seeds includes

- Ghani pressed (Hydraulic pressure method): Oil seeds are pressed under high pressure. The cake has about 8% fat.
- Expeller process: Seeds are fed into a revolving screw of diminishing circumference, the oil being collected and carried off in small channels. The cake obtained by this method has about 6% fat.
- Solvent extraction process: Seeds are crushed and placed loosely in a large container and a fat solvent like ether, benzene or petrol is allowed to percolate. Extracted material is heated with steam to remove the solvent. The cake obtained has less than 1% fat and is generally termed 'meal' e.g. soybean meal.

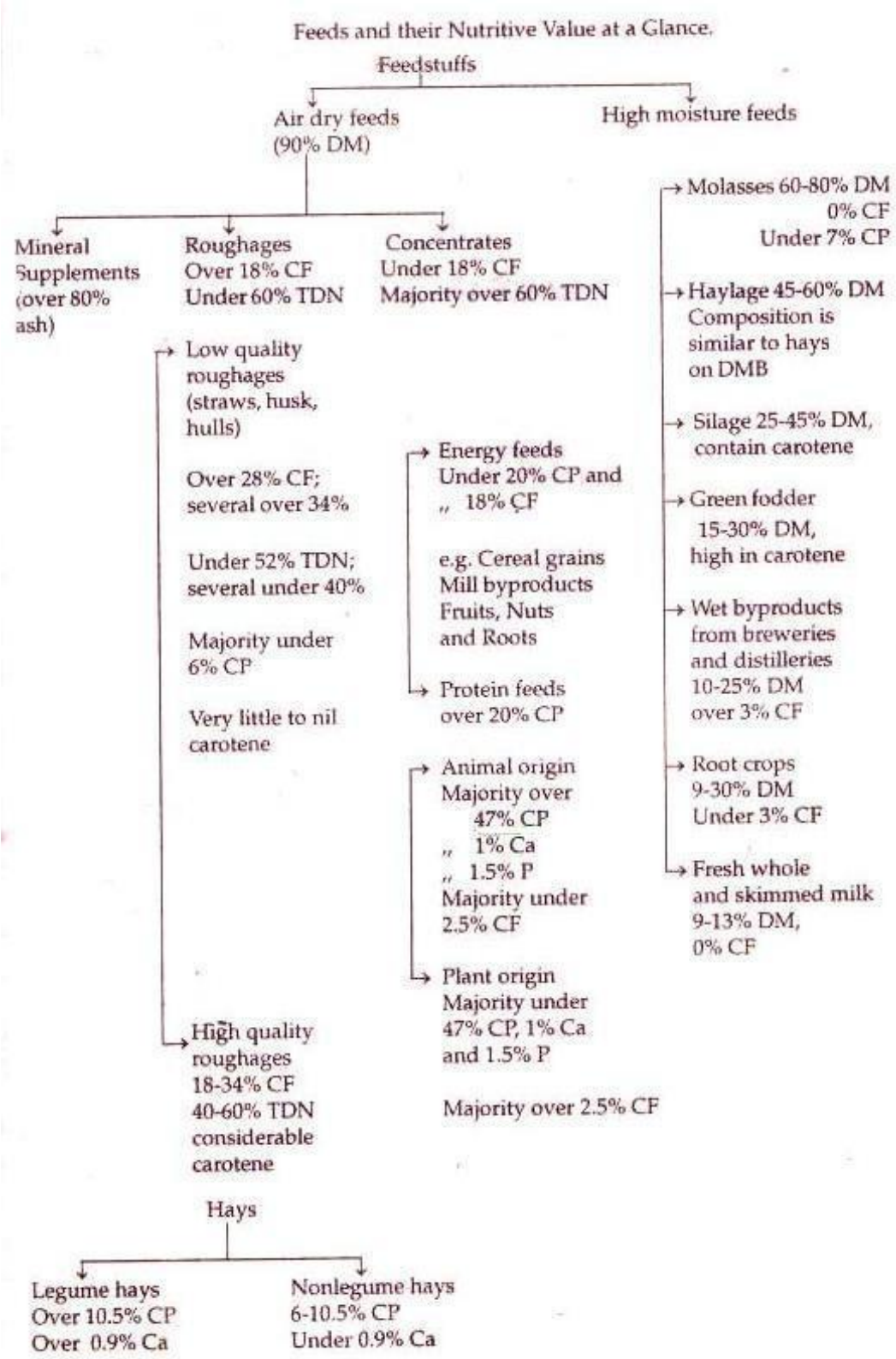
b) Animal protein supplements: Protein supplements derived from animal tissues. They are difficult to process and store without spoilage and nutrient loss. These are given to animals in much smaller amounts than the oil seed meals/cakes, since they are not used primarily as sources of protein but to make good deficiencies of certain essential amino acids like lysine.

III. Mineral supplements

IV. Vitamin supplements

V. Feed additives

COMMON FEEDS AND THEIR NUTRITIVE VALUE *(Reddy D. V, 2004)*

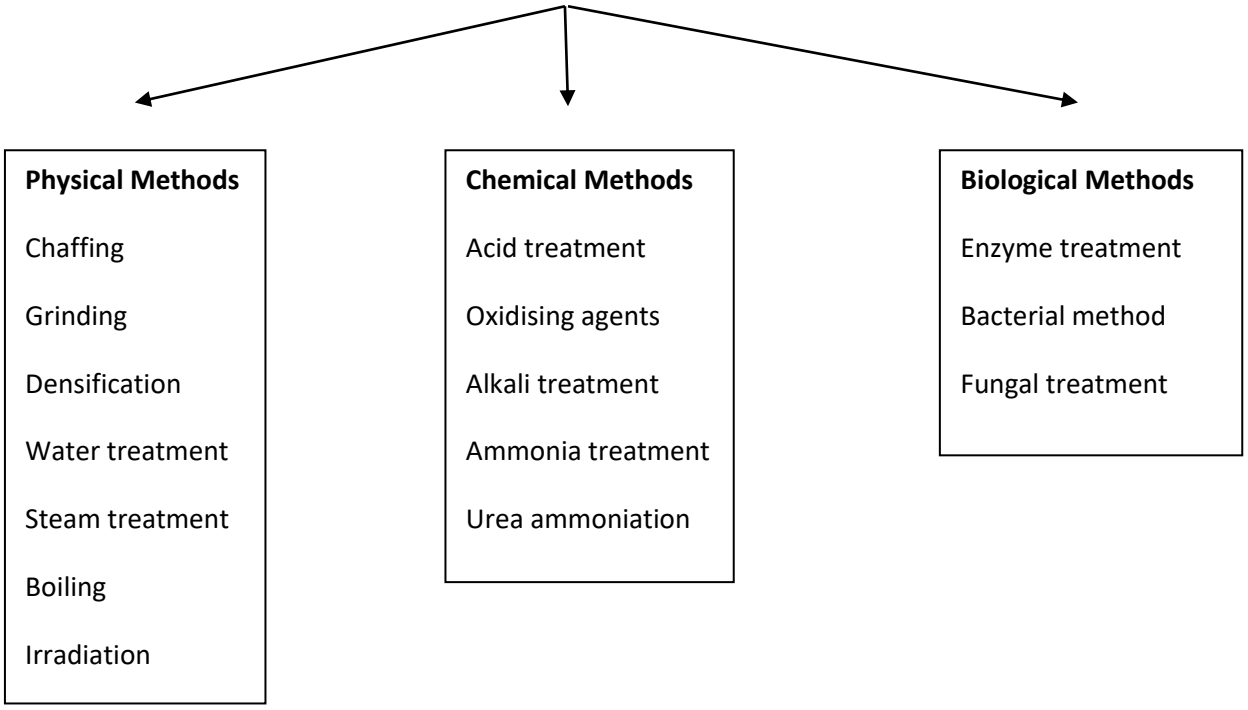


PROCESSING OF INFERIOR QUALITY ROUGHAGE

Dry fibrous crop residues available for the feeding of livestock are straws of paddy, wheat, millets etc and stovers of sorghum, pearl millet, maize etc. In India, straws and stovers are considered as conventional dry roughages for the feeding of ruminants. However, the nutrients in such roughages are not efficiently utilized even by ruminants and require appropriate treatment. The need for treatment of inferior quality roughage may be listed as follows:-

1. Low voluntary intake due to poor palatability
2. Low digestibility of fibre
3. Deficient in crude protein, essential minerals and most vitamins
4. High content of antinutritional factors like lignin, silica, tannins, oxalates, etc

PROCESSING METHODS OF INFERIOR QUALITY ROUGHAGES



I. Physical methods

1. Chaffing/ Chopping: dry fodders are chaffed into 1-4 cm long pieces in hand operated or power operated chaff cutters. This increases voluntary intake and reduces the wastage of hard parts. Moreover, chopping green fodder facilitates good silage making. Chopping increases the surface area of the fodder for microbial digestion in the fore stomach. However, chopping

will not increase the digestibility of fodder due to increased rate of passage in the digestive tract.

2. Grinding: the dried and chaffed roughages are grind in a hammer mill. Grinding is required for the densification of fodders in the form of pellets or wafers or cubes.

3. Densification: process by which bulky roughages are compressed several times and their volume is reduced to even less than 1/3rd of original loose dry fodder. The methods for densification includes

a) Baling: preparation of compressed product of about half cubic metre to one cubic metre by pressing loose straw or hay with a baling machine.

b) Block making: The process is similar to baling but blocks are smaller in size (normally 10 X 25 X 5 cm) and prepared from chaffed fodder.

c) Pelleting: dried roughage is grinded and made into pellets. Ground material is forced to pass through holes of specific size by mechanical process in a pelleting machine.

d) Wafering or cube making: wafers or cubes of desired shape and size are produced by compressing chaffed roughages through the die of desired shape and size.

4. Water treatment: It includes;

a) Water washing: chaffed straw is dipped in water for 2 hrs and then water is decanted. The washing is repeated twice. This method is useful in removing the antinutritional factor oxalate from paddy straw. Paddy straw is rich in oxalate and the major portion of it is present in the form of soluble potassium and sodium oxalates and only small fraction is present in the insoluble form of calcium oxalate.

b) Water soaking: dipping of dry roughages in water for more than 3 hrs. This causes swelling and softening of dry roughages and increases voluntary feed intake.

5. Steam treatment: steam is injected into stacked roughage to make it reasonably moist. Treatment causes softening and expansion of fodders resulting in increased voluntary intake and digestibility.

6. Boiling: it is common among dairy farmers of north eastern states where they get firewood free of cost from forest area. In this method the roughage is cooked after mixing with concentrates.

Among the physical methods, steaming and boiling has greater effect on improvement of feeding quality of straw because these methods break the bonds between lignin and other fibre constituents.

II. Chemical methods

1. Acid treatment: acids like sulphuric acid and nitric acid is used. The advantage obtained by this method is not commensurate with the expenditure and labour inputs. The process could not be adopted by the farmer due to its little practical utility.

2. Treatment with oxidizing agents: lignin in roughages can be disintegrated by treatment with oxidizing agents like bleaching powder, sodium thiosulphate, sodium sulphite, ozone, sulphur dioxide, alkaline hydrogen peroxide etc.

3. Alkali treatment: done to break the lignin-cellulose/ lignin-hemicellulose bonds in fibrous crops to improve the digestibility of cellulose and hemicelluloses.

a) Treatment with sodium hydroxide: this is the most common method of alkali treatment. Chaffed and weighed dry fodder is spread on hard floor or thick polythene sheet. 3-4% solution of sodium hydroxide is prepared in equal quantity of water. Alkali is sprinkled and the straw is thoroughly mixed. Mixing is done to assure uniformity and the mixture is left for 3-4 hrs for reaction. Now the alkali treated straw is ready for feeding. Since sodium hydroxide is corrosive, care should be taken to protect the skin during spraying and mixing. Methods of NaOH treatment during early days include

i) Beckmann method (1921): consist of treating chopped straw in 8-10 times its weight of 1.2 to 1.5% solution of NaOH for atleast 4 hrs. The treated straw is washed with a large quantity of water until free from alkali. 20-25% of DM of straw is lost during this method.

ii) Modified Beckmann method: In modified version of Beckmann method less NaOH and less water is used to decrease the DM loss.

b) Treatment with lime: since calcium hydroxide is weaker when compared to sodium hydroxide, higher concentration and longer duration is required. Nutritional improvement is also lower when compared to treatment with sodium hydroxide

c) Treatment with a combination of calcium and sodium hydroxides

4. Ammonia treatment: First systematic experiment for the nutritional improvement of straw with ammonia was conducted in Germany during early thirties (Kronberger, 1933). Treatment with 1.5% ammonium hydroxide is effective in the nutritive improvement of poor quality roughages.

5. Urea ammoniation: Most cereal crop residues has 8-12% lignin and 60-70% cellulose and hemicelluloses. Lignin is found interspersed with hemicelluloses in the cell wall fraction forming a matrix around the cellulose microfibrils. Due to this arrangement lignin limits the action of microbial cellulases and hemicellulases resulting in low digestibility of these polysaccharides. ***Urea ammoniation is the most convenient and most successful method of straw treatment for breaking the ester bond of lignin with other fibre constituents.*** Urea is easily available with the farmers in India at subsidized price. Weighed quantity of chaffed straw is spread on a thick polythene sheet in a layer of 40-50 cm (thickness). Fertilizer grade urea at the rate of 4% (it is better to use 2-3% in hot and humid climate) of dry fodder is used (4 kg urea is dissolved in 40 litres of water for each 100 kg straw). The urea solution is sprayed over the straw, mixed uniformly and then stacked airtight by covering with another polythene sheet and left for 3-4 weeks for reaction. The stack is opened from one side; required quantity for feeding the animals is spread for overnight aeration and then offered to the animals.

During urea treatment, ammonia released from urea acts on alkali labile ester bonds of lignin with cellulose and hemicellulose, making cellulose and hemicellulose available. Urea ammoniation of straw improves the digestibility of fibre, improves the crude protein content (CP increases from around 3% to 6-8%) and improves the voluntary feed intake.

III. Biological methods

1. Enzyme treatment: cellulase solution is sprayed on straw at a rate of 25 mg/100kg straw.

2. Bacterial fermentation method: chopped straw is pretreated with 3-5% NaOH and steamed at 120^0C for 15 minutes; then fermented with bran type media cultured with cellulolytic bacteria at 40-50^0C for 2 days.

3. Fungal treatment: Several varieties of wood rotting fungi posses the ability of lignin degradation and perhaps few of the strains of such fungi is developed as a potential lignin degrader without much degradation of cellulose, hemicelluloses and starch. Among wood rot fungi, white rot fungi (e.g. *Phanerochaete chrysosporium*) possess the ability of lignin biodegradation without much degradation of other constituents of fibre.

Indo-Dutch project on bioconversion of crop residues

a) Zadrazil process: straw is treated with the fungi *Pleurotus*.

b) Karnal process: straw is treated with 4% urea, ensiled for 30 days, followed by second stage in which the material is mixed with 1% super phosphate & 0.1% calcium oxide, followed by third stage in which the straw is inoculated with the fungi *Coprinus fimetarius*.

SILAGE

Silage is the feed material produced by controlled fermentation of a crop (chiefly green fodder). The best silage is moist to touch, soft (but not slimy) and fragrant. *Ensiling* is the name given to the process and the container used for the purpose is termed *silo* (pit silo, tower silo, trench silo, bunker silo etc) Commonest crops used are cereal fodders, grasses, legumes and whole cereals especially maize. The optimum dry matter (DM) content of green fodder used for making silage is 35%.

Preparation of silage in a pit silo

1. Select the crop that is to be ensiled when it has nearly 35% DM.
2. The day of silage making should be preferably fair i.e. not rainy.
3. Chop the fodder (packing is better once fodder is chopped)
4. Silo is filled rapidly with chopped fodder.
5. Trampling and tight packing of fodder should be done either with men or tractor or bullocks.
6. At the top of the silo the fodder should be packed 3-4 feet above the ground level.
7. All the sides and top of the silo should be covered with a layer of paddy straw and then with wet mud and dung to seal the material.
8. Silage would be ready in two months.

Chemical changes during silage making

After the crop has been placed in a compact mass and sealed with mud in a silo, the plant cells continue to respire for some time (aerobic phase). This completely utilizes the oxygen entrapped in the mass within five hours and the temperature gradually rises to 30-38^{0}C. Due to the production of carbon dioxide (which gives rise to carbonic acid), acid forming bacteria multiply enormously in the silage. These bacteria attack the sugars and other soluble carbohydrates and produces lactic acid and volatile fatty acids (predominantly acetic acid i.e. 0.5 to 4% of DM). In well made silages the overall amount of lactic acid produced should be 60% of total acids by the end of ensilage. There are two types of lactic acid producing bacteria namely homofermentative type and heterofermentative type. Homofermentative type produces two moles of lactic acid per molecule of glucose or fructose fermented. Heterofermentative type produces 1 mole of lactic acid, 1 mole of ethanol and 1 mole of carbondioxide per mole of glucose fermented while lactic acid, mannitol, acetic acid and carbon dioxide are produced from fructose. The production of organic acids prevents the growth of undesirable microbes is silage. Once the pH of the mass falls below 4 the bacterial fermentation is checked and practically ceases if the air doesn't enter further. pH of 4 or below normally inhibits clostridial growth. Plants like maize and sorghum are rich in soluble carbohydrates and hence considered the best crops for silage making. Protein rich leguminous crops like berseem and lucerne are not good for silage making as they are deficient in soluble carbohydrates. In

such cases clostridial organisms multiply and butyric acid type of fermentation will predominate. Saccharolytic clostridial fermentation produces butyric acid, carbondioxide and hydrogen. Butyric acid has a sharp disagreeable odour and the silage is not relished by the animals. Poroteolytic clostridia produce variety of end products like ammonia and volatile amines.

In the first 5-7 days of ensilage, proteins in silage are broken down to amino acids, amides, amines etc by the action of proteases. The optimum pH for proteolysis is around 6. Once the pH lowers from 6 to 4 the plant proteases cease to function. In badly preserved silage the principal products of proteolysis and further putrefaction are betaine, adenine and pentamethylene diamine. Other plant enzymes such as polyphenol oxidases causes formation of quinones which combines with proteins and eventually leads to formation of brown colour by the Maillard reaction. The greenish brown colour of good quality silage is due to a pigment phaecophytin, a magnesium free derivative of chlorophyll. Silage is dark brown or black when the temperature in the silo is too high.

Conditions for Silage making

1. Crops rich in soluble carbohydrates are most suitable for ensiling e.g. maize, sorghum (jowar) and bajra. Grasses are not ideal to ensile because they are low in soluble carbohydrates. Natural grasses can be ensiled with addition of molasses at 3-3.5%. Green fodder crops are harvested when they contain about 35% dry matter i.e. between flowering and milk stage (when the ears start coming). If the moisture content of the crop used in silage making is very high then there is undesirable fermentation resulting in the production of more amounts of butyric acid instead of acetic and lactic acids. If the DM of the crop is high, there will not be proper compactness of the mass and more air is entrapped resulting in spoilage.

2. Anaerobic environment: Silo is an air tight structure designed for the storage and preservation of high moisture feeds like silage. Pit silos are more common in India. Pit silo should be sufficiently deep and should be located in an elevated ground. Anaerobic environment is achieved by chopping the crop during harvesting, by rapid filling of the silo and by adequate consolidation and sealing of silo. Silage is generally ready after 6-8 weeks. If oxygen enters the silo, aerobic microbial activity occurs and the material decays to a useless, inedible and toxic product.

3. Preventing the growth of undesirable microbes: growth of undesirable microbes like clostridia produces toxic fermentation products. These organisms can be inhibited by encouraging the growth of lactic acid bacteria or by using chemical additives.

Nutrient content of silage

Nutrient content of silage is similar to the crop from which the silage is made. Vitamin C is easily decomposed and lost during silage making. β carotene appears to be relatively stable during ensiling of fodder under strict anaerobic conditions. In lactic acid type of fermentation

the overall DM losses during ensiling is less than 5% while in clostridial fermentation the nutrient losses are much higher.

Losses of nutrients during ensilage

1. *Field losses*: nutrient losses are negligible when the crops are ensiled on the same day of harvest. DM losses increases when the fodder is wilted for longer period prior to ensiling.
2. *Oxidation losses*: during early days this occurs due to action of plant/microbial enzymes on carbohydrates (in the presense of oxygen) leading to formation of carbondioxide and water. In well filled silo this accounts a loss of less than 1% of DM. if there is continuous exposure to oxygen the loss of DM may exceed even upto 75%.
3. *Fermentation losses*: Less than 5% of DM. This loss increases during clostridial and enterobacterial fermentations.
4. *Effluent losses*: In most silos, free drainage occurs and the liquid or effluent carries with it the soluble nutrients. Effluent losses vary with initial moisture content and little effluent is produced when crops are ensiled having the optimum moisture content of 65 %.

Classification of silage

PARAMETER	**VERY GOOD**	**GOOD**	**FAIR**	**POOR**
pH	Less than 4.2	4.2-4.5	4.5-4.8	More than 4.8
Ammoniacal nitrogen as a % of total nitrogen	Less than 10%	10-15%	15-20%	More than 20%
Butyric acid content	Less than 0.2%	0.3-0.5%	More than 0.5%	Very high
Smell	Good (acidic)	Satisfactory (acidic)	Slightly acidic	Bad (pungent)
Fungal/ mould growth	Absent	Absent	Slight	More

***Flieg index*:** flieg index is calculated to evaluate silage quality. The index is calculated by determining the relative amounts of lactic, acetic and butyric acids expressed as percentage of the total acids in silage. If the silage is of very good quality its total score range between 44-50 and it is below 19 for poor quality silage.

Additives in silage

1. Salt 0.5% and urea 1% are added to improve the palatability and nitrogen content.
2. In grass silage molasses is added 3-3.5% to improve the sugar content and thus quality of silage.
3. Limestone can be added at the rate of 0.5-1%.
4. Organic acids such as propionic acid (1%)
5. Bacterial cultures e.g. lactobacillus

6. Sodium metabisulphite (4-8 kg/1000 kg fodder) is added as preservative to check the growth of undesirable microbes.

Silo fillers disease: illness of farm workers that is caused by inhalation of oxides of nitrogen during ensiling or while entering a silo after filling. Oxides of nitrogen when inhaled forms nitrous acid and nitric acid in lungs and thus cause chemical pneumonia.

Advantages of silage making

1. Helps in preserving green fodder when the weather does not permit for hay making.
2. Can be prepared from plants having thick stems and are generally not suitable for hay making e.g. sorghum, maize etc
3. The organic acids produced in the silage are similar to those produced normally in the rumen and therefore are absorbed and used in the same manner.

Disadvantages of silage making

1. Transportation is difficult when compared to hay
2. Permanent structure (silo) is required

AIV method of silage making: Developed by A I Virtanen in Finland (1925). A mixture of dilute HCl and dilute H_2SO_4 is added while ensiling. Generally the method is employed while making silage from clover and clover grass mixtures.

Haylage: when grasses and legumes which are generally meant for hay are ensiled, it is called haylage. They are wilted to 40-45% DM before ensiling.

Wastelage: silage prepared by anaerobic fermentation of animal wastes (poultry droppings, swine excreta, cattle dung etc) along with other feed ingredients with the help of lactic acid producing bacteria.

HAY & STRAW

Hay is the product obtained by cutting and curing the entire herbage of thin stemmed grasses (Cyanadon, Cenchrus, Marvel etc), cereals (oats, barley etc) or legumes (Lucerne) so that the moisture content of the product is not more than 12-14%. The best time for cutting a crop for hay making is when it is 1/3 to 1/2 blossom; in case of cereals the grain is in the milk stage while in legumes tender pod formation stage is optimum. The later the date of cutting the more will be the yield, the lower the digestibility & nutritive value and lower the voluntary intake by animals.

Kinds of hay

a) *Legume hay*: they have higher content of digestible nutrients especially protein. Moreover, the protein of legumes is of superior quality compared to grasses and cereal fodders. The legume hays are rich in calcium and are generally palatable. Lucerne or alfalfa (*Medicago sativa*) is a very important legume which is grown as a hay crop in many countries. Crude protein content of Lucerne hay is as high as 20% on DM basis if it is made from crop cut in the early bloom stage.

b) *Non legume hay*: they are made from grasses and cereals. They are less palatable and contain less protein, minerals, vitamins than legume hays but the cereal hays are rich in carbohydrates. Cereal crops like oats and barley are generally used in hay making. Non legume hays have the advantage over legume hays because their outturn per hectare is more than that of legume hays and the former can be grown easily.

c) *Mixed hay*: hay prepared from mixed crops of legumes and non legumes.

Methods of hay making

1. **Field curing**: as the name indicates the plant are cut and cured in the field itself. After ***cutting*** the crop, it is left in the swath to dry partially (***swath curing***). Forage is left to cure in the swath until it is wilted sufficiently but before there is danger of shattering and loss of carotene due to bleaching action of sun. By the end of swath curing the moisture is roughly 40%. Partially dried forage is then rolled into small loose fluffy cylindrical bundles known as windrow (***raking***)**.** It is better to do raking in the morning as the dew makes the hay a little tougher and prevent shattering. Once the hay has been partially cured in windrows, bigger heaps are made and the process is termed ***cocking***. In automated systems where baler is attached to tractor picks up hay in the form of windrows and bale it for storage (***baling and storing***).

2. **Mow curing (barn drying)**: it is the practice of curing partially dried hay (i.e. after swath curing) inside the barns in mows. It takes 7-14 days on the mows with unheated air to cure the hay fully. With heated air it takes less time. After the end of mow curing the moisture is reduced to 20-25%. Hay produced by this method will be greener & leafier and of a higher quality than field cured hay.

3. **Artificial drying**: process of chopping freshly cut or wilted fodder and drying it in artificial driers. In western countries alfalfa leaf meal for use chiefly as vitamin supplement for poultry and swine are produced by this method. For ruminants the artificially dried hay can be packaged into different forms described as pellets, cobs or wafers. A *pellet* is a package made in a rotary die press from milled dried forage; a *cob* is made in a rotary die press from chopped and dried forage, while a *wafer* is usually made in a piston type machine from either milled or chopped dried forage.

Preservatives for hay: Generally preservatives are used only when there is a need to store the hay at high moisture levels. Propionic acid and its less volatile derivative ammonium bispropionate at a rate of 12kg/ton can be used for storage of hays with a moisture content of 30%. Anhydrous ammonia is also identified recently as a preservative for storing high moisture hay under aerobic and anaerobic conditions.

Nutrient losses in hay making: In normal curing of hay in the field there is a loss of 5-9% of DM. In legumes the overall loss may reach even up to 20-30% and for grasses it may be up to 10-15%

1. *Losses by shattering*: over drying or handling of hay during warm periods of the day causes shattering of leaves and finer parts especially in the case of legumes. Baling the crop prior to complete drying will reduce mechanical losses considerably.
2. *Losses due to oxidation*: exposure of green plants to sun causes bleaching of the colouring matter of grasses (carotene content falls from 0.02% to below 0.002%). Thus the Vitamin A content of hay is decreased. However, the sun cured hays are rich in Vitamin D_2.
3. *Losses due to fermentation*: after the crop is harvested the plant enzymes act on the soluble carbohydrates forming carbon dioxide and water. Therefore, in normal hay making process some of the nutrients are thus lost. If drying is prolonged because of bad weather conditions, bacterial fermentation takes place in cut herbage and leads to production of small quantities of acetic and propionic acids. In certain cases there will be mould growth. Mouldy hay is unpalatable and is toxic to the animals. Such hay may also contain *Actinomycetes* which are responsible for the allergic disease affecting man known as 'farmers lung'.
4. *Losses due to leaching*: partially cured hay in the field when exposed to heavy and prolonged rains results in severe losses of nutrients through leaching.

Brown hay: If hay is stored with moisture above 12-14%, fermentation takes place and the hay become very hot and turns brown. The dark brown colour of over heated hay can be attributed mainly to Maillard reactions. Such hay is unpalatable and less nutritious (protein is damaged).

Straws and related by-products

Straw: Straw consists of stems and leaves of plants after the removal of the ripe seeds by threshing, and is produced from most cereal crops and from some legumes. Common cereal straws are rice straw, wheat straw, maize straw, barley straw and oat straw. Cereal straws has low nutritive value (CP about 3%, DCP is 0 and TDN is about 40%). The legume straws are the

straws of beans and peas and are richer in protein, calcium and magnesium than cereal straws. Because of their thick fibrous stems they are more difficult to dry than cereal straws and frequently become mouldy on storage.

Chaff: Chaff consists of the husk or glumes of the seed which are separated from the grain during threshing.

Bagasse: When the sugarcane crop is processed for manufacturing sugar two by-products namely molasses and bagasse are obtained. Molasses is a high energy low protein food. Fibrous residue bagasse is a low protein product of very low digestibility and is sometimes mixed with cane molasses for cattle feeding.

HARMFUL NATURAL CONSTITUENTS, TOXIC ELEMENTS, METAL BINDING SUBSTANCES, CHELATED MINERALS AND COMMON ADULTERANTS OF FEEDS AND FODDERS

Harmful natural constituents

1. Alkaloids: these are basic substances that contain nitrogen in heterocyclic ring. Most alkaloids are derived from amino acids in their synthesis by plants.

a) Pyrrolizidine alkaloids: e.g. heliotrine and serecionine. The plants used in livestock feeding which contain this alkaloid are senecio, crotalaria, heliotropium and echium. The toxin causes liver damage.

b) Piperdine alkaloids: e.g. conine. It is found in poison hemlock (*Conium maculatum*). The toxin affects the central nervous system and is a potent teratogen.

c) Pyridine alkaloids: e.g. nicotine in tobacco. The toxin affects the central nervous system.

d) Indole: e.g. ergot, perloline and 3 methyl indole. They are derivatives of tryptophan. Found in tall fescue. Causes pulmonary emphysema.

e) Quinolizidine alkaloids: lupines contain these alkaloids which cause acute poisoning in sheep and teratogenic effect in calves (crooked calf disease).

f) Tryptamine alkaloids: found in *Phalaris tuberosa*, a forage grass grown in Australia. Phalaris poisoning results in acute neurological symptoms and chronic muscular in coordination.

g) Tropane alkaloids: e.g. atropine found in Datura (jimson weed). It has pronounced effect on central nervous system

2. Glycosides:

a) Cyanogenic glycosides: when hydrolysed by enzymatic action HCN/ prussic acid is released, which is highly toxic. HCN affect the electron transport chain by affecting cytochrome oxidase. Some common cyanogens are

i) Amygdalin (lactrile): found in wild cherries and in the kernels of almonds, apricots, peaches and apples.

ii) Dhurrin: occur in sorghum species and Johnson grass.

iii) Linamarin: found in the white clover, linseed, cassava and lima beans.

iv) Lotaustralin: found in cassava

Rubber leaves and rubber seeds also contain cyanogenic glycosides.

b) Glucosinolates: found in crucifers like cabbage, broccoli, kale, rapeseed, mustard and turnips (genus *Brassica*). Hydrolytic products of glucosinolates inhibit the function of thyroid gland. Glucosinolates in the presence of enzyme thioglucosidase is hydrolysed to isothiocyanates, having goitrogenic property.

c) Coumarin: found in spoiled sweet clover (*Melilotus*). Coumarin is metabolized in body producing dicoumarol. Dicoumarol is an inhibitor of Vitamin K, so toxicity increases susceptibility to haemorrhage.

d) Saponins: widely distributed in legumes like chick peas, soybean, alfalfa, berseem and common beans. Saponins forms stable foam with proteins & cholesterol and are involved in causing froathy bloat in ruminants. Saponins causes decreased growth rate and lowered egg production in poultry. Cotton seed oil is able to bind saponins and thus can be added in feeds as protective.

e) Isoflavones and coumestans: these are phytoestrogens. The estrogens in clovers are isflavones, while alfalfa contains coumestans. They cause clover disease. Genistein is an isoflavone found in soybean seeds. When sheep graze on estrogenic pastures, the fertility is affected, and in severe cases results in structural and functional changes to cervix and in some cases may lead to uterine prolapse.

3. Proteins and amino acids

a) Trypsin/ protease inhibitors: soybean is the major vegetable protein supplement used in swine and poultry feeds. The trypsin inhibitors of soybean are the best known e.g. Kunitz inhibitors and Bowman-Brik inhibitors. Raw soybean must be heat treated (100^0C for 15 minutes) to destroy trypsin inhibitors. Feeding of raw soybean to chicken causes pancreatic hypertrophy.

b) Haemagglutinins/ lectins: they cause agglutination of RBC *in vitro* by binding to mannose on the glycoproteins. First isolated from castor beans, which contain a potent lectin called ricin. Their biological effects are due to their affinity for sugars. They are found in soybean and other field beans such as kidney bean, pinto bean and navy beans. They cause damage to the intestinal cell lining and impair the immune system.

c) Mimosine: toxic factor of subabul (*Leucaena leucocephala*), which is a tropical legume with great potential as a protein source for livestock. The toxic amino acid mimosine is very similar to tyrosine and in rumen it is metabolized to 3, 4 dihydroxypyridine (DHP). DHP is a goitrogen impairing the incorporation of iodine in the thyroid gland. In non ruminants, mimosine causes poor growth, alopecia and cataract. Ruminant animals grazing *Leucaena* shows symptoms such as poor growth, loss of hair, swollen and rough coronets, mouth and esophageal lesions, depressed serum thyroxine level and goiter.

4. Erucic acid: found in rape and mustard seed. It is an unsaturated fatty acid. It causes poor growth, low feed intake and poor feed efficiency. Mustard cake contains 40-46% erucic acid in residual oil.

5. Lanceolatin: Toxic principle found in karanja (*Pongama glabravent*). It causes damage to liver, kidney, heart and reproductive system.

6. Lantadene: Found in *Lantana camara*. Consumption of this plant while grazing in forest area causes blindness, staggering gait, digestive disturbances, jaundice and dermatitis in cattle, sheep and goats.

7. Mowrin: present in mahua (*Bassia latifolia*) seed. This toxic component is bitter in taste and affects the palatability. It even hinders the growth of bacteria in rumen and affects the rate of fermentation.

8. Parthenium: found in a weed which grows in fields along with conventional crops. The toxic principle causes rhinitis and gastro-enteritis.

9. Nerioside and Oleandroside: found in oleander plant (*Nerium oleander*) which on ingestion causes toxicity leading to diarrhea, convulsions, paralysis and death.

10. Nimbidins: found in neem seed meal

11. Lathyrogens: lathyrism (croppling disease) is a disease in human beings caused by consumption of seeds of Lathyrus (mainly chick pea). Lathyrism is of two types

i) Osteolathyrism: it is the principal form that affects livestock. The toxin causes skeletal deformity and aortic rupture due to defective synthesis of cartilage and connective tissue.

ii) Neurolathyrism: paralysis of legs due to nerve damage in the spinal cord caused by neurotoxins in lathyrus.

12. Antivitamins

a) Antivitamin A: lipoxygenase in soybean seeds. Lipoxygenase oxidizes carotene, a precursor of vitamin A

b) Antivitamin D: in raw soybean seeds

c) Antivitamin E: kidney bean

d) Antivitamin K: Dicoumarol found in spoiled sweet clover

e) Antivitamin B_6: linatin in linseed meal

f) Antiniacin: niacytin found in maize and wheat bran.

13. Phenols:

a) Gossypol: found in cotton seed. Free gossypol at more than 150 mg/kg diet is toxic to poultry. In chick, gossypol causes poor growth, low feed intake, ascitis and cardiac irregularity. In layers it causes olive green discoloration of egg yolk. Ferrous salts are added in poultry rations when cottonseed meal containing gossypol is fed. The ferrous ion forms a complex with gossypol, making it non toxic to the animal.

b) Tannins: found in sorghum, rape and mustard meal, salseed meal, mango seed kernel, alfalfa meal, tamarind seed meal etc. Tannins bind with proteins and inhibit enzymes like trypsin, amylase, lipase etc. Tannins are classified into two types, hydrolysable tannins and condensed tannins. Condensed type tannins affect digestion more while the hydrolysable tannins are absorbable and affect certain organs like liver, intestine and kidney.

14. Mucilage: found in linseed meal

15. Non starch polysaccharides (NSP): found in creal grains and vegetable proteins. They are harmful to monogastrics especially poultry.

a) Arabinoxylans: found in wheat, rye and triticale. These are soluble NSP's and they increase the viscosity of digesta, and impairs nutrient uptake. Therefore, the enzyme xylanase is added in poultry ration based on wheat, rye and triticale.

b) β glucans: found in barley and oats. They cause increased viscosity of digesta and promotes bacterial multiplication. Therefore, the enzyme β glucanase may be added in barley and oat based rations for poultry.

c) Pectic polysaccharides: includes the galacturonans and associated arabinogalactans. Found in soybean meal.

d) Water soluble carbohydrates: e.g. sucrose and galactose.

16. Dioxins: produced as an unintentional byproduct of many industrial processes involving chlorine, importantly combustion and incineration, chemical manufacturing and processing, paper making and pesticide production. Dioxins released into the environment reach the food chain and get accumulated in body fat. Even minute amounts of dioxin have been shown to cause damage to the nervous system and liver, apart from causing cancer.

17. Mycotoxins

a) Aflatoxins: these are a group of closely related toxic substances produced by the fungi *Aspergillus flavus* and *Aspergillus parasiticus*, mostly in improperly stored feed stuffs such as cereal grains and oil meals. Four major aflatoxins are named as B_1, B_2, G_1 and G_2. These are named according to the fluorescence properties under short wave ultraviolet light on thin layer chromatography. B_1 and B_2 fluoresce blue and G_1 and G_2 fluoresce green. The toxic metabolite of aflatoxin excreted in milk is named aflatoxin M_1. Mouldy ground nut cake is an important source of aflatoxin in livestock feeds. Aflatoxins are hepatotoxins and in high doses they may impair kidney also. It is also a potent carcinogen. Maximum permitted level of aflatoxin in animal feeds as per Prevention of food adulteration act is 30 ppb or 0.03 ppm, while United States Food and Drug Administration (FDA) permit only a level of 20 ppb for dairy animals and immature poultry. Symptoms of aflatoxicosis include, decreased appetite, decreased production, weight loss, high liver enzymes, loss of liver function, abortion and ultimately death. The spoiled feed can either be reduced in quantity or removed. Among domestic animals, rabbits are most susceptible to aflatoxicosis followed by pig, cattle and sheep. Among birds tolerance for aflatoxin is least for duck followed by chicken and guinea fowl. There is no specific antidote for aflatoxicosis. Symptomatic and supportive care, tailored to the severity of the liver disease may include intravenous fluids with dextrose, active vitamin K, B vitamins, oral liver tonics and a restricted, but high-quality protein diet with adequate carbohydrate content.

b) Zearalenone: it is an estrogenic mycotoxin produced by fungus *Fusarium*, under certain specific environmental conditions on a wide variety of cereal grains. In swine the symptom of zearalenone toxicity is vulvo-vaginitis.

c) Ochratoxin: it is a mycotoxin produced almost always on grains and almost always as a result of poor storage conditions by molds of the *Penicillium* family and by *Aspergillus ochraceus*.

d) Deoxynivalenol (DON): produced by molds of the *Fusarium* species.

e) T-2 toxin (one of the trichothecenes): produced by several molds of the *Fusarium* species. T-2 toxin is found commonly in corn silage and in some haylages.

f) Ergot toxicity: caused by the *Claviceps purpurea*, differs from other mycotoxicosis. It results from the consumption of considerable amounts of fungal tissue and not because of the consumption of mycotoxin. The ergot is a mold that infects the flowering portion of many grains and grasses. Abortion and lowered fertility are associated with consumption of ergot-infected feeds

Toxic elements

1) Cadmium: the outbreak of cadmium toxicity in human beings was reported in Japan in the form of *itai itai* or *ouch disease*. Cadmium poisoning causes fragile bones, anemia, bone marrow disorders and kidney damage.

2) Arsenic: commonly found in many insecticides and fungicides. Arsenic binds with SH groups of several enzymes (e.g. pyruvate dehydrogenase) and inhibits many biochemical reactions. Further, arsenic causes coagulation of proteins and blockage of ATP generation.

3) Lead: It is the most common inorganic pollutant found in water, air, feeds and soils. The sources include petrol, paints, cigarettes, news papers, lead pipes and Xerox copies. The principal target of lead toxicity is central nervous system. Moreover, lead inhibits several enzymes, particularly, δ-aminolevulinate (ALA) synthase, ALA dehydratase and ferrochelatase of heme synthesis.

4) Mercury: it is a common industrial (plastic, paints, electrical apparatus, fungicides) pollutant. Acute poisoning cause's gastritis, vomiting and pulmonary edema. Chronic poisoning adversely affects the nervous system. Organic mercury poisoning is commonly referred to as *minamata* disease (it first occurred in a town named Minamata in Japan, by consuming fish containing methyl mercury an industrial pollutant).

5) Phosphide: phosphorus as phosphate or phospholipid, is an essential food; as zinc phosphide it is a poison and is used to control rodents.

6) Sulphur: livestock and poultry require sulfur containing amino acids. Inorganic sulphate also has some value when added in the diet. However, elemental sulphur when added to the diet of chicks the growth is impaired.

7) Common salt: consumption of salt in excess has deleterious effect on health. The tolerance of livestock for salt is however; remarkably high provided adequate drinking water is

available. Excessive intake of salt causes salt poisoning in pigs and poultry. Among domesticated ruminants, sheep are most tolerant to salt.

8) Flourine: rock phosphate can be added in diet as mineral supplement. Some rock phosphate contains fluorine in excess. Other sources of fluorine are fluoride containing water and herbage contaminated by dust from industrial pollution. Fluorine toxicity causes bone and joint abnormality due to deposition of calcium fluoride on bones. Bones lose their normal colour and lusture gets thickened and softened. In severe cases there is exostosis. In teeth there are enamel defects and in children there is mottled enamel and discoloration of teeth (dental fluorosis). Chicken is more tolerable to fluorine than other farm animals.

9) Molybdenum: herbage grown on soil high in molybdenum accumulates the metal in the foliage. When this is offered to animals, scouring and weight loss may occur.

10) Selenium: grains and herbage grown on seleniferous soils may have toxic quantity of selenium in them. Livestock eating them is poisoned and show symptoms like dullness, stiffness of the joints, loss of hair from tail and hoof deformities. *Alkali disease, blind staggers and degnala* disease are selenium toxicity diseases.

11) Nitrates and nitrites: certain fodders accumulate nitrate either due to plant specificity or having tendency for higher uptake of nitrogen from soil leading to poisoning in animals consuming them (e.g. oat hay poisoning). In rumen, nitrate is converted to nitrite by rumen microorganisms. Nitrite causes its toxicity by converting hemoglobin to methaemoglobin (it do not transport oxygen). In severe cases of nitrate poisoning, the blood becomes almost chocolate brown in colour and death may result due to anoxia.

Metal Binding Substances

1. Oxalates: paddy straw, pusa giant napier grass, some other green fodders and tree leaves are rich in oxalate. Excess oxalate in diet causes precipitation of dietary calcium in gastrointestinal tract as calcium oxalate. Therefore, oxalate containing feed stuffs causes calcium deficiency in livestock. Insoluble calcium oxalate after its absorption may crystallize in kidneys and bladder where calculi formation may occur.

2. Phytate: found naturally in all vegetable feed ingredients particularly in bran's. About half the quantity of phosphorus in cereals is in the form of phytin phosphorus which is hexaphosphoric acid ester of inositol. Six phosphate molecules are bound in one phytic acid molecule. Calcium, magnesium salts of phytic acid is phytate. Trace minerals like manganese and zinc can also bind with phytic acid. Phosphorus present in phytate is less available to monogastric animals. In ruminants, microbial phytase hydrolyses phytate and releases phosphorus, calcium and trace minerals. In poultry feeds the enzyme phytase (produced by certain bacteria and fungi) is added to increase the availability of phytate phosphorus and other minerals bound to phytate.

Organic minerals/ Chelated minerals: organo metallic complexes are called chelates. In chelated minerals, the mineral is bound to organic compounds like amino acids or partially hydrolysed proteins e.g. copper lysine complex, zinc methionine complex etc. Organic minerals have higher bioavailability as they are absorbed into the system along with the organic compound

Common adulterants in feeds: adulteration is defined as the intentional admixture of a pure substance with some cheaper and low quality substances.

Feed ingredient	**Adulterant**
Groundnut cake	Groundnut husk, urea, non edible oil cakes
Mustard cake	Argemone: It is a weed found in mustard field. Seeds from *Argemona maxicana* are found as adulterant in rape and mustard seed meal. It is rich in oil. Sanguinarine is the toxic alkaloid present in argemone. It causes swelling of leg, diarrhea, damage to optic nerve and edema in poultry.
Soybean meal	Urea
De-oiled rice bran and wheat bran	Ground rice hulls, saw dust
Fishmeal	Common salt, Urea
Mineral mixture	Common salt, marble powder, sand, limestone
Molasses	Water

FEED SUPPLEMENTS AND ADDITIVES

What is Supplement?

The term, supplement, refers to feedstuffs that are used to improve the value of basal feeds. They can be used in large quantities, such as protein supplements, or in extremely small quantities, such as trace minerals.

While formulating ration, attention is first given to its dry matter, proteins and energy requirements. After this micronutrients such as individual amino acids, minerals, and vitamins are added to correct any deficiency in the ration.

Energy supplements are rich in energy ie above 60% TDN or 2500 Kcal ME. Eg Cereal grains, millets, brans, fats and oils.

Protein supplements contain more than 18 % protein. They can be from animal origin or plant origin

Animal origin	**Plant origin**
Mostly over 47% protein	Mostly under 47% protein
Mostly over 1.0% Ca	Mostly under 1.0% Ca
Mostly over 1.5% P	Mostly under 1.5% P
Mostly under 2.5% fibre	Mostly over 2.5% fibre

Other sources includes NPN compunds, single cell protein etc.

Mineral supplements are rich sources of any one of the essential minerals. Eg shell grit, bone meal, dicalcium phosphate.

What is an Additive?

An additive is a substance that is added to a basic feed, usually in small quantities, for the purpose of fortifying it with certain nutrients, stimulants or medicines other than as a direct source of nutrient.

In general, the term “feed additive” refers to a non-nutritive product that affects utilisation of the feed or productive performance of the animal.

Classification of feed additives

Feed additives and implants can be classified according to their mode of action.

1. Additives that enhance feed intake

(a) Antioxidants:

Antioxidants are compounds that prevent oxidative rancidity of polyunsaturated fats. Rancidity once develops, may cause destruction of vitamins A, D and E and several of the B complex vitamins. Breakdown products of rancidity may react with lysine and thus affects the protein value of the ration. Ethoxyquin or BHT (butylated hydroxytoluene) can serve as antioxidant in feed.

(b) Flavouring Agent:

Flavouring agents are feed additives that are supposed to increase palatability and feed intake. There is need for flavouring agents that will help to keep up feed intake

1. when highly unpalatable medicants are being mixed
2. During attacks of diseases
3. When animals are under stress, and
4. When a less palatable feedstuffs is being fed either as such or being incorporated in the ration.

Ruminants prefer sweet compounds. Additionally cattle and goats respond positively to salts of volatile fatty acids. Horses will often refuse musty feed when there is so little mould that the owner fails to detect it.

2. Additives that enhance the colour or quality of the marketed product

In Poultry the yellow colour will be oftenly enhanced by incorporating xanthophylls into broiler feed. Among various additives, arsanilic acid, sodium arsanilate and roxarsone are added for the purpose.

3. Additives that facilitate digestion and absorption

a. **Grit:** Poultry do not have teeth to grind any hard grain, most grinding takes place in the thick musculated gizzard. The more thoroughly feed is ground, the more surface area is created for digestion and subsequent absorption. Hence, when hard, coarse or fibrous feeds are fed to poultry, grit is sometimes added to supply additional surface for grinding within gizzard. When mash or finely ground feeds are fed, the value of grit become less. Oyster shells, coquina shells and limestone are used as grit.

b. Buffers and Neutralisers: During maximum production stage ruminants are given high doses of concentrate feeds for meeting demands for extra energy and protein requirement of the animal. The condition on the other hand lowers the pH of the rumen. Since, many of the rumen microbes cannot tolerate low pH environment, the normally heterogeneous balanced

population of microbes become skewed, favouring the acidophilic (acid-loving) bacteria. The condition often leads to acidosis and thereby upsets normal digestion.

The addition of feed buffers and neutralisers, such as carbonates, bicarbonates, hydroxides, oxides, salts of VFA, phosphate salts, ammonium chloride and sodium sulphate have been shown to have beneficial effects. Recently the use of baking soda ($NaHCO_3$) has been shown to increase average daily gain by about 10 per cent, feed efficiency by 5 to 10 per cent, and milk production by about 0.5 liter per head per day.

c. Chelates: The word "Chelates" is derived from the Greek word "Chele" meaning "claw" which is a good descriptive term for the manner in which polyvalent cations are held by the metal binding agents. Prior to union with the metal these organic substances are termed as "ligands". Ligand + mineral = chelate element.

Organic chelates of mineral elements which are cyclic compounds are the most important factors controlling absorption of a number of mineral elements. A particular element in chelated form may be released in ionic form at the intestinal wall or might be readily absorbed as the intact chelate. Chelates may be of naturally occurring substances such as chlorophyll, cytochromes, haemoglobin, vitamin B12 some amino acids, etc., or may be of synthetic substances like ethylenediaminetetracetic acid (EDTA.)

In biological systems there are three types of chelates:

Type I. Chelates that Aid in Transport and to store Metal Ions

Chelates of this group behave as a carrier for proper absorption, transportation in the circulatory system and passing across cell memberances to deposit the metal ion at the site where needed.

a. Among amino acids, cysteine and histidine are particularly effective metal binding agents and may be of primary importance in the transport and storage of mineral elements throughout the animal body.

b. Ethylene diamine tetracetic acid (EDTA) and other similar synthetic ligands also may improve the availability of zinc and other minerals.

Type II. Chelates Essential in Metabolism

Many chelates of animal body are holding metal ions in such a cyclic fashion which are absolutely necessary to be in that form to perform metabolic function. Vitamin B12 cytochrome enzymes and haemoglobin are some of the examples of this type. Haemoglobin molecule without its content of ferrous form of iron will be of no use in transporting oxygen.

Type III. Chelates Which Interfere with Utilisation of Essential Cations

There are some chelates found in the body which might have accidentally formed and are of no use to the subject. Rather, those chelates may be detrimental for the proper utilisation of the element. Phytic acid-Zn chelate or oxalic acid calcium chelate are examples of this type.

d. Probiotics: is defined as a live microbial feed supplement which beneficially affect, the host animals by improving its intestional microbial balance. The probiotic preparation are generally composed of organisms of lactobacilli and/or streptococci species, few many contain yeast caltones.

They benefit the host by:

1. Having a direct antagonistic effect against specific group of undesirable or harmful organism through production of antibacterial compounds, elemanatry or minimising their competition of nutrients.
2. Altering the pattern of microbial metabolism in the gastro intestional tract.
3. Stimulation of immunity.
4. Neutralization of entrotoxins formed by pathegenic organism.

Thus resulting in increased growth rate, improved feed efficiency.

4. Additives that promotes growth and production

a. Antibiotics: These are substances which are produced by living organisms (mould, bacteria or green plants) and which in small concentration have bacteriostatic or bactericidal properties. They were originally developed for medical and veterinary purposes to control specific pathogenic organisms. Later it was discovered that certain antibiotics could increase the rate of growth of young pigs and chicks when included in their diet in small amounts. Soon after this report a wide range of antibiotics have been tested and the following have been shown to have growth promoting properties: penicillin, oxytetracycline (Terramycin), chlortetracycline, bacitracin, streptomycin, tyrothricin, gramicidin, neomycin, erythromycin and flavomycin. Increased weight gain is most evident during the period of rapid growth and then decreases. Differences between control and treated animals are greater when the diet is slightly deficient or marginal in protein, B-vitamins or certain mineral elements.

Mode of Action of Antibiotics

1. Antibiotics “spare” protein, amino acids and vitamin on diets containing 1 to 3 per cent less protein, but balance experiments have often failed to show increased nitrogen retention. Growth stimulation has been greatest when the antibiotic penicillin supplement has been added to a ration containing no protein supplements of animal origin or to a ration low in vitamin B12. Under hygienic conditions growth increases are small.
2. Intestinal wall of animals fed antibiotics is thinner than that of untreated animals which might explain the enhanced absorption of calcium shown for chicks.

3. Reduce or eliminate the activity of pathogens causing “subclinical infection.”
4. Reduce the growth of micro-organisms that compete with the host for supplies of nutrients.
5. Antibiotics alter intestinal bacteria so that less urease is produced and thus less ammonia is formed. Ammonia is highly toxic and suppresses growth in non-ruminants.
6. Stimulate the growth of micro-organisms that synthesise known or unidentified nutrients.

Following points should be kept in mind while using antibiotics for animal feeding:
1. Antibiotics should be used only for (a) growing and fattening pigs for slaughter as pork or bacon; (b) growing chicks and turkey poults for killing as table poultry.
2. Antibiotics should not be used in the feed of ruminant animals (cattle, sheep and goats), breeding pigs and breeding and laying poultry stock.
3. While adding antibiotics at the recommended level, care should be taken that they are thoroughly and evenly mixed with the feed.
4. For best results, antibiotics should be used with properly balanced feeds. Also, the feeds containing antibiotics should be fed only to the type of stock for which they are intended.
5. Antibiotics are not a substitute for good management and healthy living conditions, or for properly balanced rations.

(b)**Arsenicals**

5. Additives that alter metabolism

(**a**) **Hormones:** These are chemicals released by a specific area of the body (ductless glands) and are transported to another region within the animal where they elicit a physiological response.
Extensive use is being made of synthetic and purified estrogens, androgens, progestogens, growth hormones and thyroxine or thyroprotein (iodinated casein) to stimulate the growth and fattening of meat producing animals. There is concern, however, about possible harmful effects of any residues of these materials in the meat or milk for the consumers.
The whole question whether hormones should be used as growth promoters is still debatable but it seems logical that with any feeding system the economic advantages, however great should never take precedence over any potential risk to human health. These substances may induce cancer in human beings if taken over a prolonged period through products of the treated animals. The use of such substances in poultry rearing has been prohibited by law in U.S.A.
(**b**) **Implants:** Implants are hormone or hormone like products that are designed to release slowly, but constantly, the active chemicals for absorption into the bloodstream. These are implanted subcutaneously in the ear.(eg.) diethylstilbesterol (DES).

6. Additives that affect the health status of livestock

a. Antibloat compounds: Surfactants such as poloxalene is used as a preventive for pasture bloat,several other products have been shown to be highly effective to prevent bloat are also available in the market.

b. Antifungal additives: Mould inhibitors are added to feed liable to be contaminated with various types of fungi such as Aspergillus flavus, Penicillium cyclopium etc. Before adding commercial inhibitors all feedstuff should be dried below 12 cent moisture. Propionic, acetic acid and sodium propionate are added in high moisture grain to inhibit mould growth. Antifungals such as Nystatin and copper sulphate preparations are also in use to concentrate feeds to prevent moulds.

c. Anticoccidials: Various brands of anticocidials are now available in the country to prevent the growth of coccidia which are protozoa and live inside the cells of the intestinal lining of livestock.

d. **Antihelmintics:** Under some practical feeding conditions anthelmintics have also been used. The compounds act by reducing parasitic infections..

7. Additives that improves digestion

Enzymes:

Enzymes are protein which have the property of catalysing specific biochemical reactions. They are found in all plants and animals and are responsible for growth and the maintenance of health.

Microorganism also produce enzymes and in recent years it has been possible to produce enzymes using microorganism on an industrial scale, extract and use these enzymes in a wide range of processes for the production of feed and natural products.

Poultry feeds are largely composed or plant and vegetables materials and there are enzymes developed to degrade, modify or extract the plant polymers found in some of the cereals and their by-products.

The enzymes can be used to improve the feeding of poultry in the following way:

1. By improving the efficiency of the utilisation of the feed.
2. By upgrading cereals by-products or feed components that are poorly digested
3. By providing additional digestive enzymes to help poultry to withstand stress conditions eg. Hot climates.

Some of the cereals are compounds of polymers either of glucose (beta glucan) or arabinose and xylose (pentosan or hemicellulose). These polymers are not well digested by poultry and this can be result in loss of energy in two ways:

1. Energy may be lost become these polymers hinder the digestion of starch by coating starch granules and preventing the action of starch digesting enzymes in the intestine.
2. Energy may be lost because the animals own enzymes are not capable of degrading the polymers and therefore they pass through the digestive system untouched.
By adding microbial enzymes to the feed these polymers can be degraded and their energy value made available to the bird.
The dual role of enzymes has been demonstrated in trials with barley based feed supplemented with beta-glucanase, where the apparent increase in available energy was far in excess of that available in the beta-glucan of the barley. Inm this case not only was the problem of sticky dropping completely eliminated but the chicken's rate of growth was equivalent to that observed normally with feeds containing a higher energy density (eg. Wheat based).

Choice of enzyme:
Because of feed is normally composed of a single raw material of constant quality, it is important that the correct choice of enzyme product be made. Even in the case of a relatively well defined problem such as that in barley, the use of multi enzyme activity products in an advantage.
The enzymes should fulfil the following criteria for practical application:
1. The enzymes must be active at the pH of the animals digestive system and capable of surviving transit through the stomach.
2. They must be in a physical form in which they can be safely and easily mixed into all forms of animal feed.
3. The products should be or a high standarised activity that will remain stable both before and after incorporation into the feed or pre-mix.
4. The enzymes must be capable of surviving normal pelleting conditions.

8. Additives that improves feed quality
Anticaking agents:
Anticaking agents are anhydrous substance that can pick up moisture without themselves becoming wet. They are added to dry mixes to prevent the particles clumping together and so keep the product free flowing.
They are either anhydrous salts or substance that hold water by surface adhesion yet themselves remain free flowing:
1. Salt or long chain fatty acids.
2. Calcium phosphate
3. Potassium and sodium ferryocyanide
4. Magnesium oxide
5. Salts silicic acid – Al, Mg, Ca, Salt.

Sodium aluminium silicate
Sodium calcium aluminium silicate
Calcium aluminium silicate

Humectants:

These are substance which are required to keep the product moist, as for example, bread and cakes. Anticaking agents immobilise moisture that was picked up. Humectants are not or much use in poultry feed.

Firming and crisping agents:

These are substance that preserve the texture or vegetable tissues and by maintaining the water pressure inside them, keep them turgid. It prevents a loss of water from the tissues.

Sequestrants:

Certain metals – copper, iron can act as pro-oxidant catalytic and there fore need to the immobilised. Sequestrants are compounds added to do this.

These compounds should have affinity to metal ions and should prevent the metal in becoming engaged in oxidative action. Most effective sequestrants EDTA (Ethylene diamine tetraacetic acid). Calcium salt of EDTA works satisfactorily as a sequestrants without interferring with trace mineral metabolism.

Sweeteners:

It is common constitution of food but yet used as additives. Eg. Sugar

Some are poorly digestible, may cause digestive upsets.

Saccharin – extensively used during World War I. It is a compound without any calorific value.

EVALUATION OF ENERGY VALUE OF FEED

Energy: the word energy took its origin from Greek words 'en' (which means *in*) and 'ergon' (which means *work*). Energy describes a property of matter and reflects the ability of that matter to do work. Only source of energy, to do work is provided by the chemical energy stored in food. All forms of energy can be converted quantitatively into heat. Basic unit of energy is calorie (1 calorie = 4.184 J).

Calorimetry: In the nutritional context calorimetry is usually understood to mean the measurement of metabolic rate (energy expenditure/ heat loss/ heat production).

Energy retention: the difference between energy expenditure and energy intake.

Systems of description of the energy supplied by feeds

1. Total digestible nutrients (TDN): it is a figure which indicates the relative energy values of feed. It can be expressed in pounds or kilograms or in percent

TDN = DCP + DCF + DNFE + (DEE X 2.25)

Since fat on oxidation provides 2.25 times more energy as compared to carbohydrates, the figure of EE is multiplied by 2.25

Limitations of TDN system

a) it over estimates the value of roughages
b) in feeds with high fat content TDN value sometimes exceed 100
c) only the energy losses through faeces is accounted in this method

2. Nutritive ratio (NR): it is the ratio of the digestible protein to the sum of digestible carbohydrates and fat, the latter being multiplied by 2.25. It is also called albuminoid ratio.

