

ANIMAL NUTRITION (Paper-I) SYLLABUS

UNIT-1 PRINCIPLES OF ANIMAL NUTRITION AND FEED TECHNOLOGY

History of animal nutrition. Importance of nutrients in animal production and health. Composition of animal body and plants. Nutritional terms and their definitions. Nutritional aspect of carbohydrates, protein and fats. Role and requirement of water, metabolic water. Importance of minerals (major and trace elements) and vitamins in health and production, their requirements and supplementation in feed. Common feeds and fodders, their classification, availability and importance for livestock and poultry production.

Measures of food energy and their applications - gross energy, digestible energy, metabolizable energy, net energy, total digestible nutrients, starch equivalent, food units, physiological fuel value. Direct and indirect calorimetry, carbon and nitrogen balance studies. Protein evaluation of feeds - Measures of protein quality in ruminants and non-ruminants, biological value of protein, protein efficiency ratio, protein equivalent, digestible crude protein. Calorie protein ratio. Nutritive ratio.

Introduction to feed technology - Feed industry; Processing of concentrates and roughages. Various physical, chemical and biological methods for improving the nutritive value of inferior quality roughages. Preparation, storage and conservation of livestock feed through silage and hay and their uses in livestock feeding. Harmful natural constituents and common adulterants of feeds and fodders. Feed additives in the rations of livestock and poultry and their uses.

UNIT-2 APPLIED RUMINANT NUTRITION-I

Importance of scientific feeding. Feeding experiments. Digestion and metabolism trial. Norms adopted in conducting digestion trial. Measurement of digestibility. Factors affecting digestibility of a feed. Feeding standards, their uses and significance, merits and demerits of various feeding standards with reference to ruminants. Balanced ration and its characteristics.

Reference Books

1. **Animal Nutrition**, P.McDonald, R.A.Edwards, Morgan and J.F.D Greenhalgh.
2. **Feeds and Principles of Animal Nutrition**, G.C.Banerjee.
3. **Animal Nutrition**, Aron, A. Bondi.
4. **Principles of Animal Nutrition and Feed Technology**, D.V.Reddy.
5. **Animal Nutrition in the Tropics**, S.K.Ranjhan.
6. **Advances in Dairy Animal Production**, V.D. Mudgal and Co-workers
7. **The Mineral Nutrition of Livestock**, E.J.Underwood and N.F. Suttle.
8. **Vitamins in Animal Nutrition**, L.R.McDowell.
9. **Text Book of Feed Processing Technology**, N.N.Pathak

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UNIT-1

PRINCIPLES OF

ANIMAL

NUTRITION AND

FEED

TECHNOLOGY

CHAPTER 1

HISTORY OF ANIMAL NUTRITION

The word 'Nutrition' means "Nourish" i.e. all the processes whereby food and oxygen are presented to and utilized by living cells, and waste products are eliminated. Nutrition involves various chemical reactions and physiological processes which transform foods into body tissues and activities. It involves the ingestion, digestion, and absorption of the various nutrients, their assimilation to all body cells through various metabolic functions, and the removal of unusable elements and waste products of metabolism.

The French chemist **Antoine Lavoisier** (1743 – 1794) is frequently referred as the Founder / Father of the science of nutrition. He established the chemical basis of nutrition in his famous respiration experiment carried out before the French revolution. His studies led him state, "Life is a chemical process". Thereafter chemistry became an important tool in nutrition studies.

A. Lavoisier introduced the balance and thermometer into nutrition studies. He discovered that combustion was an oxidation and he showed that respiration in the body involved the combination of carbon and hydrogen with oxygen from inspired air and that the quantities of oxygen absorbed and carbon dioxide given off depended on the food intake and the work done. With Laplace, he designed a calorimeter by means of which it was demonstrated that respiration is the essential source of body heat.

The need for protein, fat, and carbohydrates become recognized during 1826 to 1900. For the remainder of the century, nutritional science and practice were concerned primarily with these nutrients and a few mineral elements Ca, Cl, F, Fe, Mg, K, Na, S were known and considered to be important in the body although critical research proving their essentiality was meagre or lacking. The large expansion in the nutrition field has occurred from around 1910 onwards with the discovery of the vitamins, of the role of amino acids, and of several more essential mineral elements.

Objective of Nutrition

The objective of nutrition is to provide all essential nutrients in adequate amounts and in optimum proportions;

- For better growth, optimum productive and reproductive performances
- To improve the health status
- By utilization of industrial waste and by-products as feed resources with application of advanced feed technologies.

Babcock Single Plant Experiments

The feeding experiment planned by M. Babcock (1843 - 1931) at Wisconsin Experiment Station with single plant (Grain and forage from either Maize (Corn) or Wheat plant were combined) and fed to 5 months old heifer calves through till they calved. Though weight gain was similar, large differences became evident during reproduction. Wheat plant fed cows delivered bad or dead calves and milk production was also less. This was before the vitamins had been identified and very little was known about mineral requirements. It stimulated the use of the purified diet method which resulted in the discovery of the first vitamin in 1913.

Role of Animals in Discovery of Nutrients

The modern discoveries in nutrition have resulted from studies with a wide variety of animal species. The contributions of the laboratory rat to our knowledge of vitamins, amino acids and minerals have been enormous.

Animal Study	Discovery
Guinea Pig experiment	Specific cause of Scurvy
Chick experiment	Thiamin deficiency
Chick experiment by Hart and Associate	Classic studies of Vitamin A & D
Chick experiment by Norris and Heuser	Information concerning Pantothenic acid, Vitamin B ₂ , Folic acid and Vitamin B ₁₂
Chick experiment by Henrik Dam	Studies on Vitamin K

Role of Specialists in Expansion of Nutritional Knowledge

Microbiologists have assisted greatly in the discoveries of the nutritional roles that bacteria play in the rumen of ruminants and in the intestine of other species. R.E. Hungate discovered rumen bacteria, Gruby and Delafond (1843) discovered rumen protozoa while C.G.Orpin and T.Bauchop (1975) discovered the presence of rumen fungi.

Genetists have developed new strains of certain lower forms that will detect specific vitamin and amino acid deficiencies in our foods. E.g. *Tetrahymena pyriformis*, *Streptococcus zymogenes*.

Soil-Plant-Animal Relationship

Studies on some of the "trace" mineral elements have shown that the character of the soil on which we grow our food crops plays an important role in determining their nutritive value. Varieties of the same crop differ in nutritional quality and various cultural factors have an influence on nutritional quality. Thus, animal and human nutrition ties back into agriculture and to the soil, stressing the importance of yields of nutrients as distinguished from yield of a crop per unit of land.

Study questions

Fill in the blanks

1. Nutrition involves various ----- and ----- which transform foods into body tissues and activities.
2. ----- who is the father of the science of nutrition.
3. Chick experiment carried out by Henrik Dam to study on -----.
4. R.E. Hungate who discovered -----

Short answer

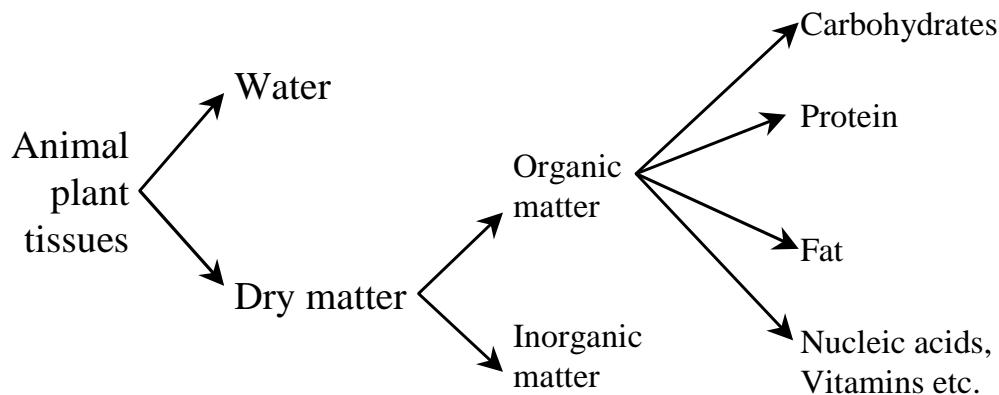
1. Role of animals in discovery of nutrients.
2. Babcock single plant experiments.

CHAPTER 2

COMPOSITION OF ANIMAL BODY AND PLANTS

Plants synthesize complex substances from simple substances like CO₂, N, H₂O etc making use of solar energy. They use carbon dioxide from the air, water and other inorganic salts from the soil to synthesise carbohydrates, proteins and fats. Animals ingest these plants and utilise this energy for their bodily functions, tissue growth and production of products.

An important constituent of the animal or plant body is water. The dry matter in both plants and animals is made up of organic and inorganic matter. Organic matter comprises mainly of three important nutrients ie carbohydrates, proteins and fat. Some minor constituents of organic matter are vitamins, nucleic acids and others. Inorganic matter is made up of various minerals.



Composition of Animal Body

The composition of animal body is affected by factors such as species, strain, age, sex and state of nutrition.

The following table gives the composition (%) of animal body of various species.

Species	Water	Protein	Fat	Ash	Organic matter
Calf (new born)	74	19	3	4.1	82.2
Calf (fat)	68	18	10	4.0	81.6
Steer (thin)	64	19	12	5.1	79.1
Steer (fat)	43	13	41	3.3	79.5
Sheep (thin)	74	16	5	4.4	78.2
Sheep (fat)	40	11	46	2.8	79.3
Pig (8 kg)	73	17	6	3.4	83.3
Pig (30 kg)	60	13	24	2.5	84.3
Pig (100 kg)	49	12	36	2.6	82.4
Hen	56	21	19	3.2	86.8
Horse	61	17	17	4.5	79.2
Man	59	18	18	4.3	80.7

Water / Moisture:

- Water content of animal body is variable and decreases as age increases.

Example

A cattle embryo contains 95% water

A new born calf contains 75-80% water

5 months old calf contains 66-72% water

Mature animals contains 50-70% water

- The distribution of water within the body is not uniform. Blood plasma contains 90-92%, heart, kidney and lungs - 80%; muscles - 75%, bones - 45% and tooth enamel only 5%.
- Water content of animal body also depends on nutritional status of the animal.

Fat:

Fat is the most variable of all components. Fat content of animal body increases with age. Fat is usually found in adipose tissues, which is present under the skin, around kidney, around intestine and other internal organs.

Protein:

It is found in the highest concentration of any nutrient (except water) in all living organisms and animals. It is also a major constituent of dry matter in muscles, soft tissue, liver, heart, kidney, lungs, intestines, etc. Muscles contain nearly 75-80% protein. Protein is also present in hair, nails, feathers, hooves, skin, wool, tendons and bones. Protein along with some inorganic elements is responsible for the structure of the animal body.

Carbohydrates:

It is present only around 1% of the total animal body. It is being constantly formed and broken down and serves a multitude of functions. It is usually present in the form of glucose or glycogen present in liver and muscles.

Inorganic elements:

Animal body contains many numbers of minerals. Different parts of the body contain varied amount of mineral depending on the function of the particular part. The concentration of some minerals in animal body is as follows:

Calcium - 1.3%

Phosphorus - 0.7%

Sodium - 0.16%

Potassium - 0.19%

Magnesium - 0.04%

Sulphur - 0.15%

Calcium is the mineral that occurs in largest amount in the body and is almost entirely present in bones and teeth. Phosphorus is present in bones in close association with calcium. Phosphorus is also present in association with proteins, fats and other inorganic salts. Na, K and Cl are present in inorganic form in various fluids. Other minerals form component of tissues fluids or enzymes.

Composition of individual tissues

Blood forms 5-10% of body weight, 90% of it is water and 10% solids. Nearly half of the solid content is protein other nutrients present are fatty substances, sugar, amino acids, NPN and inorganic salts.

Muscles contain around 75% water. The 25% DM comprises of 75% protein and the rest is fat, carbohydrates and inorganic matter.

In epithelial tissues (skin, hair, feathers, etc) the protein is predominantly keratin.

In connective tissues (bone, ligaments) the protein is predominantly collagen.

Composition of Plants

The composition of plants shows wide variations.

Water / Moisture

The principal constituent of living plants is moisture. The moisture content of plants is highly variable. Young plants have more moisture content as the plant maturity

increases the moisture content decreases. Often overlooked and not considered as a nutrient when formulating diets for animals, but extremely important.

Carbohydrate

The dry matter of plants contains mainly carbohydrates. Hydrates of carbon formed by combining CO_2 and H_2O (photosynthesis). These are primary component found in animal feeds. Carbohydrate serves as a structural and reserve material in plants. In seeds carbohydrates occurs principally as starch while in stems and to a certain extent in leaves a considerable proportion of carbohydrate is present in the form of structural carbohydrates; cellulose, hemicellulose and lignin. Though lignin is not a carbohydrate it is present in close association with cellulose and the lignin content of plant tissues increases with maturity of the plant.

Protein

All cells synthesize proteins, and life could not exist without protein synthesis. Protein is primarily present in active tissues of the plant such as the leaf. As the plant matures there is migration of the protein from the leaves to the seeds to serve as a reserve material for germination. Young tissues of plant, fruits, and seeds especially leguminous are rich in protein.

Fat/Lipid

These are organic compounds that are characterized by the fact that they are insoluble in water, but soluble in organic solvents. Fat is present at highest level in plants in the seeds followed by leaves and stem. Oil-bearing seeds have higher percentage of protein and fat compared to cereals.

Minerals

These are inorganic, solid, crystalline chemical elements that cannot be decomposed or synthesized by chemical reactions. The mineral content of plants is highly variable. It differs with species, plant parts and is also influenced by soil and other environmental factors.

Vitamins

Both fat-soluble and water-soluble vitamins are also present in plants and required by animal tissues in very small amounts.

Other substances

In plants there are various organic acids (citric, malic and fumaric) which are important for metabolism in the cells of plant.

Difference between plants and animals in composition

PLANTS	ANIMALS
1. Dry matter of plants contain 75-80% carbohydrates	Dry matter in animal body contains only about 1% carbohydrates
2. Energy storage in plants in primary in the form of soluble carbohydrates – starch	In animals fat deposited in adipose tissue serve as reserve energy
3. Insoluble carbohydrates (Cellulose, hemicelluloses, etc.) preserve structure and mechanical stability of the plant	In animals protein provides the structure of soft animal tissue and protein along with inorganic elements (Calcium, phosphorus) provides the structure of bones.

4. Except for protein rich oil seeds and pulses plant tissue are poor sources of protein. Protein content of animal body is much higher than that of plants.

Study questions

Fill in the blanks

1. Inorganic matter is made up of various _____.
2. Water content of animal body is variable and decreases as age _____.
3. Fat content of animal body _____ with age.
4. Fat is usually found bound in _____, which is present under the skin, around kidney, around intestine and other internal organs.
5. _____ is the major constituent of dry matter in muscles, soft tissue, liver, heart, kidney, lungs, intestines, etc
6. Carbohydrates are present only around _____ of the total animal body.
7. In epithelial tissues (skin, hair, feathers, etc) the protein is predominantly _____.
8. In connective tissues (bone, ligaments) the protein is predominantly _____.
9. The dry matter of plants contains mainly _____.
10. Though lignin is not a carbohydrate it is present in close association with _____ and the lignin content of plant tissues increases with _____ of the plant.
11. Young tissues of plant, fruits, and seeds especially _____ are rich in protein.

Short answer

1. Differentiate between composition of plant Vs that of animals.
2. Explain the factors that influence composition of animals.
3. Explain the factors that influence composition of plants.

CHAPTER 3

ROLE AND REQUIREMENTS OF WATER; METABOLIC WATER

Water makes up 65 percent of the animal body. In certain tissues the water content may be even as high as 80-90%. Water is very vital for the animal. **Max Rubner** as early as in the 18th century observed that an animal could loose all its fat, half of its protein and yet survive however if the animal loses 1/10th of its water it leads to death. Water is also a nutrient and is probably the most extraordinary substance in nutrition, being far more complex than its simple chemical formula suggests.

Functions of water:

- Water is the ideal dispersing medium because of its solvent and ionizing powers which facilitate cell reactions.
- All the biochemical reactions that take place in an animal body require water.
- Solvent - Water acts as solvent for a wide variety of compounds.
- Transport of nutrients - It helps in the transport of dissolved nutrients in the system.
- Excretion - It helps in the excretion of end products of metabolism.
- Ionisation - Many compounds readily ionise in water. Salts within the body dissociate into ions, which have specific action in body tissues.
- It is concerned in digestion, absorption and transport of nutrients and excretion of waste products.
- It serves as a carrier of digestive juices, enzymes and hormones.
- It is a medium for hydrolysis of the nutrients in the system.
- It provides cell rigidity and elasticity.
- It serves as lubrication fluid in the synovial cavities.
- It serves as a medium for transportation of semisolid digesta in the gastro intestinal tract.
- It provides for dilution of cell content and body fluids so that relatively free movement of chemicals may occur within the cell, in the fluids and GI tract. Thus, water serves to transport absorbed substances, convey them to and from their site of metabolism.
- As a component of CSF it acts as a water cushion for the nervous system.
- Helps to regulate the temperature of the animal body. Because of the high specific heat capacity of water sudden change in body temperature is avoided.
- It act as a water cushion for the nervous system as cerebrospinal fluid. In the ear, it transports sound; in the eye, it is concerned with sight.
- Water softens coarse feeds and makes them palatable.

Sources of water

The animal obtains its water from three sources (1) Drinking water (2) Water present in the food and (3) Metabolic water.

Water content in foods is variable it ranges from 10% in dry feeds to 90% in succulent / high moisture feeds.

Metabolic water (or) Oxidation water

Water that is provided to the animal by metabolic process is called as metabolic water or oxidation water. Oxidation of carbohydrates yields 60% of its weight as water. Protein on oxidation yields 42% of its weight as water, whereas fats yield 100% its weight as water. More specifically 1g each of starch, protein and fat produce 0.56, 0.40 and 1.07 g of metabolic water. Metabolic water is also produced by the dehydration synthesis of body proteins, fats and carbohydrates.

Nutrient	Oxygen needed to Oxidize	Metabolic water formed
Starch (1g)	0.83 L	0.56 g
Protein (1g)	0.97 L	0.40 g
Fat (1g)	2.02 L	1.07 g

Increased respiration needed to oxidize body fat and protein would result in an increased loss of water by evaporation. Camel, therefore, eats mostly carbohydrates during desert travel.

Metabolic water plays important role under certain physiological conditions of the animal. Metabolic water comprises only 5 to 10 % of total water intake of domestic animals and varied only with the metabolic rate. However, In hibernating animals it is the only source of water. To certain extent metabolic water is a source of water for animals living in deserts.

Free Water;

Interstitial fluid constitute about 22.5% of total water and it act as solvent for organic and inorganic compounds known as free water.

Bound Water;

It bound with proteins inside the cells, and having connection with ability of the body to resist low temperature and draught conditions.

Effect of water deprivation

- The first symptom of water deprivation especially in a hot environmental is thirst.
- When water deprivation exceeds 4 to 5% of body weight there is discomfort and anorexia.
- As the loss of water still increases there is lack of co-ordination dyspnoea, cyanosis, eyes become shrunken, skin shrivels, inability to swallow and delirium
- 12 per cent dehydration is fatal in man and dog.
- Certain desert animals such as camel can tolerate a higher rate of dehydration.

Water excretion:

Water is excreted through the intestinal tract, kidney, lungs, skin and products such as milk. Water is lost from the body constantly in the respired air, evaporation from the skin and periodically through the faeces and urine.

Excretion of water is highly variable and is governed by several factors.

- Depends upon the species of animal.
- Nature of diet
- Condition of intestinal tract.
- Depends upon the amount of catabolic products ie. Minerals and nitrogen substances produced in the animal system.
- By high environmental temperature and physical activity.

Water requirements

Animals will consume 2 to 5 kg of water for every kg of dry feed consumed when they are not heats stressed.

Factors Governing the Water Requirements of Livestock and Poultry

- I. Biological factors
- II. Environmental factors
- III. Nature of the feed

I. Biological Factors;

1. Class; 2. Species; 3. Age; 4. Breed; 5. Sex; 6. Body weight; 7. Productivity.

- Birds require less water compared to mammals because uric acid is the end product of protein metabolism. Higher evaporative water loss in birds is partially balanced by their reduced urinary water excretion relative to mammals
- Among mammals, Cat, Goats and Camels require less water because of their capacity to conserve water. Camel needs only 1/7th as much water needs per unit body weight as man in the summer.
- Young animals have higher water needs per unit body size than do mature ones.
- Milch animals require more water. A dairy cow needs 1.5 L of water for each litre of milk Produced.

II. Environmental Factors;

- Temperature and relative humidity of the environment reversely regulate the water requirement of the animals.
- In a hot environment dehydration of about 12% is fatal to man. However, a camel can lose 20% of its body weight before any decrease in appetite was noted.

III. Nature of the Feed;

- Water requirements are highly related to dry matter intake of the animals

Species	Water Requirement / Day	DM intake: Water Consumption
Adult Cattle	30 L	1.0 : 3.0 to 3.5
Calves	-	1.0 : 6.0 to 7.0
Sheep and Goats	4 – 6 L	1.0 : 4.0
Swine	6 – 8 L	1.0 : 3.0
Poultry	250 ml	1.0 : 2.0

- Diet of high crude fibre content involve excretion of faeces of greater water content than when the food is less in fibre. So, animal's intake of more fibre containing diet increases more water consumption.
- Diet with high fat level, high protein level and high salt intake increase the water intake.

Nutrients and Toxic Elements in Water

Water may carry many of the essential elements as well as toxic materials because of its properties as a solvent. Total dissolved solids (TDS) or salinity is a measure of the usefulness of water for animals. There may be mild temporary diarrhea when animals are changed suddenly from salt free water to slightly saline water. Water containing 3000 - 5000 mg /L is unsatisfactory for poultry. Ruminants and horses refused at first water containing 5000 - 7000 mg/L. But after adaptation animals gave satisfactory performance.

Study questions

Fill in the blanks

- 1 An animal could loose all its fat, half of its protein and yet survive however if the animal loses _____ of its water it leads to death.
- 2 The animal obtains its water from three sources _____, _____ and _____.
- 3 Oxidation of carbohydrates yields _____ of its weight as water. Protein on oxidation yields _____ of its weight as water, whereas fats yield _____ its weight as water.
- 4 Animals will consume _____ of water for every kg of dry feed consumed when they are not heats stressed.

5 Water is excreted through _____, _____, _____, _____
and _____.

Short Answers

1. Metabolic water
2. Functions of water

CHAPTER 4

NUTRITIONAL ASPECT OF CARBOHYDRATES, PROTEINS AND FATS CARBOHYDRATES

They are organic substances containing carbon, hydrogen and oxygen. They are hydrates of carbon produced by combination of CO_2 and H_2O by photosynthesis, widely distributed in plants. Carbohydrates form the largest part of animals food supply.

Classification of Carbohydrates

A. Sugars

I. Monosaccharides

They contain only one molecule of sugar and they cannot be broken down by hydrolysis. Depending on the number of carbon atoms they are classified as Trioses (3 carbon), Tetroses (4 carbon), Pentoses (5 carbon) and Hexoses (6 carbon).

Triose - eg. Glyceraldehyde and dihydroxy acetone.

Tetrose - eg. Erythrose.

Pentose - Ribose, xylose and arabinose, ribulose and xylulose.

Hexoses;

Glucose also called as dextrose occurs as free form in many fruits (2-5%), Honey (30-40%), blood, lymph, CSF. Sole component of many polysaccharides like starch, cellulose, dextrans and glycogen. It is the principal end product of digestion of higher carbohydrates. It has a sweet taste.

Fructose (levulose) occurs along with glucose in free state in fruits (2-5%), honey (30-40%) and green grasses. It is the only important keto hexose. It is also called as fruit sugar.

Galactose - It does not occur free in nature. It occurs in milk sugar (lactose) in combination with glucose. Certain compounds of galactose, galactosides occur in the brain and nervous tissue. It is also a component of pigments, galactolipids, gums and mucilages.

II. Oligosaccharides;

1. Disaccharide – Yields 2 monosaccharides on hydrolysis;

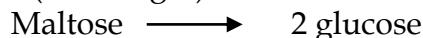
a) **Sucrose** (Cane sugar 10-12%, beet sugar 12-18%)

Water



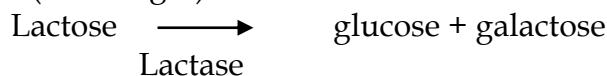
Sucrase

b) **Maltose** (Malt sugar) found in cereal grains (Barley, Jowar, Ragi etc.)



Maltase

c) **Lactose** (Milk sugar) occurs in milk of all animals.



Lactase

Classification of carbohydrates

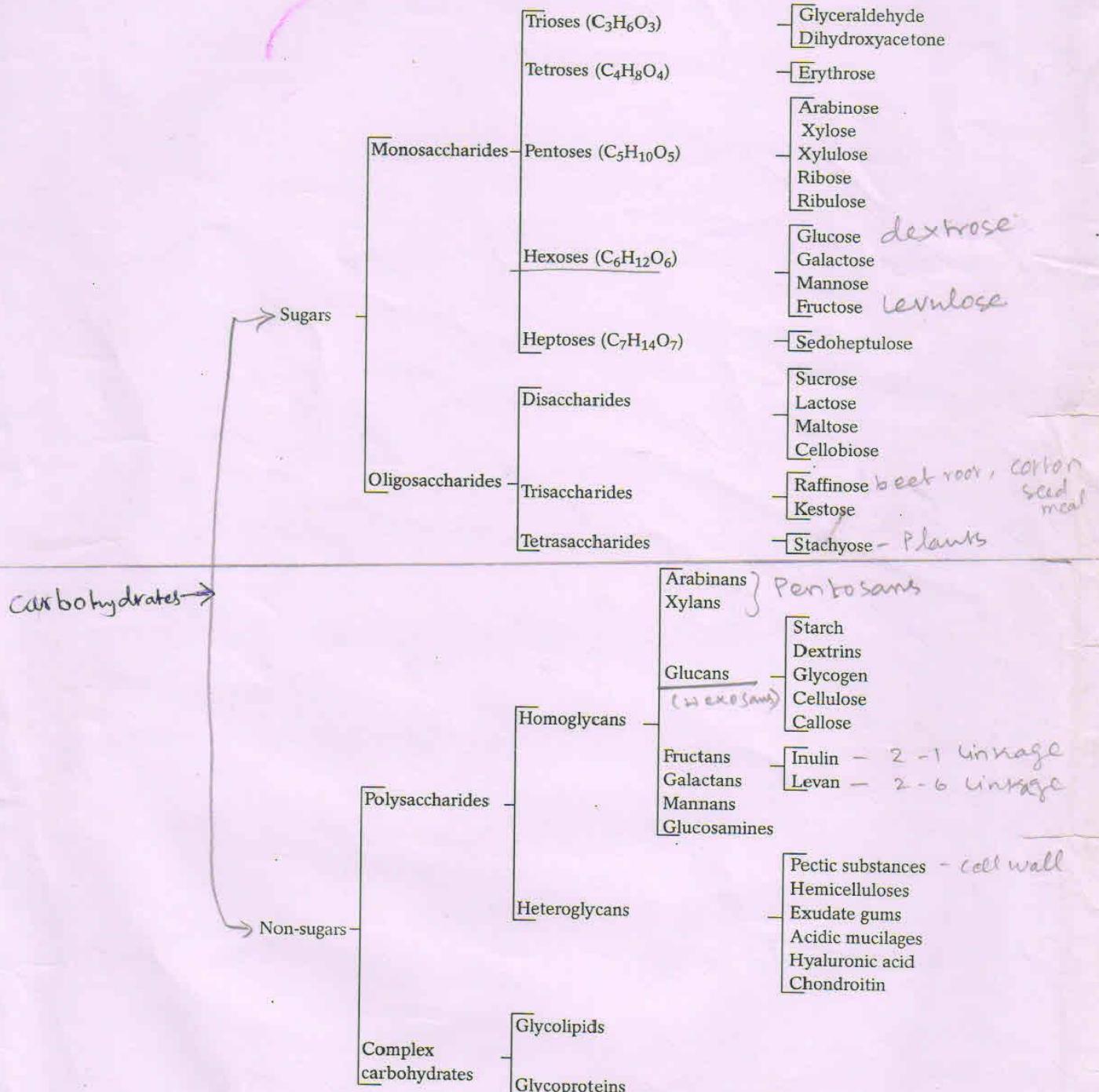


Fig. 2.1 Classification of carbohydrates.

2. **Trisaccharides:** Yields 3 Monosaccharides on hydrolysis.
Raffinose: On hydrolysis yields glucose, galactose and fructose. It is present in fair amount in beet root and cottonseed meal.
3. **Tetrasaccharides:** Yields 4 monosaccharides on hydrolysis. Eg Stachyose present in plants.

B. Non-Sugars

I. Polysaccharides:

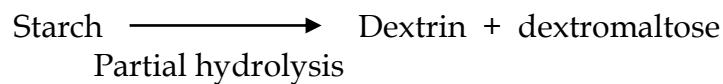
Classified as Homoglycans and Heteroglycans.

a. Homoglycans (Homopolysaccharides);

1. **Pentosans** e.g. Araban, Xylan

2. **Hexosans** e.g. Starch, glycogen, dextrin, and cellulose.

Starch: It is a reserve polysaccharide present in plants. This polysaccharide consists of two component amylose (17-25%) and amylopectin (75-83%). Starch is made up of glucose units linked together by α 1-4 linkages in the case of amylopectin there is also α 1-6 linkages.



Complete hydrolysis gives maltose in monogastrics. Starch is present in the form of starch granules in the plant. The size and shape of which is variable in different plants. On treatment with moist heat the starch granules swell and burst open liberating the starch and this process is called gelatinisation. Starch gives a characteristic blue colour with iodine.

Glycogen: It is the reserve carbohydrate present in human and animal body mainly in muscles (0.5-1%) and liver (3.7%). It is similar to starch formed by the condensation of 5,000 – 10,000 glucose molecules. It is sometimes referred to as **animal starch**. It gives a brown red colour with iodine.

Dextrins: It is an intermediate compound formed on partial hydrolysis of starch or glycogen.

Cellulose: It is a polysaccharide that contains linear chain of glucose units attached by beta 1- 4 linkages. Cellulose occurs nearly in pure form in cotton. It occurs in plants in combination with lignin. Cellulose in plants are organised as fibrils many fibrils aggregate and are held by intramolecular hydrogen bonding.

3. Fructans

Inulin: which yields fructose on hydrolysis. Fructose units are linked together by 2-1 linkages.

Levans: It is a polysaccharide, which yields fructose on hydrolysis. Fructose units are linked together by 2-6 linkages.

4. Galactans: It is a polysaccharide that contains galactose units and is present in many leguminous seeds.

5. Mannans: It is a polysaccharide that contains mannose units and is present in palm seeds.

b. Heteroglycans (Heteropolysaccharides):

Hemicellulose, gums, pectins, mucilage etc.

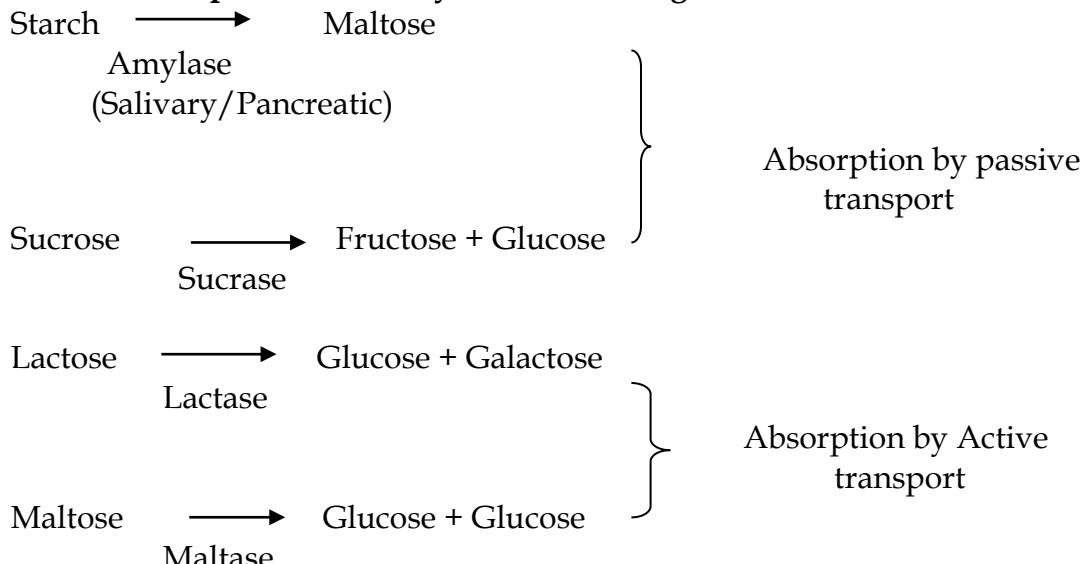
1. **Hemicellulose:** This includes a group of substances including araban, xylan, certain hexosans and poly uronides. They are distributed widely in forages.

2. **Pectins:** They are a group of substances, which occur in cell walls of plants. Their fundamental structural unit is galacturonic acid.

II. Complex Polysaccharides;

Eg. Glycolipid, Glycoprotein.

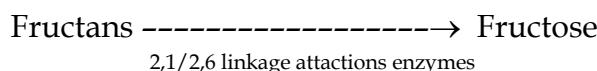
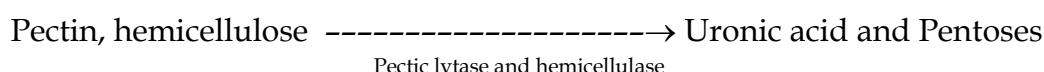
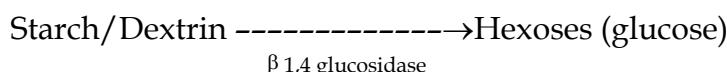
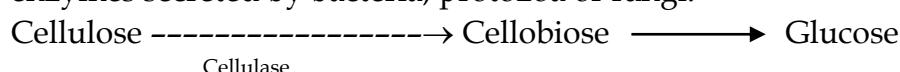
Digestion and absorption of carbohydrates in monogastrics:



Digestion and absorption of carbohydrates in ruminants

Feed enters rumen \rightarrow regurgitated back - **rumination** - broken down into small particles increased surface area for action of microbial enzymes. Rumination also helps in increased salivation.

The breakdown of carbohydrates in the rumen may be divided into two stages. First storage complex carbohydrates are broken down to simple sugars by the action of enzymes secreted by bacteria, protozoa or fungi.

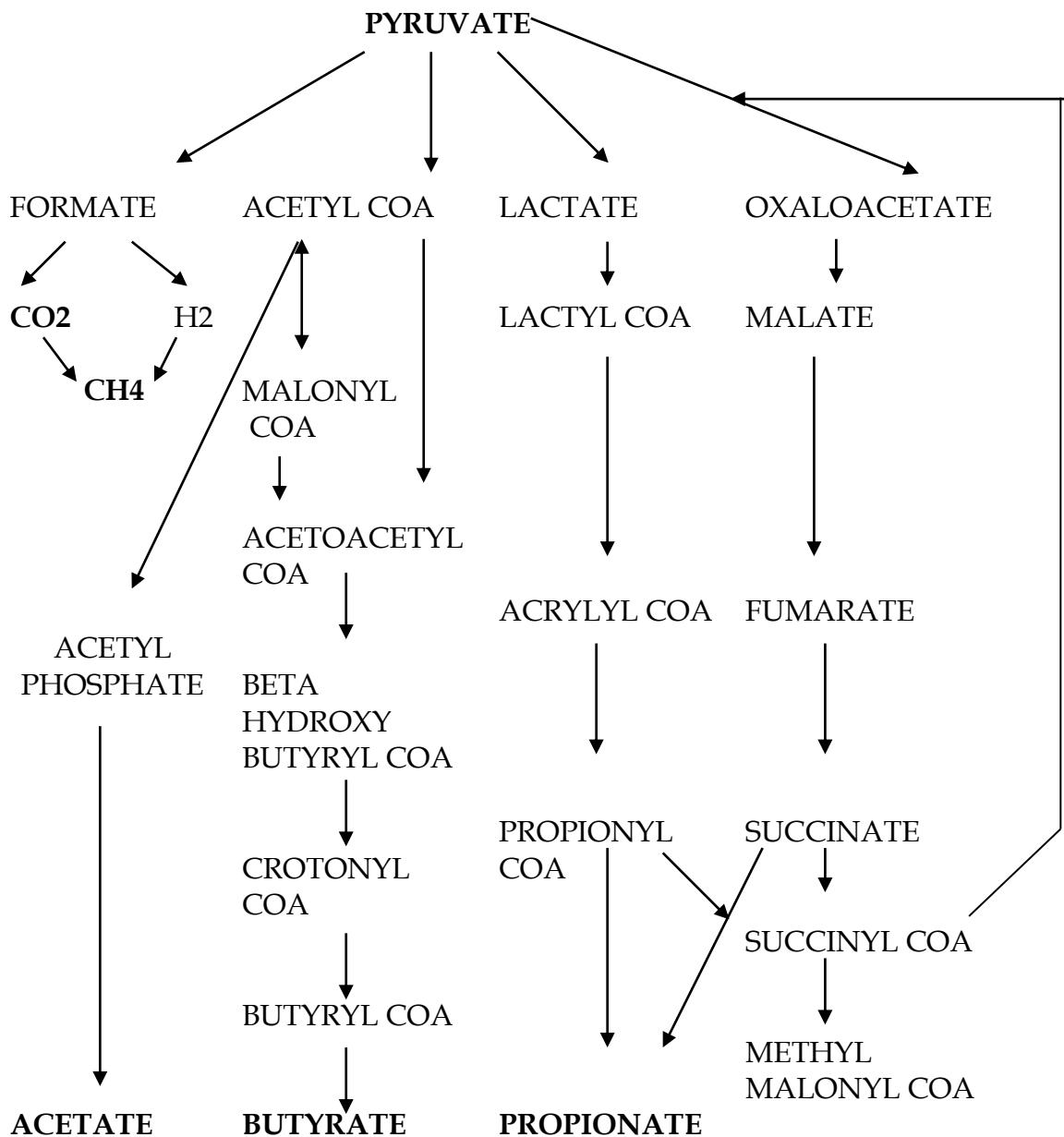


The simple sugar produced in the first stage of carbohydrate digestion are taken up and metabolised intracellular by rumen microbes. Pathways are similar to those involved in the metabolism. The key intermediate is pyruvate. The major end products of rumen carbohydrate digestion are acetic, propionic, butyric acid, CO₂ and methane.

Volatile fatty acid production the VFA production in rumen varies widely according to diet. Normally forages gives high proportion (70%) of acetic acid. The addition of concentrates increases the production of propionic acid at the expense of acetic acid.

Gas production in rumen is around 30 L/hour and it depends on the type of feed. Rumen gas composition CO₂ - 40%, CH₄ - 30-40%, H - 5% and small amounts of O₂ and N₂. Gases produced in the rumen are lost by a process of **eructation**. If the gases accumulate it leads to a condition called **bloat**.

Methane production: Methane is produced by methanogenic bacteria through a process of methanogenesis. This process involves folic acid and B₁₂. 4.5g of methane is produced for every 100g carbohydrate digested in the rumen. 7% of total feed energy is lost as methane.



FUNCTIONS OF CARBOHYDRATE:

- 1) Source of energy for muscular activity of heart muscles etc.
- 2) Carbohydrates are needed for oxidation of fat.
- 3) Synthesis of ribose from glucose. Ribose is incorporated in RNA and nucleotides.
- 4) In liver carbohydrates function in detoxification and they regulate protein metabolism.
- 5) Protein sparing action: Carbohydrates if inadequate protein is used as source of energy. Tissue protein break down can be avoided by providing adequate carbohydrates.

- 5) Production of VFA in the rumen.
- 6) Component of protein, fat, vitamins and coenzymes.

Study questions

Give two examples of each of the following:

1.	Triose	
2.	Tetrose	
3.	Pentose	
4.	Hexose	
5.	Disaccharide	
6.	Hexosan	
7.	Pentosan	
8.	Fructan	
9.	Heteropolysaccharide	
10.	Volatile fatty acids produced in rumen	
11.	Gases of rumen fermentation	

Fill in the blanks

- 1 _____ of methane is produced for every 100g carbohydrate digested.
- 2 _____ of total feed energy is lost as methane.
- 3 Normally forages gives _____ proportion of acetic acid on rumen fermentation.
- 4 Gas production in rumen is around _____ and it depends on the type of feed.
- 5 Maltose on hydrolysis yields _____ and _____.
- 6 Lactose on hydrolysis yields _____ and _____.
- 7 Enzyme _____ is needed to digest starch.
- 8 Glycogen is also called as _____.
- 9 Cane sugar is _____.
- 10 Fruit sugar is _____.
- 11 _____ and _____ are the examples of heteropolysaccharide.

Short answers

1. Glycogen
2. Starch
3. Cellulose
4. Digestion of carbohydrates in monogastrics
5. Classification of carbohydrates
6. Functions of carbohydrates.

Essay

1. Rumen fermentation of structural carbohydrates.

PROTEINS

Proteins are complex organic compounds of high molecular weight. In common with carbohydrates and fats they contain carbon, hydrogen and oxygen, but in addition they all contain nitrogen and generally sulphur.

AMINO ACIDS

Amino acids are produced when proteins are hydrolysed by enzymes, acids or alkalis. Amino acids are the building block of proteins. Although over 200 amino acids have been isolated from biological materials, only 20 of these are commonly found as components of proteins.

