DEPARTMENT OF ANIMAL NUTRITION

CLASS-NOTES

ANIMAL NUTRITION **Credit Hours: 3+1**

THEORY

UNIT-1

PRINCIPLES OF ANIMAL NUTRITION AND FEED TECHNOLOGY

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Syllabus

- 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.

INTRODUCTION

Nutrition (Definition)

- The science of nutrition deals with many physiological processes and biochemical reactions which convert feeds into body tissues and various activities of living organism.
- It involves processes such as feed intake, digestion and absorption of nutrients into the animal body.
- In addition, it also deals with the study of composition of feeds and their processing for animal feeding.

Father of Nutrition: Antoine Laurent Lavoisier

Reference Text Books:

1) Principles of Animal Nutrition and Feed Technology – by D.V. Reddy
2) Textbook of Animal Nutrition – by Maynard and Loosli
3) Animal Nutrition – by McDonald & others
1) Textbook of Feed Processing Technology – by N.N. Pathak

Feed Technology (Definition)

Feed technology is the study of various feed sources used for animal feeding, their classification, processing, storage and conservation, anti-nutritional factors and feed formulation for various species of livestock animals.

History of Animal Nutrition

1) Santario Sanctorius

- Weighed himself on balance before and after eating food, to find out what happened to the food.
- His weight increased by the amount of food he consumed which came to original after a time.
- But what happened to the food he could not answer.
- This was the first experiment on human nutrition/metabolism.

2) Antoine Laurent Lavoisier

- He introduced balance and thermometer in nutrition studies.
- He also discovered that combustion was an oxidative process.
- He further told that respiration involved the combination of C and H with inspired O2.
- The quantity of oxygen absorbed and carbon di-oxide given off depend up on the food intake and work done.
- With Laplace, he designed animal calorimeter and demonstrated that respiration is the essential source of body heat.
- He stated that life is a chemical process.
- Founder of Science of Animal Nutrition/Father of Animal Nutrition

3) G.J. Mulder

- Gave name "Protein" to nitrogenous food.
- Protein means – to take first place

4) Francois Magendie

- Founder of modern experimental method in animal feeding experiments.
- He used pure carbohydrates & fats to prove that food nitrogen is essential.
- He published "gelatin report" (stating importance of protein/amino acids).

5) Justus von Liebig

- He postulated that proteins are used for body building.
- And carbohydrates & fats are burned/metabolized to produce heat.

6) Thaer

- Noted that feeding of well cured hay kept animals healthy.
- He developed "Hay Equivalent"
- Used Meadow hay

7) Lawes and Gilbert

- They performed pioneer and laborious task of analysing entire bodies of farm animals.
- They gave "Animal body composition"

8) Stephen Babcock

- Known for his Babcock Test – to determine fat content in milk
- Feeding experiments with single plant. Corn/Wheat/Oat plant feeding
- Purified diet method

9) Nathan Zuntz

- Did the pioneer work in the field of basal metabolism and in respiration studies with farm animals.
- Developed first portable respiration apparatus.
- Given "Fermentation" hypothesis: to explain forage utilization in ruminants.

10) W.O. Atwater

- Constructed first human respiration calorimeter with assistance of E.B. Rosa.
- Studied heat production in human
- Gave energy requirement various body functions and energy values of foods.
- ATWATER 'S GROSS ENERGY VALUE

  Carbohydrate: 4.15 Kcal/g

  Protein: 5.65 Kcal/g

  Fat: 9.4 Kcal/g
- ATWATER 'S PHYSIOLOGICAL FUEL VALUES

  Carbohydrate: 4.0 Kcal/g

  Protein: 4.0 Kcal/g

  Fat: 9.0 Kcal/g

11) H.P. Armsby

- Gave “Net Energy” system of energy evaluation.
- Used calorimetry technique to determine Net Energy values

12) G. Haubner

- First to conduct digestion trial.
- Discovered that fibre is partially digested.

13) Henneberg and Stohmann

- Developed the system for proximate analysis at Weende Research Station, Germany
- Chemical composition/proximate analysis of feeds.

14) Regnault and Reiset

- Developed a closed circuit respiration chamber.