NR = {DNFE + DCF + (DEE X 2.25)} / DCP

A feed rich in digestible protein will have a narrow nutritive ratio (e.g. for groundnut cake NR is 1: 2) and a feed with low DCP have a wider nutritive ratio (e.g. for straws and hays NR is about 1: 60). For cereal grains the nutritive ratio has a medium value.

3. Physiological fuel value (PFV): these are calorific values of nutrients originally established by Atwater to calculate the portion of gross energy consumed which is available for transformation in the body. These are derived by multiplying the gross energy values of nutrients with their digestibility coefficients. In the case of protein, 1.25 kcal per gram was subtracted from gross energy of protein as an allowance for the loss of energy through urine.

Nutrient	**GE (kcal/g)**	**Digestibility coefficients**	**PFV (kcal/g)**
Carbohydrate	4.15	98	4
Fat	9.40	95	9
Protein	(5.65-1.25)=4.4	92	4

4. Starch equivalent (SE): the concept of starch equivalent was put forward by German scientist Kellner. He studied the fat producing power of various feeds. Starch equivalent of a feed is defined as the number of kilograms of starch that would be required to produce the same amount of fat as 100 kg of the feed. For example maize grain has SE of 81 kg which means that 100 kg of maize grain can produce as much animal fat as 81 kg of pure starch when fed in addition to maintenance ration. A series of factors were established later to calculate SE of feeds from the values of digestible nutrients present in feeds by considering the fat producing power of various nutrients.

Nutrient	**Factor**
Carbohydrates (starch & fibre)	1.0
Proteins	0.94
Fat (roughages)	1.90
Fat (cereals)	2.10
Fat (oil cakes)	2.40

When different feed stuffs where tested by Kellner he found that the fat producing power of feeds were lower than that calculated from their content of digestible nutrients. This discrepancy was higher for those feeds rich in fibre. Therefore, Kellner instituted two types of correction factors

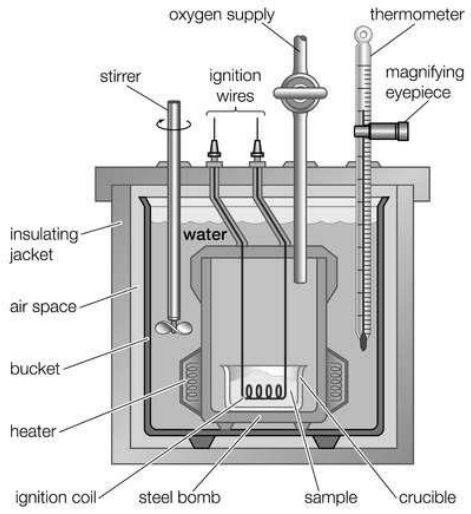
a) Value number/ Golden number/ Werticeit number for concentrates: the number ranges from 95-100 for different feeds. The SE calculated from the content of digestible nutrients is multiplied by this number to get the corrected SE

b) In the case of roughages for every 1% CF present in the original feed, the following units are deducted as shown below to obtain the corrected SE

Type of roughage	**Unit to be deducted for each 1% CF**
Long ordinary dry roughage	0.58
Chaffed dry roughages	0.29
Green fodder with 4-16 % or more CF	0.29-0.58

5. Gross energy (GE): also called heat of combustion or the calorific value. Primary determinant of the gross energy content of an organic substance is its degree of oxidation, as expressed in the ratio of carbon plus hydrogen to oxygen. **Bomb calorimeter** is the instrument used to measure the gross energy of feeds or feaces/ urine. Bomb calorimeter is a strong metal chamber resting in an insulated tank of water. The material under test is burned, in an excess of oxygen (25-30 atmosphere pressure/ 2500-3000 kPa), inside the calorimeter bomb. Heat

liberated by the combustion of the test sample warms the surrounding water and can be calculated from the increase in temperature.



Energy liberated= water equivalent X temperature difference

{water equivalent/ bomb equivalent is the number of calories of heat input necessary to change the temperature of the standard amount of water by 1^0C and is determined previously by calibrating the instrument with a compound of known caloric content such as benzoic acid (6.318 kcal/g)}.

(Adapted from *precisionnutrition.com*)

Modern adiabatic bomb calorimeter has an extra outer water jacket which is maintained in a temperature identical to the water surrounding the bomb by electronically controlled infusions of hot water. Once an initial thermal stability has been obtained the test sample in the bomb is ignited electrically and the heat liberated by burning the sample warms the bomb and the water surrounding it. This rise in temperature is precisely mimicked by the water present in the outer jacket.

The ballistic bomb calorimeter is simpler and less expensive than the adiabatic bomb calorimeter. However it is less accurate compared to the adiabatic bomb calorimeter. The bomb assembly is similar to the adiabatic but there is no water. The peak temperature following the ignition is recorded using a thermocouple and a galvanometer. Calculation of the calorific value is made by reference to peak temperatures obtained while burning standards like benzoic acid.

6. Digestible energy (DE): apparent digestible energy is obtained when the gross energy of the faeces (faecal energy/ FE) voided is subtracted from the gross energy of the feed consumed (GE_{intake})

Apparent DE = GE_{intake} – FE

DE thus calculated is termed apparent because the FE includes energy of undigested feed, energy of microbial cell residues and energy of metabolic products like spent digestive fluids and abraded intestinal mucosa. The term true DE means the DE calculated by deducting, only the faecal energy of feed origin from the gross energy of feed consumed. Therefore, the true digestible energy of feeds is higher than the apparent digestible energy. Faecal energy losses per unit of feed intake increases with level of feeding. In ruminants on roughage diet 40-50% of GE of feed is lost as FE. However, in case of concentrates it is only 20-30%. For horses 35-40% of GE of feed is lost as FE while it is only 20% for pigs.

7. Metabolisable energy (ME): it is the portion of the total energy ingested which is actually capable of transformation in the body. While calculating ME for non ruminants, the energy loss through faeces (FE) and urine (UE) is considered. For ruminants apart from these, the energy loss through gases/gaseous products of digestion (GPD_{energy}) is also taken into account while calculating the ME.

ME (non ruminants) = GE_{intake} – FE - UE

ME (ruminants) = GE_{intake} - FE – UE- GPD_{energy}

Among the gaseous loss of energy, methane forms a significant part and it accounts 7-8% of GE_{intake}. Methane has very high energy value because it consists solely of carbon and hydrogen. Energy content of methane is 13.34 kcal/g. Gaseous losses are generally measured by placing the experimental animals in respiration chamber which is really expensive. Therefore, scientist have developed formula to calculate the methane losses from the amount of digested carbohydrates consumed.

a) For sheep

Methane (gm) = 2.41 X + 9.80

b) For cattle

Methane (gm) = 4.012 X + 17.68

(X is the digested carbohydrates in hundreds of grams)

Urinary Energy (UE) is the gross energy of the urine. It accounts 2-3% of GE_{intake} in pigs and 4-5% of GE_{intake} in cattle.

For most species of animals, estimation of DE is easier when compared to ME. However, with birds, it is more convenient to determine the ME of a diet by treating the excreta as a single material (faeces and urine) representing the unutilized portion of the feed energy.

Studies conducted in various species revealed that 1 g TDN equals 4.41 kcal DE or 3.6 kcal of ME. A factor of 0.82 is used to calculate ME from DE in ruminants (ME = 0.82 DE) and a factor of 0.96 is used to calculate ME from DE in pigs (ME = 0.96 DE).

Nitrogen corrected ME (ME_n)*:* the ME value of a feed will vary according to whether amino acids it supplies are retained by the body or are deaminated and their nitrogen is excreted in urine as urea/uric acid. ME_n is the ME corrected for nitrogen retained or lost from the body i.e. the ME value of a feed at zero nitrogen balance (NB). In the case of ruminants for each gram of urinary nitrogen derived from the catabolism of proteins, 7.45 kcal are added to get the ME_n and for each gram of nitrogen retained in the body 7.45 kcal is subtracted to get the ME_n.

ME_n = GE – FE- UE - GPD_{energy} ± NB X 7.45 (NB is nitrogen balance i.e. nitrogen intake – nitrogen outgo)

(The factor 7.45 used in ruminants was actually estimated for dogs. The factor for pigs is 6.77. For birds the factor used is 8.22 kcal because it represents the energy equivalent of uric acid per

gm of nitrogen. Some times 8.7 kcal is used for birds because it gives approximately the average energy content of urine per gram of nitrogen)

Factors affecting ME value of a feed

1. Species: in ruminants there is loss of energy as gases while in non ruminants there is no such losses
2. Composition of feed: if the protein in the feed is unbalanced greater proportion of amino acids will be deaminated and the excretion of nitrogen in urine as urea is increased resulting in energy loss. Therefore, ME values are frequently corrected to zero nitrogen balance.
3. Processing of feed
4. Level of feeding: at high level of intake ME values of feeds are reduced.

8. Net Energy (NE): it is the portion of feed energy which is completely useful to the body for maintanence, growth, milk production or work. This term was coined by Armsby. It is calculated by deducting heat increment (HI) from ME. ***Heat increment*** is the increase in heat production following the consumption of feed when the animal is in a thermoneutral environment. Heat increment is due to *heat of fermentation* (heat produced as a result of microbial digestion of feeds taking place in the digestive tract) and *heat of nutrient metabolism* (heat produced due to metabolism of absorbed nutrients). Heat of nutrient metabolism is also termed specific dynamic effect or calorigenic effect or thermogenic action. When the temperature of environment is below the critical temperature, energy of heat increment is used to keep the body warm. However, the energy of HI is wasted in all other conditions.

Net energy includes the amount of energy used either for maintenance only or for maintanence and production. Net energy for maintenance includes the energy required for basal metabolism, voluntary activity and to maintain body temperature. As already mentioned, below the critical temperature some of the heat increment becomes a part of net energy for maintenance. Net energy for production includes the fraction of net energy required for growth, fattening, milk production, wool production, work, egg production etc

Methods for measuring the heat production and energy retention

There are two ways by which heat production can be measured for determining the NE values of feeds

a) **Direct calorimetry**: heat production is measured directly with the aid of an animal chamber and calorimeter (animal calorimeter). The apparatus was first used in human beings by Atwater and in farm animals by Armsby. Animal calorimeter is an air tight and insulated chamber in which the experimental animal is placed. In this apparatus there is provision for recording the intake of feed, water and oxygen and the outgo of faeces, urine, gases and heat loss from the body. The heat loss from the body occurs through conduction, convection, radiation and evaporation of water from skin and lungs. The heat loss is measured by the rise in temperature of the cold water flowing in various pipes suspended in the chamber from the

ceiling. The rate of flow of water and differences in the temperature at the entry and exit are used for the calculation of heat loss. Animal calorimeters are expensive to build and require much labour to operate them. Therefore, most of the studies for measuring heat production are carried out by the indirect methods.

b) **Indirect calorimetry**: in this method the heat loss is measured indirectly by carbon nitrogen balance or through gaseous exchange using a respiration calorimeter.

i) ***Carbon nitrogen balance method***: carbon and nitrogen enter the body only through feed. Carbon leaves the body through faeces, urine and gases such as carbondioxide and methane. Nitrogen leaves the body through faeces and urine only. Therefore, the carbon nitrogen balance trial must be conducted in a respiration chamber. The heat production is calculated by deducting the total energy retained in the body (as protein and fat) from the intake of metabolisable energy.

ii) ***Respiration calorimetry/ Respiratory exchange of gases method***: this method takes into account the oxygen consumption, carbon dioxide production and urinary nitrogen to calculate the non protein RQ. Heat production is estimated from the non protein RQ and energy retention is calculated as the difference between ME intake and heat production.

The respiratory quotient (RQ) is the ratio between the volume of carbondioxide produced and the volume of oxygen used by the animal.

RQ= volume of CO_2 produced/ volume of O_2 used

When carbohydrates are being oxidized in the body for energy purposes the RQ is 1 and when fats are being oxidized in the body for energy purposes the RQ is 0.7. The quantity of protein catabolized can be estimated from the output of nitrogen in the urine i.e. 0.16g of urinary nitrogen being excreted for each gram of protein catabolized. Heat produced from protein metabolism is calculated using equations. For each gram of protein oxidized, 0.77 litre of carbondioxide is produced and 0.96 litre of oxygen is used (giving an RQ of 0.8). Therefore, the oxygen used and carbondioxide produced during protein metabolism can be calculated. The values thus obtained can be deducted from the total (i.e. amount of oxygen consumed and carbondioxide liberated as recorded by the respiration chamber) to get the quantity of oxygen consumed and carbondioxide liberated during the metabolism of fat and carbohydrate together. Once the amount of oxygen consumed and carbondioxide liberated during carbohydrate and fat metabolism is known, the non protein RQ is calculated. Heat liberated from fat and carbohydrate metabolism is calculated by multiplying the oxygen used during the process with the thermal equivalent of oxygen corresponding to the value of non protein RQ (heat produced by utilization of 1 litre of oxygen is called thermal equivalent of oxygen). Total heat produced is calculated by adding the heat produced from protein metabolism with that produced from fat and carbohydrate metabolism.

Brouwer has developed an equation to calculate the heat production directly from oxygen consumed, carbondioxide & methane produced and urinary nitrogen excreted as follows

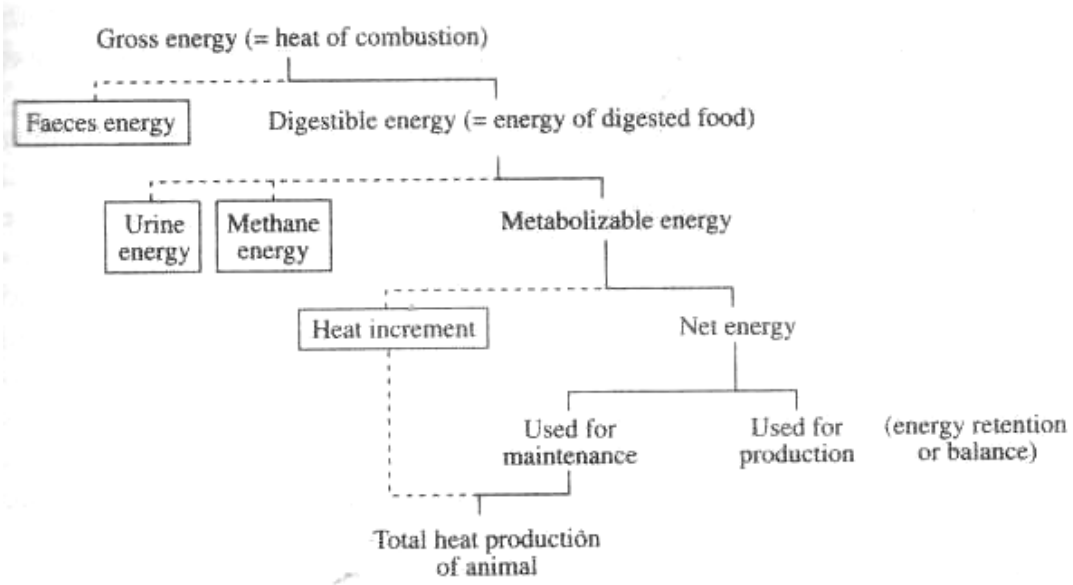
Heat production (kcal) = 3.866 (litres oxygen) + 1.2 (litres carbondioxide) – 0.229 (urinary nitrogen in grams X 6.25) – 0.518 (litres methane)

Respiration chambers used in indirect calorimetry:

a) *Closed circuit type*: designed by Regnault and Reiset. In this chamber the same air is continuously circulated, with provision for the removal of the waste products and the addition of oxygen. It consist of an airtight container for the animal, together with vessels holding absorbants for carbon dioxide and water vapour. The oxygen of the circulating air is renewed through a meter. The output of carbondioxide and water vapour is determined by recording the increase in weight of the absorbing vessels. Methane produced is measured by sampling and analyzing the air at the start and at the close of the experiment. The main disadvantage of the closed circuit chamber is that large quantities of absorbants are required. A cow needs 100 kg of sodalime to absorb carbondioxide and 250 kg of silica gel to absorb water vapour per day.

b) *Open circuit type*: developed by Pettenkofer. In this chamber air is drawn inside at a metered rate and sampled for analysis at entry and exit. Thus, carbon dioxide production, methane production and oxygen consumption can be estimated. With the development of automated systems and the availability of modern equipments with infrared analysis, open circuit type chambers have largely replaced the closed circuit ones.

PARTITIONING OF FEED ENERGY *(Reddy D. V, 2004)*



EVALUATION OF PROTEIN VALUE OF FEEDS

Common systems for expressing protein value of feeds

A) **Crude Protein (CP):** CP is calculated by multiplying N content of feed with the factor 6.25. Nitrogen content is estimated by Kjeldahl method. The factor 6.25 is used based on the assumption that all proteins contain 16% nitrogen.

Following assumptions used while calculating CP are unsound

1. All feed proteins has 16% nitrogen (nitrogen content of common feeds ranges from 15-19% and hence the conversion factor to be used should be different for different feeds)
2. All of the nitrogen in the feed is present as protein (CP actually represents true protein and non protein nitrogen)

B) **Digestible crude protein (DCP):** it is calculated by multiplying CP content of a feed with its digestibility coefficient. DCP content of feeds is determined by digestibility trials (in digestibility trials, the apparent digestibility is estimated). It is the most common way of expressing the protein values and requirement of ruminants in most of the countries including India. DCP gives idea about the digestibility of protein in a particular feed stuff (i.e. the amount of dietary protein absorbed into the system). However, it will not give information about the efficiency with which the absorbed protein is utilized.

C) **True protein (TP)**: Protein only i.e. doesn't include non protein nitrogenous compounds. True protein in feed stuffs can be precipitated by cupric hydroxide (Stutzer's reagent), filtered and the residue is subjected to nitrogen estimation.

MEASUES OF PROTEIN QUALITY FOR NON RUMINANTS

I. Methods based on weight gain of animals

1. Protein efficiency ratio (PER) = gain in body wt (g)/protein intake(g)

PER normally uses the growth of the rat as a measure of the nutritive value of dietary proteins. The value of PER vary with different protein sources as the composition of proteins of various sources varies with regard to the content of essential amino acids.

2. Net Protein Retention (NPR) It is a modification of PER method, where the weight gain of the experimental group is compared with a group on a protein free diet. NPR is calculated as (wt gain in test protein group - weight loss in non protein group)/wt of protein consumed

3. Gross protein value (GPV): GPV of a feed protein is estimated using chicks. The body weight gains of chicks receiving a basal diet containing 8% CP are compared with those of chicks receiving the basal diet plus 3% CP from test protein, and of others receiving the basal diet plus 3% CP from casein. The extra live weight gain per unit of supplementary test protein, stated as

a proportion of the extra live weight gain per unit of supplementary casein, is the GPV of the test protein.

GPV = A/A_0

A=extra live wt gain per unit of supplementary test protein

A_0=extra live wt gain per unit of supplementary casein (standard protein)

II. <u>Methods based on nitrogen balance experiments</u>

1. Protein replacement value (PRV): it is based on the nitrogen balance. Two nitrogen balance studies are conducted, one for the standard protein such as egg protein or milk protein and another for the protein under test. PRV is calculated as follows

PRV = (A-B) / N intake

A=nitrogen balance for standard protein (mg/basal kilocal)

B=nitrogen balance for test protein (mg/basal kilocal)

2. Biological value (BV): Karl Thomas was the first man to use this term. It is the percentage of absorbed nitrogen that is retained within the body. Biological value of a protein is dependent upon the amino acid composition. If all the essential amino acids are present in right amount and proportion the protein will have a higher biological value because the protein will be efficiently utilized for body tissue formation rather than being diverted for energy supply. Animal proteins have higher BV since the essential amino acids present in them are very near to the proportion in which they are needed by the body. In feed proteins, deficiency or excess of any one of the amino acids lowers the BV of protein. Among the common foods, egg protein has the highest BV.

Thomas Mitchell formula

$$BV = 100 \times \frac{\text{N intake} - [\text{faecal N} - \text{MFN}] - [\text{urinary N} - \text{EUN}]}{\text{N intake} - [\text{faecal N} - \text{MFN}]}$$

MFN (Metabolic faecal nitrogen): fecal nitrogen excreted on a nitrogen free energy adequate diet. Consist principally of unused digestive enzymes, abraded mucosa and bacterial nitrogen.

EUN (Endogenous urinary nitrogen): minimum urinary nitrogen excreted on a nitrogen free energy adequate diet. This is due to nitrogen catabolism taking place in the body to maintain the vital processes.

3. Net protein utilization (NPU) = BV X Digestibility coefficient.

NPU is developed based on the assumption that the usefulness of a feed protein to an animal depend upon its digestibility as well as its BV.

4. Net protein value (NPV)= NPU X CP%

III. Methods based on amino acid composition

1. Chemical score: it is a method in which protein quality of feeds is estimated without conducting the animal experimentation. Chemical score is the ratio of greatest deficient amino acid in test protein to that in standard protein (e.g. egg protein). In this method the content of each essential amino acid in test protein is determined and expressed as the percentage of their content in the standard protein, the lowest percentage is taken as the chemical score.

2. Essential amino acid index (EAAI): like chemical score, here the protein quality of feeds is estimated without conducting the animal experimentation. However in this case all the 10 essential amino acids are considered for determining the score. EAAI is the geometric mean of the egg ratios of all the 10 essential amino acids to the feed amino acids. It has the advantage that all the essential amino acids are considered but in this method proteins having different amino acid composition may have the same index.

EAAI is calculated as follows:

$$\text{EAAI} = \sqrt[n]{\frac{a}{a_e} \times \frac{b}{b_e} \times \frac{c}{c_e} \times \frac{d}{d_e} \times \ldots \times \frac{J}{J_e}}$$

Where a, b, c, d, ……,j = concentration (g/100g) of the essential amino acids in the feed protein

a_e, b_e, c_e, d_e,……., j_e = concentration (g/100g) of the same amino acids in egg protein

n = number of amino acids entering into the calculation, 10 n this case).

IV.Biological assay: the available amino acid content of a feed protein is assayed by measuring the live weight gain, feed conversion efficiency or nitrogen retention of animals given the test protein as a supplement to the diet deficient in the particular amino acid under investigation. The chick is the usual experimental animal in such studies. The response to test protein is compared with the response to supplements of pure amino acids. This method is used to study the availability of amino acids like lysine and methionine.

V. Microbiological methods: certain microorganisms having amino acid requirements similar to those of higher animals are used in the evaluation of feed proteins e.g. *Streptococcus zymogenes* and *Tetrahymena pyriformis*. *S. zymogenes* is used after an acid or enzymic predigestion of feed protein. The availability of amino acids such as lysine and methionine from feed protein estimated using *S. zymogenes* are similar to those estimated by conducting chick assays and measurements of NPU. *T. pyriformis* has intrinsic proteolytic activity and is used for soluble proteins, without pre digestion. However, pre digestion of feed with the enzyme pronase had given better results while estimating the availability of lysine, methionine and tryptophan from feeds using *T. pyriformis*. Measurement of tetrahymanol (characteristic pentacyclic terpene synthesized by *T.pyriformis*) content of the culture medium is done to evaluate the utilization of amino acids by *T. pyriformis* from the feed protein.

VI.Chemical methods: the most common chemical method is the estimation of FDNB reactive lysine which was originally proposed by K.J. Carpenter. Justification for the use of this method is that, practically the only source of utilizable lysine in feeds is that which has the epsilon amino group free to react with various chemical reagents. The protein under test is allowed to react under alkaline conditions with fluoro-2, 4-dinitrobenzene (FDNB) to give DNP-lysine. The concentration of DNP lysine is measured colourimetrically.

Dye binding methods which are used in protein estimation can be used for measuring the content of total basic amino acids and reactive lysine in feeds. Orange G is the most commonly used dye. However, the epsilon amino group of lysine present in feed protein has to be blocked to prevent its reaction with the dye. 2,4,6 trinitrobenzene sulphonic acid and propionic anhydride are used commonly as blocking agents. This method has proved effective for estimating the lysine content of cereals. However, it is less effective for evaluating the quality of animal protein supplements.

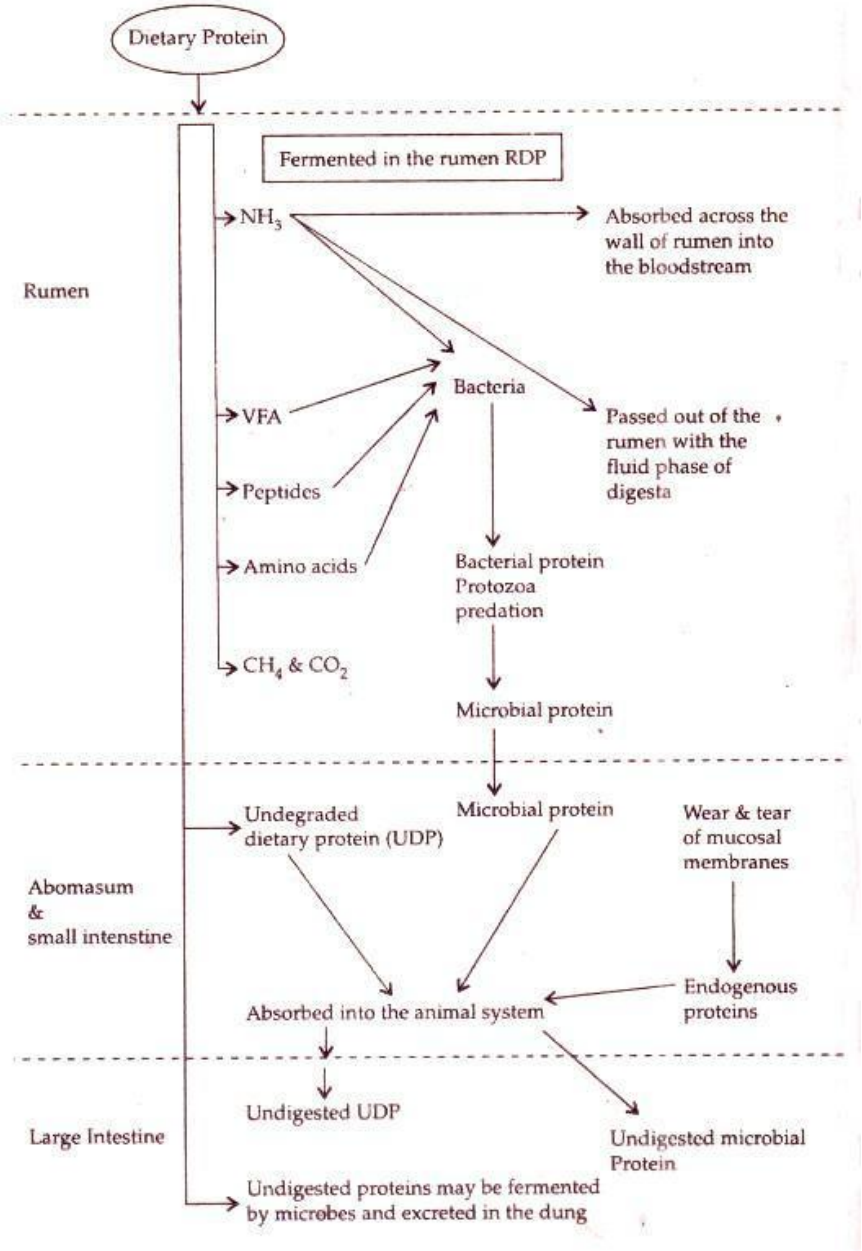
VII. Ileal digestibility of protein: here the digestibility coefficient of protein is calculated by the analysis of digesta collected from the terminal ileum. Ileal collection eliminates the large intestine as a source of errors, and the method is justified since large intestine makes no contribution to the protein status of the animals.

Protein quality evaluation methods which are commonly practiced in swine and poultry feeding

Practical pig and poultry feeds are based largely on cereals. The main deficiencies in such diets are the amino acids lysine and methionine. The determination of '***available lysine***' is the most accepted method for evaluating the quality of protein in their feeds. A recent method for evaluating the quality of dietary protein for growing pigs is based on the concept of ***'ideal protein'***. As if in 'chemical score method' the amino acid composition of the feed protein is compared with a standard protein. Here the standard protein taken is the tissue protein of pigs. The main limiting amino acid in the feed protein when compared with tissue protein is lysine. So generally in the ideal protein concept the ratio between the lysine content of feed protein with that of tissue protein is taken into consideration.

For poultry, evaluation of feed protein is based upon the content of the three major limiting amino acids (lysine, methionine and tryptophan).

FATE OF DIETARY PROTEIN IN RUMINANTS *(Reddy D. V, 2004)*



Fate of Dietary Protein in Ruminants.

MEASURES OF PROTEIN QUALITY FOR RUMINANTS

1. Protein equivalent (PE): this concept was introduced in 1925 but is no longer in use. This method gives the non protein nitrogen fraction of feed, half the nutritive value of the true protein. Currently it is used instead of DCP in some European countries in connection with feeds containing urea.

PE= (%DCP + %DTP)/2

2. Degradability of nitrogen fraction in the ration: degradability of nitrogen fraction in the feed will depend upon factors such as the surface area for microbial attack, the physical and chemical nature of the protein and the protective action of other constituents in the feed. Degradability of nitrogen fraction in the ration has no relationship with the solubility of protein. The major factor affecting degradability is the amino acid sequence within the protein molecule. Degradability can be measured *in vivo*, *in sacco/ in situ* and *in vitro*.

a) Measurement of degradability *in vivo*: this involves the measurement of dietary nitrogen intake (DNI), the non ammonia nitrogen (NAN) the microbial nitrogen (MN) of dietary origin passing the duodenum and the endogenous nitrogen (EN). Degradability (Dy) of nitrogen is expressed as

$$Dy = 1 - \frac{NAN - (MN + EN)}{\text{Dietary N intake}}$$

b) Determination of degradability *in sacco* (in situ): this involves incubation of feed in synthetic fibre bags suspended in the rumen. Degradability is calculated as the difference between the nitrogen initially present in the bag and that present after incubation, stated as a proportion of the initial nitrogen.

c) Determination of degradability *in vitro*: nitrogen degradability of protein fraction of feeds can be determined by several laboratory procedures

i) Solubility in buffer solutions such as McDougall artificial saliva, borate phosphate buffer and Wise Burroughs's buffer.

ii) Solubility in enzyme solutions: the enzymes produced by microbes such as *Streptococcus griseus*, *Streptococcus bovis*, *Bacteriodus amylophilus* and *Butyrovibrio* are used. Protease enzme produced by *S. griseus* is the preferred source of enzyme for estimating the degradability in the French 'Protein Digested in the Intestine' (PDI) system.

iii) Chemical analysis: chemical composition of feeds is determined. The degradability is calculated by using equations based on chemical composition.

iv) Near infrared reflectance spectroscopy (NIRS): this method gives idea about the organic structures within a material. This method can be used for analysis of feeds and their nutritional evaluation. Relationships have been demonstrated between degradability characteristics of a feed and reflectance.

3. Yeild of microbial protein: The methods generally used for determining rumen microbial protein synthesis depend on the use of natural microbial markers such as RNA (ribonucleic acid) and DAPA (diamino-pimelic acid) or isotopes of sulphur, nitrogen and phosphorus. The technique of using urinary purine derivatives (allantoin, uric acid, xanthine and hypoxanthine) as a specific marker for rumen microbial biomass has been developed recently.

4. Rumen degradable and undegradable protein (RDP and RUP) system of U.K.

5. Metabolisable protein system used in USA: metabolisable protein includes that part of dietary protein un degraded in the rumen and the microbial protein, which are absorbed by the host animal and is available for use at tissue level.

6. Other protein evaluation systems

a) The Nordic system (followed in Denmark, Finland, Iceland, Norway and Sweden) based on the amino acid truly absorbed in the rumen and the protein balance in the rumen (AAT-PBV).

b) The American 'Absorbed True Protein' (AP) system.

c) The German system based on the crude protein flow at the duodenum

d) The Dutch DVE/ OEB system. The following characteristics are calculated for each feed: true protein digested in the intestine (DVE) and the rumen degradable protein balance (OEB).

e) The Australian 'Apparently Digested Protein Leaving the Stomach' (ADPLS) system.

CALORIE PROTEIN RATIO

Calorie protein ratio is important for poultry rations because poultry stops feeding once the requirement of energy is met. If the diet is rich in energy and low in protein, there is chance of protein deficiency in poultry. Calorie protein ratio is defined as the ME (kcal/kg) content of ration divided by the percentage of CP in the ration. The ratio varies with age of the bird. Calorie protein ratios for BIS requirements are given below *(Reddy, D. V., 2004)*:

Type	**Calorie Protein ratio**
Broiler starter feed	122
Broiler finisher feed	145
Chick feed	130
Growing chicken feed	156
Laying chicken feed	144

Systems used for representing the nutrient requirement of animals as per ICAR standard 1998

Species	**Energy requirement**	**Protein requirement**
Cattle and buffaloes	TDN, ME	DCP
Sheep and goat	TDN, ME	DCP
Camels	TDN	DCP
Layer & Broiler chicken*	ME	Protein %, Lysine %, Methionine %, Methionine + cystine %
Pig	TDN , DE	CP
Rabbits	DE	CP, DCP
*similar system is followed in BIS 1992		

KERALA VETERINARY AND ANIMAL SCIENCES UNIVERSITY
COLLEGE OF VETERINARY AND ANIMAL SCIENCES, POOKODE
DEPARTMENT OF ANIMAL NUTRITION

Title of Unit : Applied Ruminant Nutrition-I

Unit No. : 2

Credit Hours : 3 + 1

Compiled by

Dr. Biju Chacko
Dr. S. Senthil Murugan
Dr. Surej Joseph Bunglavan
Dr. Jinsy. V. S

Reference books

1. Animal Nutrition : Maynard L. A., Loosli, J. K., Hintz, H.F. and Warner, R. G (7th edi)

2. Animal Nutrition : McDonald P., Greenhalgh, J. F. D., Morgan, C. A., Edwards, R Liam Sinclair, L . and Wilkinson, R (7th edi)

3. Animal Nutrition : Banerjee G. C.

4. Principles of Animal Nutrition and Feed Technology : D.V. Reddy

Tile of the course: **Applied Ruminant Nutrition-I** **Unit No.: 2**

Credit hours: 3 + 1

Sl. No	Theory
1	Importance of scientific feeding,
2	Feeding experiments-different types.
3	Experimental designs.
4	Digestion trials: Norms adopted in conducting a digestion trial.
5	Measurement of digestibility by conventional method.
6	Indirect method of determining digestibility: Indicator method, pasture consumption and digestibility.
7	Factors affecting digestibility of a feed
8	Feeding standards: uses, significance, merits and demerits
9	Balanced ration and its characteristics.

SCIENTIFIC FEEDING, FEEDING EXPERIMENTS & EXPERIMENTAL DESIGNS

Importance of scientific feeding

Animals have to be fed to meet their requirement for maintenance, growth, reproduction, production and work. Therefore, knowledge of the quantity of the nutrients required by the animals during different stages of life and knowledge of the nutritive value of different feeds is the basis of scientific feeding. This knowledge can be attained by conducting feeding experiments and can also be gained gradually by experience over many years.

Different types of feeding experiments/ feeding trials

1. Comparative feeding trials:

Eg:- a study to compare between fish meal (FM) and groundnut oil cake (GNC) as protein supplement in the ration of growing pigs.

In such feeding trials, there will be two similar groups of growing pigs. One group is fed the ration containing FM as protein supplement and the other with a ration containing GNC as protein supplement. During the experimental period, parameters like growth rate, feed conversion efficiency etc is studied and the results obtained are compared.

2. Feeding trials using laboratory animals: certain factors like individual variability and cost for conducting the experiment (animal cost, feed cost, labour cost, expenses for slaughter etc) are lower when laboratory animals like mice, rat, hamster, guinea pig etc are used in experiments instead of larger farm animals. Moreover, the processes of growth, reproduction and lactation can be effectively investigated in a lesser time when the lab animals are used for feeding experiments. However, such studies provide only preliminary information and later a detailed investigation should be done with the species of interest. Some of the special methods of feeding experiments practiced using lab animals are

a) *Purified diet method*: purified diets contain various nutrients from purified sources. For example, protein is supplied as casein or soy protein or egg protein or urea; carbohydrates as starch or sugar or glucose or lactose; fat as some vegetable oil or fish oil or as lard; minerals as pure salts and vitamins as pure compounds. Such a diet makes it possible to include or withdraw a given nutrient with minimum disturbance to any of the other nutrients.

b) *Germ free technique*: when dietary requirements of various vitamins are studied by feeding trials in lab animals, the contribution of vitamins synthesized by the intestinal microorganisms to the nutrition of the host animal may complicate the interpretation of experimental data. In such cases, scientist prefers animals which are free of intestinal microorganisms (Germ free animals). Germfree animals are obtained by conducting caesarian and are reared by appropriate techniques in specially designed cages by feeding sterilized diets. Similarly

techniques have also been developed for producing animals which are free of specific pathogens (SPF animals/ specific pathogen free animals).

3. Group feeding trial versus individual feeding trial: in certain feeding experiments animals under same treatment are fed in groups and are referred to as group feeding. Equipments needed and labour costs are less in such experiments. However, group feeding becomes complicated when there is variability in individual behavior as far as feed intake, production, growth rate etc are concerned. The difficulty is increased when an animal owing to disease or accident has to be removed from the experiment. In individual feeding the animals are fed individually and it is possible to obtain individual performance record and the feed consumption. However, certain species of farm animals consume less feed when fed individually due to lack of competition.

4. Controlled feeding experiment versus *ad libitum* feeding experiment: in controlled feeding, experimental animals are fed a weighed quantity of feed as decided while planning the experiment. In *ad libitum* feeding the animals are offered feed as much as they can consume.

5. Equalized paired feeding: e.g. experiment to compare two rations (ration A & ration B)

Animals are selected by pairs. Two animals of the pair are to be similar in size, age and previous history. But such equalities are not essential from pair to pair. One animal of the pair is fed with ration A and the other with ration B. The animals of a pair are offered same quantity of feed limiting the intakes of both to that of the animal consuming the lesser amount (as determined during a preliminary feeding period by providing same feed to both the animals in the pair). Minimum of 4 pairs of animals are generally used in such experiments.

6. Slaughter experiments: Laues and Gilbert were the first to conduct slaughter to study the body composition of animals. The increase in the body weight during feeding experiment may be due to water, fat, minerals as well as protein, the relations of which may vary. Slaughtering the animals after conducting feeding trial gives idea regarding the specific effect of the ration in terms of the composition of the tissue formed.

Experimental designs in animal nutrition research

For any experiment, it will be most ideal if the experimental subjects are alike in all respects i.e. their genetic makeup, age, sex, body weight, body size etc. Unfortunately, in animal experiments it is difficult to get even two identical animals. Many a time's even animals of the same litter may not be similar in all aspects. Under these circumstances, for conducting experiments we have to think of the suitable experimental design. The following are the common experimental designs.

1. Completely randomized design (CRD): it is the simplest of the designs and is most suited when the experimental animals are homogenous with regard to sex, breed, live weight etc. Here the animals are allotted to treatments randomly i.e. each animal has equal chance of being allotted to a treatment.

2. Randomised block design (RBD): used when the experimental animals are not homogenous with regard to sex, breed, live weight etc. The subjects are divided into homogenous sub groups or blocks. From each block equal numbers of animals are allotted to each treatment at random.

3. Latin square design (LSD): this is generally used when experimental animals are not homogenous and only smaller number of animals is available for conducting the experiment. This is most suited for rumen fermentation studies using fistulated animals where it is difficult to maintain large number of animals. In this design, the number of animals is the same as that of the treatments and each treatment is allotted to each animal in different periods.

Solve the following:

1. Select the suitable design and group the calves for conducting an experiment to compare the growth rate by feeding four different rations (Ration A, B, C & D)

a) 20 HF female calves of about 3 months age of following body weight (kg) are available

75, 74.5, 76, 75.5, 76.5, 75, 77, 74, 76.5, 75, 77, 75, 74.5, 76.5, 75, 77, 74, 76.5, 75, 77

b) 20 HF female calves of 3 -6 months age of following body weight (kg) are available

71, 76, 83, 93, 104, 103, 102, 96, 92, 77, 101, 95, 84, 82, 75, 81, 75, 77, 74, 75

2. Chose an experimental design to conduct rumen fermentation study using four different rations (A, B, C & D) in 4 adult fistulated cattle of following body weights.

450 kg, 300 kg, 350 kg, 480 kg

METHODS FOR EVALUATING THE DIGESTIBILITY OF FEEDS

Digestion trial: the amount of feed or nutrient intake by an animal which is not excreted in the faeces is considered to be digested and absorbed. Digestion trials are conducted to study the digestibility of feed/ nutrients. For the determination of digestion coefficient/ digestibility, the daily intake of feed/ nutrients and daily faecal voided values are to be recorded.

Metabolism trial: the availability and retention of nitrogenous nutrients and minerals is studied by conducting metabolism trial/ balance or retention studies. The daily intake of feed/ nutrients is recorded. The routes of elimination considered during such metabolism trial are faeces, urine, expired air, skin secretions, milk (for lactating animals) and eggs (laying birds). In case of certain specific studies, materials like shed hair and scurf are also collected. In routine metabolism trials/ balance studies using male animals, quantity of feed intake and void in faeces & urine are only taken into account.

Procedure for conducting digestion/ metabolism trial

Male animals are preferably used for conducting the trials because it is easier to collect faeces and urine separately with the male.

Stages

a) Pre-collection feeding period: in order to remove the effect of previous feeding and also to adapt the animal on the feed to be evaluated, the animals are fed the test feed for a period of 2-3 weeks.

b) Collection period: it may be 6 to 10 days for herbivores like ruminants and 4 days for simple stomached animals like pigs.

Methods followed and devices used

a) Trial in stall: it is a special animal house having facilities for offering feed and water to individual animal in such a manner that it is not eaten by neighbor animal. In such stalls there will be provision for collecting the residues of feed offered, faeces and urine.

b) Trial in cages: it is the most common method used now-a-days. These metallic cages provide the animal adequate space for standing and lying down but not turning back. A detachable feed box or trough is provided in front part of the cage. A window is provided in the anterior half of the cage for offering drinking water. The floor of the cage has a gradual slope towards the middle to facilitate quantitative collection of urine. Feaces will be collected manually, immediately after it is voided by the animal.

c) Digestion trial using faeces collection bag: a canvass bag with rubber lining fitted on the animal is used for quantitative collection of faeces.

Digestibility

Digestibility is defined as a portion of feed or any nutrient in feed which is absorbed and not recovered in faeces.

$$\text{Digestibility coefficient of a nutrient (\%)} = \frac{\text{Nutrient intake} - \text{Nutrient outgo}}{\text{Nutrient intake}} \times 100$$

However, this does not represent the true value of digestibility of a feed or nutrient because some part of digested material is returned to the digestive tract after absorption and is excreted in faeces. In addition, debris of abraded gastro intestinal epithelial cells, unspent digestive enzymes and microorganisms are also excreted through faeces. Therefore, the digestibility thus calculated is referred to as ***apparent digestibility***, which is always less than the ***true digestibility***. Methods for evaluating digestibility of animal feeds are given below.

I. Measurement of digestibility by conventional method

Digestibility of feeds/ nutrients is determined *in vivo* by conducting digestion trials

II. Indirect method of determining digestibility

Some feeds, e.g. concentrates cannot be fed alone as they do not supply the bulk and therefore, their digestibility coefficients cannot be determined directly. Similarly non maintenance type of roughages e.g. straw, stovers etc do not supply the required amount of nutrients and so they cannot be fed alone to the experimental animals. In such cases digestibility is determined indirectly i.e. 'by difference' by conducting two or more digestion trials.

e.g. Determination of digestibility of ground nut cake (GNC) by 'difference'

Two digestion trials are conducted. In the first trial, a basal maintenance type fodder is fed and the digestibility of nutrients is determined. In the second trial basal maintenance type fodder and GNC are fed together. Digestibility of nutrients in GNC is calculated by difference on the assumption that the nutrients in the original basal roughage have the same digestibility.

Calculation of digestibility coefficient by difference method may not be fully correct since the addition of oil seed cake to the basal diet may influence the digestibility of basal diet (***associative effect of feeds***). But the credit is given to the supplement i.e. oil seed cake, assuming that the digestibility would remain the same when the basal diet is fed alone.

III. Indicator/ marker method of determining digestibility

The assumption in this method is that an indicator or reference material is excreted uniformly through the faeces and therefore, a small amount of faeces collected at any time during 24 hrs

is sufficient to provide the amount of nutrient per unit of indicator. The digestibility of nutrient is calculated by estimating the concentration of indicator in feed and faeces and that of the nutrient in feed and faeces without quantitative collection of total faeces and without measuring the feed consumption. This method is easier when compared to conventional digestion trial which is a laborious and time consuming procedure.

Digestibility coefficient of a nutrient = $100 - \left(100 \times \frac{\%\ \text{indicator in feed}}{\%\ \text{indicator in faeces}} \times \frac{\%\ \text{nutrient in in the faeces}}{\%\ \text{nutrient in the feed}}\right)$

Indicators: it can be internal (natural constituent of feed) e.g. lignin, silica and acid insoluble ash or external e.g. chromic oxide, magnesium ferrite, carmine red, radioactive isotopes etc. Internal indicators are indigestible and can easily be determined. Chromic oxide is the most common external marker for digestion trials with avian, swine and carnivores. However, it will not yield accurate results with herbivores.

Characteristics of an ideal indicator

1. Totally indigestible and un absorbable
2. It should be inert i.e. it should not have any pharmacological action in digestive tract.
3. It should be uniformly distributed in the digesta.
4. It should pass through the tract at a uniform rate and should be voided entirely.
5. It can readily be determined chemically.
6. Preferably be a natural constituent of the feed.

IV. Measurement of pasture consumption and digestibility in grazing animals

For determining the digestibility of pasture grasses, the grasses are harvested and fed in stalls and the digestibility coefficients are determined. Once the digestibility coefficient of pasture grass is known, the pasture consumption can be calculated if there is provision to collect the faeces voided by grazing animals (using faeces collection bags). There are certain limitations for this method. Since animals have a tendency of selective grazing, it is difficult to obtain the representative sample of forage actually eaten by grazing animals for determining the digestibility. Moreover, it is difficult to do quantitative collection of faeces using collection bags. Therefore, markers are used both for the determination of digestibility of the pasture herbage and the dry matter intake through grazing. Digestibility can be determined by using an internal marker and faecal output is measured by using an external marker. Once the digestibility and faecal output is known, dry matter intake can be calculated.

V. Laboratory methods of determining degradability/digestibility: determination of degradability of feeds in the laboratory gives idea about its digestibility.

1. *In Sacco method* (semi *in vivo*): degradability of feeds in the rumen is determined by keeping the feed sample in bags (made of nylon, dacron or silk) which are immersed in rumen contents of rumen fistulated animals. Bags should have a porosity of 40-60µm so that the test feed particles should not pass out of the bag un-degraded but at the same time it should allow the rumen microbes to enter into the bag and act on the test feed. The bags on removal at different time intervals are washed till the wash water is clear and dried at 60^0C for 48 hrs. The percentage disappearance of dry matter, nitrogen, fibre fractions etc are determined.

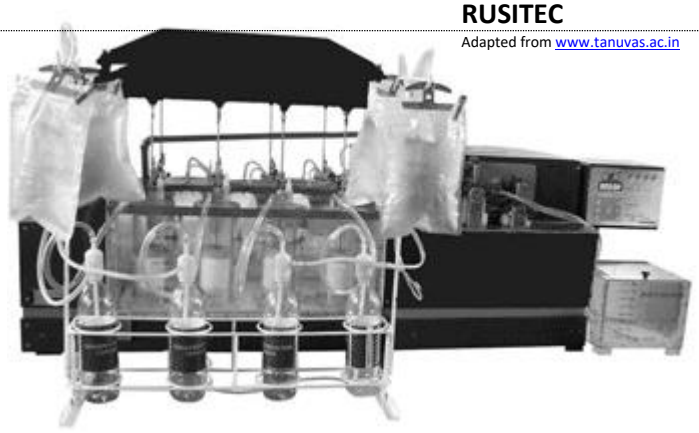


2. *In vivo* artificial rumen technique (VIVAR technique): it is a semi *in vivo* method. VIVAR tube is made up of stainless steel or glass and is fitted with semi permeable membranes. Test feed is kept inside the VIVAR tube, which is suspended properly in the rumen of fistulated animals. Rumen microflora can enter the tube through semi permeable membranes and can degrade the feed sample. After completion of a particular time period, VIVAR tube is removed and the dry matter disappearance is recorded.

3. *In vitro* dry matter digestibility (Tilley and Terry, 1963): this is also known as two stage *in vitro* method. During the first stage, finely ground sample of feed is incubated for 48 h with buffered rumen liquor in a tube under anaerobic conditions. In the second stage the microbial activities are stopped by acidifying with hydrochloric acid and then digested by incubating with pepsin for another 24 h. The insoluble residue is filtered off, dried and the dry matter loss is calculated.

4. *In vitro* gas production (Menke *et al*., 1979): this system is basically a Tilley and Terry (1963) system but in this method, gas production rather than dry matter loss is measured. The amount of gas (carbondioxide and methane) released when feeds are incubated at 39^0C inside a calibrated glass syringe with rumen liquour is closely related to digestibility of feed. The feeds of different digestibility produce different volume of gases within a stipulated time.

5. The rumen simulation technique (RUSITEC): RUSITEC is an apparatus developed for artificially creating conditions somewhat similar to those in the rumen, but complete perfection is never achieved. With the RUSITEC it is possible to determine all the inputs and outputs' including gases to investigate what goes on inside the reaction vessel.



6. Digestibility determination using *in vitro* enzyme solubility technique.

7. Digestibility determination using regression equations.

Factors affecting digestibility of feeds

I. Animal factors

1. Species of the animal: roughages are better digested by ruminants when compared to non ruminants due to pregastric microbial fermentation.

2. Age of the animal: very young or very old animals are less efficient in digesting the feed.

3. Work: light exercise and work improves the digestibility of feeds while heavy exercise/ work depress it.

4. Individual: individual variation is observed in digestibility of feeds.

5. Level of feeding: at high level of feed intake the digestibility of DM and various nutrients falls due to less retention time in the alimentary canal.

II. Plant factors

1. Chemical composition of feed: digestibility of forage is closely related to chemical composition. Chemical composition of forage is affected by soil composition, manuring and fertilization, water supply, stage of maturity of the plant, frequency of cutting, variety and strain of plant, climate etc.

2. Stage of maturity: with progressive maturity the crude fibre of forage is gradually lignified and the digestibility is decreased.

3. Protein content: feeds higher in protein content have higher apparent digestibility for the consumed protein because MFN output depends upon the amount of feed consumed and not on the amount of protein consumed.

III. Preparation of feed

1. Particle size of feed: in general grinding of grain increases digestibility because of disruption of grain coat and increased surface area for enzymatic action. However, if the particle size after grinding is too small, the feed becomes less palatable and less digestible. If roughages are finely ground, digestibility of fibre decreases due to shorter retention time in the rumen. However, the total consumption is increased due to increased rate of passage.

2. Soaking of feed in water before feeding generally increases the digestibility.

3. Processing of grains by boiling, steam processing, micronization, pelleting, extrusion cooking etc improves the digestibility.

4. Nutrient content in the ration

a) Protein level: digestibility of all the nutrients increases when the level of dietary protein is high in the diet

b) Carbohydrates: the higher the percentage of crude fibre in a ration lower is the digestibility of DM and all other nutrients.

c) Lipids: higher level of fat in the diet lowers the digestibility of other nutrients particularly fibre.

d) Minerals: deficiency of minerals in ruminants limits the growth of microorganisms and this will reduce the digestibility of nutrients particularly crude fibre.

FEEDING STANDARDS: HISTORY, USES, SIGNIFICANCE, MERITS AND DEMERITS

Feeding standards: To guide farmers in selecting properly balanced rations for their livestock, scientists have prepared feeding standards. These are the tables which indicate the quantities of nutrients to be fed to the various classes of livestock for different physiological functions like maintenance, growth, lactation, egg production, wool production, work etc. The recommendations in feeding standards must provide a sufficient margin of safety to cover the usual variations in the composition of feeds and the differences in the individual animals to be fed. There are two terms which have been used in the feeding standards. One is the *nutrient allowance* which gives the margin of safety and the other is *nutrient requirement* which gives the optimum requirement for the purpose.

Classification of feeding standards

1. Comparitive type: a) Thaers b) Scandinavian
2. Digestible nutrient type: a) Groven's b) Kuhns's c) Wolff's d) Haecker's e) Savage's
3. Productive type: a) Kellner's b) Armsby's c) Morrison's d) NRC e) ARC f) Indian

History and development of feeding standards:- uses, significance, merits and demerits

Old days feeding standards

1. Thaer's feeding standard: Albrecht Thaer a German scientist in 1810 published 'hay equivalents' as measure of relative value based on determining the materials in feeds extractable with water and other solvents. He used meadow hay as a unit to compare other feeds. Each feed stuff was given a number which represented the number of pounds of feed stuff in question that contained the same amount of soluble nutrients as 100 lb of meadow hay. Earlier, Einhoff in 1808 and Bohimia in 1725 also had similar opinion. Since there was no knowledge of physiological needs of the animal and chemical composition of feed stuff, this feeding standard was considered as unscientific and incomplete. Though this system had various demerits it spread very quickly through Central Europe.
2. William Prout, in 1827, recognized protein, fat and carbohydrate as essential organic nutrients
3. Magendie's and his coworkers feeding standard: In 1836, the work of Magendie, Macaire and Marcet showed that nitrogenous substances play an important role in the

diet of animals. On the basis of nitrogen content Boussingault published a table of 'Hay equivalent'.

4. Leibig in 1842 recognized the presence of nitrogenous compounds in animal body and later Lawes and Gilbert examined the proportion of nitrogenous and non nitrogenous substances in animal body.

5. Claude Bernard explained the role of non nitrogenous substances in animal body.

6. Grouven's feeding standard: In 1859, he proposed the first feeding standard based on total quantity of crude protein, fat and carbohydrate as measured by chemical analysis. This feeding standard is based on total nutrients present in the ration. However, these nutrients may not be fully utilized by animal body. Therefore, this feeding standard was not continued for a longer period.

7. Henneberg and Stohmann found that the total nutrients contained in the feed are not the correct guide and only the digestible nutrients are available. They conducted series of trials on feeds and proved unsoundness of Thaer's hay equivalent.

8. Wolff's feeding standard: Emilvon Wolff in 1864, devised a feeding standard based on digestible protein, digestible fat and digestible carbohydrates derived from results obtained from feeding trials. Ratio of digestible protein to digestible carbohydrate was expressed as *albuminoid ratio*. This was the first standard based on scientific lines and continued for a longer period of time. However, neither the maintenance nor the production requirements were separately discussed in this standard. This standard has not considered the quantity and quality of milk produced.

9. Kuhn's feeding standard: Keeping in view of the demerits of Wolff's standard, professor Kuhn in 1867 published requirements for maintenance, production (allowances for the quantity of milk produced) and work.

10. Scandinavian feed unit system: Professor Fjord in 1884 considered 1 lb of barley as a single unit for comparing different feed stuffs. He recommended 1 such feed unit for every 150 lbs body weight and additional feed unit for every 3 lbs of milk yield. Being simple and easy to calculate this feeding standard is still continued in a number of Scandinavian countries.

11. Julius Kuhus in 1887 made distinction between maintenance and production part of ration. He also considered the DM of the ration and distinguished between digestible albuminoids and amide compounds in estimating the protein requirements.

12. Atwater in 1890, proposed a feeding standard based on available fuel values of the feeds. Available fuel values were obtained by the use of Rubner's factor applied to digestible nutrients. Since the Rubner factor for protein contained a deduction for urine losses of 1.25 kcal/g of protein, Atwater's value took account of both fecal and urine losses.

Middle days feeding standard

1. Wolff-Lehmann feeding standard: Keeping in view of the demerits pointed out by professor Kuhn, Lehmann in 1896 revised the Wolff's standard. In this standard an allowance was fixed for the quantity of milk produced by animals. However, there was no consideration for the percentage of fat in the milk.

2. Haecker's feeding standard: Haecker in 1903 formulated the first feeding standard which took into account allowance for quality of milk (fat percentage) in addition to the requirement for maintenance and quantity of milk produced. The standard was based upon the digestible crude protein, digestible carbohydrates and digestible fats which later appeared as DCP and TDN. Some scientists criticized it by saying that the protein requirement fixed in this standard has been under estimated.

3. Kellner's feeding standard: Kellner in 1907 published his feeding standard as starch equivalent system. It was based upon the net energy and digestible true protein. Since digestible true protein was used instead of digestible crude protein, this standard did not credit the NPN substances in feed.

4. Savage feeding standard: Savage in 1912 criticized Haecker's standard as being low in proteins and published his feeding standard by increasing 20% of the protein requirements. He expressed his standard in terms of DCP and TDN, and suggested that about 2/3rd requirement of the DM should be met by feeding roughages and the remaining 1/3rd from concentrates.

5. Frap's feeding standard: Frap formulated his feeding standard based on DM, DCP and productive values (stated as therms of net energy).

6. Morrison's feeding standard: Morrison published his feeding standard in 1915 in the 15th edition of his book entitled "Feeds and Feeding". It was based upon DM, DCP and TDN requirement of the animals. Morrison indicated the nutrient requirements of animals in a range rather than in a single figure. This standard is in fact the modification of Wolff-Lehmann standard. This standard was later modified by Morrison and Henry

and included the allowances for Ca, P & carotene and the requirement was expressed in terms of DCP, TDN and NE.

7. Armsby's feeding standard: Armsby in 1917 published his standard based on digestible true protein and net energy values (estimated by conducting experiments using respiration calorimeter). Net energy values were expressed in therms. Since digestible true protein was used instead of digestible crude protein, this standard did not credit the NPN substances in feed.

Present day feeding standards

1. National Research Council's (NRC) standard: From 1945 the committee of the animal nutrition under the auspices of the United State National Research Council and US Department of Agriculture (USDA) started publishing the nutrient requirements for dairy cattle, beef cattle, pigs, poultry, sheep, dog, horses and laboratory animals. Nutrient requirements are expressed in single figure as DM, DCP, TDN, Ca, P, carotene and Vitamin D. These standards are being constantly reviewed and revised standards are published from time to time.

2. Agricultural Research Council's (ARC) standard: In UK a technical committee was set up to develop the standards in 1959, by the Agricultural Research Council which later came to known as Agricultural Food Research Council (AFRC). Between 1960 and the mid 1980s, feeding standards in UK was translated into practical manuals by extension workers of the Ministry of Agriculture, Food and Fisheries (MAFF) and associated Governmental and commercial organizations. In 1983 AFRC set up a single organization for the UK, Techinical Committee on Responses to Nutrients (TCORN) and this became responsible for both revising the standards and producing practical manuals. Requirements are given for ruminants, pigs and poultry in three separate reports.

3. Japanese feeding standard: The first feeding standard for dairy and beef cattle in Japan were evolved from the results of experiments conducted during 1957-1966. These feeding standards were revised and published during 1974 and 1975. The requirements are expressed as protein, energy, minerals and vitamins.

4. Indian Feeding Standards

    a) Sen and Ray standard: In 1964 Sen and Ray compiled the feeding standard based on mid Morrison values.

b) Ranjhan feeding standard: Ranjhan in 1980, published feeding standards for farm animals including poultry based on the extensive work done in India during the last decades. The requirements are expressed in terms of DM, DCP, TDN, ME, Ca, P, Carotene and Vitamin A.

c) ICAR feeding standard: This standard is based on the recommendations of scientific panel on Animal Nutrition and Physiology, and brings together information arising from experimental work carried out in India over the past several years. The panel had constituted expert groups on each species to compile the information after critical review, and recommended the nutritional standards in 1985, which was later revised in 1998.

Advantages of feeding standards

1. Serves as a general guide for feeding of livestock
2. Gives idea about the requirement of nutrients for various physiological functions.
3. Useful in planning the experiments and interpreting the results depending upon nature and objective of the investigation.
4. Useful for calculation of total requirement of herd and thus helps in planning of feeding schedule for future.

Limitations of feeding standards

1. Cannot give exact needs of individual animals according to its genetic makeup.
2. May not be useful under the situations were palatability and physical nature of feed alters its voluntary intake.
3. Not useful in conditions were environmental and climatic conditions alter the nutrient metabolism.
4. Factors such as biological value, availability of minerals and vitamins are not taken into account.