Amino acids are characterized by having a basic nitrogenous group, generally an amino group (NH_2) and an acidic carboxyl unit (COOH). In acidic pH, amino acid is a cationic characteristic; in basic pH, it is anionic characteristic, and the pH at which it is electrically neutral dipolar characteristic called as Zwitterion; that pH is isoelectric point for that amino acid.

Chemical classification of amino acids;

I. Aliphatic Amino Acids

a. Monoamino- monocarboxylic acids:

Glycine, Alanine, Valine, Leucine, Serine, Threonine and Isoleucine

b. Monoamino-dicarboxylic acids (Acidic):

Aspartic acid, Asparagine and Glutamic acid

c. Sulphur containing amino acids:

Cystine, Methionine and Cysteine

d. Diamino monocarboxylic amino acids (Basic):

Lysine and Arginine,

II. Aromatic and heterocyclic amino acids:

Phenylalanine, Tyrosine, Tryptophan, Proline

III. Heterocyclic amino acids;

Proline, Hydroxy Proline, Tryptophan, Histidine

IV. Special amino acids - Some proteins contain special amino acids, which are derivatives of common amino acids. *Hydroxylsine, Triiodothyronine and Tetraiodothyronine*

INDISPENSABLE AMINO ACIDS / ESSENTIAL AMINO ACIDS

Plants and many microorganisms are able to synthesize proteins from simple nitrogenous compounds such as nitrates. Animals cannot synthesize the amino group, and in order to build up body proteins they must have a dietary source of amino acids. Certain amino acids can be produced from others by a process known as transamination, but a number of them cannot be effectively synthesized in the animal body and these are referred to as **indispensable or essential amino acids**.

The following ten indispensable amino acids are required for growth in rat:

Arginine	Methionine
Histidine	Phenylalanine
Isoleucine	Threonine
Leucine	Tryptophan

Lysine

Valine

The **chick** also requires in the diet the 10 amino acids listed above, but in addition needs a dietary source of **Glycine**. The list of indispensable amino acids required by the **pig** is similar to that of the rat, with the exception of **Arginine and Histidine, which the pig can synthesize**. **Cats** have a dietary requirement for **Taurine** in addition to the other essential amino acids.

In the case of the ruminant, all the indispensable amino acids can be synthesized by the rumen micro-organisms, which theoretically make this class of animal independent of a dietary source. However, maximum rates of growth or milk production cannot be achieved in the absence of a supply of dietary amino acids in a suitable form.

CLASSIFICATION OF PROTEINS

Proteins may be classified into three main groups according to their shape, solubility and chemical composition.

FIBROUS PROTEINS:

These proteins are insoluble animal proteins, which are very resistant to animal digestive enzymes. They are composed of elongated, filamentous chains, which are joined together by cross linkages. This group contains the **Collagens**, which are the main proteins of connective tissues. **Elastin** is the protein found in elastic tissues such as tendons and arteries, while **Keratins** are the proteins of hair, nails, wool and hooves. These proteins are very rich in the sulphur-containing amino acid cystine; wool protein, for example, contains about 4 per cent of sulphur.

GLOBULAR PROTEINS:

This group includes all the enzymes, antigens and those hormones which are proteins. They can be subdivided into albumins which are water-soluble and heat-coagulable and which occur in eggs, milk, blood and many plants. The globulins are insoluble or sparingly soluble in water and are present in eggs, milk and blood and are the main reserve protein in seeds.

COMPLEX PROTEINS:

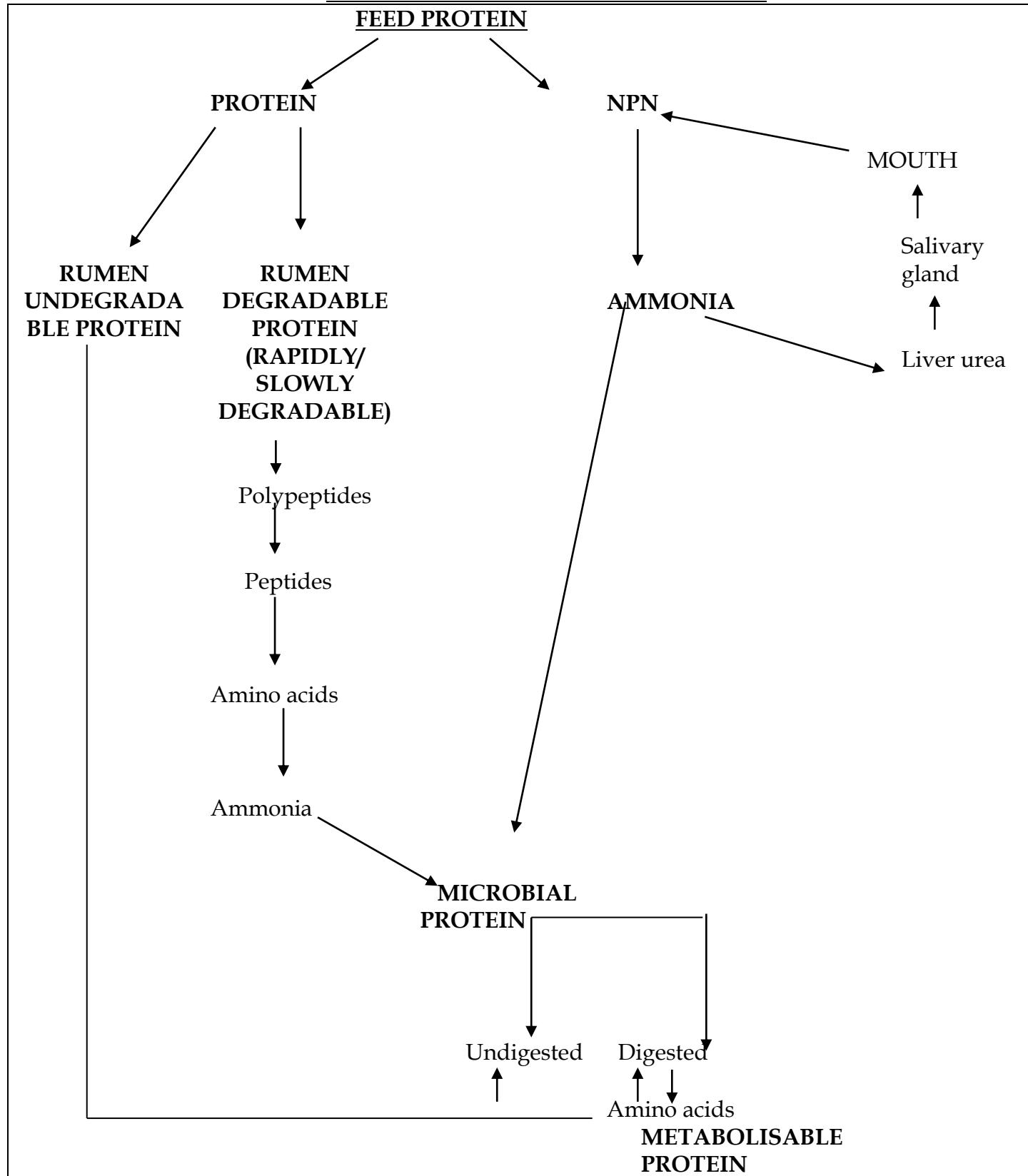
The complex or compound proteins on hydrolysis, yield non-protein groups, usually called '**prosthetic groups**', as well as amino acids. The prosthetic group varies and may be phosphoric acid (**phosphoproteins**), a carbohydrate or carbohydrate derivative (**glycoproteins**), a lipid (**lipoproteins**), a pigment (**chromoproteins**) or a nucleic acid (**nucleoproteins**).

NON-PROTEIN NITROGENOUS COMPOUNDS

A considerable variety of nitrogenous compounds, which are not classed as proteins, occur in plants and animals. In plant analysis these compounds have been frequently classed together as non-protein nitrogenous compounds, to distinguish them from 'true proteins' determined in routine chemical analysis. Amino acids from the main part of the non-protein nitrogenous fraction in plants, and those present in greatest amount include glutamic acid, aspartic acid, alanine, serine, glycine and proline. Other compounds are nitrogenous lipids, amines, amides, purines, pyrimidines, nitrates and alkaloids. In addition many members of the vitamin B complex contain nitrogen in their structure.

DIGESTION OF PROTEIN

PROTEIN DIGESTION IN RUMINANTS



Enzyme **ENTEROKINASE** is released from duodenal wall. Enterokinase **activate** small amount of trypsinogen into **trypsin**. Trypsin converts all three proenzymes (Zymogens) into active form:

- TRYPSINOGEN \longrightarrow trypsin
- CHYMOTRYPSINOGEN \longrightarrow chymotrypsin
- PROCARBOYPEPTIDASE \longrightarrow carboxypeptidase

These three proteolytic enzymes then attack and degrade feed proteins, breaking down into small peptides and amino acids.

Study questions

Fill in the blanks

- 1 Sulphur containing amino acids are _____, _____ and _____.
- 2 Basic amino acids are _____ and _____.
- 3 Cats have a dietary requirement for _____ in addition to the other essential amino acids.
- 4 Chicks have an additional requirement of the amino acid _____.
- 5 _____ is the protein found in elastic tissues such as tendons and arteries.
- 6 Inactive precursors of proteolytic enzymes are _____.
- 7 The protein present in the wool is _____.
- 8 _____ is an example of phosphoprotein
- 9 _____ is an example of chromoprotein.
- 10

Short answers

3. Essential amino acids
4. Protein digestion monogastrics
5. Classification of amino acids
6. Classification of protein
7. NPN
8. Undegradable protein / Protected protein / Bypass protein
9. Degradable protein
10. Metabolisable protein

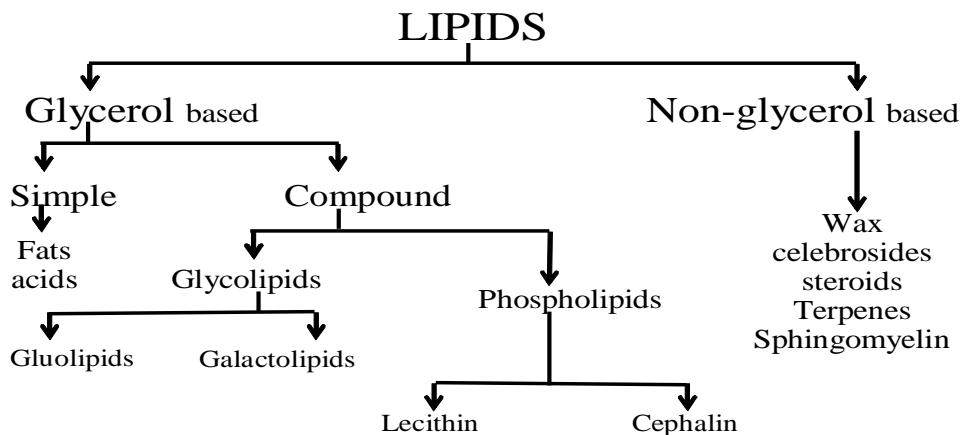
Essay

1. Rumen fermentation of protein

LIPIDS (FATS)

Plants and animal material contain a group of substances insoluble in water but soluble in ether, chloroform and benzene, which are commonly called as lipids. Like carbohydrates the fats contain carbon, hydrogen, oxygen but the first two elements C and H) are present more in fats.

CLASSIFICATION OF LIPIDS



1. Simple lipids:

- True fats – Esters of fatty acids with glycerol.
Waxes – Esters of fatty acids with alcohol (not glycerol).

2. Compound lipids:

- Esters of fatty acids with glycerol and contain additional elements like phosphorus and nitrogen.
- Phospholipids – fats containing nitrogen and phosphorus: lecithin, cephalin and sphingomyelin.
 - Glycolipids: fats with molecule of carbohydrate, eg. cerebrosides.

3. Derived lipids:

- Substances derived from simple lipids and compound lipids above 2 classes on hydrolysis. Sterols: Cholesterol, ergosterol etc.

FATS: True fats are esters of fatty acids with glycerol (Trihydric alcohol). They are also known as *triglycerides* because each one of glycerol is combined with three molecules of fatty acids. Fatty acids are long chain organic acids, having 4-24 carbon atoms and a single carboxyl group (COOH). The chain length and degree of unsaturation of the fatty acids making up the triglyceride determine its physical and chemical properties. Triglycerides of saturated fatty acids containing at least ten carbon atoms are solid at room temperature, whereas those with less than ten carbon atoms are liquid at room temperature.

BIOLOGICAL SIGNIFICANCE OF FATS:

- Fats are important source of stored energy in plants and animals and are characterised by their high energy value (1 gram fat = 9.3 Kcal or 38.9 KJ)

Brown fat present in hibernating animals break down to yield energy. This fat is supplied with cytochrome (respiratory electron carrier) giving them their brown colour.

2. Components of biological membrane
3. Carrier for fat soluble vitamins – A, D, E and K
4. Useful as electron carrier
5. Useful source of metabolic water
6. Deposits of fat underneath the skin exert insulating effect to the body thus protecting it from excessive heat or cold. The mesenteric fat acts as a padding to protect the internal organs.
7. Sources of **essential fatty acids – linolenic, linoleic and arachidonic acids.**
8. Normal breakdown products of fatty acids such as acetic acid and bile acids form important building blocks of biologically active materials like cholesterol, sex hormones and steroids

CHEMICAL PROPERTIES OF FATS:

Saponification: Fat can be hydrolysed by boiling with alkali yielding glycerol and water-soluble alkali salts of fatty acids (soaps), which is called as **saponification**. Triglycerides also undergo enzymatic hydrolysis by lipases either from pancreas or from bacteria and moulds. The **saponification value** is defined as the number of milligrams of potassium hydroxide required to saponify one gram of the fat. Fats with a high saponification value will thus contain a high proportion of low molecular weight acids and vice-versa.

Iodine Value: The iodine value is defined as the number of grams of iodine absorbed by 100g of the fat. The unsaturated fatty acids contain double bonds to which halogens may be added. The amount of halogen taken up by a given fat depends upon the degree of unsaturation of its constituent acids. Oils with a high content of unsaturated acids show high values.

Rancidity

Auto-oxidation occurring in natural edible fats, which are rich in unsaturated fatty acids is called **rancidification**. The chemical changes which occur during rancidification are known as **rancidity** and this takes place in two stages, namely;

1. Hydrolytic rancidity
2. Oxidative rancidity

Hydrolytic Rancidity: Involves partial hydrolysis of the glycerides to mono and diglycerides, while glycerol and free fatty acids are also liberated. The hydrolysis is hastened in the presence of moisture, warmth and lipases present in fats. Hydrolytic rancidity of butter (high in volatile fatty acids) produces disagreeable odour and taste due to the liberation of the **butyric acid**.

Oxidative Rancidity: The unsaturated fatty acids are oxidised at the carbon atom adjacent to the double bond to form hydroperoxides which may breakdown to give unsaturated aldehydes or ketones. Development of oxidative rancidity is accelerated by the presence of heavy metals, –copper and irons and by exposure of the fat to ultra-violet light.

Ketonic Rancidity: Oxidation of fatty acids due to the presence of methyl ketones resulting the development of a sweet, heavy taste and smell is known as **ketonic rancidity**.

ANTIOXIDANTS – prevent the oxidation of unsaturated fats until they themselves have been transformed into inert products. A number of compounds have the antioxidant property. They include vitamins C and E, phenols, gallic acids, quinones, propyl, octyl or dodecyl gallate, butylated hydroxyl anisole (BHA) or butylated hydroxy toluene (BHT).

Prevention of Rancidity:

- i) Proper storage of the fats in airtight non metallic receptacles kept in cool place away from light, moisture.
- ii) Addition of antioxidants.

Hydrogenation:

Triglycerides containing largely unsaturated fatty acids, which are liquid at room temperature, can be converted into solid fats by hydrogenation of their double bonds. This process is widely employed for converting vegetable and fish oils into margarine and it is catalysed by addition of finely divided nickel. The hardening results from the higher melting points of the saturated acids and improves the keeping quality of the fat, since removal of double bond eliminates the chief centres of reactivity in the material. Rumen microbes enzymatically hydrogenate dietary unsaturated fatty acids (**Biohydrogenation**), therefore feeding of highly unsaturated fat also causes deposition of high saturated fat in ruminant body.

Essential Fatty Acids:

Arachidonic and Linolenic and Linoleic are commonly referred to as **essential fatty acids**. Though the body can synthesize unsaturated fatty acids, it is suggested that the body does not have enzyme system to synthesise unsaturated fatty acids with 2 or 3 double bonds. Though these acids are referred to as essential fatty acids (EFA) there is possible intra conversion between them. There is species variation as regards to the extent of intraconversion. In rat, either linoleic or Arachidonic will serve as precursor for the other two. In chick linolenic is convertible to the other two. Essential fatty acids are required by chicks, calves and goats. Only linolenic acid is an essential nutrient for chicken.

Digestion and Absorption:

As fats are non-polar and immiscible with water, its digestion principally differs from the digestion of carbohydrates and proteins. The object of lipid digestion is to arrange the lipids in a form that it can be absorbed through the micro villi, which are covered by an aqueous layer.

Fat digestion in Mono-gastric animals:

There is no enzyme in the saliva capable of attacking fats. In the stomach warming, softening, dispersion and mechanical separation of lipids from the other nutrients occurs. A coarse fat emulsion enters the duodenum, which is the site of the major process of fat digestion and absorption.

Emulsification of fat occurs in the small intestine after contact with bile salts – sodium glycocholate and sodium taurocholate. This process reduces the lipid particle size to 500-1000 Å° (500-1000mμ diameters).

The common bile acids such as cholic, taurocholic and glycocholic acids are detergents sterol nucleus being lipids soluble and the ionised conjugates of glycine and taurine being water-soluble. The bile salts form aggregates called **micelles** where the polar or water soluble portion is towards the periphery and the inner core comprises of the apolar or water insoluble fraction

The small size of fat particles allow for greater surface exposure to pancreatic and intestinal lipases, which absorb on the particle surface and attack fatty acids resulting in hydrolysis of triglycerides to β -monoglycerides and free fatty acids (FFA).

Free fatty acids then combine with salt-phospholipids - cholesterol micelles to from **mixed micelles** for efficient absorption.

Digestibility of fatty acid decreases when the length of carbon chain increases.

Absorption of the products of lipolysis occurs primarily in the duodenum and upper jejunum, whereas bile salts are absorbed in the ileum and are recirculated in the portal blood o the liver and hence to the bile for re-entry to the duodenum. An important property of the lipid-bile salt micelle is to take up significant amounts of non-polar compounds such as sterols, fat soluble vitamins and carotenoids within this lipids non-polar interior. Otherwise these lipids would not be absorbed.

The major route of fat absorption in mammals and birds in via micelles; in addition, limited amounts of triglycerides may be absorbed intact as a fine emulsion and glycerol, liberated by lipolysis is absorbed like glucose by simple diffusion with a carrier.

From the Free fatty acids and monoglycerides triglyceride are resynthesised in the mucosa which are then conjugated with a protein to form **chylomicron** and are transported to various tissues where they are deposited as an energy reserve or enter a wide range of metabolic processes.

Study questions

Fill in the blanks

- 1 _____ is an example of phsopholipid.
- 2 _____ is an example of glycolipid.
- 3 Lipids are the esters of _____ and _____.
- 4 _____, _____ and _____ are called as essential fatty acids.
- 5 _____ and _____ are the examples of natural antioxidants.
- 6 _____ and _____ are the examples of synthetic antioxidants.
- 7 _____ is helping in the digestion of fat.
- 8 _____ is the enzyme involved in the digestion of fat.

Define the following

1. Rancidity
2. Saponification number
3. Iodine value
4. PUFA
5. Antioxidants
6. Hydrogenation
7. Essential fatty acids
8. Micelle
9. Chylomicron

10. Biohydrogenation
11. Emulsification
12. Mixed micelle

Short answer

1. Functions of fat
2. Properties of fat
3. Rancidity
4. Classification of lipids

Essay

1. Digestion and absorption of fat in monogastrics

CHAPTER 5

IMPORTANCE OF MINERALS AND VITAMINS IN ANIMAL HEALTH AND PRODUCTION

Minerals;

Minerals form the inorganic part of the feed. The essential minerals are classified as major minerals / elements and trace or minor minerals / elements. The classification is based on the concentration of the elements in the animal;

1. **Major Minerals / Macro Elements :** Ca, P, Mg, S, Na, K, and Cl.
2. **Minor Minerals / Trace Minerals / Trace Elements:** Iron, Iodine, Copper, Zinc, Manganese, Cobalt, Molybdenum, Selenium, Tin, Vanadium, Fluorine, Chromium, Silicon, Nickel and Arsenic.
3. **Newer Trace Elements:** Tin, Vanadium, Fluorine, Chromium, Silicon, Nickel and Arsenic. Their essentiality is based on the growth effects of animals under specialized conditions.

General functions of minerals;

1. **Structural component** of body organs or tissues. Eg. **Calcium and phosphorus**.
2. Constituent of **body fluids as electrolytes**. Maintenance of **acid base balance, osmotic pressure, membrane permeability and tissue irritability**. (Sodium, potassium, chlorine, calcium, magnesium).
3. **Transmission of nerve impulses** and contraction of muscles.
4. **Catalysts** in enzyme and hormone systems.
5. Specific component of certain enzymes, hormones and vitamins.
6. Essential for normal **reproduction**.
7. Some minerals are needed for maintenance of **immunity** in the animals.
8. Minerals are essential for **production** of milk, meat, egg, wool etc.

Enzymes that contain minerals as their integral part are called **metalloenzymes**. Some enzymes are activated by presence of minerals and they are called as **metal activated enzymes**.

	Mineral	Metalloenzymes
1	Iron	: Cytochromes
2	Copper	: Cytochrome oxidase
3	Zinc	: Carbonic anhydrase, carboxypeptidase
4	Manganese	: Pyruvate carboxylase
5	Molybdenum	: Xanthine oxidase
6	Selenium	: Glutathione peroxidase

MAJOR MINERALS

CALCIUM (Ca)

Most abundant mineral in the animal body.

Functions:

- Structural component of body (Skeleton and teeth).
- 99% of the calcium in the body is present in the bones and teeth.
- In the Bone it is present as calcium hydroxy appatite crystals along with phosphorus.
- Calcium in the bone is present in a dynamic state.
- It is essential for the activity of a number of enzyme systems.
- It is necessary for the transmission of nerve impulses and for the contractile properties of muscle.
- It is also concerned in the coagulation of blood.

Blood Calcium level

In blood the element occurs in the plasma. The plasma of **mammals** usually contains 8 - 12mg Calcium/dl, but that of **laying hens** contains 30 - 40 mg/dl.

Regulation of calcium metabolism:

Whenever blood calcium level decreases below the normal, parathyroid gland is stimulated to secrete **paratharmone**. This hormone mobilizes calcium from the bone and also facilitates reabsorption of calcium in the kidney. It also increases calcium absorption in the small intestine by increasing the synthesis of 1, 25 di-hydroxy cholecalciferol (active form of vitamin D) from 25 hydroxy cholecalciferol in the kidneys which in turn increases the synthesis of calcium binding protein resulting in increased calcium absorption. High level of blood calcium stimulates the secretion of calcitonin, which has antagonistic action to that of paratharmone.

Deficiency symptoms:

If calcium is deficient in the diet of young growing animals, then satisfactory bone formation cannot occur and the condition known as **rickets** is produced. The symptoms of rickets are misshapen bones, enlargement of the joints, lameness and stiffness. Enlargement of the osteochondral joints in the ribs produces a condition called as **Rickety Rosary**. **Pigeon chested appearance** is also another symptom due to enlargement of sternum. In adult animals calcium deficiency produces **osteomalacia**, in which the calcium in the bone is withdrawn and not replaced. In osteomalacia the bones become weak, fragile and are easily broken. In hens, deficiency symptoms are soft beak and bones, retarded growth and bowed legs, the eggs have thin shells or there is production of leathery eggs.

Milk fever (parturient paresis) is a condition, which is most commonly occurs, in dairy cows shortly after calving. It is characterized by a lowering of the serum calcium level, muscular spasms and in extreme case paralysis and unconsciousness. The exact cause of hypocalcaemia associated with milk fever is obscure, but it is generally considered that, with the onset of lactation, the parathyroid gland is unable to respond rapidly enough to

increase calcium absorption from the intestine to meet the extra demand. Normal levels of blood calcium can be restored by intravenous injections of calcium gluconate, but this may not always have a permanent effect. It has been shown that avoiding excessive intakes of calcium while maintaining adequate dietary levels of phosphorus during the dry period reduces the incidence of milk fever. Deliberate use of low calcium diets to increase calcium absorption in the practical prevention of milk fever requires a good estimate of calving date or calcium deficiency may occur. Administration of large doses of vitamin D₃ for a short period prior to parturition has also proved beneficial.

Sources of calcium: Animal by-products containing bone, such as fishmeal and meat and bone meal and ground limestone, steamed bone meal and dicalcium phosphate (DCP) are excellent sources. Milk and green leafy crops, especially legumes, are good sources of calcium.

Calcium: Phosphorus ratio: The calcium phosphorus ratio considered most suitable for farm animals other than poultry is generally within the range 1:1 to 2:1, The proportion of calcium for laying hens is much larger, since they require great amounts of the element for eggshell production.

An excess of dietary phosphorus in relation to calcium may result in a bone disorder called **nutritional secondary hyperparathyroidism**. An excess of phosphorus depresses calcium absorption and leads to decrease in blood calcium level which stimulates the release of PTH which mobilizes calcium from the bone. The demineralised bone is replaced by fibrous connective tissue. Nutritional secondary hyperparathyroidism occurs in horses fed large amount of grains or their byproducts without calcium supplementation. The condition is also referred to as **miller's disease or bran disease or big head disease**.

PHOSPHORUS (P)

Functions: Phosphorus has more known functions in the animal body than any other mineral element. Phosphorus occurs in close association with calcium in bone. In addition it occurs in phosphoproteins, nucleic acids and phospholipids. The element plays a vital role in energy metabolism in the formation of sugar-phosphates and adenosine di- and triphosphates. The phosphorus content of the animal body is rather smaller than the calcium content. Whereas 99 per cent of the calcium found in the body occurs in the bones and teeth, the proportion of the phosphorus in these structures is about 80-85 per cent of the total.

Sources of phosphorus: Milk, cereal grains, fish meal and meat products containing bone are good sources of phosphorus; Much of the element present in cereal grains is in the form of **phytates**, which are salts of phytic acid, a phosphoric acid derivative: In ruminants hydrolysis of phytates by bacterial phytases occurs in the rumen. Ruminants utilize phytate phosphorus as readily as other forms of phosphorus.

Deficiency symptoms:

Like calcium, phosphorus is required for bone formation and a deficiency can also cause **rickets (or) osteomalacia**. '**Pica' or depraved appetite**' has been noted in cattle when there is a deficiency of phosphorus in their diet; the affected animals have abnormal appetites and chew wood, bones, rags and other foreign materials. Pica is not specifically a sign of phosphorus deficiency since it may be caused by other factors. In chronic phosphorus deficiency animals may have stiff joints and muscular weakness.

Low dietary intakes of phosphorus have also been associated with **poor fertility**, apparent dysfunction of the ovaries causing inhibition or depression and irregularity of oestrus. There are many examples, where phosphorus supplementation increases fertility in grazing cattle. In cows a deficiency of this element may also reduce milk yield.

Subnormal growth in young animals and low live weight gains in mature animals are characteristic symptoms of phosphorus deficiency in all species.

MAGNESIUM (Mg)

Functions: Magnesium is closely associated with calcium and phosphorus. About 70 per cent of the total magnesium is found in the skeleton but the remainder, which is distributed in the soft tissues and fluids, is of crucial importance to the well being of the animal. Magnesium is the commonest enzyme activator, for example in systems with thiamine pyrophosphate. Magnesium is an essential activator of phosphate transferases (e.g. creatine kinase) and it activates pyruvate carboxylase, pyruvate oxidase and reactions of the tricarboxylic acid cycle. Therefore, it is essential for the efficient metabolism of carbohydrates and lipids. In reactions, forming complexes with adenosine tri-di- and monophosphates. The formation of cycle AMP and other secondary messengers requires magnesium.

Deficiency symptoms: Symptoms due to a simple deficiency of magnesium in the diet have been reported for a number of animals. In adult ruminants a condition known as **hypomagnesemic tetany** associated with low blood levels of magnesium (hypomagnesaemia) has been known under a variety of names including **magnesium tetany, lactation tetany and grass staggers**, but most of these terms have been discarded because the disease is not always associated with lactation or with grazing animals. Because the tetany can develop within a day or two of animals being turned out to graze, the condition has been referred to as the acute form. In this acute type, blood magnesium levels fall so rapidly enough. In the chronic form of the disease plasma magnesium levels fall over a period of time to low concentrations.

Clinical signs of the disease are often brought on by stress factors such as cold, wet and windy weather. The normal magnesium content of blood serum in cattle is within the range of 1.7 to 4.0 mg/dl blood serum, but levels below 17 frequently occur without

clinical symptoms of disease. Subcutaneous injections of magnesium sulphate, or preferably magnesium lactate, can generally be expected to cure the animal if given early.

Typical symptoms of tetany are nervousness, tremors, twitching of the facial muscles, staggering gait and convulsions. Some research workers consider the condition to be caused by a cation-anion imbalance in the diet and there is evidence of a positive relationship between tetany and heavy dressing of pasture with nitrogenous and potassic fertilizers.

A high degree of success in preventing hypomagnesaemia may be obtained by increasing the magnesium intake. Feeding with magnesium-rich mineral mixtures, or alternatively by increasing the magnesium content of pasture can affect this by the application of magnesium fertilizers.

Sources of Magnesium: Wheat bran, dried yeast and most vegetable protein concentrate, especially cottonseed cake and linseed cake, are good sources of magnesium. The mineral supplement most frequently used is magnesium oxide, which is sold commercially as calcined magnesite. When hypomagnesaemic tetany is likely to occur it is generally considered that about **50g of magnesium oxide should be given to cows per head per day as a prophylactic measure.** The daily prophylactic dose for calves is 7 to 15 g of the oxide, while that for lactating ewes is about 7g. The mineral supplement can be given mixed with the concentrate ration. Alternatively a mixture of magnesium acetate solution and molasses can be used, which is frequently made available on a free-choice basis from ball feeders placed in the field.

POTASSIUM (K)

Functions: Potassium plays a very important part, along with sodium, chlorine and bicarbonate ions, in the osmotic regulation of the body fluids and in the acid-base balance in the animal. Whereas sodium is the main inorganic cation of extracellular tissue fluids, potassium functions principally as the cation of cells. Potassium plays an important part in nerve and muscle excitability, and is also concerned in carbohydrate metabolism.

Deficiency symptoms: Potassium deficiency is rare in farm animals kept under natural conditions. There are certain areas in the world where soil potassium levels are naturally low. Deficiency symptoms have been produced in chicks given experimental diets low in potassium. They include retarded growth, weakness and tetany followed by death. Deficiency symptoms, including severe paralysis, have also been recorded for calves given synthetic milk diets low in potassium.

SODIUM (Na)

Functions: Most of the sodium of the animal body is present in the soft tissues and body fluids. Like potassium, sodium is concerned with the acid-base balance and osmotic

regulation of the body fluids. Sodium is the chief cation of blood plasma and other extra cellular fluids of the body. The sodium concentration within the cells is relatively low, the element being replaced largely by potassium and magnesium. Sodium also plays a role in the transmission of nerve impulses and in the absorption of sugars and amino acids from the digestive tract. Much of the sodium is ingested in the form of sodium chloride (common salt) and it is also mainly in this form that the element is excreted from the body.

Deficiency symptoms: A deficiency of sodium in the diet leads to a lowering of the osmotic pressure, which results in dehydration of the body. Symptoms of sodium deficiency include poor growth and reduced utilization of digested proteins and energy. In hens, egg production and growth are adversely affected.

Sources of sodium: Most foods of vegetable origin have comparatively low sodium contents, animal products, especially meat meals and foods of marine origin, are richer sources. The commonest mineral supplement given to farm animals is common salt.

CHLORINE (Cl)

Chlorine is associated with sodium and potassium in acid-base relationships and osmotic regulation. Chlorine also plays an important part in the gastric secretion, where it occurs as hydrochloric acid as well as chloride salts. Chlorine is excreted from the body in the urine and is also lost from the body, along with sodium and potassium, in perspiration. A dietary deficiency of chlorine may lead to an abnormal increase of the alkali reserve of the blood (alkalosis) caused by an excess of bicarbonate, since inadequate levels of chlorine in the body are partly compensated for by increases in bicarbonate.

Sources of chlorine: With the exception of fish and meat meals, the chlorine content of most foods is comparatively low. The main source of this element for most animals is common salt.

Salt: Since plants tend to be low in both sodium and chlorine. It is the usual practice to give common salt to herbivores. Unless salt is available deficiencies are likely to occur in both cattle and sheep. Salt is also important in the diet of hens, and it is known to counteract feather picking and cannibalism. Salt is generally given to pigs on vegetable diets, but if fishmeal is given the need for added salt is reduced.

Salt toxicity Too much salt in the diet is definitely harmful and causes excessive thirst, muscular weakness and oedema. Salt poisoning is quite common in pigs and poultry, especially where fresh drinking water is limited. When the concentration of salt in the diet of hens exceeds 40 g/kg DM and the supply of drinking water is limited, then death may occur. Hens can tolerate larger amounts of salt if plenty of water is available. Chicks cannot tolerate salt as well as adults, and 20g/kg DM in the diet should be regarded as the absolute maximum. This value should also not be exceeded in the diets

of pigs. Turkey poult are even less tolerant, and 120g/kg of salt in the diet should not be exceeded.

SULPHUR (S)

Most of the sulphur in the animal body occurs in proteins containing the **amino acids Cystine, Cysteine and Methionine**. The two-vitamin **Biotin and Thiamin**, the hormone **Insulin** and the important metabolite **Coenzyme A** also contain sulphur. The structural compound **chondroitin sulphate** is a component of cartilage, bone, tendons and the walls of blood vessels. Sulphur-containing compounds are also important in elements of the respiratory process from haemoglobin through to cytochromes. Only a small amount of sulphur is present in the body in small quantities. Wool is rich in cystine and contains about 4 per cent of sulphur.

In recent years however, with the increasing use of urea as a partial nitrogen replacement for protein nitrogen, it has been realized that the amount of sulphur present in the diet may be the limiting factor for the synthesis in the rumen of cystine, cysteine and methionine. Under these conditions the addition of sulphur to urea-containing rations is beneficial. There is evidence that sulphate (as sodium sulphate) can be used by ruminal microorganisms more efficiently than elemental sulphur. Tissue protein and milk have a ratio of **nitrogen to sulphur of 10 -12:1 and the ratio in wool is 5:1**. The nitrogen to sulphur ratio of 10-12:1 should be maintained whenever NPN compounds are used as supplements in ruminant feeds. Toxicity can result from excess dietary sulphur, which is converted to hydrogen sulphide, a toxic agent, by the gastrointestinal flora. This reduces rumen motility and causes nervous and respiratory distress.

TRACE ELEMENTS

IRON (Fe)

Functions: More than 90 per cent of the iron in the body is combined with proteins, the most important being **haemoglobin**. Iron also occurs in blood serum in a protein called **transferrin**, which is concerned with the transport of iron from one part of the body to another. **Ferritin**, is a protein containing iron, is present in the spleen, liver, kidney and bone marrow and provides a form of storage for iron. **Haemosiderin** is another storage form of iron. Iron has a major role in many biochemical reactions, particularly in connection with enzymes of the electron transport chain (**cytochromes**). Electrons are transported by the oxidation and reduction activity of bound iron. Among the enzymes containing or activated by iron are **catalase, peroxidases, phenylalanine hydroxylase** and many other including all the tricarboxylic acid cycle enzymes.

Deficiency symptoms: Since more than half the iron present in the body occurs as haemoglobin, a dietary deficiency of iron would clearly be expected to affect the formation of this compound. The red blood corpuscles contain haemoglobin, and these cells are continually being produced in the bone marrow to replace those red cells

destroyed in the animal body as a result of catabolism. Although the haemoglobin molecule is destroyed in the catabolism of these red blood corpuscles, the iron liberated is made use of in the resynthesis of haemoglobin, and because of this the daily requirement of iron by a healthy animal is usually small. If the need for iron increases, as it would after prolonged haemorrhage or during pregnancy, then haemoglobin synthesis may be affected and anaemia will result.

Anaemia due to iron deficiency occurs most commonly in rapidly growing suckling animals, since the iron content of milk is usually very low. This can occur in piglets housed in pens without access to soil. The piglet is born with very limited iron reserves and sow's milk provides only about 1mg per day. The rapidly growing piglet's requirement is 50mg per day, which, in extensive systems, could be obtained by ingestion of soil. Providing the sow with supplementary iron in gestation does not increase the foetal piglets liver iron or the amount in the milk. Therefore, it is routinely supplied by intramuscular injection as a dextran complex by 3 days of age. Usually 200 mg of iron is injected. Alternatively oral iron supplements are available in the form of a paste of the citrate or fumarate or granules of iron dextran but these may not be eaten or the iron may be lost if diarrhoea occurs. Anemia in piglets is characterized by poor appetite and growth. Breathing becomes labored and spasmodic-hence the descriptive term '**thumps**' for the condition.

Although iron deficiency is not common in older animals, increased supplementation is required when high levels of copper are used for growth promotion. Iron deficiency anemia is not common in lambs and calves because in practice it is unusual to restrict them to a milk diet without supplementary feeding. It does, however, sometimes occur in laying hens, since egg production represents a considerable drain on the body reserves.

Sources of iron: Iron is widely distributed in foods. Good sources of the element are green leafy materials, most leguminous plants and seed coats. Feeding of animal origin, such as meat, blood and fish meals, are excellent sources of iron.

Iron absorption: Iron is absorbed throughout the gastro-intestinal tract, but mainly in the duodenum and jejunum. Absorption is poor and is, to a large extent, independent of the dietary source. The efficiency of absorption is increased during periods of iron need and decreased during periods of iron overload. The mechanisms whereby the body carries this out are not fully understood. A number of theories have been advanced and one of these, the **mucosal block theory**, propounded in 1943, is still widely held by many to explain the mechanism. According to this **mucosal block theory**, the mucosal cells of the gastro-intestinal tract absorb iron and convert it into ferritin, and when the cells become physiologically saturated with ferritin, further absorption is impeded until the iron is released and transferred to plasma. The adult's need for iron is normally low, as the iron

produced from the destruction of haemoglobin is made available for haemoglobin regeneration, only about 10 per cent of the element escaping from this cycle.

Iron toxicity: Iron toxicity is not a common problem in farm animals, but it can result from prolonged oral administration of the element. Chronic iron toxicity results in alimentary disturbances, reduced growth and phosphorus deficiency.

COPPER (Cu)

Functions: Copper is present in certain plasma proteins such as **ceruloplasmin (ferrooxidase)**, which are concerned with the release of iron from the cells into the plasma ie the conversion of iron into transferrin. A deficiency of copper impairs the animal's ability to absorb iron, mobilize it from the tissues and utilize it in haemoglobin synthesis. Copper is also a component of other proteins in blood. One of these, **erythrocuprein**, occurs in erythrocytes where it plays a role in oxygen metabolism. The element is also known to play a vital role in many enzyme systems; for example, it is a component of **cytochrome oxidase**, which is important in oxidative phosphorylation. Cytochrome oxidase is involved in the synthesis of myelin lipid compounds. Copper containing enzyme **lysyl oxidase** is needed for the conversion of lysine to desmosine which forms cross links in elastin and collagen fibres. The element also occurs in certain pigments, notably **turacin, a pigment of feathers**. Copper is necessary for the normal pigmentation of hair, fur and wool. Copper containing enzyme **Tyrosinase** is needed for the conversion of the amino acid tyrosine to melanin. It is thought to be present in all body cells, being particularly concentrated in the liver, which acts as the main copper storage organ of the body. Copper has been shown to reduce directly the susceptibility to infection in lambs.

Deficiency symptoms: Since copper performs many functions in the animal body there are a variety of deficiency symptoms. These include **anaemia**, poor growth, **bone disorders, scouring, infertility, depigmentation of hair and wool**, gastro-intestinal disturbances and lesions in the brain stem and spinal cord. The lesions are associated with muscular incoordination, and occur especially in young lambs - **swayback** condition also known as '**enzootic ataxia**' or **neonatal ataxia** has been known for some time in Australia. The signs range from complete paralysis of the newborn lamb to a swaying staggering gait, which affects, in particular, the hind limbs. The condition can occur in two forms, one congenital, in which the signs are apparent at birth and are due to the failure of the myelin sheath of nerves to develop, and the other in which the onset of the clinical disease is delayed for several weeks. The congenital form of the condition is irreversible and can only be prevented by ensuring that the ewe receives an adequate level of copper in her diet. Delayed swayback can be prevented or retarded in copper deficient lambs by parenteral injection of small doses of copper complexes. Copper plays an important role in **the production of 'crimp' in wool**. The element is present in an

enzyme, which is responsible for the disulphide bridge in two adjacent cysteine molecules. In the absence of the enzyme the protein molecules of the wool do not form their bridge and the wool, which lacks crimp, is referred to as '**stringy**' or '**steely**'. **Nutritional anaemia** resulting from copper deficiency has been produced experimentally in young pigs by diets very low in the element and this type of anaemia could easily arise in such animals fed solely on milk. In older animals copper deficiency is unlikely to occur and copper supplementation of practical rations is generally considered unnecessary. There are, however, certain areas in the world where copper deficiency in cattle occurs. A condition in Australia known locally as '**falling disease**' was found to be related to a progressive degeneration of the myocardium of animals grazing on copper deficient pastures. Copper deficiency also leads to reproductive problems in cattle.