15) Max Rubner

- Formulated the Isodynamic law of calorie.
- He showed that carbohydrate and fat are interchangeable on an energy equivalent basis.
- “Surface hypothesis”: body metabolic rate is proportional to body surface area.
- “Rate-of-living theory“: slow metabolism increases an animal's longevity.

16) J. L. Hills

- First time used the term TDN (Total Digestible Nutrients)

17) Osborne and Mendel/ McCollum and Davis

- Discovered vitamin A using purified diets

18) P. J. VanSoest (1970)

- Developed the fibre analysis system
- Detergent system of fibre fractationation

19) R.E. Hungate

- Discovered rumen bacteria

20) Gruby and Delafond

- Discovered rumen protozoa

21) C.G. Orpin

- Discovered rumen fungi

22) W.C. Rose

- Concept of Essential Amino Acids

23) R.T. Holman

- Concept of Essential Fatty Acids

24) C. Funk

- Gave term vitamin

25) Parker

- Gave term probiotic

26) Max Kleiber

- Kleiber observed that heat production from animal body is most appropriate with body weight raised to the 0.75 (3/4).
- $W^{0.75}$

27) E.J. Underwood

- Famous for his work on mineral nutrition

Wrote books:

1) The Mineral Nutrition of Livestock
2) Trace elements in Human and Animal Nutrition

Indian Scientist

1) **K.C. Sen**
   - Nutritive Value of Indian Cattle Feeds and Feeding of Farm Animals
2) **Sen, Ray and Ranjan**
   - Complied Chemical Composition of Indian feedstuffs
3) **N.D. Kehar**
   - Nutritive value of non-conventional feeds. (Agro-industrial by-products, tree leaves, etc.)
4) **U.B. Singh**
   - Worked on rumen digestion and metabolism by using radioisotopes
5) **S.K. Talapatra**
   - Developed methods for estimation of minerals (phosphorus) in feeds and fodders.

1928

Animal Nutrition Division at Indian Veterinary Research Institute, Izatnagar was established under the chairmanship of lord Linlinthgow

1952

4 Regional Research stations at Anand, Banglore, Kalyani and Palampur were established to conduct the research in animal nutrition

1956

Dairy Cattle Nutrition Dept. was started at National Dairy Research Institute, Karnal

1995

National Institute of Animal Nutrition and Physiology (NIANP) was established at Banglore.

FEED AND ITS CLASSIFICATION

Feed:

Feed is the ingredient or material fed to animals for the purpose of nourishment.

Feed classified mainly as roughages, concentrates, feed supplements and feed additives.

I. Roughages:

Roughages are bulky feeds containing crude fibre (CF) more than 18% and TDN less than 60%.

Roughages are further classified as succulent and dry roughages.

(A) Succulent Roughages:

Succulent roughages contain moisture from 60 to 90 %.

The succulent feeds are further classified into **Pastures, Cultivated fodder crops, Tree leaves, Silage and Root crops.**

1) **Pastures:**

Pastures referred to the land on which different types of edible grasses and other plants are grown for grazing of livestock.

eg. Para grass, Guinea grass, Napier grass, Anjan grass

2) **Cultivated fodder crops:**

a) Legumes:

Legumes containing 2 – 3% DCP & 12% TDN on fresh basis

eg. Cowpea, Barseem, Lucerne

b) Non-legumes:

Contains 0.5 – 1% DCP & 11 – 15% TDN on fresh basis.

eg. Maize, Jowar, Barley, Oat

3) **Tree leaves:**

Tree leaves may serve as potential feed source during shortage of feed

eg. Babul, Lucaena, Mulberry, Banayan

4) **Root crops:**

Root crops used as alternate feed source during scarcity period

eg. Tapioca, Sugar beet, Carrot, Turnip

5) **Silage:**

Silage is an anaerobically fermented feed prepared from green fodder whenever the supply of green fodder is plenty.

Oat is the best crop for silage making.

(B) Dry Roughages:

Dry roughages contain moisture from 10 to 15 %.

They are further classified into **Hay and Straws.**

1) **Hay:**

For hay preparation the crop is harvested at pre-flowering stage and air-dried to reduce moisture content below 15%.