BALANCED RATION AND ITS CHARACTERISTICS

FORMULATION OF RATIONS FOR CATTLE AND BUFFALOES

Ration: feed offered for a given animal during a day of 24 hrs.

Balanced ration: a balanced ration is one that furnishes nutrients in such proportions and amounts that it will properly nourish a given animal for 24 hrs.

Characteristics of balanced ration

1. The required nutrients must be contained in the amount of DM the animal is able to consume in the 24hr period.
2. The feed ingredients in the ration should be highly digestible
3. Feed must be palatable
4. The ration should be fairly laxative
5. The ration should be fairly bulk to satisfy the hunger
6. The ration should include green fodder
7. All the changes made in the feeding pattern should be gradual and slow
8. Time of feeding should be evenly distributed
9. Feed should be properly prepared to render it more digestible and palatable

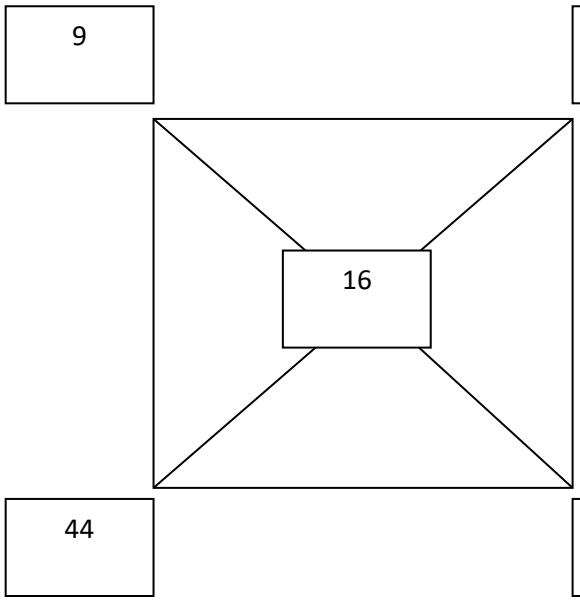
Ration formulation: process by which different feed ingredients are combined in the right proportion to provide the animal with proper amount of nutrients needed at a particular stage of life.

Methods

a) *Pearson Square Method*

1. When only two feeds are involved

E.g. A farmer has yellow maize (9% CP) and a protein supplement with adequate minerals and vitamins (44 % CP). Formulate a concentrate mixture with 16% CP?



% of maize in ration is (28/35) X 100 = 80%

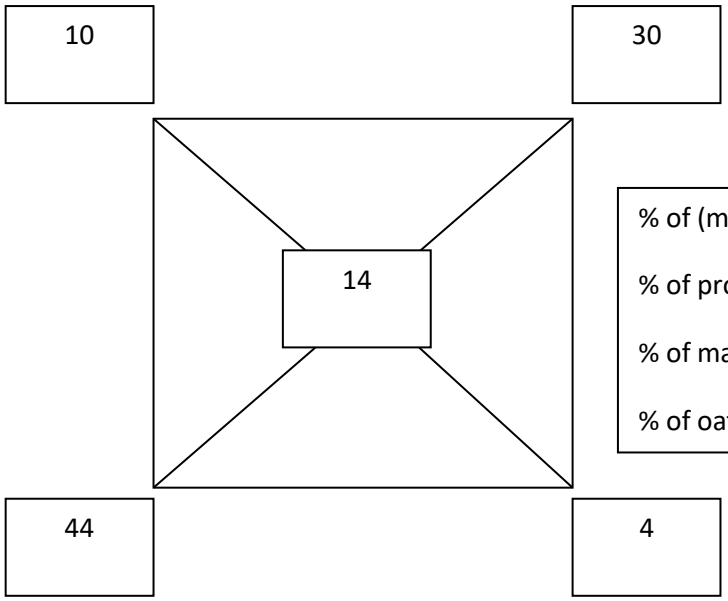
% of protein supplement in ration is (7/35) X 100 = 20%

2. When two or more feeds are involved

E.g. A farmer has yellow maize (9% CP), oats (12% CP) and a protein supplement with adequate minerals and vitamins (44 % CP). Formulate a concentrate mixture with 14% CP having maize and oats in the ratio 2:1?

The average % of protein when maize and oats is combined=

$\frac{(2 \times 9) + (1 \times 12)}{3} = 10\%$



% of (maize + Oats) in ration is (30/34) X 100 = 88.24%

% of protein supplement in ration is (4/34) X 100 = 11.76%

% of maize = 2/3 X 88.24 = 58.83 %

% of oats = 1/3 X 88.24 = 29.41 %

3. With a fixed percentage of one or more components of the ration

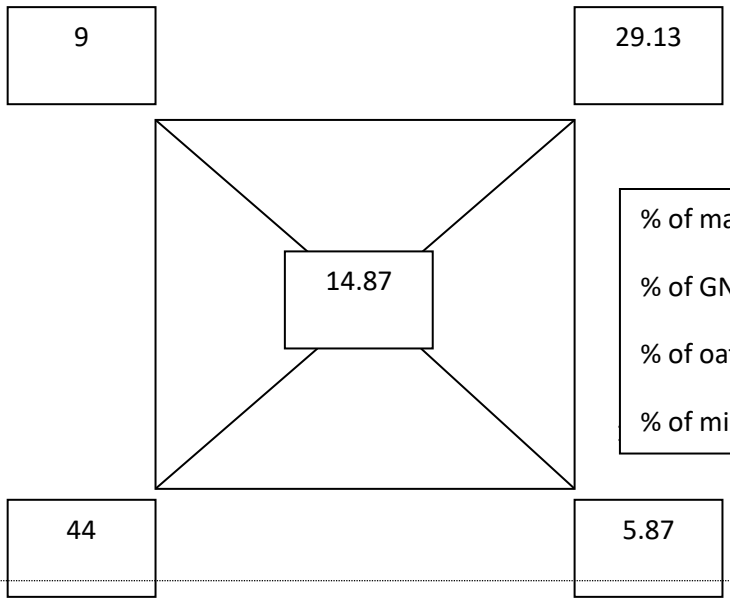
E.g. A farmer has yellow maize (9% CP), GNC (44% CP), oats (12% CP) and a mineral and vitamin supplement. Formulate a concentrate mixture having 14% CP with 20 parts oats and 2 parts mineral and vitamin supplement?

CP contributed by 20 kg oats = 20 X 12/100 = 2.4 kg

CP contributed by 2 kg mineral and vitamin supplement = 0kg

100-22=78 kg of maize and GNC should supply the remaining (14-2.4 = 11.6 kg) CP.

So % protein in maize and GNC combination is (11.6/78) X 100 = 14.87%



% of maize in ration is (29.13/35) X 78 = 64.92%

% of GNC in ration is (5.87/35) X 78 = 13.08%

% of oats = 20 %

% of minerals and vitamins = 2 %

.***Algebraic method***: in this method it is possible to balance two or more feed ingredients to achieve optimal value of nutrients. However, this method is not practical for solving a problem which takes many nutrients at a time.

Q. Prepare a corn soybean based ration with 16% CP by incorporating 10 % bran (CP-12%) and 2% Vitamins and minerals (V&M)

Total [100 %] = %Corn + %SBM + %Bran + %V&M (1)

CP = (% Corn) (CP corn) + (% SBM) (CP SBM) + (% Bran) (CP bran) + (% V&M) (CP V&M) (2)

Total - Bran – V&M - SBM = Corn

on % basis, total = 100.

SBM = 100 - Bran - V&M - corn.

Bran = 10 % and V&M = 2 % then SBM = 100-10-2- corn = 88-corn

If % Corn is X and % SBM is Y, then

a) X + Y = 88

b) Y = 88 - X

Corn contains 9% CP, SBM contains 44% CP, and bran contains 12% CP.

Substitute into 2nd equation and solve.

16 = X (0.09) + (88 - X) (0.44) + 10 (0.12) + 2 (0)

16 = 0.09X + 38.72 - 0.44X + 1.2 + 0

16 - 38.72 - 1.2 = 0.09X - 0.44X

-23.92 = -0.35X

X = 68.34

Y= (88 -X) = 88-68.34= 19.66

Therefore, ration can be formulated by adding 68.34 % corn, 19.66 % SBM, 10 % bran and 2% Vitamin and mineral mixture

R. ***Trial and error method***: This is the most popular method of formulating rations for animals. As the name implies, the formulation is manipulated until the nutrient requirements of the animal are met.

S. ***Using computer software***: the speed and simplicity of the equipment allows considering more ingredients and more nutrients at a time. Moreover, it is possible to pay attention to the cost of the formulated ration.

Least cost ration: if a ration is balanced using a combination of ingredients with the lowest possible total cost, the resulting mixture is called a 'least cost' ration. The technique employed to calculate least cost and profit maximizing rations is called *linear programming*. A simple definition of linear programming is the 'maximizing or minimizing of some functions subject to constraints'. In the case of livestock rations, it is the minimizing of the cost of a ration or maximizing the income above feed cost.

Total Mixed Ration (TMR) or complete ration or Complete feed blocks

Concentrate and roughages are mixed together in correct proportion in the Total Mixed Ration. Roughages are chaffed into particles of 1 to 2 cm before mixing with the concentrate. TMR can be fed in the mash form (it will be very bulky) or can be made into pellets, cubes or blocks. Different types of TMR blocks can be made for cows in different stages of lactation or depending upon their production. The main advantages of TMR blocks are,

1. Animals cannot select feed ingredients from the block - each bite will be a balanced ration
2. Automation in feeding is possible
3. Animals can be fed *ad libitum* without the risk of over feeding or under feeding with regard to certain nutrients
4. Unconventional or unpalatable feed items can also be included
5. Less dusty and easy to store and transport

Concentrate mixture for cattle

In general, a concentrate mixture for cattle is formulated with 14-16% DCP and 68-70% TDN by incorporating:

Cereals: 25-35 parts, Oil cakes: 25-35 parts, Cereal by-products: 10-25 parts, Pulses: 5-15 parts

fortified with 2% mineral mixture, 1% salt and 20-30g Vit AD_3/100kg feed (if required).

KERALA VETERINARY AND ANIMAL SCIENCES UNIVERSITY
COLLEGE OF VETERINARY AND ANIMAL SCIENCES, POOKODE
DEPARTMENT OF ANIMAL NUTRITION

Title of Unit : Applied Ruminant Nutrition-II

Unit No. : 3

Credit Hours : 3 + 1

Compiled by

Dr. Biju Chacko
Dr. S. Senthil Murugan
Dr. Surej Joseph Bunglavan
Dr. Jinsy. V. S

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3. Animal Nutrition : Banerjee G. C.

4. Principles of Animal Nutrition and Feed Technology : D.V. Reddy

Title of the course: **Applied Ruminant Nutrition-II** **Unit No.: 3**

Credit hours: 3 + 1

Sl No	Theory
1	Energy requirements of Livestock for maintenance: basal metabolism, factorial method and feeding trial
2	Method of estimating energy requirement.
3	Protein requirement for maintenance: different methods of estimation.
4	Mineral and vitamin requirement for maintenance
5	Nutrient requirements for growth: estimation of energy, protein, mineral and vitamin requirements.
6	Determination of nutrient requirements for pregnancy.
7	Determination of energy, protein, mineral and vitamin requirements for lactation.
8	Requirements of nutrients for work, fattening and wool.
9	Formulation of rations for cattle and buffaloes.
10	Feeding of cattle: growing, mature, dry, lactating and pregnant cows, breeding bulls and working bullocks.
11	Formulations of rations for various classes of goats.
12	Feeding of kids, growers, lactating and pregnant does, meat goats.
13	Formulation of rations for various classes of sheep.
14	Feeding of lamb, growers, lactating and pregnant ewes, breeding rams, wool producers.
15	Utilization of agro industrial byproducts and agricultural wastes as animal feeds.
16	Unconventional feeds.
17	Use of urea molasses with concentrates and roughages.
18	Feeding of high yielding animals and role of bypass nutrients
19	Metabolic disorders and nutritional interventions

ENERGY REQUIREMENTS OF LIVESTOCK FOR MAINTENANCE

Energy is the driving force for maintenance of life, growth, reproduction, production and work.

Maintenance: state in which there is neither gain nor loss of a nutrient by the body

Fasting catabolism: when the need for feed is not met, tissue break down occurs and this destruction of body tissues is referred to as the fasting catabolism. The destruction of body tissues occurs in order to support the activities essential to life.

Basal metabolism: fasting catabolism measured at its minimum value. Measurement of basal metabolism provides a direct estimate of the quantity of net energy which the animal must obtain from its feed to meet the demand for maintenance. Basal metabolic rate (BMR) is highest for new born and it declines 8% per year of age. BMR is lowered by under nutrition, increased by emotional stimuli, and declines with castration. True minimum value of basal metabolism is attained in the case of man and the conditions for its measurement are

a. Good nutritive condition: a poor state of nutrition tends to decrease heat production during fasting.
b. Thermo neutral environment (around 25^0C): the range between the lower and upper critical temperatures is referred to as the thermoneutral zone (*zone of comfort*).

   Lower critical temperature: Environmental temperature below which heat production is increased by body to maintain the body temperature.

   Upper critical temperature: Environmental temperature above which heat production is reduced by body to maintain the body temperature.

   Ruminants have a wider thermo neutral zone and lower critical temperatures than pig and poultry.
c. Post absorptive state: heat increment due to digestion and assimilation has been dissipated. At post absorptive state, RQ of fat is reached in the case of non ruminants and in ruminants the methane excretion will decline to a minimum level. Human beings have simple digestive system and hence overnight fasting will result in post absorptive state. Ruminants have four chambered stomach involving microbial digestion and hence post absorptive state can be obtained only after a prolonged period of fasting (at least 4 days). The same period of fasting is recommended for the pigs to attain the post absorptive state while fowl reaches the post absorptive state in two days of fasting.
d. Relaxation on bed: it is difficult in farm animals and hence activity increment has to be considered. Activity increment is the amount of energy required for activity. In cattle sheep and swine the activity increment is 20-30% of basal metabolism while in poultry it is 50%

   In general the basal metabolism is 10-15% greater when animals are standing (horse being an exemption) and grazing animals have maintenance requirements 25-50% greater than that of housed animals.

***Fasting metabolism*:** it is the terminology used in ruminants instead of basal metabolism. Fasting metabolism refers to heat production at specified times after the last feeding.

Standard metabolism: to avoid problems associated with prolonged fasting in ruminants, some workers have determined heat production over a specific time period after the last feeding and have referred this value as standard metabolism.

Resting metabolism: heat eliminated when an animal is lying at rest though not strictly in a thermo neutral environment or in the post absorptive state.

Surface area law (Rubner): heat produced by all warm blooded animals is directly proportional to body surface area and that expressed on this basis, heat production is a constant for all species. Surface area is proportional to two-thirds power of body wt ($W^{0.67}$) i.e. metabolic body size rather than body weight. Therefore, heat production per kilogram is greater in smaller animals when compared to larger ones

Brody, studied the basal metabolism of all animals ranging from mice to elephant and developed the following equation.

Basal metabolism (k cal) = 70.5 $W^{0.734}$ (Cattle have a fasting metabolism 15% higher than the interspecies mean and for sheep it is 15% lower)

67.6 $W^{0.756}$ (modification by Kleiber)

70 $W^{0.75}$ (NRC, ***General formula***)

Lusk suggested that basal metabolism is 1000 kcal per square meter of body surface per 24hrs regardless of the size of the animal.

Methods for the estimation of energy requirement for maintenance

A. *Direct calorimetry*: using animal calorimeter (an adult, healthy non producing animal in post absorptive stage is put inside an animal calorimeter with arrangement for the collection of feces, urine, gases and the determination of sensible heat loss as well as heat loss by evaporation of water from lungs and skin surface).

B. *Indirect calorimetry*:

   *(1)*Factorial method: by adding factors such as activity increment to the fasting metabolism to obtain the maintenance energy requirement.

   *(2)*Feeding trial method:

      a) Short term feeding experiments: heat loss is measured indirectly by carbon nitrogen balance or through respiration calorimetry (measurement of respiratory gases exchange and urinary nitrogen excretion) to assess the net energy requirement of animals.

      b) Long term feeding experiments: energy equilibrium is assumed when the body weight changes is absent or negligible

C. By using regression equations (most common method recently): feeding experiments with different levels of feed intakes is conducted. Maintenance requirement is obtained by extrapolation of intake of feed towards zero level of production.

D. Comparative slaughter experiments (Lofgreen and Garrett): More accurate than other methods. Fasting heat production estimated by this method in beef cattle lies between 72-82 kcal/kg$W^{0.75}$, with a mean of 77 kcal/kg$W^{0.75}$

Maintenance energy requirement of various species

a) Dairy cattle

1. Net Energy= 80 kcal/kg$W^{0.75}$/day
2. Metobolisable Energy= 133 kcal/kg$W^{0.75}$/day (for Indian cattle and buffaloes Sen and Ranjhan proposed the value 122 kcal/kg$W^{0.75}$/day)
3. Digestible Energy= 155 kcal/kg$W^{0.75}$/day
4. TDN= 35.2g/kg$W^{0.75}$/day
5. Net Energy [MJ/day] (ARC)=0.53 $(W/1.08)^{0.67}$ + Activity increment (activity increment is 0.0071 W for growing cattle and 0.0091 W for dairy cows; W is the body wt in Kg)

b) Sheep

1. Metabolisable Energy= 98 kcal/kg$W^{0.75}$/day (NRC, 1981)
2. TDN= 27.3g/kg$W^{0.75}$/day
3. Net Energy [MJ/day] (ARC) = 0.226 $(W/1.08)^{0.75}$ + Activity increment (activity increment is 0.007 W; W is the body wt in Kg)

c) Goat

1. Metabolisable Energy= 119 kcal/kg$W^{0.75}$/day
2. TDN= 30g/kg$W^{0.75}$/day

PROTEIN REQUIREMENT FOR MAINTENANCE – DIFFERENT METHODS OF ESTIMATION

The amount of protein lost in the urine and feces of animals, and additional losses such as hair, skin and hooves represent the amount of protein required for maintenance. The estimation of maintenance requirement of protein is more complicated than that of energy. The reasons are

1. Protein may be used as a source of energy in case of energy shortage.
2. Excessive intake of protein results in de-amination of protein and the resulting nitrogen free substances will be used as a source of energy.
3. Adult growth has to be considered: adult growth is the growth and renewal of epidermal tissues like wool, feathers, hooves etc

Urinary N: it includes, urea (more than 80%), creatinine, ammonia, uric acid, allantoin, amino acids etc

Endogenous Urinary Nitrogen or EUN (Folin, 1905): minimum urinary nitrogen excreted on a nitrogen free energy adequate diet. This is due to nitrogen catabolism taking place in the body to maintain the vital processes.

Terroine and Sorg-Matter observed that 2.3 to 2.9 mg nitrogen is excreted per kilocalorie BMR

(Commonly used value is 2 mg EUN/ kilocalorie basal metabolism or 500 mg EUN/ MJ basal metabolism. In ruminants the value is 350 mg EUN/ MJ fasting metabolism, and the value is lower due to recycling of urea to the rumen or large intestine)

Brody and coworkers:

EUN= 146 mg / kg $W^{0.72}$/day

EUN of Indian cattle is 0.02g/kg body wt while that of *Bos taurus* is 0 .289 g/kg body wt.

It is very difficult to find out the EUN value although theoretically the procedure seems to be very simple because experimental animals will hardly continue to consume normal quantity of feed for a long time required for the experiment without any nitrogen (protein) in their ration.

Exogenous urinary nitrogen: urinary nitrogen in excess of the endogenous portion.

Faecal Nitrogen: includes undigested or un-absorbed feed nitrogen along with MFN

Metabolic faecal nitrogen (MFN): faecal nitrogen excreted on a nitrogen free energy adequate diet. Consist principally of unused digestive enzymes, abraded mucosa and bacterial nitrogen. Amount of MFN in feces is directly proportional to the DM consumption. MFN of

a) European cattle=5g/kg DMI
b) Indian cattle=3.5g/kg DMI
c) Buffalo=3.4g/kg DMI

[#] EUN and MFN put together in ruminants is 350 mg/kg $W^{0.75}$/day

Methods for the estimation of protein requirement for maintenance

A) **Nitrogen balance method**: the minimum protein intake at which the nitrogen equilibrium is achieved on a ration adequate in energy, minerals and vitamins is considered as the requirement of protein.

   In general the nitrogen balance study will be a short term experiment, and the question always arises that how accurately the results apply to long term feeding.

   During nitrogen equilibrium the nitrogen intake is equal to nitrogen excreted. Established nitrogen equilibrium in any subject shows the following facts

   a) animal is no more growing

b) protein in diet is sufficient in quality and quantity

c) diet is adequate in energy

d) animal is not suffering from any wasting disease.

Negative nitrogen balance means the excretion of nitrogen exceeds the intake (e.g. fasting, starvation, high fever, prolonged illness, low protein diets, diets poor in protein quality, inadequate calorie content in the diet, injury etc)

Positive nitrogen balance means the Intake of nitrogen exceeds the excretion (growth, pregnancy, recovery from fasting etc)

B) **Feeding trial method**: the level of protein in ration at which animal maintains its body wt without loss or gain over an extended period of feeding with ration adequate in energy, minerals and vitamins is considered as the maintenance requirement of protein.

C) **Factorial method**: EUN, MFN and dermal losses of hair and scurf is included (2.2gN/d for cattle and 0.6-1 gN/d for sheep). Biological value (BV) of protein is also considered.

Requirement of truly digestible protein (TP)

TP (g/d)= (EUN + MFN + S_1 or S_2) X 6.25 X 100/BV

EUN = endogenous urinary nitrogen (g/d)

MFN = metabolic fecal nitrogen (g/d)

S_1 (for cattle) = N loss through scurf (g/d)

S_2 (for sheep) = N loss through fleece (g/d)

BV of dietary protein is 70% for cattle and 65% for sheep

DCP requirement (g/d) = TP - (MFN X 6.25)

Protein requirement for maintenance

A) Cattle : 2.84g DCP/ kg $W^{0.75}$/day

B) Sheep : 2.73g DCP/ kg $W^{0.75}$/day

C) Goat : 3g DCP/ kg $W^{0.75}$/day

D) Horse : 3g DCP/ kg $W^{0.75}$/day

As per BIS specification Type I cattle feed should contain minimum 22%CP and Type II cattle feed should contain minimum 20% CP.

New systems for expressing protein requirement of ruminants

The fundamental principle underlying the new systems for expressing the protein requirements is that nitrogen requirement of a ruminant animal is considered both as requirement of nitrogen by rumen microorganisms and requirement of protein by host ruminant animal.

1. Metabolizable protein (NRC): that part of dietary protein un-degraded in the rumen and the microbial protein, which are absorbed by the host animal and is available for use at tissue level. Metabolizable protein requirement for maintenance of ruminants could be met entirely by microbial protein. For each MJ of ME intake 7.8 g of microbial protein is synthesized if there is sufficient nitrogen in the diet.

2. RDP/ UDP (UK Metabolizable protein system): rumen degradable and undegradable protein system proposed by ARC.

3. French PDI system: true protein digested in the small intestine

Non protein nitrogenous (NPN) substances: ruminants natural feed contains 30% of the nitrogen as NPN substances such as amino acids, amides and amines. 30% of the protein requirements of dairy cattle and buffaloes can be met by feeding NPN compounds like urea, biuret etc. Urea contains 46% N and the compound is 100% degradable in the rumen. For efficient utilization of urea, simultaneous feeding of soluble carbohydrate (1kg/every 100g urea) is a must for the sake of providing necessary energy requirement of the microbes. Urea can be added at the rate of 3% in concentrate mixture (BIS specification is 1% in concentrate mixture) and at the rate of 1% in total ration.

Urea recycling: Blood urea enters back into the rumen directly by transfusion through rumen wall and also indirectly through saliva. Blaxter has estimated that about 20% of the N absorbed as ammonia is recycled in sheep on normal nitrogen intakes.

Protein reserves: protein reserves form 5-7% of the total body protein. They are labile, drawn upon on periods of starvation or reduced protein intake, and restored in times of plenty, thereby contributing to the free amino acid pools of the body during depleting processes. In times of emergency, among all the tissues liver is very much affected. About $1/4^{th}$ of the body protein especially that in liver, followed by kidney, heart and skeletal muscles are depleted and repleted. Less metabolic importance is attributed to the existence of protein reserves than to energy reserves which are stored in larger amounts and in specific organs.

Bypass protein/protected protein: bypass protein means rumen un-degradable protein. In normal ruminant diet 60% of the dietary protein is degraded in the rumen and rest 40% is UDP. By protecting the good quality dietary protein from ruminal degradation it is possible to provide greater amounts of essential amino acids to the host ruminant. Methods employed for protein protection are heat treatment, treatment of proteins with tannins and treatment with formaldehyde.

MINERAL REQUIREMENT FOR MAINTENANCE

If animals are deprived of minerals in diet, they continue to excrete small amount of minerals from body. Inorganic elements like calcium, sodium, potassium and magnesium are lost through urine as a result of maintenance of acid base balance and also through faeces as a result of secretion of these minerals into digestive juices. The endogenous excretion of minerals is very low when compared to the total mineral content of the body. The requirement of minerals for maintenance can be assessed in the same way as for energy or protein. A theoretical estimate can be made on the basis of endogenous losses whereas practical estimates on the basis of feeding trials. It is difficult to make a ration totally absent in any mineral and hence the estimation of endogenous losses is difficult.

Factors governing mineral requirement

1. Interrelationship between minerals/minerals and organic matter
2. Form in which the mineral is present in diet
3. Mineral status of the animal
4. Quantity of mineral present in the diet

VITAMIN REQUIREMENT FOR MAINTENANCE

Requirement of vitamins can be assessed on the basis of

1. freedom from signs of deficiency
2. estimation of vitamin in the blood
3. analysis of tissues for the content of vitamins

The requirement of fat soluble vitamins is dependant on the body weight in adult animals. For those vitamins involved in metabolism (chiefly water soluble vitamins) the requirement is based on feed intake or specific nutrient intake. In ruminants the entire requirement of vitamin B complex and vitamin K is generally met by microorganisms in the digestive tract. In pigs and poultry though there is considerable synthesis of B complex vitamins in lower gut, these vitamins fails to get absorbed and is excreted in faeces .

NUTRIENT REQUIREMENTS FOR GROWTH

Growth (Schloss): correlated increase in the mass of the body in definite intervals of time in a way characteristic of the species.

Growth curve: The pattern by which animals grow from conception to maturity can be represented by a sigmoid (S shaped) curve. From the fetal period till puberty the rate of growth accelerates; after puberty it decelerates and reaches a very low value as the mature weight is approached.

Development: When animals grow they do not simply increase in size and weight, but various anatomical components grow at different rates, so that the proportion of the animal change as it matures. John Hammond of Cambridge University described the development of farm animals as a series of growth waves i.e. in early life nerve and bone tissue grow rapidly, later the muscles and finally the adipose tissue. When growth rate is faster these waves may overlap.

Attainment of maximum adult body size and development are governed by inheritance or heredity but an optimum nutritional regime is the one which enables the organism to take full advantage of its heredity.

Empty body weight: Live weight less the extraneous gut and bladder contents. When empty body weight increases the weight of all chemical constituents in body (fat, energy and protein) increase, but at different rates. Fat is deposited at increasing rate and protein at decreasing rate. The energy content of body follows a curve similar to that of fat content. The relationship of the weight of each component to empty bodyweight is curvilinear.

Allometric equations for growth (J S Huxley): allometry designates the changes in relative dimensions of parts of an organism that are correlated with changes in overall size; or, more concisely: “the relationship between changes in shape and overall size”

$y=b\ x^{a}$

y= weight of the component (a part of the body), x= empty body wt, a=growth coefficient (measure of the rate of growth of the part relative to the rate of growth of the whole animal) and b is a constant. If a>1 then that body part is relatively growing faster than the whole body (late maturing part) and vice versa if a<1 (early maturing). Among the nutrients involved in growth, protein and water have growth coefficient less than 1 and fat/energy has growth coefficient more than 1. During the early stages of growth more protein and minerals are required in comparison to energy, whereas later energy requirement become more than rest of the nutrients.

ENERGY REQUIREMENT FOR GROWTH

Methods for the estimation of energy requirement for growth

1. Factorial method

Energy of the tissue formed + basal metabolism + activity factor, (the maintenance requirement usually exceed the requirement for formation of new tissue)

in the case of pigs

NE (maintenance and wt gain)= DE X 0.70

NE (maintenance and wt gain)= ME X 0.96

Energy requirement calculated by factorial method may be inaccurate as the gains can vary widely in the proportions of fat and protein according to genetic makeup and nutritional regime of the animal.

2. Feeding trial method

Different groups of animals are maintained at different energy levels and the optimum level of energy intake required for satisfactory growth is determined. Data regarding the energy requirement for growth contained in the currently used feeding standards for farm animals are based on the results of feeding trials.

PROTEIN REQUIREMENT FOR GROWTH

During early stages of growth, most important nutrient deposited in body apart from water is protein. Protein requirement has to be assessed at least two or three times during the growth period because maintenance requirement of protein increases with increase in body wt where as requirement of protein for growth decreases as age advances. The minimum quantity of protein required for growth is the amount that is deposited in the new tissue formed. The theoretical requirement of protein is far below the actual requirement because of the wastage in the digestion and metabolism. The protein wastage in metabolism depends primarily on the efficiency with which the digested protein supplies the essential amino acids required for the construction of body tissues. Therefore, the requirement of protein means the requirement of essential amino acids. The amino acid requirements are expressed in terms of the utilizable form i.e. the L form. In chicks' arginine, lysine, tryptophan and the sulfur containing amino acids need attention while in pigs it is lysine, methionine/cysteine and threonine. The requirement of essential amino acids can be estimated by

1. Feeding the animals a basal ration deficient in a particular essential amino acid to which the amino acid is added in graded levels i.e. animals in different groups are fed with different levels of amino acid. The level that is required for satisfactory growth is taken as the requirement.
2. By analyzing the amino acid composition of the body of the animal and the feeds that are available for feeding.

Methods for the estimation of protein requirement for growth

1. **Factorial method**: The requirement of protein by growing animals is equal to the sum of requirement for maintenance and the requirement for the formation of new tissue with an allowance for the loss in metabolism.

2. **Nitrogen balance studies**: minimum intake of nitrogen required to produce maximum retention in the animal making satisfactory growth is taken as the requirement.

3. **Feeding trials**: minimum level of protein required to promote optimum growth of the animal is taken as the requirement.

MINERAL REQUIREMENT FOR GROWTH

a) Calcium, phosphorus: required in bone formation.

b) Magnesium: deficiency occur only when the animals are fed on sprouting grass (grass staggers or hypomagnesaemic tetany)

c) Sodium and chlorine: deficiency tested by their excretion in urine and saliva.

d) Sulfur: deficiency occur when diet is deficient in sulfur containing amino acids (methionine, cysteine and cystine)

e) Iron: deficiency occur in milk fed animals (e.g. piglet anemia or thumps)

Iron deficiency anemia is common in milk fed piglets. Occur when piglets are reared in concrete floors without any access to soil or other feeds. Anemic piglets are weak with pale mucous membrane and unhealthy appearance. In severe cases there will be labored breathing because of the deficiency of haemoglobin and the animal will have swollen appearance around the head and shoulders. The condition can be prevented either by drenching the piglets with a saturated solution of ferrous sulphate ($1/3^{rd}$ teaspoon for animals below 1 week and gradually increased to 1 teaspoon for animals above 4 weeks age) or by swabbing the udder of mother with saturated solution of ferrous sulphate. Another method is to inject 100mg of iron dextran compound when piglets are 3 days old and then repeat the same dose at 21 days.

VITAMIN REQUIREMENT FOR GROWTH

Vitamin A: requirement is proportional to body wt. If green fodder is not offered to the dam, the calf should be given 10000 IU of Vitamin A within few hours after birth and may be reduced to 5000 IU/d for next 7 days and later to 1000 IU/d.

Vitamin D: not dietary essential in tropical countries

Vitamin B complex and Vitamin K: not critical because the rumen microbes will synthesize these vitamins when the rumen starts functioning.

NUTRIENT REQUIREMENTS OF LIVESTOCK FOR REPRODUCTION

Nutritional factors play vital role in the development of reproductive organs and subsequent reproductive functions. Puberty in cattle is influenced by level of nutrition, the

faster an animal grows, the earlier it reaches sexual maturity. In cattle, puberty occurs at a particular live weight or body size rather than at a fixed age. The attainment of puberty in sheep is more complicated by their seasonal breeding pattern. In pigs on the other hand, the primary determinants of puberty is age, breed, and the age at which gilt meets boar. In general the tendency today is to mate the animals (cattle/ sheep/ pig) when they are relatively young, which means that in the female the nutrient demands of pregnancy are added to those of growth.

Commonly the reproductive troubles arise from multiple deficiencies. Under nutrition delay puberty in both sexes and if severe can cause retrogressive changes or degenerative changes even after the organs are completely developed. Death of fetus in the uterus or birth of weak or permanently damaged young ones can also occur. Over feeding is also disadvantageous, due to excessive fat deposition, there will be irregularity or cessation of estrus, improper implantation and interference with production of fertile sperms. Qualitatively nutrient requirements are similar for both males and females where as quantitatively the requirements are more in case of females. On inadequate nutrition during pregnancy the mother sacrifices her bones and tissues for the development of fetus. Therefore, nutrition of pregnant mother should not only for producing a normal offspring but also should prevent any drain from her body tissues.

1. Energy: most critical nutrient for pregnancy is energy. The main source of energy for a growing fetus is glucose (during glucose scarcity, amino acids are used). Energy requirement for reproduction consist of energy stored in new tissues formed and that is spend in the entire process. Tissues formed consist of fetus and its membranes, enlargement of uterus and development of mammary gland. The organs and tissues that grow with the fetus are known collectively as the ***adnexa***. In pregnant animals which are still growing, allowance for growth also should be given. In some cases mature animals may have poor body conditions because of previous lactation. In such cases, they should be given enough feed to improve the condition. If a pregnant animal is given a constant daily allowance of food, its heat production will rise towards the end of gestation. The increase is due to additional energy required by the fetus for both maintenance and growth. It has been found that ME taken in by mother in addition to her own maintenance requirement is utilized by the fetus with comparatively low efficiency. For each additional 1 MJ, only about 0.13 MJ is retained in the fetus.

Pregnancy toxemia: the disease is due to carbohydrate deficiency and occurs in pregnant ewes during last month of gestation when there is scarcity of feed and also when they are subjected to stress. The affected sheep becomes dull and lethargic, appetite goes down, and may even show nervous symptoms such as trembling and folding the head at an unusual angle. Animals showing nervous symptoms are likely to have a high (90 %) mortality. These animals show hypoglycemia, ketonemia (increased levels of ketone bodies such as acetone, acetoacetate and β hydroxybutyrate in blood) and an increase in plasma free fatty acids. When the disease progresses, there will be metabolic acidosis.

In general, fetus has high priority for nutrients compared to mother and it is able to maintain a blood glucose level higher than that of the mother. For growing fetus there is high requirement of glucose. When there is low availability of carbohydrates to the mother, the level of blood glucose goes down to such a level that nerve tissues of mother are seriously affected. Oxaloacetate is produced in body from glucose or glucogenic substances such as glycerol propionate or glucogenic amino acids. There will be deficiency of oxaloacetate during carbohydrate deficiency. Acetyl CoA produced in body cannot enter Kreb cycle unless there is adequate level of oxaloacetate. Therefore, by an alternate pathway the Acetyl CoA is converted to ketone bodies.

The disease can be treated by intra venous administration of glucose or by feeding gluconeogenic substances (sodium propionate/propylene glycol) or feeds rich in starch. The occurrence can be prevented by supplementation of enough quantity concentrate feed during late pregnancy.

2. Protein: low protein diets causes cessation of estrus, fetal death, and birth of weak or permanently damaged young ones or even still birth. Growth of fetus increases during the second half of pregnancy and it during this period that deposition of protein becomes more. Pregnant animal should get sufficient protein for maintenance (in growing animals, allowance for growth also should be given), fetal growth and also to provide some protein reserve in the animal (protein reserve will be useful during early stages of lactation). Recently it has been suggested that supplementation of rumen undegradable protein (UDP) can increase the ovulation rate of both cattle and sheep. In Australia, lupin seed (contains high concentration of UDP) is used to **flush** ewes. Flushing is the technique of improving the reproductive efficiency in ewes by increasing the plane of nutrition. Flushing is started 2-3 weeks before the start of breeding season. During the flushing period along with the maintenance ration ewes are provided with an additional quantity of 250-500g of concentrate depending upon the condition of the animal. The practice of transferring the animals from low plane of nutrition to high plane will definitely improve the body condition of the animal during mating and will promote the factors for multiple ovulation. Flushing increases ovulation rate by stimulating the pituitary gland to produce more of the hormone involved in ovulation, luteinizing hormone. There will be production of more twins and triplets. Flushing will increase the lambing percentage by 10-20%.

A recently discovered peptide, neuropeptide Y has been shown to provide a link between the control of feed intake (especially protein intake) and the secretion of GnRH.

Pregnancy anabolism: live wt gained by pregnant animals are considerably greater than that accounted by the products of conception alone. The difference represents the growth of the mother herself and in their own tissues deposits 3-4 times as much protein and 5 times as much calcium as is deposited in the products of conception-***pregnancy anabolism***. The energy requirements for maternal growth are much larger than that for fetal growth. However, much of the weight gained during pregnancy is lost in the ensuing lactation.

3. Minerals: most important minerals needed in reproduction are calcium and phosphorus. Calcium deficiency upsets the normal reproductive processes and a very common sign is reduction in the number of viable offspring's in multiparous animals. In severe cases there can be intrauterine death of fetus. Even if young ones are born alive they will be weak and show pathological changes in osseous system. In such cases mothers bone will also be depleted of calcium. Chief symptom of phosphorus deficiency is irregularity or cessation of estrus. Most of the storage of calcium and phosphorus take place in last one fifth of pregnancy. So intake should be adequate during this period.

Iron is another element important in reproduction. Intake should be sufficient not only for maintenance and growth but also to provide storage both in mother and fetus. Inadequate intake will result in depletion of iron store in mother.

Iodine is very important in reproduction. Severe deficiency leads to intra uterine death of fetus. Other symptoms include goitre in newborn and birth of hairless piglets. Inclusion of iodised salt (0.0076% iodine) in ration will prevent the condition.

In selenium deficient areas, supplementation of selenium increases lambing percentage. A possible effect of selenium deficiency on reproduction is the delayed expulsion of the placenta after calving in dairy cows. In addition, the trace elements copper, molybdenum, manganese and zinc are important in influencing fertility. Level of copper in herbage below 3 ppm (on DM basis) will delay the return of dairy cow to oestrus after calving. Excess molybdenum causes copper deficiency and it delays and depresses estrus by reducing the secretion of LH. Copper deficiency in pregnant ewe lead to '**swayback**' in the lamb. Swayback or swing back or gingin rickets or enzootic ataxia occurs in lambs, kids and calves as a result of feeding copper deficient ration to the mother during pregnancy. Symptoms include uncoordinated movements of the hind legs, a stiff and staggering gait with swaying of the hind quarters after few weeks following birth. Nervous symptoms are due to demyelination of the spinal cord.

Zinc deficiency prevents spermatogenesis in males (zinc is a component of enzyme thymidine kinase, which is required for spermatogenesis) and causes embryo mortality in females.

4. Vitamins: in males deficiency of vitamin A causes degeneration of germinal epithelium of testes leading to reduction in spermatogenesis or complete cessation of spermatogenesis. In females the deficiency leads to keratinization of vaginal epithelium and it may lead to cessation of estrus or irregularity of estrus. In severe cases of vitamin A deficiency there can be intra uterine death of the fetus or birth of premature or weak young ones. There can be even abortion and retention of placenta in mother. Congenital deformities due to Vitamin A deficiency includes eye and bone malformations. Inclusion of sufficient green fodder in diet will prevent the Vitamin A deficiency.

Vitamin D is needed for the proper utilization of Calcium and Phosphorus

Vitamin E is needed in reproduction in some species (rats, pigs, poultry). For cattle, sheep and goat, Vitamin E has no much role in normal reproduction

B complex vitamins: requirement is high during pregnancy

Nutrient requirements for foetal growth

The quantities of nutrients deposited in the foetus can be determined by killing animals at birth and analyzing them, and the time course of nutrient deposition during gestation can be determined by analysis of fetuses and adnexa obtained from slaughtered animals. The pattern of fetal growth can be described by **Gompertz growth equations**, which have the form:

$\text{Log } Y = A - Be^{-C\,x}$

Where Y = the wt of the fetus or a component of it

A, B and C are constants

x = day of gestation

Differentiation of Gompertz equations allows the calculation of nutrient deposition at successive stages of gestation.

After 5 months of pregnancy the cow should be given an additional amount of 0.14 kg DCP, 0.67 kg TDN, 12g Ca, 7g P daily, over and above the maintenance and production requirements. This can be attained by feeding an extra quantity of 1.5kg concentrate mixture and by incorporating 2% calcium carbonate in the concentrate mixture.

Steaming up: feeding practice in which the concentrate allowance for dairy cows is increased 2-3 weeks prior to calving so that there is increased mammary development and increased body reserves which later results in high milk production.

Nutrient requirement for maintenance and pregnancy (last two months) for cattle weighing 400 kg (Ranjhan, 1998)

DM = 7.2 kg, DCP = 350g, TDN = 4kg, Ca = 23g, P = 18g

NUTRIENT REQUIREMENTS OF LIVESTOCK FOR LACTATION

A high yielding dairy cow may secrete about 4-5 times the DM contained in her body through milk in a single lactation. The major constituent of milk is water (water- 87.5%, protein-3.3%, fat-3.7%, lactose 4.8%, Ash-0.72%). About 95% of the nitrogen in milk is in the form of protein, the remainder 5% being NPN compounds (urea, creatinine, glucosamine and ammonia). Protein in milk includes casein (78% of the total milk nitrogen), β lactoglobulin, α lactalbumin, bovine serum albumin and immunoglobulins. Proteins except the bovine serum albumin and immunoglobulins are synthesized in the mammary gland from amino acids in blood, while the bovine serum albumin and immunoglobulins are absorbed directly from the blood. Lactose the milk sugar is synthesized in the mammary gland from glucose and galactose. Lactose is the least variable constituent of milk for all species, while fat is the most variable constituent. The milk fat is synthesized from plasma lipids and blood glucose (glucose is converted to acetate in the mammary gland for fat synthesis) in the mammary gland of non ruminants while in ruminants the precursors are plasma lipids, acetate and β hydroxybutyrate. Ruminants cannot convert glucose to fat

because they do not have the two key enzymes, *ATP citrate lyase* and *NADP malate dehydrogenase*. Triacyl glycerols make up about 98% of the fat phase, the remainder being composed of certain fat associated substances such as phospholipids, cholesterol, the fat soluble vitamins and pigments. The predominant saturated fat in milk fat is palmitic acid and the unsaturated acids consist mainly of oleic with small contributions from linoleic and linolenic. The fat phase is referred to simply as 'fat' and the remaining constituents other than water are classified 'solid not fat' or SNF. The minerals present in milk are directly absorbed from blood with considerable selectivity. Milk contains 13 times more calcium, 10 times more phoshorus, 5 times more potassium and contains only $1/7^{th}$ sodium and $1/3^{rd}$ chlorine when compared to blood. Vitamins present in milk are directly absorbed from blood. Carotene enters milk, from plants. The occurrence of carotene in milk is limited to the bovine species. The milk of sheep, goat, sow, water buffalo and camel has little or none and women's milk is nearly colorless. The principal water soluble pigment in milk is riboflavin, while the principal fat soluble pigment in milk is carotene.

Factors affecting milk composition are given below:

a) milking technique: incomplete milking lowers the fat content

b) diseases: alters milk quality

c) breed: jersy-highest quality, Holstein-poorest

d) age: as age advances quality becomes poorer

e) stage of lactation: poorest quality when yield is highest

Energy: required in highest quantity. Additional energy required for lactation apart from maintenance requirement will be proportional to the energy secreted in the milk. Energy content of milk can be found out either by bomb calorimetry or by analysis of milk constituents. Energy value (E) of milk (kcal/kg) can be calculated by using the formula,

E (kcal/kg) =304.8 + 114.1 F (F is the fat content in g/kg of milk)

$$\text{ME requirement for lactation} = \text{Maintenance requirement} + \frac{\text{Energy in milk produced}}{\text{Efficiency of utilization of ME for milk production}}$$

Average value of efficiency of utilization of ME for milk production is 62% (0.62). Van Es has suggested that the efficiency of utilization of ME for milk production is related to the metabolizability (q_m) of the diet, defined as the ME (MJ/kg DM) at the maintenance level as a proportion of the Gross Energy (MJ/kg DM).

Efficiency of utilization of dietary ME for maintenance (k_m) in a lactating dairy cow may be calculatd as

$k_m = 0.35\ q_m + 0.503$

and the requirement of ME for maintenance for a lactating dairy cow (ME_m in MJ/d)

$$ME_m\ (MJ/d) = \frac{0.53\ (W/1.08)^{0.67} + 0.0091\ W}{k_m} = \frac{0.53\ (W/1.08)^{0.67} + 0.0091\ W}{0.35\ q_m + 0.503}$$

Dietary factors which affects the efficiency of utilization of ME for milk production

1. The level of protein in the diet: when protein content is inadequate, body tissues are catabolized to make good the deficiency, a process which is wasteful of energy. On the other hand, when protein content is too high, excess amino acids are used as source of energy. Since protein is used relatively inefficiently for this purpose the overall efficiency of utilization of ME is reduced.

2. Proportion of acetate produced in rumen: When the proportion of acetate is below 0.5, the cow is unable to synthesize sufficient of the lower and medium chain fatty acids which form a large part of milk fat. Similarly when acetate level is lower propionate predominates and there is increased energy storage as body gain.

Fat corrected milk (FCM): usually the milks are adjusted to a 4% fat equivalent by the Gaines formula to compare them on an equal energy basis

Fat corrected milk (FCM) kg = (0.4 X milk yield in kg) + (15 X fat yield in kg)

The net energy content of 1 kg FCM is 750 kcal, thus 750 kcal of NE is required for 1 kg of FCM. Since the efficiency of conversion of ME to NE of milk is 62%, the ME required to produce 1 kg FCM is 750/0.62 = 1210 kcal

Since the efficiency of conversion of DE to ME is 82%, the DE required to produce 1 kg FCM is 1210/0.82 = 1476 kcal

The amount of TDN required per kg of FCM is 1476/4400 = 0.335 kg

Peak yield: after calving, milk yield gradually increases and reaches the peak by 35-42 days. Thereafter there is weekly decline of 2.5% in milk yield. Peak yield may be calculated as 1.1 times the yield recorded two weeks post partum. P D P Wood suggested that the milk yield of any day post partum (*y*) may be calculated using equations of the following type.

$y(n) = an^b e^{-cn}$, where *n* is week of lactation, *a* is a positive scalar directly related to total milk production, *b* is an index of the animals capacity to utilize energy for milk production and *c* is the decay rate. Values for a, b and c may be obtained from lactation yield data by a least squares procedure. The constants for yield groups may then be used to predict week of peak yield (*b/c*) and daily yield in a given week of lactation.

Intake of energy should be sufficient during the peak production otherwise tissue break down occurs. Inadequate intake of energy will lower the efficiency of utilization of energy for milk production. Therefore, during peak production the level of concentrate should be increased. However, the change in feeding pattern should not affect rumen function and

milk fat percentage. Considering these factors, even in a very high producing dairy cow the proportion of roughage should not be less than 40%. High yielding animals even fed with optimum feed there will be loss in body weight during early lactation. This is restored during later stages of lactation by providing extra feed. There is general agreement that the efficiency with which ME is used for tissue deposition in the lactating cow is higher than in the non lactating animal.

Ketosis: In high producing dairy cows there is often a negative energy balance in the first few weeks of lactation. In dairy cow the intake of DM will reaches its maximum only by 8-10 weeks after calving while the milk production reaches its peak by 4-6 weeks postpartum. Therefore, the intake of energy may not keep up with the demand during the period of peak production. Generally the disease occurs during the first 6 weeks following calving. In response to negative energy balance and low serum concentration of glucose the cows will mobilize adipose tissue with consequent increases in serum concentrations of non esterified fatty acids. Moreover, there will be deficiency of oxaloacetate during carbohydrate deficiency and the Acetyl CoA produced in body (from fat or from acetate) cannot enter Kreb cycle. Therefore, by an alternate pathway the Acetyl CoA is converted to ketone bodies resulting in ketonemia and ultimately ketonuria. Clinically the disease is manifested in two forms

a) Wasting form: symptoms include gradual reduction in appetite and milk yield. The cow refuses to eat concentrate feed and continues to eat hay. There will be woody appearance (loss of cutaneous elasticity due to loss of subcutaneous fat) and sweet odour of ketone bodies in breath and milk.

b) Nervous form: symptoms include walking in circles, crossing of legs, head pushing and aimless movements

The disease can be treated by intra venous administration of glucose or by feeding gluconeogenic substances (glycerol/sodium propionate/propylene glycol) or feeds rich in starch.

Protein: Additional protein required for lactation apart from maintenance requirement will depend on the quantity of protein secreted in the milk. Protein content of milk can be assessed by chemical analysis or by using Gaines and Overman formula:

Protein in milk (g/kg) = 21.7 + 0.31 F (F = fat g/kg milk)

DCP required *for a lactating dairy cow* (g/d) =

$$\text{Maintenance requirement} + \frac{\text{Protein secreted through milk}}{\text{Biological value}}$$

Average Biological value is 70% (1 kg FCM with 35 g of protein needs 35/0.70 i.e. 50g digestible protein in diet)

Metabolisable protein *requirement for a lactating dairy cow* (g/d) =

maintenance component + dermal component + milk component – component reflecting live wt change

$$\text{maintenance component g/d} = \frac{2.19\text{g X kg } W^{0.75}}{\text{efficiency of utilization of Metabolisable protein for maintenance i.e. 1}}$$

$$\text{dermal component g/d} = \frac{0.1125\text{g X kg } W^{0.75}\text{/day}}{\text{efficiency of utilization of Metabolisable protein for dermal losses i.e. 1}}$$

$$\text{milk component} = \frac{\text{CP of milk (g/kg) X 0.95 X kg milk produced}}{\text{efficiency of utilization of Metabolisable protein for milk production i.e. 0.68}}$$

$$\text{component reflecting live wt change} = \frac{\text{body wt loss (kg/d) X 138}}{\text{efficiency of utilization of Metabolisable protein for weight loss i.e. 1}}$$

Effective rumen degradable protein (ERDP): represents the protein requirement of rumen microorganisms.

ERDP *requirement for a lactating dairy cow* (g/d) = FME (MJ/d) X y

where FME is the fermentable metabolizable energy and y is the requirement of ERDP in g/MJ of FME. y=9 for animals at maintenance and 11 for lactating animals

Requirement of truly digestible undegradable protein: *m*icrobial crude protein (MCP) contains 75% of true protein and have a true digestibility of 0.85. The contribution of microbial protein to metabolizable protein (MP) is MCP X 0.75 X 0.85 or 0.64 MCP. Therefore, the requirement of truly digestible undegradable protein is MP – 0.64 MCP

Minerals and Vitamins:

Potassium is the mineral occurring in milk in largest amount; it is always abundantly supplied in the feeds of plant origin commonly consumed.

Calcium and phosphorus

There is 1.2 g calcium (Ca) and 0.9 g phosphorus (P) in each kg of milk produced.

Availability values for Ca and P are 0.68 and 0.58 respectively

The best approach in feeding dairy cow is to keep the Ca:P ratio between 1:1 and 2:1. Feeding of diets high in Ca during the pre-partem period can result in a high incidence of parturient paresis in dairy cattle. A 500kg cow requires only about 30g of Calcium to meet the maintenance and fetal Ca demands in late gestation. Low Ca diets (<20 g Ca/d) fed during the last two weeks before parturition is effective in preventing parturient paresis. Maintaining a Calcium: Phoshorus ratio 1:3.3, two weeks prior to parturition will prevent the occurrence of milk fever. But feeding of phosphorus above 80 g/d increase the incidence of milk fever, because it will reduce the intestinal Ca absorption. If the ration is low in Ca, the resulting negative balance of Ca can stimulate the activity of parathyroid gland. Low Ca

intake will make the cow in negative Ca balance and in a state of withdrawal of Ca from bone thus maintaining the normal blood Ca level of 9-12 mg/dL.

A method of controlling parturient paresis in dairy cows when the Ca intake exceeds the requirement is to manipulate the anion cation balance of the diet. Diets high in cations especially sodium and potassium tend to induce milk fever compared with those high in anions, primarly chloride and sulfur (reduces the incidence of milk fever). Analyzing the feed stuffs for sodium (Na), potassium (K), chlorine (Cl) and sulfur (S) and determining the value of (Na + K) – (Cl + S) to produce a significantly negative total will effectively prevent parturient paresis (**-ve DCAB concept**). To prevent the occurrence of milk fever when high Ca diets are fed to dry cows, dietary cation anion balance must be reduced below -3 mEq/100g of dietary DM.

Daily requirement of magnesium (Mg) for maintenance is 3 mg/kgbwt and the concentration of Mg in milk is 0.125g/kg milk. Availability of dietary Mg is very low (0.17)

Daily requirement of Na for maintenance is 8 mg/kgbwt and the concentration of Na in milk is 0.6g/kg milk. It is recommended that 28 g of sodium chloride/day should be provided in addition to that in the food, or 15g/ton of concentrate ration.

Daily requirement of Vitamin A for a lactating cow is 99 IU/kgbwt

Daily requirement of Vitamin D for a lactating cow is 10 IU/kgbwt

Effect of feed intake on yield and composition of milk

When cows are fasted, there is decline in milk yield but the level of SNF and fat rises

Limitation of the energy part of the diet has a greater effect on the SNF content of milk than does limitation of the protein, although it is the protein fraction which is reduced in both cases. Most of the fall in protein content is probably due to increased gluconeogenesis from amino acids, owing to a reduced propionate supply on low energy diets.

Lactose concentration shows little change, as would be expected of the major determinant of the osmotic pressure of milk.

Drop in fat content of milk becomes more obvious when the proportion of roughage falls below 40% and the fat % of milk goes to 2% when the proportion of roughage falls below 10%. Generally the acid detergent fibre content of the diet of dairy cow should be maintained above 19% and the minimum chop length of forage should be 7 mm for optimum fat content in milk. On high fibre diets the proportions of VFA would be about 70% acetic acid, 18% propionic acid and 12% butyric acid. When the proportion of concentrate is increased the level of acetic acid may go below 40% and thus lowers the milk fat.

Non- glucogenic ratio (NGR): an increase in the level of acetate and butyrate in the rumen enhances the milk fat % whereas the increase in propionate content lowers the milk fat%. If the ratio of acetic acid to propionic acid in the rumen contents falls below 3:1 then milk of

low fat content will be produced. Some workers have claimed that the most important determinant of milk fat content is the balance of glucogenic to non glucogenic VFA in rumen contents and that is defined as the non glucogenic ratio

NGR = (A + 2B + V)/ (P + V), where A, P, B and V are molar proportions of acetate, propionate, butyrate and valerate in the rumen contents. Milk fat drops if the ratio falls below 3.

Challenge feeding: challenge feeding is started two weeks before the expected date of calving and is continued until the peak yield is attained. By increasing the amount of concentrate in ration the animals are challenged to produce at their maximum potential. Concentrate allowance is increased so long as the animal respond with a high yield. Challenge feeding lowers the chance for ketosis, however, there is more chance for udder edema at the time of calving.

Nutrient requirement for 1 kg milk produced with 4% fat (Ranjhan, 1998)

DCP = 45 g, ME = 1.13 Mcal, TDN = 315g, Ca = 2.7g, P = 2g

The requirement for TDN and DCP have been calculated per kg of milk production taking 1188 kcal of ME per kg of 4% fat corrected milk and 132g digestible nitrogen for 100g of milk nitrogen.

Nutrient requirements of the lactating dairy goat

Peak yield is attained by about 4 weeks postpartum. Nutrient requirements of the lactating goat may be derived factorially from estimates of the requirements for maintenance, milk production and live weight change. On an average the lactation requirement is 345g TDN and 45g DCP per kg of 4%FCM over and above the maintenance requirement. The mineral requirement for lactation is 1.3g Ca, 1.1g P and 0.2g Mg/kg milk produced.

Nutrient requirements of the lactating ewe

Peak yield is attained by about 2-3 weeks postpartum. The lactation requirements during the first 2 months are approximately twice the requirements for maintenance at the corresponding body weight.

NUTRIENT REQUIREMENTS OF LIVESTOCK FOR WORK, FATTENING AND WOOL PRODUCTION

Nutrient requirements for work

The source of energy in skeletal muscle is the absorbed products of digestion from the diet. When food supply is adequate, a working animal first draws up the carbohydrates and fats in the feed. If supply is inadequate, the body fat is used for the purpose and as last

resort muscle and other protein tissues are used. Theoretically, only carbohydrates need to be supplied to meet the extra energy required for work. High carbohydrate diet increase work performance because carbohydrates yield more energy per litre of oxygen and also promote greater build up of muscle glycogen. However, fats can be utilized as their catabolism can be used by the system to furnish energy. It has been found that high fat diets can be equal to or superior to high carbohydrate diets for horses on endurance rides.

Immediate energy for muscle contraction is met by ATP. Muscle contains only small amounts of ATP as such, but the supply is renewed by phoshocreatine (labile reservoir of ATP). Glucose is the primary source of ATP for short term exhausting efforts, but fatty acids becomes the predominant source during long term less intensity work. Glucose is completely broken down in aerobic condition to CO_2 and water yielding 36/38 moles of ATP/mole of glucose. This occurs only when there is sufficient oxygen in the tissue. During tremendous exertion, because of the inability of respiration to provide sufficient oxygen (anaerobic condition), glucose is converted to pyruvate and then to lactate yielding 2 moles of ATP. Accumulation of lactic acid in muscle makes the muscle into an inactive stage called *rigor*. When this occurs the deficit of oxygen is spoken off as the *oxygen debt*. However, training or conditioning decreases the level of lactate production. In general training increases the efficiency of energy utilization by muscle because

1. Increases size and number of mitochondria per cell
2. Increases aerobic capacity
3. Increases glycogen content of muscle
4. Increase turnover rate of adipose tissue fatty acids
5. Increase efficiency and utilization of free fatty acids
6. Decrease lactate production

Working animals normally doesn't need extra protein over the maintenance, except probably when the work done is very hard. The need of B complex vitamins is increased in work because they are needed in energy metabolism (however, its need is met from feed due to increased feed consumption). There is no evidence that the requirement for fat soluble vitamins is increased during exercise. The requirement of salt is increased during heavy exercise due to its loss in sweat. If the diet contains adequate amount of calcium, the increased need for calcium during work will be corrected by the increased intake of the feed due to greater energy needs. There is increased phosphorus requirement during work. Working animals should have access to water to prevent the dehydration.

In India bullocks are the main stay of agriculture. The requirement of nutrients for bullocks for work production is comparatively lower than for fast moving horses. For bullocks, work is categorized into 2 types- normal (2-4 hrs/d) and heavy work (6-8 hrs/d). Nutrient requirements for a 400kg working bullock are given below (Sen, Ray and Ranjhan; 1978).

Normal work				Heavy work			
DM (kg)	DCP (kg)	TDN (kg)	ME (Mcal)	DM (kg)	DCP (kg)	TDN (kg)	ME (Mcal)
7.6	0.45	4	14.4	9.8	0.57	4.8	17.3

Nutrient requirements for fattening

Lean meat from a well fattened animal is better flavored and more juicy than that from a lean one. The improvement in the quality of lean meat and not the storage of thick masses of fat is the main objective in fattening animals before they are slaughtered for meat. During fattening fat is stored in the lean meat tissues, chiefly between the bundles of muscle fibres. The storage of fat, which forms the so-called '*marbling*' of meat, adds to the juiciness and flavor, besides increasing the digestibility and nutritive value. Lean meat from a well fattened animal is more tender than from a lean one of the same age. In the case of young animals, fattening may not make the lean meat appreciably more tender, though it does greatly improve the juiciness and flavor. Fattening beef cattle generally makes the lean meat more tender, but fattening may not increase the tenderness of the lean of lamb or pork. In the fattening of mature animals or those which have completed their growth, the gain consists primarily of fatty tissue. Proportion of fat in the gain made by an animal steadily increases during the fattening period and it is the chief reason why the feed cost per unit gain increases rapidly after an animal has become fairly well fattened. Such flesh contains much more fat and less water, and it is correspondingly more expensive to produce.