Copper-molybdenum-sulphur interrelationship: Certain pastures on calcareous soils for over 100 years to be associated with a condition in cattle described as '**teart**', characterized by unthriftiness and scouring. A similar disorder on reclaimed peat lands is known as '**peat scours**'. Molybdenum levels in teart pasture are of the order of 20 to 100 mg/kg DM compared with 0.5 to 3.0 mg/kg DM in normal pastures, and teart was originally regarded as being a straight forward molybdenosis. In the late 1930s, however, it was demonstrated that feeding with copper sulphate controlled the scouring and hence molybdenum - copper relationship was established. It is now known that the effect of molybdenum is complex, and it is considered that the element exerts its limiting effect on copper retention in the animal only in the presence of sulphur. Sulphide is formed by ruminal microorganisms from dietary sulphate or organic sulphur compounds; the sulphide then reacts with molybdate to form thiomolybdate which in turn combines with copper to form an insoluble copper thiomolybdate (CuMoS_4) thereby limiting the absorption of dietary copper. In addition it is considered likely that if thiomolybdate is formed in excess; it may be absorbed from the digestive tract and exert a systemic effect on copper metabolism in the animal.

Sources of copper: Copper is widely distributed in foods and under normal conditions the diet of farm animals is likely to contain adequate amounts. The copper content of crops is related to some extent to the soil copper level, but other factors such as drainage conditions and the herbage species affect the copper content. Seeds and seed by-products are usually rich in copper, but straws contain little. The normal copper content of pasture ranges from about 4 to 8 mg/kg DM. The copper content of milk is low, and hence it is customary when dosing young animals, especially piglets, with an iron salt to include a trace of copper sulphate.

Copper toxicity: It has long been known that copper salts given in excess to animals are toxic. Continuous ingestion of copper in excess of nutritional requirements leads to an accumulation of the element in the body tissues, especially in the liver. Copper can be regarded as a cumulative poison, so that considerable care is required in administering

copper salts to animals. The tolerance to copper varies considerably between species. Pigs are highly tolerant and cattle relatively so. On the other hand, sheep are particularly susceptible and chronic copper poisoning has been encountered in housed sheep on concentrate diets containing 40 mg/kg of copper. Chronic copper poisoning results in necrosis of the liver cells, jaundice, loss of appetite and death from hepatic coma.

COBALT (Co)

Cobalt is required by microorganisms in the rumen for the synthesis of vitamin B₁₂, and if the element is deficient in the diet then the vitamin cannot be produced in the rumen in amounts sufficient to satisfy the animal's requirements, and symptoms of pining occur. **Pining** is therefore regarded as being due to a deficiency of vitamin B₁₂. When ruminants are confined to cobalt-deficient pasture it may be several months before any manifestations of pining occur because of body reserves of vitamin B₁₂ in the liver and kidneys. When these are depleted there is a gradual decrease in appetite with consequent loss of weight followed by muscular wasting, pica, severe anemia and eventually death. If the deficiency is less severe then a vague unthriftiness, difficult to diagnose, may be the only sign. Deficiency symptoms are likely to occur where levels of cobalt in the herbage are below 0.1 mg/kg DM. Under grazing conditions, lambs are the most sensitive to cobalt deficiency followed by mature sheep, calves and mature cattle in that order. Vitamin B₁₂ is needed for utilization of the volatile fatty acid propionic acid. It acts as a co enzyme in conversion of succinyl COA to methyl malonyl COA. Hence deficiency of vitamin B₁₂ brings about energy deficit in ruminants leading to emaciation condition also referred to as **Marasmus**. There is evidence that the intestinal microorganism in non-ruminants also can synthesize vitamin B₁₂ although in pigs and poultry this synthesis may be insufficient to meet their requirements.

Apart from importance of cobalt as a component of vitamin B₁₂, the element is believed to have other functions in the animal body as an activating ion in certain enzyme reactions. Cobalt can be supplemented either through salt licks and mineral mixtures or by placing cobalt bullet in the ventral sac of rumen using a cobalt gun.

Cobalt toxicity: Cobalt toxicosis is extremely unlikely to occur under practical farming conditions. Excessive cobalt supplementation of ruminant diets can lead to the production of analogues of vitamin B₁₂ and a reduction in the quantity of the true vitamin.

IODINE (I)

The concentration of iodine present in the animal body is very small and in the adult is usually less than 600 µg/kg. Although the element is distributed throughout the tissues and secretions its only known role is in the synthesis of the two hormones, **triiodothyronine and tetraiodothyronine (thyroxine)** produced in the thyroid gland. The element also occurs in the gland as monoiodotyrosine and diiodotyrosine, which are

intermediates in the biosynthesis of the hormones from the amino acid tyrosine. The two hormones are stored in the thyroid gland as components of the protein thyroglobulin, which releases the hormones into the blood capillaries as required. Thyroid hormones accelerate reactions in most organs and tissues in the body, thus increasing the basal metabolic rate, accelerating growth, and increasing the oxygen consumption of the whole organism.

Deficiency symptoms: When the diet contains insufficient iodine the production of thyroxine is decreased. The main indication of such a deficiency is an enlargement of the thyroid gland, termed **endemic goitre**, and is caused by compensatory hypertrophy of the gland. The thyroid being situated in the neck, the deficiency condition in farm animals manifests itself as a **swelling of the neck, 'big neck'**. Reproductive abnormalities are one of the most outstanding consequences of reduced thyroid function; breeding animals deficient in iodine give birth to hairless, weak or dead young.

A dietary deficiency of iodine is not the sole cause of goiter, it is known that certain foods contain **goitrogenic compounds** and cause goitre in animals if given in large amounts. These foods include most members of the Brassica genus, especially kale, cabbage and rape, and also soya beans, linseed, peas and groundnuts. Goitrogens have been reported in milk of cows fed on goitrogenic plants. A goitrogen present in brassicas has been identified as L-5-vinyl-2-oxazolidine-2-thione (OZT) (goitrin) which inhibits the iodination of tyrosine and thus interferes with thyroxine the diet. Thiocyanate, which may also be present in members of the Brassica genus, is known to be goitrogenic and may be produced in the tissues from a cyanogenetic glycoside present in some foods. Supplying adequate iodine in the diet prevents goitrogenic activity of the thiocyanate type.

Sources of Iodine: Iodine occurs in traces in most foods and is present mainly as inorganic iodide in which form it is absorbed from the digestive tract. The richest sources of this element are foods of marine origin and values as high as 6g/kg DM has been reported for some seaweeds, fish meal is also a rich source of the element. In areas where goiter is endemic, precautions are generally taken by supplementing the diet with the element, usually in the form of iodized salt. This contains the element either as sodium or potassium iodide or as sodium iodate.

Iodine toxicity: Symptoms of toxicity include depressions in weight gain and feed intake.

MANGANESE (Mn)

Manganese is important in the animal body as an activator of many enzymes such as hydrolases and kinases and as a constituent of arginase, pyruvate carboxylase and manganese superoxide dismutase. Manganese through its activation of glycosyl transferases, is required for the formation of the mucopolysaccharide which forms the organic matrix of bone.

Functions: Manganese deficiency has been found in ruminants, pigs and poultry. The effects of acute deficiency are similar in all species and include retarded growth, skeletal abnormalities, ataxia of the newborn and reproductive failure.

Deficiency: Low manganese diets for cows and goats have been reported to depress or delay oestrus and conception, and to increase incidence of abortion. Manganese is an important element in the diet of young chicks, a deficiency leading to **perosis or 'slipped tendon'**, a malformation of the leg bones. There is enlargement of hock joint, thickening and shortening of the tibia which causes Achilles tendon to slip from its condyle causing the leg of the bird to be pulled sideward and backward. Manganese deficiency in breeding birds reduces hatchability and shell thickness, and causes head retraction in chicks, causes a condition called as **nutritional chondrodystrophy** which is characterized by the shortening of the bones of the wings and legs, shortening of the lower mandible leads to **parrot beak condition**. In pigs lameness is a symptom due to thickening and shortening of bones of the legs. Other abnormalities associated with Mn deficiency include impaired glucose utilization and a reduced vitamin K induced blood clotting response.

Sources of manganese: Rich sources are rice bran and wheat offals. Most green foods contain adequate amounts.

ZINC (Zn)

High concentrations of zinc have been found in the skin, hair and wool of animals. Several enzymes in the animal body are known to contain zinc; these include Carbonic Anhydrase, Pancreatic Carboxypeptidase, Lactate Dehydrogenase, Alcohol Dehydrogenase, Alkaline Phosphatase and Thymidine Kinase. In addition zinc is an activator of several enzyme systems.

Deficiency symptoms: Subnormal growth, depressed appetite, poor feed conversion and **parakeratosis** characterize zinc deficiency in pigs. The latter is a reddening of the skin followed by eruptions, which develop, into scabs. A deficiency of this element is particularly liable to occur in young, intensively housed pigs offered a dry diet ad libitum, though a similar diet given wet may not cause the condition. It is aggravated by high calcium levels in the diet and reduced by decreased calcium and increased phosphorus levels. Pigs given diets supplemented with high levels of copper, for growth promotion, have an increased requirement for zinc. Gross signs of zinc deficiency in chicks are retarded growth, foot abnormalities, 'frizzled' feathers, parakeratosis and a bone abnormality referred to as the '**swollen hock syndrome**'. Symptoms of zinc deficiency, in calves include inflammation of the nose and mouth, stiffness of the joints, swollen feet and parakeratosis. The response of severely zinc-deficient calves to supplemental zinc is rapid and dramatic. Improvements in skin condition are usually noted within 2 to 3 days. Zinc deficiency also leads to reproductive disorders in farm animals.

Sources of zinc: Yeast is a rich source, and zinc is concentrated in the bran and germ of cereal grains. Animal protein by-products such as meat meal and fish meal are usually richer sources of the element than plant protein supplements.

MOLYBDENUM (Mb)

The biological functions of molybdenum, apart from its reactions with copper, are concerned with the formation and activities of these three enzymes. In addition to being a component of Xanthine Oxidase, molybdenum participates in the reaction of the enzyme with Cytochrome - C and also facilitates the reduction of Cytochrome - C by aldehyde oxidase.

Deficiency symptoms: Low molybdenum diets resulted in reduced levels of Xanthine Oxidase, but did not affect growth or purine metabolism. Molybdenum deficiency has not observed under natural conditions in any species.

Molybdenum toxicity: The toxic role of molybdenum in the condition known as '**teart**' is described under the element copper.

SELENIUM (Se)

A biochemical role of selenium in the animal body was demonstrated in 1973 when it was discovered that the element was a component of **Gluthathione Peroxidase**, an enzyme which catalyses the removal of hydrogen peroxide, thereby protecting cell membranes from oxidative damage. Glutathione peroxidase contains four selenium atoms and forms a second line of defence after vitamin E, since some peroxides remain even if vitamin E levels are adequate. Selenium has a sparing effect on vitamin E by ensuring normal absorption of the vitamin. This is due to its role in preserving the integrity of the pancreas and thereby ensuring satisfactory fat digestion. Selenium also reduces the amount of vitamin E required to maintain the integrity of lipid membranes and aids the retention of Vitamin E in plasma. Conversely, vitamin E spares selenium by maintaining the element in its active form and preventing its loss. It reduces the production of hydroperoxides and thus the amount of glutathione peroxidase needed to protect cells. However, there are limits to the mutual substitution of selenium and Vitamin E.

Selenium toxicity: Some species of plants that grow in seleniferous areas contain very high levels of selenium. One such plant, *Astragalus racemosa*. **Alkali disease and blind staggers** are localized names for chronic diseases of animals grazing certain seleniferous areas in the USA. Symptoms include dullness, stiffness of the joints, loss of hair from mane or tail and hoof deformities. Acute poisoning, which results in death from respiratory failure, can arise from sudden exposure to high selenium intakes.

FLUORINE (Fl)

The importance of fluorine in the **prevention of dental caries** in man is well established. Fluorine is a very toxic element, with ruminants being more susceptible than non-ruminants. It causes a condition called as **flurosis**. There is dental pitting and wear, leading to exposed pulp cavities. Further increase in fluorine causes inappetance, lameness and reduced production. Bone and joint abnormalities also occur, probably owing to ingested fluorine being deposited in the bone crystal lattice as calcium fluoride. The commonest sources of danger from this element are fluoride-containing water, herbage contaminated by dust from industrial pollution and the use of soft or raw rock phosphate supplements. Processed phosphates are generally safe.

SILICON (Si)

In silicon-deficient rats and chicks, bone abnormalities occur because of a reduction in mucopolysaccharide synthesis in the formation of cartilage. Silicon is required for maximal activity of the enzyme prolyl hydroxylase, which is involved in collagen synthesis. It is also thought to be involved in other processes involving mucopolysaccharides such as the growth and maintenance of arterial walls and the skin. Silicon toxicity (**silicosis**). Silica urolithiasis occurs in grazing steers in western Canada and north western parts of the USA.

CHROMIUM (Cr)

Chromium was first shown to be essential for normal glucose utilization in rats. Chromium appears to have a role in glucose tolerance, possibly forming a complex between insulin and its receptors. Chromium may also play a role in lipid synthesis.

VANADIUM (Va)

May have a role in the regulation of the activity of sodium-potassium ATPase, phosphoryl transferase enzymes, adenyl cyclase and protein kinase.

NICKEL (Ni)

A discrete biochemical function has not been firmly established for nickel but it is thought it may be a cofactor of structural component in metallo-enzymes. It may also play a role in nucleic acid metabolism.

TIN (Ti)

Tin contributes to the tertiary structure of protein or other macromolecules.

ARSENIC (Ar)

Animals given an arsenic-deficient diet had rough coats and slower growth rates than control animals given a supplement of arsenic. A long term study with goats showed interference with reproduction (abortion, low birth weights) and milk

production and sudden death. The toxicity of the element is well known; symptoms include nausea, vomiting, diarrhoea and severe abdominal pain.

STUDY QUESTIONS

Indicate the mineral that is deficient

1.	Rickets	
2.	Osteomalacia	
3.	Milk fever	
4.	Lactation tetany/ grass stagger	
5.	Parakeratosis	
6.	Neonatal ataxia	
7.	Falling disease	
8.	Thumps	
9.	Pining/salt sickness	
10.	Steely wool	
11.	White muscle disease	
12	Exudative diathesis	
13	Goitre	
14	Nutritional chondrodystrophy	
15	Perosis	
16	Swollen hock syndrome	

Fill in the blanks

1. _____ and _____ are the sulphur containing B vitamins
2. Depigmentation of wool/hair in sheep is caused by due to the deficiency of _____ mineral.
3. Selenium is a component of _____ enzyme.
4. Cobalt is a component of _____ vitamin.
5. _____ is a metalloenzyme which contain molybdenum.

Define the following

1. Major mineral
2. Trace mineral
3. Newer trace mineral
4. Metalloenzyme
5. Metal activated enzyme
6. Calcium to phosphorus ratio
7. Nitrogen to sulphur ratio
8. Alkali disease
9. Blind staggers

10. Goitrogens

Short answer

1. Thumps
2. General functions of minerals
3. Calcium, phosphorus and vitamin D interrelationship
4. Hormonal regulation of calcium metabolism
5. Functions of copper
6. Functions of sulphur
7. Salt toxicity
8. Electrolytes
9. Factors influencing iron absorption
10. Nutritional secondary hyperparathyroidism
11. Copper-molybdenum-sulphur interrelationship
12. Iodine deficiency
13. Factors affecting phosphorus digestion/absorption

Essay

1. Function and deficiency diseases of calcium
2. Function and deficiency diseases of copper

VITAMINS

Vitamins are organic compounds required in tiny amounts for essential metabolic reactions in a living organism. Absence or deficiency of vitamins causes deficiency disorders.

Vitamins may be classified based on their solubility as fat soluble vitamins and water soluble vitamins.

Fat-soluble vitamins include vitamin A, D, E and K.

Water-soluble vitamins include vitamin B complex group and vitamin C.

The B complex group of vitamins includes the following:

1. Vitamin B₁ (thiamin)
2. Vitamin B₂ (Riboflavin)
3. Vitamin B₃ (Niacin/Nicotinamide/Nicotinic acid)
4. Vitamin B₆ (Pyridoxine)
5. Pantothenic acid
6. Folic acid
7. Vitamin B₁₂ (Cyano cobalamine)
8. Biotin
9. Choline
10. P-amino benzoic acid
11. Inositol

Differences between fat soluble and water soluble vitamins

Differences	Fat soluble vitamins	Water soluble vitamins
Names	Vitamin A,D,E and K	Vitamin C B Vitamins
Solubility	Soluble in fats and organic solvents	Water soluble
Digestion and absorption	Requires fat and bile	Easily absorbed in intestine
Excretion	Via faeces	Via Urine
Storage	Stored in the body in fat depots and in liver	Not stored in body except Vitamin B ₁₂
Toxicity	On over dosage can lead to toxicity	Usually not toxic as it is readily excreted when given in excess

TABLE 1. Vitamins and their Synonyms.

Vitamin	Accepted name	Alternate names (some obsolete)
Vitamin A	Retinol	Vitamin A ₁ Antiinfective vitamin
	Retinal	Vitamin A aldehyde
	Retinoic acid	Vitamin A acid
Vitamin D	Ergocalciferol	Vitamin D ₂
	Cholecalciferol	Vitamin D ₃
Vitamin E	D-alpha-Tocoferol	Antirachitic Vitamin
Vitamin K	Phylloquinone	Antisterility Vitamin
		Vitamin K ₁
	Menaquinone	Antihaemorrhagic Vitamin
Vitamin B ₁	Menadione	Vitamin K ₂
Vitamin B ₂	Thiamin	Vitamin K ₃
Nicotinic acid	Riboflavin	Vitamin F
Vitamin B ₆	Nicotinic acid	Vitamin G
	Nicotinamide	Vitamin B ₅
	Pyridoxine	Adermine
Pantothenic acid	Pantothenic acid	Yeast eluate factor
Biotin	Biotin	Vitamin B ₃
Folic acid	Pteroylmonoglutamic acid	Vitamin H Coenzyme R Egg white injury preventing factor
Vitamin B ₁₂	Cyanocobalamin	Folacin Vitamin M Vitamin B _e , B ₁₀ , B ₁₁
Choline	Choline	APP
Vitamin C	Ascorbic acid (or) L-Ascorbic acid	APA factor Vidin Antiscorbutic Vitamin

VITAMIN A

Chemical name and structure: Retinol, Vitamin A₂ - Dehydro Retinol, Retinoic acid, Retinaldehyde.

Properties: Vitamin A is a pale yellow crystalline solid insoluble in H₂O but soluble in fat and fat solvents, readily destroyed by oxidation on exposure to air and light.

Source: Oils from livers of certain fish (Cod and Halibut) egg yolk, milk fat. Vitamin A does not exist as such in plants but is present as **precursors or pro vitamins**.

Provitamins: Vitamin A in plants exists in the form of **Carotenoids** which can be converted to vitamin A. Carotenoids are yellow, orange or red in colour. Carotenoids may be divided into two main category i.e. carotenes and xanthophylls. **Carotenes include alpha, beta and gamma carotenes.** Vitamin A cannot be released from xanthophyl. Conversion of carotene to vitamin A takes place in the intestinal mucosa. One molecule of beta-carotene is converted into two molecules of retinol. Conversion efficiency depends upon the species of animal. Highest efficiency is in chicken and rat.

Vitamin A value is expressed as IU. **One IU = 0.3 micro gram of crystalline retinol.**

Functions

- Synthesis of glycoprotein to maintain integrity of **epithelial cells**
- Bone formation synthesis of **mucopolysaccharide**
- Synthesis of **Rhodopsin**

Deficiency:

Vitamin A and Vision

Rhodopsin synthesis – Visual cycle

- The retina is located at the back of the eye. When light passes through the lens, it is sensed by the retina and converted to a nerve impulse for interpretation by the brain.
- Retinol is transported to the retina via the circulation, where it moves into retinal pigment epithelial cells.
- There, retinol is esterified to form a retinyl ester, which can be stored. When needed, retinyl esters are broken apart to form 11-cis retinol, which can be oxidized to form 11-cis retinal.
- 11-cis retinal can be shuttled to the rod cell, where it binds to a protein called opsin to form the visual pigment, rhodopsin (visual purple).
- Rod cells with rhodopsin can detect very small amounts of light, making them important for night vision.
- Absorption of a photon of light catalyzes the isomerization of 11-cis retinal to all-trans retinal and results in its release.
- This isomerization triggers the generation of an electrical signal to the optic nerve.

- The nerve impulse generated by the optic nerve is conveyed to the brain where it can be interpreted as vision.
- Once released all-trans retinal is converted to all-trans retinol, which can be transported to the retinal epithelial cell to complete the visual cycle.
- Inadequate retinol available to the retina results in impaired dark adaptation, known as "**night blindness or nictalopia**."

Disintegration of epithelial cells in eyes

Mild vitamin A deficiency may result in changes in the conjunctiva (corner of the eye) called **Bitot's spots**.

Severe or prolonged vitamin A deficiency causes a condition called **xerophthalmia (dry eye)**, characterized by changes in the cells of the cornea that ultimately result in **corneal opacity, keratinization of the cornea**, corneal ulcers, scarring and blindness. Sometimes vitamin A deficiency can lead to obstruction of lacrimal ducts due to degenerated epithelial cells leading to decreased out put of tears.

Congenital blindness: Vitamin A is needed for bone formation. If vitamin A is deficient optic foramen is not formed properly. Small size optic foramen leads to the constriction of optic nerve. Permanent damage to the nerve can lead to permanent blindness.

Anti-infective vitamin: Vitamin A is involved in the formation and protection of epithelial cells. Damage to epithelial cells can cause easy entry of pathogenic microbes leading to infection. So infection of gastrointestinal tract, respiratory tract, urogenital tract and skin is common in Vitamin A deficiency. As vitamin A helps to prevent these infections it is called **anti- infective vitamin**.

Vitamin A and immunity: Vitamin A is commonly known as the anti-infective vitamin, because it is required for normal functioning of the immune system. The skin and mucosal cells (cells that line the airways, digestive tract, and urinary tract) function as a barrier and form the body's first line of defense against infection.

Bone formation: Vitamin A is essential for normal bone formation as it is involved in the synthesis of mucopolysaccharides needed for laying down of the bone matrix. Hence a deficiency of vitamin A can lead to **developmental bone deformities**.

Reproduction: Normal levels of vitamin A are required for sperm production. Similarly, normal reproductive cycles in females require adequate availability of vitamin A. Deficiency of vitamin A can lead to infertility or sterility in male and lead to vaginitis, abnormal oestrous cycle, early embryonic mortality, abortion and defective formation of foetus in females.

Elevated CSF pressure: One of the initial effects of vitamin A deficiency is elevated CSF pressure. The mechanism whereby the increase in CSF pressure is brought by thickened duramater leading to under absorption of CSF.

Growth and development: Both vitamin A excess and deficiency are known to cause birth defects. Retinol and retinoic acid (RA) are essential for embryonic development.

During fetal development, RA functions in limb development and formation of the heart, eyes, and ears. Additionally, RA has been found to regulate expression of the gene for growth hormone.

Vitamin A deficiency species wise:

Cattle: Roughened hair, scaly skin, and excessive watering, softening, cloudiness of the cornea leading to xerophthalmia. In calves constriction of the optic nerve canal leads to blindness. In breeding animal's it leads to infertility.

Sheep: Deficiency is not common because of adequate intake. In addition to night blindness severe cases of deficiency may result in lambs being born weak or dead.

Pigs: Night blindness and xerophthalmia may occur. Deficiency in pregnant animals may result in the production of blind deformed litters. In less severe cases appetite is impaired and growth retarded.

Poultry: Nutritional Roup - Mortality rate is high. Early symptoms include retarded growth, weakness, ruffled plumage and a staggering gait. Egg production and hatchability are reduced. Nasal and ocular discharge, drowsiness, pale comb and wattles, eyelids stuck with thick exudates.

Toxicity: The condition caused by vitamin A toxicity is called **hypervitaminosis A**. It is caused by over consumption of preformed vitamin A. Symptoms include nausea, headache, fatigue, loss of appetite, dizziness and dry skin.

VITAMIN D

Chemical structure: Vitamin D₂ - Ergo calciferol - plant origin,
Vitamin D₃ - Cholecalciferol - Animal origin

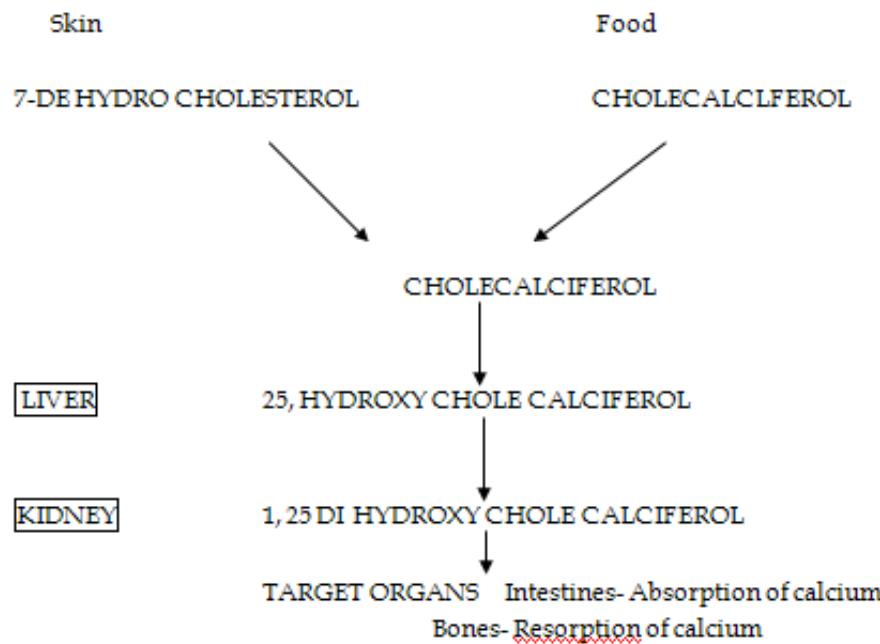
In most mammals, including humans, D₃ is more effective than D₂ at increasing the levels of vitamin D hormone in circulation; D₃ is at least 3-fold, and likely closer to 10-fold, more potent than D₂. However, in some species, such as rats, vitamin D₂ is more effective than D₃.

Properties: It is soluble in fat and fat solvents. More stable than vitamin A with regard to oxidation.

Sources: Cod liver oils (rich source), Egg yolk and sun dried roughage's/grains. Cow milk is a poor source. Colostrum contains 6 to 10 times the amount present in ordinary milk.

Provitamin: Ergosterol - plant and 7-dehydrocholesterol - skin

Metabolism and function



- Dietary vitamin D₂ and D₃ are absorbed through the small intestine and are transported in the blood to the liver where they are converted into 25, hydroxy cholecalciferol.
- The latter is then transported to the kidney where they are converted into 1, 25 dihydroxy cholecalciferol, the most biologically active form of the vitamin. This is also called as **local hormone**.
- This compound is then transported in the blood to the various target tissues the intestines, bones and the egg shell gland in the birds.
- 1, 25 dihydroxy cholecalciferol acts similar to a steroid hormone and is responsible for the production of calcium binding protein in the intestinal villi.
- This protein is involved in the absorption of calcium in the small intestine.
- The amount of 1, 25 dihydroxy cholecalciferol produced in the kidney is controlled by parathormone.
- When the level of calcium in the blood is low parathyroid gland is stimulated to secrete more parathormone.
- Which stimulates the kidney to produce more 1, 25 dihydroxy cholecalciferol, which in turn enhances absorption of calcium in the small intestine.
- 1, 25 dihydroxy cholecalciferol also increases the intestinal absorption of phosphorus and reabsorption of calcium from the kidney and the bone.

Deficiency: In young animal's deficiency of vitamin D causes **rickets** and in adults it causes **Osteomalacia**.

Rickets: Calcium and phosphorus deposition in bones is affected and the bones are weak, more prone to fractures and deformities. The conditions commonly seen are

bowing of legs, swollen knees and hock and arching of back. Occasionally there is paralysis. **Rickety Rosary** – enlargement of osteochondral junction in ribs are also noticed

Osteomalacia: Resorption of the bone already laid down. Bones become weak, more prone to fractures and deformities. It can occur in pregnant and lactating animals, which require increased amount of calcium and phosphorus.

In poultry bones and beak become soft and rubbery legs become weak. Egg production is reduced and eggshell quality deteriorates.

Toxicity: Vitamin D toxicity (hypervitaminosis D) induces abnormally high serum calcium levels (hypercalcemia), which could result in bone loss, kidney stones, and calcification of organs like the heart and kidneys if untreated over a long period of time.

VITAMIN E

Chemical name – Vitamin E is a group name of a number of closely related compounds. They are alpha, beta, gamma and delta tocopherols and alpha, beta, gamma and delta tocotrienols. Alpha tocopherol is the most biologically active and widely distributed.

Sources: Green fodders, cereal grains, vegetable oils, fats, and nuts, oil seeds and legumes.

Functions and interrelationship with selenium

- Vitamin E functions in the animal mainly as biological antioxidant.
- In association with the selenium-containing enzyme glutathione peroxidase, it protects cells against oxidative damage caused by free radicals.
- Free radicals are formed during cellular metabolism and, as they are capable of damaging cell membranes, enzymes and cell nuclear material, they must be converted into less reactive substances if the animal is to survive.
- This protection is particularly important in preventing oxidation of polyunsaturated fatty acids, which function as primary constituents of subcellular membranes and precursors of prostaglandins. Oxidation of unsaturated fatty acids produces hydroperoxides, which also damage cell tissues and more lipid free radicals so that prevention of such oxidation is of vital importance in maintaining the health of the living animal.
- The animal has two main methods of protecting itself against oxidative damage. Firstly, radicals are scavenged by vitamin E as a first line of defence and secondly, glutathione peroxidase destroys any peroxide formed before they can damage the cell.
- These two defence mechanisms complement one another.
- Vitamin E also plays an important role in the development and function of the immune system.

Deficiency symptoms:

The most frequent and, from a diagnostic point of view, the most important manifestation of vitamin E deficiency in farm animals is muscle degeneration (myopathy). **Nutritional myopathy**, also known as muscular dystrophy, frequently occurs in cattle, particularly in calves. The myopathy primarily affects the skeletal muscles and the affected animals have weak leg muscles, a condition manifested by difficulty in standing and, after standing, a trembling and staggering gait. Eventually, the animals are unable to rise and weakness of the neck muscles prevents them from raising their heads. A popular descriptive name for this condition is **white muscle disease**. The heart muscle may also be affected and death may result. Nutritional myopathy also occurs in lambs, with similar symptoms to those of calves. The condition is frequently referred to as **stiff lamb disease**.

In pigs, the two main diseases associated with vitamin E and selenium deficiency are myopathy and cardiac disease. The pigs demonstrate an uncoordinated staggering gait or are unable to rise. The pigs heart muscle is more commonly affected. Sudden cardiac failure occurs and on post-mortem examination the lesions of the cardiac muscles are seen as pale patches or white streaks. This condition is commonly known as **mulberry heart disease**.

Vitamin E deficiency in chicks may lead to a number of distinct diseases: myopathy, **encephalomalacia** and **exudative diathesis**. In nutritional myopathy the main muscles affected are the pectorals although the leg muscles also may be involved.

Nutritional encephalomalacia or **crazy chick disease** is a condition in which the chick is unable to walk or stand, and is accompanied by hemorrhages and necrosis of brain cells.

Exudative diathesis is a vascular disease of chicks characterized by a generalized oedema of the subcutaneous fatty tissues, associated with an abnormal permeability of the capillary walls. Both selenium and vitamin E appear to be involved in nutritional myopathy and in exudative diathesis but the element does not seem to be important in nutritional encephalomalacia. It should be stressed that selenium itself is a very toxic element and care is required in its use as a dietary additive.

VITAMIN K

Chemical name:

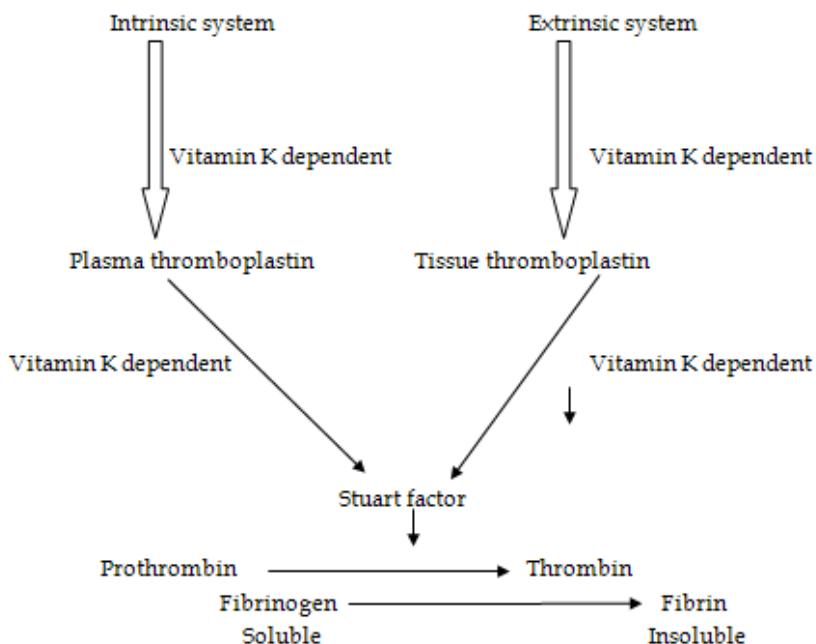
- | | |
|---|-----------------------|
| Phylloquinone (Vitamin K ₁) | - Present in plants, |
| Menaquinone (Vitamin K ₂) | - Bacterial synthesis |

Both are derived from Menadione.

Source: Green leafy vegetables, Egg yolk, Liver, Fish and synthesised by bacteria in GI tract.

Functions:

Vitamin K is required for synthesis of prothrombin in the liver and also for the synthesis of factors involved in the conversion of prothrombin to thrombin. They are stuart factor, plasma thromboplastin and tissue thromboplastin. The inactive vitamin K dependent zymogens are converted into calcium binding proteins which activate them.



Deficiency: Low prothrombin level in blood leads to haemorrhagic conditions. Deficiency is rare in ruminants. In cattle sweet clover disease is associated with Vitamin K. Sweet clover that is spoiled contains a compound **Dicoumarol**, which lowers prothrombin content of blood. In chicks vitamin K deficiency causes anemia and delayed clotting time of blood.

Toxicity: There is no known toxicity associated with high doses of phylloquinone (vitamin K₁), or menaquinone (vitamin K₂) forms of vitamin K. Some times mild allergic reaction is possible; however menadione (vitamin K₃) and its derivatives can interfere with the function of glutathione, body's natural antioxidant, resulting in oxidative damage to cell membranes. Menadione given by injection has induced liver toxicity, jaundice and hemolytic anemia.

Vitamin K antagonists: **Dicoumarol** is similar in structure to vitamin K. When consumed by livestock it inhibits vitamin K production. **Warfarin** is a synthetic toxicant derived from coumarol. It is used in rat poisons it also acts as a vitamin K inhibitor to block the blood clotting process and provokes haemorrhage. It is toxic to livestock that may accidentally consume it in its pelleted form and to dogs and cats that consume poisoned rats.

WATER SOLUBLE VITAMINS

Vitamin C (L Ascorbic acid)

Properties - Colourless, crystalline, water soluble compound. Heat stable in acid solution readily destroyed in alkaline medium.

Sources: Citrus fruits and green leafy vegetables.

Functions: Plays an important role in the oxidative reduction reaction of living cells.

- Formation of collagen and intercellular cement substance (Capillaries, teeth, bone),
- Metabolism of tyrosine,
- Absorption of iron (Fe) and incorporation of plasma Fe into ferritin,
- Hydroxylation of deoxycorticosterone, tryptophan, phenylalanine.

Essentiality - Vitamin C is dietary essential **only in man, other primates, guinea pig and fruit eating bat** these species lack the enzyme **L-gulonolactone oxidase**. Other species synthesise vitamin C from glucose.

Deficiency:

Scurvy in adults: Weakness, bleeding from gums, loosens teeth, swollen joints haemorrhages.

Infantile scurvy: Anorexia, listlessness, leg drawn up to abdomen, swelling at ends of long bone. Gums swollen, dyspnoea, cyanosis, convulsions and death if not treated. Delay in wound healing.

Stress increases the requirement of this vitamin.

VITAMIN B COMPLEX

All vitamins of the group are H₂O soluble. Most of them are co-enzymes.

THIAMIN (VITAMIN B₁)

Chemical structure Main form of thiamine in animal tissues is TPP (Thiamin pyrophosphate).

Properties: It is H₂O soluble and has a meaty flavour.

Sources: Yeast, germ and bran of cereal grains. Pork is rich in thiamin.

Functions: Thiamin diphosphate is a coenzyme involved in oxidative decarboxylation of pyruvate to acetyl coenzyme A and of alpha ketoglutarate to succinyl CoA in TCA cycle.

Deficiency:

Early symptoms: Anorexia, emaciation, muscular weakness and progressive dysfunction of the nervous system.

Chicks: Anorexia, emaciation, polyneuritis characterized by head retraction, nerve degeneration and paralysis which is called as **star gazing posture**.

- Thiamin deficiency leads to a deficiency of TPP.

- Oxidative decarboxylation of pyruvic acid does not take place and there is accumulation of pyruvic acid, which undergoes reduction to form lactic acid, which in turn causes muscular weakness.
- Nerve cells are also dependent on carbohydrate as source of energy.
- Thiamin deficiency leads to improper utilization of carbohydrate causing nervous lesions.

Ruminants:

- Thiamin deficiency is not common because of synthesis in the rumen by certain bacteria.
- However certain bacteria are capable of synthesizing **thiaminase** which destroys the vitamin causing thiamine deficiency.
- It is characterized by circular movements, head pressing, muscular tremors and blindness.
- Lactic acidosis caused by the feeding of rapidly soluble carbohydrate may predispose to the production of thiaminases.

Antivitamin - Thiaminase is also present in bracken fern and thiamin deficiency has been reported in horses feeding it. **Raw fish** also contains **thiaminase**, which is destroyed on cooking.

Thiamin deficiency in foxes causes **Chastek paralysis**.

RIBOFLAVIN (VITAMIN B₂)

Structure - It consists of a dimethyl isoalloxazine nucleus combined with ribitol.

Properties - It is a yellow, crystalline compound that has yellowish green fluorescence in aqueous solution. It is only sparingly soluble in water, stable in acid or neutral solution but destroyed in alkaline solution. It is unstable in light.

Sources: Synthesised by yeast, bacteria and fungi. Rich sources are liver, yeast, milk and green leafy vegetables.

Functions: It is a constituent of flavoproteins, Flavin mononucleotide (FMN) and Flavin adenine dinucleotide (FAD). They are involved in amino acid and carbohydrate metabolism.

Deficiency

- Poor appetite, retarded growth, vomiting, skin eruptions and eye abnormalities.
- In sows riboflavin is necessary to maintain normal oestrous activity and prevent premature parturition.
- In chicks riboflavin deficiency causes **Curled Toe Paralysis** caused due to peripheral nerve degeneration, in which the chicks walk on their hocks with the toes curled inwards.

- In breeding hens deficiency causes decreased hatchability. Embryonic abnormalities occur including the **clubbed down condition** in which the down feather continues to grow within the follicle leading to curled feather.

NIACIN (NICOTINAMIDE)

It is the amide of nicotinic acid. It is a stable vitamin not readily destroyed by heat, acids or alkali.

Sources: It can be synthesised from amino acid **Tryptophan** in the body tissues. If the diet is rich in protein containing tryptophan than dietary requirement of the vitamin is low. Rich sources of the vitamin are liver, yeast, groundnuts and sunflower meals. In cereals the vitamin is present in the bound form.

Function: Nicotinamide functions in the animal body as the active group of two important coenzymes, nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP). These coenzymes are involved in the mechanism of **hydrogen transfer** in living cells.

Deficiency symptoms: In pigs, deficiency symptoms include poor growth, anorexia, enteritis, vomition and dermatitis. In fowls a deficiency of the vitamin causes bone disorders, feathering abnormalities and inflammation of the mouth and upper part of the oesophagus. Deficiency symptoms are particularly likely in pigs and poultry if diets with a high maize content are used, since **maize contains very little of the vitamin or of tryptophan**.

VITAMIN B₆ (PYRIDOXINE)

The vitamin exists in three forms, which are interconvertible in the body tissues. The parent substance is known as pyridoxine, the corresponding aldehyde derivative as pyridoxal and the amine as pyridoxamine. The term vitamin B₆ is generally used to describe all three forms. The amine and aldehyde derivatives are less stable than pyridoxine and are destroyed by heat.

Sources: The vitamin is present in plants as pyridoxine whereas animal products may also contain pyridoxal and pyridoxamine. Pyridoxine and its derivatives are widely distributed in yeast, pulses, cereal grains, liver and milk.

Function: Of the three related compounds, the most actively functioning one is pyridoxal in the form of the phosphate. Pyridoxal phosphate plays a central role as a coenzyme in the reactions by which a cell transforms nutrient amino acids into mixtures of amino acids and other nitrogenous activities of transaminases and decarboxylases, and over 50 pyridoxal phosphate-dependent enzymes have been identified. This vitamin is believed to play a role in the absorption of amino acids from the intestine.