Lucerne is the best crop for hay making.

2) **Straws:**

Straws are the crop residue left after harvesting the main product of crop.

Straws have low nutritive value.

II. Concentrates:

Concentrates are less bulky feed containing crude fibre less than 18% & TDN more than 60%

Concentrates are further classified as energy rich and protein rich concentrates.

A) Energy Rich Concentrates:

The crude protein content is generally less than 20 %

eg. Cereal grains – Maize, Jowar, bajara, Barley, Oat

Grain by products – Wheat & Rice brans, Rice polish

Molasses – by product of sugar factories

B) Protein Rich Concentrates:

The crude protein content is generally more than 20 %

1) **Plant origin:**

Ground nut oil cake, Seasame oil cake, Mustard oil cake, Cotton seed cake, Sun flower oil cake

2) **Animal origin:**

Fish meal, Blood meal, Meat meal, Feather meal

III. Feed Supplements:

Feed supplements are nutritive substances used to improve the nutritive value of basal feeds.

They are nutrient in nature, added to the diet to meet nutrient requirement of the animal.

eg. Mineral supplements, vitamin supplements, amino acid supplements

IV. Feed Additives:

Feed additives are the non-nutritive substances added to basal feed in small quantity to improve feed efficiency and productive performance of the animals.

eg. Antibiotics, Hormones, Probiotics, Prebiotics

COMPOSITION OF ANIMAL BODY AND PLANTS

INTRODUCTION

- Plants synthesize complex substances from simple substances like CO_2, N, H_2O 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 fat. Animals ingest these plants and utilise this energy for their bodily functions, tissue growth and production.
- 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 namely 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 species, strain, age, sex and state of nutrition.

Water

- Water content of animal body is variable and decreases as age increases.
- For example,
  - A cattle embryo contains -- 95% water
  - A new born calf contains -- 75-80% water
  - 5 months old calf contains -- 66-72% water
  - Mature animal contains -- 50-70% water

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 as glucose or glycogen in liver and muscles.

Protein

- It is the 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 animals.

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.

Inorganic elements

- Animal body contains many minerals. Concentration of some minerals in animal body is as follows:
    - Calcium - 1.3%, Phosphorus - 0.7%
- Calcium is the mineral that occurs in largest amount in the body, followed by phosphorus.

COMPOSITION OF PLANTS

Water/Moisture

- The principal constituent of living plants is moisture.
- Young plants have more moisture content.
- As the plant mature, the moisture content decreases.

Carbohydrates

- The dry matter of plant contains mainly carbohydrates.
- Carbohydrate serves as a structural and reserve material in plants.
- In seeds carbohydrates occur 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).
- The lignin content of plant tissues increases with maturity of the plant.

Protein

- Protein is primarily present in active tissue such as the leaf. As the plant mature 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

- Fat is present at highest level in the seeds followed by leaves and stem. Oil-bearing seeds have higher percentage of protein and fat compared to cereals.

Minerals & Vitamins

- The mineral content of plants is highly variable. It differs with species and plant parts and is also influenced by soil and other environmental factors.
- In plants there are various organic acids (citric, malic and fumaric), which are important for metabolism in the cells of plant.
- Vitamins both fat-soluble and water-soluble are also present in plants.

Difference between plants and animals in their composition

S.N.	**Parameters**	**Animal**	**Plant**
1.	Major constituent	Water	Water
2.	% carbohydrate	1	75
3.	Reserve energy as	Fat	Carbohydrate (Starch)
4.	Structural component	Protein and mineral	Carbohydrate (Cellulose, hemicelluose)
5.	As source of protein	Good	Poor (except oil seeds)
6.	Mineral content	Calcium & Phosphorus	Potassium & Silicon
7.	Variation in composition	Less	Wide

Nutrient (Definition)

The chemical substance found in feed necessary for the maintenance, production and health of animals.