Tallow produced by cattle and the mutton suet formed by sheep have higher melting points than lard from swine. This is because lard contains much more oleic acid, which is liquid at ordinary temperatures, and less stearic acid and palmitic acid, which melt at higher temperatures. In the case of swine and chicken if the feed contains considerable fat, the kind of fat in the food may have a pronounced effect upon the character of fat stored in the body. This is because the fatty acids in the food fats are to some extent deposited unchanged in the fatty tissues. Thus if the swine are fed considerable amounts of soybeans or peanuts, the pork will be so soft that the carcasses will be undesirable from the market standpoint. Just opposite in effect, cottonseed meal and coconut oil meal tend to produce hard pork. However, the character of body fat formed by ruminants is apparently not changed appreciably by the kind of fat in the feed.

The first requirement of a ration for fattening animals is an abundance of total digestible nutrients or net energy. The amount of protein needed and also of vitamins and minerals will depend chiefly on the age of the animals, the requirement being much greater for young animals than for those that are well grown when fattening begins. Fattening

young animals should be fed liberally, otherwise they may merely continue to grow, because of their strong growth impulse, and may fail to fatten properly. Young animals when fattened, they make rapid growth of muscles and other protein tissues, and therefore, they need an abundant supply of protein. However in the fattening of mature animals there is little storage of protein in the gain produced and much less protein is therefore needed than for growing animals. If fattening animals are fed rations that are rich in carbohydrates and fat, but too low in protein, they are apt to go 'off feed' and may even suffer from digestive disturbances. Considering all these factors, it is recommended that even for mature animals a ration for fattening should not generally have a wider nutritive ratio than 1:10. Mature fattening animals do not require a much greater amount of minerals than they need for mere maintenance, and their vitamin requirements are also low. On the other hand, young fattening animals have even greater needs for minerals and vitamins than those that are merely making normal growth.

Nutrient requirements for wool production

Production of better quality wool is confined to temperate regions of the world while carpet type wool production is prevalent in the tropics. In India about 51.7 million sheep produce 41.18 million kg wool annually. Different breeds of sheep have different capacity for wool production. In India average annual wool production per sheep is 0.8 kg. Efficiency of wool production ranges from 0.3 to 2.2g wool per 100g DM intake depending upon the breeds and quality of diet. Wool growth is distinct from the growth of other tissues in respect of two factors.

1. Wool growth continues even on a negative energy and nitrogen balance (sub-optimal growth only)

2. Amino acid configuration of wool is entirely different from that of other tissues.

The quantity and quality of wool produced is dependent on the nutrition. Keratin molecules serve as the main building blocks of wool and hair. Wool protein requires all the amino acids similar to other animal tissues, but the requirement for sulfur containing amino acids is higher. Keratin is formed by the oxidation of cysteine molecules to cystine by the formation of disulphide bonds. Keratin contains 10-12% sulphur containing amino acids (9% as cystine) compared with 2-3% in plant proteins and in the microbial proteins synthesized in the rumen. In the ARC system, wool protein deposition (P_w) is linked to protein deposition in other tissues (P_t) by the equation: $P_w = 3 + 0.1\ P_t$

Protein nutrition seems to be more important than energy intake on wool production. Feeding of rumen protected proteins rich in sulphur containing amino acids enhances wool production (e.g. formaldehyde treated casein). Sheep are able to produce maximum wool at moderate level of energy intake, only when sufficient good quality protein is provided in the diet. The supply of methionine and cysteine in diet is important

for wool production. Methionine can be converted to cysteine in body. The wool produced in animals consuming tyrosine deficient diet will be weak in strength.

Energy requirement for wool growth is less than 5% of BMR in sheep. During dietary energy deficiency animals produce wool of shorter staple length. The dependence of wool growth on energy intake is due in part to the association between energy intake and the synthesis of microbial protein. The efficiency with which metabolizable energy is used for wool production is estimated to be about 18%. Very high levels of nutrition increases the diameter of the fibre, and it is significant that finer wools come from nutritionally less favourable areas of the land. However, periods of starvation may cause an abrupt reduction in wool growth; this leaves a weak point in each fibre and is responsible for the fault in fleeces –"*break*".

Sulfur requirement of wool producing animals is quite high as it required for the synthesis of sulphur containing amino acids and proteins. Copper is associated with the formation of disulfide linkages in the wool fibre and its deficiency also affects the keratinization process. Copper is involved in crimp formation in wool fibre. Wool produced due to Copper deficiency (loss of crimp or waviness in wool accompanied by a general deterioration in quality, losing its elasticity and affinity for dyes thus resembling hair rather than wool) is called *steely wool* or *stringy wool*. Deficiency of copper also affects the process of pigmentation in the wool due to inhibition of tyrosinase (a copper containing oxygenase) required in the conversion of tyrosine to melanin. Zn deficiency leads to parakeratosis due to keratinization of epithelial cells and results in falling of hair or wool. Selenium is another important mineral in wool production because it is essential for the activation of deiodinase enzyme that converts thyroxine into tri-iodotyrosine. In animals grazing on poor quality pastures dietary deficiency of Vitamin A reduces staple length and clean fleece weight.

The requirements for wool production in India have been derived by ICAR from data on experiments conducted at the Central sheep and wool research institute, Avikanagar and the requirement for wool production for a sheep weighing 30 kg is given below.

DM (g)	Energy		DCP(g)	Ca(g)	P(g)	S(g)
	TDN (g)	ME (Mcal)				
1000	450	1.62	54	2	1.3	2.4

Write short notes

1. Physiology of muscle contraction
2. Trans sulfuration reaction related to wool protein synthesis

FEEDING OF CATTLE

Feeding of calves

a) Pre-ruminant growth (upto 3 months age)

Calves may be weaned immediately after birth, wherever it is possible. The first secretion of the mammary gland of the dam following parturition is known as colostrum, which is designed by nature to give young one a good start in life. Calves should be fed colostrum soon after birth, within half an hour or at the most within two or three hours. Colosutrum feeding should be continued for a minimum of 4 days (fed at the rate of $1/10^{th}$ of their body weight). Colostrum should be fed fresh as milked from the mother and should not be warmed as it will clot if heated. It greatly differs from milk produced later during lactation. The major difference between normal milk and colostrum is that the latter contains a large proportion of immunoglobulins, albumin and minerals. Colostrum is richer than normal milk in most nutrients (including vitamins:-especially vitamin A) except lactose and fat and has a laxative effect. However, its major function is to confer passive resistance on the new born against pathogenic microorganisms. Immunoglobulins present in colostrum are absorbed intact by pinocytosis, passing through the mucosa of the gut into the lymphatic system, and reach the circulation through the thoracic duct. The capacity of the new born to absorb the antibodies intact from the gut contents declines rapidly and last for only about 12-24 hours after birth. This passive immunity is necessary for the young one until they develop active immunity. The colostrum of ruminants contains a trypsin inhibitor which protects the immunoglobulins from digestion. The globulin fraction in colostrum declines quite rapidly with successive milkings. Within three or four days after parturition milk loses its colostral properties and becomes normal.

Composition of colostrum of cow:-

Water : 77.5%, Fat: 3.6%, Lactose: 3.1 %, Protein: 14.3%, Minerals: 1.5%

Artificial colostrum: In the absence of colostrum from the dam or from other newly calved cows, a mixture (though not a complete substitute) can be prepared as follows:- Whip an egg in 300 ml of warm water, add half a teaspoonful of castor oil, one teaspoon of cod liver oil (equal to 10,000 I. U. of vitamin A), 500 ml of warm whole milk, stir well and feed at body temperature. This is sufficient for one time feeding. The calf should be fed thus 3-4 times a day.

Calf starter: concentrate feed consisting of ground grains, oilcakes, animal protein supplements and brans, fortified with vitamins, minerals and antibiotics (23-26% CP and 72-75% TDN). After 15^{th} day of age small quantity of calf starter and good hay can be fed to calves along with milk.

	Ingredients	*Percentage*
1.	Finely ground maize	45
	Groundnut cake	35
	Fish meal	8
	Wheat bran	10
	Mineral mixture	2
2.	Groundnut cake	32
	Dried tapioca chips	15
	Ragi	10
	Wheat bran	25
	Fish meal	10

Molasses	6
Mineral mixture	2

To every 100 kg of the mixture add 0.5 kg of common salt and 25-30 g of Vitamin AB_2D_3 supplement

B.I.S standards for calf starter meal

Characteristics	Requirement
Moisture per cent by Wt. (max.)	10
Crude protein (Nx6.25) per cent by weight	23-26
Crude fat per cent by Wt. (min.)	4
Crude fibre per cent by weight (max.)	7.0
Total ash per cent by weight (max.)	5.0
Acid insoluble ash per cent by weight (max.)	2.5
Common salt (on dry basis) per cent by weight (max.)	1.0
Calcium on dry basis per cent by weight (min.)	1.2
Phosphorus (on dry basis) per cent by weight (min.)	0.8
Vitamin A IU/kg	10,000

Milk replacer: On dairy farms, where production cost are high and the product is sold as whole milk, many dairy men are turning to milk replacers as a means of lowering the cost of raising young stock. It is a constituted food mixture capable of replacing whole milk on DM basis when fed to young calves in gruel form, from 2 weeks of age. Usually milk replacer will be a dry feed mixture that is reconstituted with warm water and fed as a substitute of milk. The successful raising of calves on milk replacers depends very largely on how nutritionally complete the product is.

Objectives:

1. To raise orphan calves
2. To supplement dams milk
3. To wean calves at early age
4. To make raising of calves cheaper

Eg: for a milk replacer

Ingredients	Parts/100
Dried skim milk	48
Dried whey	20
Dextrose	7
Linseed meal	13
Oat flour	5
Coconut oil	3.5
Minerals	2
Antibiotics	1
Common salt	0.5

To every 100 kg of the mixture add 25-30 g of Vitamin AB_2D_3 supplement

Feeding Schedule up to 3 months

Age of calf	Milk	Calf starter	Hay
1-4 days	Colostrum- $1/10^{th}$ body wt in 3 feeds		
5-14 days	milk-$1/10^{th}$ body wt in 3 feeds		
15-21 days	Milk- $1/10^{th}$ body wt	A little	A little
22-42 days	Milk- $1/10^{th}$ body wt	100g	adlib
Up to 2 months	Milk- $1/15^{th}$ body wt	250g	adlib
2-3 months	Milk-$1/20^{th}$ body wt	500g	adlib

If green fodder is not offered to the dam, the calf should be given 10000 IU of Vitamin A within few hours after birth and may be reduced to 5000 IU/d for next 7 days and later to 1000 IU/d.

b) Feeding of calves from 4 months to 1 year

Age of calf	Concentrate mixture (16%DCP, 70% TDN)	Green fodder
4 months	0.75 kg	2-3 kg
5 months	1 kg	3-5 kg
6-9 months	1.5-2 kg	5-10 kg
9-15 months	2-2.1 kg	10-15 kg
15-20 months	2.1-2.25	15 kg
Above 20 months	2.25-2.5	15-20 kg

Cross bred calves grow at the rate of 0.5kg/d

c) Feeding of bull calves

Calves which are intended to be raised as future breeding bulls should be kept on liberal amount of milk for the first 6 months of their life (supplemented with calf starter and good quality hay from 2 weeks of age). They should be fed 2.5 kg concentrate mixture/day from 6-12 months of age and 3 kg concentrate mixture/day from 1-2 years of age.

Bull calves to be used for draft purposes should be castrated at 12-15 months of age and their feeding schedule should be identical to that of heifers.

Bull calves which are reared for meat production are generally fattened before slaughter. Such animals are given extra feed to supply 50% extra DCP and TDN to attain a body weight of 200 kg at 1 year of age to be marketed for slaughter.

Feeding of breeding bulls

Breeding bulls are to be fed good quality green fodder together with concentrates and to be exercised regularly to keep them in thrifty condition. Nutrient requirements for 500kg breeding bull is given below (Sen, Ray and Ranjhan 1978)

DCP (g)	TDN (kg)	ME (M cal)	Ca (g)	P (g)	Carotene (mg)	Vitamin A (IU)
450	4.5	16.2	20	15	53	21000

Feeding of working bullocks

During off-season when the animals are not working, they should be fed as per the maintenance requirement. However, while working, they should be fed with rations containing more energy. Green grass (e.g. 30 kg of green maize for 500 kg animal) and legume fodder (e.g. 10 kg of cow pea for 500 kg animal) alone can meet the requirement of a working animal. During very heavy work and when straw forms the basal roughage, a concentrate mixture (1-2 kg) should be incorporated in the ration.

Feeding of pregnant cows

Ideally, a dairy cow should calve every year, should have a lactation length of 305 days and a dry period of 60 days. During this last 60 days of pregnancy the cow should build up the body reserve lost in early lactation and will require nutrients to provide for the rapid growth of fetus and for the regeneration of mammary tissues. In the practice called steaming up, dry cows are offered extra quantity of concentrate during the last few weeks of pregnancy. During the last 60 days about 20-30 kg of live weight is increased. Normally during the last trimester of gestation 50% of DCP and 25% of TDN of the maintenance requirements are fed above the maintenance requirement by providing 1-1.5 kg of additional concentrate mixture.

Feeding of dry animals

Some times in farms, the animals may be dry and not pregnant due to one or other reason. Dry animals needs to be fed the maintenance ration. Maintenance requirement can be met by 30 kg of good quality green alone or 7-8 kg straw supplemented with 1 kg concentrate mixture.

Feeding of lactating cows

Feeding of cattle and buffaloes is based on their nutrient requirements. The nutrients required by the animal should be met by providing sufficient quantity of concentrate and roughage. As roughages paddy straw, green grass, legume fodders or silage can be used. By feeding good quality green grass alone in sufficient quantity the entire maintenance requirement of the animal can be met. Concentrate mixture, in such cases need to be provided to meet the extra requirement of the production. If good quality legume fodder is available in plenty, the DCP content of concentrate mixture can be reduced, since a major part of the protein requirement would be met from the fodder itself and in such cases the major nutrient to be provided from the concentrates becomes energy. On the basis of protein content, 1kg of concentrate mixture with about 15-16% DCP and 68-70% TDN can be replaced by either 20 kg of good quality green grass or 6-8 kg of legume fodder. On the basis of dry matter content, one kg of paddy straw can be replaced by 4-5 kg of green grass.

The feeding schedule for different classes of adult cows (approximate body weight 250 kg)

	Concentrate Mixture (kg)	**Roughage (kg)**
Dry cows (Maintenance)	1.2	25-30 kg grass or 5kg grass + 5-6 kg straw
Milking	1kg concentrate mixture for every 2.5 kg Milk produced, plus maintenance allowance	
Pregnant	1 kg concentrate mixture plus 1 kg energy supplement (rice gruel/ ground maize/ tapioca/ tamarind seed meal/jack fruit seed meal) from 6th month of pregnancy in addition to the maintenance and production allowance.	
Growth allowance	1kg concentrate mixture in first lactation and 0.5 kg in second lactation if they are below 4 years of age	

Note: For every additional 50 kg in body weight, an additional allowance of 500 g of concentrate mixture may be given. The quantities given above are only approximate. The exact quantity to be given for each cow should be decided by the condition of the animal at any time. High yielding cows in early lactation (up to 90 days) may be fed up to one kg of energy supplements in addition to the above ration for optimum production and reproduction. (It is also advisable to add 100 g buffer/day/animal [e.g. Soda bicarb/ MgO] to prevent acidosis when energy supplements are added). Rumen bypass fat can also be used to increase the energy density of the diet @ 100 – 150 g per animal per day.

B.I.S. specifications for compounded feeds for cattle (1992)

	Grade I	**Grade II**
1. Moisture % (maximum)	11	11
2. Crude protein (Nx6.25) %by weight (min)	22	20
3. Crude fat % by weigh t (min)	3	2.5
4. Crude fibre % by weight (max)	7	12
5. Acid insoluble ash % by weight (max)	3	4
6. Common salt, % by weight (max)	2	2

7. Calcium, % by weight (Min)	0.5	0.5
8. Phosphorus, % by weight (Min)	0.5	0.5
9. Vitamin A (I.U. / kg)	5000	5000

Items 2, 3, 4, 5, 6, 7, 8 and 9 on dry matter basis.

Example of a concentrate mixture

Dried tapioca meal	28 parts
Groundnut cake	22 parts
Gingelly cake	10 parts
Rice bran	27 parts
Cotton seed	10 parts
Min. mixture	2 parts
Common salt	1 parts

B.I.S specification for mineral mixtures for cattle

	Type I *(With salt)*	**Type II** *(Without salt)*
Moisture % by Wt (max.)	5	5
Calcium % by wt (min.)	18	23
Phosphorous % by wt (min)	9	12
Salt (chlorine as sod. Chloride) % by wt (minimum)	22	-
Iron % by wt (min)	0.40	0.50
Iodine (as KI) % by wt. (min)	0.02	0.026
Copper % by wt.(min)	0.06	0.077
Manganese %by wt (min)	0.10	0.12
Cobalt % by wt. (min)	0.01	0.013
Fluorine % by wt. (max)	0.05	0.07
Zinc %by wt(min)	0.30	0.38
Sulphur Max	0.40	0.50
Acid insoluble ash % by wt (max)	3.0	2.5

Nutrient requirements for cattle and buffaloes (ICAR, 1998)

The requirements are expressed in terms of DM, DCP, TDN, ME, Ca, P, Carotene and Vitamin A.

Maintenance requirement

Body wt (kg)	**DM (Kg)**	**DCP (g)**	**TDN (kg)**	**ME (Mcal)**
200	3.5	150	1.7	6.0
250	4.0	170	2.0	7.2
300	4.5	200	2.4	8.4
350	5	230	2.7	9.4
400	5.5	250	3.0	10.8
450	6.0	280	3.4	12.4
500	6.5	300	3.7	13.2

550	7.0	330	4.0	14.4
600	7.5	350	4.2	15.5

Feeding of protected proteins/ by pass protein

Bypass protein means rumen undegradable protein (UDP). In normal ruminant diet 60% of the dietary protein is degraded in the rumen and rest 40% is UDP. By protecting the good quality dietary protein from ruminal degradation it is possible to provide greater amounts of essential amino acids to the host ruminant. Methionine and lysine are generally considered as the limiting amino acids for milk production. Feeding of bypass protein sources that supply these limiting amino acids post ruminally will result in increased milk production in ruminants. The benefit of feeding bypass protein is more pronounced in high producing animals. Methods employed for protein protection are heat treatment, treatment of proteins with tannins and treatment with formaldehyde. Protected amino acids are also used now a days as feed additives. Encapsulation procedures to protect amino acids from ruminal degradation includes coating or mixing the most limiting essential amino acids like methionine and lysine with a combination of fats or fatty acids and sometimes by addition of carbonates, kaolin, lecithin or glucose.

Feeding of protected fat/ bypass fat/ rumen inert fats

In dairy cows the intake of DM will reaches its maximum only by 8-10 weeks after calving while the milk production reaches its peak by 4-6 weeks postpartum. Therefore, the intake of energy may not keep up with the demand during the period of peak production. Hence high producing dairy cows are often in a state of negative energy balance in the first few weeks of lactation. The diminished ingestion capacity of dairy cows during the first three months of lactation makes it obvious to increase the energy density of diet by adding fat to the ration. However, excess fat in ruminant ration depresses the rumen microbial activity and thus reduces the digestibility of all the nutrients. Therefore, rumen protected fats have been developed for feeding high yielding dairy cows during early lactation. Protecting dietary fats from ruminal degradation can be achieved by:

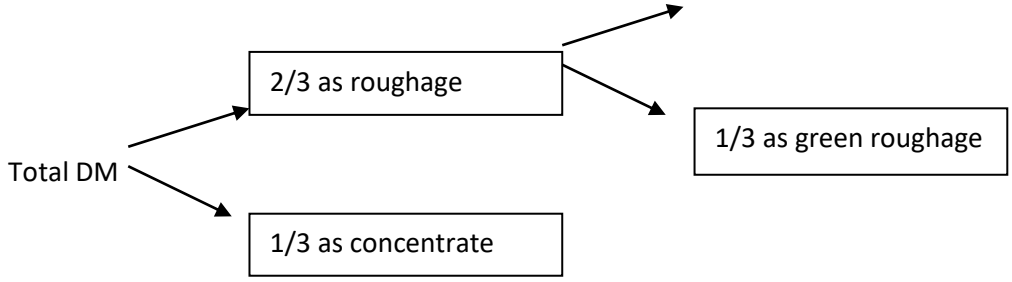
a) Feeding of fat products containing saturated or hydrogenated fatty acids (saturated fatty acids have high melting point of above 50^0C and hence they remain intact at the rumen temperature of 39^0C). But the disadvantage is that they are less digestible even in the small intestine.
b) Fatty acid calcium salts: calcium salts of fatty acids remain intact in the slightly acidic pH of the rumen (5.5 to 6.5) but dissociate in an acid environment of abomasum (pH 2-3). The free fatty acids liberated in the abomasum are absorbed in the intestine.
c) Encapsulation of fat by formaldehyde treated proteins.

<u>Feeding of cattle and buffaloes by thumb rule method</u>

Cattle consume 2-2.5kg of DM for every 100 kg body wt.

Crossbred cattle/buffaloes consume 2.5-3kg of DM for every 100 kg body wt

2/3 as dry roughage



If the green fodder is a legume, the proportion of green fodder may be reduced to 1/4DM of the total roughage component and remaining 3/4 as dry roughage

Extra allowance during pregnancy: during the last trimester of pregnancy an allowance of 1-1.25 kg and 1.5-1.75 kg of concentrate is recommended for cattle and buffalo/ cross bred cattle respectively. During the last week of gestation, the amount of concentrate mixture should be reduced and a little bran is fed to keep the animal in laxative condition before calving. After parturition the cow/buffalo should be given fresh warm water and a mash consisting of 1kg wheat bran, 1-1.5 kg ground/cooked grain, 0.5kg jaggery and 25g each of common salt and mineral mixture. Feeding of this mash is continued for 3-4 days and the regular feed is introduced gradually.

Extra allowance for milk production: additional amount of 1 kg concentrate mixture is required for every 2.5 kg milk produced by dairy cow and an additional amount of 1 kg concentrate mixture is required for every 2 kg milk produced by buffalo (cow milk is assumed to have 4% fat and buffalo milk 6% fat). If the lactating animal is in first and second lactation, extra allowance needed to take care of growth has to be added.

Azolla as livestock feed

Azolla pinnata is a free floating aquatic fern. The plant had nitrogen fixing blue green algae (*Anabaena*) as symbiont in the leaf cavities which use their own photosynthetic energy to reduce atmospheric nitrogen and convert it to plant nitrogen. Therefore, like a legume it is good source of protein for animals.

Nutritive value: Azolla has high protein (28% on DM basis) and mineral content. In addition it has high digestibility of 68% which compares well with that of concentrates. It can be fed either fresh or dried and can be stored after drying.

Yeild: Azolla grows and multiplies well in artificial ponds and can be harvested once daily after 10-15 days of initial growth. A small area of 9'' X 6'' would yield about 500-600g (fresh basis) at each harvest. Yield of azolla is approximately 730 metric tons/hectare/year at the rate of 200 g/sqm/day.

NUTRIENT REQUIREMENTS AND FEEDING OF GOAT AND SHEEP

Salient features

- Goat (*Capra hircus*) is believed to have descended from the Pasang (*Capra aegagrus*).
- India has 20% of the world's goat population.

- India has 20 breeds of goats.
- Goats are most efficient domestic animal in the use of water (approaching the camel in the low rate of water turnover per unit of body weight).
- Feeding habit of goat is termed browsing. They stand on their hind limbs and pluck the tender leafy twigs of herbs, shrubs and small trees.
- Goat has a wider range of feed acceptability and fibre digestibility compared to cattle and buffaloes.
- For its size, goat is capable of consuming more feed than a cow does (**the DM consumption is 3-7% of body weight i.e. it is 3-4% for meat goats and 5-7% for lactating goats**).
- When expressed in percentage of body weight, the DM intake of small breeds of goats is greater than larger breeds.
- DM intake of goats rises just after parturition and reaches maximum between 6 and 10 weeks of lactation and then decreases.
- Goats due to their liking for herbs, shrubs and tree leaves (top feeds), can also be reared in those parts of the country where fodder cannot be grown sufficiently.
- Goat produces more milk than a cow or buffalo from the same quantity of nutrients. The nutrient conversion efficiency for milk production of a dairy cow is on an average 38%, where as for goat it ranges between 45-71%.
- Goats are known for their round the clock eating habit.
- Central Institute for Research on Goats (CIRG) is located at Mathura, U.P.
- Nutrient requirements for goat is published by NRC in 1981 and ICAR in 1985 (Revised in 1998).
- Goats have very prehensile tongue and movable upper lip and they are called mobile pruning machine/poor mans cow.
- Goats are less sensitive than other ruminants to the toxic effects of tannic acid
- Goats are more sensitive than other ruminants to the toxic effects of cyanogenic glycosides.
- In general goats refuse to eat soiled feed.
- Goats can distinguish between bitter, sweet, salty and sour tastes and they have high tolerance for bitter tastes than cattle.
- Goat meat is termed 'chevon'.
- When compared to sheep:- a) Goats are more capable of using cell wall rich and nitrogen poor forages. b) Goats retain the feed for longer time in the digestive tract, have a higher concentration of cellulolytic bacteria in the rumen and are more efficient in recycling of blood urea (greater rumen ammonia concentration).
- Goats show preference for leaves when the whole plant is put before them.

Nutrient requirements and feeding of goats

Principle of computation of ration for goats is similar to that of cattle. Dry matter consumption is widely variable. Varies from 3-7% of body weight. Goats can consume more feed per unit body weight than either cow or sheep. Practical rations should be based on cheap feeds such as browse. Nutrient requirements for goat were published by NRC in 1981 and ICAR in 1985 (revised in 1998). On an average the ME requirement for maintenance is 119 kcal/kg $W^{0.75}$, TDN requirement for maintenance is 30g/kg $W^{0.75}$ and the DCP requirement for maintenance is 3g/kg $W^{0.75}$. Nitrogen to sulphur ratio of diet should be generally 10:1.

Nutrient requirements for maintenance of goats (ICAR, 1998)

Live weight (kg)	DM (g)	DCP (g)	TDN (g)	Ca (g)	P (g)
15	500	23	240	1.1	0.7
20	615	29	295	1.3	0.9
25	730	34	350	1.6	1.1
30	830	39	400	1.8	1.2
40	1040	48	500	2.3	1.5
50	1230	57	590	2.7	1.8
60	1410	66	675	3.1	2.1

Feeding of kids

Upto 3 months of age, milk feeding is done. Milk is fed at the rate-1/6th of the body weight for the 1st month, 1/8th during the second month and 1/10th-15th during the 3rd month. Kid starter and good quality fodder can be offered from the 2nd week onwards.

i) The feeding schedule for kids of different age is given below

Age of kid	Body weight (kg)	Milk (g)	Kid starter (g)	Green fodder (g)
`Birth to 4 days	1.5 – 2.0	Colostrum	-	-
5 – 30 days	2.0 - 3.0	300 – 500	Small quantity	Small quantity
30 – 60 days	3.0 - 5.0	400 - 600	50 – 100	Small quantity
60 – 90 days	5.0 – 7.5	500 – 750	100 - 200	250 – 500
Age of kid	**Body weight (kg)**	**Milk (g)**	**Concentrate mixture(g)**	**Green fodder (g)**
90 - 120 days	7.5 – 10.0	-	200 – 250	500 – 750
5th and 6th month	10.0 – 15.0	-	250 – 300	750 - 1000

Examples of a kid starter is given below:

Ingredients	*Parts*
Deoiled groundnut cake	12
Horse gram	30
Wheat/Maize/Jowar	30
Rice polish/Wheat bran	15
Dried unsalted fish	10
Mineral mixture	2
Common salt	1
Vitamin AB_2D_3	25 g/100 kg of the mixture

Feeding schedule for different categories of goats

Category of goat	Body weight (kg)	Quantity to be fed per day

		Concentrate (g)	Green fodder (kg)
Growing (6-12 months)	15-20	300-400	1-2
Adult goats	25-30	200-300	2-3
Breeding bucks	30-40	400-500	3-5

Reproduction

For meeting the demands of the growing foetus in advanced pregnancy and spermatogenesis in breeding males, an extra allowance of 55g DCP, 400g TDN, 2g calcium and 1.4g phosphorus should be provided over and above maintenance requirement. During the non-breeding period, the buck doesn't require additional concentrate mixture and can be maintained only on good quality grass legume mixture. During the last 6 weeks of gestation there should be liberal feeding of good quality fodder and 400-500 g of concentrate mixture. Few days before the expected date of kidding, reduce the quantum of concentrate feed to one half and add bran to provide more bulk. After kidding, feed a bran mash for a few days, gradually bringing the doe to the full feed for milk production.

Milk production

For each litre of 4%FCM produced, the dairy goat should be provided with 45g DCP and 345g TDN. The requirement of nutrients for milk production at various levels of fat has not been worked out as sufficient data on this aspect are not available. To supplement the extra nutrients for lactation a good quality concentrate mixture should be provided at the rate of 350 g for each litre of milk produced over and above the maintenance requirement.

The feed ingredients used for feeding of cattle can be used for feeding goats also. As concentrate feeds, it is preferable to add grams. Compounded cattle feeds of good quality available in the market are also useful for feeding of goats. As roughage, mostly tree leaves are used. Green grass, legume fodders, agricultural byproducts, silage etc. can also be used as roughage.

Finisher ration

Since goats are slaughtered mostly for lean meat, the ration should be planned to include 30-40% of the DM from roughage source and the balance amount from concentrate (12-14% DCP and 60-65% TDN). In general slaughtering age for goats is 10-12 months.

NUTRIENT REQUIREMENTS AND FEEDING OF SHEEP

Salient features

- Sheep (*Ovis aries*) originated from the wild ancestor Visnei (*Ovis orientale*).
- Dry matter consumption is 2-3% of body weight.
- India has 4% of the world's sheep population.
- India has 44 descript breeds of sheep.
- Young tender grasses and common leguminous green fodder are more relished by sheep.
- Sheep with their small muzzle and split upper lips, can nibble tiny blades of vegetation which cannot be eaten by bigger animals.
- Sheep depend more on natural pastures for their nutrient requirements and require less concentrates. More than any other class of farm livestock sheep is dependent on natural pastures for maintenance and production.
- Ration computation of sheep is similar to that of goats
- Feeding of lambs is similar to that of kids
- Creep feed:- composition similar to that of kid starter

- Nutrient requirements for sheep was published by NRC in 1985.
- A minimum of 3% fat in sheep ration is essential.
- Sheep are superior to goats in their growth rate as young animals.
- Methionine appears to be the first amino acid to be limited in microbial protein for both wool growth and body gain.
- Sulphur should be present in the diet of ewes at a ratio of 10 parts Nitrogen to 1 part Sulphur.

Nutrient requirements for maintenance (Ranjhan, 1998)

Live wt (kg)	DM (g)	DCP (g)	TDN (g)	Ca (g)	P(g)
20	575	28	258	1.1	0.8
25	678	33	305	1.3	0.9
30	775	38	350	1.5	1.0
35	873	43	393	1.7	1.2
40	964	48	434	1.9	1.3
45	1055	53	475	2.3	1.5
50	1140	56	513	2.3	1.5
55	1225	60	551	2.4	1.6
60	1310	65	588	2.6	1.7

Maintenance requirement for sheep

1) DCP:- 2.73 g/kg $W^{0.75}$
2) TDN:- 27.3 g/kg $W^{0.75}$
3) ME:- 98 kcal/kg $W^{0.75}$
4) Water: intake of water is influenced by atmospheric temperature and humidity, stage of growth, gestation, lactation and other stresses. An adult sheep require about 2 litres of water a day during winter and 3.5 to 4 litres during summer.

Feeding of pre-weaned lambs

Immediately after birth, the lamb should be assisted to suckle in order to get the advantages of colostrum. During early stages, the growth rate of lambs is greater when compared to kids. Up to three months of age, major nutritional requirements are met by the mother's milk. From the age of two weeks creep feed can be given. The amount of creep feed consumed is dependent upon the dam's milk production. An example of a creep feed mixture is given below:

Ingredients	*Parts*
Maize	40
Oats	30
Dried unsalted fish	10
Barley	17
Mineral mixture	2
Common salt	1

Vitamin AB_2D_3 25 g/100 kg of the mixture & Antibiotics (as per dosage) should be incorporated in the creep feed mixture. With good feeding and management practices lambs can be weaned at

three months of age. The body weight at weaning is 12-16 kg (14 kg avg bwt) depending upon the breed.

Reproduction

Flushing is practiced in ewes 2-3 weeks prior to the onset of breeding season. Ewe in last 6 weeks of gestation needs more energy, protein, minerals and vitamins to meet the increased requirement. Excessive energy intake may lead to obesity which results in birth difficulties in ewes. Low energy intakes can result in low birth weights of lambs and perhaps *pregnancy toxemia* in ewes. As the pregnant ewe cannot consume sufficient bulky roughages as the space in abdomen is reduced due to growth of fetus and its membranes it has to be fed with good quality forage. During the last 6 weeks of gestation, in addition to grazing, 250-400g of good quality concentrate mixture is generally fed. A body weight gain of about 100 g/day (for smaller breeds) to 150 g/day (for larger breeds) is a fair measure of nutrient intake status during the last few weeks of pregnancy.

Generally rams are maintained on the same feeding system as ewes. During breeding season they require supplementary feeding for a month before and as well as during the whole breeding season. At this time an average ram should be offered 250- 500 g of concentrate mixture depending upon the breed and body condition.

Lactation

For a lactating ewe during the first 3 days after lambing there is only a need of a little grain and bran mixture as concentrate feed with enough quantity of good quality forage. Concentrate mixtue should be gradually increased in amount with liberal feeding of roughage. During the peak lactation, the DM intake may even go up to 4% of body weight. At this stage the shepherd should be cautious to increase the supplemented concentrate feed upto 250-500g along with legume hays (1-2 kg). Where good pastures are not available all care must be made to provide extra protein and minerals particularly of copper, sulphur, zinc and cobalt other than common salt. Feeding of supplemental concentrate can be gradually diminished after 12 to 13 weeks of lambing as the lambs are weaned from the mother. Until the next breeding season the ewes may be maintained on grazing alone.

Feeding schedule for different categories of sheep under farm conditions

Body weight (kg)	Quantity to be fed per day	
	Concentrate (g)	Oat hay (g/d)*
12-15	200	400
16-25	250	600
26-35	300	700
Breeding ram	450	800
Pregnant ewe	400	800
Lactating ewe	500	800

*6-8 hr grazing in pasture land is sufficient to meet the requirement of roughage

Diet related diseases

1. *Pregnancy disease or pregnancy toxemia or ovine ketosis or twin lamb disease*
2. *Stiff lamb disease or white muscle disease*: It is a strange disease of young suckling lambs, which usually becomes apparent when the lambs are 1-5 weeks old. The affected lambs become characteristically stiff that they are unable to walk or to nurse without assistance.

The disease occurs due to dietary deficiency of vitamin E. The disease can be prevented by incorporation of wheat germ meal (rich source of vitamin E) in the concentrate mixture of pregnant ewes and the creep feed of lambs.

3. *Polioencephalomalacia or Cerebrocortical necrosis* : Occurs in sheep and goats. Acute thiamine deficiency is the cause of this disease. Even when the intake/ rumen microbial synthesis of thiamine is adequate, abnormally high concentrations of thiaminase enzyme from unusual plants or microflora destroy the vitamin before the absorption, leading to a deficiency condition. Sick animals are excitable, incoordinated and have impaired vision. In sheep the incidence is highest in feed lot lambs 5-8 months of age. Treatment consist of iv/ im administration of thiamine.
4. *Urinary calculi*: Affected animals excrete alkaline urine with high phosphorus content. The incidence can be greatly reduced by preventing an excessive intake of phosphorus and by maintaining a proper Ca: P ratio of 2:1. Reducing the alkalinity of urine by feeding ammonium chloride at 0.5% of complete diet is also effective. In grazing sheep, the disease is associated with consumption of forages having high silica content. Sodium chloride supplementation at 4% of the total diet helps to prevent urinary calculi in them.
5. *Overeating disease or Enterotoxemia or Pulpy kidney disease*: This usually occurs in lambs which have been on full feed for some time and which are being provided with a heavy allowance of grain. The animals affected are almost always the largest, fattest, most vigorous and greediest in the lot. More commonly, the lambs live a few hours, showing typical nervous symptoms, such as the head being thrown back or the lamb running in circle or pushing against a fence. Sometimes the disease causes sudden death, the lamb throwing back its head, staggering, falling to the ground and dying in convulsions. One opinion regarding the cause of this disease is attributed to the production of type D toxin in the gut by the anaerobic bacteria *Clostridium perfringens.* Indigestion produced by eating too much concentrates causes inflammation of the walls of the intestines, which then becomes permeable to poisonous products/ toxins formed in the gut. To reduce the occurrence of this disease the following precautions must be taken
    1. The grain/concentrate mixture should be distributed in the troughs so that no lamb can get more than its share.
    2. While feeding, mix the grain with some bulky feed like ground hay.

Write Short notes on

1. Pregnancy disease or Pregnancy toxemia or Ovine ketosis or Twin lamb disease
2. Flushing

AGROINDUSTRIAL BY PRODUCTS, AGRICULTURAL WASTES AND OTHER UNCONVENTIONAL FEEDS

Feed ingredient which is not generally used in the conventional system of animal feeding is termed as unconventional feed or non conventional feed. The term unconventional feed is a relative term and may differ from region to region. The use of non conventional feed resources (NCFR) has become essential in animal feeding in our country due to the limited

availability of conventional feed ingredients. The use of NCFR will decrease the competition for food grains between livestock and human beings and will decrease the feeding cost. However, the constraints in the utilization of unconventional feeds include:

a) Presence of anti-nutritional factors.

b) Availability of such feeds is restricted to particular season.

c) Difficulties involved in the processing and detoxification of such feeds.

I. Agricultural crop residues

a) Straws: straws consist of stems and leaves of plants after the removal of the ripe seeds by threshing. Cereal straws are conventional feeds for livestock in India. However, in the temperate countries straw is considered as unconventional feed and the conventional feeds includes cereals, milling byproducts, oil cakes, green fodder, legumes and hays.

b) Stovers: stover is the leaves and stalks of maize, sorghum or soybean plants that are left in a field after harvest. It can be directly grazed by cattle or dried for use as dried roughage.

c) Husk (hulls): these are the outer covering of cereal grain, pulses and some oil seeds. They are available in bulk in the milling industry like rice milling and solvent extraction plants for ground nut oil and corn oil in the form of rice hulls, ground nut husks, maize husks etc.

II. Byproducts from sugar industry

a) Sugarcane tops: in most of the commercial plantations, sugar cane tops are burnt in the field at the time of harvesting the canes. However, in Asian countries the farmers feed their animals with the cane tops either fresh or dried as a roughage source to meet the energy requirement for maintenance.

b) Bagasse: It is the fibrous residue of sugar cane stalks after the juice has been pressed out in sugar factories and is mostly utilized by factories as fuel. Dried bagasse consists of fibre and pith and is used in rations of ruminants. It is a good source of cellulose but poor in protein content and has large amounts of lignin.

c) Molasses: the word molasses comes from the Portuguese word melaço, which has its origin from mel, the Latin word for "honey". In sugar industry the juice obtained by crushing of sugar cane is boiled to concentrate it, which promotes the crystallization of the sugar and the rest forms the molasses. In animal feeding, molasses is mostly used as a binder for commercially pelleted feeds. It can also be used as a carrier for urea impregnation of poor quality roughages. Cane molasses contains 3% CP, 0% DCP and 10% ash comprising excellent source of minerals except phosphorus. The term molasses brix is used in referring to the amount of sugar content of molasses. Brix is determined by measuring the specific gravity of molasses, the value is then applied to a conversion table from which the level of sucrose (or degrees Brix) can be determined.

d) Pressmud: it is a byproduct of sugar industry during the process of precipitation of impurities.

III. Minor oil seeds and cakes

a) Sal seed meal: sal seed is obtained from sal tree. The sal seed oil is used locally for cooking and lighting and is said to be employed for adulterating ghee. It is suitable for soap making and is used as a substitute for coco butter in the manufacture of chocolates. Sal seed meal has very high tannin content and contains about 7% CP and 45% TDN. Sal seed meal does not have DCP and hence it is used as energy source and not protein source. Treatment with alkali is found to be effective in removing tannins from the meal. It can be incorporated in poultry rations to a level of 5-10%.

b) Mahua cake: it contains 14% CP and 2% mowrine (a saponin) which is an antinutritional factor. It can be substituted for wheat bran in concentrate mixture for livestock after water treatment.

c) Neem cake: neem cake is obtained after the removal of neem oil (used in soap industry) from neem seed. Neem cake is also used as a fertilizer. It contains 8.45% DCP and 57.8% TDN. It is bitter due to nimbidin and nimbadiol and hence is not palatable when given exclusively. It can be incorporated up to 10% in concentrate mixtures for cattle.

d) Castor bean meal: it is rich in protein (30-40% CP). Ricin is the major toxic factor and it acts by the inhibition of protein synthesis. Ricinus communis agglutinin (RCA) is yet another toxin present in castor bean. Ricin is a potent cytotoxin but a weak haemagglutinin, whereas RCA is a weak cytotoxin and a powerful haemagglutinin.

e) Karanj cake: *Pongamia pinnata* or karanj is a medium sized tree. The cake left after oil extraction from seeds can be detoxified to be used in animal feeds. The major toxic principle is karanjine a furanoflavanoid.

f) Rubber seed cake: it contains 18.6% DCP and 54% TDN. Cyanogenic glycosides identical to that present in cassava is present in rubber seed kernels. Rubber seed cake can be incorporated upto 20% in the concentrate mixture for cattle.

IV. Fruit and vegetable factory byproducts

a) Mango seed kernel: mango peels and kernels are byproducts of the canning industry. Mango seed kernel has a DCP of 6.1% and TDN of 50%.

b) Pineapple wastes: it contains 80-95% moisture and 5% CP.

c) Banana peels

d) Citrus peels

e) Dried cocoa pod husk: it contains 6% CP and can be incorporated up to 15% in ruminant diets

f) Tomato processing wastes

g) Potato processing wastes

V. Forest residues

a) Woods and barks: woods are undigestible and unpalatable. The bark is partially digestible.

b) Fallen leaves/ forest foliage: fallen leaves from the forest can be commercially exploited for livestock and poultry feeding as source of carotene, trace minerals and vitamins. The term *Muka* is generally used to describe the animal feed produced from tree foliage.

c) Saw dust: it is not palatable and is practically indigestible. Digestibility of saw dust can be increased by breaking the ester bond between lignin and cellulose in them. Acid treatment, alkali treatment, biochemical methods (using white rot fungi) and high energy electron irradiation has been found successful in breaking this ester bond. However, none of these has been found to be economically viable and technically feasible under commercial conditions.

d) Pulp mill and paper mill residues: primary sludge collected at pulp mills and paper mills has high content of cellulosic fibres (acid detergent fibre) and hence they can be incorporated in ruminant ration. However, these may contain toxic chemicals which need to be removed prior to feeding them to livestock.

e) Fodder tree leaves: most of the tree leaves generally contain 30-45% DM and 9-25% CP. The crude fibre in tree leaves is complex and highly lignified in the mature stage. The calcium content of tree leaves is 2 to 3 times higher than that of cultivated fodders. However, phosphorus content is low, resulting in a wide calcium-phosphorus ratio. Commonly used fodder tree leaves are discussed below

   i) Bamboo leaves: tender leaves are relished by livestock. The leaves contain about 9.4% DCP.

   ii) Banyan (Ficus): Pipal or *Ficus religiosa* leaves are relished by sheep and goats. Leaves form a maintenance ration for goats when fed alone. The leaves contain 5.5% DCP and 39.2% TDN. However, cattle and buffaloes do not relish these leaves.

   iii) Banana leaves: after the harvest the banana leaves are available for feeding ruminants. Cattle and buffalo relish the leaves. The leaves contain 16-17% CP on DM basis.

   iv) Babul/ Acacia: acacia leaves are lopped for feeding of small ruminants while camels browse on them. Acacia pods are very good source of protein (30-55) and are relished by sheep and goats.

   v) Guava: small ruminants relish the leaves which contain about 10% CP

   vi) Glyricidia: it is a deep rooted legume. It is mostly grown as a live fence and is used as a support plant for black pepper. The leaves contain 25-30% CP and can be harvested at every 3-4 months interval. It is a good fodder for sheep, goats, buffaloes and cattle.

vii) Subabul/ Ipil-ipil/ *Leucaena leucocephala*: it is a perennial shrub. The leaves contain 21-25% CP. The fodder is suitable for ruminants but is toxic to pigs and horses because of mimosine, a toxic amino acid.

viii) Imli/ *Tamarindus indica*: the leaves of tamarind tree are rich in protein (14% CP) and are relished by small ruminants.

Ix) Jack: the leaves are palatable to sheep and goats. The leaves contain 13-14% CP.

x) Tapioca: leaves are rich in protein (8.3% DCP on DM basis). It contains cyanogenic glycosides and hence may cause adverse effects in ruminants if fed above the rate of 0.8% of body weight.

xi) Rain tree pod: the pods are quite palatable due to sweet taste. It contains about 8-9% DCP and 64% TDN.

VI. Animal wastes

a) Meat meal: it is prepared by rapid drying and sterilizing the meat of fallen animals in wet rendering plants. It contains 60-70% CP and is a good source of essential amino acids and B complex vitamins. It is incorporated at 8-10% level in rations for swine and poultry. Some meat plants prepare meat cum bone meal which is also a rich source of calcium and phosphorus.

b) Bone meal: it is obtained as a powder by grinding crushed bones and then pressing them through a 1-mm mesh. Steamed and sterilized bone meal is an important source of calcium and phosphorus in livestock and poultry rations.

c) Blood meal: it is a slaughter house byproduct and contains about 80% CP on DM basis. Unlike other animal protein sources it has a poor amino acid balance with lysine and leucine being relatively high and isoleucine being very low.

d) Tankage: it is an ideal protein supplement for swine and it includes the offal's of slaughtered animals.

e) Feather meal: feathers are processed at a temperature of 130-145^{0}C and dried to about 60^{0}C and ground. It is high in protein content (80%) however deficient in several essential amino acids and hence incorporated below 5% in poultry ration.

f) Hatchery by-product meal: made by drying and grinding of hatchery refuse consisting of infertile eggs, dead embryos and shells of hatched eggs.

g) Poultry excreta: it is a rich source of nitrogen. The NPN fraction of poultry excreta consist chiefly of uric acid which can be utilized by ruminants for rumen microbial protein synthesis. On an average poultry litters contains 31% CP.

VII. Wastes from aquatic foods

It includes fish wastes, frog meal and prawn wastes

VIII. Aquatic plants

It includes algae, African payal, lotus, water spinach, water hyacinth etc.

IX. Miscellaneous byproducts

a) Acacia pods

b) Brewery waste: it is mostly the brewer's grain left after the extraction of malt required for the production of beer. It is used in feeding ruminants. It has 20-23% DM and about 19% CP.

c) Coffee husk: it contains 3.2% DCP and 42% TDN.

d) Tapioca starch waste: it is available from the processing plants after the extraction of starch. It contains about 64% TDN on DM basis.

e) Tamarind seed powder: it contains 13% DCP and 64% TDN. It contains tannin, but overnight soaking in cold water reduces the tannin content.

X. Single-cell protein (SCP): SCP is obtained from single cell organisms such as yeast, bacteria and algae that have been grown on specially prepared growth media. Yeast propagated specifically for animal feed is usually *Torulopsis utilis* (fodder yeast). Unicellular algae such as *Chlorella vulgaris, Spirulina maxima and Scendesmus obliquus* are used in producing SCP. Among various types of bacteria *Methanomonas methanica* has been more thoroughly investigated for SCP production.

Certain unconventional feeds and their recommended levels of inclusion in livestock rations

Sl. No.	Name of feed	Percentage level of inclusion		
		Cattle/goat	Pig	Poultry
1.	Tapioca leaf meal	30	5	5
2.	Tapioca starch waste	25	15	-
3.	Silk cotton seed cake	20	-	-
4.	Rubber seed cake	30	10	-
5.	Coffee husk	20	-	-
6.	Tea waste	25	10	-
7.	Spent annatto seeds	10	-	-
8.	Cocoa pod	20	-	-
9.	Shrimp shell powder	-	5	5
10.	Fish silage	-	10	10
11.	Beer waste	- 25% on Dry matter basis in cattle ration		

FEEDING OF UREA TO RUMINANTS

Non protein nitrogen (NPN) feedstuffs: Feeds which contain nitrogen in a form other than protein or peptides are termed as NPN feeds. NPN compounds include ammonia, amides, amines, amino acids, urea, biuret and ammonium salts such as monoammonium and diammonium phosphate.

Urea: urea is an organic compound with the chemical formula $(NH_2)_2CO$. The molecule has two amine ($-NH_2$) groups joined by a carbonyl (C=O) functional group. Urea dominates as a source of NPN for animals with a functional rumen. Microbes in the rumen degrade the dietary urea into ammonia which is used for the synthesis of microbial protein. For the efficient utilization of the ammonia thus liberated, a readily available source of energy is a must because the carbon skeleton for the synthesis of microbial protein from ammonia is provided by soluble carbohydrates in the diet. Starch is the most satisfactory source, being fermented at a moderate rate. Molasses is of moderate value as it is fermented too rapidly, while cellulose is least valuable as it is fermented very slowly. A level of 1 kg of starch per 100 gram urea is often suggested as a guideline. Urea having an average of 46% nitrogen has a crude protein equivalent of 287.5% (46 X 6.25). Therefore, urea can be used as a source of nitrogen when high energy concentrates with a crude protein level below 12-13% is fed. Mineral content of the feed affects the utilization of urea because some of the minerals are also involved in the production of microbial protein. For example, sulphur in the form of sulphate must be provided as it is needed in the synthesis of sulphur containing amino acids. Urea should be introduced slowly in ruminant diets since the animals require an initial adaptation period. Methods of urea feeding includes

1. *Mixed with concentrates*: Urea can be incorporated upto a level of 3% in concentrate mixtures for dairy cattle. However, the level should not exceed 1% of the total DM in the ration. BIS recommends a level of 1% urea in the concentrate mixtures for cattle and buffalo. While mixing urea to concentrates, care should be taken for uniform distribution otherwise there is a chance of occurrence of toxicity. Urea should never be mixed with raw soybean as it contains urease enzyme which causes degradation of urea liberating ammonia and carbon dioxide.
2. *Urea Molasses Liquid Diet (UMLD)*: it is a homogenous mixture of urea in the liquid molasses along with minerals, vitamins and common salt (Urea-2.5 parts, Molasses-92 parts, Water-2.5 parts, Mineral mixture-2 parts, Salt-1 part and Vitablend AD_3 is added at the rate of 25gm per 100 kg of UMLD). UMLD should be introduced gradually and it can substitute the concentrate mixture to a certain extent.
3. Urea Molasses Mineral Block (UMMB): a simple method of supplying protein precursors to ruminants on pasture is through the use of urea in salt licks or blocks. Solidified blocks containing molasses, urea, minerals and small amount of oil cakes are placed in front of the animals in the manger so that they can lick as and when necessary. National Dairy Development Board (NDDB), Anand has developed UMMB which contain molasses-45%, urea-15%, mineral mixture-15%, salt-8%, calcite powder-4%, bentonite-3% and cotton seed meal-10%.

4. *Urea mixed with silage*: urea can be added at the rate of 0.5% on fresh basis in silage prepared using plants rich in soluble carbohydrates. This will increase the CP content of silage by about 5%.

5. *Urea ammoniation of dry roughages*: most cereal crop residues has 8-12% lignin and 60-70% cellulose and hemicellulose. Lignin is found interspersed with hemicellulose in the cell wall fraction forming a matrix around the cellulose microfibrils. Due to this arrangement lignin limits the action of microbial cellulases and hemicellulases resulting in low digestibility of these polysaccharides. Urea ammoniation is the most convenient and most successful method of straw treatment for breaking the ester bond of lignin with other fibre constituents. Weighed quantity of chaffed straw is spread on a thick polythene sheet in a layer of 40-50 cm (thickness). Fertilizer grade urea at the rate of 4% (it is better to use 2-3% in hot and humid climate) of dry fodder is used (4 kg urea is dissolved in 100 litres of water for each 100 kg straw). The urea solution is sprayed over the straw, mixed uniformly and then stacked airtight by covering with another polythene sheet and left for 3-4 weeks for reaction. The stack is opened from one side; required quantity for feeding the animals is spread for overnight aeration and then offered to the animals. During urea treatment, ammonia released from urea acts on alkali labile ester bonds of lignin with cellulose and hemicellulose, making cellulose and hemicellulose available. Urea ammoniation of straw improves the digestibility of fibre, improves the crude protein content (CP increases from around 3% to 6-8%) and improves the voluntary feed intake.

Urea toxicity: reasons for toxicity includes poor mixing of urea in feed, accidental ingestion of urea, inadequate adaptation period, low availability of drinking water and very low level of carbohydrate in the ration. In such cases, the liberated ammonia is absorbed at a high rate. When the level of absorbed ammonia in the blood exceeds the capacity of the liver to convert it into urea, the animal develops nervous signs. Symptoms of toxicity include tetany, ataxia, convulsions, bloat, excessive salivation, respiratory difficulty and bellowing. In cattle, clinical signs are visible when rumen ingesta levels of ammonia are 100 mg/dL, serum levels of ammonia nitrogen are 1 mg/dL and when blood ammonia nitrogen concentration reach 0.7-0.8 mg/dL. As a treatment measure oral administration of vinegar (0.5 L for goat and 4L for cow) is recommended. Repeated dosing may be necessary as the clinical signs tend to recur about 30 minutes after treatment. The most effective treatment when the toxicity is detected at an early stage is prompt and efficient emptying of rumen by rumenotomy.

KERALA VETERINARY AND ANIMAL SCIENCES UNIVERSITY
COLLEGE OF VETERINARY AND ANIMAL SCIENCES, POOKODE
DEPARTMENT OF ANIMAL NUTRITION

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Compiled by

Dr. Biju Chacko
Dr. S. Senthil Murugan
Dr. Surej Joseph Bunglavan
Dr. Jinsy V.S

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Economic Importance of feed for Horses

In horse business also food constitutes the greatest single cost item and its relative economic importance varies widely than any other class. This is because many horses are mainly kept for recreation, sports whereas other species are kept for business reasons and labour for keeping horses is much high in relation to cost of feed. 1000 lb horse- consume 25 lb feed (hay and grain) daily or 4.6 T/year. Cost of horse feed varies depending on quality, feed price, proportion of concentrate and roughage. Many additives are added to horse feed which are costly. In addition to cost of horse feed, faulty nutrition also adds to the economic importance. Bone ailments due to faulty nutrition occur during foetal and early growth stages.

Basics of Horse Nutrition

Weight of digestive tract of horses-20% of total weight (Cattle-45%, Sheep- 37.5%, Pigs-14%

Human- 8%)

Horses are specialized herbivores adapted to life on open grasslands. However, the anatomy and physiology of horse's digestive tract differs greatly than ruminants. In horse-digestive system or alimentary canal is about 100ft long from mouth to anus. Feed passage time in equine is quicker than in ruminants (36-48 hr compared to 72-96 hr) on a similar diet. Entire tract can be divided into 2 functional parts: foregut and hind gut. Fore gut functions similar to pigs. Hind gut – qualitatively similar to ruminant animal though efficiency wise it is incomparable. That is horse is somewhere between pig and ruminant in its utilization of feeds. Ruminants are fore gut fermenters while horses are hind gut fermenters.

Horses have mobile nostrils and flexible upper lip to assist in the selection and gathering of food. The grass is cropped close to the ground using the incisor teeth. Horses have to process the fibrous feeds that contain silica (hard-sand like) before swallowing. To overcome quick wear and tear to the teeth, cement like substances forms a layer resembling bone over the dentine of tooth. Horse has a high crowned teeth which grow continuously throughout its life to compensate for wear.

Digestive System- Digestion and Absorption

Fore gut- mouth, pharynx, esophagus (4-5 ft), stomach (8-10% of total digestive tract) and SI (30% of digestive tract, about 70 ft long) and LI 60-62%. Capacity of cows stomach is 10 times than a mature horse. Hind gut- (LI-60-62% of digestive tract) consists of caecum (15%; 4ft long), large colon (38-40% of digestive tract, 10-12ft long) small colon 9% (10-12ft long) rectum (1ft long) and anus.

Lactose can be digested by young horses but horses older than 3 years have limited lactase activity. As a consequence, sudden introduction of lactose containing feed stuffs to mature horse may induce digestive disturbances. Feeds and nutrients not digested in the stomach and SI and flow to LI, where they are digested by anaerobic microbial fermentation. However, the horse is only two-third as efficient as ruminant in the digestion of average quality grass hay. The higher the quality of forage better it is digested by the horse. The horse comes closer to the ruminant in the digestion of high quality lucerne hay. Microbial digestion in caecum produces VFA, vitamins and amino acids. The VFA produced supply about ¼ of horse's energy needs. VFA concentration in caecum and colon will vary with kind of diet fed and with ratio of grain to roughage used. With high grain diets total concentration in VFA and % of acetic acid decreases, and the levels of propionic, isovaleric and valeric acids increases.

Glucose derived from digestion of nonstructural dietary carbohydrates enters portal vein. VFA available from fermentation of structural carbohydrates are absorbed in caecum and colon and constitute important sources of energy. Foal has a small digestive tract and caecum does not become fully functional until it is about 15-24 months old and young horses are limited in their ability to use much forage.

Protein digestion starts in the small intestine which is the main site for conversion to amino acid and absorption of majority of amino acid. But amino acid synthesized by bacteria in caecum and large intestine are not too efficiently utilized by the horse. Young horses therefore cannot depend on amino acid synthesis in the caecum to supply the indispensible amino acid needs. Hence diet must supply the indispensible amino acid especially lysine.

Horses do not have gall bladder, but doesn't appear to affect the digestion of fat. Composition of body fat in the horse is similar to that of dietary fat since the FA are absorbed from small intestine before they can be altered by microbes in large intestine.

Carbohydrates

Carbohydrates form the largest part of the energy supply. There are soluble and insoluble carbohydrates. Soluble carbohydrates (starches and sugars) are digested in small intestine and are absorbed as simple sugars. High starch feeds such as oats and barley are rapidly digested in the small intestine and provide instant energy to horse. This burst of energy- reason why cereals grains can have a heating effect on a horse's temperament. If soluble sugar content is high as in high fertilized grasses, all that is ingested is not digested in

small intestine and passes to hind gut upsetting pH of contents and cause digestive upset and in severe cases laminitis. Some horses become hot excited when soluble carbohydrates such as oats or barley are fed and alternate way is to fed other energy sources like sunflower oil.

Most of complex/insoluble carbohydrates (cellulose or fibre) are digested by micro organisms in caecum and colon, producing VFA, vitamins and amino acid. Release of energy is slow and such feeds are considered as non heating. Horses digest crude fibre about 2/3 as efficiently as ruminants do. Digestion coefficients are similar for ponies and horses. Legume forages are better for horses over grasses because of their higher content of soluble carbohydrates. Horses need quality forage at a minimum of 0.5% body weight.

Fats and Energy

Fats and Fatty acids are important in horse nutrition. Adding fat to their diet increases energy density and decrease diet volume, total feed intake. Fat provides energy in a non heating form and is unlikely to cause temperament upset. Adding fat also increases level of protein required and may increases level of certain vitamins and minerals. Normally 5-10 % fat may be added in diet of high level performing horses, though levels up to 20 % fat can be added. Extra fat in diet demands addition of Vitamin E. Linoleic acid is the primary source of essential fatty acids.