Deficiency symptoms: Affects the animal's growth rate. Convulsions may also occur, possibly because a reduction in the activity of glutamic acid decarboxylase results in an

accumulation of glutamic acid. In addition, pigs exhibit a reduced appetite and may develop **anemia**. Chicks on a deficient diet show jerky movements, while in adult birds hatchability and egg production are adversely affected. In practice, vitamin B₆ deficiency is unlikely to occur in farm animals because of the vitamins wide distribution.

PANTOTHENIC ACID

It is an amide of pantoic acid and beta-alanine.

Sources: Rich sources are liver, egg yolk, groundnuts, peas, yeast and molasses. Cereal grains and potatoes are also good sources of the vitamin.

Function: Pantothenic acid is a constituent of coenzyme A, which is the important coenzyme of acyl transfer. It is also a structural component of acyl carrier protein, which is involved, in the cytoplasmic synthesis of fatty acids.

Deficiency symptoms: Deficiency of pantothenic acid in pigs causes slow growth, diarrhoea, loss of hair, scaliness of the skin and a characteristic '**goose-stepping**' gait; in severe cases animals are unable to stand.

In the chick, growth is retarded and dermatitis occurs. In mature birds, hatchability is reduced. Rumen microorganisms can synthesize pantothenic acid, like the entire B-complex vitamin. **Escherichia coli**, for example, is known to produce this vitamin. Pantothenic acid deficiencies are considered to be rare in practice because of the wide distribution of the vitamin, although deficiency symptoms have been reported in commercial herds of Landrace pigs.

FOLIC ACID

Chemical name for folic acid is pteroylmonoglutamic acid and it is made up of three moieties: p-aminobenzoic acid, glutamic acid and a pteridine nucleus.

Sources: Folic acid is widely distributed in nature; green leafy materials, cereals and extracted oilseed meals are good sources of the vitamin. Folic acid is reasonably stable in food stored under dry conditions but it is readily degraded by moisture, particularly at high temperatures. It is also destroyed by ultraviolet light.

Functions: After absorption into the cell, folic acid is converted into tetrahydrofolic acid which functions as a coenzyme in the mobilization and utilisation of single-carbon groups (e.g. formyl, methyl) that are added to, or removed from, such metabolites as histidine, serine, glycine, methionine and purines.

Deficiency symptoms: A variety of deficiency symptoms in chicks and young turkeys have been reported, including **poor growth, anaemia**, poor bone development and poor egg hatchability. Folic acid deficiency symptoms rarely occur in other farm animals because of synthesis by intestinal bacteria.

BIOTIN

A part of the vitamin B complex, biotin is chemically 2-keto-3, 4 imidazolido 2-tetrahydrothiophene-n-valeric acid.

Sources: Biotin is widely distributed in foods; liver, milk, yeast, oilseeds and vegetable are rich sources.

Functions: Biotin serves as the prosthetic group of several enzymes which catalyse the **transfer of carbon dioxide from one substrate to another**. In animals there are three biotin-dependent enzymes of particular important: **pyruvate carboxylase, acetyl coenzyme A carboxylase and propionyl coenzyme A carboxylase**.

Deficiency symptoms: In pigs, biotin deficiency causes foot lesions, alopecia (hair loss) and a dry scaly skin. In growing pigs, both growth rate and food utilization is adversely affected. In breeding sows, a deficiency of the vitamin can adversely influence reproductive performance.

In poultry, biotin deficiency causes reduced growth, dermatitis, leg bone abnormalities, cracked feet, poor feathering and **fatty liver and kidney syndrome (FLKS)**. The last condition, which mainly affects two-to five-week-old chicks, is characterized by a lethargic state with death frequently following within a few hours. On autopsy, the liver and kidneys, which are pale and swollen, contain abnormal depositions of lipid.

Giving animal's **avidin**, a protein present in the **raw white of eggs** can induce biotin deficiency, which combines with the vitamin and prevents its absorption from the intestine. Certain streptomyces spp. Bacteria present in soil and manure produce **streptavidin and stravidin**, which have a similar action to the egg white protein. Heating inactivates these antagonist proteins.

CHOLINE

Sources: Green leafy materials, yeast, egg yolk and cereals are rich sources of choline.

Function: Unlike the other B vitamins, choline is not a metabolic catalyst but forms an essential structural component of body tissues. It is a component of lecithin which plays a vital role in cellular structure and activity. It also plays an important part in lipid metabolism in the liver by preventing the accumulation of fat in this organ. It serves as a donor of methyl groups in transmethylation reactions and is a component of acetylcholine which is responsible for the transmission of nerve impulses. Choline can be synthesized in the liver from methionine and the level of **methionine** in the diet therefore influences the exogenous requirement for this vitamin.

Deficiency symptoms: Deficiency symptoms, including slow growth and fatty infiltration of the liver, have been produced in chicks and pigs. Chorine is also concerned with the prevention of **perosis or slipped tendon in chicks**. The choline requirement of animals is unusually large for the vitamin, but in spite of this, deficiency

symptoms are not common in farm animals because of its wide distribution, its high concentrations in foods and because it can be readily derived from methionine.

VITAMIN B₁₂ (CYANOCOBALAMINE)

Vitamin B₁₂ has the most complex structure of all the vitamins. The basic unit is a corrin nucleus which consists of a ring structure comprising four five membered rings containing nitrogen. In the active centre of the nucleus is a cobalt atom. A cyano group is usually attached to the cobalt as an artefact of isolation and, as this is the most stable form of the vitamin, it is the form in which the vitamin is commercially produced.

In the animal, the cyanide ion is replaced by a variety of ions, e.g. hydroxyl (Hydroxocobalamin), methyl (methylcobalamin) and 5'-deoxyadenosyl (5'-deoxyadenosylcobalamin), the last two forms acting as coenzymes in animal metabolism. **Sources:** Vitamin B₁₂ is considered to be synthesized exclusively by microorganisms and its presence in foods is thought to be ultimately of microbial origin. The main natural sources of the vitamin are foods of animal origin, liver being a particularly rich source. Its limited occurrence in higher plants is still controversial, since many think that its presence in trace amounts may result from contamination with bacteria or insect remains.

Functions: Before vitamin B₁₂ can be absorbed from the intestine it must be bound to a highly specific glycoprotein, termed the **intrinsic factor**, which is secreted by the gastric mucosa. In man, the intrinsic factor may be lacking which leads to poor absorption of the vitamin and results in a condition known as pernicious anemia.

The coenzymic forms of vitamin B₁₂ function in several important enzyme systems. These include isomerases, dehydrases and enzymes involved in the biosynthesis of methionine from homocysteine. Of special interest in ruminant nutrition is the role of vitamin B₁₂ in the metabolism of **propionic acid into succinic acid**. In this pathway, the vitamin is necessary for the conversion of methylmalonyl coenzyme A into succinyl coenzyme A.

Deficiency symptoms:

Poor growth, poor feathering, decreased hatchability, dermatitis and rough coat. In poultry housed with access to litter, majority, if of the vitamin requirements can be obtained from the litter. Microorganisms in the rumen synthesize. However, if levels of cobalt in the diet are low, a deficiency of the vitamin can arise and cause reduced appetite, emaciation and anemia.

STUDY QUESTIONS

Indicate the vitamin that is deficient

1.	Night blindness or Nictalopia	
2.	Xerophthalmia/Microphthalmia/anophthalmia	

3.	Nutritional Roup
4.	Rickets
5.	Osteomalacia
6.	White muscle disease
7.	Stiff lamb disease
8.	Mulberry heart disease
9.	Crazy chick disease
10.	Bleeding sickness
11.	Scurvy
12.	Star gazing posture
13.	Chastek paralysis
14.	Curled toe paralysis
15.	Clubbed down condition
16.	Pellagra/ Blue tongue
17.	Goose stepping gait
18.	Fatty liver and Kidney syndrome (FLKS)
19.	Slipped tendon/Perosis
20.	Anti pernicious anaemia
21.	Exudative diathesis
22.	Sterility

Fill in the blanks

1. _____ is the provitamin for vitamin-A.
2. _____ is the only vitamin can be stored in the animal body.
3. _____ is essential for the formation rhodopsin pigment in the retina of eye.
4. One International Unit (IU) of vitamin A is equivalent to _____ micro gram of crystalline retinol.
5. _____ is the vitamin essential for maintenance of epithelial cells.
6. The hormone involved in the metabolism of calcium and phosphorus is _____.
7. _____ and _____ are the precursors of vitamins D₂ and D₃ respectively.
8. _____ is the biologically active form of vitamin - E.
9. _____ is a selenium containing enzyme which works along with vitamin - E as anti-oxidant.
10. _____ is called as anti-sterility vitamin.

11. Vitamin-K is essential for the synthesis of _____ which is essential for blood clotting.
12. _____ is the synthetic form of vitamin-K.
13. _____ is an antagonist of vitamin-K.
14. For guinea pigs _____ vitamin is dietary essential due to lack of _____ enzyme in their body.
15. Citrus fruits are very good source of _____ vitamin.
16. Stress increases the requirement of _____ vitamin.
17. Accumulation of _____ acid in the nervous system causes star gazing posture.
18. _____ vitamin is involved in the metabolism of propionic acid.
19. In the animal body thiamin is present in the form of _____.
20. Ingestion of raw fish causes _____ vitamin deficiency.
21. The amino acid tryptophan is essential for the synthesis of _____ vitamin.
22. Co-enzyme - A contains _____ vitamin.
23. Avidin is an anti-nutritional factor for _____ vitamin.
24. Mineral present in the vitamin B₁₂ is _____.
25. _____ vitamin is called as animal protein factor (APF).

Define the following

1. Provitamin
2. Anti-oxidants
3. Hypovitaminosis
4. Hypervitaminosis
5. Bitot's spot
6. Corneal opacity
7. Xerophthalmia
8. Intrinsic factor
9. Perosis or slipped tendon

Short answer

1. Difference between fat soluble and water soluble vitamins
2. Role of vitamin- A in vision
3. Mechanism of action of vitamin-D in calcium homeostasis
4. Interrelationship between vitamin-E and selenium

Essay

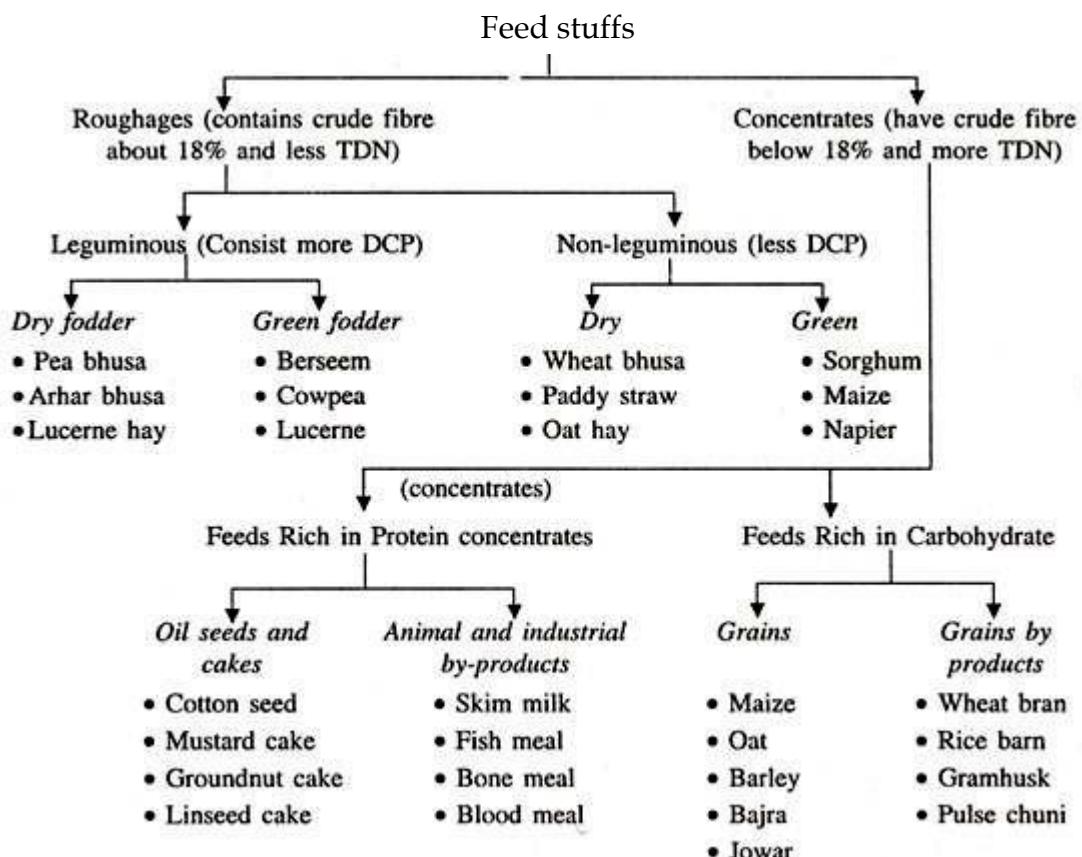
1. Function and deficiency diseases of vitamin-A
2. Function and deficiency diseases of vitamin-E
3. Role of B-complex vitamins in nutrient metabolism

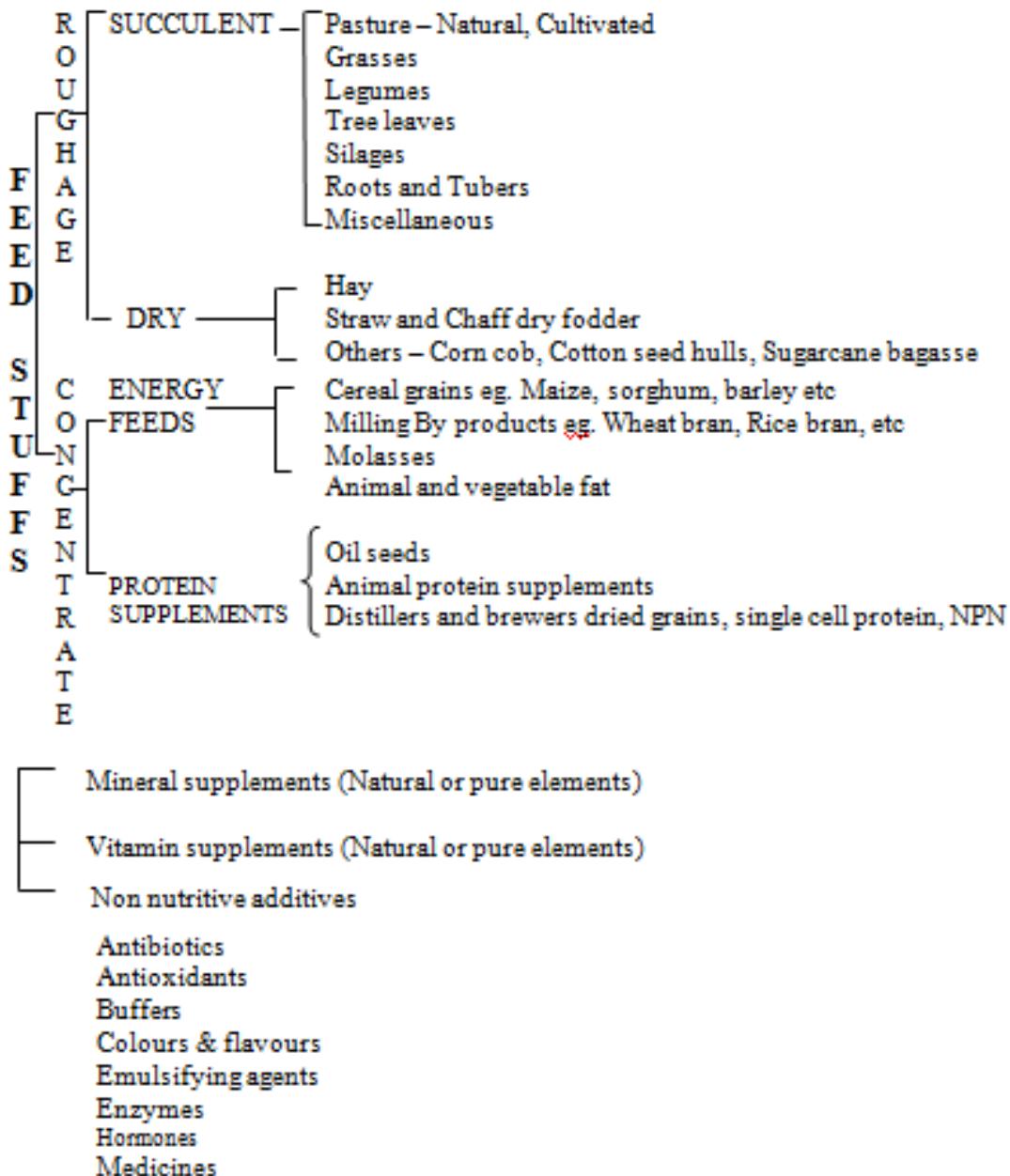
CHAPTER 6

COMMON FEEDS AND FODDERS THEIR CLASSIFICATION, AVAILABILITY AND IMPORTANCE FOR LIVESTOCK AND POULTRY PRODUCTION

Common Feeds and Fodders their Classification

- Feeds can be classified based on their moisture content or based on their fibre content.
- Feeds having high moisture are called **high moisture or succulent feeds**. Feeds having below 15% moisture are called **dry feeds**.
- Feeds having **higher than 18 - 20% crude fibre** are called **roughages** and feeds having **below 18% crude fibre** are called **concentrates**.
- Roughages can be succulent or dry based on moisture content.
- Concentrates may be dry concentrates or high moisture concentrates (Molasses).
- Concentrates having high protein above 18% are called protein supplements.
- Concentrates having high energy (above 60% TDN) are called energy supplements.
- Concentrates rich in minerals are called mineral supplements.





I. SUCCULENT ROUGHAGES

Forage Grasses - As bulk feed of the livestock, grasses are the best and cheapest.

1. Cultivated Grasses

Guinea grass - *Panicum maximum* (*Guinea pul*)

Valuable grass for grazing, green soiling, hay and silage making. Nutritive value of guinea grass is quite high when leafy and young (10% crude protein), but nutritive value falls rapidly with increasing maturity.

Para grass - *Brachiaria mutica* Water grass/ Buffalo grass

It can be used for green soiling, hay or browse and should be grazed rotationally as it will not withstand heavy grazing.

CO₁, CO₂, CO₃, CO₄ Grasses

Cumbu napier hybrid grasses. Have a better yield and nutritive value compared to other non hybrid grasses. These grasses can be converted to hay or silage.

Elephant grass - Napier Grass - *Pennisetum purpureum*

Young leafy fodder palatable and of fair quality, but mature grass has a large proportion of stem and becomes rough.

2. Pasture Grasses

Cenchrus glaucous, C. ciliaris and C. setigerus - Excellent grazing grass for hot, dry areas in tropics and sub-tropics.

Hariyali grass - *Cynodon dactylon*

Bermuda grass is a fine leafed perennial spreading and forming a dense turf. A good fodder grass.

3. Cultivated Cereal Fodders

Fodder maize (*Zea mays*) (Makka cholam)

Green maize is eaten fully by all kinds of livestock if it is chaffed. It also makes excellent silage. Maximum yield and digestibility are obtained when the crop is harvested at 50% flowering to dough stage.

Fodder finger millet (*Eleusine corocana*) Ragi

It can be fed at any growth stage of the crop without fear of any toxic principles.

Fodder pearl millet (*Pennisetum glaucum*) Cumbu / Fodder bajra / Indian millet

It is a useful fodder crop in areas where irrigation facilities are inadequate. Bajra can be cut and fed to livestock at any growth stage and it is completely free from toxic substances like HCN.

4. Cultivated Legume Fodder Crops

Among leguminous fodders, cowpea (*Vigna catjang*), cluster bean (Guar; *Cyamopsis psoraloides*), Berseem (*Trifolium alexandrinum*) and lucerne (*Medicago sativa*) are common leguminous fodder in India. Lucerne and berseem contain on an average 2.5 to 3 per cent D.C.P. and 12 per cent T.D.N. on fresh basis. The phosphorus content of these two forages are poor and thus have wide calcium to phosphorus ratio. It is advisable to supplement a ration containing a large amount of leguminous fodder with a limited quantity of wheat or rice bran.

Per cent DCP and TDN of green roughages on DMB

GREEN ROUGHAGES	DCP	TDN
NAPIER GRASS	2.5	44.0
PARA GRASS	3.5	59.0
GUINEA GRASS	3.0	51.0
CYANADON DACTYLON (Arugam pull)	2.5	45.0
FODDER SORGHUM	2.5	50.0
FODDER MAIZE	3.5	60.0

GREEN ROUGHAGES	DCP	TDN
COW PEA	12.5	60.0
LEUCERNE	13.5	60.0
SOOBABUL	14.0	55.0
SESBANIA (AGATHI)	15.0	50.0

II. DRY ROUGHAGES

Crop Residues

The left over portion of the crop after the main crop is harvested for human consumption is called as **crop residues**.

Crop residues may be grouped under the following headings

Straws	Stovers	Aerial portion of other crops	Others
Wheat	Maize	Soybean	Corn cobs
Paddy	Sorghum	Groundnut	Bagasse
Oats		Sunflower	Peanut hull
Barley			Rice hull
Millets			

Nutritional quality of crop residues

- Low crude protein, calcium, carotene and available energy.
- High in cell wall constituents, lignin and silica.
- Reduced palatability - low voluntary intake.
- Low digestibility of dry matter and bioavailability of energy.
- Bulky in nature.

Straws and chaff:

Straws consist of the stem and leaves of plants after the removal of the ripe seeds by thrashing and are produced from most cereal crops and from some legumes chaff consists of the husk or glumes of the seed which are separated from the grain during threshing. These products are extremely fibrous, rich in lignin and of extremely low nutritive value. They should not be used as pig or poultry food.

Paddy straw:

It has an exceptionally high ash content which consists mainly of silica. The lignin content of this straw, is about 6-7% dry matter is however lower than that of other cereals straw.

The poor nutritive values of straws may be attributed to the following facts.

1. The digestibility of straw is limited due to the formation of strong physical and/or chemical bonds between lignin and the structural polysaccharides (Hemicellulose).
2. Crystalline structure of cellulose is also responsible for low digestibility of cellulose.
3. Highly deficient in other nutrients like minerals, vitamins, fatty acids and in proteins. The minimum crude protein requirement for efficient lignocellulose break down of roughages fed as the sole diet is claimed to be from 3.8 to 5.0%.
4. High silica content of straw is known to depress organic matter digestibility.

In some cases, it is economical to increase the nutritive values of all types of poor quality roughages by physical chemical or biological treatment.

Other straws (Cereals) which are commonly fed to animals are: Wheat straw and Rye straw, whereas in European Countries Oat straw.

Legume straws:

After harvesting, seeds of pulses, the husks of the pods with leaves and tender stems are left behind as by-products and can be utilised as fairly nutritious cattle feeds. The energy value of these straws is comparable with those of cereal straws but they are a fairly good source of digestible protein. They can as well meet the production requirements of the animals to certain extent. Supplementation with energy-rich feeds like cereal grains will, however, be necessary in the case of high-milk-producing cattle.

Succulent Crop Residues

Tapioca Leaves:

Cassava is a tuber crop extensively grown in Tamil Nadu and Kerala State. Annual production of tapioca in the country is estimated at 3.5 million tonnes. At the time of harvest, the tuber is harvested and the leaves are thrown away. Tapioca leaves are a rich source of protein having a DCP value of 8 and TDN value of 45 per cent of dry leaves. The tapioca leaf meal contains 7 mg of HCN per 100 g of material.

Groundnut haulms:

Groundnut is the major oilseed produced in the country. At the time of harvesting large quantities of leaves and stem become available for feeding of livestock. The DCP value of groundnut haulms is superior to that of non-leguminous crops.

SUGARCANE - *Saccharum officianarum*

Sugarcane tops are important source as fodder during harvesting season, which may last for four to ten months in a year. Sweetness makes it very palatable and they are often fed hand chaffed green, which can easily provide the animal's maintenance ration. i.e. it requires considerable supplementation with concentrates for productive purposes.

Leaves of cane tops are lower in digestibility than stalks and its rate of digestion is also very low. Supplementation with urea helps to increase the organic matter digestibility. Nutritive value of cane tops can be enhanced when the chopped cane tops are mixed with legume and fed. Sugarcane trash and tops can be ensiled with 2% urea, 10% molasses, mineral mixture, 1% NaCl and 25g vitamin mixture and fed to animals.

CONCENTRATES

1. High Moisture Concentrates

Roots and Tubers

Roots: A root crop consists of the under ground part of the harvested plant. The main characteristic of roots are their high moisture content (75-94%) and low Crude fibre (4-13%). The organic matter of root, consists mainly of sugars, roots are generally low in crude protein eg.turnip, beet, carrot etc.

Tubers: Tubers are short thickened, fleshy stems, usually formed underground such as potatoes, cassava, sweet potatoes etc. Tubers differ from the root crop in containing either starch or fructose instead of sucrose. They have higher dry matter and lower crude fibre content and consequently are more suitable than roots for feeding pig and poultry.

Potatoes: The crude protein content is approximately 11% about half of this being in the form of non protein nitrogenous compounds, one of these compounds is the alkaloid '**Solanidine**'. Solanidine and its derivatives are toxic to animals, causing gastroenteritis. Green potatoes should be regarded as suspects, although removal of the eye and peel, in which solanidine is concentrated will reduce toxicity. Raw potatoes has a protease inhibitor which is destroyed on heating.

Cassava: Cassava tubers are used for production of tapioca starch for human consumption, although tuber is also given to cattle, pig and poultry. Cassava tubers contains two cyanogenetic glycosides (**linamrin and lotaustralin**), which readily break down to give hydrocyanic acid. Boiling or grating and squeezing or grinding to a powder reduces the toxicity.

Molasses

Molasses is a product of the sugar refining industry; it is a black syrupy sweet solution. The principal types of molasses are cane and beet molasses.

Cane molasses

- Liquid molasses contain 20-25% water, 46% of sugars, 10-15% ash.
- Molasses can be used to a maximum of 30 percent of the diet, however to be on the safe side it can be included up to 10 percent of ration.
- At higher inclusion levels it has a laxative effect due to the high mineral content.
- Molasses is used in compounded feeds up to 2-5%
- To improve palatability and prevent dustiness of feed.
- It is also used as a pellet binder.

- When included above 10% it may cause milling problems due to stickiness.
- Molasses is used in liquid feeding systems for ruminants along with urea or other NPN sources.
- Molasses serves as readily available carbohydrate source during NPN supplementation.
- In molasses based feeding systems molasses toxicity may occur which is characterized by neurological symptoms such as incoordination and blindness.
- The other types of molasses are citrus and wood molasses, which are available to a limited extent. **Citrus molasses** is a by product of citrus processing has a bitter taste due to its high organic acid content and is unpalatable. **Wood molasses** is a mixture of hemicelluloses and soluble carbohydrates produced during the process of manufacturing particle boards. It is primarily used as a pellet binder. It contains pentose sugar xylose which is toxic to non ruminants. It causes poor growth, diarrhoea and eye cataracts in pigs.

2. Dry Concentrates

i. Energy Rich Concentrates

a. Cereal Grains:

- Cereal grains are essentially carbohydrate concentrates, the main component of the dry matter being starch.
- The **crude protein ranges from 8-12%**, deficient in certain essential amino acids, particularly **lysine and methionine**.
- The oil content varies from 2-5% cereal oils are unsaturated the main acids being linoleic and oleic and because of this they tend to become rancid quickly and also produce a soft body fat.
- The crude fibre content is highest in oats and rice, which contains "husk or hull".
- The cereals are all deficient in calcium, containing less than 0.15%.
- The phosphorus content is higher, being 0.3-0.5%, but part of this is present as **phytates**.
- The cereal grains are deficient in vitamin A with the exception of yellow maize, which is rich in pro-vitamin A.
- They are good sources of vitamin E and thiamine, but have a low content of riboflavin.
- Commonly fed cereals are maize, wheat, rice etc.

Maize or Corn: (*Zea maize*)

- Maize appears in a variety of colours, yellow, white or red.
- Yellow maize contains a pigment, cryptoxanthin, which is a precursor of vitamin A.

- Maize contains about 65% starch, is low in fibre less than 5% and has a high metabolisable energy value 3300 Kcal/Kg.
- The crude protein content ranges from 8-13%.
- The maize protein is deficient in the essential amino acids, **tryptophan and lysine**.
- New varieties of maize with amino acid components different from those present in normal maize; one such **variety is Opaque-2, which has a high lysine content**. The difference between this variety and normal maize is primarily attributed to the zein: glutelin ratio. A newer **variety Floury-2 has both increased methionine and lysine content**.
- Maize is generally crushed or even roughly ground for feeding farm animals.

Wheat (Triticum aestivum)

- The crude protein ranges from 6-12%
- The most important proteins present in the endosperm are a prolamin (gliadin) and glutelin (Glutenin).
- The mixture of protein present in the endosperm is often referred to as gluten.
- The amino acids present in wheat gluten are the non-essential acids glutamic acid (33%) and proline (12%).
- All glutens posses the property of elasticity.
- This property of gluten is considered to be the main reason why finely ground wheat is unpalatable to animals.
- Wheat if finely milled forms a pasty mass in the mouth, and may lead to digestive upset.

Millets

Millets are cereals, which produce small grain and have higher percentage of fibre . e.g. Sorghum, Bajra, etc.

Sorghum (Sorghum Vulgare)

Sorghum is similar to maize in chemical composition except that sorghum is slightly higher in protein and low in oil than maize. Whole grain can be given to sheep, pig and poultry but are usually ground for cattle.

Bajra (Pennisetum typhoides)

It resembles sorghum in its nutritive value contains 8-12% crude protein, is rich in tannin content. As the seeds are hard, they should be ground or crushed before being fed to cattle.

b. Milling by-products:

Bran: It is the outer coarse coat of the grain, separated during processing e.g. Rice bran, wheat bran, maize bran etc. Because of the fibrous nature and low digestibility bran is used only to a limited extent in pig and poultry feed.

Rice bran: Rice bran is valuable product containing 12-14% protein and 11-18% oil. The oil is particularly unsaturated and may become rancid very quickly. Presently the oil is removed from the rice bran and a product known, as **deoiled rice bran** is available in market for livestock feeding.

Wheat bran: Wheat bran is popular food for horses contain more fibre. When made into a mash with warm water, it acts as a laxative, but when given dry it tends to counter act scouring.

Gluten: When flour is washed to remove the starch, a tough, substance remains, which are known as gluten e.g., corn gluten. Gluten feed is generally not feed to non-ruminants due to bulkiness, poor quality protein and unpalatability.

Grain Screening: Small imperfect grains, weed seeds and other foreign material of value as a feed that is separated through the cleaning of grain with screen is called grain screening. The nutritive value depends on the composition.

Hulls: Outer covering of the grain, generally not utilized as livestock feed.

Polishing: By-product of rice, consisting of a fine residue that accumulates during polishing of rice kernel contains about 10-15% protein, 12% fat and 3-4% crude fibre. It is an excellent source of energy and vitamin B complex. Due to high fat content rancidity can pose problem.

c. Fats and Oils

- They contain 2.25 times more energy than carbohydrates and are concentrated sources of energy for animals.
- Fats are usually added to high-energy rations.
- Fats also increase the palatability of feeds and prevent the dustiness of feeds, acts as a lubricant in feed manufacturing and improves pelleting efficiency.
- Animal fats used in feeding are beef tallow, mixed animal fat and greese.
- Animal fats contain a high amount of saturated fatty acids.
- And are less digested. Vegetable oil (sunflower oil, ground nutoil, etc) and marine oils (cod liver, Sardine) contain a high amount of unsaturated fatty acids and adding these oils to feeds may lead to the development of rancidity which can cause the destruction of a number of fat soluble vitamins.
- Rancidity can be prevented or reduced by adding a number of antioxidants (Vitamin E, BHT) to the feed.

ii. Protein Rich Concentrates

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 2.5% fibre	Mostly under 1.5% P Mostly over 2.5% fibre
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Other sources includes NPN compounds, single cell protein etc.

a. Protein Rich Concentrates of Plant Origin:

Oil seed cake/meal: A number of oil bearing seeds are grown for vegetable oil for human and for paints and other industrial purposes. In processing these seeds, protein rich products of great value as livestock feeds are obtained. The by products left after extraction of oil from oil seeds are used for feeding all kinds of livestock. According to the method of processing, oil content and protein content varies.

Three main processes are used for removing oil from oil seeds. Two employ pressure to force out the oil (ghani and expeller), while the other uses an organic solvent to dissolve the oil from the seed. Only material with an oil content of less than 35% is suitable for solvent extraction. If material of higher oil content is to be solvent extracted it first undergoes a modified screw pressing to lower the oil content to a suitable level.

Groundnut oil cake or peanut oil meal:

- It is most widely used high protein feed that can be included upto 50% of the ration.
- It has about 45% protein and 10% oil in expeller variety. It is deficient in lysine, methionine and cystine.
- Particularly in warm rainy season liable to contain a toxic factor - Aflatoxin a metabolite of fungus *Aspergillus flavus*.

Soybean oil meal:

- The protein (44%) contains all the indispensable amino acids, but the concentrations of cystine and methionine are sub-optimal.
- The cake is used for all kinds of livestock including poultry upto 30% of the ration.
- As with most other oil seeds, raw soyabeans have a number of toxic, stimulatory and inhibitory substances.
 1. A **goitrogenic material** is found and its long term use may result in goitre in some animal species.
 2. It also contains **antigens**, which are specially toxic to young pre-ruminants.
 3. It contains **protease inhibitors** of which six have been identified. Two of these, the **kunitz anti-trypsin factor and the Bowman-Brik chymotrypsin inhibitor** are of practical significance. Trypsin inhibitor affects the digestibility of proteins specially in monogastric animals. These inhibitors will interfere with protein digestion, leading to poor growth rate, egg production and feed efficiency. This interference with protein digestion, leads to hypertrophy of pancreas and excess endogenous loss of essential amino acids. Since, the trypsin inhibitors can be

destroyed by heat treatment, proper heat treatment of the feed stuffs like soyabean is essential, before feeding them to livestock and poultry.

4. A **haemagglutinin**, agglutinates red blood cell in rats, rabbits and human beings but not in sheep and calves.
5. Soyabeans also contain **genistein**, a plant estrogen, which may account, in some cases for part of the high growth inducing properties.

Fortunately, these inhibitors and other factors like saponins are inactivated by proper heat treatment during processing.

Linseed Meal:

- It contains 40 % crude protein
- Linseed meal contains from 3-10% of mucilage.
- Immature linseed contains a small amount of a cyanogenetic glycoside, **linamarin** and an associate enzyme, linase, which is capable of hydrolysing it with the evolution of hydrogen cyanide.
- Normal processing conditions however, destroy linase and most of linamarin, and the resultant meals are quite safe.
- The protein of linseed meal is having a lower methionine and lysine content. Linseed meal has only a moderate calcium content but rich in phosphorus part of which is present as phytase.
- It is a useful source of Vitamins like riboflavin, nicotinamide, pantothenic acid and choline.
- Linseed meal can be included upto 10% in poultry diet.

Coconut meal (Copra meal):

- The crude protein content is low (20-26%) and poor in lysine and histidine.
- The oil content of coconut meal varies from 2.5 to 6.5% the higher oil meals tends to get rancid and thus will cause diarrhoea. Hence low oil content type should be preferred.
- Due to poor quality of protein and high fibre, its use should be restricted in swine and poultry rations. If it is fed to monogastric, it should be supplemented with lysine and methionine

Cotton seed meal:

- The protein (35 %) of cotton seed meal is of good quality, but has the common disadvantage of oil seed residues of having a low content of cystine, methionine and lysine.
- The calcium content is low and as the calcium to phosphorus ratio is about 1:6 deficiencies of calcium may easily arise.
- Pigs and poultry do not readily accept the meal largely owing to its dry dusty nature.

- No such difficulty is encountered with lactating cows but complications may arise where large amounts are given, since the milk fat tends to become hard and firm and butter made from such fat is often difficult to churn and tends to develop tallory taints.
- Cotton seed may contain from 0.3 to 20g/kg dry matter of a yellow pigment known as **gossypol**.
- Gossypol is a polyphenolic aldehyde which is an antioxidant and polymerisation inhibitor and is toxic to simple stomached animals.
- The general symptoms of gossypol toxicity are depressed appetite and loss of weight, death usually result from circulatory failure.
- Addition of one per cent calcium hydroxide or iron salts to the diet decreases the Gossypol toxicity.

Sunflower seed meal:

- The meals are useful sources of protein (40%) which is low in lysine but has about twice as much methionine as does soya protein.
- The meal is palatable but is laxative and has a very short shelf life.
- The expeller variety of sunflower meal or cake tends to produce soft pork and it also makes the butter soft if fed in large amounts in cows because of the character of the oil it contains.
- This can be used in cattle ration and safely included at 20 per cent level.

Mustard cake (Sarson)

- Widely used in many parts of Northern India for cattle feeding.
- Nutritive value is much less than that of ground nut cake.
- D.C.P. and T.D.N. values are 27% and 74% respectively.
- It should preferably be mixed with other, more well-liked feeds.
- The deoiled type can be used for poultry upto 10 per cent of the ration and for pigs the amount may go as high as 20 per cent.
- The calcium and phosphorus content are much higher, being about 0.6 per cent and 1.0 per cent.
- **Glucosinolates or goitrogens** are the antinutritional factor present in the mustard cake.

Sesame seed meal (Til Cake)

- Sesame seed meal is produced from what remains following production of oil from sesame seed and the meal is extensively used for all classes of livestock including poultry .
- Contains about 40% protein which is rich in leucine, arginine and methionine and low in lysine.

- There are three varieties – white, black and red. Nutritive value is highest in white while lowest in red variety.

Rape seed meal / Cannola seed meal

- Contains more fibre (14%) with low ME Though low in protein content than soyabean meal, the balance of essential amino acid,
- Calcium : Phosphorus are favourable.
- Grown in Europe fed to pig and poultry, contains **glucosinolates** which may lead to goitre, liver and kidney dysfunction.

b. Protein Rich Concentrates of Animal Origin

Fish meal:

- Fish meal is the product obtained by drying and grinding whole fish or parts of various species.
- The quality of the protein in fish meal is high.
- Fishmeal protein has a **high content of lysine, methionine and tryptophan** and is a valuable supplement to cereal-based diet.
- **Fishmeal has high mineral content (Ca 8%, P 3.5%),**
- Good source of vitamin B complex
- Has an enhanced nutritional value because of their content of growth factor known collectively as the **Animal protein factor (APF)**.
- Fishmeal should be tested for salt content, as excessive salt may lead to salt toxicity in monogastric animals and birds.
- Fishmeal should have minimum amount of scales, as their nitrogen content is of little value, since the scales are keratinised tissue.
- Fishmeal should be tested for E. coli bacteria.
- Fishmeal find their greatest use with simple-stomached animals.
- They are used mostly in diets for young animals whose demand for protein and the indispensable amino acids is particularly high and for whom the growth-promoting effects of APF are valuable. Such diets may include up to 15% of fishmeal.
- With older animals, which need less protein, the level of fishmeal in the diet is brought down to about 5% and it may be eliminated entirely from diets for those in the last stages of fattening.

Meat meal:

- It is the product obtained by drying and grinding carcasses and parts of carcasses of warm blooded land animals.
- It should be free from hair, feathers, horn, hoof and skin and contents of stomach and viscera.

- Meat meal contains 60-70% protein with 9% fat, various unidentified beneficial factors have been claimed to be present in meat meal, among them. The enteric growth factor from the intestinal track of swine, the '**Ackerman**' factor and a growth factor located in ash are important.
- However, the **low methionine** and **tryptophan** levels in meals affect their protein quality.

Liver residue meal:

- This can profitably be used as animal protein supplement in place of fishmeal.
- Liver residue can be favourably introduced in poultry rations at 10 per cent level or at 5 per cent level along with the same level of fish as an animal protein supplement.
- A good quality of liver residue meal should contain about 65 per cent protein, 5 per cent lysine, 1.2 per cent methionine and 1 per cent cystine apart from other amino acids

Blood meal:

- Blood meal is a product obtained by drying the blood of slaughtered animals and poultry.
- Blood meal contains about 80% protein, rich in lysine, arginine, methionine, cystine and leucine.
- The meal is **unpalatable** and its use has resulted in reduced growth rates in poultry so that it is not recommended for young stock.
- For older birds, rates of inclusion are limited to about 1 to 2% of the diet. It should not be included in creep foods for pigs.
- Normal levels of inclusion for older animals are of the order of 5% of diet and it is usually used along with a high quality protein source.
- At levels over 10 % of the diet it tends to cause scouring and is best regarded as a food for boosting dietary lysine levels.

Hatchery Waste:

Incubator waste or Hatchery By-product Meal (HBPM):

- It is a mixture of eggshells, infertile and unhatched eggs which have been cooked, dried and powdered.
- Broiler chicks when fed at levels of 3 or 6 per cent of the total ration with dried incubator waste proved a satisfactory substitute for fishmeal or soybean oil meal.

Hydrolysed feather meal:

- Product obtained by hydrolysing, drying and grinding poultry feathers is called as Hydrolysed feather meal.
- The meal is of low palatability and must be introduced into the diet gradually.

- Dietary rates of inclusion are generally low, being of the order of 2.5 to 3.0 % of the total ration for adult ruminants, 2.5 % for layers, broilers and turkeys, and 1.0 % for calves, lambs, sows and growing and finishing pigs.
- The meal is not used for weaner and creep-fed pigs or chicks.
- There is a risk of contamination of the base material with *Salmonella* and it is important that strict control of processing conditions should be maintained in order to minimize the risk of this in the finished product.

c. Non Protein Nitrogen Compounds as Protein Sources (NPN):

- Non-protein nitrogen compounds are recognised as useful sources of nitrogen for ruminant animals.
- Their use depends upon the ability of the rumen microorganisms to use them in the synthesis of their own cellular tissues and they are thus able to satisfy the microbial portion of the animal's demand for nitrogen and, by way of the microbial protein, at least part of its nitrogen demand at tissue level.