The chief classes of nutrients are:

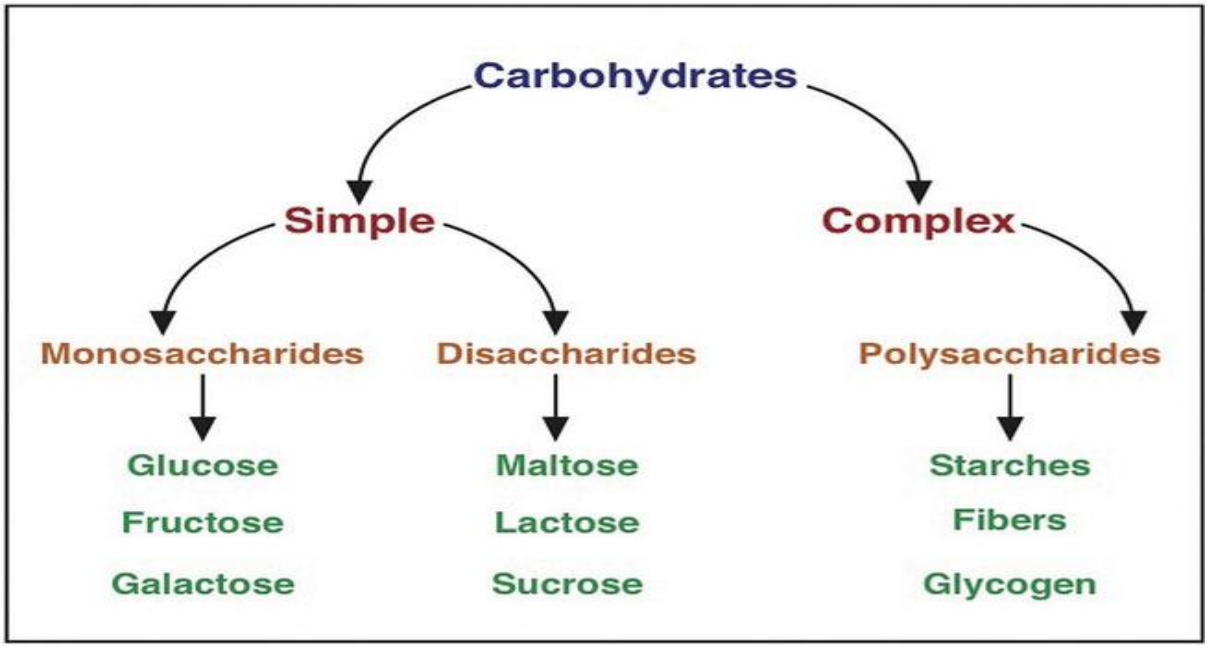
1) Water 2) Carbohydrates 3) Proteins

4) Fats 5) Minerals 6) Vitamins

Nutritional aspect of Carbohydrates, Protein and Fats

Nutritional aspect of Carbohydrates

Carbohydrates are poly-hydroxy aldehydes or ketones.



Functions of carbohydrates

- **Major sources of energy:**
- **Carbohydrates are the principal source of energy, supplying 60-80% of the caloric requirements of the body.**
- **Proteins paring action:**
- **Carbohydrates come to the rescue & spare the proteins from being misused for caloric purpose.**