Protein and Amino Acid

Protein in diet is not required as such. It is needed as a source of indispensible amino acid and of nitrogen for synthesis of dispensable amino acid. Lysine is an indispensible amino acid for young horse. Methionine and threonine may also be indispensible under certain conditions. High energy diets increases protein needs as protein requirements are directly related to calorie level. Adding urea is not recommended although horse may make use of it under low protein diet. Horse can tolerate some excess protein in diet. Extra protein may be used as a source of energy like carbohydrate or fat. As protein is more expensive it should be fed excess only as insurance against a possible need for more protein or amino acid in diet for valuable horses.

Utilization of protein for energy produces 3-6 times more heat than utilization of carbohydrate or fat. This may be beneficial in a cold environment but contributes to excessive sweating and heat exhaustion during physical activity particularly in warm environment. Horse should be cooled before allowed to drink. Occasionally allergies to a specific protein in certain feed stuffs occur. This results in urticaria or heaves or frequently called protein bumps, all over the body or in small portions of body. Sometimes diarrhoea or respiratory problems may be seen.

Water needs

An adequate intake of clean, fresh water is very important. A horse will survive longer without feed than without water. A loss of 10% of horse's body water can lead to disorders (digestive disorders such as colic or founder) and a 20% water loss results in death. A Horse needs 2-4 kg water per kg of feed. Water needs of animal may be considerably

increased by duration and degree of physical activity, temperature, humidity, stage of life cycle, kind and level of diet fed etc.

A number of minerals, sodium, chloride, K, Ca, etc are lost in the sweat and urine during physical activity. Electrolyte loss increases as per duration and degree of physical activity and with increased temperature and humidity. Loss of minerals cause depressed feed intake, fatigue muscle weakness and decreased performance.

Feed stuffs

Cereal grains

Oats, barley and maize are the principal cereal grains for horse. Among these oats are preferred because they have the lowest energy and highest fibre levels. Oats can be fed whole or crushed or rolled. Oats contain approximately 5% oil with high levels of unsaturated fatty acids and are liable to rancidity once the grain is crushed. Oats have a better protein quality (lysine content) compared with other cereals. Oats are least likely to cause colic compared to other cereals due to their high fibre content (single meal of cereal remain in horse stomach for long periods and may ferment producing lactic acidosis and in extreme cases result in colic or stomach rupture. The starch content in oats and hulled oats is 46-47 % and 48-63% respectively. Oat starch is more readily digestible in the SI compared to other cereals like maize and barley. This is due to different morphology of the starch granules of oats and higher amylase activity in jejunum following the intake of oats.

Barley and maize are hard grains and should not be fed whole. Barley may be rolled, flaked or boiled while maize is fed as flaked maize (flaking involve the use of heat and gelatinize the starch, making it more digestible). It is also reported that substituting maize for oats decreased diet and intestinal tract volume and improved racing time. Among cereals wheat is the most likely one to be cause colic because of its high gluten content since gluten leads to the formation of a doughy lump on the stomach. Hence wheat should not be used except in very small quantities or in low levels in compound feed. Freshly harvested cereal grains may be associated with digestive disturbances and it is better to store them for a couple of months before use.

Brans

Fibre in equine diet is most important to maintain a stable hindgut environment that is less susceptible to acidosis. Wheat bran is a favored feed for horses. It has less energy and more fibre, protein and minerals than wheat. But feeding high levels of wheat bran is associated with Big head disease or Miller`s disease or Bran disease in mature horses due to its poor calcium to phosphorus ratio (that is high P &low Ca). Bran has laxative action (draws lot of water in to gut due to high fibre level)

Protein supplements

Soya bean meal is the protein supplement of choice due to its high lysine content. Ground nut cake is an alternative. Feeding of linseed produces a glossy coat (blooming hair

coat) due to the relatively high level of unsaturated fat. Linseed can be boiled in water before feeding, also incorporate any vegetable oil such as olive oil, maize oil, sunflower oil etc.

Roughages

Young grass liked by the horses because young grass have a high sugar content. Succulents such as carrots may be fed up to 2 kg per day. Dried molasses and sugar beet pulp is the commonest alternative energy supplement to cereals.

A horse can eat fresh grass at 10% of its body wt. every day. Requirements for maintenance as well as part of production can be supplied through *ad libitum* feeding of good quality fodders as a single feed or the mixture of fresh leguminous and cereal fodders in the ratio of 3:1. Lucerne, berseem, cowpea, oats and maize fodders are excellent for horses. Lucerne leaf meal is a rich source of protein, Ca, P, carotene and other micronutrients. The legume and cereal hays are also popular in feeding of horses. Green legumes may cause bloat in cattle, buffalo or sheep but not in horses. Pasture grasses such as dub, timothy and orchard grasses are popular. Straws and stovers are poor quality fodders. Soy hulls are being used as a source of fibre in place of hay and they can replace up to 75 % (as fed basis) of total forage in diet for horses.

Adding Fat to the Diet of Exercising Horses

It would appear that horses developed for maximum racing performance might be benefited by the use of 5-10% fat in the diet. It is apparent that adding fat to the diet of exercising horses increases the caloric density and allows a reduction in total feed intake. A lowered feed intake minimizes the possible incidents of founder, colic, tying-up and digestive disturbances which might otherwise occur with carbohydrate overloading.

The addition of fat to the exercising horse's diet has a sparing effect on muscle glycogen reserves. It may be due to a sparing effect on muscle glycogen or possibly to stimulation of muscle glycogen synthesis. Regardless of the exact mechanism of glycogen sparing effect, if a high level performance horse can be conditioned to utilize fat as an energy source during aerobic work, the resulting increase in glycogen storage can add to the energy supply to the muscles of horses working in a state of oxygen debt. This could delay the onset of fatigue in the exercising horse.

Some Hints on Feeding Horses

- It is often quoted to feed the horse a little and often. The horse has to chew each mouthful of feed as it takes it. On fibrous feeds of low digestible energy, therefore, it has to spend a very substantial part of its day in eating enough to obtain sufficient nutrients. The physiological stimulus for gastric emptying would appear to be chewing of more food in the mouth. As the amount of roughages in the diet decreases, less time is spent for eating. Concentrate feeding increase leisure time and the stabled horse will spend its time displaying signs of boredom and inactivity, such as crib-biting, weaving, wind-suckling and other stable vices.

- It would seem prudent to limit meals of high dietary density (complete pelleted feed), those of concentrated carbohydrate sources, to no more than 0.5 kg DM per 100 kg body weight per meal and, if necessary for energy intake, to feed up to four meals per day.
- The timing of feeding in relation to work should be considered. Horses take approximately 40 min to eat 1 kg of hay and 10m min to eat 1 kg of cereals or concentrate pellets. It is unwise to work horses within 1.5 hr of their completion of a concentrate feed. In the case of racehorses, no hay and only very small concentrate feeds should be offered on race days before the race. It may be necessary to muzzle some horses or to take other action to prevent them from eating their beds on such occasions. Hay deprivation on the day of a race means that hay will no longer be in the stomach and thus not impeding the diaphragm, it will be residing in the hind gut along with the large quantity of water required for its digestion; most of its will not have left the body until 36-48 h have elapsed.
- Feed the horse according to its condition. The rule of feeding according to condition is more easily said than practiced and considerable experience is necessary. The horses are to be weighed periodically to know the effect of the feeding schedule followed. During times of less work, its intake of digestible energy should be reduced by reducing the concentrate part of the total diet and increasing forage intake. By doing so the energy density of the total diet is reduced while leaving total dry matter intake constant. As workload increases, gradually increase the concentrate mixture at the rate of 0.25 kg/day.
- Whenever the proportion of concentrates and roughage in the total diet are altered or changes in feed ingredients are effected to the reality of the animal's nutrient requirements, it is unwise to introduce new feedstuffs all of a sudden. Digestive enzymes can adapt to new feeds but only over period of days and not hours. Allow 7-10 days to change onto new feed.
- Some horses are greedy feeders and consume their concentrate feed without proper mastication. Such animals are subject to colic and digestive disturbances. Various strategies to show down the eating need to be explored. These included diluting the energy of concentrate with bran, chopped hay, or placing large sized round stones in the feed box.
- Fats and oils are efficiently digested in the small intestine, so we can add extra 'non-heating' energy to the horses ration by including oil. Substances such as potassium, magnesium, chromium, amino acids and B vitamins may be added to maintain calmness and reduce anxiety.

Rules of Good Feeding

The golden rules for good feeding are

1. Feed according to work, condition and temperament
2. Feed only good quality feedstuffs
3. Feed plenty of roughage
4. Feed little and often
5. Make any changes gradually
6. Keep to the same feeding time every day
7. Feed something succulent every day
8. Leave 1 hour after feeding before work
9. Water before feeding
10. Keep utensils clean
11. Reduce the amount of feed on the horse's rest day

Feeding the Foal

Feeding the foal (foal is young horse until it is weaned) starts in utero with feeding the pregnant mare a well-balanced diet to supply all the nutrients to the developing foal in the womb and to enable the mare to be a better milk producer after foaling. Mare's milk meets the foal's needs during the first 2 or 3 weeks of life.

Composition of mare's milk: Milk composition of mammalian species varies widely due to genetic, physiological and nutritional factors and environmental conditions. Gross composition of mare's milk in comparison to human and cow's milk is presented in Table given below. Milk represents the essential source of nourishment of mammals during the neonatal period. Hence it is physiologically and structurally correlated to the nutritional requirements of the newborns of each species. Mare's milk has noticeably less fat content compared to human and cow's milk, similar lactose content to that of human milk but higher than that of cow's milk and more protein and ash contents than those of human milk but less than those of cow milk. The energy supply of mare's milk is clearly lower than that of human milk, which in turn is comparable to that of cow's milk.

Gross composition of Mare's Milk in Comparison to Human and Cow's Milk

Constituent	Mare Milk	Human Milk	Cow Milk
Fat, %	1.21	3.64	3.61
Crude protein, %	2.14	1.42	3.25
Lactose, %	6.37	6.70	4.88
Ash, %	0.42	0.22	0.76
Gross energy, Kcal/kg	480	677	674

Antibodies are not provided to the foal by the mare during gestation because antibodies are too large to pass through the mare's thick placenta into the foal's bloodstream. Immunity for the foal is available only through the antibodies in the mare's first milk, the colostrum. One should help the foal suckle, if there is no need to do so, as soon as possible after birth. A majority of normal foals will nurse within 1-2 hr after foaling, while the most vigorous will nurse within 30-45 min. This is crucial because the intestinal tract is permeable to the colostral antibodies (through the special absorption cells in the duodenal lining) for about the first 24-36 hr of foal's life. These special cells decrease rapidly over the first 24 hours of the foal's life. After 48 hours they are replaced with normal duodenal lining. This process of transfer of antibodies from the mare to the foal is called passive transfer.

Colostrum may be collected from the mares after their foals have suckled and it can be frozen for later use. During the needy times this colostrum should be slowly heated to body temperature and administer to the foal. This provides immune protection to the foal. Blood IgG levels below 400 mg/dl indicate a failure of passive transfer. Plasma transfusions can be used to raise the IgG levels in the foals that are more than 24 hours old. Generally 1 litre of plasma is administered over a 30 to 60 minute period, depending upon the foal's vigour.

If the foal is restricted to milk alone, it soon becomes anaemic as milk is deficient in iron, copper and possibly other nutrients. Total solids in milk decrease from 25.2 to 10 % while lipids (0.7 to 1.3%) and lactose (4.6 to 6.5%) increase from the parturition to 4 months later. The crude protein in milk dropped from 19.1% shortly after birth to 3.8% 12h later and to 2.2% 2 months later. Other nutrients in milk such as gross energy (135 to 49 kcal/100mg), ash (0.72 to 0.27 %), Ca (847 to 614

ug/g), Mg (474 to 43 ug/g), Na (524 to 161 ug/g) and K (1143 to 370 ug/g) also follow the same trend. This is the reason why a good creep feeding programme is recommended 7-14 days of age.

The creep feed is kept in creep, which is an enclosure with openings for the foals to get in but not the mares. Supplemental feeds for suckling foals should be provided at least once daily, more often if warranted. The creep feed plus the milk the foal gets from its mother should be designed to provide a well-balanced diet. The creep feed given to the foal should be kept clean and fresh so that no mouldy or sour feed is consumed. The use of a creep feed helps to ensure that the inherited potential for growth and development is realized. At 5-6 weeks of age, a foal should be consuming creep feed at the rate of 0.5% body weight. By weaning time, the foal should be consuming 2.27-3.64 kg of creep feed per day. An example of creep feed is given below. One of the most important advantages of creep feeding is to accustom foals to eating concentrates before they are weaned. Creep-fed foals are less susceptible to the stress of weaning. Foals are weaned usually at 6 months of age. The nursing foal is assumed to be approximately 10% more efficient in utilization of DE than are mature horses.

Creep Diet for Nursing Foal.

Feed	Percent in diet
Oats groats, rolled	15.00
Oats rolled or flaked	20.00
Maize, barley, sorghum, rolled or a combination of them rolled or flaked	35.75
Soybean meal	15.00
Dried skim milk	05.00
Molasses	05.00
Dicalcium phosphate	02.00
Ground limestone	00.75
Trace mineralized salt	01.00
Vitamin supplement	00.50

Feeding the Orphan Foal

An orphan foal may have to be hand-reared by using a nursing bottle, if a foster mother cannot be found. The foal should be taught to drink milk (mare's milk) from a bucket as soon as possible: first allow the foal to lick milk of the fingers and then immerse the fingers in the bucket; this will encourage the foal to follow the fingers and discover the milk.

A foal with proper care can be raised on cow's milk. In case the foal has not secured colostrum from its dam, hypodermic injection of horse serum is usually given. As mare's milk contains less fat and more sugar compared to cow's milk, the milk should be modified for a very young foal. Hence use the milk from cows in their first part of lactation and those giving milk with less fat content. It is suggested to add 150 ml lime water to 600 ml cow milk along with one teaspoon full of sugar. On the first day, the foal should be fed at hourly intervals with milk warmed to 100◦ F using nursing bottle. During the first two week, normal healthy foals should be fed every two hours and during the second two weeks they should be fed every four hours. They should then be fed four times a day until weaning. The amount and frequency of feeds needed will vary according to the size, age and health status of the individual foal, but initially foals should be fed about 150 ml. Each week the amount fed should be increased to the maximum that the foal will eat without scouring. Scouring without fever or any other signs of illness may indicate that the foal is being overfed and its diet should be adjusted accordingly.

The orphan foal should be introduced to solid feed as quickly as possible. This will encourage gut development in the foal, which facilitate early weaning from the bucket. Some solid feed need to be kept at the bottom of the pail to teach the foal to eat solid feed. Later balanced creep feed has to be introduced. The foal can be put on good pasture soon.

Feeding through Stomach Tube

If the foal is premature or lacks a normal suck reflex, it must be fed through a stomach tube until it has learned to suckle. A soft rubber tube is passed into the foal's nostril, down its throat and into its stomach. The foal's nostril should be greased and when the tube reaches the back of its throat the foal should swallow so that the tube passes down the gullet, not into the lungs. The person must listen to the end of the tube before putting any milk down the tube. If the tube is in the lungs a characteristic noise will be heard and the tube should be slowly withdrawn. Milk is then slowly poured into a funnel attached to the tube.

Feeding the Weanling (Horses that are 6 months to 1 Year of Age)

One of the most critical times in the life of a growing horse occurs between weaning and about 1 year of age. Foals which have been given a creep feed and are already used to consuming concentrate mixture are better prepared for the shock of weaning. Studies indicated that light horses reached about 45, 66 and 88% of their mature weight at 6,12 and 18 months of age. They also have about 83, 91 and 95 % of their mature height at the withers at 6,12 and 18 months of age. Therefore, during the first few months after birth the fastest growth and most elongation of bones occurs. After weaning the foal should be increased in concentrate mixture 1-1.5 kg and 1 kg forage per 100 kg body weight. An example of such ration is given below. The ration should provide 18% CP, 0.85% Ca and 0.75% P. The concentrate ration constitutes 65 to 70% of the total ration fed to the weanlings. The remainder of the ration would be a hay with at least 12% protein. It has been suggested that dietary imbalances may be the causative factors in a variety of developmental orthopedic diseases in young horses.

Ration for Weanling Foals

Feed	Percentage
Oats, rolled or flaked	25.0
Maize, barley or a combination of them, rolled or flaked	30.8
Sorghum, rolled or flaked	15.0
Soybean meal	15.0
Dehydrated alfalfa meal, 20% CP	05.0
Molasses	05.0
Vitamin supplement	00.7
Dicalcium phosphate	02.0
Ground limestone	00.5
Trace mineralized salt	01.0

Feeding the Yearling (Horses that are 1 to 2 years of old)

If the horse reaches a year of age and is well grown, and has sound feet and legs, it has successfully passed a critical period in its life cycle. Weight gains will decrease during the second year of the foal's life. But the foal is still growing and should continue to be fed a high-quality ration.

The horse should be placed on a feeding programme of 1 to 1.5 kg of forage and 1-1.5 kg of concentrate mixture per 100 kg of body weight. Concentrate mixture should contain 16% CP, 0.8% Ca and 0.65% P, while forage should have at least 10% CP. The level of feeding can vary considerable depending on how the horses are to be used, the kind and quality of ration, and the response of the horses to the feeding programme followed.

The long yearling (1.54 years to 2 year old) requires a little less protein, calcium, and phosphorus than the yearling. The roughage intake is about 60% of the total feed intakes as compared to 40% of concentrate. Long yearlings not required for racing or high-performance can be fed largely on roughage, but the roughage should contain at least 11% protein.

Feeding for Performance

Feeding horses for racing, show, or performance is more complicated than feeding any other farm animal. These horses have widely differing feed requirements. Successful performance depends upon a combination of good stable management, feeding and exercise. While good feeding will not make a horse jump higher or run faster, poor feeding will undoubtedly damage a horse's ability to perform. Overfeeding or underfeeding will impair a horse's performance. A good feeding programme for the horse includes the actual feed and the feeder, who feeds the horse. The good feeder or more aptly the good trainer is one who can balance horse's work and feed to produce an athlete ready to give its best.

A well-balanced feed is the first requirement and competent feeder is equally important. There is no substitute for dependability, regularity, alertness, hard work, and integrity of the person doing the feeding. There is a need for individual feeding and for a constant study of the peculiarities and needs of each individual horse. Some horses eat slowly, whereas others eat fast. Some will consume more feed than others. Some horses may like more concentrate or hay than others. Proper attention to these small details will mean the difference between developing a champion or just another horse.

Show horses and dressage horses are trained to have impeccable manners and to move freely and well. They need to be in very good condition with a gleaning coat, radiating good health. The show horse has to have enough stamina to remain at ease at the end of a long day while the dressage horse has to perform strictly controlled exercises. The work may be light work. The feeding regime must ensure that the horse is calm, well mannered and responsive in the ring.

The event horse to be fit enough to gallop and jump at speed and yet disciplined enough to perform dressage and show jumping. The show jumper has to be well conditioned and responsive, without displaying excitable behavior. Hence the event riders have to keep their horse happy mentally and physically by feeding as few concentrates as possible and leaving the horse out in the field every day. The hunter carries its rider for as long as 6 hours (40-48 km distance may be covered in a day), spending periods standing still interspersed with short periods of galloping and jumping over varied terrain. The animal may work like this twice a week. Obviously the hunter cannot eat enough on that day morning to supply the energy it will use up during the day. This means that it has to burn up body reserves which are then replaced over the next 2 or 3 days.

Feeding the High-level Performance Horse/Race Horse

The high-level performance horse needs to be treated like an athlete and its likes and dislikes are to be taken care of while feeding, training, housing and management. It is already stated that the

energy needed for a strenuous effort, such as racing at full speed, is 70 times greater than that required for walking. This tremendous difference in energy requirement indicates the need for understanding how to provide energy for maximum racing speed and endurance.

The race horse is trained to compete at its maximum capacity during an approximate 1-3 minute racing period. This means that maximum availability and utilization of energy must occur during this short time. Diet must be manipulated to maximize the amount of energy available in the muscles during the exercise or racing.

Feeding and training programmes are very important in maximizing energy storage and availability for optimum muscular activity and performance. The muscle glycogen and free fatty acids play a dominant role in supplying energy to the muscles for work in both unconditioned and conditioned horses. The conditioned horse adapts itself to utilize fat, in addition to glycogen, to meet the increased energy requirements of exercise and training. The unconditioned horse, however, is not able to oxidize or use fat as efficiently as the conditioned horse. The unconditioned one uses more muscle glycogen for exercise. Adding 5 and 10 % fat to the diet of the exercising horse had a sparing effect on muscle glycogen reserves. This glycogen reserve could later be mobilized to help defer fatigue in the exercising horse. The level of protein, vitamins and minerals used need to be increased as the fat level in the diet is increased. Enhanced level of vitamin E appears to be beneficial with the unsaturated vegetable oil.

The use of 5-10 % fat and a small increase in grain level in the diet may be beneficial for the high-level performance horse to increase energy density, reduce total feed intake, and decrease intestinal tract volume. It is reported that maximum bone strength does not occur in horses until they are 4-7 years old. But they are in training and performance much before this time.

Sweating occurs as a horse runs to exercise. Any minerals that are lost in the sweat will increase their need on the diet. Sweat losses are influenced by temperature and humidity. The loss of sodium and chlorine appears to be of great concern since sweat contains 0.7 % salt. Highly exercised horses in high temperatures and high humidity zones sweat considerably and become exhausted and fatigued. Similarly excess heat is generated during prolonged exercise. This heat must be dissipated by sweating. If the exercise or running is excessive and prolonged, there may be a significant electrolyte loss (salts dissolved in the body fluids). Hence there is a need to keep salt licks in horse stables though minerals are added to the diet. Electrolytes are to be given in water or feed during long distance endurance trails.

The need for magnesium, iron, selenium and iodine would be expected to increase with exercise. Magnesium is involved in energy release, iron is essential for the formation of haemoglobin in the red blood cells, selenium is important for muscle function, and iodine is necessary for general metabolism. Vitamin E is considered important for the exercising horse and stress increases the horses need for B complex vitamins.

Horses being developed for racing must not be allowed to become fat. In developing a race horse, it is important that they receive the protein, energy, vitamins and other nutrients needed to develop the body of a well-trained athlete. They must also obtain adequate nutrition to perform to the maximum of their inherited potential. An example of ideal ration is furnished below. The ration should provide 18% CP, 0.95% Ca and 0.85% P. The concentrates mixture should be at a level of 40 to 50% of the total feed intake and this level can be increased during heavy training or racing. Roughage should be of high quality hay/pasture. If the horse is standing in the stable without exercise,

the concentrate part should be cut the night before the rest day to reduce the risk of 'tying up' (azoturia) and then reintroduced over 2 days once work has resumed.

Ration for Race Horses.

Feedstuffs	% in the ration
Oats rolled	35.00
Maize, ground	10.75
Barley, rolled	12.50
Wheat bran	07.00
Alfalfa meal, 20% CP	08.00
Soybean meal, expeller 4-5% fat	15.00
Molasses	07.00
Dicalcium phosphate	02.00
Limestone	00.75
Trace mineralized salt	01.00
Vitamin supplement	01.00

Slow release energy feeds that are broken down during exercise provide a continuous supply of energy to the working muscles. Hence high-digestible fibre sources such as sugar beet pulp, Lucerne chaff and high fat diets are better than grain diets. Fibre in the diet traps water I the large intestine and acts as an essential reservoir of fluid which is used to replace sweat loss and to prevent dehydration during a ride. The provision of water to endurance horses is vitally important and they should be accustomed to drinking during the ride whenever possible. Electrolytes need to be given one or two days prior to ride in the feed and during the ride in water.

Feeding the Pregnant Mare

The most important period during gestation is the last 90 days. This is the period when growth rate of the embryo is the greatest. About 60-65 % of the weight of the foetus is grown during this period. The products of conception accounts for 10-12% of the body weight of the mare. During the last 90 days of gestation, the mare will gain 50 kg weight at the rate of 0.55 kg per day. The gestation diet should have 11-12% protein. The foal weighs approximately 40-45 kg at birth. The concentrate mixture should supply 16% CP, 1.0% Ca and 0.9% P. The concentrate should form 35% of the total ration.

Feeding the Lactating Mare

Proper nutrition is very critical since the mare needs to recover from parturition, produce enough milk and rebreed successfully. The mare has to be fed enough balanced feed to produce milk as well as to maintain her body. An inadequate diet may account for much of the alternate year foaling that occurs because the mare fails to conceive while nursing the foal. Lactating mares should be fed 12-14% protein diet. Peak milk production usually occurs at 6-12 weeks after foaling. It then gradually declines until the foals are weaned at about 6 months of age.

During first 3 months of lactation feed intakes increases and it is 37 % over that of during the last 90 days of the gestation period. This is an increase from about 1.5 to 2.0 % of body weight to 2.0 to 3.0% of body weight as DM intake. The concentrate part of the complete ration will be 45%. After 3 months, milk production decreases and accordingly the level of feed decreases. The dry matter intake is about 2.0-2.5% of body weight and the concentrate mixture forms 40% of the total diet.

Feeding the Stallion

During the non-breeding season, a high-quality pasture/ forage will supply a large part of the feed for the stallion. Concentrate feeds should be fed in small amounts to supplement the forage and to keep the stallion in a trim, thrifty condition. A free choice mineral supply provides opportunity to obtain minerals not present in adequate amounts in the feed consumed.

Two or three weeks before the breeding season begins, the concentrate feed given to the stallion should be increased so that it will gain a little weight. This is similar to flushing practiced in ewes/sows and is important for the stallion to have good libido and fertile semen. During the breeding season the stallion should need more energy, protein, minerals and vitamins. This is accomplished by feeding a higher level of concentrates in the diet. The concentrate mixture should be fed at the rate of about 1% DM of the body weight, the remaining being green and leafy forage or hay. The total diet should contain about 13% protein and the stallion should not be allowed to get too far or too thin. The stallion should receive some exercise but excessive exertion may reduce libido.

Feeding Adult Horses

The energy requirements for mature horses at maintenance are low and can be met by feeding good quality roughages. However, salt and a balanced mineral supplement need to be provided free-choice. If good quality roughages are not available, some concentrates are fed to meet the nutritional requirements.

Horses have tremendous capacity for compensatory intake from the feeds of low energy content provided they are palatable. Mean voluntary intake of non pregnant adult mares (about 530 kg BW) on a composite ration with about 2.27 and 2.06 Mcal ME per kg dry matter was, respectively, 2.07 and 2.46 DM per 100kg BW. However, this trend of feed intake was not seen in pregnant mares in their last quarter of gestation period and energy density of rations could not influence the feed intake significantly.

Systems of Feeding Horses

Stall feeding: The daily allowance if concentrate mixture is divided into 2 or 3 parts and fed to horses at 6-8 hours interval. Working horses are generally fed twice, while growing foals and lactating mares are fed three times in a day. Afterwards, mixture of cereal and leguminous fodders are offered.

Grazing: The animals are allowed gazing on pastures for 6-10 hours daily. Depending on the availability of herbage and the physiological stage of the animal, the supplements are offered.

Use of feeding bags: Working horses and ponies used for traction are required to be fed away from the home. The feeding bags are used to feed concentrate mixture. The concentrate is moistened and filled to half of the bag and tied behind the pole after putting the mouth of the horse to enable it eats comfortably. The bags are used for feeding the working and race horses in the intervals during the working hours. Buckets are also used for feeding the tonga ponies.

Proper Bone Formation

It is estimated that only one in five Thoroughbred horses which start training gat to the race track. Of those that get there, only one in five is still racing after one year. Feet and leg problems account for a large percentage of the horses that drop out along the way. Proper bone formation in

horses is a very complex problem. It requires not only calcium and phosphorus, but other minerals, vitamins (A, D and C), protein, hormones and possibly other factors.

The ash in the bone contains about 36% calcium, 17% phosphorus and 0.8% magnesium. In addition to Ca, P and Mg, copper, manganese, sodium, chloride and possibly fluorine are concerned with proper bone formation. Proper protein nutrition is important in bone formation since bone contains about 20%protein. The weanling horse requires about 0.6-0.7% lysine. Bone is not static and is continually being re-formed throughout life in a continuous interchange of calcium and phosphorus between the bone, the blood supply and other body systems. If more calcium and phosphorus leaves the bone than is being replaced, the bone will eventually become porous, weak and may be pulled out of shape, deformed, or broken down by the weight of the horse and the pull of the body muscles.

A high-level performance horse is comparable to a human athlete but it has the disadvantage of training at a very young age compared to the human. If a human has a life span of approximately 77 years and horse a life span of 22 years, 2-year-old horse could be compared to a 7-year-old human. Most performance horses start training at about one year of age. This early age stress of training for high-level performance accounts for some of the breakdown which occurs in the feet and legs of horses. The pushing of young horses too early and too hard for high-level performance may result in damage to immature, partially ossified bones. When young horses are fed for rapid body and skeletal growth, they may develop bone abnormality and lameness problems. Further, proper attention has to be paid while selecting breeding stock and avoid those with a tendency toward poor feet and legs.

Feeding and Health related problems

Laminitis/ Founder- Inflammation of the lamina on the inner hoof wall. Affects feet, cause extreme pain, high fever and horse has a difficult time moving or walking.

Causes

1) Over feeding or irregular feeding of concentrate grain mixture to horse. Use of mouldy/rancid and wet feeds when fed cause indigestion and laminitis.
2) Enterotoxaemia resulting from high production of lactic acid due to increased grain feeding. Lactic acid damage gut wall and allow bacteria to enter the blood. These endotoxins affect the lamina by decreasing the blood flow to the lamina.
3) One of the reasons why laminitis is so complicated and enigmatic is its association with gastrointestinal disturbances, particularly a diet of lush grass at certain times of the year. Certain equine hindgut bacteria produce amino acid decarboxylase enzymes that convert free amino acids into monoamines. Therefore, amines formed and released from the gastrointestinal tract are hypothesized to act as the link between the ingestion of lush grass and the digital ischemia thought precede laminitis. Equine caecal contents contain a range of amines (tryptamine is the most potent one) that are present in micro molar concentrations. Thus the monoamines could potentially induce laminar ischemia and so trigger laminitis.
4) Colic- which cause laminitis by direct damage to intestinal wall such as with torsion (twist of intestine). The wall will die in that area and allow bacteria to get into the blood to cause laminitis.
5) Retained after births may cause uterine infections followed by laminitis.

6) Hard work and exercise on hard surfaces- since this may bruise the lamina and cause laminitis. In such cases change the horse to a diet of good quality hay.

Symptoms:

Extreme pain, fever (103-105ºF) and reluctance to move- moves as if walking on eggs. Untreated cases acute or chronic degeneration of the joining of the sensitive and insensitive lamina of feet and in severe cases even exposure of bone occurs.

Treatment – remove the cause of founder

1) Mineral oil- for easy passage of ingesta, avoid absorption of lactic acid/toxin.
2) Analgesics
3) Antihistamines
4) Antibiotics
5) Sodium bicarbonate- to neutralize acidic toxicity
6) Water soaks and bandaging

A brittle cracked hoof may be seen in case of deficiency of minerals and amino acids.

1) Sulphur involved in chemical bonds that maintain the integrity of internal hoof.
2) Biotin improves resistance of hoof wall
3) Methionine and cysteine are building blocks of keratin the protein which makes up hoof and hair.
4) Zn is a mineral needed for hoof growth and skin condition
5) Ca is needed for healthy bones and teeth and has a role in hoof growth.

Colic

Refers to abdominal pain. Most common ailment causing death in horse.

Cause

1) Improper feeding. As it has a small stomach and if fed too much it cannot relieve the distended stomach by vomiting and thus colic may develop. If distension is too much stomach may rupture and death results.
2) Small intestine is long and twisting and herniation through a body opening may cause colic
3) Caecum and large and small colons are large in relation to the stomach. Impaction may occur in all the three and cause colic.
4) Internal parasites play an important role in intestinal disturbances which may lead to colic.
5) Obstruction in digestive tract may result in colic
6) Sand colic can result when horse ingest large amounts of sand while grazing

Symptoms

1) Severe pain usually in abdomen. Horse keep a looking at its belly, disturbed abdomen,
2) Violent rolling and pawing, profuse sweating, constipation and refusal of feed and water.

Treatment

1) Place animal in a large well bedded stall
2) Take animal for a small walk
3) Sedative/laxative (mineral oils)

Prevention and control

1) Regular deworming
2) Provide sufficient roughage
3) Daily exercise

Nutritional management

1) Feed at regular times daily avoid sudden diet changes
2) Horses that are greedy or fast eaters are to be slowed down. This can be achieved by keeping mineral blocks. Improper chewing of feed may cause colic. Hence check the teeth of horse.
3) Feed optimum level of fibre to avoid impaction of feed
4) Inadequate water intake may cause colic. Hot tired horse should be cooled out slowly and allowed only small quantities of water slowly.
5) Dropping should be observed for consistency and unusual odour
6) Mouldy feeds/rancid feed may cause digestive disturbances and colic. So manger should be clean
7) Need adequate exercise
8) Horse sweat greatly and it contains 0.7% salt and other minerals. So these minerals should be available in the stall.

Azoturia (Haemoglobinurea/ Monday morning disease/Exertional rhabdomyolysis/ Tying up or exercise related muscle problems)

Sudden exercise following a day or 2 days of rest during which the horse has been on full feeding resulting in partial spasms or Tying up. It is caused by abnormal amount of glycogen being stored in muscle. Glycogen converted to lactic acid- increased concentration in muscle causing sever muscle destruction and release of myoglobin manifested as spasms or tying up with wine coloured urine.

Symptoms

Develop 15-60 minutes after the beginning of exercise. There will be profuse sweating, elevated temperature and pulse. Wine coloured urine and cramping, reluctance to move. Breath and urine will have peculiar odour

Treatment

Rest- sedation, muscle relaxants, sodabicarb injection to adjust muscle pH

Prevention

Restrict grain ration increase good quality roughage and do daily exercise. Give wet bran mash on the evening and on the day prior to an idle day.

Fescue foot (Fescue toxicosis)

Caused by a fungus (*Acremonium coenophialum* seen on fescue plant and seeds)

Symptoms

Some animals show lameness. In others varying degrees of sloughing/necrosis of ends of tail, mild cases- poor conception rate, decreased body condition, lowered milk production., prolonged gestation, abortion and thickened placenta.

Heaves

Heaves or pulmonary emphysema results in a loss of elasticity in the lungs and an accumulation of air in the lung tissue since it cannot be exposed properly. It is a condition associated with feeding of dusty/damaged/mouldy hay and use of dusty bedding.

Cough, nasal discharge and horse has a difficulty in breathing in forcing air out of lungs resulting in a jerking of flanks and coughing.

Periodic Ophthalmic (Moon blindness)

ERU-equine recurrent uveitis

Cause

1) Some feeds forages and medicines
2) Autoimmune reaction or allergic reaction

Cloudy vision in one or both eyes-clearing in one or two minutes

Similar to size of moon.

Prevention- Feed green grass/well cured grass

Photo sensitization (Primary/secondary)

Sweat clover disease- dicumerol Vitamin K antagonist

Feeding with lush green rapidly growing grass- metabolites which may sensitize the skin to sunlight. Lesions are confined to white or lightly pigmented areas redness, sweating of skin tissue fluid oozes out.

Lactation tetany

Tetany is a condition in which there are localized spasmodic contractions, twitching or cramps. It is due to a fall in the plasma Ca concentration that occurs in lactating mares as a

result of loss of Ca into the milk. Lactation tetany is prevented in subsequent lactations by feeding a low Ca ration during the last 2.5 weeks before foaling then switch to a high Ca ration after foaling. Low Ca diet stimulates parathyroid gland so that it is able to respond more rapidly to a fall in plasma Ca concentration and mobilize Ca more rapidly from bone to prevent tetany. Low Ca ration also increase efficiency of intestinal Ca absorption.

Wood chewing

Animals which are short of minerals will eat dirt and chew wood. To prevent this make sure that the diet is adequate in minerals. Some horses chew each other's tail when they are fed only a completely pelleted diet. This may be due to lack of enough roughage may be due to lack of some minerals/other deficiencies.

Nitrate Toxicity

Horses are less susceptible to nitrate toxicity than are ruminants. Intakes of excessive amounts of nitrates may result in acute toxicity. Ingested nitrates are converted to nitrites. Nitrites are absorbed and convert blood haemoglobin to methaemoglobin. This compound prevents the blood from picking up oxygen from the lungs. This compound gives the blood a chocolate-brown colour. Clinical signs of acute nitrate toxicity are usually observed within one-half to four hours after excessive nitrate ingestion. These signs include colic, diarrhea, frequent urination and signs of hypoxia (inadequate oxygen). Hypoxia causes a rapid, weak pulse, increased depth and rate of respiration, labored breathing, in coordination, muscle tremors, weakness and a dark bluish tinge to body tissues (cyanosis), noted particularly on the mucous membranes of the mouth. Acute nitrate toxicity is treated by methylene blue given intravenously (10mg/kg BW) at several-hour intervals. Methylene blue assists in converting methaemoglobin to haemoglobin.

HypomagnesaemicTetany

Feeding fertilized spring grass may cause Hypomagnesaemic Tetany (grass staggers) in animals due the very poor availability of magnesium.

Quidding or Dropping Half-chewed Feed

Quidding or dropping half-chewed feed out of the mouth may be observed in some horses. This may be due to sharp edges of molar teeth. The sharp edges on outside of upper molar and inside of lower molar can lacerate the tongue and cheeks and make eating painful. The signs of sharp edges include very slow eating, bolting the feed i.e., swallowing feed quickly, loss of condition of the animal.

Osteochondrosis

It is reported that osteochondrosis (cartilaginous hypertrophy) in foals is clinically similar to lameness that has been associated with a simple copper deficiency. Horses with the genetic predisposition for fast growth and those that are fed heavily for faster growth are frequently prone to develop osteochondrosis, epiphysitis and other skeletal disorders are

found in grazing horses, where forages and feeds are deficient in copper and zinc. But all such cases are not attributed due to deficiencies of copper and zinc. (The place where bone growth occurs is **epiphysis)**. Inflammation of the epiphysis is called **epiphysitis.** The mineral imbalance in the milk may result in epiphysitis, causing enlarged joints and crooked legs, or in a decreases growth rate.

Enteroliths

Enteroliths are also known as calculi or stones. The presence of nidus (nails, pins, needles, pebbles, etc) and adequate concentrations of ammonia, magnesium and phosphorus are needed for calculi formation. Calculi found in the intestines of horses are primarily composed of magnesium, ammonium and phosphate. The elimination of a nidus from the feed by making sure clean feeds are use is a very important way of preventing calculi formation. Some horses pass small calculi in the faeces and never develop any problems. In some cases, enteroliths can grow large enough to block the intestines and cause serious damage

Thumps or Synchronous Diaphragmatic Flutter (SDF)

Synchronous diaphragmatic flutter, that is concentration of the diaphragm in synchrony with the heart, may occur owing to electrolyte losses as a result of physical exertion. Here a decrease in the plasma concentration of calcium, chloride and/ or potassium is observed.

Prussic Acid Poisoning and Cystitis

Immature sorghum, sudangrass and sudan-sorghum hybrids contain a glycoside which may breakdown to prussic acid or hydrocyanic acid in the digestive tract. This cyanogenetic glycoside is also present in the second growth following periods of drought, frost or heavy trampling. Prussic acid poisoning is very rapid. Sometimes the first sign of trouble is finding horses dead or dying. Prussic acid poisoning results in abnormal breathing, trembling muscles, spasms or convulsions, nervousness, respiratory failure and death.

The sorghum-sudan hybrids and sudangrass hybrids are also cause a disorder known as cystitis (urinary tract inflammation). This disease causes continuous urination and in coordination in gait and the mares appears to be constantly in heat. Animals seldom recover after the in coordination or dribbling of urine occurs. Hay made from such grasses will not produce the disease. Hence, one needs to exercise caution if sudan or sorghum-sudan hybrid pastures are used for horses

Purified Diets for Horses

The term purified or synthetic diet is used interchangeably. They both refer to a diet that consists of purified ingredients instead of grain, protein supplements and other feeds.

Purified diet ingredients are used to know exactly what the diet contains. Purified diet method makes it possible to subtract a vitamin, mineral, fat, carbohydrate, protein or amino acid (if synthetic amino acids are used instead of casein in the diet) or to vary the level of

protein, energy, minerals and vitamins and to determine their effect on the test animal. This cannot be done with a natural or practical diet consisting of maize, barley, oats, soybean meal, linseed meal, Lucerne meal, bone meal and salt.

However, one needs to be careful in applying nutrient requirement data obtained with purified diets directly to practical diets. This is because the feeds in the purified diets are much more digestible than those in the practical diet. The nutrients in practical diets are in their natural state and they are in different forms from those fed in purified diets. These result in a difference in availability and in requirements between purified and practical diets. Further, the two types of diet may have different effect on the synthesis and requirements of certain nutrients by the intestinal tract microorganisms present in the horse. Hence, there is a need to conduct experiments with practical diets as well.

Example of a Purified Diet

Sl. No.	Ingredients	Supplies
1	Casein (vitamin free)	Protein
2	Glucose	Carbohydrates
3	Cornstarch	Carbohydrates
4	a-cellulose	Fibre or roughage
5	Corn oil	Fat
6	Dicalcium phosphate	Calcium and phosphorus
7	Salt	Sodium and chlorine
8	Individual minerals as mineral salts	Magnesium, iron, copper, cobalt, manganese, zinc, potassium, sulphur, iodine and selenium
9	Individuals vitamins as synthetic vitamins	A, D, E, K, C, B_1, B_6, B_{12}, pantothenic acid, niacin, riboflavin, choline, inositol, p-aminobenzoic acid, biotin.

FEEDING AND NUTRITION OF SWINE

Pigs are highly prolific among meat producing livestock. Feed accounts for 80 % of cost of production. During the past half century swine husbandry for pork production in India has gradually emerged from the traditional scavenging system to semi intensive and intensive system. If adequately fed a young pig of breeds like large White Yorkshire, Landrace etc. can reach 5 times its birth weight at the end of 3 weeks and 10 times of its birth weight in 5 weeks.

Characteristics of swine and their production

1 Superior feed conversion ability: - on an average pigs produce 100 kg gain from 300-350 kg feed (1: 3 - 3:5 feed conversion efficiency). Pigs are superior to beef cattle, goats, or sheep in converting animal feed to human feed.

Factors affecting feed conversion efficiency

1. Age of the pig: the ratio increases with age. For a 6 week old piglet, only 2 kg of creep feed is normally required to produce 1 kg live wt. gain. For a bacon pig approaching slaughter wt. It could be 4 – 6 kg.
2. Optimum balance of nutrients in diet: - diet should have optimum energy protein ratio. Diet should be balanced with vitamins and minerals.
3. Genetic variation: marked genetic variation exists within breeds and improvement can be done by selection. Feed efficiency in swine is 30 – 40% heritable.

2. Swine are prolific and bring back quick return. A unit of 10 sows and one boar will produce about 160 piglets during 1st year.

3. High dressing percentage. Dressing yield is 65 – 80% of live wt.

4. High energy value of pork (higher than lamb)

5. The growing – fattening pig must be fed a maximum of concentrates and a minimum of roughages.

6. Hogs are hard on pasture because of their rooting and close grazing habits.

NUTRIENT REQUIREMENTS

Successful swine production requires a carefully planned and efficient feeding programme.

Pigs are generally fed in groups (rather than individual feeding)

FEEDING STANDARDS FOR PIGS

In most of the countries feeding standards suggested by National Research Council (NRC) of USA or Agriculture Research Council (ARC) of UK are followed. In India, BIS has also suggested a standard for feeding pigs. The NRC requirements are on 90% dry matter basis while BIS specifications are on 100% dry matter basis.

NRC requirements

Since 1944, the NRC has published 11 editions of nutrient requirement for swine. The latest NRC is 11 the revised edition of NRC published on 2012.

NUTRIENT REQUIREMENT OF GROWING SWINE (NRC, 1998)

BODY WEIGHT	3- 5 KG	5-10 KG	10-20 KG	20-50 KG	50-80 KG	80-120 KG
DE content of diet(kcal/kg)	3400	3400	3400	3400	3400	3400
ME content of diet (kcal/kg)	3265	3265	3265	3265	3265	3265
ESTIMATED FEED INTAKE (g/day)	250	500	1000	1855	2575	3075
CP %	26	23.7	20.9	18.0	15.5	13.2

The high environmental temperature and high relative humidity of tropical climate affects the nutrient requirements of pigs. High temperature reduces the appetite of pig. A poor appetite reduces the feed intake resulting in poor growth performance. So calorie protein ratio of the diet should be optimum.

The NRC, 2012 uses values for metobolisable energy (ME), Standardised ileal digestible (SID) amino acids and standardized total tract digestibility (STTD) of phosphorus as the basis for all calculation. Requirement of all nutrients for weaning, growing and finishing pigs are calculated for7 separate weight groups (5-7 kg, 7-11 kg, 11-25 kg, 25-50 kg, 50-75 kg, 75-100 kg and 100-135 kg). Requirements of all nutrients are provided for mixed sex groups. But for pigs above 50 kg body wt. Requirements of Ca, P and amino acids are calculated separately.

Energy Requirements:

These are expressed as DE, ME, NE, or TDN. In pigs ME is assumed to be 96 % of DE (94% -97%). The loss of energy as gas produced in the digestive tract of swine is usually between 0.5 and 1% of DE. The quality and quantity of protein in the diet affect the relationship between ME & DE.

BIS Requirements of pig feeds. (IS 7472:1986) Reaffirmed in 2011

SI.NO	CHARACTERISTIC	Pig starter/ Creep feed	Pig growth meal (weaning - 35kg wt.)	Pig finishing/breeding meal (from 35 kg live wt.)
1.	Moisture content % by mass , max	11.0	11.0	11.0
2.	Crude Protein % by mass ,min	22.0	18.0	16.0
3.	Crude fat or EE % by mass , min	2.0	2.0	2.0
4.	Crude fibre, % by mass , max	5.0	6.0	8.0
5.	Total ash, % by mass ,max	8.0	8.0	8.0
6.	AIA, % by mass	4.0	4.0	4.0
7.	ME(Kcal/kg), min	3360	3170	3170
8.	Calcium % by mass, min	0.6	0.6	0.6
9.	Available P, % by mass ,min	0.6	0.4	0.5
10.	common salt % by mass, max	0.5	0.5	0.5

ENERGY REQUIREMENTS OF SOW

A factorial approach was used to arrive at the daily energy and feed intake recommended for pregnancy and lactation. The energy metabolism of pig is influenced by the physiological state of the animal, ambient temperature and physical activity.

Maintenance energy requirement (NRC, 2012)

MEm (growing finishing pigs) = 197 kcal/kgBW$^{0.60}$

ME m (gestating sows) = 100 kcal/kgBW$^{0.75}$

MEm (lactating sows)=110kcal/kgBW$^{0.75}$

The energy requirement for milk production is 2 Mcal of DE /kg milk (energy content of milk is 1.3 Mcal DE /kg of milk and 65% efficiency of utilization).

Carbohydrate and fibre in pig diet

Swine diets compose chiefly carbohydrates. Sugars and starches are readily digested where as cellulose and lignin has low digestibility for pigs. Pigs are less able to utilize crude fibre in comparison to ruminants and horses.

Fat

There are special advantages in adding fat to the diet

1. Minimize dustiness in feed.
2. Improve feed efficiency.
3. Increase acceptability and palatability
4. Improve physical appearance
5. Increase ease of pelleting, reduce feed wastage

Disadvantages of adding fat to the diet

1. Feed difficult to handle

2. Feed needs to be stabilized with a suitable antioxidant to prevent rancidity

With growing – finishing pigs, higher levels of fat (10 %-20 %) can be included in the diet

Essential FA

Linolenic, linoleic and arachidonic acids are designated as essential FA. Among them most important one is linoleic acid. A deficiency of EFA in young growing pig results in scaly skin necrosis esp. in tail region, dullness, dry hair coat

Requirements for protein and amino acids

Swine must have good quality protein in the diet. The growing pig needs dietary source of each of the 10 essential amino acids. Gilts and boars require higher % of AA. Tryptophan, lysine, and methionine are the AA most likely to be deficient swine rations. Lysine is the first limiting AA in swine growth. Proper combination of vegetable animal and fish proteins can be made in to supply the entire essential AA.

Ideal protein system

It is a method for evaluating dietary protein for growing pigs. This is modification of chemical score with the amino acid (AA) of particular tissue protein serve as the reference pattern. The concept of ideal protein envisages the supply of correct ratios of essential AA in

balance with the availability of non essential AA so that excess protein is not fed. In this system, there is no scope of feeding any AA. The supply of any essential AA should not be allowed to exceed 20% of reference value. The reference values of AA in the diet for growth, pregnancy, lactation & maintenance will be different in the reference protein.

Excess protein in the diet is equally bad as feeding diet deficient in protein. Clinical signs of AA deficiencies or imbalances in swine include increased feed wastage, impaired growth and general unthriftiness. However, large intake of individual AA can lead to AA toxicity, antagonism and imbalance depending on the nature of the diet. The e.g. for AA antagonism is lysine- arginine antagonism (excess lysine increases arginine requirement). The use of urea in swine ration is completely balanced.

Mineral requirements of the pig

Twenty mineral elements are essential for pigs. They are Ca, P, Mg, Na, K, Cl, S, Mn, Fe, Cu, I, Zn, F, Vanadium, Mo, Se, Cr, Tin, Ni and silicon.

Disorders caused by mineral deficiency

Minerals	Deficiency disorders
Calcium and Phosphorus	1. Rickets in young ones and slow growth 2. Osteomalacia in adults 3. Reproduction disorders in sow 4. Posterior paralysis
Sodium	1. Reduced growth 2. Impaired utilization of energy and protein
Chlorine	Alkalosis
Iron	Anemia, piglet anemia
Iodine	Goiter, alopecia, birth of hairless litter, still birth
Copper	Anemia, slow growth , scours, skeletal deformity in young ones
Manganese	Poor growth, skeletal deformity, ataxia, lameness and reproductive insufficiency leading too failure in prolonged deficiency.
Zinc	Loss of appetite, poor growth , decreased FCE, parakeratosis
Selenium	Mulberry heart disease, hepatic necrosis, hepatosis dietetica causing death.

Posterior paralysis: Due to deficiency of Calcium and Phosphorus in high producing sows, Paralysis of hind limbs occurs. Commonly seen towards the end or just after the end of lactation.

Parakeratosis: Zn deficiency results in mange like symptoms called Parakeratosis. Zn requirement increases when high levels of calcium are fed.

Piglet anemia: Iron is necessary for the formation of hemoglobin in RBC and for the prevention of nutritional anemia. As the unborn pig develops, a supply of iron is stored in its body. The amount stored varies greatly between pigs of same litter. This stored Fe is adequate for up to 2 weeks after birth. Sows milk is very low in Fe. If piglets have no access with soil or feed, serious losses from anemia results. Once the pigs start to consume natural feed stuffs, the danger of anemia is practically nil, since most feed contains sufficient amount of iron to meet the pigs requirement.

Anemic pigs lose their appetite and become weak and inactive. In more advanced stages of deficiency, pigs will have labored breathing called "thumps". In this condition they are more susceptible to other diseases and parasites and death occur in severe cases.

Prevention and treatment:

- Inject suitable iron preparation at 100-200 mg Fe into baby pigs of 1-3 days of age.
    - Swab sows udder with iron solution
    - Allow access to oral iron preparation
    - In addition pigs should be encouraged to eat a grain ration.

Vitamin requirements of the pig

Vitamins are essential for health and normal body function.

Vitamin deficiency diseases

Vitamins	deficiency diseases
Vit A	-Nerve degeneration signs like inability to stand properly, in-coordination, muscular spasms and staggering gait. -xeropthalmia /complete blindness on prolonged deficiency -loss of appetite, slow growth & decreased resistance against pathogenic infections
Vit D	-impaired metabolism of Ca, P leading to rickets in young -osteomalacia in adults
Vit E	-nutritional myopathy or muscular dystrophy , cardiac dysfunction leading to cardiac failure
Riboflavin	-loss of appetite, poor growth, dermatitis, crooked legs, stiffness in joints and ocular disorders
Niacin	-pig pellagra, anorexia, poor growth, enteritis, vomiting and dermatitis
pyridoxine	-slow growth, anemia, weakness & convulsion
Pantothenic acid	-diarrhoea, poor growth, scaly skin ,alopecia, goose stepping
Biotin	-alopecia, dry and scaly skin at lowered feed intake, poor growth & reproductive disorders in sows
Choline	-fatty infiltration of liver, retarded growth
Vit B12	-slow growth, weakness, in-coordination in piglets, dermatitis, loss of appetite, rough coat & weakness in growing- finishing pigs

Approximate water requirements for pigs

Class of pigs	Water requirement
Growing pigs (weeks of age)	Requirement in litres
8-12	3.5
13-18	6
19-24	7.5
25	8
Pregnant gilts and sows	
First half	10-15
Last half	16-20
Lactating sows with	
5-7 piglets	20-25
8-10 " "	22-27
11-14" "	28-35
Boars	20-25

If water is used for cleaning and washing, requirements may be double this figure

Feeding of pigs

In all commercial farms pigs are maintained as intensive animals and fed a diet based on concentrates. Pig is omnivorous i.e., it can eat all types of feed. Fermentative digestion occurs in cecum and colon. The fermentation products - VFA meet 25-30 % of maintenance requirement of pigs. An adult pig can consume 3-5 kg of leafy succulent green feeds (10-15 % DM). In growing fattening pigs 6-8 % CF can be used while the adults ration may contain 10-12 CF %. An increase in dietary fibre by 1 % above the specified level depressed the digestibility of gross energy by about 3.5 %.

Pigs less than 2-3 weeks old have insufficient pancreatic amylase and intestinal disaccharidase. Hence after 2 weeks of age only, pigs are to be fed starch or cereal based diets. Glucose and lactose are effectively used by pigs less than 7 days old. Afterwards only, pigs can utilize fructose and sucrose.

Diet formulation for different classes of pigs

The various diets include pre-starter, starter, grower, finisher and diets for pregnant and lactating gilts, sows and breeding boars.

Feeding of piglets

Pre-starter diet: This diet is introduced in the second week to fourth week of life. Special care is given for adequate supply of iron and lactose. Iron dextran injection is to be given on the 4^{th} and 14^{th} day of age to prevent piglet anemia.

E.g. for pre-starter diet : dried skim milk 40 %, ground maize 30 %, ground soya bean cake 10 %, fish meal 8 %, molasses 10 %, mineral mixture 1.5 %, common salt 0.5 %.

Starter diets: fed from 5^{th} week to weaning (6-8 weeks of age). By this age carbohydrate and protein utilizing enzymes are secreted in adequate quantity. The piglets are now capable of digesting starch, sugars and proteins efficiently due to which lactose rich ingredient like

skim milk powder can be safely replaced by energy rich cereal like maize, wheat, sorghum and rice etc.

E.g. for starter diet : ground maize - 38 %, ground wheat 30 %, fish meal 10 %, GNC-20%, mineral mixture 1.5 %, salt- 0.5 %.

Creep Ration

The high protein, high energy balanced diets fed inside the creep to sucking piglets is knows as creep rations. These include both pre starter and starter diets fed up to weaning. The practice of self feeding concentrates to young piglets in a separate enclosure away from their mother is known as creep feeding. It should be given when piglets are two weeks old and it is essential for sucking piglets for their faster growth, since mother's milk is unable to support the growth of piglets exclusively on milk.

Each active and healthy piglet consume about 10 Kg feed before reaching the age of 8 weeks and two third of this will be consumed between 6-8 weeks.

Feeding of Orphaned piglets

When a sow dies or fails to produce milk or does not claim her pigs, the piglets should be promptly shifted to a faster mother. Some sows may refuse to suckle alien piglets. Care should be taken to simulate the conditions including the odour and body size of piglets when admitted to a foster mother or another suckling sow. If a sucking sow is not available, hand feeding would be necessary. Cow's milk is the best substitute for sow milk. Butter milk or skim milk can also be used. Each piglet may consume 300-500 ml milk per day. Best result can be secured by feeding 5-6 times. Any standard vitamin preparation may be administrated to piglets until they start taking solid feed. Injectable iron preparation (E.g. Imferon) may also be given. A 60 watt electric bulb may provide enough warmth or the piglets during early days of life.

Feeding of growing and finishing pigs

The pig may be given complete feed that they can consume to attain maximum growth. They may be fed a fixed quantity twice or thrice a day. When the pigs are weaned, they should be switched from starter diet to grower diet. When the piglets grow about 35 kg body weight, they are offered lighter bulker finishing ration for lean carcass. These rations contain lower level of protein and energy. On an average the post weaning feed conversion efficiency till market is around 3.5-4. Under Indian conditions 70-80 kg is the optimum weight of slaughter for economic park production (in US & Europe it is 90-100 kg.)

In Indian conditions, three different types of grower and finisher diets are used for pigs reared under intensive system. These are

1. Cereal based diets
2. Grain less diets
3. Diets containing non-conventional feeds

E.g. of cereal based grower diet: Crushed mazie-50 %, crushed GNC -20 %, Wheat bean-10 %, Fish meal -8 %, Molasses- 10%, mineral mixture-1.5%, Salt-0.5%

E.g. of a grain less diet for growing pigs: Wheat bran -40 %, de-oiled rice bran-20 %, GNC – 15 %, Fish meal-8 %, Molasses-15 %, mineral mixture--1.5%, Salt-0.5%

E.g. of cereal based finisher diet: Crushed Maize-45 %, De-oiled GNC-10 %, Wheat bran -25 %, Fish meal 5%, Molasses-13%, mineral mixture--1.5%, Salt-0.5%

Gestation Ration

An excellent, well balanced diet is very important during gestation. Gilts have greater requirements than mature sows. During gestation period, gilts and sows are fed on restricted feeding (2-3 kg/day) without getting them over fat. A daily gain in weight of 0.25-0.3 kg throughout gestation period is satisfactory. Green leaves are to be included in their feeding. The ration for gestation females may be relatively coarse in structure. The gestation ration should contain 16 % CP

Farrowing Ration

It is considered a good practice to feed with bulky feeds from 4-5 days before and after farrowing by substituting wheat bran, oats, ground legume hay. At farrowing about 1/3rd of the ration may be made up of these bulky feeds. Adding bulk to the ration at farrowing will help to present constipation and reduce problems associated with mastitis metritis –agalatia (MMA).

Feeding of breeding Boar

A breeding boar daily requires 2-2.5 kg concentrate per 100 kg body weight depending on the age, condition and breeding demand. Feed allowances should be adjusted so that the pig is neither too fat nor too lean. Greens should be provide if kept in doors

Feeding of breeding sows

The demand resulting from pregnancy and need for conserving nutrients for the lactation are accelerated during the later third of pregnancy. There is an increased need for protein, vitamins and minerals. Mature sows gain 30-35 kg and gilts 40-45 kg during pregnancy. Feed should be so regulated that sows and guilt are neither too fat of thin. Individual feeding is preferred.

Flushing: Practice of conditioning or having the sows gain in weight just prior to breeding. The purpose of flushing is to increase the number of ova released during breeding period. Flushing is done 10-14 days prior to the expected date of breeding. Generally a high energy diet (2.5-3.5 kg/head/day), well balanced in minerals and vitamins is adequate.

Feeding of sows with litter/ Feeding of lactating sow

Feed the sows with bulky laxative feed immediately before and after farrowing. Bring the sow to full feeding in 10 days of period. Plenty of greens may be provided. The diets of lactating sows should contain about 15-16 % CP and 3200-3300 Kcal DE per kg of feed.

Feed allowances may be calculated as 2.5-3 kg /100k g BW along with additional amount of 0.2 kg feed per piglet sucking the dam. However, total diet should not be less than 3 kg daily. Thus a sow weighting 100 kg with 8 piglets should receive 4.6 kg feed per day. The piglet may be provided with a special nourishing diet called creep separately.