Urea:

- It is a white, crystalline solid.
- Pure urea has nitrogen content of 46.6% which is equivalent to a crude protein content of $46.6 \times 6.25 = 291\%$
- Urea is hydrolysed by the urease in the rumen micro organisms with the production of ammonia.
- The ease and speed with which this reaction occurs when urea enters the ruminant gives rise to two major problems owing to excessive absorption of ammonia from the rumen.
- Thus wastage of nitrogen may occur and there may be a danger of ammonia toxicity.
- This is diagnosed by muscular twitching, ataxia, excessive salivation, tetany, bloat and respiration defects.
- Urea should be given in such a way as to slow down its rate of breakdown and encourage ammonia utilisation for protein synthesis.
- The diet should also contain a source of readily available energy so that the microbial protein synthesis is enhanced and wastage reduced.
- Supplementation of the diet with a sulfur source may be necessary.
- Urea does not provide energy, minerals or vitamins for the animal, and when it is used to replace conventional protein sources care must be taken to ensure that satisfactory dietary levels of these nutrients are maintained by adequate supplementation.

- To avoid the danger of toxicity, not more than one third of dietary nitrogen should be provided as urea, and where possible this should be in the form of frequent and small intakes.
- Urea can be included in total ration upto 1 % and in concentrate feed upto 3%.

Single-cell protein:

- Single-cell organisms such as yeast and bacteria grow very quickly and can double their cell mass, even in large scale industrial fermentors, in three to four hours.
- A range of nutrient substrates can be used including cereal grains, sugar beet, sugar cane and its by-products, hydrolysates from wood and plants, and waste products from food manufacture.
- The protein content of bacteria is higher than that of yeast and contains higher concentrations of the sulfur-containing amino acids but a lower concentration of lysine.
- Single-cell protein (SCP) contains unusually high levels of nucleic acids, ranging from 5.0 to 12.0 % DM in yeast and 8.0 to 16.0 % DM in bacteria.
- Large amounts of uric acid or allantoin, the end - products of nucleic acid catabolism, are excreted in the urine of animals consuming SCP.
- The oils themselves are rich in unsaturated fatty acids.
- Although SCP does contain a crude fiber fraction, and this can be quite high in some yeast, it is not composed of cellulose, hemi-cellulose and lignin as in foods of plant origin; it consists chiefly of glucans, mannans and chitin.
- In the case of poultry, dietary SCP concentrations of 2.0 to 5.0 % have proved optimal for broilers and 10.0 % has been suggested for diets for laying hens.

STUDY QUESTIONS

Fill in the blanks

1. Feeds having higher than _____ % crude fibre are called roughages and feeds having below _____ % crude fibre are called concentrates.
2. _____, _____ and _____ are the examples of cultivated grasses.
3. _____ and _____ are the examples of pasture grasses.
4. _____, _____ and _____ are the examples of legume fodders.
5. _____ is an anti-nutritional factor present in the sorghum fodder.
6. _____, _____ and _____ are the crop residues which can be used for feeding the livestock.
7. DCP content of paddy straw is _____ %.

8. _____ is the major sugarcane by-product used in the feed industry.
9. Cyanogenetic glycoside present in the cassava (tapioca) is _____.
10. Molasses can be included in the compounded feed up to _____ %.
11. _____, _____ and _____ are the examples of cereal grains.
12. _____ is a cereal grain rich in beta carotene.
13. _____ is a variety of maize rich in lysine and methionine.
14. In general the crude protein content of cereal grains ranged from _____ to _____ %.
15. _____, _____ and _____ are the examples of cereal by-products.
16. _____, _____ and _____ are the examples of vegetable protein source.
17. The fungal toxin present in the groundnut oil cake is _____.
18. _____, _____ and _____ are the anti-nutritional factors present in the raw soybean meal.
19. Anti-nutritional factor present in the cottonseed meal is _____.
20. _____ and _____ are the examples of animal protein source.
21. _____ and _____ are examples of non-protein nitrogenous compounds.
22. Crude protein content of urea is _____ %.
23. Urea can be included in total ration up to _____ % and in concentrate feed up to _____ %.
24. Cereal grains are low in _____ and _____ amino acids.
25. _____ and _____ are the cyanogenetic glycosides present in the liseed.

Write the statement True or False

1. Legume fodders are good source of protein and calcium ()
2. In cereal grains phosphorus is present in the form of phytate phosphorus ()
3. Paddy straw is rich in oxalate ()
4. Feeding of excess quantity of legume fodder results in bloat ()
5. The oil content is more in solvent extracted oil cake than in expeller variety oil cake ()
6. The keeping quality of cereal fodders can be improved by silage or hay making ()

7. Glucosinolates or goitrogens are present in the rapeseed meal and mustard cake ()
8. Urea can be incorporated in the ration of non-ruminants ()
9. The protein quality of animal protein sources are inferior than vegetable protein sources ()
10. Cereal grains are good source of protein ()
11. Bran is a good source of phosphorus ()
12. Gluten is a good source of starch ()
13. Fish meal is a good source of calcium and phosphorus ()
14. Feeding of raw fish results in thiamin deficiency ()

Define the following

1. Concentrate
2. Roughage
3. Anti-oxidants
4. Gluten
5. Animal protein factor
6. Single cell protein
7. Silage
8. Hay
9. Milling by-products

Short answer

1. Classification of feedstuffs
2. Nutritional quality of crop residues
3. Milling by-products
4. Utility of urea in livestock feeding
5. Single cell protein

Essay

1. Write an essay on cultivated cereal and legume fodders
2. Discuss in detail about vegetable protein sources for animal feeding
3. Use of animal protein sources in animal feeding

CHAPTER 7

MEASURES OF FEED ENERGY AND THEIR APPLICATION

Energy may be defined as the capacity to do work. Energy exists in various forms. They are **chemical, thermal, electrical and radiant energy**. Energy can neither be created or destroyed one form of energy can be changed into another form. Energy from the sun ie radiant energy is trapped by the plants and stored in the form of chemical energy. When animals consume these plants or other animals the stored energy is released by the process of digestion and metabolism and is used for doing mechanical work or maintenance of the functions of the tissues in the animal body.

The basic unit of expression of energy is the **calorie**. One calorie is the quantity of heat energy required to raise the temperature of one gram of water by one degree Celsius.

1000 calories = one kilo calorie (Kcal)

1000Kcal = one mega calorie (Mcal) or Therm

Another unit of expression of energy is the **joule** and is adopted in most of the European countries. (1 joule = 0.239 calorie)

One calorie = 4.184 joules

1000 joules = one KJ

1000 KJ = one MJ

British thermal unit (BTU): It is the amount of heat required to raise 1 lb of water by 1 degree F. One kilo calorie approximately equals to 4 BTU.

Gross Energy: The total energy present in a feed / food is called gross energy. It is the energy obtained by complete oxidation of food or any biological material in a bomb calorimeter. Not all the gross energy is useful to the animal because energy losses in the animal take place due to digestion and metabolism.

Digestible Energy: The gross energy minus energy loss through faeces is called as digestible energy. Digestible energy can be determined by conducting a digestibility trial and estimating the energy content of the feed and faeces. The DE thus estimated is only apparent DE since the faecal energy comes not only from undigested feed residues but metabolic products derived from body tissues are also present.

Apparent DE - metabolic products Losses = True DE

In ruminants fed on roughages faecal energy losses can range between 40-50%. In case of concentrates energy loss is between 20-30%. In horses faecal energy loss is 40 % whereas in pigs this loss is only 20%.

Metabolisable Energy: Digestible energy minus energy loss through urine and gasses is metabolisable energy. This ME estimation is easy in poultry since both the urinary and faecal losses are voided together in the birds. ME is that portion of feed energy that is

available for metabolic procedures in the animals. Urinary losses of energy is due to excretion of incompletely oxidized nitrogenous compounds associated with protein metabolism primarily urea in mammal and uric acid in birds. In cattle urinary losses is 4-5% of GE. In pigs it is 2-3% of GE. Energy loss through gaseous products of digestion is high in ruminants. To estimate ME in ruminant's collections of gases is essential. For this a respiration chamber is needed. On unavailability of a respiration chamber 8% of GE can be taken as loss of energy through methane.

ME can be calculated from DE. $DE \times 0.82 = ME$

Factors that influence utilization of ME

1. Nature of the chemical compound that contains the energy.
2. For what purpose it is used.

Net Energy: Net energy can arrived from ME by subtracting HI (Heat increment). Heat increment or specific dynamic effect is the amount of heat lost as a result of physical and chemical processes associated with digestion and metabolism. HI is only useful to those animals that are maintained in cold environment. It helps in the maintenance of body temperature. Otherwise it is a waste.

Heat increment is due to;

1. Work of Nutrient metabolism.
2. Heat of fermentation in ruminants.
3. Work of excretion by the kidneys.
4. Work of digestion ie mastication of food, propulsion through G.I tract
5. Increased muscular activity of various organs due to metabolism of nutrients.

Factors that cause variation in Heat increment

1. Species of animals
2. Types of Nutrients used.
3. Character of diet.
4. Specific purpose for which feed is used.

The NE thus obtained after subtracting HI from ME is the useful form of energy to the animal. A portion of NE is used for sustenance of the animals life it is called **Net Energy maintenance (NE_m)**. It serves for muscular work needed for minimal movement, maintenances and repair of tissues and maintenance of body temperature. Another portion of ME is the energy retained for tissue gain in growing or fattening animals or for milk or egg produced. This portion of NE is called **Net Energy for production (NE_p)**, the portion of net energy used for milk production is called **net energy for lactation (NE_l)**.

TOTAL DIGESTIBLE NUTRIENTS (TDN)

This is the simplest form of energy evaluation. The digestibility of nutrients is determined by digestibility trials. It is ordinarily expressed in Kg or in percent. It can be calculated by the formula

$$\text{TDN (\%)} = (\% \text{ digestible crude protein} + \% \text{ digestible crude fibre} + \% \text{ digestible NFE} + (2.25 \times \% \text{ digestible ether extract}))$$

The digestible ether extract is multiplied by 2.25 because on oxidation fat provides 2.25 times more energy as compared to carbohydrates. The digestible protein is included in this equation because of the fact that excess of protein eaten by the animals serve as a source of energy to the body.

Factors affecting TDN value of feed;

1. **Dry matter Percentage;** In high moisture feed the nutrient concentration is less and so the TDN value on fresh matter basis will be less.
2. **Digestibility Percentage of dry matter;** The presence of indigestible substances like lignin, acid insoluble ash will interfere with the digestibility of other useful nutrients. Hence feeds with high lignin and/or acid insoluble ash will have low TDN values.
3. **Presence of minerals;** Since minerals as such contribute no energy, high mineral containing feeds will have low TDN.
4. **Digestible fat percentage in the feeds;** The feeds containing high digestible fat will have high TDN value because due weightage is given for its high energy content in TDN system. For feeds containing more digestible fat the TDN value sometime exceeds 100%.

Merits

1. It is easiest to determine the digestible values through digestive trials unlike the ME and NE, which require complicated equipments and procedures.
2. The TDN values for most of the feedstuffs are obtained from carefully conducted digestion trial and are available in standard books.
3. The energy requirements of ruminants are expressed in TDN.

Limitations

1. Only the loss in faeces is accounted for in this method, but losses in combustible gases, heat of fermentation and urine are not considered. This is a strong limitation to the usefulness of TDN for evaluating feeds for ruminants.
2. It over estimates the value of roughages. This is because the losses in methane and heat are relatively larger per unit TDN for roughages than for concentrate
3. If feeds are high in fat content, the TDN value some time exceeds 100 in percentage

Utility of TDN system as an energy measure

In India TDN system is commonly followed energy evaluation system for ruminants. The famous Morrison standard, which is extensively used by American farmers, is based on TDN system. It can be used for feeding pigs and horses and it is also reliable for comparative evaluation of ruminant rations of similar composition.

It is often preferred to express TDN in calories of DE. DE can be calculated by multiplying TDN with a factor of 4.4. It is found experimentally that the average caloric value of 1 gram of TDN is 4.4 Kcal (= 17.5 KJ).

KELLNER'S STARCH EQUIVALENT

This classical method was developed by Kellner in 1907 in Germany it is a **net energy system**, since the production value of feeds is measured by their utilization for fat deposition in adult animals relative to the fat producing power of 1 kg of starch.

Definition: SE is defined as the number of Kg of starch that produces the same amount of fat as 100 kg of the respective feed. This value is also called as **starch equivalent value** of the feedstuff.

$$SE = \frac{\text{Weight of fat stored per unit of food}}{\text{Weight of fat stored per unit weight of starch}} \times 100$$

Kellner expressed the energy value of feedstuff by its fat producing ability relative to that of pure starch.

Eg. When we say that the SE of wheat bran is 45, it means that 100 kg of wheat bran can produce as much animal fat as 45 kg of pure starch when fed in addition to maintenance ration or in other words 100 kg of wheat bran contains as much net/productive energy as 45 kg of the starch.

Starch value of typical feedstuffs has been determined by carbon-nitrogen balance experiments. For rationing diets, starch values are computed from their content in digestible nutrients. Kellner determined the actual fat producing power of isolated nutrients typical of the proximate constituents of feedstuffs and the results are summarized in the table below.

Digestible nutrients	Starch equivalent factor
Starch	1
Crude fibre	1
Ether extract	
From oil seeds	2.4
From cereals	2.1
From roughages	1.9
Protein	0.9

It appears from the table that the **starch values of starch, crude fibre and NFE are equal**. The fat producing power of protein is lower, since breakdown of protein to nitrogen free substances and formation and excretion of urea need energy. The fat producing power of ether extract from oil seeds is considerably higher than that from cereals and roughages because the latter fractions contain a greater percentage of non-glyceride compounds such as waxes and pigments than the pure fat from oil seeds.

Calculation of SE

The percentages of the digestible nutrients are multiplied by the respective starch equivalent factors. The arithmetic sum of these products is called as production value/starch value. As the calculated production values differed with the actual values Kellner used a standard for concentrates called as golden number and correction factor for roughages.

Concentrate - Golden number (0.95)

For concentrates the actual starch value is obtained from the production value by multiplying with the 'golden number' or 'value number'. The value number expresses the ratio between the starch value of a feedstuff and that of the pure nutrients contained in the feedstuff.

$$\text{Actual SE of concentrates} = \text{Calculated production value} \times 0.95$$

Roughages (correction factor)

The production value of roughage would be reduced by 0.58 units for every 1 per cent crude fibre present in the roughages.

$$\text{Actual SE of roughages} = \text{Calculated production value} \times (\text{CF\%} \times 0.58)$$

Merits

1. To express the energy value of feedstuff Kellner used starch, which is well known by the farmers. So the farmers easily understand it.
2. In many European countries this system was once very popular and even now used .
3. It is a productive type system, which considers all the energy losses including faecal, urinary, gaseous and heat losses.

Limitations

The starch equivalent system suffers from the same weaknesses as other net energy systems namely,

1. The starch value of the ration is not constant at different levels of feeding..
2. The starch value differs considerably for different productive purposes, even at the same level of feeding.

3. Kellner expressed energy values for feedstuffs and requirements for all functions in starch equivalents for fattening. For fattening the efficiency is lower than for other functions like growth, lactation, etc.

PHYSIOLOGICAL (ATWATER) FUEL VALUES

From the gross chemical composition of the feed samples the amount of energy yielding nutrients namely carbohydrate, fat and protein are estimated. If the amount of each is known it is easy to workout the heat of combustion of the feed sample using appropriate factors. The heat of combustion of individual carbohydrates, proteins and fats differ with their composition

(Eg.) As determined by Atwater GE of sucrose is 3.96 Kcal/gram and that of starch is 4.23 Kcal/gram. Energy yield of butterfat was found to be 9.21 Kcal/gram and that of lard, 9.48 Kcal/gram.

For practical use individual figures were averaged to apply to the major food stuffs (carbohydrate, fat and protein) as gross energy of food, ie., heat of combustion:

Atwater's average Gross energy value factors

Carbohydrate	-	4.15 Kcal/gram
Fat	-	9.4 Kcal/gram
Protein	-	5.65 Kcal/gram

Since the GE value of feedstuff does not represent the energy actually available to body cells, some potential energy therefore never enters the body and is excreted in the faeces. In this connection, the following digestibility figures are used to correct the GE values.

Carbohydrates	-	98% digestible
Fats	-	95% digestible
Protein	-	92% digestible

The calorific values of the three nutrients were multiplied by the corresponding digestible coefficients to get the DE values.

Atwater's digestible energy value factors

1 gram carbohydrate	=	$4.15 \times 0.98 = 4$ Kcal
1 gram fat	=	$9.40 \times 0.95 = 9$ Kcal
1 gram protein	=	$5.65 \times 0.92 = 5.2$ Kcal

After digestion and absorption, carbohydrates and fats are completely oxidized to CO₂ and water in body cells similar to that of calorimeter. Protein, on the other hand, is less efficient to be completely oxidized by the cell wherein there is loss of nitrogenous components in the form of urea, creatinine, uric acid, etc. which are excreted in the urine. Many experiments of combustion of urine showed that the unoxidised matter is equivalent to 7.9 Kcal/gram of nitrogen. In terms of protein 1.25 Kcal/gram of protein. This energy represents metabolic loss and must be subtracted from the 'digestible

protein'. After considering this Atwater has given factors for ME, which is also known as physiological fuel values.

Atwater physiological fuel value factors

Carbohydrate - $4.15 \times 0.98 = 4$ Kcal/g

Fat - $9.40 \times 0.95 = 9$ Kcal/g

Protein - $(5.65 - 1.25) \times 0.92 = 4$ Kcal/g

These physiological fuel values are not applicable in the case of ruminants because the digestibility of the nutrients is low in comparison to monogastrics moreover in ruminants gaseous loss also costs much of energy.

STUDY QUESTIONS

Fill in the blanks

1. The basic unit of expressing energy value of a feed is _____.
2. One mega calorie is equal to _____ kcal.
3. One calorie is equal to _____ joules.
4. Total energy present in the feed/food is called as _____.
5. The gross energy minus energy loss through faeces is called as _____.
6. Digestible energy minus energy loss through urine and gases is called as _____.
7. _____ is the useful form of energy for the animal for different purposes.
8. The average caloric value of 1 gram of TDN is _____ kcal of DE.
9. Starch equivalent system of energy expression was developed by _____.
10. Starch equivalent expresses the _____ producing power of a feed.
11. The starch equivalent factor of carbohydrate is _____.
12. Atwater physiological fuel value of carbohydrate, protein and fat are _____, _____ and _____ kcal/gram respectively.
13. Fat has _____ times more energy than carbohydrate and protein.

Write the statement True or False

1. Legume fodders are good source of protein and calcium ()
2. Gross energy value of protein is greater than fat ()

Define the following

1. Energy
2. Calorie
3. Joule

4. British Thermal Unit (BTU)
5. Gross energy (GE)
6. Metabolizable energy (ME)
7. Net energy (NE)
8. Metabolic faecal nitrogen (MFN)
9. Faecal nitrogen
10. Heat increment (HI)
11. Total digestible nutrients (TDN)
12. Starch equivalent (SE)
13. Golden number
14. Physiological fuel value

Short answer

1. Partitioning of feed energy.
2. Merits and demerits of TDN system of energy expression.
3. Calculation of starch equivalent value of a feed.

CHAPTER 8

DIRECT AND INDIRECT CALORIMETRY

Measurement of heat production in an animal is called as **calorimetry**. Heat produced in an animal can be measured by **direct method** (direct calorimetry) or by **indirect method** (Indirect calorimetry).

Direct Calorimetry

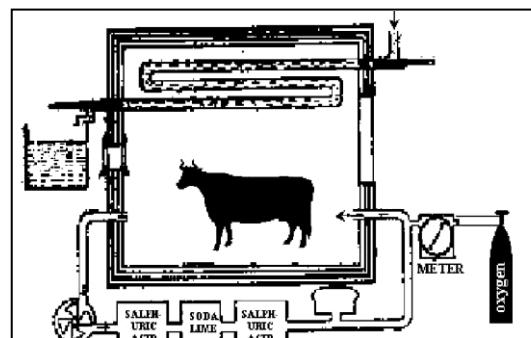
This is simple in theory, difficult in practice; sensible heat loss (heat of radiation, conduction) from the animal body can be measured with two types of calorimeters, **adiabatic and gradient**. The insensible heat (latent heat of water vaporized from the skin and the respiratory passages) is estimated by determining in some way the amount of water vapour added to the air, which flows through the calorimeter. For this, rate of airflow and change in humidity is measured.

1. Adiabatic Calorimeters

In this type an animal is confined in a chamber constructed in such a way that heat loss through the walls of the chamber is reduced to near zero. This is attained by a box within a box. When the outer box or wall is electrically heated to the same temperature as the inner wall, heat loss from the inner wall to the outer wall is impossible. Water circulating in a coil in such a chamber absorbs the heat collected by the inner wall; the volume and change in temperature of the water can be used to calculate sensible heat loss from animal body. The construction and operation are complicated and very expensive.

2. Gradient Calorimeters

Calorimeters of this type allow the loss of heat through the walls of the animal chamber. The outer surface of the wall of the calorimeter is maintained at a constant temperature with a water jacket; the temperature gradient is measured with thermocouples, which line the inner and outer surfaces of the wall. By the use of appropriate techniques it is possible to measure separately the radiation component of the sensible heat loss.



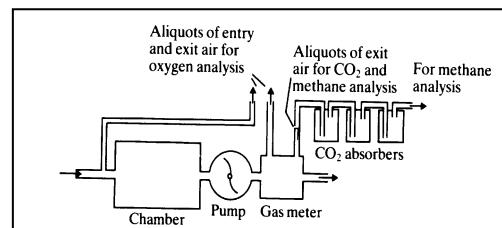
The BMR of the animal can be measured by measuring the heat produced by a fasting animal maintained at rest in a thermo neutral environment. The HI of the feed under investigation is determined as the difference in heat produced by the animal at two levels of intake. An increase in food intake causes an increase in heat production but BMR remains the same.

Indirect Calorimetry

Because the animal body ultimately derives all of its energy from oxidation, the magnitude of energy metabolism can be estimated from the exchange of respiratory gases. Such measurements of heat production are more readily accomplished than are measurements of heat dissipation by direct calorimetry. A variety of techniques is available for measuring the respiratory exchange; all ultimately seek to measure oxygen consumption and CO₂ production per unit of time.

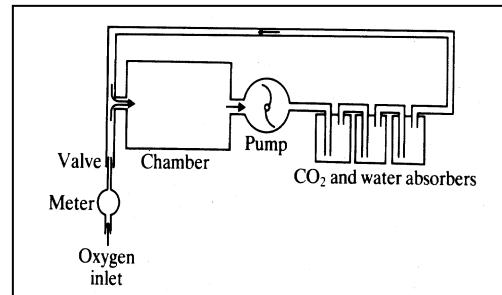
1. Open Circuit System

Devices allow the animal to breathe atmospheric air of determined composition; the exhaust air from a chamber or expired air from a mask or cannula, is collected or else metered and sampled, then analysed for O₂ and CO₂ content and is not reused. Analysis of gases has been accomplished with chemical and volumetric or manometric techniques.



2. Closed Circuit System

Devices require the animal to rebreathe the same air. CO₂ is removed with a suitable absorbent which may be weighed before and after use to determine its rate of production. The use of oxygen by the animal body decreases the volume of the respiratory gas mixture, and this change in volume is used as a measure of the rate of oxygen consumption. Oxygen used by the animal is then replaced by a metered supply of the pure gas. Both O₂ consumption and CO₂ production must be corrected for any differences in the amounts present in the circuit air at the beginning and end of the experiment. Methane is allowed to accumulate in the circuit air, and the amount present is determined at the end of the experiment.

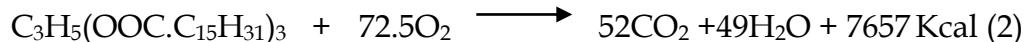


Indirect Calorimetry by the measurement of respiratory exchange:

The substances which are oxidised in the body, and whose energy is therefore converted into heat, fall mainly into the three nutrient classes of carbohydrates, fat and proteins. The overall reaction for the oxidation of a carbohydrate such as glucose is



And for the oxidation of the typical fat, tripalmitin, is



Respiratory quotient (RQ).

- This is the ratio between the volume of carbon dioxide produced by the animal and the volume of oxygen used.
- Since, under the same conditions of temperature and pressure, equal volumes of gases contain equal numbers of molecules, the RQ can be calculated from the molecules of carbon dioxide produced and oxygen used.
- From equation (1) the RQ for carbohydrate is calculated as $6 \text{ CO}_2 / 6 \text{ O}_2 = 1$, and from equation (2) that of the fat, tripalmitin, as $51 \text{ CO}_2 / 72.5 \text{ O}_2 = 0.70$.
- If the RQ of an animal is known, the proportions of fat and carbohydrate oxidised can then be determined from standard tables.
- For example, an RQ of 0.9 indicates the oxidation of a mixture of 67.5% carbohydrate and 32.5% fat, and the thermal equivalent of oxygen for such a mixture is 4.924 Kcal/litre.
- The mixture oxidised generally includes protein.
- The quantity of protein catabolised can be estimated from the output of nitrogen in the urine, 0.16g of urinary N being excreted for each gram of protein.
- The heat of combustion of protein (i.e. heat produced when it is completely oxidised) varies according to amino acid proportions but averages 5.3Kcal per g.
- Protein, however, is incompletely oxidised in animals because the body cannot oxidise nitrogen, and the average amount of heat produced by the catabolism of 1 g. of protein is 4.3 Kcal.
- For each gram of protein oxidised, 0.77 litres of carbondioxide is produced and 0.96 litres of oxygen used, giving an RQ of 0.8.
- In practice heat production calculate from respiratory exchange in ruminants is corrected for this effect by the deduction of 0.5 Kcal for each litre of methane.

An example of the calculation of heat production from respiratory exchange is shown below:

Calculation of the heat production from a calf using values of its respiratory exchange and Urinary Nitrogen excretion. Results of the experiment (per 24 hours)

Oxygen consumed		392.0 litres
Carbon dioxide produced		310.7 litres
Nitrogen excreted in urine		14.8 g.
Heat from protein metabolism		
Protein oxidized	(14.8×6.25)	92.5 g.
Heat produced	(92.5×4.3)	398 Kcal
Oxygen used	(92.5×0.96)	88.8 litres
Carbon dioxide produced	(92.5×0.77)	71.2 litres

Heat from carbohydrate and fat metabolism		
Oxygen used	(392.0 – 88.8)	303.2 litres
Carbon dioxide produced	(310.7 – 71.2)	239.5 litres
Non-protein respiratory quotient		0.79
Thermal equivalent of oxygen when	RQ = 0.79	4.79 Kcal/litres
Heat produced	(303.2 x 4.79)	1452 Kcal
Total Heat produced	(398 + 1452)	1850 Kcal

Measurement of Energy retention by the Carbon and Nitrogen balance Technique:

- The main forms in which energy is stored by the growing and fattening animal are protein and fat, for the carbohydrate reserves of the body are small and relatively constant.
- The quantities of protein and fat stored can be estimated by carrying out a carbon and nitrogen balance trial; that is by measuring the amounts of these elements entering and leaving the body and so, by difference, the amounts retained.
- The energy retained can then be calculated by multiplying the quantities of nutrients stored by their calorific values.
- Both carbon and nitrogen enter the body only in the food, and nitrogen leaves it only in faeces and urine. Carbon, however, leaves the body also in methane and carbon dioxide and the balance trial must therefore be carried out in a respiration chamber.
- The procedure for calculating energy retention from carbon and nitrogen balance data is best illustrated by considering an animal in which storage of both fat and protein is taking place.
- In such an animal intakes of carbon and nitrogen will be greater than the quantities excreted, and the animal is said to be in positive balance with respect to these elements.
- The quantity of protein stored is calculated by multiplying the nitrogen balance by $100/16$ ($=6.25$), for body protein is assumed to contain 16% nitrogen. It also contains 51.2% carbon, and the amount of carbon stored as protein can therefore be computed.
- The remaining carbon is stored as fat, which contains 74.6% carbon. Fat storage is therefore calculated by multiplying the carbon balance, less that stored as protein, by $100/74.6$.
- The energy present in the protein and fat stored is then calculated by using average calorific values for body tissues. These values vary from one species to another, for cattle and sheep those used are commonly 9.37 Kcal per g for fat and 5.32 Kcal per g for protein.

Results of the experiment (per 24 hours)	C(g)	N(g)	Energy (MJ)
Intake	684.5	41.67	28.41
Excretion in faeces	279.3	13.96	11.47
Excretion in urine	33.6	25.41	1.50
Excretion as methane	20.3	-	1.49
Excretion as CO ₂	278.0	-	-
	--	--	--
Balance	73.3	2.30	-
Intake of metabolisable energy	-	-	13.95

Protein and fat storage		
Protein stored	(2.30 × 6.25)	14.4 g
Carbon stored as protein	(14.4 × 0.512)	7.4 g
Carbon stored as fat	(73.3 – 7.4)	65.9 g
Fat stored	65.9 ÷ 0.746	88.3 g
Energy retention and heat production		
Energy stored as protein	(14.4 × 23.6)	0.34 MJ
Energy stored as fat	(88.3 × 39.3)	3.47 MJ
Total energy retention	(0.34 + 3.47)	3.81 MJ
Heat production	(13.95 – 3.81)	10.14 MJ

One gram protein = 23.6 J energy, one gram fat = 39.3 J energy

STUDY QUESTIONS

Fill in the blanks

1. Measurement of heat production in an animal is called as _____.
2. _____ and _____ are the two types of animal calorimeters to measure the heat production in an animal.
3. Sensible heat loss from an animal body is measured by _____.
4. The ratio between the volume of carbon dioxide produced by the animal and the volume of oxygen used is called as _____.
5. _____ and _____ are the two types of indirect calorimetry.
6. The RQ value of carbohydrate, fat and protein are _____, _____ and _____ respectively.
7. Energy retention in an animal can be measured by _____.
8. The carbon content of protein and fat are _____ and _____ % respectively.

Write the statement True or False

1. RQ value of protein is greater than carbohydrate ()
2. BMR of the animal can be measured by measuring the heat produced by a fasting animal ()
3. In adiabatic calorimeter heat loss from the inner wall to the outer wall is possible ()
4. In open circuit system the animal rebreathe the same air ()

Define the following

1. Animal calorimetry
2. Basal metabolic rate (BMR)
3. Respiratory quotient (RQ)
4. Sensible heat loss
5. Direct calorimetry
6. Indirect calorimetry
7. Thermal equivalent of oxygen

Essay

1. Animal calorimetry to measure heat production in an animal.
2. Carbon nitrogen balance technique to measure energy retention in an animal.

CHAPTER 9

PROTEIN EVALUATION OF FEEDS

Protein quality of feed in both ruminants and monogastrics

Crude Protein

The crude protein content of a feed sample is determined by estimating its nitrogen content and then multiplying by 6.25 on the assumption that protein contains 16% nitrogen. Another assumption made in this estimation is that all the nitrogen in the feed sample is contributed by protein. However feed samples also contain NPN substances which also contribute to nitrogen.

True Protein

In estimation of true protein the actual protein present in the feed sample is separated out by some precipitation method and then analysed for nitrogen as in crude protein estimation.

Digestible Crude Protein

This can be determined by carrying out digestibility trials. In this trial the feed to be tested is fed to the animal for a few days and faeces excreted by the animal is collected and weighed. Feed and faecal samples are determined for their crude protein content. Difference between the crude protein in feed and that in faeces gives digested crude protein. Digestible crude protein can be calculated as follows.

$$DCP = (\text{Digested crude protein} / \text{total feed intake}) \times 100$$

A. Protein Quality Determination in Monogastrics

Nutritive value of protein can be determined either by chemical evaluation or through biological experiments.

I. Weight Gain Methods

1. Protein Efficiency Ratio (PER):

The protein efficiency ratio normally uses growth rate as a measure of the nutritive value of dietary proteins. It is defined as the weight gain per unit weight of protein eaten and may be calculated by using the following formula.

$$PER = \frac{\text{Gain in body weight (g)}}{\text{Protein consumed (g)}}$$

2. Net Protein Retention or Ratio (NPR):

A modification of PER method, where the weight gain of the experimental group is compared with a group on a protein free diet, gives the "Net protein retention".

$$NPR = \frac{\text{Weight gain by test protein group} - \text{weight loss of nonprotein group}}{\text{Weight of protein consumed}}$$

3. Gross Protein Value (GPV)

The live weight gains of chicks receiving a basal diet containing crude protein are compared with those of chicks receiving the basal diet plus extra protein through test protein, and of others receiving the basal diet plus extra protein through casein. The extra live weight gain per unit of supplementary test protein, stated as a proportion to the extra live weight gain per unit of supplementary casein, is the gross protein value of the test protein.

$$GPV = \frac{A}{A^o}$$

Where A is g increased weight gain/g test protein, and A^o is g increased weight gain/g casein.

II. Nitrogen Balance Experiments;

1. Biological Experiments:

Knowledge of the amino acid content of proteins can only help to interpret nutritional differences among proteins in terms of their amino acid make up. Quantitative data regarding the relative digestibility co-efficient and nutritive value of protein i.e. suitability to meet the protein requirements of the body can be obtained only through experiments on animals or human beings.

Digestibility Co-efficient: Before the ingested food becomes available, it must undergo digestion during which it is broken down to simpler substances, which are absorbed in the body. Proteins differ in their digestibility. The term digestibility co-efficient of protein refers to the percentage of the ingested protein absorbed into the blood stream after the process of digestion is complete. The digestible protein in a food may be determined by digestibility trials.

For determination of digestibility co-efficient the following data are required.
1) Food nitrogen intake. 2) Total faecal nitrogen excreted and metabolic faecal nitrogen (MFN) (when an animal is fed on nitrogen free diet certain amount of nitrogen is excreted in the faeces. This is derived mainly from the digestive juices. This is called **metabolic faecal nitrogen (MFN)**).

Digestible protein figures are not entirely satisfactory assessments of a protein, because the efficiency with which the absorbed protein is used differs considerably from one source to another.

Nitrogen Balance Experiments: A more accurate evaluation of protein may be obtained by using the results of nitrogen balance experiments. In such experiments the 'N' consumed is measured as well as that voided in faeces, urine and any other 'N' containing products such as milk, wool or eggs. Where the 'N' intake is equal to the out put of nitrogen the animal is in 'N' equilibrium. Where the intake exceeds the out go,

it is in positive nitrogen balance, where the out go exceeds the intake the animal is in, negative nitrogen balance.

Biological value: It is a direct measure of the proportion of the food protein which can be utilised by the animal for synthesising body tissues and compounds and may be defined as the percentage of the nitrogen absorbed which is retained by the animal.

A balance trial is conducted in which nitrogen intake and urinary and faecal excretion of nitrogen is measured and the results are used to calculate the biological value as follows.

$$BV = \frac{N \text{ intake} - (\text{Faecal N} + \text{Urinary N})}{N \text{ intake} - \text{faecal N}}$$

Part of the faecal N is not derived from the feed but from endogenous losses and is called metabolic faecal N. Urinary N also contains a proportion of N known as Endogenous urinary N. It is N derived from irreversible reactions involved in the break down and replacement of various proteins structures and secretions. MFN and EUN can be estimated in an animal fed a nitrogen free diet. Since these fractions represent the already used up protein they have to be subtracted from faecal and urinary N losses to arrive at a more precise BV.

$$\text{True BV} = \frac{N \text{ intake} - (\text{fecal N} - \text{MFN}) - (\text{Urinary N} - \text{EUN})}{N \text{ intake} - (\text{fecal N} - \text{MFN})}$$

Animal proteins generally have higher biological values than plant proteins, although there are exceptions such as gelatine, which is deficient in several indispensable amino acids.

2. Net Protein Utilization (NPU):

The usefulness of a protein to animal will depend upon its digestibility as well as biological value. The products of these two value is the proportion of the nitrogen intake which is retained and is termed as "Net protein utilization".

$$NPU = \frac{\text{Digestibility Co-efficient} \times \text{Biological value}}{100}$$

3. Protein Replacement Value (PRV)

This value measures the extent to which a test protein will give the same nitrogen balance as an equal amount of a standard protein. Two nitrogen balance determinations are carried out, one for a standard such as egg or milk protein, which is of high quality, and one for the protein under investigation. The PRV is calculated as follows:

$$PRV = \frac{A - B}{N \text{ intake}}$$

Where A = N balance for standard protein, B = N balance for protein under investigation. The method can also be used to compare two proteins under similar conditions, when no standard value for replacement is required. The PRV measures the efficiency of

utilisation of the protein given to the animal. Other methods measure the utilisation of digested and absorbed protein.

III. Estimation of Protein Quality from Amino Acid Composition (Chemical Evaluation):

The level of individual essential amino acids in the test materials is assessed and the results are interpreted as follows:

1. Chemical Score:

- In this concept it is considered that the quality of a protein is decided by that essential amino acid which occurs in greatest deficit when compared with a standard.
- The standard generally used is egg protein.
- The content of each of the essential amino acid of the protein is expressed as a proportion to that of the standard protein.
- The lowest proportion is taken as the score of the protein.
- Eg. In wheat protein the essential amino acid in greatest deficit is lysine. The lysine content of egg and wheat protein is 72 and 27g/kg DM respectively and the chemical score for wheat protein is $27/72 = 0.37$.

Disadvantage: No account is taken of the deficiencies of amino acids other than amino acid in greatest deficit.

2. Essential Amino Acid Index (EAAI): is defined as the geometric mean of the egg or standard pattern ratios of essential amino acids. It is calculated as;

$$\text{EAAI} = \sqrt[n]{\frac{a}{ae} \times \frac{b}{be} \times \frac{c}{ce} \times \dots \times \frac{j}{je}}$$

Where a, b, c, \dots, j = concentrations (g/kg) of essential amino acids in feed protein, ae, be, ce, \dots, je = concentrations (g/kg) of essential amino acids in egg protein and n is the number of amino acids entering into calculation.

Advantage: Predicting the effect of supplementation in combination of proteins.

Disadvantage: Protein having different amino acid profile may have same or a very similar index.

IV. Biological Assay of Available Amino Acids Microbiological Methods

Certain methods have amino acid requirements similar to that of higher animals and they could be used to evaluate protein quality. The method is to study the growth of micro organism in culture media having the protein under test in it. Commonly used microorganisms are *Tetrahymena pyriformis* and *Streptococcus zymogenes*.

Protein quality evaluation In Ruminants

Crude protein: The proximate composition of the feed provides this information. However, the evaluation of feed based on the Crude protein content is not satisfactory as the utility of protein cannot be judged based on chemical composition.

Digestible crude protein: As determining the DCP of large number of foods is impracticable, Often the crude protein value of the feed and the digestible coefficient of crude protein is referred from the tables available in the literature.

Degradable Protein (RDP) and Undegradable Protein (UDP)

The quantity of protein that undergoes degradation in the rumen is called as RDP. RDP content of feed samples can be determined by various methods like in vitro methods or semi in vivo methods. The feed is allowed to incubate in the rumen liquor for a particular period of time. The protein content of feed before and after degradation is determined and the loss of protein on incubation is the rumen degraded protein.

The quantity of protein that does not undergo degradation in the rumen is called as UDP. UDP content of feed samples can be determined by various methods like in vitro methods or semi in vivo methods. The feed is allowed to incubate in the rumen liquor for a particular period of time. The protein content of feed before and after degradation is determined and the protein present in the residual feed after incubation is the rumen undegraded protein.

Metabolisable Protein: Metabolisable protein is that part of the dietary protein which is absorbed by the host animal and is available for use at tissue level. It consists partly of dietary true protein which has escaped degradation in the rumen but which has been broken down to amino acids which are subsequently absorbed from the small intestine. It also includes microbial protein, synthesised in the rumen.

Nutritive Ratio

Nutritive ratio of a particular feed may be defined as a ratio between the digestible protein and digestible non-nitrogenous nutrients (digestible carbohydrates + digestible ether extract $\times 2.25$). A feed or ration rich in digestible protein in proportion to non-nitrogenous nutrients will have a narrow nutritive ratio like groundnut cake (1:2). In rations where digestible crude protein (DCP) is low then it will have a wider nutritive ratio like in wheat straw, grass hays, etc. (1:60). In cereal grains the nutritive ratio is medium.

Calculation of Nutritive Ratio (NR)

$$\text{NR} = \frac{(\% \text{ Digestible fibre} + \% \text{ Digestible NFE} + (\% \text{ Digestible fat} \times 2.25))}{\% \text{ Digestible Protein}}$$

(Or)

$$NR = 1 : \frac{\% TDN - \% DCP}{\% DCP}$$

Calorie/Protein Ratio

There is a close association between the number of calories of metabolizable energy in the ration and the percent of protein necessary to balance the energy. The calorie/protein ratio is defined as the metabolizable energy kcal per kilogram divided by the percentage of crude protein in the ration. The ratio varies with species of animal, the age of animal and physiological status.

A ratio of energy to protein exerts an influence on feed intake and feed efficiency. The calorie/protein ratio influences over consumption of feed and body composition. High-energy rations need to have increased concentration of nutrients to avoid nutrient deficiencies since feed intake will be low on such diets. Similarly on low energy diets the nutrients density may be diluted because of higher intake of feed on such diet.

Suggested calorie/protein ratio (Kcal ME / % protein) in poultry rations.

Broiler starter (0-5 weeks)	132-142
Broiler finisher (after 5 weeks)	152-165
Chick starter (0-8 weeks)	140-145
Chick grower (8-18 weeks)	170-190
Layer 70% production	185-190
Layer 90% production	175-183

STUDY QUESTIONS

Fill in the blanks

1. All proteins on an average contain _____ % nitrogen.
2. Nitrogen content of a feed is multiplied by a factor _____ to calculate the crude protein content.
3. To calculate the digestible crude protein value, crude protein is multiplied by _____.
4. Net protein utilization is the product of biological value multiplied by _____.
5. _____ and _____ are the microorganisms used for the microbiological assay of protein.
6. _____ and _____ are the two methods used to evaluate the protein quality in ruminants.
7. Protein degraded in the rumen is called as _____.
8. The nutritive ratio of groundnut oil cake and paddy straw are _____ and _____ respectively.

9. Nitrogen intake exceeds the outgo, the animal is in _____ nitrogen balance whereas nitrogen outgo exceeds the intake, the animal is in a _____ nitrogen balance.
10. Wide calorie protein ratio in a broiler ration leads to deposition of more _____ in the carcass.
11. Chick ration must contain _____ calorie protein ratio.

Define the following

1. Crude protein (CP)
2. Digestible crude protein (DCP)
3. True protein
4. Essential amino acid index (EAAI)
5. Digestibility coefficient
6. Protein efficiency ratio (PER)
7. Net protein ratio (NPR)
8. Gross protein value (GPV)
9. Biological value (BV)
10. True biological value
11. Net protein utilization (NPU)
12. Rumen degradable protein (RDP)
13. Undegradable dietary protein (UDP)
14. Nutritive ratio (NR)
15. Calorie protein ratio
16. Metabolic faecal nitrogen (MFN)
17. Endogenous urinary nitrogen (EUN)
18. Metabolizable protein

Short notes

1. Nutritive ratio
2. Biological value and true biological value
3. Calorie protein ratio

Essay

1. Discuss in detail about various protein evaluation methods for monogastric animals.
2. Write an essay on different protein evaluation methods for ruminant animals.

CHAPTER 10

FEED TECHNOLOGY - FEED INDUSTRY AND PROCESSING OF CONCENTRATES AND ROUGHAGES

Feed technology may be defined as the application of physical, chemical, biochemical, biological and engineering techniques to increase the nutrient utilization of feeds and fodders in animal system for the development of livestock and poultry and feed industry. It deals with processing of feeds, fodders and preparation of formula feeds for which the knowledge of nutritional requirements of various livestock and poultry, quality control of feed ingredients, feed plant management and the storage of feed ingredients and feeds are essential.

The growth of commercial feed industry has been closely tied to the introduction of new byproducts. The Association of American Feed Control Officials (AAFCO) which was established in 1909, defined 38 ingredients in its official publication published in 1911 and 440 in 1969 and more than 540 ingredients in 1985 publication.

Development of Feed Industry in India

Feed industry came into existence in India in 1961 with the establishment of a feed plant in Ludhiana, Punjab. Compound Livestock Feed Manufacturers Association (CLFMA) was formed on 1967, and it is sole, national, representative body of compound animal feed manufacturers in India.

Processing of Feeds and Forages;

The processing of feeds is primarily for;

- 1. To make more profit:** Feed efficiency can be routinely improved as much as 10% and occasionally as much as 15 to 20 % by changing the method of grain processing.
- 2. To alter particle size:** some feeds need to be reduced in size to increase their intake or digestibility, e.g. grinding. In some instances, particle size is increased by pelleting or cubing to overcome dust problem.
- 3. To change moisture content:** the moisture content of a feedstuff may need to be changed to make it safer to store (reduced to 10 % level), more palatable, more digestible, or to prepare it for other processes.
- 4. To change the density of feed:** Bulky feeds (low density feeds) reduce feed intake. These are sometimes prepared for the purpose of limiting energy intake. Very bulky feeds are pelleted or cubed to increase energy density and feed consumption. Transportation cost is reduced and storage space required is less.
- 5. To change palatability:** Feeds are processed to increase acceptability and feed intake. Molasses, flavours and fats are added. Processing may be used to decrease palatability and limit feed consumption. E.g. Salt-feed mixtures.

6. **To increase nutrient content:** When used alone and in their natural state, few feedstuffs meet the nutrient requirements of the animals.
7. **To increase nutrient availability:** Starch and protein appear to be less available in jowar than in other grains; but gelatinization of the starch granules by pelleting rendering them more digestible.
8. **To detoxify or remove undesirable ingredients:** the toxicity of linseed meal can be removed by adding 2 or 3 parts of water to the meal and allowing it to stand for 12 to 18 hours at a temperature between 22 to 37°C.
9. **To improve keeping qualities:** High moisture grains may be preserved by either drying or chemical treatment (adding an organic acid).
10. **To lesson moulds, salmonella, and other harmful substances:** Proper harvesting, drying and storage of feed resources are important factors in lessoning Aflatoxin contamination and toxin production. Propionic and acetic acids will inhibit mould growth. Hence, they are used increasingly in the preservation of high moisture grains.

Processing Methods of Grains;

Dry Processing	Wet Processing
Grinding	Soaking
Dry rolling	Steam rolling
Popping	Steam processing & Flaking
Micronizing	Pressure cooking
Extruding	Exploding
Roasting	Pelleting
	Reconstitution

I. Dry Processing Methods;

1. **Grinding:** It is the simplest, commonly used least expensive grain processing for its particle size reduction. Modulus of uniformity is expressed as a ratio of course, medium and fine particles in ground feed (optimum ratio is 1:6.3). Modulus of fineness of ground grains varies from 1 to 7; it decreases with decrease in the particle size of ground feed.
2. **Dry rolling:** Rolled or cracked grains are usually prepared by passing the grain through a roller mill by crushing. Their physical properties would be very similar to that of grains coarsely ground in a hammer mill. Wheat and barley are dry rolled for beef cattle rations.
3. **Popping (Puffing);** Popping is produced by the action of dry heat (370 - 425 ° C for 15 to 30 seconds) causing a sudden expansion of the grain which rupture the endosperm and this results in rupture of starch granules and makes the starch more available to rumen micro organisms and/or to the animals.
4. **Micronizing;** It is similar to popping except heat is furnished in the form of infra-red energy.

- 5. Extruding;** Extrusion cooking technology is become popularfor manufacturing fish feeds since product densities can be readily controlled and so the feed is utilized by fish completely. Density of expanded and gelatinized feed is 20 to 30 pounds per cubic feet.
- 6. Roasting;** It is accomplished by passing the grain through flame resulting in heating to about 300°F and some expansion of the grains which produces a palatable product.

II. Wet Processing Methods;

- 1. Soaking;** Grains soaked for 12 – 24 hrs in water has long been used for livestock feeding. Soaking of mustard cake, neem seed cake in water and offering of filtered product eliminates the toxic effect since the toxic factors are soluble in water.
- 2. Steam rolling;** the grain is subjected to live steam for different periods of time depending upon the pressure used prior to rolling. Pressure preconditioning of grains prior to rolling increases gelatinization of starch to 45 - 50 %. Steam rolled grains are usually less dusty than dry rolled grains.
- 3. Steam processing and flaking;** The process is a modification of steam rolling to which rigid quality control standards are practiced. After steam treatment, grain is passed through the roller mill. The tolerance set between the rollers depends upon the flatness of the flake desired. If the steam processed and flaked material is to be stored for more than one day, it must be dried.
- 4. Pressure cooking;** Pressure cooked grains are similar to steam processed and flaked grain. Grains are cooked with live steam at 50 psi for 1.5 minute in air tight pressure chambers. Temperature of 300°F is obtained. The temperature is reduced to below 200°F and the moisture to 20% bypassing them through cooling and drying tower prior to flaking. Pressure cooked flakes are less brittle and don't break.
- 5. Exploding;** It is accomplished by subjecting the grain to high pressure steam (250 psi) for about a very short time (20 sec.) followed by sudden decrease to atmospheric pressure. This results in rapid expansion of the grain kernels.
- 6. Reconstitution;** Reconstituted grain is mature grain (10 % moisture) to which water is added to raise the moisture level to 25 – 30 % and the wet product is stored in an oxygen limiting silo for 14 - 21 days prior to feeding. It will increases the solubility of the grain protein.
- 7. Pelleting;** Pelleted feeds are agglomerated feeds formed by extruding individual ingredients or mixtures by compacting and forcing through die opening by any mechanical process with application of optimum amounts of heat, moisture and pressure. The normal size of pellets is 3.9 mm to 19 mm though the maximum used diameter is 6.25 to 9.40 mm.

Processing Methods of Roughage;

Dry Processing	Wet Processing
Baling	Green Chopped
Field Chopped	Soaking
Grinding	
Pelleting	
Cubing	
Dehydration	

- 1. Baling;** The forage is cut and permitted to dry in the field. Dried forage is then baled with a stationary or field baler.
- 2. Cubing;** It is modification of wafer production. Density of long hay is 7 lb/cft while density of cubed hay and density of pelleted hay are 25-32 lb/cft and 40 lb/cft, respectively. Most of the cubing is done with excellent quality alfalfa hay.
- 3. Grinding;** Grinding of roughages is a prerequisite for mixing and pelleting. Roughage should ground to 1 - 2" long for roughage feeding alone or from 0.5 to 1.0" when it is to be incorporated in complete rations.
- 4. Pelleting;** Roughages are usually ground before they are pelleted, size of the pellets range from 12/64" to 48/64". Pelleted roughages weigh about 40 lb /cft as compared to 5 – 6 lb/cft for long hay.
- 5. Dehydration;** green forages such as young growing alfalfa / Lucerne can be preserved by dehydrating the forage at high temperature (600 - 1500°F) in a dehydrator for a short time (3 – 5 min.). this method of forage preservation retains a maximum amount of dry matter and protein, and there is no loss of leaves in the process.

Physical, Chemical and Biological Methods of Processing Inferior or Poor Quality Roughages to Improve their Nutritive Value;

Physical	Chemical	Biological	Combination
Soaking	Acid treatment	SCP production	Physico chemical
Grinding	Alkali treatment	Use of cellulolytic organisms	Karnal process
Steam pressure	Use of other chemicals-	Mushroom Growth	
Explosion	Ozone,H ₂ O ₂		
Irradiation			
Pelleting			
Supplementation			

I. Physical treatment

Soaking – Chopped straw is soaked in water overnight. Softens the straw leading to increased intake. Disadvantage is mould growth.

Chaffing - Decreasing particle size. Increases surface area for action of rumen microbes and hence increase digestibility.

Grinding - Particle size reduced still further. (0.1 to 0.3 cm). Disadvantage is that it increases rumen flow rate, decreases retention time in the rumen leading to decreased production of acetate causing a condition of low milk fat syndrome.

Steam pressure - Straw treated with Steam at pressure of 21.1 kg/cm^2 for 10 to 30 seconds. Causes rupture of ligno cellulosic bonds to a certain extent and makes cellulose available for microbial action.

Explosion - Chopped or ground straw is treated with steam at pressure of 22.5 kg/cm^2 for two minutes and pressure is suddenly released. Causes rupture of ligno cellulosic bonds to a certain extent and makes cellulose available for microbial action.

Irradiation - Straw is treated with γ irradiation. Causes rupture of ligno cellulosic bonds and makes cellulose available for microbial action.

Pelleting - Particle size reduced to 0.1 to 0.3 cm and pelleted through 1-2 cm die. Retention time in the rumen increases and the disadvantage of only grinding is overcome.

II.Chemical Treatment

Acid treatment - Straw is soaked in dilute acids for a specified period of time, washed with water drained and fed to the animals. Not popular due to the corrosive action of acids. Causes rupture of ligno cellulosic bonds and makes cellulose available for microbial action.

Alkali treatment - Straw is treated with NaOH, NH₄OH, CaOH, KOH, Urea.

When straw is exposed to the alkali the ester linkages between lignin and cellulose / hemicellulose are hydrolysed causing the cellulose / hemicellulose to be available for digestion by microbes.

NaOH treatment

Beckman Process: Straw is soaked for 1-2 days in dilute solution of NaOH (15-30 g / litre), washed to remove excess alkali and fed to the animals.

Dry Method: Straw is chopped and sprayed with NaOH 300g/ litre (170 litre / tonne of straw).

Ammonia Treatment:

Anhydrous form or concentrated solution used - 30 to 35 kg/ tonne of straw. Straw is stacked, ammonia solution is sprayed over the straw, kept covered for 20 days and then fed to the animals. This method not only increases the digestibility of the straw it also increases the nitrogen content of it. Disadvantage - On opening the stack most of

the ammonia is lost by volatilization. Sometimes there is formation of toxic imidazoles from reactions between ammonia and sugars leads to dementia (Bovine bonkers)

Procedure for preparing Urea Enriched Paddy Straw

Required Materials:

1. Paddy straw - 100 kg.
2. Urea - 4 kg.
3. Water (Clean) - 65 litres
4. Spinkler

Procedure:

To enrich 100 kg of paddy straw

1. Dissolve 4 kg urea in 65 litres of water
2. Spread a polythene sheet/Gunny bag on the floor. Initially spread 5 kg of paddy straw in layers.
3. Using the sprinkler, sprinkle the prepared urea solution over the paddy straw ensuring that all the paddy straw is wet by it.
4. Similarly spread another layer of paddy straw over the first layer and repeat the sprinkling of urea solution.
5. Repeat the spreading and sprinkling for the entire 100 kg of paddy straw and heap it and cover the straw with polythene sheets to prevent the escape of ammonia libareted from urea. This step facilitates the breakage of lignocellulose bond by ammonia thereby releasing cellulose from lingin bondage for digestion and utilisation.
6. After 21 days the urea treated paddy straw is ready for feeding available.

Advantages:

TDN increased from 45 to 60%

CP increased from 2% to 10%

Palatability increased therefore feed intake increases.

Feeding Urea treated Paddy Straw:

- It is advisable to feed the urea treated Paddy Straw for calves above 6 months of age
- Adaptation period is required. The same precautions adopted when feeding NPN substances are to be followed.
- The urea enriched paddy straw, may be left in the open for 5 minutes prior to feeding in order to remove the pungent odour of urea.

Biological treatment

1. Growing cellulolytic microorganisms white rot fungi (*Trichoderma viride*, *Trichoderma lignorum*).
2. Growing mushrooms: Straw is steam treated, packed in polythene bags, inoculated with seed material of mushroom, bag when filled with mycelia slit open to allow fruiting, after harvesting of mushrooms the spent straw is used as feed.
3. Single cell protein production: Straw is hydrolysed, steam treated, treated with ammonia, inoculated with *Candida utilis* and incubated, after harvesting of SCP the spent straw is used as feed.
4. Enzyme treatment- pretreatment of straw with lignase
5. Preparation of silage - Straw sprayed with water, additives such as molasses added and ensiled in a silo. Nitrogen content is increased by adding urea or poultry manure.

The above treatments cause biodegradation of lignin and increases the digestibility of cellulose. They also increase the protein content of the straw.

Karnal process: Technology developed at NDRI, Karnal. Straw treated with 4% urea at moisture level of 60%. Stacked in a silo pit under cover for 30 days. A temporary loose brick structure constructed. Thin layer of urea treated straw spread evenly in this structure. A solution of the following composition is prepared. 60g superphosphate, 60g calcium oxide dissolved in 8 litre water. Sprinkled over the urea treated straw. Inoculated with 3% *Coprinus fimerarius* culture. Allowed to remain for 5 days then used for feeding. Main advantage of this process is that urea a NPN compound is converted into microbial protein and degradation of lignin.

Effect of various treatments

- Increases palatability
- Increases digestability
- Certain treatments increase nitrogen or protein content
- Improves animal performance

Disadvantage

- Increase feed cost Created by Nutrition Attention:
- Technology or methodology involved

STUDY QUESTIONS

Fill in the blanks with suitable words

1. Soaking of straw reduces _____ and improves_____.

2. Grinding of straw reduces the production of _____ VFA in the rumen which results in low milk fat syndrome.
3. Alkali treatment of straw breaks the bond between _____ and _____ thereby improves the digestibility of fibre.
4. _____ and _____ are the chemicals used to treat the poor quality roughages to improve their digestibility.
5. _____ is a gas used to improve the nutritive value of crop residues.
6. For chemical treatment of every 100 kg of straw, the amount of urea required is _____ kg.
7. Urea treatment of straw not only improves digestibility of nutrients, it also improves _____ content.
8. _____ is a fungi used for the biological treatment of straw to improve the nutritive value.
9. Straw available after the cultivation of mushroom is called as _____.
10. Urea treated straw can be fed only to _____.

Write the statement True or False

1. Soaking of straw in water improve its digestibility ()
2. Urea treated straw can be fed to calves below 4 months of age ()
3. Protein content of poor quality roughages can be improved by urea treatment ()
4. Wet method of alkali treatment leads to loss of more dry matter ()

Define the following

1. Chaffing
2. Grinding
3. Pelleting
4. Irradiation
5. Biological treatment of straw
6. Explosion
7. Spent straw

Short notes

1. Physical methods of improving nutritive value of poor quality roughages.
2. Explain the practically feasible method to improve nutritive value of paddy straw.
3. Karnal process of straw treatment.
4. To improve the nutritive value of straw, urea treatment is more preferable than sodium hydroxide treatment. Explain.

Essay

1. Write an essay on physical, chemical and biological methods improving nutritive value of poor quality roughages.
2. How the feeding value of poor quality roughages and crop residues can be improved?

CHAPTER 11

PREPARATION, STORAGE AND CONSERVATION OF LIVESTOCK FEED THROUGH SILAGE AND HAY AND THEIR USES IN LIVESTOCK FEEDING

Silage

Silage is the material produced by the controlled fermentation of a crop of high moisture content.

Ensilage is the name given to the process.

Silo is the container used to prepare silage.

Methods of Silage Making

This involves the following steps.

A. Preparation of forage

The crops which can be used for silage making generally harvested at the proper stage of maturity, cut to proper length, control the moisture content, add an additive or preservative when needed, fill rapidly, distribute forage uniformly in the silo and seal the silo.

The crop for silage making is generally harvested at the flowering stage when it has the maximum amount of nutrients. Silage materials containing less than 25 % dry-matter (more than 75 % moisture) will form a very sour silage juices during storage, incurring a considerable loss of nutrients. Thus, plants for silage making should be allowed to mature till the dry matter content attains 35-40 per cent.

Silage material should be cut to a proper size in order to fit it in silo and ensure good quality of silage. The length varies from a fraction of an inch to over an inch in length.

Moisture content of silage material beyond 60 - 65 % is not desirable. In such a condition, it will be costlier to handle, susceptible to decay and loss of juices and nutrients. Due to high acidity a large amount of silage near the wall is spoiled. Fresh grass should be wilted for 3 to 4 hours on a good sunny day.

B. Addition of preservatives

Preservatives are those materials which are mixed with the silage material to improve the quality. Some important functions of the preservatives are given below.

1. They supply nutrients.
2. Provide fermentable carbohydrates.
3. Furnish additional acids which are essential for proper fermentation.
4. Inhibit the growth undesirable types of bacteria and moulds.
5. Reduce the amount of oxygen present in silos.
6. Reduce the moisture content of silage if it is too high.
7. absorb some acids which might otherwise be lost in seepage.
8. Increase nitrogen content of silage.

Some important preservatives are discussed below.

1. Molasses

When the lactic acid in silage is about 1-2%, the product is invariably well preserved and palatable because the pH value is usually below 4 and there is no butyric acid. About 1 to 2 % sugar is required to produce this amount of lactic acid. The common and cheapest source of sugar for silage making is molasses.

2. Urea

Adding urea at the rate of 0.5 % of fresh forages is to enrich the silage with nitrogen as cereal forages are mostly deficient in this element.

3. Limestone

This is calcium carbonate and may be added at a level of 0.5 to 1.0% to maize silage to increase acid production. It neutralizes some of the initial acids as they are formed, allowing the lactic acid bacteria to perform longer and to produce more desirable acids.

4. Sodium metabisulfite

This chemical preservative causes partial sterilization. It is spread over the silage material in powder form, at the rate of 4 to 8 kg per tonne of forage. It evolves sulphur-dioxide gas which keeps down the bacterial population. Sometimes, however, it causes undesirable fermentation.

5. Salt

Salt makes the silage more palatable. It does not inhibit bacterial activity.

6. Addition of acids

Some organic acids especially propionic and formic acids are used in sufficient quantities as the crop is being filled into the silo to bring the pH value immediately to about 4.0 to 3.5.

C. Filling the silo

The material should be trampled, especially well near the walls of silo. It is believed that keeping the centre higher than the outside while filling the upper part of the silo loosens the tendency of the silage to draw away from the wall as it settles. To avoid a large amount of spoilage at the top, the silage should be leveled off and trampled thoroughly from the lower few metres.

The filling of the pit should be completed within the least possible time say one or two days. To create favourable anaerobic condition inside the silo, adequate compression of the material through trampling is essential. It helps in driving air pockets from the silo which may otherwise spoil the silage.

D. Covering and sealing the silo

It is essential to keep off air from the silage materials of silo. An anaerobic atmosphere in the silo is essential for proper fermentation of silage. Therefore, the silo, should be covered with wet straw, sawdust or other materials and plastered with 15-30 cm thick layer of clay soil. If possible, put plastic sheet before plastering with soil. After covering, weights such as paving slabs, concrete posts, concrete cylinders and wooden logs should be kept for better compression.

E. Opening the silo

The silage is ready within the three months time begining from covering of silo. In case of tower and trench silos, excavation should begin from the entire top surface and in case of bunker silo, silage can be taken out from the front side. After opening it becomes necessary to fill the pit completely.

Fermentation in silo

The process of fermentation can be divided into four phases

Phase I: Aerobic phase, plant enzymes continue their action utilising soluble carbohydrates and breaking it down to CO₂ and H₂O.

Phase II: Action of Enterobacter species of bacteria on soluble carbohydrates producing acetic acid and lowering the pH marginally.

Phase III: Action of lactic acid producing bacteria (Lactobacillus and Streptococcus spp) fermentation of soluble carbohydrates present in the plant material to lactic acid, resulting in a lowering of pH .

Phase IV: Lactic acid production reaches a peak and stabilises to within the region of 3.8 – 4.2. At this pH the crop is preserved.

Phase V: Due to unfavourable conditions or if rain is allowed to enter the silage (or) if lactic acid concentration is inadequate, then a secondary clostridial fermentation is likely to occur. The lactate fermenting clostridia cause a break down of the lactic acid with the production of butyric acid. Proteolytic clostridia attack amino acids, with the formation of ammonia, organic acids, amines and CO₂.

An entirely different process of silage making involves the sterilisation of the mass in the silo by adding **chemical sterilisation** agents such as formaldehyde, sulphur dioxide or sodium metabisulphite. The success of this method depends largely upon ensuring adequate mixing with the crop, which may often be difficult in practice. If satisfactory sterilisation is achieved and provided effluent production is not great, the nutritive value of the preserved material should be very similar to that of the original herbage.

Another method of preserving herbage is by the direct acidification of the crop, and one such system is the finished **A.I.V. process**, named after originator A.I.Vittanen. The mixture of acids used in this process varies, but generally consists of HCl & H₂SO₄. These acids are added to material during ensiling in sufficient quantity to lower the pH value below 4. The resultant product may appear to be a very unnatural food for farm animals, but provided the correct amount of acids is properly, distributed through out the ensiled material no free mineral acids occur. A.I.V. silage has been shown to be palatable and harmless to ruminants even when as the sole item of diet.

Factors affecting the nutritive value of silage

Chemical changes:

1) Plant enzymes:

In the first category the main changes are caused by aerobic respiration, which will continue, as long as oxygen is present, until the plant sugars are depleted. Sugars are oxidised to carbondioxide and water, with the production of heat causing a considerable rise in temperature of the mass.

Apart from carbohydrate break down, proteolysis also occurs immediately after the herbage is cut. Protein is rapidly broken down to simpler substances mainly amino acids.

2) Microorganisms:

After aerobic respiration has ceased, microbial changes continue. Fresh herbage contains bacteria on its surface, and these organisms multiply, using the contents of a cell as medium. As a result of this activity many chemical components of the grass are broken down. Where conditions are favourable for bacteria which produce lactic acid, the acidity of the mass increases until, at about pH 4.0 – 4.2 organisms other than the lactic acid bacteria are inhibited as long as conditions remain anaerobic.

Nature of crop:

In order to obtain silage of high nutritive value, grass should be cut shortly after, the ear emergence stage of growth as digestibility falls rapidly with increasing herbage maturity.

High protein grass crops and legumes are difficult to ensile satisfactory, because of **low soluble carbohydrate** content and because of their high buffering capacity. If the soluble carbohydrate content of the crop is known to be a limiting factor, then a sugar additive, such as molasses, may be sprayed on to the crop at the time of filling the silo.

The physical nature of the crop at the time of ensiling is important factor in the fermentation process, and it is known their chopping or brushing tends to produce more favourable condition for microorganism activity than leaving the material long.

Losses of Nutrients during ensilage:

Field losses: With crops cut and ensiled the same day, nutrient losses are negligible and even over a 24 hours wilting period losses of not more than 1 or 2% dry matter can be expected. Dry matter losses as high as 6% after 5 days and 10% after 8 days wilting in the field have been reported. The main nutrients affected are the water soluble carbohydrates and protein which are hydrolysed to amino acids.

Oxidation losses: These result from the action of plant and microbial enzymes on substrates such as sugars in the presence of oxygen, leading to the formation of CO₂ and water.

Effluent losses: In most silos, free drainage occurs and the liquid (or) effluent carries with it soluble nutrients. The amount of effluent produced depends largely upon the initial moisture content of the crop, but it will obviously be increased if the silo is left uncovered so that rain enters. Effluent contain sugars, soluble nitrogenous compounds, minerals and fermentation acids all of which are of high nutritional value. Crops ensiled with a dry matter content of 15% may result in effluent dry matter losses as high as 10%, whereas crops wilted to about 30% dry matter produce little, if any, effluent.

Silos and other containers

The container in which the silage made is of greatest importance and will determine to a large extent the nature and quality of the final product. The size of the container will generally depend upon the number and kind of animals to be fed from it, and its height on the length of the feeding different types of silos have been designed.

Clamp silo

In silo, greater part of crop remains above ground and the rest remains in slight excavated trench or pit. In addition the clamp will be long and narrow, and low in relative to length.

Pit silo

The pit silo is cylindrical or rectangular and its shape is like that of clamp silo, but extends below ground. The pit can be excavated in any suitable soil, not subjected to waterlogging. If silage is to be made annually, it better to have a concrete floor, making provision for effluent to escape. The dimension of the pit varies with circumstances and the number of stock to be fed. A pit of average width of 4m and with silage settled to a depth of 2m will hold 1½ m tonnes of silage for each 30 cm length.

Advantages of pit silo

1. A pit silo is very economical to build
2. Owing to its depth and shape, the pit silo has a large capacity for its size
3. Less power is required for filling
4. The smooth plastered walls allows the silage to settle and retain the juices
5. Pit silo if kept in good condition will last indefinitely.

Disadvantage of pit silo

1. It is inconvenient to take out the feed

2. The pit silo occupies farm land which is permanently inaccessible for cultivation, and requires lots of labour.
3. The main difficulty is to ensure adequate compression, since depth of the silage is always out of proportion to the area covered in strong contrast to the tower silo.

Trench silo

The difference between the pit and the trench silo is merely one of size, the latter usually having greater length in relation to breadth. The process of ensiling is more or less similar to that for pit silo.

Advantages of trench silo

1. Horses, cows (or) tractors can be used to pack the silage
2. Power required for filling the trench silo is less
3. It is well adopted to the ensilage of immature corn and emergency feeds
4. The major part of the material conserved will settle into the trench below ground level, the chance of air getting in is reduced to a minimum.
5. Unloading and carrying of silage are much easier.

Disadvantages of trench silo

1. Once constructed, it is not easy to abandon
2. More silage is spoilt
3. The trench silo must be trimmed upon the edges and cleaned up if the silage is to be kept best.

Tower silo

It is round, cylindrical and is placed above the ground the height varies from 6 to 10m or more with a varying diameter (6 to 10m). The erection of such a silo is expensive. The material used include wood, reinforced concrete or sheet metal. Use of wood is of much advantage is that it is not affected by silage acids, on the other hand wood tends to preserve it. For filling up the silo a chopper blower is necessary. In this type 3 types of silage are found

1. In the bottom third it will be over compressed sour and will give out smell of butyric acid
2. In the centre it will be good, not too tightly packed and yet compressed well enough to give well-preserved material.
3. In the top third it is often dark and over heated, near the surface it will be of low value, perhaps with some moulds. In the tower silo, the sealing is not much important as the pit silo.

Advantages

1. Material can be well preserved, with no wastage due to air leakage
2. Wilting of crop and the sealing of silo are not as important as in pit silo, because the mass itself applies pressure and acts as an air seal to the lower layer.
3. The loss of dry matter is minimal

Disadvantages

1. It is very expensive to make
2. Chopper blower is needed for filling up of the silo
3. Emptying is very laborious
4. In dry hot places the silage gets dehydrated

Tube Silo

The grass is filled in plastic cylindrical tubes of varying capacity.

Advantages

Does not occupy permanent location, can be shifted to various location with ease.

Disadvantages

Requires machinery to fill as well as to evacuate the silo.

Additives used in silage making

In order to regulate the microbial activity various additives can be used during ensiling. They may be grouped as

Fermentation stimulants - Culture of lactic acid producing bacteria, soluble carbohydrate sources.

Fermentation inhibitors - Inorganic acids, sterilants (antibiotics, Sodium metabisulphite, Formaldehyde) and organic acids.

Others - Urea, limestone, poultry manure etc.

Haylage

Haylage, sometimes called low moisture silage is a preserved forage with characteristics between those of hay and silage. It is made from grass and/or legume to a moisture level of about 45-55% when harvested (or) wilted to this level. If the harvested forage is having higher moisture percent, it should be brought down before ensiling. It must be preserved by processes somewhat different from those for wilted or unwilted silage. The silos should be well constructed and as airtight as possible so the oxygen present is soon used up, the CO_2 that is produced is trapped and held within the silo. These conditions prevent the forage from spoiling by moulding, oxidising, heating etc. Air exclusion likely to the success or failure of making low moisture silage.

Advantages

1. Properly made haylage, has a pleasant aroma palatable high quality feed. Animals usually received more dry matter and feed value than silage made from the same cut.
2. If forage is moved, with the intention of making hay and weather becomes unfavourable for drying, the partially dried forage can be made into haylage.

Disadvantages

- With haylage, fine chopping, good packing and complete sealing against air entrance inside the silo is a must and more critical than with silage.
- The danger of excessive heating which lowers protein digestibility is more acute in haylages than silages.

Characteristics of a good silage

1. VERY GOOD SILAGE

It is clean, the taste is acidic, and has no butyric acid, no moulds, no sliminess nor proteolysis. The pH is between 3.5 and 4.2. The amount of ammonical nitrogen should be less than 10 per cent of the total nitrogen. Uniform in moisture and green or brownish in colour. Taste is pleasing, not bitter or sharp.

2. GOOD SILAGE

The taste is acidic. There may be traces of butyric acid. The pH is between 4.2 and 4.5. The amount of ammoniacal nitrogen is 10-15 per cent of the total nitrogen. Other points same as of very good silage.

3. FAIR SILAGE

The silage is mixed with a little amount of butyric acid. There may be slight proteolysis along with some mould. The pH is between 4.5 and 4.8. Ammonical nitrogen is 15-20 per cent of the total nitrogen. Colour of silage varies between tobacco brown to dark brown.

4. POOR SILAGE

It has a bad smell due to high butyric acid and high proteolysis. The silage may be infested with moulds. Less acidity, pH is above 4.8. The amount of ammonical nitrogen is more than 20 per cent. Colour tends to be blackish and should not be fed.

Hay

The aim in hay making is to reduce the moisture content of the green crop to a level low enough to inhibit the action of plant and microbial enzymes. In order that a green crop may be stored satisfactorily in a stack or bale, the moisture content must be reduced to 15-20%.

Process of hay making in steps

Selection of crop – Soft pliable stem

- Harvesting of crop – Preflowering stage
- Drying of crop – Natural drying or artificial drying

Schedule for harvesting and curing of hay

For efficient production of good quality hay the crop should be harvested early in the morning and left in the **field** as such for curing. Drying the harvested crop in the field is continued until the moisture content is reduced to about 40%. During the process of drying frequent turning is necessary to facilitate uniform drying. Usually in autumn it may take 2 to 3 days for field airing but in dry summer months the duration can be still less. At the end of 1st day, turn the grass with the side rake into small fluffy **windowrows**. On the 2nd day, turn the windowrows and watch its state of drying to note its readiness for staking or fit to be baled straight from the windowrows. Caution is needed to store them in well ventilated place as otherwise, possibility of catching fire exist. In case, if the windowrows require still more drying they may be placed **over tripods or tetrapods** or over the **fence**.

Characteristics of good hay

- Hay must be leafy and green and have soft and pliable stems.
- It should be free from mustiness or mould and be palatable.
- It should be free from any weeds and should have the aroma of the original crop.
Hay should be prepared out of herbage, cut at a stage nearing maturity, preferably at the flowering stage when it has the maximum of nutrients. Delay in cutting would mean losses of a part of nutrients which would be used up by the plant in seed formation.
- Hay should be green in colour. The green colour of leaves indicates the amount of carotene which is a precursor of vitamin A.
- Hay of average quality will usually run from 25-30 per cent crude fibre and 45-60 per cent TDN.

Factors influencing the nutritive value of Hay

Chemical changes	Plant species	Stage of cutting	Mechanical damage	Changes in stack
Plant & microbial enzymes	Oxidation	Leaching	Microbial action	

I. Chemical Changes

a. Plant & microbial enzymes

As a result of plant enzyme respiration, sugars are oxidised to CO₂ and H₂O with the result increase in concentration of cell wall constituents especially cellulose and lignin. Protein are also altered by the action of plant enzymes. Due to proteolysis free amino acids are formed and can be lost due to leaching.

b. Oxidation

When herbage is dried in the field a certain amount of oxidation occurs. The visual effect of this can be seen in the pigments many of which are destroyed eg. carotene. On the other hand sunlight has a beneficial effect on vitamin D content in the hay, because of irradiation of ergosterol present in green plant.

c. Leaching

It causes loss of soluble minerals, sugars and nitrogenous constituents. It may also encourage the growth of moulds.

d. Microbial action

If drying is prolonged because of bad weather conditions, changes brought about by the activity of bacteria and fungi may occur. Mouldy hay is unpalatable, and may be harmful to farm animals and man because of the presence of **mycotoxins**. Such hay may also contain actinomycetes which are responsible for the allergic diseases affecting man known as farmers lung.

II. Plant species

Hay made from legumes are generally rich in protein and minerals than grass hay. Non legume hay has more carbohydrate but is less palatable. The other advantage being high yielding quality of these crops. The quality of mixed hay depends on the species and proportion of the mixture of leguminous crop in the hay.

III. Stage of growth/cutting

The stage of growth of the crop at the time of cutting is the most important factor determining the nutritive value of the conserved product. The latter the date of cutting the larger will be the yield, the lower the digestibility and net energy value and the lower the voluntary intake of dry matter by animals. It follows that if the drying conditions are similar hays made from early crops will be of higher nutritive value than hays made from mature crops.

IV. Mechanical damage

During the drying process the leaves lose moisture more rapidly than the stems, so becoming brittle and easily shattered by handling, handling of the hay during early morning minimized the loss of leaves.

Another way to reduce shattering of leaves is by brushing or flattening of the herbage through which uniform drying is possible.

V. Changes during storage

At a higher moisture level during stacking, chemical changes brought about by the action of plant enzymes and micro organism are likely to occur. There may be oxidative degradation of sugars, although hexoses may also combine with amino acids or proteins. This chemical combination is probably partly responsible for dark brown colour observed in overheated hays. Browning has been observed at temperature as low as 32°C.

Dried grass/Artificially dried forages

The process of artificial drying is a very efficient, though expensive, method of conserving forage crops. The drying is brought about by allowing the herbage to meet gases at a high temperature which varies with the type of drier used. In the 'low-temperature' type equipment, the hot gases usually at a temperature of about 150 °C, the drying time varies from about 20 to 50 minutes depending upon the drier design and the moisture content of the crop. With high temperature design the temperature of gases is initially within the range of 500-1000°C, the time taken to pass through the drier varies from about 0.5 to 2 minutes.

STUDY QUESTIONS

Fill in the blanks

1. _____ and _____ are the two common techniques of fodder preservation.
2. _____ is the container used to prepare silage.
3. The process of making silage is called as _____.
4. The process of reducing moisture is called as _____.
5. The optimum stage of harvesting fodder crops for the preparation of silage is _____.
6. A.I.V method of silage making was developed by _____.
7. Time required for the conversion of fodder into silage is _____.
8. Good quality silage should have a pH value of about _____.
9. Silo located below the ground level is called as _____.
10. _____ and _____ are the fermentation stimulants added at the time of ensiling.
11. The green fodder is preserved as hay with a moisture content of _____ %.
12. _____ and _____ are the fodders suitable for silage making.

Write the statement True or False

1. The predominant acid produced in the silage is lactic acid ()
2. Good quality silage is brown in colour ()

3. Fodder crops with high content of protein is suitable for silage making ()
4. Legume fodders are suitable for silage making ()
5. Ammonical nitrogen content of poor silage is less than 20% ()
6. Nutritive value of legume hay is superior than non legume hay ()
7. Loss of nutrients due to rain while hay making is called as bleaching ()
8. The silo should located in a elevated place to prevent the entry of rain water ()
9. Addition of molasses at the time of ensiling will increase the lactic acid production ()

Define the following

1. Silage
2. Silo
3. Ensiling
4. Effluent
5. Haylage
6. Hay
7. Wilting
8. Leaching
9. Bleaching
10. Soilage

Short answer

1. Process of silage making
2. What are the characteristics of good silage?
3. What are the losses of nutrients during ensiling process?
4. List out the characteristics of good quality hay.
5. Factors influencing the nutritive value of hay.

Write essay

1. Write an essay on preservation of green fodder as silage.
2. Write in detail about hay making.

CHAPTER 12

HARMFUL NATURAL CONSTITUENTS AND CONTAMINANTS IN FEEDS AND FODDERS

Animal feeds are routinely subject to contamination from diverse sources, including environmental pollution, activities of insects and microbes.

Environmental contaminants

A wide range of organic and inorganic compounds may occur in feedstuffs, including pesticides, industrial pollutants, radionuclide and heavy metals.

Fungal contaminants

Aspergillus is the predominant genus in dairy and other feeds. Other species include *Penicillium*, *Fusarium* and *Alternaria*, which are also important contaminants of cereal grains. Fungal contamination is undesirable because of the potential for mycotoxin production.

Mycotoxins

Mycotoxins are those secondary metabolites of fungi that have the capacity to impair animal health and productivity. The diverse effects caused by these compounds are considered under the term "**Mycotoxicosis**". Mycotoxin contamination of forages and cereals frequently occurs in the field following infection of plants with particular pathogenic fungi.

Aflatoxins

Aflatoxins are the most potent toxic, mutagenic, teratogenic and carcinogenic metabolites produced by the species of *Aspergillus flavus* and *A.parasiticus* on food and feed materials. Aflatoxin B₁, B₂ and G₁ produce liver cancer in cats. The occurrence of these toxins in food and feed materials and their consumption has caused not only health hazards in animals and humans, but also resulted in economic losses, especially to the exporting countries.

Type of naturally occurring toxins / anti nutritional factors

On the basis of the type of nutrient affected and the biological response produced in the animal of the toxic factors can be classified into five major groups as follows:

- 1) Substance depressing digestion or metabolic utilization of protein:
 - Protease inhibitors
 - Lectins or Ricin (hemagglutinins)
 - Saponins

- Polyphenolic compounds (TANNINS)
- 2) Substance reducing the solubility or interfering with the utilization of mineral elements:
- Phytic acid
 - Oxalic acid
 - Glucosinolates
 - Gossypol
- 3) Substance inactivating or increasing the requirements of certain vitamins and hormones:
- Antivitamins A, D, E, K and anti-pyridoxine
 - Mimosine (Anti hormone)
- 4) Cyanogens
- 5) Nitrate and Nitrite
- 6) Moulds and mycotoxins in animal feedstuffs

I. Substance depressing digestion or metabolic utilization of proteins:

1. Protease inhibitors:

Substance that inhibit proteolytic enzymes and thereby growth and non-ruminants are distributed throughout the plant kingdom but are particularly abundant in seeds and legumes. In the case of soybeans identification of two main groups of protease inhibitors have recently been made namely: (1) **Kunitz** inhibitors have few disulphide bonds and specificity towards trypsin (2) **Bowman-Brik** inhibitors has a high proportion of disulphide bonds, inhibiting both trypsin and chymotrypsin. The inhibitory substances are mostly heat labile and thus before feeding any leguminous grain to non-ruminants, the situation is generally corrected by proper heat treatment.

2. Lectins or ricin (hamagglutinins):

This important group of anti-nutritional factor are found in both plant and animal tissue. A toxic fraction capable of agglutinating human red blood cells. Lectins are protein in nature, resistant to digestion by pancreatic juice. Although very resistant to destruction by dry heat, lectins are destroyed by the same conditions as those used to inactive protease inhibitors.