Miscellaneous feeds which can be fed to pigs

Swill (kitchen waste including left over of human food, vegetables, meat and fish cutting etc) composition and quantity vary so widely that it is difficult to indicate feeding values. It has been observed that pigs weighting 30 kg reached a body weight of 70 kg in 70 days when fed exclusively on kitchen wastes. Ensure that swill feed is not old and purified. On average 4-8 kg swill is needed per pig per day

Level incorporation of some unconventional feeds in swine ration

Item	Level of corporation (%)
Tapioca starch waste	15-20
Rubber seed cake	15
Tamarind seed roasted	20
Tea waste	20
Meat offal	20

NUTRIENT REQUIREMENTS AND FEEDING OF POULTRY

The term "poultry" includes a number of avian species such as chicken, duck, quail, turkey, geese, emu, ostrich, etc. domesticated for economic purposes. While chicken, duck and quail are raised for commercial egg and meat production, turkeys and guinea fowls are maintained only for meat production. Red jungle fowl found in India and neighboring countries is considered to be the progenitor of all domestic breeds of fowl.

Over all domestic poultry market size is estimated at Rs.47, 000 crores with broiler meat and table eggs contributing more than 95% of the market. Broiler meat market is estimated at Rs. 30,000 crores while table egg market size is Rs.15, 000 crores. Globally India ranks fourth in broiler meat production and third in table egg production (USA & China leads in both markets). The ICAR has established two poultry institutes viz. Central Avian Research Institute [CARI], Izatnagar and Project Directorate on Poultry [PDP], Hyderabad to provide necessary research training and extension support to the growing poultry industry.

Nutrient Requirements for Chicken Feeds

Nutrient requirements for various classes of poultry are published by Bureau of Indian Standards-BIS (2007), Nutrient requirements for poultry (9^{th} edition NRC, 1994) and ARC (UK). ICAR has also given nutrient requirements for poultry [ICAR, 2013]. The best method to express the requirements for animals is to express the requirements for animals is to express in amounts per day per animal. However, this is difficult in poultry as they are fed in groups. Therefore, the only alternative is to feed them diets containing all the nutrients in right proportions. The BIS specifications include a margin of safety (nutritional allowances) to allow for the nutrients lost during feed processing storage, digestion, etc. For majority of vitamins, usually twice the requirements are added as a margin of safety. In case of minerals, 20 to 30% of the minimum requirement is added as a safety margin. However, requirement figures of NRC and ARC are the minimum requirements established under experimental conditions and do not include margin of safety.

BIS (2007) specifications for various nutrients in the feeds of chicken

Chicken feeds shall of the following 15 types:

Broiler

a) Broiler Pre-Starter Feed: - for broiler chicks from 1 to 7 days.
b) Broiler Starter Feed: - for broiler growing chickens from 8 to 21 days.
c) Broiler Finisher Feed: - for broiler growing chickens from 22 day to finish.

Layer

d) Chick Feed for layer:-for larger chicks from 0 to 8 weeks.
e) Grower Feed for layer:- for layer growing chickens from 9 to 20 weeks or until laying commences.
f) Layer Feed for Phase I:- Ration to laying birds from 21 weeks to 45 weeks.

g) Layer Feed for Phase II:- Ration to laying birds from 46 weeks to 72 weeks. Phase I and II feed in layer cycle is necessary because there are changes in production, egg size, requirement of Ca, efficiency of digestion, age, etc.

Broiler Breeder

h) Breeder chick Feed for Broiler :- Ration to be fed to chicks intended for broiler breeding from 0 to 4 weeks.
i) Breeder grower Feed for Broiler:- Ration to chicks intended for broiler breeding from 5 to 22 weeks.
j) Breeder layer Feed for Broiler:- Ration to laying birds intended for broiler breeding from 23 weeks onwards.
k) Breeder Broiler Feed for male:- Ration to male birds, intended for broiler breeding from 23 weeks onwards.

Layer Breeder

l) Chick Feed for Layer Breeder:- Ration to be fed to chicks intended for layer breeding from 0 to 4 weeks.
m) Grower feed for Layer Breeder:- Ration for chickens for layer breeding from 5 to 22 weeks.
n) Breeder Layer Feed:- Ration to laying birds for layer breeding from 23 weeks onwards.
o) Breeder Layer Feed for Male:- Ration to male birds from 23 weeks onwards.

BIS (2007) specifications for various nutrients in the feeds of chicken

Table 1

Sl. No.	Characteristics	Broiler Feed			Layer Feed			
		Pre-Starter	Starter	Finisher	Chick	Grower	Layer Phase I	Layer Phase II
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i	Moisture percent by mass. Max	11.0	11.0	11.0	11.0	11.0	11.0	11.0
ii	Crude protein (N×6.25) percent by mass, Min	23.0	22.0	20.0	20.0	16.0	18.0	16.0
iii	Ether extract, percent by mass, Min	3.0	3.5	4.0	2.0	2.0	0.2	2.0
iv	Crude fibre, percent by mass, Max	5.0	5.0	5.0	7.0	9.0	9.0	10.0
v	Acid insoluble ash, percent by mass, Max	2.5	2.5	2.5	4.0	4.0	4.0	4.5
vi	Salt (as NaCl), percent by mass, Max	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Table 2

Sl. No.	Characteristics	Broiler Breeder Feed				Layer Breeder Feed			
		Chick	Grower	Layer	Male	Chick	Grower	Rom	Male
(1)	(2)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
i	Moisture percent by mass, Max	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
ii	Crude protein (N×6.25) percent by mass, Min	20.0	16.0	16.0	15.0	20.0	16.0	17.0	16.0
iii	Ether extract, percent by mass, Min	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0
iv	Crude fibre, percent by mass, Max	7.0	9.0	9.0	9.0	7.0	9.0	9.0	9.0
v	Acid insoluble ash, percent by mass, Max	4.0	4.0	4.0	4.0	2.5	2.5	2.5	2.5
vi	Salt (as NaCl), percent by mass, Max	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Table 3

Sl. No.	Characteristics	Broiler Feed			Layer Feed			
		Pre-Starter	Starter	Finisher	Chick	Grower	Layer Phase I	Layer Phase II
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i	Calcium (as Ca), percent by mass, Min	1.0	1.0	1.0	1.0	1.0	3.0	3.5
ii	Total phosphorus, percent by mass, Min	0.7	0.7	0.7	0.7	0.65	0.65	0.65
iii	Available phosphorus, percent by mass, Min	0.45	0.45	0.45	0.45	0.40	0.40	0.40
iv	Lysine, percent by mass, Min	1.3	1.2	1.0	1.0	0.7	0.7	0.65
v	Methionine, percent by mass, Min	0.5	0.5	0.45	0.40	0.35	0.35	0.30
vi	Methionine + Cystine, percent by mass, Min	0.9	0.9	0.85	0.70	0.60	0.60	0.55
vii	Metabolizable energy (Kcal/Kg), Min	3000	3100	3200	2800	2500	2600	2400
viii	Aflatoxin B1 (ppb), Max	20	20	20	20	20	20	20

Table 4

Sl. No.	Characteristics	Broiler Breeder Feed				Layer Breeder Feed			
		Chick	Grower	Layer	Male	Chick	Grower	Layer	Male
(1)	(2)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
i	Calcium (as Ca), percent by mass, Min	1.0	1.0	3.5	1.0	1.0	1.0	3.5	1.0
ii	Total phosphorus, percent by mass, Min	0.70	0.70	0.70	0.70	0.65	0.60	0.60	0.60
iii	Available phosphorus, percent by mass, Min	0.45	0.45	0.40	0.40	0.45	0.40	0.40	0.40
iv	Lysine, % by mass, Min	1.0	0.8	0.85	0.80	0.95	0.70	0.70	0.80
v	Methionine, percent by mass, Min	0.45	0.40	0.45	0.40	0.40	0.40	0.40	0.40
vi	Methionine + Cystine, percent by mass, Min	0.70	0.70	0.70	0.70	0.70	0.60	0.60	0.60
vii	Metabolizable energy (Kcal/Kg), Min	2800	2750	2800	2750	2800	2600	2600	2600
viii	Aflatoxin B1 (ppb), Max	20	20	20	20	20	20	20	20

ENERGY

In poultry feed, energy content is specified in terms of ME because determination of ME values of feeds is easier in poultry when compared to other species (since both faeces & urine are voided together as poultry excreta). Moreover, ME value of a feed ingredient is independent of other dietary component and it remains relatively constant regardless of age, type or nature of production of the bird. NRC (1994) gave the energy requirements in terms of nitrogen corrected ME (MEn).

Nitrogen-Corrected ME (MEn)

MEn is the ME corrected for nitrogen retained or lost from the body i.e., the ME value of a feed at zero nitrogen balance. All the computations are adjusted to a condition of zero nitrogen retention. True ME value always higher than nitrogen corrected ME value. In case of poultry for each gm nitrogen retained in the body 8.22 Kcal/g is subtracted to get MEn. A correction factor of 8.22 Kcal/g nitrogen retained

True ME for poultry feed = GE of feed ---- GE of excreta of feed origin

MEn = ME ---- (gm nitrogen retained per gm diet X 8.22)

Energy requirement for maintenance of layers

NEm requirement of adult hen = 83 BW $(kg)^{0.75}$ kcal/day

NE requirement for maintenance (NEm) is approximately 82% of the ME requirement for maintenance (MEm) in poultry.

Activity increment is 50% of the maintenance energy requirement in backyard poultry (or deep litter system) while it is 37% for caged birds

Energy requirement for egg production= 86 kcal/egg.

Energy for Growth

The energy for growth ranges from 1.5 to 3 kcal per gm of body gain. This depends upon the amount of fat in relation to protein in body gains. The energy requirements of growing cockerels are higher than that of pullets.

Growth rates, basal metabolism, type of tissue deposited and efficiency of a feed utilization are determined to a certain extent by the level of various hormone secretions esp. growth hormone, thyroxine and sex hormone.

PROTEINS AND AMINO ACIDS

The total protein requirement for poultry can be met easily. However, it is difficult to meet the requirement of essential amino acids. Ideal protein concept is followed and ideal ratios of essential amino acids to lysine are developed

Ideal protein: It is a modification of chemical score. Quality of protein decided by the amino acids which is in greatest deficit when compared with a standard, with the amino acid pattern of the tissue protein serving as reference pattern. A protein which contains a perfect balance of amino acids, both among the essential amino acids and between the essential. amino acids and non essential amino acids has been described as Ideal Protein.

Essential amino acids for poultry:- Essential amino acids are 10 in number. Apart from 10 essential amino acids, the amino acids glycine is also dietary essential for poultry since it is needed for the biosynthesis of uric acid. Certain amount of glycine synthesized from creatine and serine.

Cysteine and tyrosine are semi essential amino acids, which can be obtained from methionine and phenylalanine respectively. The amino acids serine can be obtained from glycine. Arginine is essential for poultry and yields urea and ornithine on metabolism. [Ornithine and glycine are for detoxification of aromatic compounds in liver.]

The amino acids those are critical in the common diets for poultry includes methionine, lysine, arginine, threonine and tryptophan. Methionine and lysine are considered to be the first and second limiting amino acids in practical poultry diets. The amino acid in a feed that is most deficient relative to the bird's requirement is referred to as the first limiting amino acids. Inclusion of Soybean meal [rich in lysine], gingelly oil cake [rich in methionine] or animal protein supplements like fish meal [rich in lysine and methionine] can prevent the deficiency of those amino acids in poultry diets. Groundnut cake is rich in arginine and deficiency of arginine in poultry diets can be prevented by including ground nut cake. Threonine is limiting amino acids in sorghum, wheat, etc. The needed amino acids can be

supplemented in practical diets [eg:-synthetic L-Lysine and DL-methionine. Excess of amino acids like methionine and threonine is toxic as they can cause growth depression in chicks.

Supplementary action between different proteins

Blood meal and maize gluten meal:- Blood meal is rich in lysine and tryptophan but deficient in isoleucine. While maize gluten meal is deficient in lysine and tryptophan but rich in isoleucine. One part of blood meal to 4 parts of corn gluten meal mixture is more effective in promoting chick growth.

Soybean and sesame meal:- Soybean meal is rich in lysine but less in methionine while sesame meal (Gingelly oil cake) is deficient in lysine but rich in methionine.

Factors affecting amino acids requirement

1) Energy content of the diet: As the energy content of diet increases the requirement of all essential amino acids also increases.
2) Content of polyunsaturated fats: Polyunsaturated fats upon peroxidation produce aldehydes which may bind with lysine.
3) Raw soybeans cause hypertrophy of pancreas: The increased production of trypsinogen (it is high in methionine) increases dietary methionine requirement.
4) Lasalocid (a coccdiostat) reduced the sulfur amino acids requirement by 0.1%.
5) Excessive levels of one or more of the essential amino acids will increase the requirement of first limiting amino acids.

$$\text{Calorie-Protein Ratio} = \frac{\text{ME/Kg feed}}{\%\ \text{CP feed}}$$

Calorie-Protein Ratio is defined as the metabolizable energy (kcal per kg feed) divided by the % of CP in the ration. The ratio varies with age of the bird. Calorie-Protein Ratio is of paramount important in poultry and swine for efficient feed utilization.

Calorie-Protein Ratio for various categories of birds.

Sl No.	Type	Calorie-Protein Ratio
1)	Broiler starter feed	122
2)	Broiler finisher feed	145
3)	Chick feed	130
4)	Growing chicken feed	156
5)	Laying chicken feed	144

Protein Requirements of Chicken

1. Daily protein requirement for a growing chicken

= [(Body wt (g) X 1.6/1000) + (Daily gain in gm X 0.18) + (Daily gain (gm) X 0.07 X 0.82] / % efficiency of protein utilization

Maintenance requirement of protein for a grower = 1.6 gm protein per kg BW per day

Tissue growth - Tissue contains 18% protein

Feather growth: Feathers contain 82% protein and feathers comprise 7% of BW at fourth weeks of age

Growing white leghorn chicken has 61 % of efficiency of protein utilization.

2. Protein requirement for egg production:

Maintenance requirement of protein for white leghorn hen = 3 gm/day

Protein content in one egg = 6 gm /day

Total requirement of protein = 3 + 6 = 9 gm/day

Efficiency of protein utilization for maintenance and egg production=55%

The protein requirement of the hen= $9\times\frac{100}{55}$ = 16.36g/day.

Feed Consumption

On an average a layer consumes 110 gm feed per day or 1.8 to 2 kg feed per dozen of egg layed. The total feed consumption during the entire laying period is about 44 kg. Broilers consume about 3 to 4 kg feed during their entire life period of 6 to 8 weeks.

Importance of feeding during different physiological stages

Feed requires a special consideration since it represents nearly 65-70% of the cost of production of meat and eggs. The cost of producing a dozen egg or a kg of meat is the true criterion for evaluating a diet.

During embryonic development, only half of the ME present in the egg is utilized. The remaining half is adequate to meet the requirement of the hatched chicks for 60-70 hours. However, it is recommended that chicks should be provided their first feed as soon as possible without waiting for absorption of yolk.

Physical form of the Diet

Feed may in the form of mash or pellet. Pelleting and crumbling will result in less feed wastage. Crumbled feeds are ideal for chicks and broilers. The mash feed for poultry should have a gritty feeling and it should not be either too fine or too course.

Free choice or Cafeteria system:- If birds are given a chance to select their own feed (feed ingredients are made available separately), it is believed that a hen can balance her ration, if given the opportunity.

Feeding of Broilers

The growth of bird depends upon the level of balanced protein in their diet along with other nutrients. In the absence of optimum level of protein and amino acids, the growth is retarded and birds may need a longer time to reach the marketable weight. High protein diets are fed during the pre-starter phases. Feeding of high protein pre-starter diet is beneficial since it gives a stimulus for early growth of broilers and it does not cost much because of very small intake during the first week.

Enhancement of energy level of the diet in the finishing stage, accompanied with a decrease in protein content cause the broiler chicken to consume more calories than it can use for growth. This excess energy will be converted into body fat, there by producing the desired body finish for the market broiler.

Feeding of the Growers

Nutrition of growers (8 to 20 weeks) is critical as it influences their age at sexual maturity, size of the pullet eggs and overall performance of the bird in the layer house. Sometimes, it is desired to delay the sexual maturity of growing pullets to obtain uniform sized eggs and to avoid management problems incidental to laying. This is achieved by altering the lighting programme in the grower house and restricting the feed intake.

Restricted Feeding

Restricted feeding of bird means an actual reduction of nutrient intake below the minimum requirement of birds. Feed intake is reduced either by limiting the feed offered to 85-90 % of normal feed intake or by diluting the conventional feed with fibrous material of low nutrient density or following a skip-a-day feeding. In the skip-a-feeding, feed is provided on every alternate day or by skip feeding one day per week.

Feed restriction is generally practiced in broiler breeders to check their weight gain, since excess of weight gain in breeders affects fertility and egg production. In layers feed restriction during growing period (12-20 weeks) causes a reduction in the number of under sized eggs which are generally laid at the commencement of egg production. In layers feed restriction can be recommended until 22 weeks of age or up to 5 % egg production level.

Voluntary Feed Intake

Voluntary feed intake is the amount of feed that a bird consumes when it has unlimited access to diet. Voluntary feed intake of birds reflects the quality of feed, health of the flock and management of farm. The mechanisms controlling appetite are complex. However, the overall control of feed intake is influenced by hypothalamus in the base of brain. The current hypotheses related to voluntary feed intake are:

1) Thermostatic theory:- The heat produced after feed consumed causes the temperature of blood and hypothalamus, so that the desire to eat is lessened. This theory explains why birds eat less at high ambient temperature.
2) Glucostatic theory:- This theory proposes that there are glucose receptors in the hypothalamus which are sensitive to the rate at which glucose is utilized by them. Low utilization rates leads to huger sensation.
3) Lipostatic theory:- The hypothalamus is sensitive to concentrations of circulating metabolities mobilized from endogenous fat stores. Since the amount of fat mobilized is proportioned to the size of fat deposits, a lipostatic mechanism keeps the body fat content constant and control the body weight.

However none of the above hypothesis describes adequately the observed feed intake behavior.

Factors influencing voluntary feed intake

The most important factors that affect feed intake are the characteristics of bird, quality of feed and the environment.

Characteristics of Bird:- The characteristics of bird that influence feed intake are body weight, rate of live weight gain and output of eggs. Heavy birds consume more feed than light birds. Birds that grow faster than the average normally consume more feed than the average. A 1% increase in egg production is associated with a 2% increase in feed intake. Laying birds consume 20% more feed on egg forming days than days when eggs are not formed.

Dietary factors:- An increase in dietary energy results in a decrease in intake. If the diet is deficient is one or more essential nutrients, appetite is depressed and the growth or reproductive performance is affected.

Environmental factors:- Light intensity and day length have some effect on voluntary feed intake. Longer days stimulate egg production and encourage hens to consume more feed. In case of chicks, maximum feed intake and growth rate are obtained when they are reared in continues light. With broilers too much light may increase activity and reduce efficiency of feed utilization.

Calcium for growing pullets

Additional calcium may be given when 5% of pullets come to lay. Feeding a diet containing high calcium just before the onset of laying help the birds to store calcium in the medullary bones which can be used for subsequent eggshell formation. A ratio of 2 calcium to 1 nonphytate phosphorus is approximate for most poultry diets, except for layer birds where it is as high as 6%. An excess of dietary Ca interfere with availability of other minerals such as P,Mg,Mn and Zn.]

Calcium for layers

Layer rations should be adequate in calcium and the minimum recommended level of inclusion is 3 % for phase I layer and 3.5 % for phase II layer. A part of the dietary Ca may be fed as oyster shell or limestone chips for better shell quality. The requirement for Ca is more in the afternoon hours of the day (egg will be in shell gland during the period)

An average egg contains 2-2.2 gm of Ca. Birds retain only about 50 % of the ingested Ca. Medullary bones act as reserves for Ca in birds. During peak egg production, whenever there is a depletion of medullary bone reserves the bird utilizes cortical bone as a source of Ca for the egg shell formation.

Phase feeding in layers

Phase feeding refers to changes in the protein level of laying diet during the normal production cycle. Such changes are designed to regulate the intake of dietary protein to meet the hen's requirements at various stages of egg production. Phase feeding programme is suggested to reduce feed cost and also to maintain the egg size. The suggested level of protein in layer diets at different stages of egg production is given below.

% of egg production	Level of protein in ration %
100	18
90	17
75-90	16
65-75	15

Influence of diet on egg size, egg yolk colour and broiler skin colour

Egg size is largely depend upon the level of dietary protein and level of linoleic acid. A level of 1% linoleic acid in the diet is optimum for maximum egg size.

Pigment xanthophyl present in feeds (eg:-Zeaxanthin in yellow maize, lutein in alfalfa meal) imparts yellow colour to skin and egg yolk.

Diet related abnormalities

Thin shelled eggs: a deficiency of calcium or deficiency of vitamin D will result in the production of thin shelled eggs. Manganese deficiency causes thinning of egg shell and characteristic alteration in shell texture and appearance. Copper appears to be required for the synthesis of egg shell membranes and hence its deficiency results in enlarged and misshapen eggs with wrinkled shells.

Cage layer fatigue: recommended level of calcium in layer diets is 3-3.5%. This is obtained by adding sufficient quantity of oyster shell or lime stone chips in layer diets. An average egg

contains 2-2.2 g of calcium. Birds retain only about 50% of the ingested calcium. Medullary bones act as reserves for calcium in birds. During peak egg production, whenever, there is a depletion of medullary bone reserves, the bird utilizes cortical bone as a source of calcium for the egg shell formation. This results in the fracture of the vertebrae and subsequently affects the spinal cord. This condition is referred to as cage layer fatigue (CLF), because it is common in caged birds and is rarely seen in birds reared under deep litter system. Reduced activity or exercise may act as a predisposing cause for this condition. The condition can be prevented by ensuring the attainment of normal body weight of pullets at sexual maturity and by providing adequate amount of calcium (3.5%) in diets of pullets at least two weeks prior to first oviposition.

Fatty liver and kidney syndrome (FLKS): the disease occurs in young broilers (2-4 week old) fed biotin deficient diet (wheat based). Biotin is needed for the functioning of the enzyme pyruvate carboxylase involved in hepatic gluconeogenesis. Death occurs due to hypoglycemia.

Fatty liver haemorrhagic syndrome (FLHS): the disease occurs in layers and breeders fed high energy diets low in protein or fed rations with amino acid imbalance/ deficiency. Diets low in lipotropic factors (e.g. choline, methionine and vitamin B_{12}); high content of mycotoxins and antinutritional factors (e.g. glucosinolates in rape seed meal) may predispose the condition. The disease is due to increased accumulation of fat in the liver.

Blood spots in eggs*:* the major nutritional factor behind blood spot formation in eggs is vitamin A deficiency. Although blood spots do not adversely affect the nutritional value of eggs they are objectionable to consumers.

Discolouration of eggs*:* there will be pink discolouration of egg white when birds are fed with cotton seed oil. It is caused by cyclopropane fatty acids (malvalic acid & sterculic acid) present in the cotton seed oil. Gossypol the antinutritional factor present in cotton seed cake can cause bluish green discolouration of yolks along with severe mottling.

Undesirable flavor*:* certain feeds stuffs, such as onions, rape seed, mustard, flax seed, turnips and some fish meals are reported to cause undesirable flavor to meat and egg when fed in sufficient quantity. Rapeseed and mustard contains erucic acid which causes accumulation of fat in the heart muscles. Off flavor in eggs from birds fed flax seed is due to trimethylamine. Polyunsaturated fatty acids present in fish meal imparts fishy flavor to meat and eggs.

Oily or greasy bird syndrome: characterized by oily appearance of broiler carcass and a tender skin which is easily torn during processing. One of the causes of this syndrome is the use of fat supplements with higher contents of PUFA.

Scabby hip dermatitis: characterised by poor feathering and scabby areas around feather follicles particularly on hips. This condition is reported to be caused by molybdenum deficiency and feeding with diets containing monensin (coccidiostat).

Cannibalism and feather picking: chicken diet should contain 0.5- 0.6%, common salt and 3-4% crude fibre. Deficiency of salt and fibre may results in cannibalism and feather picking in poultry flocks. Methionine deficiency may also lead to feather picking.

Salt poisoning: the safe upper limit of salts in drinking water is 3000 ppm. Water containing 1.5% salt is toxic for layers. Turkeys and ducks are more susceptible to salt poisoning than chicken.

Disease/ abnormality	Cause
Rickets	Deficiency or imbalance of calcium, phosphorus and vitamin D
Swollen hock syndrome, parakeratosis and frizzled feathers	Deficiency of zinc
Bowed legs in duck, hock enlargement in chicks, ducklings, poult and goosling	Deficiency of Niacin
Perosis/ slipped tendon	Deficiency of manganese/ choline/ biotin/ folic acid/ vitamin B_{12}
Shortening and thickening of leg bones in chicks	Deficiency of zinc/ manganese
Curled toe paralysis in chicks	Deficiency of riboflavin
Clubbed down condition of chick embryo	Deficiency of riboflavin
Penguin like squat (due to leg weakness in hen)	Deficiency of vitamin D
Gizzard myopathy in turkey poults	Deficiency of vitamin E or selenium
Muscular dystrophy in chicks, ducks, poults	Deficiency of vitamin E or selenium
Nutritional encephalomalacia/ crazy chick disease	Deficiency of vitamin E
Polyneuritis	Deficiency of thiamin
Cervical paralysis in poults and quail	Deficiency of folic acid
Dermatitis (scabs and crusts around eyes, beaks, vent and upper surface of feet)	Deficiency of pantothenic acid
Ulcerated foot pad dermatitis (haemorrhagic cracks and necrotic toes)	Deficiency of biotin
Parrot beak (crooked beak) condition in chick embryo	Deficiency of biotin
Nutritional chondrodystrophy in embryonic chicks characterized by shortening of lower mandible (parrot beak)	Deficiency of manganese
Inflammation of mouth cavity and tongue	Deficiency of niacin
Macrocytic anaemia	Deficiency of folic acid
Microcytic hypochromic anaemia	Deficiency of iron/ copper

Dissecting aneurysm of aorta/ enlarged heart in chicks and poults	Deficiency of copper
Fatty liver	Deficiency of choline
Nutritional roup	Deficiency of vitamin A
Pancreatic hypertrophy in chicken	Feeding of raw soybean (trypsin inhibitor)
Reduced feed intake, reduced growth, lack of vigour, uneven feather growth	Protein deficiency/ amino acid imbalance
Hemorrhages	Deficiency of vitamin K
Hyper excitability and convulsions	Deficiency of pyridoxine
Hyperirritability	Deficiency of magnesium
Depigmentation in turkeys	Deficiency of selenium

Dietary Fatty Acids and Body Fat

The composition of body fats can be influenced by dietary fatty acids in monogastrics and birds. Cotton seed oil, rape seed oil and fish oil can impart undesirable colour and flavor to meet eggs. Cotton seed oil has two cyclopropenoid FA (sterculic acid and malvalic acid) which cause a salmon coloration of the yolk [FA incorporated into yolk membranes. On storage yolk membranes become permeable to albumin]. Some iron also diffuses out of the yolk to give pink albumen. Cycloproprenoids increases the deposition of stearic acid and palmitic acid in fat depots (as the desaturuse enzymes are inhibited). The amount of stearic acid also increases in egg yolk and on refrigeration yolk becomes rubbery like balls. Residual gossypol present in some oils can give an olive colour to yolks. Off flavour in eggs is observed in birds fed with flaxseed/linseed (due to frimethyl amine). Rapeseeds contain Erucic acid, which cause accumulation of fat in heart muscles. .Fish oils present in poultry diets tend to impart a fishy flavor to meat and eggs because they are rich in poly unsaturated FA.

Effect of Diet on egg hatchability

A marked efficiency of any one or more of the nutrients such as Calcium, Mn, protein, Vit A, Vit D, riboflavin and choline in practical diets causes a reduction of even a cessation of egg production. Riboflavin deficiency results in poor hatchability and is reflected in clubbed down embryos. Biotin deficiency is reflected in parrot beaks (Crooked beaks) in embryo. Pantothenic acid deficiency shows un hatched embryos suffering from subcutaneous haemerrages. Mn deficiency in the diet of breeding hen causes a condition in embryonic chicks known as nutritional chondrodystrophy. Parrot beak (disproportionate shortening of lower mandible) is also seen. In case of Zn deficiency, absence of legs and wings are noticed in embryos and down feather may appear tufted steps in.

Feed formulation in chicken

Information of feed ingredients and nutritive value of common poultry feed ingredients;

Ingredients	ME (Kcal/Kg)	CP (%)
Yellow Maize	3300	9
White Jowar	3200	10
Broken Rice	2900	8.5
Wheat	3000	10
Ragi	2800	9
Oil or Fat	8000	-
DORB	2200	13
Rice polish	3100	12
Wheat bran	2000	15
SBM	2500	45
GNC-SE	2400	42
Fish meal	2400	42
Coconut cake	1500	22

Maximum level of inclusion of feed ingredients:- Each ingredients has its maximum level of inclusion to obtain optimum performance. This is dictated by the presence of anti nutritional/toxic factors, cost of the ingredients, difficulty in feed formulation, proper storage and shelf life of the feed its capacity to induce imbalance of nutrients and reduce the performance of bird.

Maximum level of inclusion of some common poultry feed stuffs:

Feed Ingredient	%
Maize	60
Sorghem white	30-40
Bajra, Ragi, Rice bran, DORB, Sunflower cake	10-20
Wheat	50
Wheat bran	10-15
GNC	10-30
SBM	40
Cotton seed cake	0-10
Coconut cake	5-10
Fish meal	5-10

Availability and cost of feed ingredients

Steps in feed formulation

- ✓ Fix minor ingredients and slack space (5Kg).These include nutrients and non nutrient feed additives and natural feed ingredients that are added at a later stage to balance the diet.
- ✓ Levels of Animal Protein Sources(10 Kg). Since they are rich in limiting AA.
- ✓ The levels of cereal byproducts may be fixed.
- ✓ Balance the protein requirement:- Vegetable protein sources and energy sources are added to provide the required amount of protein.
- ✓ Balancing the ME content of the diet:- By supplementation of either animal fat/ vegetable oil or maize grain depending on the cost and availability.
- ✓ Balance the Ca and P content:- Available P has to be considered. P content of BORB, maize and GNC is only 30% available. P content from animal proteins and inorganic sources is completely available.

Common Sources of Ca and P

Source	**Ca**	**P**
Calciate	34	-
CaCO3, Limestone	36-38	-
DCP	21	18.5
Monosodium phosphate	-	22.5

- ✓ The Na content usually is not calculated and 0.5% addition of common salts meet the requirement.
- ✓ Balancing the limiting AA in the diet:- Supplement synthetic AA if needed.
- ✓ Balancing the crude fibre content of the diet.

Instead of a single cereal and single vegetable protein supplement a combine of cereals and other energy sources and a combination of protein supplement may be used to reduce the cost of diet.

Vitamins A, D_3, E ,K, B_2 and Choline Chloride are necessarily added. Toxin binder and preservatives can also be added.

Feeding during hot weather/Summer management in birds

During hot weather, birds of all types require less energy to maintain body temperature. When the environment temperature raises birds of all types and ages consume 1-1.5% less feed per each $1^{\circ}C$ raise in temperature between 20 and 30°C. The egg production, egg size and shell weight is lowered during this period. The birds receive less protein,

vitamins and minerals and therefore, the density of nutrients (energy, essential amino acids, (Not CP), Ca, P) in the ration has to be increased to compensate for the reduction in feed intake. Low protein diets increase the tolerance of birds to elevated environmental temperature. (Utilization of protein is associated with more heat production than carbohydrates and fats). Avoid fibrous ingredients in the diet and provide fat to provide energy. Addition of electrolytes, Vit C (50-200 mg/Kg diet) and probiotics in drinking water helps to alleviate the hot stress feed during cool hours of the days. Provide plenty of clean, cool drinking water at all time. Crushed ice may be provided in water of possible.

Feeding of Ducks (*Anas platyrhynchos*)

Ducks are comparatively hardier than chicken and are easily manageable. Khaki Campbell ducks (250-300 eggs/year) are kept for egg production while White Pekin (broiler duck) and Muscovy (flying duck) are used for meat purpose. Vigova Super M is a meat type duck produced at Central Duck Breeding Farm, Hessarghatta, Bangalore. Local ducks of Kerala viz. Kuttanad ducks include Chara and Chemballi.

Ducks may be grown on dry mash, a combination of dry and wet mash or pellets. Feeding of ducks in rural India is mostly done under range systems. Ducks prefer wet mash due to difficulties in swallowing dry mash. However, ducks prefer pellets to mash feed when give a choice. Ducks are good foragers. They feed on fingerlings, snails, earthworms, insects and vegetation apart from compounded feeds. The use of range, pond or supplementary green feed reduces the feed cost. Ducks should never have access to feed without water. During the first 8 weeks birds should always have access t feed, but later on they may be fed twice a day 9Morning and afternoon).

Compounded feed containing 20, 18 and 16 % CP is recommended for ducks for the period from 0-2, 2-4 and 4-7 weeks respectively. NRC (1994) specifies a feed containing 22% protein and 2900 Kcal ME/Kg feed for the period of 0-2 weeks, 16% protein and 3000 Kcal ME/Kg feed for the period 2-7 weeks and 16% protein and 2900 Kcal ME/Kg feed for the breeding ducks. Adult laying ducks consumes 170-230 g feed/day. Nutritional requirements of ducks differ considerably from those of chicken and ducks are less affected by dietary bulks than chicken; hence some lower cost feed ingredients can be used at fairly high levels in duck feeds.

Aflatoxin poisoning in duck

Ducks are very much susceptible to aflatoxin while guinea fowls and chickens are the most tolerant. Ducks can tolerate only 3-10 ppb in feed as and 20 ppb in chicken. Aflatoxin B1 is more toxic to ducks than Aflatoxin M1. Ducks contain very high level of enzyme in liver to convert Aflatoxin B1 to Aflatoxicol.

The B complex vitamin, niacin feeds is very much essential for ducks because they cannot convert tryptophan to niacin. Therefore, feeds slightly deficient in niacin cause bowed leg condition and weakness in ducks. Niacin requirement for duck is 55 mg/kg diet.

Feeding of Japanese Quail [*Coturnix coturnix japonica*]

Japanese quail is a small sized domesticated bird reared for meat and egg. They multiply fast and produce 3-4 generators per year. It is ready to market for meat purpose at 4-5 weeks of age. In a year 250-300 egg are produced with an average egg weight of 9-10 g. Quail start lay from 6th week. They need more protein and AA in feed as they grow very fast. Therefore feed specially made for quails has to be provided. In addition, the size of feed particles has to be finer for birds up to 2 weeks, as Japanese quail chicks are very small quails are fed with a starter diet upto 3 weeks, a grower diet from 3-6 weeks and a layer ration after 6 weeks of age. A quail chick will take about 500-600gm feed upto 6 weeks of age. After 6th week, it takes 25-30 gm of feed per day.

Category	**CP %**	**ME (Kcal/Kg)**
Starter 0-3 weeks	27	2800
Grower 3-6 weeks	24	2800
Layer (above 6 weeks)	22	2900

Feeding of Turkey (*Meleagris gallopavo*)

Turkeys are kept mainly for meat. Broad Breasted Bronze, Broad Breasted Large White and Bettsville Small White varieties are common in India. The average age at first egg is around 30 weeks. Average egg production is 100 eggs/hen turkey/year. Eggs of a normal turkey weight around 75-80 g. Turkey meat has lowest fat content of all avian species. It is rich in unsaturated fatty acids, essential AA especially tryptophan and vitamins like Vit B6 and Vit B12.

Nutritional requirement of turkeys differ from that of chicken. Turkeys require more protein, minerals and vitamins than chicken to meet the fast growth. Turkey rations are costlier than chicken rations.

Nutritional Requirements of Turkeys (NRC)

Male	0-4 wk	4-8wk	8-12 wk	12-16 wk	16-20 wk	20-24 wk	Adult Breeder
Female	0-4 wk	4-8 wk	8-11 wk	11-14 wk	14-17 wk	17-20 wk	Adult Breeder
ME/Kg diet	2800	2900	3000	3100	3200	3300	2900
Protein (%)	28	26	22	19	16	14	14

However, instead of NRC diets, turkey can also be reared under BIS broiler feed. A broiler starter diet can be given to turkeys up to 16 weeks of age and broiler finisher diet

thereafter. Turkeys requirement especially for Vit A, Vit D, niacin and choline is higher than for the chicken.

Feeding of Geese (*Anser anser*)

Geese are grazers and can be raised almost exclusively on pasture. Birds provide meat, eggs, fat and feathers. Goose varieties include African, Sebastopol, Embden and Toulouse. The meat is lean, flavorful and of good quality. Gooslings grow rapidly and can reach market size as early as 10-12 weeks. However most gooses are marketed at 20-30 weeks of age, when they weigh from 5 to 7 kg. If managed properly goosling can produce 1kg of BW for every 2.25-3.5 kg of concentrated feed consumed.

NRC (1994) Standard of Goose

Nutrient	**0-4 weeks of age**	**>4 weeks age**	**Breeding**
ME (Kcal/kg)	2900	3000	2900
Protein (%)	20	15	15

Feeding of Emu

Ratite birds include emu, ostrich, rhea, cassowary and kiwi. Emu is reared commercially for their oil, meat, skin and feathers. The birds can be well maintained on extensive and semi intensive rearing systems with reasonably high fibrous diets [weight of adult bird 45-60 kg, height 6 feet] Emu chick weigh about 370-450g depending on the size of egg. Feed starter mash for first 14 weeks or till attaining standard body weight of 10 kg. Feed birds on grower mash upto 34 weeks of age or 25 kg body weight. Offer greens to about 10% of diet. Offer finisher ration from 35 weeks of age to slaughter or upto 12-18 months age. FCR at the time of finisher/fattening stage is 5:1. Bird's yield 53% dressed meat and 3-4 litre of fat. Inclusion of vegetable fat at 3-5% in Emu diet will fetch better FCR. Feed can be prepared by using common poultry feed ingredients. Natural foods of emu include insects, tender leaves of plant and forages on different grasses; eat different kinds of vegetables and fruits like carrot, cucumber, papaya, etc. Feed alone accounts for 60-70% of the production cost. Feed the breeder ration with sufficient calcium (2.7%) for ensuring proper calcification of egg. In commercial farms, feed intake per emu breeding pair per annum varied from 394-632 kg with a mean of 527 kg.

RABBIT NUTRITION

Scientific name: *Ornictolagus cuniculus*

In Kerala, rabbits are mainly reared for meat. Many people also rear them as pet animals and very rarely some people rear them for wool.

The most common breeds of rabbits seen in Kerala

1) **Soviet Chinchilla**
   Origin: Erstwhile Soviet Union
   Grey in colour
2) **New Zealand White**
   Origin: New Zealand
   White in colour with pink eyes. Comparatively short, soft and smooth hair than Soviet Chinchilla.

   Both these breeds are reared for meat. Also, New Zealand white is the most preferred breed to be reared as pet animals because of its lovable appearance (white colour, soft and smooth skin and pink eyes), which is especially liked by children.

Other breeds reared in Kerala, even though, not very common are:

1) **White Giant**
   Native of New Zealand.
   White colour and pink eyes similar to New Zealand White. Difference is that, White Giant is comparatively larger than New Zealand White.
2) **Grey Giant**
   Native of erstwhile Soviet Union. Grey in colour. Its fur is similar to that of the hare and is often mistaken for the hare.
   NB:- Hares are born fully haired and can run within a few minutes of birth.
3) **German Angora**
   Native of erstwhile Unified Germany. It is white in colour. It is a breed of rabbit which is reared mainly for its wool.
4) **Cross Breeds**
   These are the rabbits obtained by the cross breeding of any of the exotic breeds of rabbits described above, with the local varieties. They are found to be highly adaptive to Kerala conditions. Colour of the fur is not uniform.

Rabbits are also used as experimental animals in biomedical research.

Common terms associated with rabbits:

Rabbitry: is the term give to a rabbit unit.

Kit: Young one of a rabbit whose eyes are not opened (start by 10 days or within 15 days) (Hair starts developing by 4^{th} day)

Bunny: Young rabbit above 6 weeks (1 ½ months- Weaning age) and below 20 weeks (5 months of age).

Kindling: Act of parturition / giving birth in rabbits.

Buck: Adult breeding male rabbit.

Doe: Adult breeding female rabbit.

Some attributes of rabbit which make it a species of livestock suited for efficient food production:

1) Rabbits can be fed with high forage, low grain diet that are largely non- competitive with human food.
2) Rabbits have a high (better) feed conversion efficiency (2.5-3 on high grain diet and 3.5-4 on high forage, grain free diet).
3) They have a high growth rate (40-45 g/day), attaining market weight of about 2 kg at 12 weeks of age.
4) High reproductive potential:
   a) Rabbits have the potential of being in a constant state of reproduction ie. The ovulation is induced- it occurs 10-13 hours after mating => induced/reflex ovulation.
   b) Does can be rebred within 2-3 days after meaning of the kits.
   Gestation period is 30 days (28-32)
   c) Milk feeding period (from birth of kits to weaning) is 6 weeks= 1 ½ months
   Therefore, a single female rabbit can produce as many as 5 kindlings / year.
   c) High proliferation: average litter size is 6-8 (7).
   Therefore, nearly 35 kits can be produced from a single female rabbit/year
   d) Average birth weight of kits= 40 - 45 g
   e) Average weight of an adult rabbit=4 - 4.5 kg
5) Rabbit meat is a high quality, nutritious product. It is low in fat and cholesterol and it can be consumed even by men and women for whom, red meat of cattle, sheep and goat are not recommended because of cardiac problems.
6) Rabbits are suited to both small scale (backyard) and large scale commercial farming.

Lifting of Rabbits

Rabbits should never be lifted by the ears. They should be lifted by the skin behind the ears – the scruff. The rabbit is then held and supported by placing the other hand under the hind quarters.

Susceptibility to heat stress

Rabbits are susceptible to heat stress as they do not have sweat glands. Therefore, the optimum temperature inside the rabbitry should be 30 to 32ºC.

Housing of adult rabbits

The adult rabbit can be housed in a cage of 60 x 60 x 45 cm. The cages can be made of wood, bamboo or welded mash. If welded wire mesh is used, the space between adjacent wire meshes should be 1 cm on the bottom (or else kits will fall down) and 2.5 cm on the other 3 sides of the cage. The cages should be kept at a height of 90 cm from the ground.

For mating always take the male rabbit into the cage of the female rabbit. If the reverse occurs, the female will be restless in the unaccustomed surroundings and may not allow the male to mate.

Housing of Bunnies

Young rabbits after weaning may be housed together. About 20 bunnies can be housed in a pen of 1.5 m length, 1.2 m breadth and 0.5 m height.

Once rabbits attain puberty (5-6 months), they may be housed singly, especially the adult males. If they are kept together they will fight and get injured.

Nest Boxes

In the cage of the adult female rabbit, a nest box of 50 x 30 x15 cm has to be kept, before 5 days of the expected date of parturition. Nest boxes can be made out of wood. As parturition approaches (within 24-48 hrs), the female rabbit goes into the nest box, plucks it hairs and puts them into the nest box and thereby prepares a nice bedding. When kindling occurs, the kits are born into this bedding provided by the mother in the nest box. It is advisable to have a wire mesh bottom for the nest box to provide sufficient drainage for the urine and faces of the kits.

Feeders and waters

Feeders are generally made out of aluminium or galvanized iron sheets. Feeders are designed in such a way that they can be attached to the front panel of the cage and can be filled from outside, without opening the door of the cage. Bottle watering system using empty glass glucose bottles and iron pipes of half inch dia. is commonly adopted.

Peculiarities in the digestion and metabolism of rabbits

Rabbit is a non ruminant herbivore. It is a bind gut fermenter ie. the fermentation take place mainly in the large intestine. Of the parts of the large intestine, caecum is the major site of microbial fermentation ie. Micro organisms ferment the nutrients reaching the caecum.

The rabbit produces two types of faeces, viz. soft faeces and hard faeces. Separation of digesta on the basis of particle size occurs in the hind gut. Peristaltic action rapidly moves large particles, primarily lignin and cellulose, through the colon and excretes them as hard faecal pellets. Anti peristaltic action moves small particles and solubles into the caecum, where they undergo fermentation.

At intervals, the caecal contents are expelled as “soft faeces” and are consumed directly by the rabbit without mastication, as soon as they are voided out through the anus. The reingested material provides microbial proteins, vitamins, especially B complex vitamins and small quantities of VFA (VFA are absorbed in the caecum and large intestine). However, it should be noted that the amino acids provided by microbial protein make only a minor contribution and the diet must supply the additional amino acids.

Coprophagy / Caecotrophy / Refection

Coprophagy is the practice of eating the soft green faecal pellets produced in the caecum. This practice is seen in domestic rabbits from as early as 3 weeks of age. This occurs mainly during the dawn hours and also during night. Rabbits have a very strong physiological urge to carry out coprophagy. This practice is sometimes known as pseudorumination also. Caecotrophy is a very important part of the rabbit’s digestive process. It recycles some unabsorbed nutrients as well as returning protein (Caecotrophs / soft faeces contain nearly 3 times the amount of protein than the hard faecal pellets) and vitamin B rich bacteria for enzymatic digestion in the small intestine.

Dietary essential vitamins for rabbits

A dietary supply of vitamins A, D and E is necessary. Other vitamins are not dietary essential because bacteria in the gut synthesize vitamin K and B complex vitamins in adequate quantities.

Fibre digestion and level of crude fibre in the ration of rabbits.

Rabbits digest fibre poorly because of the selective separation and rapid exertion of large particles in the hind gut, as hard faeces. Among the herbivores such as guinea pigs, horses, sheep / goat and cattle, the rabbit has the poorest ability to digest crude fibre. This is because in rabbits, it takes only about 30 hours for the majority of the food to pass through the digestive system. They need a generous amount of fibre (about 15%) in the diet to promote intestinal mobility and minimize intestinal disease. Fibre may also absorb toxins of pathogenic bacteria and eliminate them via the ‘hard faeces’. Diets low in crude fibre promote an increased incidence of intestinal problems, Eg: enterotoxaemia. On the other hand, high fibre diets (> 20% CF) may result in an increased incidence of caecal impaction and mucoid enteritis.

Proportion of VFA is in the caecal contents is of the order 60-70% acetic acid, 15-20% butyric acid and 10-15% propionic acid. The rations are influenced by the level of fibre in the diet. A high fibre diet (> 15% CF) increases the acetate and reduces the propionate. On the other hand, a low fibre diet (< 6% CF) increases the propionate and reduces the acetate. The production and absorption of VFAs appears to take place in the caecum and proximal colon only.

Enterotoxaemia

Enterotoxaemia is a digestive disturbance seen in rabbits which is caused by the bacteria *Clostridium spiriforme*.. This condition occurs when the rabbits are fed with a diet rich in carbohydrate, ie. excess of grains and less of roughages / crude fibre. The carbohydrate rich diet will be fermented by the bacteria in the bind gut resulting in the production of lactic acid. As a result the pH in the bind gut especially the caecum will be lowered. This lowered caecal pH upsets the normal gut microflora. Instead pathogenic bacteria like *Clostridium* proliferate, produces toxin and causes the condition called enterotoxaemia which is manifested in the form of enteritis / diarrboea.

Treatment

This condition can be treated by oral administration of Sulphadimidine bolus [SULPHA VET Bolus (5g) 1/5 bolus twice daily for 3-5 days], for an adult rabbit.

Prevention

1) Addition of copper sulphate in the rabbit feed @ 250 ppm. Copper sulphate acts by inhibiting the growth as well as toxin production of Clostridium species of bacteria.
2) Vitamin C / Ascorbic acid inhibits toxin production.

Feed additives for rabbits

Commercial feed additives like Lacto –Sacc (micro encapsulated lactic acid bacteria and yeast culture) and Acid – Pack- 4- way (Buffer pack containing microencapsulated lactic acid bacteria, buffers such as sodium bicarbonate, organic acid and enzymes) are helpful in preventing enterotoxaemia.

Nutrient requirements and feeding of rabbits

Common feeds given to rabbits

Rabbits primarily are non gastric herbivorous animals. They consume as part of concentrate feed, common types of grains like rice, wheat, jowar, maize; pulses like Bengal gram, black gram, cow pea, green gram, etc; cereal byproducts like wheat bran, rice bran, etc. ; pulse byproducts like black gram husk and oil cakes such as gingelly oil cake and ground nut cake which are vegetable protein supplements.

They consume as part of roughage feed, either green legumes such as leucern / alfalafa, berseem, cowpea, Stylosanthes, Sesbania (agathi), murikku or young tender grasses of any of the cultivated fodder grasses like Hybrid Napier (CO2, CO3, CO4, etc.), Guinea or Congosignal. Hay, especially hay prepared from legume fodder, can also be given to rabbit.

Even kitchen wastes and garden vegetables (Cabbage, carrot, etc.) or other leaves are also eaten.

Toxic feeds for rabbits

1) Feeding large amount of cabbage produces goiter in rabbits as well as other species.
2) Cotton seed meal/cake should be limited to below 5% of the total DM intake, since rabbits are sensitive to gossypol, the toxic principle present in cotton seed
3) While feeding Subabul *(Leucaena leucocephala)* leaves, it should not be more than 10% of the total DM intake because Subabul contains a toxic amino acid mimosine, which causes allopacia. Hence if Subabul is fed at higher levels, allopacia or hair loss occurs in rabbits.

Nutrient requirements of rabbits

Rabbit consumes dry matter to the extent of 6-8% of their body weight and out of this roughage can be upto 60%. The nutrient requirements for various categories of rabbits are given below.

Nutrient	Maintenance (dry non-lactating does)	Growth (grower rabbits)	Lactation (lactating does with litter)	Gestation (pregnant does)
CP (Min.)	12-15%	16-20%	17-20%	15%
ME (Min.)	2100 Kcal	2400 Kcal	2600 Kcal	2400 Kcal
CF (Max.)	14%	12%	12%	12%
EE (Min.)	2%	2%	2%	25

Different types of diets for rabbits

Rabbits can be fed with either on compounded mash mixture containing the above 4 nutrients in their digested proportions or a pelleted feed.

Rabbits prefer a pelletted diet than a meal mash diet. Some rabbits may even refuse to consume a non pelleted diet while others adjust to a meal diet and accept it satisfactorily, but during the adjustment period, feed intake is very low and feed wastage is high. Molasses @ 2-3% to 6% has to be added to the meal diet to reduce dustiness and to increase palatability. Growth rate and feed efficiency were found to be significantly better with the pelleted diets. Also, pelleted diets reduces feed wastage and prevents respiratory troubles caused by dust from the conventional concentrate rations.

Pellet binder

The fibre content of rabbit rations is higher than in rations for most other livestock. When pelleted, high fibre rations are very friable (fragile) and give rise to unacceptable wastage when fed to rabbits.

This problem can be avoided by the use of pellet binders which hold together the ingredients in the pelleted mass. Sodium bentonite is the preferred pellet binder in case of rabbit feeds. Concentrate feed pellets of 3-4 mm diameter and 1-1.5 cm length are preferred in the case of rabbits.

Water requirement

Various studies have shown that rabbits drink approximately 10 ml of drinking water / 100 g body weight/day. It can go upto 90 ml /100 g body weight / day in case of lactating does. Another study has shown that the water consumption in rabbits is about twice the weight of the food dry matter consumed. However the latest stand adopted is that rabbits should be supplied with fresh clean, drinking water *adlibitum.*

Feeding schedule for different categories of rabbits

Kits: The main food of the rabbit kits is their mother's milk. They should be fed with their mother's milk from birth till weaning (6 weeks of age). The kits start to leave the nest and eat small quantities of compounded fed at about 21 days of age. The quantity of compounded feed they consume, progressively increases, thereafter.

Bunnies (> 6 weeks): After weaning food intake quickly increases until DM intake is about 5.5% of live weight and this level is maintained until maturity (5-6 months).

Adult does and bucks: Should be fed with concentrate and roughage feed @ 6-8% of their body weight.

Meat rabbits

Rabbits which are reared for meat purpose are usually slaughtered by about 10 weeks of age (preferably 8-10 weeks). By 10 weeks of age, a meat rabbit should attain a live weight of at least 2.4 kg since growth rate begins to diminish after 8 weeks. Therefore, attainment of the desired market weight by the end of 8 weeks or before 10 weeks, ie., before the end of the phase of rapid growth, is hence of paramount importance in obtaining maximum profit from rabbits. The optimum feed conversion efficiency (FCE) at 10 weeks of age is 4:1.

Lactating does

Food and water intake usually decreases shortly on the last day before parturition. As lactation becomes established, food intake increases to a maximum after 20-30 days.

The doe's milk production follows a typical mammalian lactation curve, reaching a peak at 18-21 days and then decreasing rapidly until weaning take place.

The nutrients used by the lactating mammary gland resemble those of the ruminant; acetate being the most important precursor of milk fat synthesis.

Hence based on the above data, the feeding schedule for the different categories of rabbits can be summarized as follows.

Category of Rabbit	Approximate body weight	Quantity to be fed per day	
		Concentrate	Green grass
Bucks	4-5 kg	150 g	600 g
Does	4-5 kg	150 g	600 g
Lactating Does	5 kg	200 g	700 g
Bunnies (after weaning at 6 weeks of age)	600-700 g	50 g	200 g

Economic traits in rabbits

The traits of rabbits which are instrumental in giving financial benefit to the farmer are called as economic traits of rabbits. These traits are,

1) Litter size at birth
   Usually 6-8
   Optimum is 8
   Average is 7
2) Average birth weight of kits
   Minimum 40 g / kit
   Usually 40-45 g / kit
3) Litter weight at 21 days (3 weeks)
   It iss an indication of the mothering ability of the doe.
   The optimum value of litter weight at 21 days age is 1.2-1.5 kg.
4) Litter size at 21 days
   At least 6
5) Weaning weight of litter
   Minimum 450 g
   Usually 1-1.5 kg at 6 weeks, if properly fed.
6) Number of kindlings per doe per year = 5
7) Number of bunnies available from each litter = 5
   Number of kindlings / year / doe= 5
8) Number of weaned bunnies available from doe/year = 5x5= 25
9) FCE: Usually 4:1

Maximum growth takes place till 8-10 weeks of age. Therefore, the quantity of the feed required to attain 2 kg body weight is taken as a yard stick of FCE. Animals which attain 2 kg body weight at lower age are assumed to be better converters of feed.

Importance of record keeping

Records are inevitable for analyzing the profit or losses from any enterprise. Prepare a project report for producing meat rabbits using 10 adults (8 females and 2 males). Also, see as well as take down the record of breeding history, kept in the front of the cages of the rabbit farm & SABS.

LABORATORY ANIMAL NUTRITION

Guinea Pig

Species description

Class : Mammalia

Order : Rodentia

Family : Cavidae

Scientific name: *Cavia cavia*

Uses of guinea pigs

Guinea pigs are extensively used for immunological studies, studies on delayed hypersensitivity (allergic) reactions, diagnostic tests like brucellosis, tuberculosis, stress investigation, nutritional studies, ascorbic acid studies to find out the requirement of vitamin C and disease investigation studies.

Rearing methods

1) Cage Rearing: this is the usual method adopted for rearing guinea pigs in established farms. Individual metal cages with holders for water bottles and feed hoppers, just like in the case of rabbit. If cage rearing is practiced, no bedding is required.
2) Floor Rearing: in the field, some farmers are practicing floor rearing with water container and feed containers provided on the floor. If floor rearing is practiced, it is desirable to provide a bedding to a depth of ¼-1 inch. The bedding materials may be paddy husk, saw dust or even paper cuttings.

Floor space requirement

Cage Rearing: if cage rearing is practiced, an individual cage of 30 cm x 20 cm x 8 cm is sufficient for one guinea pig (30 x 20=600 cm^2).

Floor rearing: If floor rearing is practiced, each adult guinea pig should be provided a floor space of 650 cm^2.

Handling of guinea pigs

Guinea pigs should be picked up with both hands, one around the shoulders and the other supporting the hind quarters. Great care should be taken in handling pregnant females, which should not be allowed to struggle.

Environmental control

Growing and adult guinea pigs should be maintained at a temperature of 70-80^oF, while weanlings (young ones with their mother before weaning) should be provided more warmth and a temperature of 77-80^oF should be provided for them. The relative humidity in

the shed should be between 40-50%. There should be good air movement within the shed especially if the population density is high.

Digestive system of the guinea pig

Like the rat, mouse and rabbit, the guinea pig is simple stomached; but in contrast to these species, the entire stomach of the guinea pig is lined by glandular epithelium. Intestine allows growth of gram positive bacteria. It has a large semi circular caecum with numerous lateral pouches.

This organ resembles that of rabbit and possibly has similar digestive functions. Eg:- Synthesis of B vitamins and indispensible amino acids by micro organisms and recycling of intestinal contents by coprophagy. Guinea pig has also got the ability to practice coprophagy, like rabbits.

Biological parameters of guinea pigs

1) Mature weight
   Male: 900-1500g, Female: 700-1300g
2) Birth weight: 75-100g
3) Weaning weight: 160-230g
4) Weaning age: 28 days or 170g body weight whichever is earlier
5) First mating age: 70-90 days
6) Male guinea pig is called boar and the female is called the sow.
7) Gestation period: 68 days (62-72 days)
8) Average litter size: 2 (rarely 3)
9) Life span : 6 years, but breeding life is usually only upto 2 years.
10) Number of litters /year: 3

Guinea pigs in advanced pregnancy is provided with hutches in the cage. Parturition take place in the hutches.

Feed consumption of guinea pigs

Adult guinea pigs consume diet @ 7-8% of body weight.

Quantity of concentrate feed consumed by various categories of guinea pugs

Growing guinea pigs	20-30g/day
Adult guinea pigs	30-50g/day
Pregnant and lactating guinea pigs (Depending upon the litter size and season.)	40-60g/day

Dry matter consumption is reduced during the hot summer season.

The concentrate feed to guinea pigs can be provided, either in mash form or pelleted form.

In addition to the concentrate feed, roughages like green fodder, Eg:-guinea grass @150-200g/day, any vegetable @ 10-15g and vitamin C/Ascorbic acid @ 6-10mg/guinea pig/day should be provided.

Water consumption

The daily water consumption of adult guinea pig is 80-100ml. However, it is ideal to provide additional supply of fresh clean drinking water to the guinea pigs, just like in the case of rabbits.

Feeding of Guinea pigs

Newborn animals can consume semisolid and solid food immediately, although weaning is practiced only at about 4 weeks of age. Guinea pigs normally gain as much as 5-7g/day during the rapid growth period, when allowed to eat good food, *adlibitium.* Growth slows after 2 months and maturity is reached at about 5 months, even though they can be bred at 70-90 days of age. Weight gain can continue until 12-15 months of age and level off at 700-1300g for females and 900-1500g for males. Mating is most successful when females are 450-600g (70-90 days old).

Nutrient requirements of guinea pigs	
CP	18-22% (Min. 18%)
ME	2800-3200 Kcal
CF	15% (Max.) better limit it to 10%
EE	4% (Min.)

RAT

Species: Description

Class : Mammalia

Order : Rodentia

Family : Muridae

S. name : *Rattus norvegicus*

The laboratory rats fall under 2 main breeds:

1) The black rat (*R. rattus*)
2) The Norway Rat (*R. norvegieus*)
3) The Brown Rat (*R. norvegieus*)

Uses of laboratory rats

Laboratory rats are used in toxicity research, nutrition studies, endocrinology studies, bioassay experiments, pharmacological studies and cancer research.

Rearing methods

Cage rearing is only practiced in case of rats. Cages with solid bottom and grills alone may be used. Polypropylene cages are very useful. Screen bottomed cages made of GI anodized aluminium or stainless steel cages can be used.

Clean bedding to a depth of ¼-1" may be used. The material may be paddy husk, saw dust or paper cuttings.

Floor space requirement

Rats of various age groups can be reared in cages. A standard rat cage should have a height of 17.8 cm. The individual floor space requirement varies depending upon the body weight of rats .

Body weight (g)	Floor area (cm)
< 100g	110
101-200g	150
200-300g	185
> 300g	260

Feeders and waters

Pellet feed hoppers can be used for feeding rats, just like the ones used in rabbits and guinea pigs . Water bottles made of glass or even plastic with a capacity of holding 6 ounces of water can be used, just like in the case of rabbits and guinea pigs.

Environmental control

Adults and young ones do well in a colony room with a controlled temperature between 67 and 68ºF and relative humidity of 50-55%. A room with a breeding colony and infant young should be maintained at 75-78ºF with 40-80% RH. If the colony is air-conditioned, 12-15 changes of air per hour in the animal room is recommended. 12 hours of light and 12 hours of darkness ensure optimum breeding performance.