3. Saponins

The important common forages which have caused saponin poisoning of livestock are lucerne, white clover, red clover and soybean. Saponins or Sapogenins are either steroids or triterpenoids, which are the break down products of certain glycosides. They are bitter in taste, foam forming and inhibit the action of proteolytic enzymes and cholinesterase. They also cause haemolysis of red blood cells. Water soaking and rinsing will remove the components in the feedstuffs. In ruminant saponins have been suggested as being involved in formation of bloat by altering the surface tension of the ruminal

contents due to entrapment of countless bubbles of fermentation gases throughout the ingesta.

4.Polyphenolic compounds (Tannins):

Also known as tannic acid, gallotannin and gallotannic acid. It is now defined to include those naturally occurring compounds having high molecular weight (500-3000) and containing a sufficiently large number of phenolic hydroxyl groups (1 to 2 per 100 molecular weight) to enable them to form effective cross-links between proteins and other macromolecules. Chemically tannins may be grouped two broad categories:

(i) Hydrolysable tannin and (ii) Condensed tannins.

Properties of Tannins:

1. The most important property of tannins is undoubtedly their capacity to bind proteins; they are thus inhibitors of enzymes.
2. They cause low palatability of some herbage plants
3. They are also markedly astringent – that is they cause a dry or puckery sensation in the mouth, probably by reducing the lubricant action of the glycoproteins in the saliva.

II. Substance reducing the solubility or interfering with the utilization of mineral elements:

a) Phytic acid:

Phytates are the salts of phytic acid. Phytic acid is formed due to combination of six phosphate molecules with Inositol, a cyclic alcohol with six hydroxy radicals like that of hexose sugar.

About half of more of the phosphorus in cereal grains is in the form of phytin. The availability of phytin phosphorus to all non-ruminants is influenced by the level of vitamin D, calcium, the calcium to phosphorus ratio, amount of zinc in the feed, alimentary tract pH and other factors.

b) Oxalic acid:

In both the vegetable and animal kingdoms oxalic is found as free and in salt forms. Plants which are particularly rich in oxalates include beet, spinach and a number of agro-industrial by-products used as livestock feed ingredient. The excess oxalate combined with feed calcium to form insoluble calcium oxalate and then become unavailable for absorption or excess oxalate (20-30 mg per cent) may be absorbed from the rumen into the blood stream where it can combine with calcium to produce hypocalcaemia. The insoluble calcium oxalate may then crystalise in various tissue, specially kidneys and rumen wall.

c) Glucosinolates (Thioglucosides):

Glucosinolates are responsible for the pungent flavour found in some cultivated plants belonging to the Cruciferae, specially the genus Brassica, which includes cabbage, turnips, rapeseed, mustard seed. Their main biological effect is to depress the synthesis

of the thyroid hormone (Tetraiodothyronine and Triiodothyronine), thus producing goitre. An adequate supply of iodized salt is another preventive measure specifically in areas where non-ruminants consume goitrogenic substances in a large dose. For treatment a daily injection of thyroxide @ 0.1 to 0.3 mg is advocated.

d) Gossypol

Gossypol pigments are polyphenolic compounds found exclusively in the pigment glands of cottonseed. The physiological effects of free gossypol. In addition to reduced appetite and loss of body weight, include accumulation of fluid in the body cavities, cardiac irregularity, reduced oxygen carrying capacity of the blood and an adverse effect on certain liver enzymes. It causes olive green discolouration of egg yolk.

III. Substance inactivating or increasing the requirements of certain vitamins and hormones:

1. Cyanogens

Cyanide in trace amount is fairly widespread in the form of glucosides and relatively high levels can be found in certain grasses such as 'jowar (sorghum) and sudan grass, linseed, maize and cassava root. In plants the glucoside is non-toxic in the intact tissues and as stated earlier, when the plants are damaged or begin to decay, hydrolytic enzyme from the same plant is released liberating HCN. This reaction can take place in the rumen by microbial activity. The HCN is rapidly absorbed and some is eliminated through the lungs, but the greater part is rapidly detoxified in the liver by conversion to thiocyanate.

2.Nitrates and Nitrites

Forages and drinking water when contaminated with inorganic nitrates and nitrites cause an acute toxicosis in cattle resulting from formation of methaemoglobin (a true oxidation product of haemoglobin) which is unable to transport oxygen because the iron is in the ferric (Fe^{+++}) rather than the usual ferrous (Fe^{++}) state. The situation is more common in forages where either nitrogenous fertilizers have been used at a very high dose or the forages have been harvested at a very early stage of their growth. Symptoms seen in acute toxicity include laboured breathing (dyspnoea), grinding of the teeth, uneasiness and excessive salivation.

3.Mimosine

Mimosine is a toxic amino acid, also called as 'leucenine' found in the plants belonging to the genus Leucaena like subabul. This toxic substance mimosine can cause problems when the forage is eaten in large quantities for a long period. Mimosine is a powerful depilatory agent that cannot be degraded after absorption. But it can be extensively degraded to Dihydroxy pyridone (DHP) in the rumen. Excess DHP is absorbed into the blood stream, reaches thyroid gland and inhibits biosynthesis of the hormone thyroxine. Acceptable safe daily intake of mimosine was calculated to be 0.14% g/kg body weight.

The main symptoms are reduced growth and weight loss, excessive salivation, loss of hair, eroded gums, enlarged thyroid gland and poor reproductive efficiency,

IV. Substance inactivating or increasing the requirements of certain vitamins:

Anti Vitamin A:

Raw soybean contain an enzyme **Lipoxygenase**, which catalysis oxidation of carotene, the precursor of vitamin A.

Anti-Vitamin D:

Rachitogenic activity of isolated soya protein (unheated) has been founded with chicks and pigs.

Anti-Vitamin K:

“Sweet clover disease” is characterized by a fatal haemorrhagic condition in cattle. The active principle reasonable for this disease is dicoumarol, which reduces the prothrombin level of the blood, thus interfering with the blood clotting mechanism.

Anti-Biotin:

Avidin is a anti-vitamin present in the raw egg, which inhibit the activity of biotin. The disease is called as “**Egg white injury**”

Adulterants

Undesirable substances getting incorporated in the feed intentionally or accidentally

Accidental adulterants

Most of the feed ingredients for livestock are agricultural or allied products / by-products. During the course of their processing many unwanted materials such as husk, cobs, hulls, stones, mud, pebbles, sand and weed seeds can get accidentally incorporated. These are called as accidental adulterants. The presence of these adulterants may increase the crude fibre / silica contents of the ingredient and thereby reduce the digestibility and nutritive value of the ingredient. Some weed seeds may also contain deleterious principles, which may cause harm to the animals.

Intentional adulterants

As a fraudulent practice in order to make more profit the wholesale dealers/ retailers may intentionally add husk, cobs, hulls, stones, mud, pebbles, sand, weed seeds and also some chemical substances like urea to increase the weight or nutritive value by default. The presence of these may cause harm to the animals or alter the nutritive value.

STUDY QUESTIONS

Fill in the blanks

1. Disease caused by Mycotoxins is called as _____.
2. _____ is the fungi produces aflatoxin.
3. Aflatoxin mainly affects the _____ organ.

4. _____ and _____ are the two types of protease inhibitors found in the soybean meal.
5. _____ is a compound present in the leguminous fodder responsible for the development of bloat in ruminants.
6. _____ is the anti-nutritional factor present in the subabul.
7. Anti-nutritional factor present in the castor bean causes haemagglutination is _____.
8. Tannins are classified into _____ and _____.
9. Tannin reduces the digestibility of _____ and _____.
10. In cereal grains the phosphorus is present in the form of _____.
11. Oxalic acid inhibits the absorption of _____ mineral.
12. Glucosinolates or goitrogens are present in _____ and _____.
13. The polyphenolic compound present in the cottonseed is _____.
14. Olive green discolouration of yolk is caused by _____.
15. Toxic principle present in the immature sorghum fodder is _____.
16. Cyanogenetic glycoside present in the linseed is _____.
17. Nitrate poisoning converts haemoglobin into _____.
18. _____ is the enzyme present in the raw soybean which destroys vitamin-A.
19. Anti-vitamin-K present in the sweet clover is _____.
20. _____ is the toxic factor present in the paddy straw which decreases the utilization of calcium.

Write the statement True or False

1. Wilting of sorghum fodder reduces HCN content ()
2. Protease inhibitor and lectins are heat labile ()
3. Utilization of phytate phosphorus can be improved by the supplementation of phytase enzyme in the feed ()
4. Mimosine is an antagonist of amino acid tyrosine ()
5. Heating will destroy all the toxic factors present in the soybean ()
6. Ingestion of raw egg will leads to biotin deficiency ()

Define the following

1. Anti-nutritional factor
2. Goitrogen
3. Adulterant
4. Bleeding disease
5. Mycotoxicosis
6. Egg white injury

Short answer

1. Classification of naturally occurring toxins with example
2. Anti-nutritional factors reduces protein utilization
3. Compounds affects mineral utilization
4. Write a short note on adulterants

Write essays

1. Write an essay on anti-nutritional factors present in the feeds and their effects on nutrient utilization.

CHAPTER 13

FEED ADDITIVES

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. Feed additives and implants can be classed 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, BHA (Butylated hydroxyl anisole) or BHT (butylated hydroxytoluene) can serve as synthetic 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

- when highly unpalatable medicaments are being mixed
- During attacks of diseases
- When animals are under stress, and
- When less palatable feedstuffs are 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

Poultry man will often enhance the yellow colour 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: Ethylene diamine tetra acetic acid (EDTA) and other similar synthetic ligands also may improve the availability of zinc and other minerals.

d. Enzymes: Enzymes are protein which has 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 of plant and vegetable 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:

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

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.

Mode of Action of Antibiotics

- Antibiotics “spare” protein, amino acids and vitamin on diets. Under hygienic conditions growth increases are small.
- Intestinal wall of animals fed antibiotics is thinner than that of untreated animals which might explain the enhanced absorption of calcium shown for chicks.
- Reduce or eliminate the activity of pathogens causing “subclinical infection.”

- Reduce the growth of micro-organisms that compete with the host for supplies of nutrients.
- 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.
- 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:

- Antibiotics should be used only for (a) growing and fattening pigs for slaughter as pork or bacon; (b) growing chicks and turkey poult for killing as table poultry.
- Antibiotics should not be used in the feed of ruminant animals (cattle, sheep and goats), breeding pigs and breeding and laying poultry stock.
- While adding antibiotics at the recommended level, care should be taken that they are thoroughly and evenly mixed with the feed.
- 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.
- Antibiotics are not a substitute for good management and healthy living conditions, or for properly balanced rations.

b. Probiotics: is defined as a live microbial feed supplement, which beneficially affects the host animals by improving its intestinal microbial balance. The probiotic preparations are generally composed of organisms of lactobacilli and/or streptococci species, few may contain yeast cultures.

They benefit the host by:

- Having a direct antagonistic effect against specific group of undesirable or harmful organism through production of antibacterial compounds, elementary or minimising their competition of nutrients.
- Altering the pattern of microbial metabolism in the gastro intestinal tract.
- Stimulation of immunity.
- Neutralisation of enterotoxins formed by pathogenic organism.

Thus resulting in increased growth rate, improved feed efficiency

c. Prebiotics: These are the substrates for the growth of probiotic cultures. E.g. Fructan oligosaccharide (FOS) and mannan oligosaccharide (MOS).

d. Synbiotics: This is the combination of probiotics and prebiotics.

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.

(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.) Diethylstilbestrol (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 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 anticoccidials 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.Other Additives;

a. 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:

- Salt or long chain fatty acids.
- Calcium phosphate
- Potassium and sodium ferrocyanide
- Magnesium oxide
- Salts silicic acid - Al, Mg, Ca, Salt.

Sodium aluminium silicate

Sodium calcium aluminium silicate

Calcium aluminium silicate

b. 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.

c. 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.

d. Sequestrants:

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

These compounds should have affinity to metal ions and should prevent the metal from becoming engaged in oxidative action. Most effective sequestrants EDTA. Ethylene diamine tetra acetic acid (EDTA).

Calcium salt of EDTA works satisfactorily as sequestrants without interfering with trace mineral metabolism.

e. 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.

Additives such as humectants, firming and crisping agents, sweeteners, emulsifiers, stabilisers, acid, buffers are not commonly used in poultry feeds.

STUDY QUESTIONS

Fill in the blanks

1. _____, _____ and _____ are the examples of synthetic antioxidants.
2. Antioxidants prevent the _____ of polyunsaturated fatty acids.
3. _____ and _____ are the natural antioxidants.
4. _____ is an example of buffer used to maintain the rumen pH in ruminants fed on high concentrate ration.
5. _____ is an example of chelating agent.
6. _____ and _____ are the examples of probiotics.
7. _____ and _____ are the antifungal agents used to prevent the growth of fungi in feed and production of mycotoxins.

Write the statement True or False

1. Feed additives are nutrient in nature

()

2. Addition of antioxidants will improve the keeping quality of feed ()
3. Addition of buffers in dairy ration will prevent low milk fat syndrome ()
4. Antibiotics can be added in the ration of adult cattle and goat ()
5. Antibiotics are substitute for good management and healthy living conditions ()
6. Hormones can be used to increase the meat production ()

Define the following

1. Anti-oxidants
2. Antibiotics
3. Probiotics
4. Prebiotics
5. Implants
6. Humectants
7. Sequestrants
8. Chelates
9. Antibloat agents
10. Synbiotics

Short answer

1. Mode of action of antibiotics as feed additive.
2. Feed additives which enhance the digestion and absorption of nutrients.

Write essays

1. Write an essay on use of various feed additive to augment feed efficiency and animal production

CHAPTER 14

NUTRITIONAL TERMS AND THEIR DEFINITIONS

A glossary of terms frequently used in discussing matters related to feed and nutrition is presented in this chapter

Additives: An ingredient or substance added to a basic feed mix, usually in small quantities, for the purpose of fortifying it with certain nutrients, stimulants and/or medicines. They are not nutrients.

Ad libitum: Free-choice access to feed.

Air dry (approximately 90% dry matter): This refers to feed that is dried by means of natural air movement, usually in the open. It may be either as actual or assumed dry matter content, the latter is approximately 90 per cent. More feeds are fed in the air dry state.

Amino acids: Nitrogen-containing compounds that consists the “building blocks” or units from which more complex proteins are formed. They contain both an amino (NH_2) group and a carboxyl (COOH) group.

Animal Protein: Protein derived from meat-packing or rendering plants, surplus milk or milk products and marine sources. It includes proteins from meat, milk, poultry, eggs, fish and their products.

Animal Protein Factor (APF): The term formerly used to refer to an undefined growth factor essential for poultry and swine and present in protein feeds of animal origin. It is same as vitamin B_{12} .

Anti-metabolite: A substance bearing a close structural resemblance to one required for normal physiological functioning, which exerts its effect by replacing or interfering with the utilisation of the essential metabolite.

Antioxidant: A compound that prevents oxidative rancidity or polyunsaturated fats. Antioxidants are used to prevent rancidity in feed and foods.

Anti-vitamin: Any substance which inhibits the normal function of a vitamin.

Apparent metabolisable energy (AME): It is the gross energy of the feed consumed minus the gross energy contained in the faeces, urine and gaseous products of digestion.

Appetite: This immediate desire to eat when feed is present. Loss of appetite in an animal is usually caused by illness or stress, is called as inappetance.

As-Fed: This refers to food as normally fed to animals. It may range from 0 to 100 percent dry matter.

Ash: The mineral matter of a feed. The residues that remain after complete incineration of the organic matter.

Available nutrient: A nutrient which can be digested, absorbed and/or used in the body.

Average Daily Gain (ADG): The average daily live weight increase of an animal.

Balanced Ration: One which provides an animal the proper amounts and proportions of all the required nutrients.

Basal Diet: A diet common to all groups of experimental animals to which the experimental substance(s) is added.

Basal Metabolic Rate (BMR): The heat produced by an animal during complete rest (but not sleeping) following fasting when using just enough energy to maintain vital cellular activity, respiration and circulation the measured value of which is called the basal metabolic rate (BMR). Basal conditions include thermo neutral environment, resting post-absorptive state (digestive processes are quiescent), consciousness, quiescence and sexual repose. It is measured by means of a calorimeter and is expressed in calories per square meter of body surface.

Biological value of a protein: The percentage of the protein of a feed or feed mixture which is usable as a protein by the animal. Thus, the biological value of a protein is a reflection of the kinds of amounts of amino acid available to the animal after digestion. A protein which has a high biological value is said to be of good quality.

Blended: Combined or mixed so as to render the constituent parts indistinguishable from one another such as when two or more feed ingredients are mixed.

Bomb Calorimeter: An instrument used to measure the gross energy content of any material, in which the feed (or other substance) tested is placed and burned in the presence of oxygen.

Brix: A term commonly used to indicate the sugar (sucrose) content of molasses. It is expressed in degrees and was originally used to indicate the percentage by weight of sugar in sucrose solutions, with each degree Brix being equal to 1 percent sucrose.

By-product feeds: The innumerable roughage and concentrates obtained as secondary products from plant and animal processing and from industrial manufacturing.

Cake (press cake): The mass resulting from the pressing of seeds, meat or fish in order to remove oils, fats or other liquids.

Carrier: An edible material to which ingredients are added to facilitate their uniform incorporation into feeds. The active particles are absorbed, impregnated or coated into or onto the edible material in such a way as to carry the active ingredient physically.

Cereals: A plant in the gross family (Graminae), the seeds of which are used for human and animal food; eg. Maize and wheat.

Chelate: The word chelate is derived from the Greek word meaning "claw". It refers to a cyclic compound which is formed between an organic molecule and a metabolic ion, the latter being held within the organic molecule as if by a claw. Examples of naturally occurring chelates are the chlorophylls, cytochromes, haemoglobin and vitamin B₁₂.

Coefficient of digestibility: The percentage value of a food nutrient that is absorbed. For example, if a food contains 10 grams of nitrogen and it is found that 9.5 grams are absorbed, the digestibility is 95 per cent.

Coenzyme: A substance, usually containing a vitamin, which works with an enzyme (protein mainly) to perform a certain function.

Collagen: A white papery transparent type of connective tissue which is of protein composition. It forms gelatine which heated with water.

Commercial feeds: Feeds mixed by manufacturers who specialize in the feed business.

Concentrate: A broad classification of feedstuffs which are high in energy and low in crude fibre (under 18%). For convenience concentrates are often broken down (1) carbonaceous feeds and (2) nitrogenous feeds.

Cracked: Particle size reduced by combined effect of breaking and crushing action.

Crimped: Rolled between corrugated rollers. The gain to which this term refers may be tempered or conditioned before crimping and may be cooled afterward.

Crude fat: Material that is extracted from moisture-free feeds by ether. It consists largely of fats and oils with small amounts of waxes, resins and colouring matter. In calculating the energy value of a feed the cat is considered to have 2.25 times as much energy as either nitrogen-free extract or protein.

Crumbles: Pelleted feed reduced to granular form.

Decortication: Removal of the bark, hull, husk or shell from a plant, seed or root. Removal of portions of the cortical substance of a structure or organ, as in the brain, kidney and lung.

Defluorinated: Processed in such manner that the fluorine content is reduced to a level which is nontoxic under normal use.

Dehulled: Grains or other seeds with the outer covering removed.

Dehydrate: To remove most or all moisture from a substance for the purpose of preservation, primarily through artificial drying.

Desiccate: To dry completely.

Depraved appetite (pica): A craving for and eating of unnatural substances, such as dirt, hair, dung, wood, etc.

Diet: Feed ingredient or mixed or ingredient, including water, which is consumed by animals.

Digestible nutrient: The part of each feed nutrient that is digested or absorbed by the animal.

Digestible Protein: The protein of the ingested food protein which is absorbed.

Digestion coefficient (coefficient of digestibility): the difference between the nutrients consumed and the nutrients excreted expressed as a percentage.

Dry matter: That part of a feed which is not water. It is computed by determining the percentage of water and subtracting the water content from 100 percent.

Dry matter basis: A method of expressing the level of nutrient contained in a feed on the basis that the material contains no moisture.

Dry Rolling: Refer to processing grains without added steam or other moisture.

Efficiency of feed conversion: This is expressed as units of feed per unit of product meal, milk or eggs.

Emaciated: An excessively thin condition of the body:

Energy: The capacity to perform work.

Energy feeds: Feeds that are high energy and low in fibre (under 18%), and that generally contain less than 20 percent protein.

Essential amino acid: Those amino acids which cannot be made in the body form the other substances or which cannot be made in sufficient quantities for the body's needs.

Essential fatty acid: A fatty acids that cannot be synthesised in the body or that cannot be made in sufficient quantities for the body's needs.

Ether extract (EE): Fatty substances of feeds or foods that are soluble in ether.

Evaporated: Reduced to a denser form; concentrated as by evaporation or distillation.

Expanded: As applied to feed, it refers to an increase in volume as the result of a sudden reduction in the surrounding pressure.

Expeller process: A process of the mechanical extraction of oil from seeds, involving the use of screw press.

Extracted: Having removed fat or oil from materials by heat and mechanical pressure.

Similar terms: expeller extracted, hydraulic extracted, old process.

Extrinsic Factor: A dietary substance, which was formerly thought to interact with the intrinsic factor of the gastric secretion to produce the anti-anaemic factor, now known to be vitamin B₁₂. (Also see intrinsic factor).

Extruded: A type of feed preparation in which the feed is forced through a die under pressure.

Fat: The term fat is frequently used in general sense to include both fats and oils or a mixture of the two. Both fats and oils have the same general structure and chemical properties, but they have different physical characteristics. The melting points of most fats are such that they are solid at ordinary room temperature, while oils have lower melting points and are liquids at these temperatures.

Fat soluble: Fat soluble in fat solvents but generally not soluble in water.

Fattening: The deposition of energy in the form of fat within the body tissues.

Feed (or feedstuff): Any naturally occurring ingredient or material, fed to animals for the purpose of sustaining them.

Feed supplements: They are added to the feed to meet out the deficiencies and they are nutrient in nature.

Feed efficiency: The ratio expressing the number of units of feed required for one unit of production (meat, milk, eggs) by animals.

Feed grade: Feedstuffs suitable for animals, but not for human consumption.

Fermented: Acted upon by yeasts, moulds or bacteria in a controlled aerobic or anaerobic process in the manufacture of such products as alcohols, acids, vitamins or antibiotics.

Fibre content of a feed: The amount of structural carbohydrates. Most fibre is made up of cellulose, hemicellulose and lignin.

Fibrous feeds: Feeds high in cellulose and/or lignin content.

Flakes: An ingredient rolled or cut into flat pieces with or without prior steam conditioning.

Flavouring agent: Feed additives that are supposed to increase palatability and feed intake.

Flora: In nutrition it generally refers to the bacteria present in the digestive tract.

Formula feed: A feed consisting of two or more ingredients mixed in specified proportions.

Fortify: Nutritionally to add one or more feeds or feedstuffs.

Free-choice (ad libitum): Free to eat two or more feeds at will.

Gluten: The tough, viscid, nitrogenous substance remaining when the flour of wheat or other grain is washed to remove the starch.

Grits: Coarsely ground grain, from which the bran and germ have been removed, usually screened to uniformed particle size.

Groats: Grain from which the hulls have been removed.

Gross Energy (GE): This is the energy released as heat when a substance is completely oxidised to carbon dioxide and water. Gross energy is also referred to as the heat of combustion.

Ground: Reduced in particle size by impact, sharing or attrition.

Heat of fermentation (HF): The heat produced in the digestive tract as result of microbial action.

Heat-processed: Subject to a method of preparation of involving the use of elevated temperature, with or without pressure.

Hemicellulose: A carbohydrate classified in the crude fibre fraction of feedstuffs that is similar to cellulose, expect that it contains pentoses (5-carbon sugars) and uronic acid in addition to hexose.

Hulls: Outer covering of grain or other seed.

Hydraulic process: A process for the mechanical extraction of oil from seeds, involving the use of a hydraulic press.

Hydrogenation: The chemical addition of hydrogen to any unsaturated compound.

Hydrolysis: The splitting of a substance in to smaller units by chemically adding water to the material.

Hypervitaminosis: An abnormal condition resulting from the intake of an excess of one or more vitamins.

Hypocalcaemia: Below normal concentration of ionic calcium in blood resulting in convulsion as in tetany or parturient paresis (milk fever).

Hypomagnesaemia: An abnormally low level of magnesium in the blood.

Implant: A substance that is implanted into the body from the purpose of growth promotion or controlling some physical function.

In vitro: Occurring in an artificial environment, as in a test tube.

In vivo: occurring in the living body.

Inert: Relatively inactive.

Ingest: To eat or take in through the mouth.

Ingesta: Food or drink taken into the stomach.

Ingestion: The act of taking food and water.

Ingredient: A constituent of feed.

IU (International Unit): A standard unit of potency of a biological agent eg., Vitamin, hormone, antibiotic (antitoxin) as defined by the International Conference for Unification of Formulae. Potency is based on bioassay that produces a particular effect agreed on internationally. Also called USP unit.

Joule: An international unit ($4.184 \text{ J} = 1 \text{ calorie}$) for expressing mechanical, chemical or electrical energy as well as the concept of heat.

Keratin: A sulfur-containing protein which is the primary component of epidermis, hair, wool, hoof, horn and the organic matrix of the teeth.

Kernel: The whole grain of cereal.

Kjeldahl apparatus: A apparatus used to determine the amount of nitrogen in an organic compound. The quality of nitrogen measured is then multiplied by 6.25 to calculate the protein content of the feed or compound analysed. The method was developed by the Danish Chemist, J.G.C., Kjeldahl.

Labile: Unstable or easily destroyed.

Lignification: The process of impregnating cell walls of a plant with lignin.

Lignin: A practically indigestible phenolic compound which along with cellulose is a major component of the cell wall of certain plant materials, such as wood, hulls, straws and overripe hays.

Limiting Amino Acid: The essential amino acid of a protein which shows the greatest percentage deficit in comparison with amino acids contained in the same quantity of another protein selected as a standard.

Macro (or major) mineral: Major mineral calcium, phosphorus, sodium, chlorine, potassium, magnesium and sulfur.

Malnutrition: Any disorder of nutrition commonly used to indicate a state of inadequate nutrition.

Meats: Animal tissue used as food.

Mechanically extracted: A method of extracting the fat content from oil seeds by the application of heat and mechanical pressure. The hydraulic and expeller process are mechanical extraction methods.

Medicated feed: Any feed which contains drug ingredients intended or represented for the cure, mitigation, treatment or prevention of diseases of animals.

Metabolism: Refers to all the changes that take place in the nutrients after they absorbed from the digestive tract, including (1) the building-up process in which the absorbed nutrients are used in the formation of repair of body tissue and (2) the breaking down process in which nutrients are oxidised for the production of heat and work.

Metabolizable Energy (ME): It is the gross energy of the feed consumed minus the gross energy contained in the faeces, urine and gaseous products of digestion. For poultry the gaseous products are negligible.

Metabolite: Any substance produced by metabolism or by a metabolic process.

Mill by-product: A secondary product obtained in addition to the major product in milling practice.

Minerals (ash): The inorganic elements of animals and plants determined by burning off the organic matter and weighing the residue, which is called as ash.

Mineral supplement: A rich source of one or more of the inorganic elements needed to perform certain essential body functions.

Mixing: It is the process of uniform distribution of different feed ingredients in a compounded feed.

Moisture: A term used to indicate the water contained in feed and it is expressed as a percentage.

Moisture-free (oven-dry, 100% dry matter): This refers to any substance that has been dried in an oven at 221°F (105°C) until all the moisture has been removed.

Mycotoxins: Toxic metabolites produced by moulds during growth. Sometimes present in feed materials.

National Research Council (NRC): A division of the National Academy of Science established in 1916 to promote the effective utilisation of scientific and technical resources. Periodically, this private, non-profit organisation of scientists publishes bulletins giving nutrient requirements and allowance of domestic animals, copies of which are available on a charge basis through the National Academy of Science, National Research Council, 2101 Constitution Avenue, N.W., Washington D.C., 20418.

Net Energy (NE): Is metabolisable energy minus the energy lost as the heat increment. NE may include the energy used for maintenance only (NE_m) or for maintenance and production (NE_{m+p}). Because of NE is used at different levels of efficiency for maintenance or various productive functions, there is no absolute NE value for each feedstuff. For this reason, productive energy, once a popular measure of the energy available of NE is seldom used.

Nitrogen: A chemical is essential to life. Animals get it from protein feeds; plants get it from the soil; and some bacteria get it directly from the air.

Nitrogen Balance: The nitrogen in the feed intake minus the nitrogen in the faeces and urine.

Nitrogen-Free Extract (NFE): It consists principally of sugars, starches, pentoses and non-nitrogenous organic acid. The percentage is determined by subtracting the sum of the percentage of moisture, crude protein, crude fat, crude fibre and ash from 100.

Non Protein Nitrogen (NPN): Nitrogen which comes from other than a protein source but may be used by a ruminant in the building of protein. NPN sources include compounds like urea and anhydrous ammonia, which are used in feed formulation for ruminants only.

Noxious: Harmful, not wholesome.

Nutrient allowances: Nutrient recommendation that allow for variations in feed composition, possible losses during storage and processing, day-to-day and period-to-period differences in needs of animals age and size of animal; stage of gestation and lactation; the kind and degree of activity, the amount of stress, the system of management, the health, condition, and temperature of the animal and the kind , quality and amount of feed-all of which exert a powerful influence in determining nutritive needs.

Nutrient requirements: This refers to meeting the animal's minimum needs, without margins of safety for maintenance, growth, fitting, reproduction, lactation, and work. To meet these nutritive requirements the different classes of animals must receive sufficient feed to furnish the necessary quantity of energy (carbohydrates and fats), protein, mineral and vitamins.

Nutrients: The chemical substance found in feed materials that can be used and are necessary for the maintenance, production and health of animals. The major nutrients are carbohydrates, fats, proteins, minerals, vitamins and water.

Nutrition: The science encompassing the sum total process that has as a terminal objective the provision of nutrients to the component cells of an animal.

Nutriture: Nutritional status of an animal.

Obese: Over weight due to surplus of body fat.

Off feed: Not eating with a normal healthy appetite.

Oil: Although fats and oils have the same general structure and chemical properties, they have different physical characteristic. The melting points of oils are such that they are liquid at ordinary room temperature.

Orts: Leftover feed which an animal refuses to eat.

Palatability: The result of the following factors sensed by the animal in locating and consuming feed, appearance, odour, taste, texture, temperature and in some cases, auditory properties of the feed (like the sound of pigs eating corn). These factors are affected by the physical and chemical nature of feed.

Palatable Feeds: Feeds that are well liked and eaten with relish.

Pantothenic acid: One of the B Vitamins. It is a constituent of coenzyme A, which plays an essential role in fat and cholesterol synthesis.

Parts per billion (ppb): It equals micrograms per kilo gram

Parts per million (ppm): It equals milligrams per kilo grams

Pectin: Any of the group or colorless, amorphous, methylated, pectic substance occurring in plant tissue or obtained by restricted treatment of protopectin that are obtained from fruits or succulent vegetables, that yield viscous solutions with water and when combined with acid and sugar, yield a gel.

Peelings: Outer layers of covering which have been removed by stripping or tearing.

Pellet binders: Products that enhance the firmness of pellets.

Pellets: Ground feed compacted by steaming and forcing the material through die opening.

Phase feeding: Refers to change in animal's diet (1) to adjust for age and stage of production, (2) to adjust for season of the year and for temperature and climate changes, (3) to account for differences in body weight and nutrient requirements of different strains of animals or (4) to adjust one or more nutrient as other nutrients are changed for economic or availability reasons.

Plant proteins: This group includes the common oilseed by-products - soybean meal, cottonseed meal, linseed meal, peanut meal, safflower meal, sunflower meal, rapeseed meal, and coconut (or copra) meal. They vary in protein content and nutrient value, depending on the seed from which they are produced, the amount of hull and/or seed coat included and the method of oil extraction used.

Polyunsaturated fatty acids: Fatty acids having more than one double bond. Linoleic, linolenic acids and arachidonic acid, which contain 2 and 3 bonds respectively, are essential in the diet of man.

Precursor: A compound that can be used by the body to form another compound for example, carotene is a precursor of vitamin A.

Preservatives: A number of materials are available to incorporate into feed and their products, with claims made that they will improve the preservation of nutrients, nutritive value and/or palatability of the feed.

Pressed: Compacted or moulded by pressure; having fat, oil or juice extracted under pressure.

Protein: From the Greek meaning "of first rank importance". Complex organic compounds made up chiefly of amino acids present in characteristic proportions for each specific protein.

Protein equivalent: A term indicating the total nitrogenous contribution of substance in comparison with the nitrogen content of protein (usually plant protein). For example, the non-protein nitrogen (NPN) compound urea contains approximately 45% nitrogen and has a protein equivalent of 281% ($6.25 \times 45\%$).

Protein-sparing: An effect in which less protein is used by the animal to meet the animal's glucose needs in times of glucose shortage. Propionic acid is protein sparing in

that it can be converted to glucose. Acetic and butyric acid cannot be converted to glucose. Likewise, fat cannot be converted. The glycogenic amino acids may be converted to glucose.

Protein supplements: Products that contain more than 20 percent protein or protein equivalent.

Proximate analysis: A chemical scheme for evaluating feedstuffs, in which a feed stuff is partitioned into the six fractions: (1) moisture (water) or dry matter (DM); (2) total (crude) protein (CP or $N_2 \times 6.25$); (3) ether extract (EE) or fat; (4) ash (minerals); (5) crude fibre (CF) – the incompletely digestible carbohydrates and (6) nitrogen-free extract (NFE) – the more readily digestible carbohydrates (calculated rather than measured chemically).

Purified Diet: A mixture of the known essential dietary nutrients in a pure form that is fed to experimental (test) animals in nutrition studies.

Quality: A term used to denote the desirability and/or acceptance of an animal or feed product.

Quality of protein: A term used to describe the amino acid balance or protein. A protein is said to be of good quality when it contains all the essential amino acids in proper proportions and amounts needed by a specific animal and it is said to be poor quality when it is deficient in either content or balance of essential amino acids.

Ration(s): The amount of feed supplied to an animal for a definite period, usually for a 24 hour period. However by practical usage the word ration implies the feed fed to an animal without limitation to the time in which it is consumed.

Saturated fat: A completely hydrogenated fat-each carbon atom is associated with the maximum number of hydrogens; there are no double bonds.

Selenium: An element that functions with glutathione peroxidise, an enzyme which enables the tripeptide glutathione to perform its role as a biological antioxidant in the body. This explains why deficiencies of selenium and vitamin E result in similar signs-loss of appetite and slow growth.

Sodium bentonite (clay): Used as a pellet binder. Also shows promise for improving the nitrogen utilisation of ruminants.

Solvent-extracted: fat or oil removed from materials (such as oilseeds) by organic solvents. Also called “new process”.

Specific Dynamic Action (SDA): The increased production of heat by the body as a result of stimulus to metabolic activity caused by ingesting food.

Spray-dehydrated: Material which has been dried by spraying onto the surface of heated drum. It is recovered by scraping it from the drum.

Stabilized: Made more resistant to chemical change by the addition of a particular substance.

Steamed: Treatment of ingredients with steam to alter physical and/or chemical properties.

Sun-cured: Material dried by exposure in open air to direct rays of the sun.

Supplement: A feed or feed mixtures used to improve the nutrition value of basal feeds (eg. Protein supplement-soybean meal). Supplements are usually rich in protein, minerals, vitamins, antibiotic or a combination of part or all of these and they are usually combined with basal feeds to produce a complete feed.

Toxaemia: A condition produced by the presence of poisons (toxins) in the blood.

Toxic: Of poisonous nature.

Trace elements: A chemical element used in minute amounts by organism and held essential to their physiology. The essential trace elements are cobalt, copper, iodine, iron, manganese, selenium and zinc.

Trace mineral: A mineral nutrient required by animals in micro amounts only (measurable in milligrams per kilogram or smaller units).

True metabolisable energy (TME) for poultry is the gross energy of the feed consumed minus for gross energy of the excreta of feed origin corrected for nitrogen retention, may be applied to give a TME value. Most ME_n values in the literature have been determined by assay in which the test material is substituted for part of the test diet or for some ingredient of known ME value. When birds in these assay are allowed to consume feed on an ad libitum basis, the ME_n value obtained approximate TME_n values for most feedstuffs.

True protein: A nitrogenous compound which will hydrolyze completely to amino acids.

Unsaturated fat: A fat having one or more double bonds; nor completely hydrogenated.

Unsaturated fatty acid: Any one of several fatty acids containing one or more double such as oleic, linoleic, linolenic and arachidonic acids.

Vaccum-dehydrated: Freed or moisture after removal of surrounding air while in an airtight enclosure.

Vitamins: Complex organic compounds that function as parts of enzyme systems essential for the transformation of energy and the regulation of metabolism of the body, and required in minute amounts by one or more animal species for normal growth, production, reproduction, and/or health. All vitamins must be present in the ration for normal functioning except for B vitamin in the ruminants (cattle and sheep) and vitamin C.

UNIT-2
APPLIED
RUMINANT
NUTRITION-I

Chapter 15

IMPORTANCE OF SCIENTIFIC FEEDING AND FEEDING EXPERIMENTS

Nutrients are needed for the functioning of the body cells. The quantitative requirement of these nutrients from various types of feeds is the basis of scientific feeding.

Feeding Experiments

The nutrient requirements of various animals performing different functions like growth, reproduction, lactation were developed by conducting various feeding experiments by trial and experience.

1. Comparative Feeding Trial

A feeding trial is a record of the results produced in terms of growth, milk production, etc, obtained by feeding a specific ration or feed. Two or more rations may be compared with each other. In case of two rations, 't' test is used, and for three or more rations 'Analysis of Variance' test is applied to analyse the data like feed consumption per day, average daily gain (ADG), feed consumed per kg weight gain (feed efficiency) etc. for statistical significance.

Example;

A comparison was made between fish meal and linseed meal as protein supplement for pigs. The results showed that fish meal is a better protein supplement for pigs than linseed meal. But the reason for fish meal as a better protein supplement was not known, whether it was due to higher protein level, or better biological value, or higher level of Calcium and Phosphorus content in the fish meal that influenced the growth in the pigs.

2. Feeding Trial with Laboratory Animals

Initially the nutritional studies are conducted using laboratory animals like rat, mice, hamster etc. The life cycle is short and maintenance cost is also low.

Advantages

- a. The cost of the animals, feed and labour are less. Shorter life cycle is an added time advantage.
- b. The influence of individual variability can be reduced to a minimum by the use of animals of similar genetic and nutritional history and more number of animals can be used in a similar environment to minimize the variability.
- c. Slaughter studies are easier and economical.

Disadvantages

The results obtained in feeding trials with laboratory animals cannot be considered to have direct application to various species of farm animals, because of the differences in physiological and productive attributes. However the results obtained with laboratory animals can be taken as guideline for planning experimental feeding trials in large animals.

3. Purified Diet Method

Purified diets consist of purified sources of the various nutrients. For example, Carbohydrates is supplied as starch, glucose or sucrose; Protein is supplied as Casein, Purified soyabean protein or urea; Fat as lard or some oil; Minerals as a chemically pure

salts and Vitamins as **pure crystalline compounds**. Such a diet makes it possible to include or withdraw a given nutrient with a minimum of disturbance to other nutrients.

Advantages

- a. Purified diet method helped in understanding the physiology of vitamins, minerals and different quality proteins.
- b. Purified diet method is the only method by which the role of an element needed by the body in small amounts can be effectively carried out only with basal diets where the element can be freed or added in known amounts easily.

Disadvantages

- a. In the purified diet the ingredients used like starch or vitamins are not cent percent pure. Some minerals or other impurities may be attached along with the purified diets.
- b. Some of the constituents, notably protein, in purified diets may be altered from their natural state in the process of purification.
- c. The palatability of the diet will be low in purified diets.
- d. It is easy to prepare small quantities of purified diets for small species like rats, mice and poultry, but for large animals it is difficult.

4. Germ Free Technique

The young ones are obtained by caesarian section and then reared in germ free environment where there is no bacteria, yeasts, moulds, fungi, protozoa and parasites etc. that is free of all other living organisms. The diets are also sterilized.

Germ free animals are used for conducting vitamin related nutrition experiments. Mostly rats, hamsters, mice, chickens, turkeys and monkeys are used. **Specific pathogen Free (SPF)** animals like piglets are also used for nutrition experiments.

5. Group Feeding vs Individual Feeding

For conducting feeding trials the animals are fed in group or individually. In group feeding, conducting the experiment is easy in terms of equipments needed, labour cost, shed etc, but the disadvantage is that, there will be competition among animals and the weak animals will not get sufficient feed.

To overcome these difficulties, individual feeding of animals is advised. Individual feeding of animals prevent competition, and helps in getting individual record of feed intake, though it is laborious and time consuming, it is the better method compare to group feeding.

6. Controlled vs Ad libitum feeding

Ad libitum feeding means unlimited feeding of the animals, whereas in controlled feeding only measured quantity of feed is fed per day. In growth trials usually ad libitum feeding is practiced, but in digestibility trials controlled feeding is done.

7. Equalized Paired Feeding or Paired Feeding

In paired feeding, the feed intakes are completely controlled. In this method of comparing two rations, the animals are fed alike in a preliminary period. Then animals are selected by pairs and kept on ration A and ration B and are fed same quantity of feed limiting the intakes of both to that of the animal consuming the lesser amount. The two

animals of the pair are similar in size, age and previous history. But such equalities are not essential from pair to pair. The equalization of feed intake is also limited to within the pair. Minimum of four pairs of animals are to be used to carry out statistical analysis.