Handling of rats

Rat should not be picked up by the tail, but gently by the body. Frequent handling by the regular care taker, will lead to tameness and non resistance.

Biological parameters of rats

1) Mature weight: Male:-200-400g
   Female:-180-350g
2) Birth weight: 5-6g (eyes are opened at 14-16 days of age)
3) Weaning weight: 35-45 g
4) Weaning age: 60-70 days
5) Type of oestrus cycle: Polyoestrous
6) Duration of oestrus (heat): 4-5 days
7) First mating age: 90-120 days
8) Gestation period: 21-23 days(average = 22 days)
9) Age at 1^{st} litter: 111-143 days. Usually by about 125 days, the rats give rise to their 1^{st} litter
10) Litter size: Usually 4-8. Rarely 8-16 is also observed
11) Life span: 2-$2_{1/4}$ years. (730-781 days). Rarely they live upto 1000 days = 3 years, but reproductive life span is only 1 year, Hence,
12) No. of litters in life time: 5-7/rat
13) Daily feed intake
    Growing rats: 15g/day
    Adult rats at maintenance: 20g/day
    Pregnant rats: 20g/day
    Lactating rats: 30-40g/day
14) Daily water consumption: 5-35 ml
15) Daily urine output: 11-15 ml
16) Mating system: Usually pairs and rarely colonies
17) Sex ratio: 4 breeding female/male

Nutrient requirements

Maintenance energy requirement of adult rat is 114 Kcal of ME/kg $W^{0.75}$. It has been reported that the requirement for fat rats is approximately 15% lower than the requirement for normal rats. This is because of 2 reasons:

1) The fasting heat production per kg metabolic body size is greater in working and producing animals than in now working / fat animals.
2) Also, fat non producing rats have a decreased food intake and as a result their energy expenditure resulting from food intake is less than normal animals. Hence, their maintenance energy requirement is also less.

Energy requirement for growing, pregnant and lactating rats are higher proportionate to their productivity status.

Although no definite carbohydrate requirement has been established, rats perform better with glucose or glucose precursors (such as other sugars, glycerol, glucogenic amino acids, etc.) in their diets.

MICE

Species Description

Class : Mammalia

Order : Rodentia

Family : Murinae

Scientific name : *Mus musculus*

Uses of Laboratory mice

Mice are almost similar to rats, with the basic difference that mice are smaller in size. They are extensively used in cancer research, reproductive biology diagnosis and action of drugs, immunology, toxicology and genetics.

Housing of mice

Cage rearing is usually practiced in case of mice. Cages with solid bottom and grills alone may be used. Polypropylene cages are also very useful, even though they are costly. GI wire bottomed cages with a bottom tray for collecting faeces may be used. In order to prevent the galvanized iron (GI) cages from getting rusted, it is preferable to have anodized aluminium or stainless steel, cages even though the latter two are costly.

Inside the cages, lean bedding to a depth of ¼-1" may be used. The material may be of paddy husk, saw dust or paper cuttings.

The floor space requirement of various categories of mices are as follows:

Weight (g)	Area (cm^2)	Height(cm)
<10	39	12.7
10-15	52	12.7
16-25	77	12.7
>25	97	12.7

A standard mice cage should have a height of 12.7 cm and the floor space area can be adjusted according to the body weight of the mice.

Feeders and Waterers

Usually mice prefer pelleted foods, even though mash feeds can also be given. Pellet hoppers, as in the case of rabbits, guinea pigs and rats can be used in case of mice also.

Water bottles made of glass or plastic with 6 ounces capacity can be used for providing drinking water.

Environmental control

In metal cages, adult mice do well at temperatures of 68-75ºF with infant young at 72-78ºF and relative humidity between 45-55%. If the colony is air conditioned, 12-15 changes of air per hour are needed. 12 hours of light and 12 hours of darkness should be provided for optimum production.

Handling of mice

Mice can be picked up by holding at the base of the tail. The animal should not be held by the tip of the tail, as it will be very painful to the animal.

Biological parameters

1) Mature weight: Male:- 20-40g
   Female:-20-35g
2) Birth weight: 1-1.5g
3) Weaning weight: 10-14g
4) Weaning age (days): 21 days.
5) First mating age: 45-60 days
6) Gestation time: 19-21 days
7) Litter size: 10-12 no.'s
8) Life span: 1 ½-2 ½ years, but reproductive life span is only about 1 ½ years
9) Daily food intake: 4-5g
10) Daily water consumption: 4-5 ml
11) Daily urine output: 4-7 ml
12) Mating system; pair or colony
13) Sex ratio: 3 breeding females per male.

HAMSTER

Species Description

Class : Mammalia
Order : Rodentia
Family : Cricetidae
Scientific name : *Mexoricatus auratus*

Use of hamster

Hamsters are extensively used in virology, cancer research, nutrition research, genetics, pharmacology, toxicology and reproductive physiology. It is widely used for research in diabetes, cytological investigations, tissue culture and radiation research.

Housing of hamsters

Cage rearing is usually practiced in hamsters. Cages with solid bottom and grills above may be used. Polypropylene cages are also very useful even though they are costly.

Inside the cages, clean bedding to a depth of ¼-1" may be used. The material may be paddy husk, saw dust or paper cuttings.

The floor space requirement of various categories of hamsters are as follows:

Weight (g)	Area (cm^2)	Height(cm)
Upto 60	65	15.2
60-80	84	15.2
81-100	103	15.2
>100	123	15.2

A standard hamster cage should have a height of 15.2 cm and the floor space area can be adjusted according to the body weight of the hamster.

Feeders and waterers

Usually hamsters, like other laboratory animals, prefer pelleted feeds, even though mash feeds can also be given. Pellet hoppers as in the case of rabbits and other lab animals can be used in the case of hamster also.

Water bottles made of glass or plastic with 6 ounces capacity can be used for providing drinking water.

Environmental control

Hamsters should be maintained in cages, with an environmental temperature of 70-80^{o}F and relative humidity of 45-65%.

Handling of hamsters

Hamsters should be handled frequently and gently. Removal of any odour from the hands is a good practice before handling hamsters. For inspecting or transferring from cages, place both hands around the hamster to form a cup or pick up without hand, grasping the loose fold of skin behind the neck with the thumb and the forefinger, at the same time supporting the hamster's hind quarters, to avoid injury. The second method is easier and more practicable.

Biological Parameters

1) Mature weight
   Male: 90-100g
   Female: 80-90g
2) Birth weight: 2g
3) Weaning weight: 20-30g
4) Type of oestrous cycle: Polyoestrus
5) Duration of oestrous (heat): 4-5 days
6) First mating age: 56-84 days (2-2 ¾ months)
7) Gestation period: 15-17 days (average 16days)
8) Litter size: 5-7 (average 6)
9) Life span: 2 years, but reproductive life span is only 1-1 ½ years
10) Daily food intake: 6-8g
11) Daily water consumption: 10-15 ml
12) Daily urine output: 12 ml
13) Mating system: Pair colony
14) Sex ratio: 5 breeding females per male.

VMD 513 (1+1) – Dog & Cat Nutrition

Dr. Ani Bency Jacob M V Sc, PhD
Assistant professor
Dept. of Animal Nutrition
College of Veterinary & Animal Sciences
Pookode, Wayanad-673576

Canine Nutrition

Feeding behaviour of dogs.

1. Rapid eating of food- may predispose them to choke or swallow large amounts of air.

Measures to slow down the feeding in dogs – Making the food less palatable or including large pieces of food. Adding water to the dog's food immediately before feeding decreases the rate of eating and minimizes the chance of swallowing large amounts of air.

2. **Consumption of garbage, insects and feces that** they encounter in the yard or while out walking. These behaviors can present a health and sanitation risk and generally should be prevented. Plant eating, in particular grass eating, is a normal canine behavior -

- The dog's ancestry suggests that an intermittent feeding schedule consisting of large meals interrupted by periods of fasting is the most natural way to feed dogs. However, when dogs are given free access to food, they will consume many small meals frequently throughout the day.
- This pattern is similar to that seen in cats, with the exception that dogs tend to eat only during the day time. The domestic dog is quite capable of adapting to a number of different feeding regimens. These regimens include portion-controlled feeding, time-controlled feeding, or free-choice (ad libitum) feeding.

Feeding Schedule with Home made Food

Months	No. of times
1 - 2	6 times
2 - 3	5 times
3 - 4	4 times

4 - 5	3 times
5 - 7	2 times

- Rusk, fresh bread, good quality dog biscuits, eggs, soup, porridge (Wheat flour, oats or ragi cookedt in milk) may be fed in early puppyhood.
- Gradually, change over to the dietary articles which you can afford daily, by the third month.
- Start feeding beef without much fat by the second month on wards.
- Avoid feeding the "Dog Meat" available from the market or Slaughter house as far as possible or at least up to six months of age.
- Feeding rice in early puppyhood gives it a pot-bellied appearance and hence it is advisable to commence feeding rice after three months of age.
- An adult animal requires one square meal a day but many owners prefer to give some scraps or a cup of milk or tea or an egg in the morning.
- It will be preferable to give the main meal sometimes in the afternoon rather than during the night, since the dogs have a tendency to sleep after a heavy meal.
- Cooking or warming the food after chopping it into smaller bits makes it more palatable and digestible.
- The feed shall contain 30% meat and the rest cereals, vegetables, milk, egg, bread etc. Vegetables like carrot, beetroot, etc. may be added in the dog's diet.
- Chicken and fish may be fed but the bones should be removed.
- For rearing a dog as a vegetarian vegetable soup, soybean meal, chappathi, idli etc. would be ideal choice.

Feed Requirement Chart

Body weight	**Approximate requirement of feed in kg**
2.5	0.30
5.0	0.50

7.5	0.63
15.0	1.20
22.5	1.73
32.0	2.45
50.0	3.83

PRINCIPLES OF FEEDING DOGS

- The feed shall contain at least 30% meat and the rest shall be cereals, vegetables, milk, egg, bread, etc.
- There are at least 15 known minerals that are required for the dog. The role of calcium and phosphorus is very important in growing and lactating animals, so also the requirement of vitamins. It is necessary to supplement minerals and vitamins, even from the preweaning period.
- It is a good practice to provide a large bone for the pup to gnaw. It provides calcium and phosphorus as supplement and helps to keep the teeth clean and may prevent indiscriminate biting tendency till the permanent teeth erupt. Leather bone is a good substitute.

ENERGY REQUIREMENTS FOR DOGS

- The amount of energy that is used by the body is correlated with total body surface area.
- Body surface area per unit of weight decreases as animals increase in size. As a result, the energy requirements of animals with widely differing weights are not well correlated with body weight; they are more closely related to body weight raised to a specified power. This unit of body weight is called metabolic body weight

Inactive adult dogs

ME requirement = 95 × W kg $^{0.75}$

Examples:

ME requirement of a 10-kg dog = 95 × (10 kg)$^{0.75}$= 534 kcal ME/day

ME requirement of a 22.7-kg dog = 95 × (22.7 kg) $^{0.75}$ = 988 kcal ME/day

Active adult dogs

ME requirement = 130 × W kg $^{0.75}$

Examples:

ME requirement of a 10-kg dog = 130 × (10 kg) $^{0.\ 0.75}$ = 731 kcal of ME/day

ME requirement of a 22.7-kg dog =130 × (22.7 kg) $^{0.75}$ = 1352 kcal ME/day

Energy requirements for dogs at different stages of life

Stage	**Energy requirement**
Post weaned	2 × adult maintenance ME
40% adult body weight	1.6 × adult maintenance ME
80% adult body weight	1.2 × adult maintenance ME
Late gestation	1.25 to 1.5 × adult maintenance ME
Lactation	3 × adult maintenance ME
Prolonged physical work	2 to 4 × adult maintenance ME
Decreased environmental temperature	1.2 to 1.8 × adult maintenance ME

PROTEIN REQUIREMENTS FOR DOG

- The current National Research Council (NRC) recommends a minimum protein requirement of 80 g of crude protein per kg diet in foods with an energy density of 4.0 kilo calories (kcal) ME/g, for recently weaned puppies -180 g crude protein/kg diet in a food containing 4.0 kcal/g when proteins that are of high quality are fed.

- It is important to consider that when lower-quality protein sources are fed, protein requirement estimates will increase significantly, typically as high as 20% of the ME calories.
- American Association of Feed Control Officials' (AAFCO's) recommendations-

  Adult maintenance dog foods contain at least 18% of ME calories as protein.

  For growing and reproducing dogs------- 17% and 22% of ME calories as protein

  .

FAT REQUIREMENT IN DOG DIET

- Fat is needed in the diet to provide EFAs and energy and to enhance diet palatability.
- A minimum amount of dietary fat is also needed as a carrier for the fat-soluble vitamins.
- Most dry dog foods that are marketed for adult maintenance contain between 5% and 13% fat (DM basis).
- In comparison, the fat content of dry dog foods that are formulated for gestation, lactation, or performance may be 20% or greater.
- AAFCO's Nutrient Profiles minimum fat recommendations
- 5% for adult maintenance
- 8% for growth and reproduction (DM basis) provided in a food containing 3500 kcal/kg.
- An adult dog maintenance food should also provide a minimum of 1% of the food's dry weight as linoleic acid.
- A ratio of linoleic acid to alpha-linolenic acid - 2.6 and 26 should be maintained in all foods..
- Because the n-3 and n-6 fatty acids compete for metabolic pathways, the amount of alpha-linolenic acid in the food must always be determined relative to the level of linoleic acid.
- If the linoleic acid content of the food is higher than 1%, alpha-linolenic acid should also be increased to maintain an appropriate balance between the two families of fatty acids.
- The current NRC provides an adequate intake (AI) estimate of 0.11 g of EPA and DHA combined per 1000 kcal of diet.

REQUIREMENT OF ESSENTIAL NUTRITIVE INGREDIENTS IN THE FEED

Item	Adult	Growing
Protein	3.7g/kg b.w/day	10g/ kg b. w /day
Carbohydrate	17.6g/kg.b.w/day	32.3g/kg b.w/day
Fat	1.3 g/ kg b.w/day	2.4 g/ kg b.w/day
Calcium	0.26g/ kg b.w/day	0.53g/ kg b.w/day
Phosphorus	0.22 g/ kg b.w/day	0.44g/ kg b.w/day
Sod. Chloride	0.37 g/ kg b.w/day	0.44g/ kg b.w/day
Vit. A	100 i.u.	-
Vit. D	5 i.u.	-

Life cycle feeding/Phase feeding (Feeding in different stages of life cycle)

No hard and fast regimen for the feeding of dogs.

It is always better for the individual dog owners to maintain the dogs on the food materials ordinarily prepared in the house rather than preparing special food for dogs

NUTRITIONAL MANAGEMENT OF NEWBORN PUPPIES

- The neonatal period in puppies and kittens - the first 2 weeks after birth. The offspring of dogs and cats are *altricial (puppies and kittens are born in a relatively immature state and are completely dependent upon their mother's care*.)
- Because of this immature state, preweaning mortality - as high as 40%, and the vast majority of deaths occur during the neonatal period.
- The first 36 hours of a puppy's or kitten's life are a critical time because the process of birth and the sudden environmental changes that newborns experience are physiologically

stressful. Therefore every effort should be made during this time to minimize stress and variations in the environment.

- A quiet, warm whelping area should be provided, and human visitors outside of the immediate family should be prevented from disturbing the litter during the first few days.

Colostrum feeding

- The dog and cat have an endotheliochorial placenta consisting of four layers. This type of placenta allows only about 10% to 20% of passive immunity to be transferred in utero. Therefore, for puppies and kittens, the major proportion of passive immunity is acquired after birth via the colostrum.
- This emphasizes the importance of immediate nursing and the provision of colostral antibodies and bioactive factors to puppies and kittens immediately after birth.
- The intestinal mucosa of newborn dogs is capable of absorbing intact immunoglobulins provided by colostrum. The time during which the newborn's gastrointestinal tract is permeable to the intact immunoglobulins in colostrum is very short. The term closure refers to the change in the gastrointestinal tract's absorptive capacity that precludes further absorption of large, intact proteins.
- Therefore it is vitally important that newborn puppies and kittens receive adequate colostrum as soon as possible during the first day after birth

Dog milk

- The nutrient pattern of dog's milk is somewhat different. The most recent study reported that while milk protein is very high on the first day of lactation (>10%), it decreases gradually for the following 3 weeks and then, after day 21, increases slightly until weaning.
- The lipid content of dog's milk is higher than that reported for cat's milk and does not show the dramatic decrease early in lactation that is reported for cat mammary secretions.
- Because of this higher fat content and possibly due to its slightly higher protein concentration, dog's milk is higher in energy than cat's milk.

- In both species the total energy content of the milk decreases gradually from colostrum to the milk that is produced during mid lactation. Energy concentration then increases until weaning in both species. Lactose concentration in dog's milk is lowest in colostrum and increases gradually until mid lactation.

Nutrient composition of dog milk

Protein (%)	8 - 10
Lactose (%)	3 - 4
Fat (%)	11 - 13
Calcium (mg/L)	1400 - 2200
Magnesium (mg/L)	90 - 100
Iron (mg/L)	2 - 7
Zinc (mg/L)	4 - 6
Copper (mg/L)	1.0 - 1.4
Energy (kcal/L)	1500 - 1800

- The gastrointestinal tracts of newborn puppies are uniquely suited to digest and absorb the milk produced by the mother. Immediately after birth, the ingestion of milk is a potent stimulator for enteric growth and for the development of the intestinal mucosal cells.
- Fat and lactose are the primary sources of energy in milk; puppies have high intestinal lactase activity and are capable of digesting milk fat very early in life.
- Similarly, both the type and amount of protein found in the milk are intricately matched to the developmental state of life. Gastric acid production is low in puppies and kittens until they are about 3 weeks of age. However, this does not appear to inhibit their ability to digest milk proteins. The renal capacity of neonates is also not fully developed and is sensitive to excessive or poor quality protein intake.
- Milk protein is of high quality and at a concentration that is closely matched to the metabolic capabilities of the developing young.

- Lastly, at birth, the gastrointestinal tract of puppies and kittens is sterile. Microbial colonization begins within the first day of life as the newborns ingest milk. This continues to evolve when solid food is introduced at 3 to 4 weeks of age and as the young attain adulthood.
- Volume of milk intake is affected by age, rate of growth, and for dogs, breed size..

Introduction of solid food

- Supplemental food should be introduced to puppies and kittens when they are 3 to 4 weeks of age. A commercial food made specifically for weaning puppies or kittens can be used, or a thick gruel can be made by mixing a small amount of warm water with the mother's food.
- Cow's milk should not be used to make the gruel because it is higher in lactose than bitch's and queen's milk and may cause diarrhea.
- Puppies and kittens should also not be fed a homemade "weaning formula." Although the foods that are used to make these formulas are usually of high nutrient value, many homemade formulas are not nutritionally balanced or complete. The use of this type of formula should be avoided unless its exact nutrient composition is known.
- The semisolid food should be provided in a shallow dish, and puppies can be allowed access to fresh food several times per day. The bowl should be removed after 20 to 30 minutes. At first, little of the semisolid gruel will be consumed, and the litter's major food source will continue to be the dam's milk. However, by 5 weeks of age, puppies and kittens are readily consuming semisolid food.
- The deciduous teeth erupt between 21 and 35 days after birth. By 5 to 6 weeks of age, puppies and kittens are able to chew and consume dry food. Nutritional weaning is usually complete by 6 weeks of age, although some bitches continue to allow their young to nurse for 8 weeks of age or longer.
- After weaning, a combination of cow's milk (250 ml), water (125 ml), egg yolk (one), glucose (half teaspoon) fed at intervals would be a good substitute for the dam's milk. Goat' s milk is good for pups.

- For two to three days after weaning, the pus will be crying, may be because of the separation from its dam. With the impression that the pup is crying due to hunger never overload them with 'milk and biscuits (as often done) resulting indigestion.
- Puppies will suckle occasionally and will continue to interact with the mother dog at 7 weeks of age even when offered free access to solid food.
- It is believed that the psychological and emotional benefits of suckling may be as important as the nutritional benefits in puppies that are older than 5 weeks of age. For this reason, complete weaning (behavioral weaning) should not be instituted until puppies and kittens are at least 7 to 8 weeks of age.

NUTRITIONAL CARE OF ORPHAN PUPPIES

- An orphan is any young animal that does not have access to the milk or care of its mother. Circumstances that may render young puppies orphans include the death of the dam, the production of an inadequate quantity or quality of milk or rejection of the young by the dam.
- Whatever the underlying circumstance, once puppies or kittens are orphaned they depend on humans for the provision of maternal care, proper nutrition, and a suitable environment.Although it is difficult, to fully compensate for the absence of the mother, the use of proper diet, management techniques and feeding techniques can result in the development of normal, healthy puppies .

Maintaining the Proper Environment

- Orphaned animals must be kept in a warm, draft-free and clean environment.
- Maintaining the appropriate temperature is of the utmost importance because chilling can decrease the survivability of newborns. When a bitch is present, her body heat provides an excellent heat source and protection against drafts. In her absence, the ambient temperature must be increased.
- For the first week of life, the ambient temperature should be kept between 85° F and 90° F. This temperature can be decreased slightly to between 80° F and 85° F during the second to fourth weeks and to between 70° F and 75° F during the fifth week.

- After the litter reaches 5 to 6 weeks of age, a room temperature can be maintained.
- Generally, newborn kittens and small puppies require slightly higher ambient temperatures than do large puppies. A heating pad or heat lamp may be used to provide heat, although a pad is often preferred because it allows for the maintenance of a normal day/night light cycle.

Feeding of orphan puppies

- Provide nutrition through a well-formulated milk replacer. A milk replacer will nourish the puppies and kittens for the first few weeks of life until their digestive and metabolic functions develop to the point at which semisolid food can be introduced.
- It is important that the chosen formula closely approximates the composition of the natural milk of the bitch.
- This is reflected by the lower DM content of goat's and cow's milk as compared to the milk of dogs. For example, when converted to a calorie basis, the lactose content of cow's milk is nearly three times that found in bitch's milk. For this reason, puppies that are fed straight cow's milk will develop severe diarrhea.
- Evaporated cow's milk is occasionally recommended for raising orphans because it has levels of protein, fat, calcium, and phosphorus that are similar to bitch's milk. However, the lactose content of evaporated milk is still much too high for young puppies and kittens.
- In addition, the casein-to-whey protein ratio in cow's milk is not ideal for puppies, and cow's milk contains an excessive proportion of casein for neonatal kittens.
- There are numerous recipes available for the formulation of homemade milk replacers. Most of these use a combination of cows or goat's milk and eggs. Eggs are added to increase the protein content and dilute the lactose concentration of the ruminant milk.

Practical feeding tips for orphan puppies

- Provide a warm, draft-free and clean environment.
- Feed a milk replacer that closely approximates the nutrient composition of bitch's or queen's milk.

- Estimate the correct amount of formula based on the orphan's age and weight.
- Divide the formula into four to five equal feedings per day.
- Bottle-feed or use a feeding tube.
- Weigh orphans regularly: one time per day for the first week and one to two times per week thereafter.
- Introduce semisolid food at 3 to 4 weeks.
- Wean to dry pet food by 6 to 8 weeks.

FEEDING MANAGEMENT DURING GROWING STAGE

- Proper feeding of young dogs supports normal muscle and skeletal development and a rate of growth that is typical for the dog's particular breed. All dogs grow and develop rapidly during the first year of life, but small and toy breeds reach maturity at a younger age than large breeds.
- The most rapid period of growth for all dogs occurs between 3 and 5 months of age. Overfeeding for maximal growth rate and early maturity should be avoided in all dogs, but is crucial in large- and giant-breed puppies.
- Growing dogs have a very steep growth curve, and their total daily energy needs do increase as they grow. The amount of food that is fed should be adjusted in response to a weekly or biweekly assessment of the dog's body condition and weight.
- A dog that is too thin has easily palpable ribs with little or no overlying fat layer. The tail base may be prominent, and the overhead profile will be an exaggerated hourglass. A dog that is overweight has a moderate to heavy layer of fat overlying the ribs.
- In very overweight puppies, the ribs may be difficult to even feel. There may be a thickening around the base of the dog's tail due to fat stored in that area.
- Overweight dogs that are older than 6 months lose their abdominal tuck and may show abdominal distention.
- Growing dogs that are at their ideal weight have ribs that are easily palpable with just a thin layer of overlying fat. The bony prominences of the hips are easily felt but not Prominent.

- Portion-controlled feeding is the recommended feeding regimen for growing dogs. A puppy's daily portion of food should be divided into at least two but preferably three meals per day until the puppy is 4 to 6 months of age. After 6 months, two meals per day can be fed.
- Some large and giant breeds of dogs may benefit from three or more feedings per day as a precaution against the development of gastric dilatation-volvulus. Free-choice feeding is not recommended for growing dogs because this type of feeding regimen makes it difficult to monitor and control weight gain and growth rate and has been associated with a greater incidence of developmental bone disease.
- If a pet owner eventually wishes to switch a dog to a free-choice regimen, this should be done only after the dog has achieved mature size.

Practical feeding tips

- Feed a highly digestible, nutrient-dense food formulated for growth.
- Meal-feed using a portion-controlled regimen.
- Feed three to four meals per day until 4 to 6 months of age; feed two or more meals per day after 6 months.
- Feed to achieve an average rate of growth for a pet's breed and to support a lean body condition.
- Avoid overfeeding to promote maximal growth rate.
- Energy density and calcium should be carefully controlled in foods selected for large- and giant-breed puppies.
- Provide regular daily exercise.
- Do not add nutrient supplements to a pet's balanced diet.

FEEDING MANAGEMENT DURING PREGNANCY AND LACTATION

- In pregnant bitches, less than 30% of fetal growth in size occurs during the first 5 weeks of pregnancy. Although the fetuses are developing rapidly, they are very small until the last third of the 9-week gestation As a result, there is only a slight increase in the dam's weight and total nutritional needs during the first 5 weeks of gestation.

- After the fifth week, fetal weight and size increase rapidly for the remaining 3 to 4 weeks of gestation. In the dog, more than 75% of weight, and at least half of fetal length, is attained between the fortieth and fifty-fifth day of gestation.
- Although optimal nutrition is important throughout reproduction, it is especially crucial during the last few weeks of gestation to ensure optimal fetal growth and development. If a bitch is at ideal weight at the time of breeding, no increase in food intake is necessary until the fifth week of gestation.
- Contrary to popular belief, a bitch should not receive a greater amount of food immediately after she has been bred. An increase of food at this time is unnecessary and could lead to excessive weight gain during pregnancy. It is not unusual for bitches to undergo a transient period of appetite loss at approximately 3 weeks of gestation. However, this change lasts for only a few days and is usually not a health concern.
- After the fifth or sixth week of pregnancy, the bitch's food intake should be increased gradually so that at the time of whelping her daily intake is approximately 25%to 50% higher than her normal maintenance needs, depending on the size of the litter and the size of the bitch. Her body weight should increase by approximately 15% to 25% by the time of whelping. Using the previous example, a bitch whose optimum weight is 15 kilograms should weigh between 17 and 19 kg at the end of her pregnancy.
- As the developing puppies increase in size, there is a reduction in the abdominal space available for expansion of the bitch's digestive tract after a meal. Therefore it is helpful to provide several small meals per day during the last few weeks of gestation so that abdominal space does not limit the bitch's ability to consume an adequate quantity of food.
- It is important to provide enough food during this period because dams that are underweight during middle and late gestation may have difficulty maintaining body condition for the high demands of milk production that occur during lactation. Likewise, it is also important not to over feed pregnant bitches. Excessive intake and weight gain will be reflected in heavier fetuses and may result in complications at the time of whelping.

- Mammary gland development and milk production occur 1 to 5 days before parturition, and many bitches refuse all food approximately 12 hours before whelping.
- A slight drop in body temperature, occurring 12 to 18 hours before the start of labor, is a fairly reliable indicator of impending parturition.
- Once the bitch has whelped the litter and expelled all of the fetal placentas, and when her puppies are resting normally, she should be provided with fresh water and food.
- Most bitches will begin eating within 24 hours of whelping. If necessary, the dam's appetite can be stimulated by moistening her food with warm water.
- Adding water to the food also ensures that adequate fluid is consumed, which is an important consideration. If the bitch has been adequately prepared for lactation, she should have a post whelping weight that is 5% to 10% above her pre-breeding maintenance weight.

FEEDING MANAGEMENT FOR ADULT MAINTENANCE

- Adult dogs should be fed food that is formulated for their life stage, activity level, and if appropriate, breed size.
- Although canned, semi moist or dry food can be fed. Dry foods are often preferred for this stage of life.
- In general, canned and semi moist foods have higher caloric densities on a dry-matter basis (DMB) than dry foods. When canned or semi moist foods are fed to adult dogs, they may contribute to the development of overweight conditions if intake is not closely monitored.
- Dry dog foods are less calorically dense, and they can also help to maintain proper tooth and gum hygiene. Dry foods are also easier and more economical to feed to large groups of dogs than are other types of foods.
- The availability of highly palatable pet foods coupled with the sedentary lives of many dogs has resulted in a high incidence of obesity in the adult dog population.

Feline Nutrition

GENERAL GUIDELINES FOR FEEDING CATS

- Cat should be fed individually and food selected should promote health
- The food should result in the formation of well formed stools and normal defecation frequency
- The food should contain optimum nutrients
- Rapid change in the diet should be avoided.
- New diet should be introduced gradually by mixing it with the old diet in 25% increment each day.
- Cats are carnivores in nature.
- Feed should be rich in protein of animal or fish origin.
- Either raw or cooked meat can be fed. Sometimes there may be digestive trouble.
- Also provide vegetables, green grass etc to avoid digestive trouble.
- Green grass helps to expel fur balls from the stomach.
- Grass will be having vitamins and minerals especially trace minerals and so grass feeding is advantageous.
- Cat should be given plenty of drinking water.

THE ENERGY REQUIREMENT FOR CAT

- The dietary requirement for cat is more than other omnivorous species.
- Domestic cat requires high protein along with its need for taurine, arachidonic acid and vitamin A in the diet impose requirement for the inclusion of animal tissues in the diet.

Energy requirement of cats

Age and level of activity	Calculation of energy need	Kcal per day

Adult cat (4 kg)		
Inactive	60 kcal x body weight (kg)	240
Moderately active	70 kcal x body weight (kg)	280
Highly active	80 kcal x body weight (kg)	320
Kitten		
3 months (1 kg)	250 kcal x body weight (kg)	250
5 month (2.5kg)	130 kcal x body weight (kg)	325

- During pregnancy 1.25 to 1.5 times of maintenance ration can be given up to end of gestation and during lactation it should be increased to 2 to 3.5 times of adult maintenance ration.

FAT REQUIREMENT IN CAT DIET

- In general, cat foods contain slightly higher amounts of dietary fat than do most dog foods. For example, dry maintenance cat foods contain 8% - 13% fat (DM basis).
- The AAFCO Nutrient requirement- Minimum fat during all life stages is 9% in a food containing 4000 kcal/kg.
- Exact estimates for the EFA requirement in cats are difficult to make because adequate levels of linoleic acid in the diet decrease the cat's requirement for AA, and high levels of AA can meet some of the needs for linoleic acid.
- In Addition, recent evidence suggests that most adult cats do not have a dietary requirement for AA and are capable of synthesizing adequate levels from dietary linoleic acid. The AAFCO's Nutrient Profiles for cat foods recommends 0.5% linoleic acid and 0.02% AA in diets containing 4000 kcal of ME/kg.

PROTEIN REQUIREMENT IN CAT DIET

- The cat and other obligate carnivores such as the fox and the mink, has a higher requirement for dietary protein.
- Protein requirement substantially higher than that of other mammals, including the dog. Growth rate in growing kittens will be satisfactorily only when protein exceeded 30% of the dry weight of the diet. (In comparison, growing puppies requires only 20% protein for adequate growth and development.)
- NRC recommendation- minimum requirement of protein for adult cats of 160 g crude protein/kg food in a diet containing 4 kcal/kg.
- The NRC's minimum requirement for kittens after weaning is 180 g/kg, equivalent to 15.75% of ME
- A level of 30% of the diet DM is suggested for growth and reproduction in foods containing 4 kcal of ME/g of food. This value is equivalent to 26.25% of ME calories.

Amount of food

- The amount of food one gives depends on the cat's age, weight, breed, condition, and amount of activity it gets.
- Cats and young kittens will not consume enough food in one meal to last 24 hours
- Two meals are recommended, and young kittens and females that are pregnant or nursing require more frequent feedings.
- Cats should never be given a diet of dog food because it contains large amounts of cereals and vegetables.
- Dog food also lacks necessary amounts of vitamins A and B and some essential fatty acids.
- Many times cats will be seen eating grass. The exact reason for this is not known, but it may be an attempt to increase roughage in the diet or to eliminate a hairball.

- Level of 26% of the diet, equivalent to 22.75% ME, is suggested for adult maintenance.

Feeding Frequency

- 2-3 months : 4 meals/day

- 3-5 months : 3 meals/day
- 6-8 months : 2 meals/day
- Adult: 2 meals/day
- After each feeding the stomach of kitten should be rubbed with coarse warm towel.
- Feeding pot should be very thick otherwise it will be spoiled by the cat stepping on it.

PRACTICAL FEEDING OF CAT

Feeding principles

- Cats are true carnivores and require almost twice as much protein in their diet as dogs.
- The best source of this is from animal products; 30 to 40 percent of the cat's diet should be animal-type proteins (meat, meat by-products, fish, eggs, and milk).
- About 10 percent of the diet should consist of fat; fat provides calories and the essential fatty acids.
- A cat should be fed using one of the many commercial cat foods. If feeding fresh foods, it is important to provide a variety.
- Strictly feeding meat, chicken, fish, and other muscle meats may cause bone disease, stunted growth in kittens, poor eyesight, and other problems due to the lack of calcium, and vitamin A.
- Calcium can be supplemented by adding sterilized bone flour, calcium phosphate, calcium lactate, or calcium carbonate.
- When feeding meat, it is important that all of the bone has been removed or chopped to prevent pieces of bone from becoming lodged in the throat or digestive system. Cats should never be given chicken bones.
- Canned foods contain more animal protein than the other commercial rations, have a higher fat content that makes them more palatable, and contain about 75 % water.
- Fresh and canned foods should not be fed straight from the refrigerator; these foods should be allowed to warm to room temperature before being served.

- Too much liver can cause vitamin A poisoning. Milk is a good source of calcium, but it may cause gas and diarrhoea in adult cats.
- Feeding too much of some oily fish such as tuna may destroy vitamin E through oxidation and lead to a deficiency called steatitis or yellow fat disease.
- Raw egg white contains Avidine that destroys the B Vitamin biotin, but egg yolk and cooked egg white provide valuable protein, fat, and vitamins.

Semi-moist foods

- Semi-moist foods are usually less expensive because they contain some vegetable protein and are usually supplemented with nutrients to make them nutritionally complete.
- Semi-moist foods have chemicals added to keep them from drying out or spoiling; they contain about 30 percent water.

Dry foods

- Dry foods contain about 10 percent water and less fat and protein than semi-moist foods. Cats on dry diets should have plenty of water available.
- Some cats on dry diets may develop bladder problems.
- Milk, water, or gravy can be mixed with the food to improve palatability and to ensure that the cat gets adequate water intake.
- One may wish to feed canned foods occasionally to help prevent bladder problems, get the cat used to different types and textures of foods, and ensure that the cat gets a balanced diet.
- Dry foods do have the advantage of helping to clean the teeth and prevent the buildup of tartar.

FEEDING REQUIREMENT FOR HAND REARED KITTENS

Age in week	Food	Number of meal in 24 hour	Milk meal in ml	Caloric requirement for 24 hour	Expected body weight
1	Milk mixture in bottle	12 - 9	2 - 7	40 - 80	100 - 200
2	Milk mixture in bottle	9	7 - 9	80 - 100	200 - 300
3	Milk mixture in bottle	9	10	112	300 - 360
4	Milk mixture in bottle	7	10	115	350 - 420
5	Reduce bottle introduce solid	7		120	400 - 500
6	Milk in bowl; solids	6		125	450 - 600
7	Weaning complete	3		130	550 - 700

MILK AND MILK SUBSTITUTE

- 100 gm of cat's milk contains 9.5 g protein, 6.8 g fat, 10.0 g lactose, 35 mg calcium and 70 mg phosphorus and provides 142 calories.
- Kittens do not thrive when they are hand reared on cow's milk but a mixture of dried cow's milk reconstituted at twice the normal strength is satisfactory.

FEEDING AND PREGNANCY

- The weight gain pattern that occurs in pregnant queens is slightly different from that observed in bitches.

- Although most of the bitch's weight increase occurs during the last third of gestation, pregnant queens exhibit a linear increase in weight beginning around the second week of gestation.
- A second difference between bitches and queens involves the type of weight that is gained during pregnancy. In dogs, almost all of the pre-parturition gain is lost at whelping.
- In contrast, weight loss immediately following parturition in the cat accounts for only 40% of the weight that was gained during pregnancy. The remaining 60% of the queen's weight gain is body fat and is gradually lost during lactation.
- Thus it appears that the queen is able to prepare for the excessive demands of lactation by accumulating surplus body energy stores during gestation.

- Similar to dogs, female cats should be fed a diet, that is intended for reproduction throughout gestation and lactation. Litter size is positively influenced by the provision of adequate fat in the queen's diet, and fat in the diet should provide optimal levels of EFAs, particularly arachidonic acid. Taurine is also an important nutrient to consider because both conception rate and kitten birth weight are reduced in queens when dietary taurine is limiting.
- The amount of food that the queen receives should be gradually increased beginning the second week of gestation and continuing until parturition. At the end of gestation, the queen should be receiving approximately 25% to 50% more food than her normal maintenance needs.
- Because most cats adapt well to free-choice feeding, this is often the best way to provide the pregnant queen with adequate nutrition during pregnancy. The queen's weight gain should be monitored closely to prevent excessive weight gain during this time. Queens typically gain between 12% and 38% of their pre-pregnancy body weight by the end of gestation.

CAT MILK COMPOSITION

Protein (%)	7 -8
Lactose (%)	3 - 4
Fat (%)	5 - 7
Calcium (mg/L)	700 - 1800
Magnesium (mg/L)	65 - 70
Iron (mg/L)	8 - 9
Zinc (mg/L)	6 - 7
Copper (mg/L)	1.0
Energy (kcal/L)	850 - 1600

Reference

Case, L.P., Carey, P.D. and Hirakawa, D.A., Canine and Feline Nutrition, (1995).

Pet animal Breeding, Management, Nutrition and Health Care (1+1)



Canine Nutrition



Energy requirement

- Correlated with ($W^{0.75}$) Metabolic body weight
- Adult dog (Maint)- 130 Kcal/Kg $W^{0.75}$

Post weaning	2 × adult maintenance ME
40% adult body weight	1.6 × adult maintenance ME
80% adult body weight	1.2 × adult maintenance ME
Late gestation	1.25 to 1.5 × adult maintenance ME
Lactation	3 × adult maintenance ME
Prolonged physical work	2 to 4 × adult maintenance ME
Decreased environmental temp	1.2 to 1.8 × adult maintenance ME

Protein requirement

NRC recommendation

Maintenance - 4.8 g/ kg bwt
Growth - 9.6 g/ kg bwt

Fat requirement

Adult maint -5 % (1 g /kg bwt)
Growth and reproduction - 8% (2.7 g/kg bwt)

Linoleic acid- 1% of food

Ratio of linoleic : linolenic acid -Imp

Other nutrient requirement

Item	Adult (g/kg body wt/day)	Growing(g/ kg body wt/day)
Calcium	0.26g	0.53g
Phosphorus	0.22 g	0.44g
Sod. Chloride	0.37 g	0.44g
Vit. A	100 i.u.	-
Vit. D	5 i.u.	-

Principles of dog feeding

Food shall contain 30 % meat + cereals, vegetables, milk, egg, bread, etc

15 minerals required

Calcium and Phosphorus essential for growing and lactating dogs
Start feeding Ca and P even from the preweaning period

Provide large bone to the pup to gnaw

Follow strictly routine eating habits – feeding at the same place at the same time

Practical feeding

❖Feed a highly digestible, nutrient-dense food formulated for growth.

Feed Meals using a portion-controlled regimen.

❖Feed three to four meals per day until 4 to 6 months of age; feed two or more meals per day after 6 months.

❖Feed to achieve an average rate of growth for a pet's breed and to support a lean body condition.

❖Avoid overfeeding to promote maximal growth rate.

❖Provide regular daily exercise.

❖Do not add nutrient supplements to a pet's balanced diet.

NUTRITIONAL MANAGEMENT OF NEWBORN PUPPIES

Colostrum feeding –provide passive immunity

Effective absorption of Ig within 48 hrs after birth

Upto 4 weeks sole milk feeding is practiced.

After 4 weeks- commercial food for pups

Fresh Semisolid food given in a shallow dish

5-6 wks -consume semisolid food readily
After 6 weeks chew dry food

Nutritional weaning complete by 6 weeks

NUTRITIONAL CARE OF ORPHAN PUPPIES

Provide a warm, draft-free and clean environment.

Feed a milk replacer that closely approximates the nutrient composition of bitch's or queen's milk.

Estimate the correct amount of formula based on the orphan's age and weight.

Divide the formula into four to five equal feedings per day.

Bottle-feed or use a feeding tube.

Weigh orphans regularly: one time per day for the first week and one to two times per week thereafter.

Introduce semisolid food at 3 to 4 weeks.

Wean to dry pet food by 6 to 8 weeks.

Post weaning

Post weaning food

Cow/goat milk (250 ml)+ water (125 ml) + egg yolk + glucose– fed at intervals

Level of protein and fat ----------30- 35%

Fed @ 15 % Bwt

2 month

Rusk, bread, good quality dog biscuits, eggs, soup, porridge (Wheat flour, oats, ragi, or soybeans in milk)

Beef without much fat

X Avoid rice feeding before 3 months

X Avoid meat of slaughter house origin before 3 months

Complete meal

Nov Veg- 30% meat + cereals + vegetables + milk + egg + bread

Vegetarian - Veg soup + soyabean meal+ chappathi + idli

DM needed- 50 g DM upto 6 months

40 g after 6 months

Age in months	Frequency
1-2	6 times
2-3	5 times
3-4	4 times
4-5	3 times
5-6	2 times

FEEDING MANAGEMENT DURING GROWING STAGE

Rapid growth -between 3 and 5 months of age

Portion-controlled feeding recommended feeding regimen for growing dogs.

A puppy's daily portion of food should be divided into at least two but preferably three meals per day until the puppy is 4 to 6 months of age.

After 6 months, two meals per day can be fed

Free choice feeding not advised

FEEDING MANAGEMENT DURING PREGNANCY AND LACTATION

Nutrient requirement during first 5 weeks similar to maintenance

Last 3 weeks- feed intake increased gradually

At whelping Intake 25-50% higher

Body weight -15-25% higher

Several small meals per day

Once whelped- provide fresh water and food

Commercial foods

Dry Dog food- Moisture 10-12%

CP- 18-27%

Fat: 7-15%

Carbohydrate- 35-50%

Meals, pellets, Biscuits, Kibbles



Semimoist food

Moisture 25-30%

Meat and milk products and byproducts

Preservatives : sucrose, propylene glycol, sorbate

Canned Dog food

Moisture 75%



Feline Nutrition

Peculiar Aspects

- Intestine adapted for high fat , high protein diet
- Arachidonic acid and EPA are essential for cats
- Protein requirement high
- Special requirement for taurine (β amino sulphonic acid)
- Require Arginine and lysine
- Require preformed Vit A in diet

GENERAL GUIDELINES FOR FEEDING CATS

- Cat should be fed individually and food selected should promote health
- The food should contain optimum nutrients
- Rapid change in the diet should be avoided.
- New diet should be introduced gradually by mixing it with the old diet in 25% increment each day.
- Cats are carnivores in nature.
- Feed should be rich in protein of animal or fish origin.
- Either raw or cooked meat can be fed.
- Also provide vegetables, green grass etc to avoid digestive trouble.
- Green grass helps to expel fur balls from the stomach.
- Grass will be having vitamins and minerals especially trace minerals and so grass feeding is advantageous.
- Cat should be given plenty of drinking water.

Energy requirement

Age and level of activity	Calculation of energy need	Kcal per day
Adult cat		
Inactive	60 kcal x body weight (kg)	240
Moderately active	70 kcal x body weight (kg)	280
Highly active	80 kcal x body weight (kg)	320
Pregnancy	1.25-15 X Maint	
Lactation	2-3.5 X Maint	
Kitten		
3 months (1 kg)	250 kcal x body weight (kg)	250
5 month (2.5kg)	130 kcal x body weight (kg)	325

Protein requirement

Growth and reproduction - 30% of the diet DM

Adult maintenance - 26% of the diet

Feeding Frequency

2-3 months : 4 meals/day
3-5 months : 3 meals/day
6-8 months : 2 meals/day
Adult: 2 meals/day

Feeding principles

Cats are true carnivores and require almost twice as much protein in their diet as dogs.

Best source -animal products; 30 to 40 percent of the cat's diet should be animal-type proteins (meat, meat by-products, fish, eggs, and milk).

10 percent of the diet should consist of fat; fat provides calories and the essential fatty acids.

A cat should be fed using one of the many commercial cat foods.
Calcium can be supplemented by adding sterilized bone flour, calcium phosphate, calcium lactate, or calcium carbonate.

When feeding meat, it is important that all of the bone has been removed or chopped to prevent pieces of bone from becoming lodged in the throat or digestive system. Cats should never be given chicken bones.

Type of food

Dry food -10% Moisture
provide plenty of water, milk

Semimoist food

Canned food



Feeding Kittens

- Colostrum feeding
- Orphan feeding
- Cow/buffalo milk + egg yolk+ cereal flour+ cream+ minerals and Vitamins
- Fed @ 10-15% Bwt / Day 0
- Kittens start nibbling solid food by 3rd or 4th wk

Feeding during Lactation and gestation

✓Queens should be fed a diet intended for reproduction throughout gestation and lactation.

✓Litter size is positively influenced by the provision of adequate fat in the queen's diet, should provide optimal levels of EFAs, particularly arachidonic acid.

✓Taurine is also an important nutrient because both conception rate and kitten birth weight are reduced in queens when dietary taurine is limiting.

✓The amount of food should be gradually increased beginning the second week of gestation and continuing until parturition.

✓At the end of gestation, the queen should be receiving approximately 25% to 50% more food than her normal maintenance needs.

✓Free-choice feeding preferred for the pregnant queen

Feeding sick Animals

Liver diseases

Diabetes Mellitus

Cardiac Insufficiency

Renal Insufficiency
Urolithiasis
Enteritis
Vomiting
Pyrexia
Stress conditions

Thank you

FEEDING OF PET BIRDS

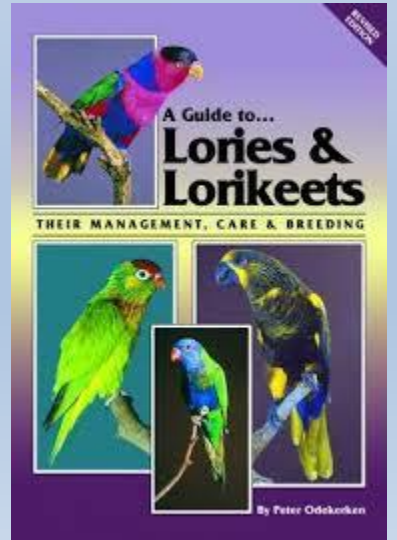


Pet bird feeding

- Wild birds have a grater variety of food than captive specimens
- Birds can be categorized based on their feeding habits into broadly as
    - *Seed eaters*
    - *Soft bills (insect and fruit eaters)*
- Different kinds of birds may have different dietary needs or restrictions
- Lories and lorikeets normally eat nectar, and therefore require a diet that simulates their normal food source.
- Toucans and Mynahs are susceptible to iron toxicosis, and therefore require low-iron diets.
- Birds are ***picky eaters*** and will consume the nuts and seeds and ignore the nutritional foods.



Lorikeets



Feed stuff used for feeding pet birds

- Seeds
- Fruits
- Live foods – Insects and invertebrates
- Meal worms and White worms
- Prepared readymade pet foods - with vitamin and mineral supplements

Pet bird feeding

- Birds require a well balance diet with plenty of *variety of the right kinds of foods* that contain essential vitamins and minerals.
- Birds should be fed a regular diet of nutritious fruits and vegetables, supplemented with common bird feed
- Birds are creatures of habit and like to see familiar, common foods at regular intervals.
- It is common for birds to shy away from new or unfamiliar foods and will take some time observing the new food before they try it



Pet bird feeding

- As new foods can cause the bird stress, it is important to keep the bird's diet consistent and familiar when they are ill.
- Introducing new foods during times of sickness will cause the bird to eat less and not recover as quickly.
- It should be noted that during sicknesses, any change from the normal routine (feeding times, cage location, etc.) will cause the bird additional stress



Seed eaters

- Does not necessarily eat seeds exclusively.
- Also take green food, fruits and large variety of insects during breeding season and young ones are reared almost exclusively on such food
- Seed eaters: A great variety of seed is essential
- Wild birds take mainly unripe seeds.
- Half ripe seed are highly recommended for caged birds (high vitamin content)

Germinated seeds

- All birds appreciate germinated seed when offered and they likely to ignore all other available food
- They are rich in vitamins A and E
- During soaking period, prior to germination , starch in the seed changes to sugar (dextrins)
- Not soak seed for too long, as this could lead to sugar content turning into alcohol by fermentation and fermentation in the crop of a bird leads to sickness such as crop swelling
- Canaries and finches are especially keen on germinated seed and during the rearing of the young germinated seeds given only in small quantities as a supplement to the main diet and not in place of it





Seeds for Canaries



Aviary birds Vs Caged canaries

- Aviary birds: Use more energy and have to withstand greater climatic fluctuations than their caged counterparts
- Bird kept in a small cage can be managed by a lighter diet than a bird in an aviary
- Aviary birds - balanced seed mix containing approximate amounts of fresh seeds
- Caged canaries (those kept for song) – not allowed to get fat. Give a basal diet with canary grass seed and rape seed. Also provide a supplementary seed diet



Canary grass seed



EXAMPLE OF A BALANCED SEED MIXTURE

Name of seed	Level of incorporation
Canary grass seed (white seed)	30 %
Rape seed	25%
Yellow millet	15%
White millet	5%
Red millet	5%
Broken oats	5%
Niger seed	5%
Poppy seed	4%
White lettuce seed	2%
Linseed	2%
Hemp seed	2%

Seed for tropical birds

- Exotic birds- small and large
- Small exotics include zebra finches, waxbills etc
- Large exotics include quail, doves, cardinals, weavers etc
- Feeding with larger exotics are more difficult since they require special seeds

Seed for Parakeets

- Simpler diet when compared to canaries
- Small parrot like birds (like budgerigars) give a mixture of Canary grass seed (30 %), Yellow millet (20 %), red millet (20%), white millet (20 %) and chopped oat groats (10 %)
- Larger Parakeets give a mixture of Canary grass seed (30 %), Yellow millet (20 %), red millet (15%), white millet (15 %) and chopped oat groats (10 %) and sunflower seed (10 %)
- Provide a supplemental daily seed mix (containing Teazle, Anise, Rape seed, Sesame seed, Niger seed, Flax, Milo and safflower) for both groups
- Larger parakeets may also be given shelled peanuts as well as supplementary greens and fruits.



Food for Parrots

A parrot's diet should consist

- mostly of pelleted feed, (provides balanced nutrition and avoids sorting)
- up to 20% dark pigmented vegetables (e.g. carrots, beats, sweet potatoes).
- Small, limited amounts of fruit (fruit such as apples, grapes, bananas and citrus are poor nutrient sources for birds)



Food for Insect eaters

- Not always possible to obtain suitable foods -Commercial diets available
- Depending on their size, most insectivorous birds are fond of small or cut up meal worms, fly maggots, cut up earthworms, grass hoppers, ant pupae, small beetles, spiders, earwigs and green flies
- Meal worms: larvae of certain beetles. Ensure the continuous supply of small mealworms by breeding
- All insect eaters are also fruit eaters. Therefore fruit should not be absent from their diet
- Seedeaters and various parrot like birds will rear their young in the breeding season with insects as a supplement to their normal food

Food for Fruit eaters

- Feeding fruit eaters is easier than insect eaters
- Commercial mixtures (called universal food) available for soft billed birds
- They contain among other things berries, raisins, honey, dried insects, crawfish, vitamins and minerals
- Type of fruit offered- depends on time of the year. But fruits should not be rotten.
- Fruits like oranges and grape fruits can be cut and placed in aviary and birds will peck out the contents
- Cut the fruit very fine and mix it with the universal food.
- Other fruits that can be given include: bananas (not too much as they are fattening), cherries, grapes, strawberries, figs, dates, grape fruit, guava, mulberries, papayas, peach, pineapple, pomegranate, pumpkin and tomato)
- When cherries or grapes are given, first remove the pits or seeds to avoid the possibility of any bird choking on them

Green food

- Essential item for birds
- Canaries and tropical finches feed their young with green food
- Bird species are particular as to what kind of green food they will eat and by experimenting we can find out what is our birds preference.
- In general all birds prefer lettuce
- Other green foods that may be enjoyed include spinach, celery, chicory, cabbage heart, cucumber, sweet potato, beet, fresh corn, alfalfa
- Carrots are also a very good food (provide carotene)

Rearing food or Egg food

- Breeders prepare make their own egg foods
- Commercial preparations
- Egg food- chicken egg + crumbs of rusks + One quarter of a grated apple or pear and juice of half orange. All mixed well together. Very small amount of cod liver oil can also be added

Fat

- During winter birds require animal fat especially to aviary birds

Nuts and seeds

- Seeds and nuts contain addictive fats that can create an energy boost, similar to a “sugar rush” that humans feels when consuming sugary products.
- This boost from fats creates a preference for high-fat foods.
- When birds become hooked and then are deprived of the fatty nuts and seeds that they prefer, they become lethargic and depressed. Recent research shows that not only are sunflower seeds common in pet bird’s diets, but also can be particularly addictive.

Vitamins

- Vitamin s essential for bird's performance

Vitamin A

- Critical to your pet bird's health.
- This vitamin helps maintain healthy feathers, skin, eyes, intestinal tract, respiratory system, and reproduction organs and tracts.
- To ensure your bird gets an amply supply of Vitamin A, be sure to provide a variety of vitamin A rich foods such as sweet potatoes, squash, carrots, spinach, corn, apricots, eggs and fish oils.
- Seeds do not contain sufficient Vitamin A - birds that prefer to eat nothing but seeds (called "seed junkies") eventually become sick due to the lack of Vitamin A and shorten the bird's overall life span.

Vitamins

Vitamin B complex

- Most of them found in wheat. Other good sources are cod liver oil, milk, green feed and sprouted seed

Vitamin C

- Synthesized in their own bodies

Vitamin D

- Can also produce if they have access to UV light

Calcium and Grit

- Need during breeding season when the eggs are being formed and during the moulting
- Caged birds can be given a piece of cuttle fish bone / a bowl of grit / DCP
- Birds that have no access to grit take greater quantities of food take greatest quantities of food than those that have a supply of grit
- Supply a separate dish with grit once or twice a month for larger birds
- Never use grit as the sole source of essential minerals
- Fine or small sized grit used for finches, canaries, parakeets
- Medium to coarse grit for large parrot and parakeets

Drinking water

- Birds should have access to fresh drinking water available at all times
- Clean water bath should also be available
- In the aviary place the water container (preferably earthen) on a slab
- Honey water given to birds once a week.
- Honey water made by dissolving 1 table spoon of honey in 5 table spoons of warm water.
- Honey drink: 1 table spoon of honey + 1 table spoon of unsweetened condensed milk and 1 table spoon of baby food consisting of mixed vegetables and meat. All of these mixed in 10 tablespoons of warm water

Food contamination

- Bird cages and food dispensers should be cleaned regularly to prevent bacterial diseases from causing sickness.
- Birds are highly sensitive to bacteria that is not considered harmful to humans.
- To prevent contamination, wash your hands each time you prepare the bird's food and wash all fresh fruits and vegetables before feeding them to the bird.
- Bird feed can be placed in the oven and baked (350 ^{0}C for 10 minutes) to "sterilize" the food.
- Foods given to birds should not be placed on the floor of the cage so as to not become contaminated with bird feces and saliva.
- Place the food in the cage in a clean, sterile bowl.
- Water dispensers should be cleaned regularly with a disinfectant soap and rinsed thoroughly with hot water.
- Because dishwashers ran at hot temperatures, they are a great place to further sterilize food bowls and water dispensers.
- When filling up your bird's water dispenser use clean bottled water, or, if you use tap water, let the tap water run for 3 – 5 minutes before filling the water container to allow for impurities to pass through the pipes.

NUTRIENTS IN FEED

Feed is composed of six nutrients :

- Carbohydrates
- Proteins
- Fats
- Vitamins
- Minerals
- Water

FUNCTIONS OF CARBOHYDRATES

- Structural support
- Energy to living body
- Contributes to the Carbon skeleton of proteins

FUNCTIONS OF PROTEINS

- Essential for both structure and function of living cells
- Plays a role in respiration
- Meets the amino acid requirements of the body
- Excess protein can be utilized to produce energy (one gram protein will yield 4.2 K Cal heat energy)

AMINO ACIDS

Amino acids are of two types, Essential and Non-essential .

Essential amino acids are not synthesized by poultry.They need to be supplied through feed for optimum growth of birds.eg. Arginine, Lysine , Histidine, Leucine, Isoleucine, Valine, Methionine, Threonine, Tryptophan, Phenyl alanine.

Non-essential amino acids are synthesized by poultry .eg.Alanine, Aspartic acid, Glutamic acid, Hydroxy proline etc.

FATS

- Fats are rich in energy.
- Insulation for vital organs
- Improves palatability of feed
- Helps in absorption of vitamins

Inclusion of fat in diet increases the cost of production. It may lead to rancidity also.Sources of fat are mustard, ground nut, corn oil, vegetable oils, animal tallow, butter etc.

VITAMINS

Needed for development of normal tissue and for normal health, growth and maintenance.

FEED INGREDIENTS USED FOR POULTRY

Classified into three types :

- Energy sources
- Protein sources
- Mineral sources

Protein sources are divided into 2 :

- Animal sources
- Vegetable sources

Energy sources

Maize, Sorghum (jowar), Bajra (pearl millet), ragi (finger millet), de-oiled rice bran , rice, oats,molasses, wheat , barley , rice bran, rice polish etc

MAIZE or CORN

The most common source of energy in poultry diet. It is highly palatable, rich in vitamin A, Methionine , linoleic acid , digestible starch and oil and a ready source of energy. It supplies 3350 kcal ME/kg. The fibre content is only 2 %. Yellow maize is the source of pigments as CRYPTOXANTHIN and CAROTENE that imparts yellow colour to egg yolk and skin of broilers. Protein content is 9.5 to 10.5 % . Low in Lysine and Tryptohan. The OPAQUE-2 variety is rich in Lysine and Tryptophan. Maize is susceptible to growth of Aspergillus *flavus* and *Aspergillus parasiticus* resulting in production of Aflatoxins.

SORGHUM or JOWAR

Protein content is 10 to 13 %. Lysine, Methionine, Crude fibre, ether extract, ash , phosphorus are almost same as maize. Calcium content is twice as that of maize. Low tannin varieties of sorghum can replace more than 50 % of maize in poultry diet.

WHEAT

Protein content ranges from 10 to 13 %. Rich in Lysine.Me is 3200 k cal/ kg. Young chicks are unable to utilize wheat effectively as Arabinoxylans and increased Gliadin/Glutenin ratio in wheat protein increases viscosity of the intestinal fluid.

RICE

Rough rice has 8.2 % CP, 6.5 % ash, 1.9 % ether extract, 9.2 % crude fibre. ME ranges from 3400-3450 kcal per kg. Can be used up to 20 % in layer diet , 30 % in broiler diet.

BAJRA or PEARL MILLET

Contains more protein and fat than maize. Can replace 50 % maize in broiler and layer diets. ME is 2800 kcal / kg.

RAGI or FINGER MILLET

Contains 7 % protein , 1.1 % fat , 4.6 % fibre and 0.31 % Calcium.ME is 2650 kcal ME per kg.