Eg. Dicalcium Phosphate (A) and Bone Meal (B) are compared as source of Phosphorus for bone growth in rats.

Limitations

1. The faster growing animal is penalized because of restricted feeding.
2. By limited feed intake the full effect of the better ration cannot be expressed.

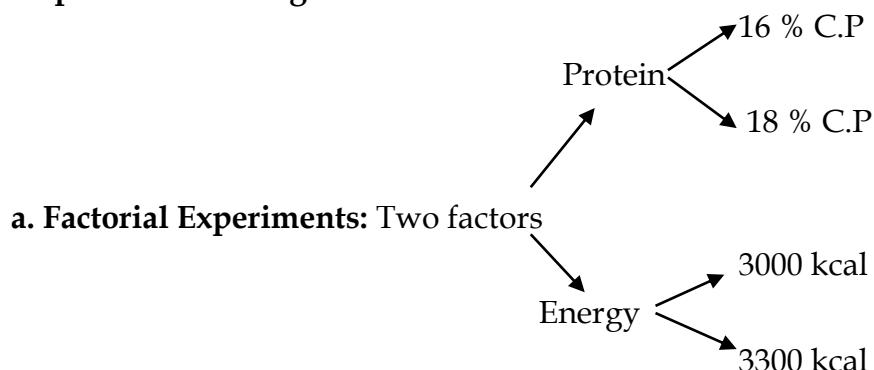
Slaughter Experiments

While conducting feeding trials, the animals are slaughtered and specific tissues are collected.

E.g. Bone tissues to estimate Calcium and Phosphorus contents.

It is a costlier method because once the animal is slaughtered, for next experiment a new set of animals are to be purchased.

Experimental Designs



2×2 factorial experiment four rations: 16 & 3000, 18 & 3000, 16 & 3300, 18 & 3300

b. Latin Square Design (LSD) : In a 4×4 LSD four experimental rations (T_1, T_2, T_3 and T_4) can be evaluated using four animals (A,B,C and D) in four periods (Preliminary period of 14 days and collection period of 7 days) for their digestibility and nutrient balance. Animals are shifted from one ration to another and at the end of four periods data from four animals are available for each ration.

		RATIONS			
P E R I O D S		T_1	T_2	T_3	T_4
	1	A	B	C	D
	2	B	C	D	A
	3	C	D	A	B
	4	D	A	B	C

Study Questions

1. Compare and contrast between group feeding and individual feeding.
2. List out the advantages of restricted feeding over that of *ad libitum* feeding.
3. Define germ free diet

4. Give examples of the following for preparing a purified diet
 - a. Carbohydrate source
 - b. Protein source
 - c. Fat source
5. Discuss the various types of experimental design.
6. Which is the best experimental design for a heterogeneous population?

Chapter 16

EVALUATION OF FEEDS BY DIGESTION EXPERIMENTS

Measurement of digestibility Coefficients:

The chemical composition of feeds and fodders gives only the potential value of feed and it does not give the actual nutritive value of feedstuffs. The difference in the nutritive value of the feed consumed and nutrients lost in faeces, urine, gases etc, gives the actual nutritive value of the feed.

$$\text{Digestibility Coefficient} = \frac{\text{Amount of nutrient consumed} - \text{Amount of nutrient in the faeces}}{\text{Amount of nutrient in the feed consumed}} \times 100$$

The digestibility coefficient determined is apparent since the faeces/dung contains metabolic (mucosal debris, unspent enzymes, undigested microorganisms) as well as undigested feed. Thus the apparent digestibility of feed is less than the true digestibility. The losses of the ingested carbohydrates as methane and carbon dioxide are also accounted in digestibility. So digestibility of carbohydrate is overestimated.

Digestion and Metabolism Trials

A digestion trial involves a record of the nutrients consumed and of the nutrients voided in faeces. In a metabolism trial in addition to the nutrients voided through faeces, the milk and urine output also measured. This gives an idea of the amount of nutrients digested and retained in the body.

Digestion trial vs. Metabolism trial

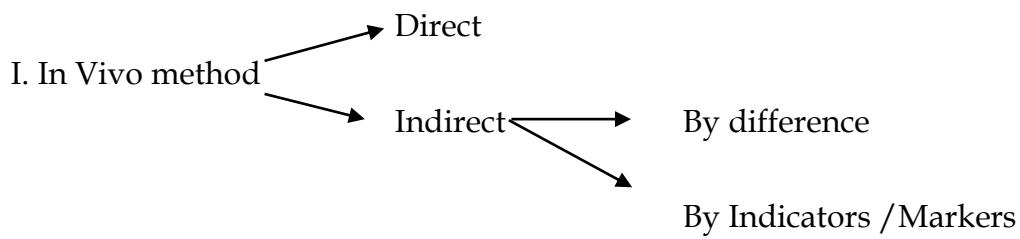
Particulars	Digestion trial	Metabolism trial
Purpose	Gives information on proportion of nutrients in a feed or diet that are absorbed from the gastro intestinal tract	Similar to digestion trials but gives more information on utilization of nutrient after absorption from the gastro intestinal tract
Information obtained	Information on digestibility coefficient of nutrients	In addition to digestibility coefficient, one gets information on nutrient balances such as Nitrogen, Calcium, Phosphorus, energy etc. Hence, metabolism trials provide complete information on nutrient digestion and utilization from feedstuffs than digestion trials
What is collected	Only feces	In addition to feces, urine, milk, gases, sloughed hair, feathers etc are also collected
Result	Apparent digestibility co-	In addition to apparent digestibility

	efficient of nutrients	co-efficient of nutrients, the information on positive or negative nutrient balance is obtained
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Norms adopted for conducting digestion and metabolism trials;

1. **Selection of animals:** The animals should be of the same breed, sex, age and body weight. Animals should be healthy and free of parasitism. Male animals are preferred to females, because it is easier to collect faeces and urine separately with the male.
2. **Preliminary Period:** The experimental feed is fed in a constant amount daily as per the requirement of the animal, for ten to fifteen days. This is called as preliminary period. The purpose is to make the gastro intestinal tract free of any indigestible material coming from the feed consumed prior to start of the digestion trial. In monogastric animals such as pigs, digestion and evacuation are usually complete in 24 hours after the test feed is ingested. In ruminants eating a roughage ration, the last residues may not be voided until 6 to 8 days. So a preliminary period of 3 to 5 days in pigs and 7 to 14 days in ruminants is followed to eliminate the feed residues of previous rations from the digestive tract and to stabilize the daily feed intake and faecal output to a constant level. Water and salt licks are provided at all times.
3. **Collection period:** Animals are transferred to cages or stalls and a 2 to 3 days adaptation period is allowed for their acclimatization. This follows a collection period of 7 to 10 days duration. In general longer the period of collection, the more accurate is the results. Water and salt licks are provided at all times. Quantitative collection of urine and faeces is done. The samples of feed, left over and faeces voided are preserved and analysed for nutrient composition.
4. **Test feed:** The test feed should not be deficient in the nutrients, because a deficiency of some of them may affect digestion process. The test feed should be fed at the level required for meeting the requirements of the animals. Normally 90 % of the actual feed intake, as measured during previous week is offered. Maintenance type fodders such as green maize, green oats, and their hays and productive type fodders such as legume fodders and hays provide satisfactory ration for the test period. Some feeds, however, cannot be fed alone as they do not supply the bulk and therefore their digestibility coefficients cannot be determined directly. Examples: Concentrates (Oil seed cakes, Cereal grains, concentrates mixture). Similarly, non maintenance type roughages like straw, stovers, dried grasses, etc. do not supply the required amount of nutrients and so they cannot be fed alone to the experimental animals. Therefore the digestibility is determined by indirect method.

Methods of Determining Digestibility:



II. In Sacco method / Semi -In Vivo Method

III. In Vitro Method

I. IN VIVO DETERMINATION OF DIGESTIBILITY

a. Direct Method (Conventional Method)

In a digestibility trial, the feed under investigation is given to the animals in known amounts and the output of faeces measured. In trial with mammals;

- More than one animal is used, because animals, even when of the same species, age and sex, differ slightly in their ability to digest, and secondly because replication allows more opportunity for detecting errors of measurement.
- Male animals are preferred to females because it is easier to collect faeces and urine separately.
- They should be docile and in good health.
- Small animals are confined in metabolism cages which separate faeces and urine by an arrangement of sieves, but larger animals such as cattle are fitted with faeces collection bags made of rubber or of a similar impervious material. For females a special device channels faeces into the bag while diverting urine. Similar equipment can be used for small ruminants.

For poultry, the determination of digestibility is complicated by the fact that faeces and urine are voided from a single orifice, the cloaca. The compounds present in urine are mainly nitrogenous, and faeces and urine can be separated from those of faeces. The separation is based either on the fact that most urine nitrogen is in the form of uric acid or that most faeces nitrogen is present as true protein. It is also possible to alter the fowl's anatomy by surgery so that faeces and urine are voided separately.

The food required for the trial should be thoroughly mixed beforehand to obtain uniform composition. It is then given to the animals for at least 10 days before collection of faeces begins, in order to accustom the animals to the diet and to clear from the tract the residues of previous foods. This **preliminary period** is followed by an **experimental period** in which the feed intake and faecal output are recorded.

The **experimental period** is usually 5 to 7 days long, with longer periods giving great accuracy. With simple-stomached animals the faeces resulting from a particular input of food can be identified by adding an indigestible coloured substance such as **ferric oxide** or **carmine** to the first and last meals of the experimental period; the beginning and the end of faecal collection are then delayed until the dye appears in and

disappears from the excreta. With ruminants this method is not successful because the dyed meal mixes with others in the rumen. Instead an arbitrary time-lag of 24 to 48 hours is normally allowed for the passage of food residues, i.e. the measurement of faecal output begins 1 to 2 days after that of food intake, and continues for the same period after measurement of food intake has ended.

In all digestibility trials, and particularly those with ruminants, it is highly desirable that meal should be given at the same time each day and that the amounts of food eaten should not vary from day to day. The trial is completed by analysing samples of the food used and the faeces collected.

Digestibility of a feedstuff:

Digestibility of a feed stuff is defined as that portion of feed or of any single nutrient of feed which is not recovered in faeces.

Calculation of Digestibility:

Digestibility coefficient (DC) may be defined as the percentage of the total amount consumed which is digested and absorbed.

$$\text{DC of Nutrient} = \frac{\text{Nutrient intake} - \text{Nutrient in faeces}}{\text{Nutrient intake}} \times 100$$

Computation of Digestible Nutrients and TDN:

Digestible nutrients are calculated directly by multiplying the percentage of each nutrient intake by its digestion co-efficient and the result is expressed as the kilogram of digestible nutrient per 100 kg of feed.

The total digestible nutrients (TDN) express the relative energy values of feeds. The calculation of TDN can be made keeping in view one more factor that 2.25 is to be multiplied with the amount of digestible ether extract because of the greater calorific value of fat which is 2.25 times more than carbohydrates or protein on unit basis.

$$\text{TDN} = \% \text{ digestible protein} + \% \text{ digestible NFE} + \% \text{ digestible crude fibre} + \\ \% \text{ digestible ether extract} \times 2.25).$$

b. Indirect Method

i. Digestibility 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 the test feed (concentrate feed eg: oilseed cake) are fed together. Digestibility of nutrients in test feed (oil seed cake) is calculated by the difference, on the assumption, that the nutrients in the original basal roughages have the same digestibility.

Associative Effect of Feeds:

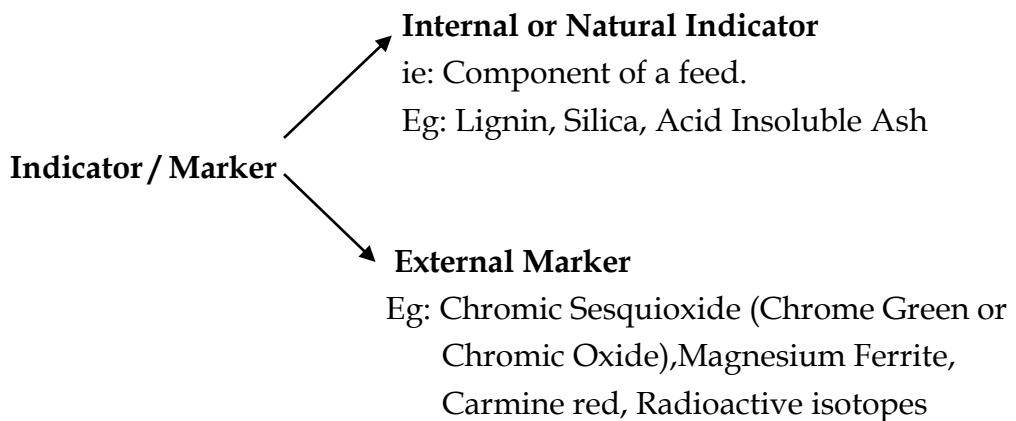
The addition of oilseed cake to the basal roughage may influence digestibility, this is known as associative effect.

ii. Indicator Method

Inert reference materials called as markers are used in digestion trials.

The ideal specifications of markers are:

1. It should be totally indigestible and unabsorbable.
2. It should not have any pharmacological action on the digestive tract. It should be inert to the digestive system.
3. It must mix intimately with and remain uniformly distributed in the digesta.
4. It should pass through the tract at a uniform rate and should be voided entirely.
5. It should be readily determined chemically.
6. It should be a natural constituent of the feed under test.



Internal indicators such as Silica, Acid Insoluble Ash and lignin are indigestible and can easily determined. **Chromic oxide** is the commonly used external marker for digestion trials with Avians, Swine and Carnivorous species.

$$\text{Dig.Coe.of feed} = 100 - \left(100 \times \frac{\% \text{ indicator in feed}}{\% \text{ indicator in faeces}} \times \frac{\% \text{ nutrient in faeces}}{\% \text{ nutrient in feed}} \right)$$

Measurement of Pasture Consumption and Digestibility in Grazing Animals:

To know the quantity of forages consumed by an animal from the pasture, and its nutritive value, the pasture was harvested and fed to the animals. But this method was not correct, since the grazing animals have a tendency of selective grazing. Subsequently, the grazing animals were harnessed with faeces bags, and a faeces voided in 24 hrs was determined. This can provide the total dry matter voided. Pasture grass was harvested and fed in the stalls to determine the digestibility coefficients. From these two figures the total dry matter intake (DMI) of the animals was calculated.

Limitations:

It is difficult, to obtain the representative sample of forage actually eaten by the grazing animal and quantitative collection of faeces by faeces bag. Therefore markers

have been used both for determination of digestibility of the pasture herbages and the dry matter intake through grazing. Digestibility can be determined through use of an internal indicator. Faecal output is measured concurrently by using an external marker and intake is calculated as follows.

Normally Chromic oxide is fed in a capsule to the grazing animals and then the numbers of grab samples of faeces are taken at different time intervals to determine the average concentration of the indicator per unit weight of faeces.

$$\text{Faecal Dry matter output} = \frac{\text{Marker consumed (gram / day)}}{\text{Marker concentration in faeces (gram / gram Dry matter)}}$$
$$\text{DM intake} = \text{Faecal DM output} \times \frac{100}{\% \text{ indigestibility of Dry matter}}$$

Uses of Markers:

1. Measurement of digestibility coefficients without total faecal collection.
2. Measurement of herbage intake in grazing animals.
3. Markers are also used for quantifying the rate of passage and extent of digestion in different segments of the gut.

Rare earths (Lanthanum, samarium, cerium, ytterbium and dysprosium) may be used as reliable markers of particulate phase of digesta. Polyethylene glycol (PEG), Chromium EDTA and Cobalt EDTA are liquid phase markers in ruminant studies.

A good marker must have the following qualities;

- (1) Distinctly mark the faeces resulting from the feed with which the marker was fed
- (2) Be insoluble and unable to be absorbed through intestine
- (3) Have no toxic, laxative, caustic or other physiological effect on the experimental diet
- (4) Not contain nutrients or react with the nutrient or nutrients under investigation.

Carmine, methylene-blue, ferric oxide, barium sulfates, copper sulfate, bismuth subcarbonate, purple green and yellow cellophane are some examples of faecal markers.

Laboratory Method of Determining Digestibility:

In vivo determination of digestibility in the animal requires minimum four animals, daily recording of feed intake and faeces voided metabolic cages. This procedure is costly and laborious.

The other techniques of determining the digestibility of feed without feeding the animal is by:

1. Calculation of digestibility of feeds and Total Digestible Nutrients (TDN) from the chemical composition.

2. Semi in vivo techniques / In Sacco method
3. In vitro technique

II. Semi - In Vivo Technique / In Sacco Method:

Digestibility/degradability of the feeds in the rumen can be determined by keeping the feed samples in nylon or dacron bags and immersing in the rumen of fistulated animals. The bags are not degraded by microbes and there pore size is fine enough to allow the microbes to enter the bag and digest the feed particles. It will not allow the feed particles to escape out. The bags are removed at different time intervals and washed and dried at 60°C for 48 hrs. The percent disappearance of dry matter, nitrogen, crude protein, fibre fractions etc are determined.

a. Nylon or Dacron Bag Technique:

The nylon bag techniques require placing of dried samples in bags made of an indigestible material such as nylon, dacron or silk which are then tightly tied. These bags are placed inside the rumen through the opening of fistulae by a variety of techniques and after incubating for a specific time are removed. The rate and extent of digestion are measured by the loss of dry matter or nutrient content from the sample.

Factors that affect the degradability:

1. Particle size of the test feed
2. Bag porosity
3. Sample size to bag surface ratio
4. Diet of the animal
5. Bags placed per animal
6. Incubation time.

b. In Vitro Artificial Rumen (VIVAR) Technique:

The rumen stimulation technique (RUSITEC) is for studying nutrient utilisation by rumen micro-organisms under controlled conditions in the rumen. The system consists of a porcelain test tube or stainless steel or glass jars fitted with bacteriological membrane to provide controlled interchange of the vivar and rumen contents. The containers are equipped with a gas escape outlet for studying volatile fatty acid production.

III. In Vitro digestibility technique:

Digestibility of feeds can be estimated in the laboratory by using in vitro rumen fermentation methods.

a. One stage technique:

The principle involved is that, the rumen microbial digestion of the animal is simulated in the laboratory, where the feedstuff is incubated with rumen liquor at 39°C under anaerobic condition in an artificial rumen. This technique involves the test feed sample, artificial saliva and the rumen inoculum. This mixture is incubated and after

specified period the disappearance of dry matter (IVDMD) or Organic matter (IVOMD) is determined.

b. Two stage technique (Tilley and Terry method);

The first stage simulates the digestive process in the rumen. The residue left after the first stage is further treated with acid pepsin solution (Tilley and Terry 1963) or with neutral detergent solution. The acid pepsin digestion (2nd stage) stimulates the in vivo breakdown of feed and microbial breakdown of feed and microbial protein by digestive enzymes of the lower gut. The 2nd stage procedure with neutral detergent solution estimates the true digestibility rather than apparent digestibility of the test forage sample because neutral detergent solubilises bacterial cell wall and other endogenous products.

CHAPTER 17

FACTORS AFFECTING NUTRIENT DIGESTIBILITY OF A FEED

The digestibility of nutrients is broadly affected by;

- A. ANIMAL FACTORS
- B. PLANT FACTORS
- C. METHOD OF PREPARATION OF FEED

A. ANIMAL FACTORS

- a. **Species of the animal:** Roughages high in crude fibre are better digested by ruminants than non ruminants. Monogastrics pigs are more efficient in digestion of high protein, low fibre feedstuffs.
- b. **Age of the animal:** Very young or very old animals are less efficient in their digestion of feeds. After six months of age a calf can digest roughages as similar to an adult cow. Digestibility of fat in young chicks is lesser than adult birds. In old animals worn out teeth impairs chewing.
- c. **Work:** Light exercise / work seems to improve digestibility, while heavy exercise / work depresses it.
- d. **Individuality:** Individual variation to an extent of 25 % has been observed in the digestive ability of the same feed among animals. Normally 4 to 5 % variation is recorded.
- e. **Level of feeding:** Higher level of feeding results in faster rate of passage of the digesta through the alimentary canal. Hence the retention time is less and nutrient digestibility is also affected.

B. PLANT FACTORS: (Chemical composition of feed).

Generally grains are well utilized by all class of livestock. The chemical composition of forages is affected by number of factors like soil composition, manuring and fertilisation , stage of maturity of the plant.

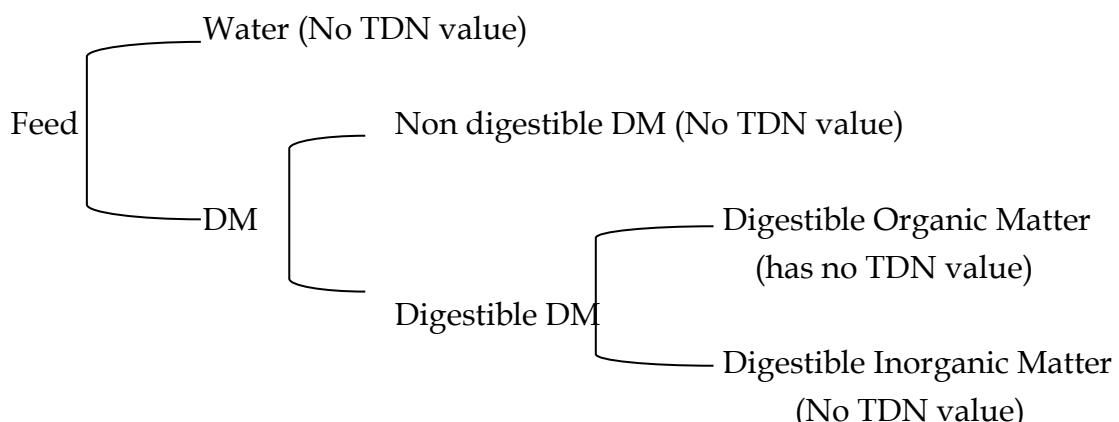
C. METHOD OF PREPARATION OF FEED :

- a. **Particle size of the feed:** Grinding of feeds helps digestibility in young animals and also in older animals due to increased surface area for enzymatic digestion. Fine grinding of roughages increases rate of passage in the rumen and thereby reduces the digestibility.
- b. **Soaking:** of grains and feed in water before feeding generally increases the digestibility.
- c. **Processing of grains / feed:** by boiling, steam processing, pelleting, extrusion cooking improves their digestibility.
- d. **Nutrient content in the ration / ration composition :**

- i. **Protein level:** When several feeds are fed in a ration, one feed may influence the digestibility of the other; this is called “associative effect”. For eg in a low protein diet fed to ruminants, addition of NPN compounds increases the microbial population and thereby the microbial digestion is also improved.
- ii. **Carbohydrates:** The nature and level of carbohydrates affects the digestibility of all nutrients present in the diet. In ruminants excessive level of soluble carbohydrates (e.g. molasses 7 % and above) result in lower microbial break down of crude fibre.
- iii. **Lipids:** Addition of oil or fats in a diet increases the digestibility coefficient of ether extract. But high levels of fat in the diet reduces crude fibre digestibility.
- iv. **Minerals:** Deficiency of minerals in ruminants limits the growth of microbes and thereby the digestibility of crude fibre.

Factors affecting the TDN value of a feed;

1. **The percent of Dry matter:** The TDN value of feed is lower when the moisture content of the feed is high. Since high moisture containing feed contains less dry matter.
2. **Digestibility of dry matter:** Feed with low digestibility of dry matter has low TDN value. Eg: Mineral oils have high gross energy value, but low digestibility.



CHAPTER 18

FEEDING STANDARDS FOR RUMINANT ANIMALS

Feeding standards are statements or quantitative descriptions of the amounts of one or more such nutrients needed by animals. Feeding standards are the tables, which indicate the quantities of nutrients to be fed to the various classes of livestock for different physiological functions like growth, maintenance, lactation, egg production and wool growth. The nutrient requirements are generally expressed in quantities of nutrients required per day or as a percentage of diet. For dairy animals, nutrient requirements are generally expressed as separate body functions but in case of poultry and pigs, combined requirements of maintenance and other body functions are given.

There are two terms, which have been used, in the feeding standards. One is the **nutrient allowance** and another is the **nutrient requirement**. The former gives an extra allowance of nutrient over the requirement, which gives a margin of safety whereas latter term gives the requirement for optimum production.

For convenience, all such feeding standards are grouped under major heading on the basis of principles of the standards such as

- 1) Comparative type
- 2) Digestible nutrient system
- 3) Production value type

<u>Feeding standards</u>		
A. Comparative Type	B. Digestible Nutrient System	C. Production Value Type
1. Hay standard	1. Grouven's Feeding standard	1. Kellner-feeding standard
2. Scandinavian Feed Unit Standard	2. Wolff's feeding standard	2. Armsby feeding standard
	3. Wolff's Lehmann feeding standard	3. Agricultural and Food Research Council standard.
	4. Haeckers's Feeding standard	
	5. Savage feeding standard	
	6. Morrison standard	
	7. National Research Council standard	
	8. Japanese feeding standard	
	9. Indian standard	

The various feeding standards of the world which are available for feeding of different categories of livestock are given below;

Name of the country	Protein	Energy
NRC (USA)	CP, DCP	TDN, DE, NE
ARC (UK)	DCP, AP	DE, ME
SCANDINAVIA	DTP	FEED UNIT

GERMANY	DCP	SE
INDIA	DCP	TDN, ME

A. COMPARATIVE TYPE

1. Hay standard

In 1810, German scientist **Thaer** suggested that different feeds should be compared using **meadow hay** as a unit. He published the "HAY EQUIVALENT" as measure of relative value on determining the materials in the feeds extractable with water and other solvents. This standard provided that 100 lbs. of meadow hay was equal in nutritive value to 91 lbs. of clover hay or 200 lbs. of potatoes or 625 lbs. of mangels. Nothing was known about the chemical value of these feeds and the physiological requirements of the animals. The only measure was the practical feeding experience.

2. Scandinavian "feed unit" standard

In 1884, Professor **Fjord** formulated the Scandinavian feeding standard. In this system only one factor, namely, the **feed unit** was taken into account. The value of one pound of common grain such as corn, barley or wheat, is given as one unit value and the value of all other foods is based upon this. According to this standard one feed unit is required for each 150 lbs. of body weight and an additional unit for every three pounds of milk production. This feeding standard was based upon the actual milk production record of the farm animals. Further as per modification to this standard it was suggested that in addition to feed unit, 0.065 lbs of digestible crude protein per 100 lbs body weight and 0.05 lbs of DCP per lbs of milk production should be given to the animals. Being simple and easy to calculate, this feeding standard is still continued in a number of Scandinavian countries for formulation of ration for livestock.

As the grains are of different types in different countries, the feed units should also be different. Hence the Scandinavian units are not applicable in our country unless experiments are conducted here with our own grains.

B. DIGESTIBLE NUTRIENT SYSTEM

1. Grouven's feeding standard

In 1859 Grouven, a German chemist published his feeding standard with crude protein, carbohydrates and fat contained in the feed as the basis of the standard. According to this standard a cow weighing 1,000 lbs. should be fed 28.7 lbs. of dry matter containing 2.67 lbs. of crude protein 0.6 lb. of crude fat and 14.55 lbs. of crude carbohydrates.

Very soon after standard of Grouven, Henneberg and Stohmaan found that the total nutrient contained in a feed did not form an accurate guide to its value. The proportion of digestible parts varied with different feeds and hence the digestible nutrient would be more valuable. So due to this defect Grouven's feeding standard is now abandoned.

2. Wolff's feeding standard

In 1864 Dr. Emil Von Wolff proposed a standard on digestible protein, digestible carbohydrates and digestible fats contained in a feeding stuff. His standard for dairy cows weighing 1,000 lbs. was 24.5 lbs. of dry matter containing 2.5 lbs. of digestible carbohydrates and 0.4 lb. of digestible fats. This has a nutritive ratio 1:5.4. This standard though an improvement over the standard of Grouven, yet it does not consider the

quantity and quality of milk produced, and the maintenance and production requirement were not considered separately. Keeping these shortcomings in mind Professor Kuhn published feeding standard in 1867 based upon the maintenance and production requirements along with quantity of milk production. Wolff's standards were published annually without fundamental change until 1897, when they were modified by G. Lehmann (German Scientist) to become Wolff-Lehmann standards for various classes of animals.

3. Wolff's Lehmann feeding standard

Dr. G. Lehmann of Berlin modified Wolff's standard in 1896. Till then Wolff's standard was in use. He took into account the quantity of milk produced, but he failed to take into account the quality of milk. The requirements of a cow with a body weight of 1000 lbs. as fixed by this standard for maintenance and maintenance cum milk production are;

Nutrient	For maintenance only	For production and maintenance
Dry matter	18 lb.	25 lb
Crude Protein	0.7 lb	1.6 lb
Fat	0.1 lb	0.3 lb
Carbohydrates	8.0 lb	10 lb

4. Haecker's feeding standard

Keeping in view the demerits of Wolff's Lehmann standard, Haecker (1903) an American worker formulated the feeding standard, who for the first time considered the quantity as well as the quality of milk produced in formulating a milk standard. He took into account the allowance for the percentage of fat in the milk in addition to the requirement for maintenance, production and total milk yield. He was also the first to separate the requirements for maintenance from the requirements of production.

His standards included digestible crude protein, carbohydrates and fats. Later it was expressed in digestible crude protein and total digestible nutrients. According to this standard a cow weighing 800 lbs will require 0.56 lbs DCP and 6.34 lbs TDN for maintenance, and 0.054 lbs DCP and 0.341 lbs TDN for every lbs of milk with 4 percent fat in it.

5. Savage feeding standard

An American scientist Savage concluded that the Haecker's standard was too low especially in protein requirement and published his feeding standard in 1912 by increasing 20 percent of protein requirements. He expressed his standard in terms of DCP and TDN, and further showed that about 2/3 requirement of the dry matter should be met by feeding roughage and the remaining 1/3 from concentrates. Fat content of the milk was also considered. He suggested that in case of milking cows at least 24 lbs. of dry matter should be provided for an average cow. The nutritive ratio should not be wider than 1:6 or narrow than 1:4.5. According to this standard a cow weighing 1000 lbs will require 0.70 lbs TDN for maintenance. In addition, a cow will require 0.065 lbs DCP and 0.35 lbs TDN for every lbs of milk produced with 4 percent fat.

6. Morrison feeding standard

Morrison F.B. observed that stockmen are spending large sums of money for entirely unnecessary amounts on protein supplement, thus considerably reducing their

profits. He therefore, endeavoured to combine in one set of standards what seem in the judgement to be the best guide available in computation of rations for the various classes of livestock. These standards were first presented in the 15th edition of "Feeds and Feeding" published in 1915 and were then called "Modified Wolff and Lehmann standard". They soon came to be known as the "**Morrison Feeding Standard**". These standards were expressed in terms of Dry Matter (D.M.), Digestible Protein (D.P.) and Total Digestible Nutrients (T.D.N.). Morrison indicated the nutrient requirement of animals in a range rather than in one figure.

In 1936 the standards were revised. For those who desired to use net energy values instead of TDN in computing rations, net energy allowances in therms were also included.

Again in 1948 with further addition to the knowledge, more changes were made in the standards.

In the year 1956, Morrison included in the standard the allowances for Calcium, Phosphorus and Carotene besides digestible carbohydrates, digestible proteins and net energy in therms. The average of Morrison standards has been accepted for Indian livestock.

7. National Research Council (N.R.C.) standard

In USA a sub-committee of the committee on Animal Nutrition under the auspices of National Academy of Sciences - National Research Council and US Department of Agriculture (USDA) recommended a nutrient allowance for dairy cattle which was first published in 1945. Since then they have been publishing the nutrient requirements for all types of farm animals.

The standard includes digestible protein and total digestible nutrients and also includes the recommended requirements for calcium, phosphorus, carotene and vitamin D for dairy cattle, beef cattle, pigs, poultry, sheep, dogs, horses, laboratory animals etc. It is believed that these N.R.C. reports representing in each case the pooled judgement of a group of experts in the field of species in question.

Today in a number of countries N.R.C. standards are followed where they use ME for poultry, DE for swine and horses, DE, ME and TDN for sheep, ME, TDN and NE_m and NE_g for beef cattle and for dairy cattle, values are given for DE, ME, TDN, NE_m and NE_g for growing animals with additional values as NE_l for lactating cows. From time to time, the NRC revises these feeding standards in keeping with new information and changing feeding practices.

8. Japanese feeding standards for dairy cattle

Maintenance requirements based on live weight raised to the 0.75 power of Maintenance = 37.37 g TDN/Kg or 116.3 kcal ME/Kg (equivalent to 0.58 lb dig. Protein 8.1 lb TDN or 11.4 Mcal ME per 1,000 lb cow).

For milk production, nutrient requirements were calculated on the basis of 154 parts dig. Protein per 100 parts milk protein and 1,444 kcal ME per 1,000 kcal milk energy.

9. Indian standards (Sen and Ray standard)

India has been almost entirely dependent on standards drawn up by late F. B. Morrison of Cornell University in U.S.A. Dr. K. C. Sen, the first Director, National Dairy Research Institute, Bangalore and Karnal has compiled the feeding standards on

Morrison's recommendations, where they adopted the average of maximum and minimum values recommended by Morrison. Later on Sen, Ray and Ranjhan (1978) revised the Sen and Ray (1964) standard on the basis of experimental trials conducted in Indian animals. These modified values are still functioning in many of our established dairy farms.

Considering the fact that nutrient needs of livestock and poultry breeds under tropical environments are different from those developed in temperate climate, the India Council of Agricultural Research realising the necessity of setting up suitable feeding standards for the Indian livestock and poultry, assigned this task to the Late Dr. N. D. Kehar, the then Chairman, I. C. A. R. scientific panel on Animal Nutrition and Physiology, as he had been associated with this type of research activities for about two decades.

The scientific panel set up subcommittees for each species by inviting experts from various institutes of the country. On the basis of the scientific information arising from the experimental work carried out in India over the past two decades, nutrient requirement of Indian livestock and poultry ultimately been published by I. C. A. R. in January 1985 under the able Chairmanship of the panel Dr. K. Pradhan, Haryana Agricultural University, which will no doubt form a strong basis for feeding our livestock and poultry with a scope for further revision wherever newer data on nutritional requirements become available. These standards were updated and revised in 1998.

The feeding standards are based on the experimental results and have been organized to contain information on daily DM, DCP, TDN, Calcium and Phosphorus intake. Since most of the data on energy and protein value of feed and animal's requirement in India have been expressed in TDN and DCP. The figure of total digestible nutrient can be converted into digestible and metabolizable energy by taking 4.4 Mcal DE and 3.6 Mcal ME per kg TDN.

C. PRODUCTION VALUE TYPE

1. Kellner feeding standard

In 1907 Kellner, a German scientist investigated a feeding standard based upon "Starch" as the unit of measurement. He took into account not only the digestibility of the feeds as calculated from the amount lost in faeces and urine but also the entire loss from the body including energy expended in digestion and passing the food inside the body (chewing, etc.). For measuring the amount of energy lost from the body as heat, Kellner devised a respiration apparatus. Here heat is determined indirectly by finding the amount of carbon dioxide gas liberated or by measuring the amount of oxygen gas used up in oxidation which takes place in the body. The animal breathes through an airtight mask placed over its nose and mouth.

According to this system, a 1,000 lbs. animal needs 0.6 lb. of digestible protein and 6.35 lbs. of starch equivalent. This starch equivalent in turn can be converted into energy by a method worked out by Armsby and Kellner.

Any of the feeds the composition of which known may be converted to starch equivalent by using the following factors:

$$\begin{array}{ll} \text{Dig. Protein} & \times 0.94 = \text{S.E.} \\ \text{Fat from coarse fodder} & \times 2.1 = \text{S.E.} \end{array}$$

Fat from cereal grain	X 2.1	= S.E.
Fat from oil seeds	X 2.4	= S.E.
Dig. Carbohydrates and fibre	X 1.0	= S.E.

2. Armsby feeding standard

Armsby standard is based on true protein and net energy values. By means of the respiration calorimeter, Armsby determined the net energy required for mastication, digestion, assimilation and also the amount of heat and gases given off through the excretory channels. Thus after considering the various losses of energy such as in urine, faeces, gases and in the work of digestion, he was able to estimate the amount of net energy available for productive purposes. Armsby expresses his standard in two factors, that is true protein and therms of net energy.

A common criticism of the Armsby standard is that the expense of determining requirements of the animals and the net energy in the various feeds is excessively high. The net energy values of only a very few feeds had actually been determined and most of the values have been computed from the Table of Morrison's digestible nutrients. Armsby standard is not as widely used as are the standards based on digestible nutrients.

3. Agricultural and Food Research Council (A.F.R.C.) standard

The nutritive requirement of various livestock in the United Kingdom has been presented in Ministry of Agriculture's Bulletins. The Technical Committee of the Agricultural and Food Research Council of Britain prepares these. Requirements are set forth in three separate reports dealing with poultry, ruminants and pigs, each of these reports extensive summaries of the literature upon which the requirements are based. The most attractive feature of the British Feeding Standards is that the unit of energy requirements has been expressed in terms of Starch equivalent instead of T.D.N. or ME of NE are in Morrison and in N.R.C. standards.

Study Questions

1. Tables which indicates the nutritive requirements of livestock are known as

A. Nutrient allowance	B. Feeding standard
C. Tables	D. Chart
i. A is true ii. B is true	iii. c is true iv. D is true
2. Kellner's feeding standard is

A. Comparative type	B. Digestive nutrient type
C. Production value type	D. Maintenance value type
i. A and D are true ii. B is true	iii. C is true iv. None are true
3. Morrison feeding standards express requirements in terms of

A. Dry matter, Digestible protein	B. TDN		
C. NE	D. CP and ME		
i. A and B are correct	ii. A,B & C are correct	iii. D is correct	iv. A and C are correct
4. ARC feed standard is adopted in

A. USA	B. Japan
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Chapter 19

BALANCED RATION AND ITS CHARACTERISTICS

Ration

A ration is the feed allowed for a given animal during a day 24 hours. The feed may be given at a time or in portions at intervals.

Balanced ration

A balanced ration is a ration, which provides the essential nutrients to the animal in such proportion and amounts that are required for the proper nourishment of the particular animal for 24 hours.

Desirable characteristic of a ration;

1. The Ration should be properly balanced

With a correct and balanced ration a cow can get the best out of all the constituents present in her feed resulting in production of milk at cheaper cost. In improperly balanced ration, much of the feed is wasted. What is eaten by the cow is not important but what she digests is important. Because the feed digested alone goes for milk production and maintenance of the body. A balanced ration is thus more purposeful and beneficial.

2. The ration must be Palatable

Whatever feed given to an animal must be to its liking. Evil smelling, mouldy, musty, spoiled and inferior feeds are unpalatable and must not be given to the animals. If some excellent feed is not good in taste, they should be improved by special preparations like addition of salt or other feed additives.

3. Variety of Feed in the Ration

By combining many feeds in a ration, a better and balanced mixture of proteins, vitamins and other nutrients are furnished than by depending on only a few. Variety of feeds in the ration makes it more palatable.

4. The Ration should contain enough of mineral matter

Every litre of milk yielded by a cow contains a little more than 0.7% of mineral matter. If the amount of mineral matter in the ration is not sufficient to meet the demand in the milk yield, the cow shall have to draw upon her own body supplies or fall down in milk yield. At the end of her lactation, the cow will be left as an extremely weak animal and her milk yield in subsequent lactation will go down considerably.

5. The Ration should be fairly Laxative

Constipation is often the cause of most of the digestive troubles. It is, therefore, necessary to give such feeds, which are laxative in character.

6. The Ration should be fairly bulky

The stomach of cattle is very capacious and they do not feel satisfied unless their bellies are properly filled up. From the point of providing energy and heat generated values, indigestible fibre is not of any great importance but it plays an important role in giving a feeling of fullness to cattle. If the bulk of the ration supplied is small, however rich it might be in its nourishing constituents, cattle may fall a victim to the depraved habits of eating earth, rags, dirty refuses, etc., for filling up stomachs.

7. The ration should contain sufficient green fodder

Green succulent fodders are of great importance in the feeding of milch animals because of their cooling and slightly laxative action. They aid in the appetite and keep the animal in good condition. Green fodders are bulky, easily digestible, laxative and contain enough of necessary vitamins. Leguminous green fodders are very rich in proteins.

8. Avoid sudden changes in the ration

Sudden changes are often the cause of many digestive troubles, the more notable being the "*Tymanitis*", *Impaction*", etc. All changes of the feed must be gradual and slow. An animal system receiving a certain feed or a mixture of feeds gets accustomed to it. It gets upset by sudden changes.

9. Maintain regularity in Feeding

Cattle like other animals are creatures of habits and get so much used to routine that marked changes may lead to restlessness. As the feeding hour approaches, their glandular secretions become active in anticipation of the meal. Irregularity in milking and feeding tells very badly on the productive powers of an animal. The time of feeding should be evenly distributed so that the animals are not kept too long without feed.

10. The Feed must be properly prepared

The feed must be well prepared. Some feeds require special preparations before administration in order to render them more digestible and palatable. Hard grains like gram, barley, wheat, maize, etc., should be grounded before feeding so that their mastication may become easy. Coarse fodders like dry jowar, bajra and green fodders of these crops should be chaffed before feeding. Some dry fodders, such as *bhusa* of cereals and legumes should be moistened. Soaking of feeds like various types of cakes and cottonseed soften them and makes them more palatable.

11. A Ration should not be too bulky

If the ration is too bulky, the animal will fail to get all its nutrient requirements.

12. Economy in Labour and Cost

The ultimate object of rearing animals is to make profits. The cost of the feeds and the labour charges should be minimized to make rearing of livestock profitable.