BARLEY

Not generally used in India. Contains 12 % protein. Rich in fiber. Will lead to sticky droppings in poultry because of gel forming Beta – glucans.ME is 2500 kcal per kg.

OATS

As oats contains 11-12 % fiber and low ME, it is not commonly used in poultry diets.Contains β-D glucans that will lead to sticky droppings.

TRITICALE

A cereal developed from wheat and rye. The protein will range from 14 to 18 %.

RICE BRAN and RICE POLISH

Byproducts obtained during milling of paddy. 2 types are available: 1) rice bran and de-oiled rice bran. Rice bran has 12 % fibre, protein, fat. Deoiled rice bran has 13 to 15 % protein and fibre, 0.08 to 1 % fat .ME is 2700 kcal /kg. Use of deoiled rice bran causes dustiness and reduces palatability of feed.

Rice bran is a good source of B group of vitamins.

Rice polish has 13 % oil and protein, 11 % fibre and 2900 k cal ME.

Protein sources

Vegetable sources

Soyabean meal, Linseed oil cake, coconut meal,sunflower meal, groundnut cake, Sesame or til cake, Rapeseed meal,pulses , mustard oil cake, etc

SOYABEAN MEAL

The most commonly used protein supplement and is the best source of vegetable protein. Contains 46 to 50 % protein. Soyabean meal is balanced in all aminoacids except Methionine. Anti-nutritional factors as Trypsin-inhibitor, Urease and Phytohemagglutinin are present in raw Soyabean meal.

GROUNDNUT MEAL

Not commonly used because of contamination wit Aflatoxin, poor aminoacid content etc. The two varieties available are expeller and solvent extracted varieties. Aflatoxin B_1 contamination is most common in groundnut meals.

RAPESEED MEAL

The protein content is 36 to 38 % for expeller meal. It is deficient in Lysine. Rapeseed meal contains anti-nutritional factors as tannins, erucic acid, glycosides , singrin and Goitrogen.

COTTONSEED MEAL

Contains 30 to 32 % protein only. Has high fibre of 16 to 18 %.Contains anti-nutritional factor Gossypol that causes yolk discolouration.

SESAME OR TIL OILMEAL

Contains 36 to 40 % protein, 5 to 9 % fat, 6 to 8 % fibre and 10 to 12 % ash.Rich source of Methionine, Cystine and Tryptophan, Calcium. Contains Phytic acid, that will reduce the availability of dietary Phosphorus, Calcium and Zinc.

SUNFLOWER SEED MEAL

Undecorticated type contains 27 to 30 % protein and 20 to 30 % fibre.

SAFFFLOWER SEED MEAL

Included up to 5 % in broiler diets. Meal prepared from safflower seed kernels contains 55 % protein and low fiber of 4 %.

COCONUT OIL MEAL

Residue after extraction of oil from dried coconut kernel. Contains 22 % protein, 1 % fat, 15 % fibre. The Me is 1200 kcal/kg only. Disadvantages are Mycotoxin contamination and laxative effects.

MAIZE GLUTEN MEAL, MAIZE GLUTEN FEED AND MAIZE GERM MEAL

These are byproducts of maize starch industry, obtained after removal of starch from maize. Maize gluten meal contains 50 to 60 % protein and is rich in Methionine and Xanthophylls.

GUAR MEAL

Only 2.5 to 5 % are added in diet. Contains 40 to 42 % protein . High in Lysine and Methionine.

Animal sources

Fish meal, meat cum bone meal, fish , meat meal , blood meal , liver meal, liver residue meal, feather meal, hatchery by-product meal, poultry by-product meal, silk worm pupae meal etc.

FISH MEAL

Most valuable animal protein supplement. Contains 45 to 60 % protein , 5 to 12 % fat and all amino acids except Tryptophan. Rich in vitamin B_{12} , Choline, Iodine, Phosphorus, Calcium etc. Added up to 10 % in diets as higher levels will lead to fishy odour in eggs and meat. Rancidity may lower the energy content.

MEAT MEAL

Produced from animal tissues that are not consumed by humans as hair, hoof, horn, manure, ingesta, hide etc.Contains 50 to 60 % protein.

MEAT CUM BONE MEAL

Made from whole carcass except hooves, horns and skin. Contains 5o to 60 % protein, 12 to 14 % Calcium, 6 to 7 % fat. Added up to 5 % in poultry diet.

BLOOD MEAL

Obtained from whole blood, by cooking, drying and grinding it to a meal. The meal contains high amount of protein , 80 to 85 %. Rich in Lysine, Arginine , Methionine and Leucine. Deficient in Isoleucine. Added up to 1 to 2 % in the diet.

LIVER MEAL AND LIVER RESIDUE MEAL

Liver meal is obtained from whole animal liver. Liver residue meal is the residue left after manufacture of liver extracts. Contains 65 % protein . Good source of Lysine, Methionine, Cystine, Tryptophan and Glycine. Highly rich in Riboflavin, Choline, vitamin B_{12} etc.Added only up to 5 % in diets.

FEATHER MEAL

Prepared from we feathers. Contains more than 80 % protein. Deficient in Lysine, Tryptophan and Methionine.

HATCHERY BY-PRODUCT MEAL

Consists of wastes of hatchery operation as infertile eggs, dead embryos, killed chicks and eggshells. These are cooked, dried and ground. Contains 25 to 34 % protein.

POULTRY BY-PRODUCT MEAL

It is a by-product obtained from poultry processing plants. Includes heads, feet and the internal edible parts of the body. Contains 55 to 60 % protein and 12 % crude fat. Inclusion level is 5 %.

SILKWORM PUPAE MEAL

By-product of silk industry. Deoiled silk worm pupae meal contains 80 % protein. Can be added up to 5 % in poultry diets. Vitamin content is high.

Mineral sources

Mineral supplements are supplemented through a mineral mixture or through specific mineral supplements.They are available as two types, with salt and without salt.Dicalcium phosphate, Oyster shellgrit, bone meal etc can be used.Calcium carbonate, Oyster shell etc are used as Calcium sources. Dicalcium phosphate is used as source of Calcium and available Phosphorus.Trace minerals are added in the form of trace mineral premix available at shops or prepared at feedmill.

About 40 % of bones, 1 %of broiler meat and 11 % of eggs is constituted by minerals.

LIME STONE, OYSTER SHELL

Calcium carbonate is the cheap source of Calcium for birds. It contains 34 to 38 % Calcium. It should be in granular form, if used in poultry diets. Fine grinding is to be avoided as it causes dustiness.

DICALCIUM PHOSPHATE

Most preferred Phosphorus supplementation. Produced from chemical treatment of bone or rock phosphate. Contains 25 to 28 % Calcium and 15 to 18 % Phosphorus.

VITAMIN SUPPLEMENTS

Supplemented either through premixes or as individual vitamins.The premix containing vitamin A, D_3 and Riboflavin can be added at the rate of 10 to 15 g per quintal. The premix that supplies B complex and vitamin C can be added at 25 g per quintal of feed.

VITAMINS

Vitamins are defined as organic compounds required in very minute amounts for normal growth and maintenance of animal life. They are classified into two :

- Fat soluble
- Water soluble

Fat soluble vitamins are Vitamin A,D,E and K.

Water soluble vitamins are divided into two groups:

- B complex
- Vitamin C {Ascorbic acid }

The members of B compex are :

- Thiamine or B_1
- Riboflavin or B_2
- Nicotinic acid
- Pyridoxine or B_6
- Pantothenic acid
- Biotin
- Folic acid
- Choline
- Cyanocobalamin

VITAMINS OF IMPORTANCE IN POULTRY

Name	**Sources**	**Function**	**Deficiency**
Vitamin A or Retinol	Yellow maize, Lucern meal, fish oil, alfalfa meal	For normal growth and integrity of specialised epithelial tissues. Role in vision.	Emaciation, staggering gait, ruffled plumage. Keratinization of eyelids.
Vitamin D or Cholecalciferol	Fish liver extract	Important role in Calcium and Phosphorus metabolism	Retarded growth, enlarged hock joints, bending of ribs, abnormal bone development
Vitamin E or Tocopherols	Vegetable oils, maize germ oil, green foods	Functions as co-factor in the electron transfer system operating between cytochromes	Encephalomalacia, exudative diathesis, muscular dystrophy. Sudden prostration , lying with leg outstretched and toes fixed
Vitamin K	Synthetic sources, green feed	Role in Prothrombin production and clotting of blood	Chicks may bleed to death if an injury occurs.Haemorrhages may occur s/c.

Thiamine	Cereals and their by-products	A part of coenzyme in oxidative decarboxylation reaction of alpha-keto acids.	Polyneuritis. Head is drawn over the back called "**STAR-GRAZING" position**.
Riboflavin or Vitamin B_2 or Vitamin G	Alfalfa meal, milk products	Forms part of coenzymes FMN and FAD.	Epithelium and myelin sheath of nerve trunks are affected. Changes in sciatic nerve causes **"CURLED-TOE PARALYSIS**" in chicken. Sudden appearance of chick walking on their hocks with toes curling inward.
Niacin or Nicotinic acid	Bran and groundnut cake, whole wheat, meat, soyabean cake	Involved in electron transport system through coenzymes NAD and NADP.	**BLACK TONGUE** , a condition where the entire mouth cavity including the upper part of the oesophagus get inflamed in deep red colour
Pantothenic acid	Breweries, dried yeast, dry butter milk, whey, skimmed milk, rice polish, groundnut cake	Constituent of coenzyme A required for acetylation reactions	Reduced growth rate, dermatitis
Pyridoxine or Vitamin B_6	Muscle, meat, liver, green leaves		Chicks run aimlessly. Abnormal excitability, convulsion
Biotin	Soyabean cake, grams, molasses, alfalafa meal		Feet become rough, crack open later. Poor growth, anaemia, paralysis of neck. Eyelids become granular. Embryos show parrot beak and short legs
Folic acid	Leaves, liver, yeast, cereals, soyabean		Poor growth, slow feather development
Vitamin B_{12} or Cyanocobalamin or animal protein factor	Foods of animal origin, poultry litter		Reduced growth, poor feathering, mortality in young chicks
Choline	Soyabean cake, grams, molasses, alfalfa meal		Poor growth, slipped tendon or **PEROSIS** occur.Unthrifty appearance.

MINERALS

Minerlas needed for poultry are classified into 3 groups : Macro minerals, micro minerals and trace minerals.

Minerals constitute one per cent of broiler meat, 11 % of eggs and 40 % of bones.

Macro minerals include

- Calcium
- Phosphorus
- Potassium
- Sodium
- Magnesium

Micro minerals include :

- Iron
- Manganese
- Zinc
- Copper
- Iodine

Trace minerals include :

- Cobalt
- Fluorine
- Selenium
- Molybdenum

Mineral	**Deficiency**
Calcium	Rickets in young, soft and rubbery bones. Thin shelled eggs, low egg production.
Phosphorus	Rickets, anorexia, cage layer fatigue
Sodium	Decreased egg production, poor growth, cannibalism
Potassium	Retarded growth, weakness, tetany
Magnesium	Depressed growth, low egg production
Chlorine	Poor growth rate, high mortality, dehydration
Sulphur	Retarded growth of cartilage, feather etc
Manganese	Perosis, skull deformation, parrot beak, lowered egg production
Iron	Anemia in chicks
Copper	Anemia, depigmentation of feathers
Iodine	Lowered hatchability, decreased egg production
Zinc	Growth retardation, shortening and thickening of bones and poor feathering
Cobalt	Anaemia, appetite failure
Selenium	Exudative diathesis, muscular dystrophy, pancreatic fibrosis

ANTI-NUTRIENTS AND NATURALLY OCCURING TOXICANTS IN FEEDSTUFFS

Several naturally occurring toxicants and anti-nutrients are present in feedstuffs of plant origin, especially legumes. These toxicants in feedstuffs have to be detoxified before mixing in feed, to improve their nutritional value.Common anti-nutrients are as follows:

Anti-nutrients	**Feedstuffs**
Amylase inhibitor	Wheat, rye, beans
Trypsin inhibitor	Soyabean
Betaglucans	Barley
Chymotrypsin inhibitor	Soya, peas, beans
Cyanogenic glycosides	Chick pea,yam, tapioca
Chlorogenic acid	Sunflower, Safflower
Cyclopropene fatty acids	Cotton seed
Erucic acid	Mustard and rape seed meal
Glucosinolate compounds	Mustard and rapeseed meal
Gossypol	Cotton seed meal
Haemagglutinins	Castor, Soya,Potatoes, Wheat germ
Hypoglycin-A	Jack fruit seeds
Lathyrogens	Lathyrus beans, grass pea
Linatine	Linseed
Lipoxygenase	Soyabean
Mimosine	Subabul
Niacytin	Maize, wheat bran
Oxalates	Spinach, beet root,sesame oil meal
Pentosans	Wheat
Papain inhibitor	Soya, peas
Phytates	Rice bran, legumes husk
Saponins	Alfalfa, Peas, Soya
Solanine	Potato
Tannins	Sorghum, tamarind seeds, tapioca, sal seed
Thiaminase	Fish, beans, linseed, cotton seed
Prussic acid	Linseed meal

MYCOTOXINS

Mycotoxins are the second most serious issues in poultry industry after the problem of increased feed price.Mycotoxins are the toxins produced in groundnuts, corn, cottonseed and feedstuffs derived from these, cereal grains, oil seeds etc.

When feed contaminated with mycotoxins are consumed by birds, Mycotoxicosis occur. It is more common in tropical countries like India. Among the poultry species , ducklings are more susceptible followed by turkey, poults, pheasants, chicks, mature chicken, quail etc. Khaki Campbell is most susceptible followed by Minikos and White Pekins.

If feed is not stored properly it will get infected by bacteria and fungi. Fungal infestation with Aspergillus, Penicillium and Fusarium liberates highly toxic mycotoxins as secondary metabolites. Fungi utilize the feed nutrients , leading to reduction in the content and organoleptic quality of the feed. Environmental conditions as high humidity, moderate to high temperature, higher grain moisture content, improper harvest and storage favours the development of fungi.

FAVOURABLE CONDITIONS FOR THE GROWTH OF FUNGI

- Moisture – 12 to 14 % or higher
- Relative humidity in the feed go-down –Above 70 to 75 %
- Physical condition of the grain – damaged seed coat due to insects and improper harvesting
- Ambient temperature of 25 to 30^{o} Celsius for Aspergillus and 15 to 20^{o} Celsius for Fusarium
- Storage- Leaky roof in the go-down , moist floor, improper stacking of bags, poor ventilation

Aspergillus and Penicillium are a common problem in the stored feed ingredients. Fusarium affects the grain before it is harvested. Mycotoxins of importance in poultry are Aflatoxin, Ochratoxin, T-2 toxin, Citrinin, Fumonisins and Zearalenone.

MAJOR FUNGI GENERA AND ASSOCIATED TOXINS

Genera	**Mycotoxin**
Aspergillus	Aflatoxin, Ochratoxin, Citrinin
Penicillium	Ochratoxin, Citrinin, Penicillic acid
Fusarium	Fumonisins, Zearalenone, Fusaric acid, T-2 toxin

AFLATOXIN

The most commonly occurring mycotoxin in India.It is produced mainly by *Aspergillus* flavus. It is seen in maize, jowar, ground nut cake, coconut cake , cotton seed cake meal

etc.Aflatoxins B_1,B_2, G_1,G_2 are commonly seen. Among these, Aflatoxin B_1 is the most toxic. Aflatoxin will result in decreased immunity and will lead to death.The birds develop anorexia, listlessness, poor FCR, reduced body weight,immunosuppression and susceptibility to stress. Aflatoxin is a hepato-toxin causing liver hypertrophy, paleness, fatty degeneration of liver etc.

OCHRATOXIN

It is the second major mycotoxin in poultry feed after Aflatoxin.

It is produced by *Aspergillius ochraceus* and *Penicillium viridicatum* at a wide range of temperatures.It is found in barley, maize, wheat, jowar, bajra, groundnut, sunflower extractions etc.There are 2 types of Ochratoxin, Ochratoxin A and Ochratoxin B.

Ochratoxin A is more common. It has teratogenic, mutagenic and immunotoxic effects. Depending on the degree of contamination, mycotoxins or their metabolites may be deposited in the poultry products like egg and meat. Residues of carcinogenic mycotoxins as Aflatoxins and Ochratoxin A can affect human health.

Safe levels of Aflatoxins for poultry

Aflatoxin : 20-30 ppb

Ochratoxin : 50-70 ppb

SYMPTOMS OF AFLATOXICOSIS IN POULTRY

- Severe drop in egg production
- Birds become off feed
- Growth of chicks retard
- Liver is enlarged with fat deposition and liver looks pale
- Spleen and pancreas enlarge
- Tumours are seen on liver, lungs, spleen, pancreas etc in ducks as Aflatoxin is carcinogenic.
- Aflatoxin produces paralysis, convulsion and death

PREVENTION AND CONTROL

The best method of control is to prevent fungal growth n feed. Mycotoxin contamination may be prevented by the following ways :

- Proper storage of raw materials and feed
- Moisture level should be below minimum threshold levels. Less than 12 % moisture is ideal
- Maintain proper relative humidity in the godown. Less than 60 % is ideal
- Ideal temperature during storage in the go-down .

- Protect feed against insects and rodents during storage
- Proper processing
- Addition of anti-fungal compounds during storage

CONTROL

The following control measures can be adopted:

- Mycotoxin binders or adsorbants as activated charcoal, Hydroxyl sodium calcium aluminosilicates (HSCAC) , Bentonites, Zeolitesetc are used.HSCAC and Sodium bentonites can adsorb and retain up to 95 % Aflatoxin.
- **Mannanoligosaccharides** (MOS) can adsorb and retain up to 95 % Aflatoxin. MOS derived from the cell wall of the yeast *Saccharomyces cerevisiae* has the ability to bind several pathogens in the GI tract and thereby prevent the colonization of pathogens.MOS can bind with Aflatoxin B_1, Aflatoxin B_2 and Zearalenone.
- Organic acids as Propionic acid, Formic acid etc are effective inhibitorsof Aflatoxin.They are used to inhibit mould growth and Mycotoxin development in stored raw materials.
- Supplementation of vitamin C,E,Se etc reduces the damage caused by mycotoxins as T-2 toxin,mould inhibitors as Sodium or Calcium propionate is useful

HARMFUL NATURAL CONSTITUENTS AND COMMON ADULTERANTS OF FEEDS AND FODDERS

Harmful natural constituents

❖ Toxic principles

I. Alkaloids

- Basic substances → N in heterocyclic ring
- Amino acids in plants → Alkaloids

Eg:- Nicotine in tobacco

- Toxin affects the central nervous system

Eg:- Atropine → pronounced effect on CNS

II. Glycosides

1. <u>Cyanogenic glycosides</u>

- Hydrolysed by enzymatic action
  - ➢ HCN / Hydrocyanic acid is released
  - ➢ ↑ly toxic
- Affect the electron transport chain
  - ➢by affecting cytochrome oxidase

Eg:- Tapioca leaf meal

Rubber leaves and rubber seeds also contain cyanogenic glycosides

Glycosides (Contd.)

2. Glucosinolates

Plant: cabbage, broccoli, rapeseed, mustard
Glucosinolates in the presence of enzyme thioglucosidase is hydrolysed to isothiocyanates goitrogenic property goitre

3. Saponins

- Plant: legumes, peas, soybean, alfalfa, berseem & common beans
- Saponins form stable foam with proteins & cholesterol froathy bloat in ruminants

Glycosides (Contd.)

4. Isoflavones & coumestans

- Phytoestrogens

➢Soyabean seeds contain genistein (isoflavone)

➢Estrogenic → Fertility is affected

III. Proteins and amino acids

1. Trypsin/ protease inhibitors

- soybean are the best known
- Eg:- Kunitz inhibitors & Bowman-Brik inhibitors

Proteins & amino acids (Contd.)

Trypsin/ protease inhibitors

- Feeding of raw soybean to chicken causes pancreatic hypertrophy

➢ Raw soybean must be heat treated (100^0C for 15 minutes) to destroy trypsin inhibitors

2. Mimosine

- Subabul (*Leucaena leucocephala*)

❖Toxic amino acid mimosine //r to tyrosine

- in rumen metabolized to 3, 4 dihydroxypyridine (DHP)

Proteins & amino acids (Contd.)

Haemagglutinins/ lectins

❖Other field beans kidney bean, pinto bean & navy beans

- Damage to the intestinal cell lining

➢Impair the immune system

3. Mimosine

- Subabul (*Leucaena leucocephala*)

❖Toxic amino acid mimosine //r to tyrosine

➢ in rumen metabolized to 3, 4 dihydroxypyridine (DHP)

Proteins & amino acids (Contd.)

Mimosine

- DHP is a goitrogen

➢impairing the incorporation of iodine in the thyroithyroid gland

❑ Symptoms

- Non ruminants

➢↓growth, alopecia & cataract

- Ruminants

➢poor growth, loss of hair, swollen & rough coronet region of hoof

Proteins & amino acids (Contd.)

Mimosine

❑Symptoms in ruminants (contd.)

➢mouth & esophageal lesions, ↓ serum thyroxine level & goitre

IV. Erucic acid

❑Rape & mustard seed

- Unsaturated fatty acid
- Mustard cake: 40-46% erucic acid in residual oil

➢ ↓ growth, feed intake & feed efficiency

Toxic principles (Contd.)

IV. Antivitamins

1) Antivitamin A

- Lipoxygenase in soybean seeds

➢Oxidizes carotene, a precursor of vitamin A

2) Antivitamin D

- In raw soybean seeds

3) Antivitamin E

- Kidney bean

4) Antivitamin K

- Dicoumarol found in spoiled sweet clover

Toxic principles (Contd.)

Antivitamins (Contd.)

5) Antivitamin B_6

- Linatin in linseed meal

6) Antiniacin

- Niacytin found in maize and wheat bran

Toxic principles (Contd.)

V. Phenols

1) Gossypol

❖Cotton seed

- Free gossypol@>150 mg/kg diet toxic to poultry

❑ Symptoms in chicks

➢ ↓ growth, ↓ feed intake, ascitis & cardiac irregularity

❑ Symptoms in layers

➢ Olive green discoloration of egg yolk

Toxic principles (Contd.)

Phenols (Contd.)

2) Tannins

- ❖ Sorghum, rape & mustard meal, mango seed kernel, alfalfa, tamarind seed & salseed meal
- ➢ Bind with proteins & inhibit enzymes like trypsin, amylase & lipase
- ❑ 2 types of tannins
- Hydrolysable tannins (HT)
- Condensed tannins (CT)

Toxic principles (Contd.)

Tannins (Contd.)

- Hydrolysable tannins (HT)

➢Absorbable

➢Affect organs like liver, intestine & kidney

- Condensed tannins (CT)

➢Affect digestion more

VI. Mucilage

- Found in linseed meal

Toxic principles (Contd.)

VII. Non starch polysaccharides (NSP)

- Cereal grains & vegetable proteins
- Harmful to monogastrics especially poultry

1) Arabinoxylans

- Wheat, rye and triticale
- Soluble NSP's

➢ ↑ the viscosity of digesta

➢ Impairs nutrient uptake

- Enzyme xylanase is added in poultry ration

Toxic principles (Contd.)

2) β glucans

- Barley & oats

➢They cause ↑ed viscosity of digesta & promotes bacterial multiplication

- Enzyme β glucanase added in barley & oats based rations for poultry

Toxic principles (Contd.)

VIII. Mycotoxins

1) Aflatoxins

- Group of closely related toxic substances
- *Aspergillus flavus* & *Aspergillus parasiticus*
- Improperly stored feed stuffs such as cereal grains & oil meals (mouldy GNC)

❖Four major aflatoxins

❑B_1, B_2, G_1 & G_2

- Fluorescence properties under short wave uv light on thin layer chromatography

Mycotoxins (Contd.)

Aflatoxins (Contd.)

- M1 in milk

➢ Hepatotoxins

➢ In high doses they may impair kidney also

➢ Also potent carcinogens

❖ Max. permitted level of aflatoxin in animal feeds

- ❑ 30 ppb or 0.03 ppm (PFA act in India)
- ❑ 20 ppb or 0.02ppm (USFDA act in USA)

Mycotoxins (Contd.)

Aflatoxicosis (Contd.)

❖Symptoms

- ➢↓ appetite, ↓ production, weight loss
- ➢↑ liver enzymes & loss of liver function
- ➢ Abortion & ultimately death

• Spoiled feed reduced in quantity or removed

❖Domestic animals

- Rabbits
- Pig
- Cattle
- Sheep



Mycotoxins (Contd.)

Aflatoxicosis (Contd.)

❖Birds

- Duck
- Chicken
- Guinea fowl

❖Treatment

- Symptomatic & supportive care only

➢No specific antidote

➢I/v fluids with dextrose, Vit. K & B complex

Mycotoxins (Contd.)

- Aflatoxicosis (Contd.)

Symptomatic treatment (Contd.)

- Oral liver tonics
- Restricted, but ↑quality protein diet with adequate carbohydrate content

Toxic elements

1. Cadmium

➢ Fragile bones, anemia, bone marrow disorders & kidney damage

2. Arsenic

- Insecticides and fungicides

➢ Inhibits many biochemical reactions

3. Lead

- Most common inorganic pollutant
- Petrol, paints, cigarettes, news papers, lead pipes & Xerox copies

➢ Principal target of lead toxicity is CNS

Toxic elements (Contd.)

4. Mercury

- Common industrial pollutant

➢ Plastic, paints, electrical apparatus, fungicides

❖ Acute poisoning

➢ Gastritis

➢ Vomiting

➢ Pulmonary edema

❖ Chronic poisoning

➢Adversely affects the nervous system

❖ Organic mercury poisoning *minamata* disease



Toxic elements (Contd.)

5. Phosphide

- Phosphide is a poison & used to control rodents

6. Sulphur

- Elemental S when added to the diet of chicks

➢Growth is impaired

7. Common salt

- Tolerance of livestock remarkably high ↑

➢ Sheep ↑est tolerance

❖ Provided adequate drinking water is available

❖ ↑ ed intake salt poisoning in pigs and poultry



Toxic elements (Contd.)

8. Flourine

- Fluorine toxicity → & joint abnormality

➢ due to deposition of calcium fluoride on bones

❖ Bones lose their normal colour and lusture

- Gets thickened and softened
- Severe cases → exostosis

❖ Teeth → enamel defects

- Mottled enamel & discoloration of teeth

➢ Dental fluorosis in children

Toxic elements (Contd.)

9. Molybdenum

- Scouring & weight loss may occur

10. Selenium

- Alkali disease, blind staggers & Degnala disease are selenium toxicity diseases
- Dullness
- Stiffness of the joints
- Loss of hair from tail
- Hoof deformities.

Toxic elements (Contd.)

11. Nitrates and nitrites

- Higher uptake of nitrogen from soil
- Fodders accumulate nitrate

❖Poisoning in animals consuming them

➢Oat hay poisoning

❑In rumen, nitrate → nitrite by rumen µorganisms

➢Hemoglobin to methaemoglobin

➢it do not transport oxygen

- Severe cases blood → chocolate brown
- Death may result due to anoxia

Metal Binding Substances

1. Oxalates

- Paddy straw, pusa giant napier & some other green fodders & tree leaves are ↑ in oxalate

❑Excess oxalate

➢Precipitation of dietary calcium

➢Calcium oxalate

➢Calcium deficiency in livestock

❖Kidney insoluble Ca oxalate

➢Crystallize → calculi formation

→

Metal Binding Substances (Contd.)

2. Phytate

- Found naturally particularly in bran's
- About ½ of P in cereals as phytin phosphorus

➢Hexaphosphoric acid ester of inositol

➢6 PO_4 molecules bound in 1 phytic acid molecule

➢Ca & Mg salts of phytic acid is phytate

❖P in phytate is ↓ available to monogastric animals In poultry feeds phytase enzyme

❖ In ruminants, microbial phytase hydrolyses phytate & releases P

Common adulterants in feeds

- Intentional admixture of a pure substance with some cheaper & ↓ quality substances

Feed ingredient	Adulterant
Groundnut cake	Groundnut husk, urea, non edible oil cakes
Mustard cake	Argemone: A weed found in mustard field
Soyabean meal	Urea

Adulterants in feeds (Contd.)

Feed ingredient	Adulterant
De-oiled rice bran & wheat bran	Ground rice hulls, saw dust
Fishmeal	Common salt, Urea
Mineral mixture	Common salt, marble powder, sand, limestone
Molasses	Water

FODDER CROPS

GUINEA GRASS *(Panicum maximum)*
(Ad hoc recommendation)

Guinea grass is a popular fodder grass of the tropics suited to the agro-climatic conditions of Kerala. It can be profitably grown as a component of agro-forestry systems and comes 'up well under coconut and other trees. As an excellent fodder it is much valued for its high productivity, palatability and good persistence.

It is a perennial bunch grass; 0.5 to 4.5 m high. The stem is stout to slender, erect or ascending; glabrous or hairy. Leaves are 10 to 100 cm long and 3.5 cm wide. Panicle loose and much branched, the lower most branches being in a distinct whorl. The small seeds are enclosed in smooth glumes. The seeds shatter. The root system is deep, dense and fibrous. \

The imp,Qrtant varieties are Makueni, Riv ersdale, Hamil, PGG-4, FR-600, Haritha, and Marathakom. Mak'ueni is a drought re- ' sistant cultivar suited to rainfed situations in the state.

Guinea grass thrives well in warm moist climate. It can grow from sea level to 1800 m altitude. It is frost sensitive. It thrives between a temperature range of 15 to 38 °C. The grass tolerates shade and grows under trees and bushes and is best suitable as an intercrop in coconut gardens. The grass is adapted to a wide range of soils. It usually grows on well-drained light textured soil, preferably sandy loams or loams, but is better suited to medium to highly fertile loams. It cannot tolerate heavy clays or prolonged waterlogging.

Under Kerala conditions, the best season of planting is with the onset of southwest monsoon during May-June. As an irrigated crop planting can be done at any time of the year.

Seeds and slips can be used as planting ma terial. Since seed germination is poor vege

tative propagation is preferred. To obtain slips for planting, old clumps are uprooted and slips with roots are separated. For planting one hectare, 1.25 lakhs of slips are required. If seeds are used (3 kg/ha), it should be sown in nursery and the seedlings transplanted in the main field.

The grass requires thorough cultivation to prepare a weed-free seedbed for establishment. For this, two or three ploughings and one levelling are sufficient. In the prepared field, trenches of 10 cm width and 20 cm depth are made. In these trenches, FYM should be applied along with phosphorus and potassium fertilizers. Mix with soil and cover the trenches and form ridges of 15 cm height for planting slips. In acid soils, application of lime @ 500 kg/ha in alternate years is desirable.

Slips are planted on ridges at the rate of three slips per hill. The spacing of 40 x 20 cm is followed when grown as an intercrop. For a pure crop, a wider spacing of 60 x 30 cm is required.

A basal dose of 10 tonnes of FYM, 50 kg PzOs and 50 kg KzO per ha (applied in trenches) is recommended. For topdressing, use 200 kg N per ha in two split doses, the first dose immediately after-first cutting and the second dose during the northeast monsoon period. If irrigation facilities are available, topdressing can be given in more splits. The fertilizer may be applied on either side of the plants, along the row and earthed up.

At planting two irrigations are required within seven to ten days for quick establishment. The

crop should be subsequently irrigated depending upon the rainfall and soil type. Usually irrigation once in 7-10 days is required. Irrigation with cowshed

washing or sewage water within 3-4 days after cutting gives better growth.

The delicate seedlings or newly emerged shoots from slips or cuttings require protection from weeds in the first two months. Two intercultivations should be given during this period. Later, intercultivation may be necessary after three or four cuttings.

The crop is ready for harvest when it reaches 1.5 m height. Cutting at 15 to 20 cm above the ground level is advised. The first cut is usually ready in 9-10 weeks after planting and subsequent cuts are taken at 45

to 60 days intervals. About six to seven harvests can be made in a year.

Approximately 80-100 t/ha of green fodder is obtained per year.

Guinea grass can be grown mixed with leguminous fodder crops such as cowpea, stylo and siratro.

The grass is nutritious, palatable and free from oxalates. It makes good hay and silage. The crude protein and the crude fibre content of this grass vary from 8 to 14% and 28 to 36%, respectively.

GAMBA GRASS *(Andropogon gayanus)* (Ad hoc recommendation)

Gamba grass is also known as 'Sadabahar'. It is a tufted perennial grass and the stems are usually 1-2 m high. The inflorescence is a large spathe or panicle.

The grass tolerates drought and suits areas where dry season lasts for five months or so. In areas with less severe drought it can remain green throughout the year. It tolerates deep seasonal flooding. The grass avoids heavy soil, is resistant to grass fires and develops new leaves and shoots a few days after buming. The crop comes up well in

partial shade and is a good intercrop in coconut gardens. The crop can be propagated through rooted slips or seeds lightly drilled.

Cultural operations and management are similar to that of guinea grass.

In general about 50 to 80 t/ha of green matter is produced in the first year. From the second year onwards there is a slight increase in green fodder yield. The grass has excellent palatability with 5.5 % crude protein and 32.6 % crude fibre.

SET ARIA GRASS *(Setaria anceps)* (Ad hoc recommendation)

Setaria anceps is also called as Golden Timothy. The grass comes up well in the medium rainfall areas in the tropics and subtropics.

Important varieties are Nandi, Narok and Kazungula.

The grass is a tufted perennial with erect stems and grows 1-2 m in height. Leaves are about 40 cm long, 8-20 cm wide and

green to dark green in colour. Panicle is dense, cylindrical, about 10 to. 30 cm long and orange to purplish in colour. Spikelets are two in number, the lower one is the male or sterile and the

upper one is bisexual.

Usually the grass grows under an annual rainfall of over 750 mm. It grows vigorously under high annual rainfall ranging from 1000 to 1500 mm. It can also survive long, hot and dry seasons. The grass grows

well at 20 to 25 Dc. It is more cold tolerant than most of other tropical and subtropical grasses. It can come up in a variety of soil types.

This perennial grass requires thorough land preparation; two or three ploughings / diggings followed by one levelling. The land should be free from weeds.

Propagation is through rooted slips as well as through seeds. Seedlings can be raised in nursery and transplanted during rainy season under rain fed conditions. If irrigation facilities are available, planting can be done at any time between February and November.

As a pure crop it is planted at 50 x 30 cm spacing. The row-to-row distance may be increased to 60-70 cm when the soil is poor and irrigation facility is absent. For intercropping with legU{lles, 100 x 30 cm spacing is followed. If seeds are used, seed rate varies Horn 3.5 to 4.0 kg/ha. In case of rooted slips, the number of slips required varies from 33500 to 67000 per ha.

Organic manure, either FYM or compost @ 10 tlha may be applied at the time of land preparation. The crop responds well to application of fertilizers especially N. The fertilizer requirement depends on the initial nutrient status of the soil.

The grass flourishes in moist, but not wet soils. *Setaria* plots should be well drained

during rainy season. At establishment, the crop requires two successive light irrigations in 7-10 days interval. Subsequent irrigation should be given as and when necessary.

One or two weeding or intercultivation is given in the first 2 to 3 months. To control weeds and to encourage fresh sprouts, one or two intercultivation has to be carried out every year.

The crop is ready for harvest by 9-10 weeks. Subsequent cuts can be taken after every 40 to 60 days depending on the crop growth. At harvest, a stubble height of about 8 to 10 cm is left for good regeneration.

Generally, about 25-40 t/ha of green fodder can be harvested per year under rainfed situation. Irrigated crop yields about 75-150 tlhalyear.

The grass can be used as green cut fodder, silage and hay. The grass gives satisfactory silage with molasses. The crude protein and crude fibre content of the grass range from 4.8 to 18.4 per cent and 24 to 34 per cent, respectively.

Seed yields are low due to prolonged emer"
gence of panicles, prolonged flowering of the same panicle, early shedding of spikelets, bird damage etc. Denser stands give more uniform panicle emergence than widely spaced plants. Fertilizer application is compulsory in seed production.

HYBRID NAPIER *(Pennisetum typhoides* x *P. purpureum)* (Ad hoc recommendation)

Napier grass is also called as elephant grass due to its tallness and vigorous vegetative growth. The plants tiller freely and a single clump may produce 50 tillers under favourable climatic and soil conditions. Unfortunately, the grass is coarse-textured, the leaf blade and sheaths hairy, leaf mar

gins sharply toothed and stems less juicy and fibrous. In 1953, a cross was made in India with bajra which is more succulent, leafy, fine textured, palatable, fast growing and drought resistant than Napier to combine these qualities with its high yielding potential.

Compared to Napier grass, Hybrid Napier produces more tillers and numerous leaves. It grows faster and produces more herbage but the stems are hard and the plants less persistent. Pusa Giant Napier has larger leaves, softer and less persistent hairs on leaf blades and sheaths and less sharp leaf edges. The stems are also less fibrous than Napier. The tillers are more numerous and grow faster.

The grass grows throughout the year in the tropics. The optimum temperature is about 31°c. Light showers alternated with bright sunshine are very congenial to the crop. Total water requirement of the grass is about 800-1000 mm. Hybrid *Pennisetum* can grow on a variety of soils. Light loams and sandy soils are preferred to heavy soils. The grass does not thrive well on waterlogged and flood prone lands. Phenomenal yields are obtained from very deep fertile soil rich in organic ma_ter. It tolerates pH ranging from 5 to 8.

Hybrid Napier requires a deep, thorough weed free and compact seedbed. Three or four ploughings followed by disc harrowing is ideal.

The popular hybrids are Pusa Giant Napier, Gajraj, NB-5, NB-6, NB-21 and NB-35.

Planting is done with the onset of southwest monsoon. Being a sterile hybrid, the grass is planted by rooted slips or by stem cuttings. Cuttings of moderately mature stems (3 months old) and preferably from the lower two thirds of the stem length sprout better than the older stems. The cuttings with three nodes are stuck into the soil with the basal end down, either vertically or at an angle to such a depth that two nodes remain within the soil and one above the soil surface. The under ground nodes develop roots and shoots while the upper ones develop shoots only.

A spacing of 60 x 60 cm is recommended for pure crop of Hybrid Napier. In intercropping system, spacing is adjusted to accommodate the companion crops. The planting rate depends upon the spacing and the weight of the cuttings or rooted slips used. It is modified in crop mixtures or intercropping with other forage crops.

Farm yard manure @ 25 t/ha, and P2Os and K2O @ 50 kg/ha each may be applied at the time of land preparation. Apply N @ 200 kg/ha in two or three split doses followed by gentle raking, if possible.

The field should be provided with good drainage during the rainy season, as the crop cannot withstand water stagnation. Frequency of irrigation depends upon the rainfall and weather conditions.

Early intercultivation once or twice is necessary before the plants establish and grow vigorously. Subsequently, intercultivation should be given as and when necessary.

The first cut is taken 9-10 weeks after planting. Subsequent cuts are taken after four to six weeks or when the plant attains a height of 1.5 m. Annually at least six to eight cuts are possible. In order to encourage quicker regeneration from the basal buds, stubbles of 10-15 cm is left out at harvest.

Green fodder yield ranges! 200-250 tlha per year from 6-8 cuttings.

The grass can be intercropped with legumes such as cowpea, *Calapogonium, Centrosema* and *Glycine* legumes. Intercropping with legumes improves the quality of fodder.

Hybrid Napier is superior in quality than Napier grass and contains about 10.2% crude protein and 30.5% crude fibre. The leaves are larger and greener, the sheaths are softer and the margins less serrated and hence the herbage is more palatable. It is juicier and succulent at all stages of growth. It is less fibrous and more acceptable. The oxalate content of some of the varieties may

be high. It can be mitigated if harvested at longer intervals (45 to 60 days).

The grass is ideal for green fodder, silage and hay.

The fodder can be chaffed and ensiled. Legume fodders may be mixed with the

grass in tIIe ratio of 1:2 to produce betterbalanced silage. The fodder can also converted into hay during the dry summer periods. The chaffed material is exposed to the sun only for a day. Further drying is done under the shade to preserve the colour. The quality of the silage or hay remains more or less the same as green fodder.

PARA GRASS *(Brachiaria mutica)* (Ad hoc recommendation)

This grass is also known as buffalo grass, water grass, Angola grass, Mauritius grass etc. The crop responds well to sewage irrigation and is usually grown near large sewage disposal f_rms.

It is a coarse, trailing perennial that spreads by surface runners which root profusely at the nodes with flowering stems I to 2 m high. The culms are erect, leafy, hollow, succulent and glabrous with hairy nodes. The leaf blades are dark green in colour, 25 to 30 cm long and 1 to 2 cm broad. Inflorescence is a panicle. Flowering is hastened in shorter photoperiods.

The grass prefers hot and humid climate of
the tropics and subtropics with high annual rainfall ranging between 1000 and 1500 mm. It can withstand short term flooding and waterlogging but cannot be grown in dryland in arid and semi-arid regions. It is sensitive to cold. It makes no growth during winter months.

The grass grows in moist, but not in highly wet soils. It thrives best on highly fertile clay loam to clayey textured soils with high moisture retention capacity. It can be grown even on sandy soils with good irrigation facility. It tolerates slightly acid to alkaline soils. It is highly tolerant to saline or sodic soil conditions. So it is an excellent grass in soil reclamation. It grows well on field bunds, banks of streams and canals, lowlands and soils too wet for normal farm crops.

Prepare the land thoroughly by three or four ploughings and remove weeds.

Planting can be done at any time other than winter months. The rainfed crop is planted with the first monsoon showers.

Stem cuttings or pieces of creeping shoots 15 to 30 cm long with about three joints are generally planted in a slanting position. In order to save time and labour, the planting materials are scattered in the field and covered by ploughing crosswise during monsoon season. Seeds can also be used for direct sowing or sowing in nursery for transplantation. But poor seed setting usually discourages seed propagation.

Slips can be planted 50 to 60 cm apart both ways between plants and rows. The growing

runners quickly root at the joints, tiller profusely and cover the field.

The requirement of slips for planting ranges from 27000 to 40000 per ha. The seed rate recommended is 2.5 to 3.5 kglha.

The crop is highly responsive to irrigation with cattle-shed washing or sewage water. Forty tonnes ofFYM or compost along with 30 kg P2Os and 30 kg K;O per ha is to be given as basal' dose. Topdressing N 40 kg/ha after each harvest is found to enhance the forage production.

Two or three light irrigations are to be provided for the initial establishment of the

.crop. Later on, irrigation once in 10 to 15 days in summer is advantageous.

The land should be kept weed free for the first two months. Since it is a sturdy and aggressive grass, once it gets established, the weeds that appear later are suppressed.

The competitive vigour of para grass inter_ feres with the co-existence of legumes.

The first harvest takes about three months after planting when the grass attains a height of about 60 to 75 cm. Subsequent cuts are taken at 30 to 40 days interval. Annual yield of about 70 t/ha is obtained.

The para grass herbage dries slowly when
. cut. So it is hardly suitable for hay-making. This is mainly used for ensiling. It is a nutritious high. yielding and palatable forage grass. The grass appears to be free of any toxic effect. Nutritive value is comparatively less. The crude protein. ranges from 2.8 to 16.1 per cent and crude fibre from 28 to 34 per cent.

Seed yields are generally low. It is observed that shorter or longer day lengths hasten flowering. The correct stage of harvest is soon after the end of anthesis. Germination is affected if the seed is harvested late. There is no post-harvest dormancy for seed.

CONGOSIGNAL GRASS *(Brachiaria ruziziensis)*

Congosignal can be grown as a sole crop in open areas and as an intercrop in coconut gardens. It is a creeping perennial with dense foliage and therefore can be used for soil conservation purpose as strip crop. It grows to a height of about 50 to 100 cm and produces 30 to 40 tillers on an average.

It prefers a warm moist tropical climate. It can be grown in almost all types of soils but cannot tolerate waterlogging. It also tolerates shade. So it is recommended as an intercrop in coconut garden. It can be grown either as a pure crop or mixed with other grasses and legumes.

The crop is generally planted in May-June and September-October with the onset of rains.
Prepare the land by ploughing one or two times, remove weeds and level the land.
Both seeds and slips can be used. A seed rate of2-5 kglha is recommended. For sowing, a fine seedbed is required and seeds are

broadcast at 1-2 cm depth. To protect the seeds from ants, dusting carbaryl 5% DP at the time of sowing is effective. When slips are used, they are planted at a spacing of 40 x 20 cm.

Basal application of 5 t/ha of FYM along with 50 kg/ha each of PzOs and KzO is recommended. Nitrogen @ 100-150 kglha . may be applied in two or three splits.

Intercultivation during early growth stage is advisable to check weed growth.

It can also be grown as a crop mixture with leguminous fodder crops.

The first harvest can be done 50 days after planting and subsequently at 30-40 days interval. The rainfed crop yields about 35-45 t/ha of green fodder whereas the yield will be increased to about 50-100 t/ha under irrigated conditions.

FODDER TREES SUBABUL *(Leucaena leucocephala)*

Subabul is also known as leucaena or ipilipil. It had its origin from Mexico and is

now widely spread throughout the tropical and subtropical countries of the world.

It is a perennial hardy evergreen shrub. It has deep and strong taproot and even the seedlings are deep rooted. The leaves are bipinnate, 15 to 20 cm long with 10 to 15 pairs of pinnate leaves. Inflorescence is globular and the flowers are white. There are four types of subabul.

Hawaiian *type:* The plants are short bushy and remarkably drought tolerant. It is suited to hilly terrains in drought prone areas. It is a prolific seed producer and is good for fodder purpose. K-341 is a Hawaiian variety.

Salvador *type:* Tall, tree like and fast growing having maximum annual biomass production. Possesses large leaves, pods and seeds than Hawaiian types. Responds to high fertilization. Variety K-8 is useful for fodder.

Peru: Tall and extensively branching type and is ideal for fodder purpose.

Cunningham: It is a cross between Salvador and Peru types.

Subabul is best suited for warm regions and grows well between 22 and 30°C in regions of 500 to 2000 mm annual rainfall. Because of its strong and deep root system, the tree is highly drought resistant. It is restricted to elevations below 500 m but it withstands variations in rainfall, sunlight, windstorm, slight frost and drought. It cannot withstand waterlogging. It requires a deep well drained neutral soil and can tolerate saline and acid soil. It can also be grown in steep slopes, hilly terrains, gravelly areas and sandy loams.

Planting of seedlings can be done with the onset of rains in May-June or Sept-October.

Seed viability is high, but the hard seed coat posses dormancy. To hasten germination seeds are to be dipped in concentrated sulfuric acid for four minutes and then washed or put in hot water at 80°C for four minutes.

Sundry the seeds afterwards for about one hour before sowing.

A seed rate of 3-4 kg/ha is recommended. Sowing is preferably done during February March in a nursery or polythene bags or *in situ* at 2-3 cm depth. Give irrigation if there is no rain. Seedlings (1.5 to 3 months old with 6-8 leaves) are planted in the main field. A spacing of 1 x 0.1 m is recommended for a pure crop of fodder, 1.5 x 0.2 m for planting in boundaries and borders of coconut gardens and 2 x 0.2 m when raised along boundaries.

It can grow under a wide range of conditions as a range plant, roadside plant, in pastures etc. The land should, however, be cleared of bushes, ploughed and levelled before sowing.

A basal application of N :PzOs:KzO at the rate of 20:50:30 kg/ha is recommended.

Since the early growth of the crop is slow, the tender plants are to be protected from aggressive weeds. Two or three inter-row cultivation is essential to check weeds in early life. Once established, even vigorous grasses seldom smother the plants.

Leucaena combines well with many grasses like guinea, pangola, dinanath, Hybrid Napier etc.

Subabul is a highly nutritious leguminous tree fodder with 27-34 per cent protein. The fodder is rich in carotene and vitamin A. Pro-vitamin A content is the highest among all plant species. The foliage contains an uncommon amino acid, mimosine, which is toxic to non-ruminants at levels of about 10% of the diet.

Subabul starts flowering at 125-150 days after planting: First cutting is done after 5-6 months at a height of 70-80 cm from the ground level at a time when the plants reach a height of 1.5-1.75 m. Subsequent harvests

can be made at 50-60 days interval depending on the re-growth. When planted in boundaries, the main shoot is not cut; only side branches are cut for fodder, leaving the top three branches.

In gravelly soil and in low rainfall areas, a yield of 25-30 tonnes per ha per year may be obtained. The irrigated crop may produce 100 t/ha of green fodder per year in seven to eight cuttings.

HEDGE LUCERNE *(Desmanthus virgatus)* (Ad hoc recommendation)

It is a small shrub, 2 to 3 m tall and roughly resembles leucaena. It is a native of tropics and subtropics of the new world, palatable, aggressive, persistent and tolerant to heavy grazing. It has 22 per cent protein in leaves and 10-15 per cent in stems. It is highly

productive, yielding about 40 to 70 tonnes of green fodder per ha per year. No poisonous principle is observed in the foliage. Because of its pithy stem, the harvesting is easier. It is an ideal plant for wasteland development.

AGA THI *(Sesbania grandiflora)* (Ad hoc recommendation)

The outstanding feature is its extremely fast growth rate, especially during the first three to four years. Average wood yield of 20 to 25 m3 per ha is commonly achieved. It is easy to propagate by direct seeding. Prolific nodulation and extremely large nodules are its characteristic features. Cattle relish both its leaves and pods. After cutting, shoots resprout with vigour. It is not toxic to cattle.

It can be planted very densely at the rate of 3000 stems per ha. It has been viewed as a source of pulp for paper industry. Leaves contain 36 per cent crude protein. Agricultural crops continue to grow well when intercropped with S. *grandiflora* whose open crown allows sunlight to pass. It is adapted to the moist tropics with annual rainfall in excess of 1000 mID.

SHEVRI *(Sesbania aegyptica)* (Ad hoc recommendation)

It is a promising perennial fodder shrub for both dry and wet areas. The sub-marginal lands that are not suited for agricultural purposes can be used for growing this fodder plant. The leaves and young twigs form nu

tritious forage to the livestock. The plants can be sown at a spacing of 100 cm x 50 cm. When cut at 50 cm height at 60 days interval, green fodder yield of 12 tonnes per ha per year can be obtained.

FODDER LEGUMES FODDER COWPEA *(Vigna unguiculata)*

Cowpea is the most important leguminous fodder crop suitable for both summer and rainy seasons, mainly due to its- quick growing habit and high yielding ability.

Cowpea is indigenous to Africa and India. It has been cultivated from very early times for human consumption. Fodder cowpea can be profitably grown as a summer crop in

rice fallow of sandy loam soils where water is not available to raise a subsequent crop. It can be considered as a complementary crop in the rotation sequence of rice-ricecowpea because of the leguminous organic residues available for fertility enrichment.

Cowpea can be an annual or perennial, bushy, trailing or climbing herb. Stems are 1 to 3 m long, glabrous or slightly hairy. Leaves are trifoliate, inflorescence auxiliary having a few to several flowers. Pods are linear and cylindrical.

A number of varieties like Kamataka local, RS-9, UPC-1956, UPC-5287 and UPC-9805 are recommended for cultivation for fodder purpose.

Cowpea is best suited for moderately humid areas of the tropics and subtropics. It usually grows in latitude between 30° Nand S and up to 1500 m elevation. The plant cannot withstand frost, excessive and prolonged waterlogging, while some varieties are resistant to heavy rains. The optimum temperature required for its growth varies from 15 to *2rC.* Cowpea can be grown on a wide range of soils from heavy to sandy loam with a pH range of 5.0 to 6.5. Saline, alkaline or waterlogged soils should be avoided. Heavy clays encourage vegetative growth with less seed produCtion.

Cowpea for fodder purpose can be grown in any month provided irrigation facilities exist. In Kerala, it is raised as a rainfed crop during May and also as summer crop in rice fallows.

Two to three ploughings are required to produce a coarse seedbed for the crop. Shallow furrows at 3 m apart for leading irrigation water may also be provided. It can be broadcasted or drilled in lines. For seed crop, line sowing is preferred. Seed rate recommended is 40 to 50 kg/ha for a broadcast crop and 15 to 40 kg/ha for drill sown crop. For drilling, spacing of 30 to 40 cm

between rows and 6 to 15 cm between plants is recommended.

For rainfed crop, at the time of land preparation, FYM @ 10 t/ha is applied and basal application of N, P2Os and K2O @ 25, 60 and 30 kglha is recommended. For ilTigated crop in addition to the basal dose of 40: 30: 30 kg N: P2Os: K2O / ha, topdressing ofN and K2O ea.ch at 10 kg/ha after each cut is to be given.

A pre-sowing irrigation is important for the proper germination of the crop. If there is lack of soil moisture, shallow irrigation at 3-4 cm depth once in 15 days during summer and once in a month during postmonsoon period is good.

One or two weeding may be required in the early growth stages to combat weed problems. Usually high seed rates are effective in smothering weeds.

Cowpea is tolerant to moderate shade. So it can be successfully grown as intercrop with maize, sorghum, bajra, guinea grass, Napier grass etc to get high yields. In Kerala cowpea is also raised as an intercrop in coconut gardens.

As a fodder crop, the first cutting can be given 45 days after planting and subsequent two cuttings at 30 days intervals. A single cut crop yields 25 to 30 t/ha whereas green matter yield

of 40 t/ha is obtained from multi-cut cowpea.

Cowpea is used as fodder crop for green feeding, hay-making, grazing and also for ensiling in mixtures with sorghum or maize. The grains are used as human food as well as animal feed. Cowpea is also used as green manure crop and as cover crop in plantations..
The feeding value of cowpea forage is high. It is superior to other legumes like soybean because of its low fibre content and minimum wastage in feeding livestock. It has about 16 per cent crude protein and 20 per cent crude fibre.

Cowpea is a self-pollinated short day plant. Though the seed is well fonned, harvesting is

difficult. The percentage of hard seed is low and viability under storage lasts for 3 years.

STYLO *(Stylosanthes* spp.)

Stylosanthes is a genus of summer growing perennial pasture / fodder legumes. Most of its species are native of south and central America and the Caribbean Islands. This is a fodder cum leguminous cover crop, which is suited for intercropping in coconut gardens, either alone or in combination with other fodder grasses. The crop controls soil erosion by giving a protective soil cover. It also helps to smother weed growth.

Stylosanthes consists entirely of herbs and small shrubs. Usually they have a crown of growing points near the soil surface. This enables the plants to overcome the excessive damage caused by grazing animals. They have indehiscent. seeds, regulating dormancy. The seed has hooks for dispersal through animals. The seeds can also pass through the digestive system of animals. In some species due to the presence of viscid
hairs, they are not eaten in some seasons of the year. The plant thrives well in light soils due to its deep rooting system.

The crop is suited for growing in wann, humid tropical climate. It is fairly drought resistant and shade tolerant. It can be cultivated in areas receiving less than 1000 mm of rainfall and in less fertile soil, acid soils, gravelly sandy soils and also in ill-drained soils.

In humid tropical environments, S. *gllianensis* thrives very well and can withstand flood and drought lasting for short periods. Germination and growth are favoured at high temperatures.

In less fertile soils like sandy coastal soils, phosphorus fertilizer should also be added along with sowing of seeds so as to help the development of root nodules.

Sowing is to be done with the onset of southwest monsoon during May-June. Irrigation is required if there is no proper soil moisture at the time of sowing.

The following are the perennial types of stylosanthes, ideally suited for growing in the state.

Brazilian lucerne (Stylosanthes gllianensis): This is used as a pasture legume in a number of tropical countries; recently been introduced in the pastures of India. Varieties are usually erect to semi-erect. They are generally not profusely branched at the base. It can grow up to 1.5 m in height, particularly when it gets support from the associate grasses. The trifoliate leaves are long, rather narrow and pointed. The stems are coarse and hairy. In some of the varieties the leaves are sticky. The flowers are small and yellow producing single seeded pods. It does not tolerate. shade and can grow very well in areas receiving 900 to 4000 mm of
rainfall. It is very tolerant to low fertility, but responds well to phosphate and is sensitive to copper deficiency. Stylo seed should not be sown below 7 to 13 mm. A seed rate of 2 kg/ha is usually satisfactory. Although Stylo is usually nodulated by naturally occurring *Rhizobium* strains, these however, will not be as effective as the commercial strains. The main variety commercially grown is Schofield_ This is an erect variety and very late in flowering. Other

varieties are Cook, Endeavour and Graham.

Townsville stylo (Stylosanthes hllmilis): This annual type stylo is also found suitable for growing in Kerala.

Caribbean stylo (Stylosanthes hamata cv. Verano): This is a short-lived perennial leg

legume similar to Townsville stylo. It is slow *growing* and develops a flat crown under grazing. Erect stem may grow up to 80 cm. The stems of Verano are smooth. As against the bristly stems of Townsville stylo it has a line of very fine, short white hairs on one side only. The flowering spike of Verano produces double seeds; the upper has a reduced hook about 3 to 5 mm long, while the lower seed has no hook. Verano combines many of the virtues of both annuals and perennials.

Shrubby Stylo (Stylosanthes scabra): This is a perennial shrub. Its deep root system enables the plant to remain green even in very dry season. The recommended varieties of shrubby stylo are Seca and Fitzroy.

Seeds of stylo are very small. The seed rate is 2 to 3.5 kg/ha when grown as an intercrop in coconut gardens. For grass legume mixtures, 1.5 kg/ha is sufficient. Seeds are soaked in water overnight and mixed with rhizobium culture before sowing.

Prepare a fine seedbed. Seeds are mixed with sand when sown as a pure crop or mixed with grass seeds for mixtures. Seeds are sown broadcast and covered with thin layer of soil or dibbled at a spacing of 30 cm between rows. The depth of sowing should be 5-10 mm. Seeds germinate within a week.

For seed production, the variety Cook can be recommended. A seed rate of 5 kg/ha is better for seed production. Apply phosphorus @ 120 kg and lime @ 375 kg per ha for maximum yield. For seed production, irrigate with 33 mm of water once in 9 days during summer months from January to March. A total of 10 such irrigations are required during the period.

Recommended dose ofN, P2Os and K2O for both annual and perennial stylosanthes are 20, 80 and 30 kg per ha, respectively. For perennial crops, phosphorus @ 80 kg/ha and potash @ 30 kg/ha may be applied in subsequent years. Application of lime @ 375 kg/ha is also recommended in acid soils.

Gap filling may be done 15 days after sowing. First weeding is given 45 days after sowing. A second weeding and hoeing may also be done after the first harvest. Gentle raking of the interspace after the application of fertilizers in the subsequent years may be done.

First harvest is taken 3-4 months after sowing and subsequent harvest at 45 days intervals or according to the growth of the crop. A maximum of 4-5 harvests can be taken in a year for a perennial crop, which will remain in the field for 3 years. The crop yields 25-30 tlha green fodder per year.

FODDER CEREALS FODDER MAIZE *(Zea mays)*

Maize grows best in warm climate where the day temperature is fairly light. Heavy rains and dry hot winds are not suitable. Favourable annual rainfall is 60-100 cm. The crop comes up well in soils with good drainage and fair moisture status.

The optimum season for sowing is the last week of June to second week of July and September to October. The crop can be raised throughout the year in areas where ir

rigation facilities are available. The land is ploughed two or three times and beds and channels are formed. Seeds can be either broadcasted or dibbled at a spacing of 30 cm between rows and 15 cm between plants.

Hybrid varieties are Deccan, Ganga-5, Ganga safed-2, and Ganga-3 and composite variety Vijay.

Seed rate for broadcasting is 80 kg/ha and

for dibbling 40-60 kg/ha (to be dibbled at 5-6 cm depth @ two seeds per hole).

Farm yard manure @ 10 tlha may be ap- . plied at the time of preparation of land as', basal dressing. N, P2Os and K2O at the rate of 120, 60 and 40 kg/ha respectively, may

be given as topdressing. Weeding may be done according to necessity.

First cutting of maize can be taken after 60 days of planting or at the milky stage of the crop., A second cut can also be taken if there is sufficient moisture in the soil.

FODDER SORGHUM *(Sorghum* sp.)

Fodder sorghum is an ideal tropical forage crop. It is fairly drought resistant and suited for areas where moisture is a limiting factor for crop growth. The crop can be raised during both monsoons. All soils except

sandy soils are suited for the crop. Apply N, P2Os and K2O fertilizers at the rate of 60, 40 and 20 kg per ha, respectively. Important varieties are M.P.Chari, MPK V-I, JS-20, S-1O49 and JS-3.