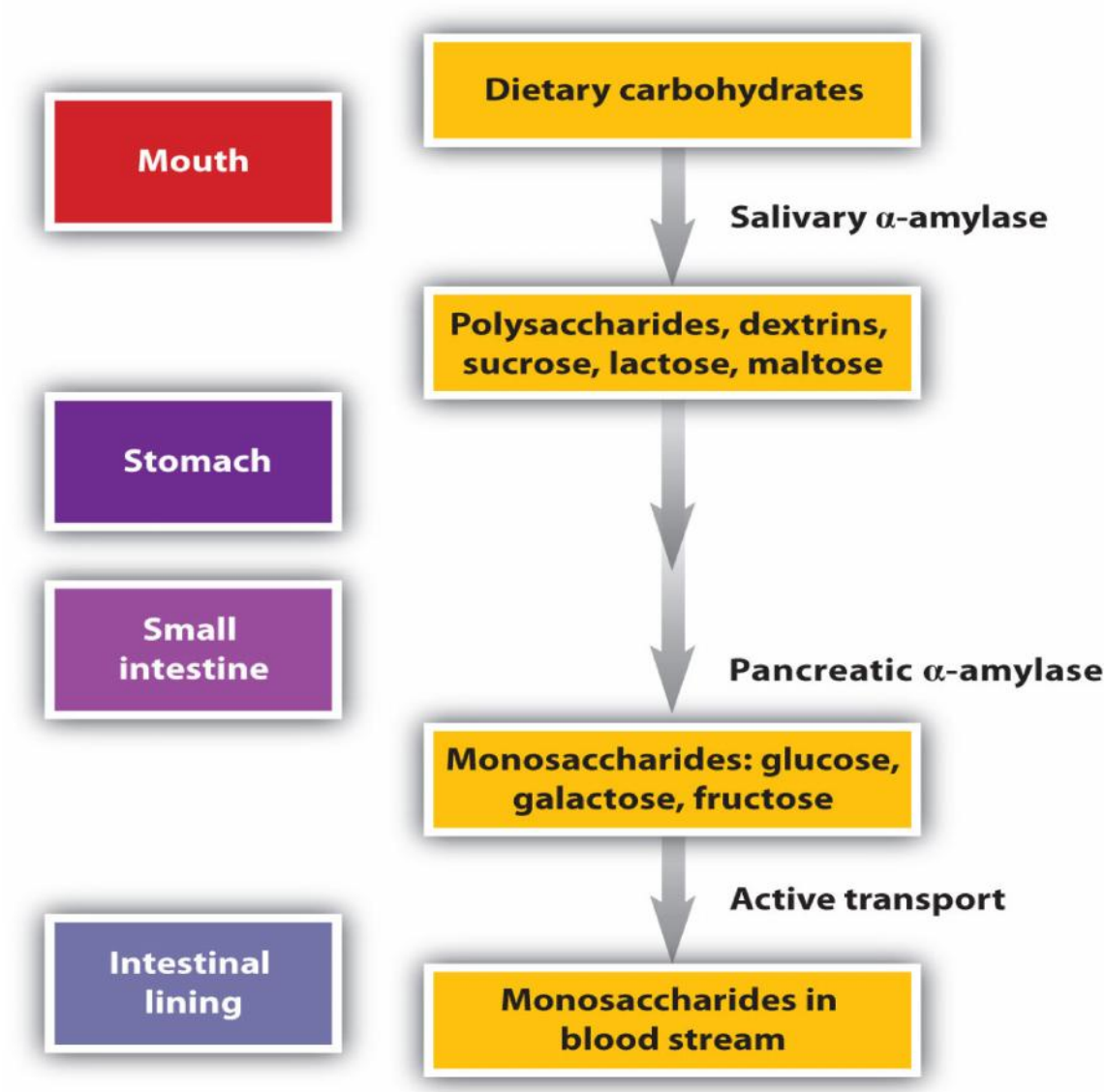
- **Absolute requirement by brain:**
- **The brain & other parts of central nervous system are dependent on glucose for energy.**
- **Required for the oxidation of fat:**
- **Acetyl CoA is formed in fatty acid oxidation.**
- **Acetyl CoA combines with oxaloacetate, the latter is predominantly derived from carbohydrate.**

- **Fats burns in a fuel of carbohydrate**
- **Excess utilization of fats coupled with deficiency of carbohydrates leads to ketosis.**
- **Energy supply for muscle work:**
- **The muscle glycogen is broken down to lactic acid (glycolysis) to provide energy for muscle contraction.**

- **Synthesis of pentoses:**
- **Pentoses (e.g. ribose) are the constituents of several compounds in the body e.g. nucleic acids (DNA, RNA), coenzymes (NAD^+, FAD).**
- **These pentoses are produced in carbohydrate metabolism (HMP Shunt)**

- **Synthesis of non-essential amino acids:**
- **The intermediates of carbohydrate metabolism, mainly the ketoacids (e.g. pyruvic acid), serve as precursors for the synthesis of non-essential amino acids.**
- **Synthesis of fat:**
- **Excess consumption of carbohydrates leads to the formation of fat.**

Digestion of carbohydrates in simple stomach animals

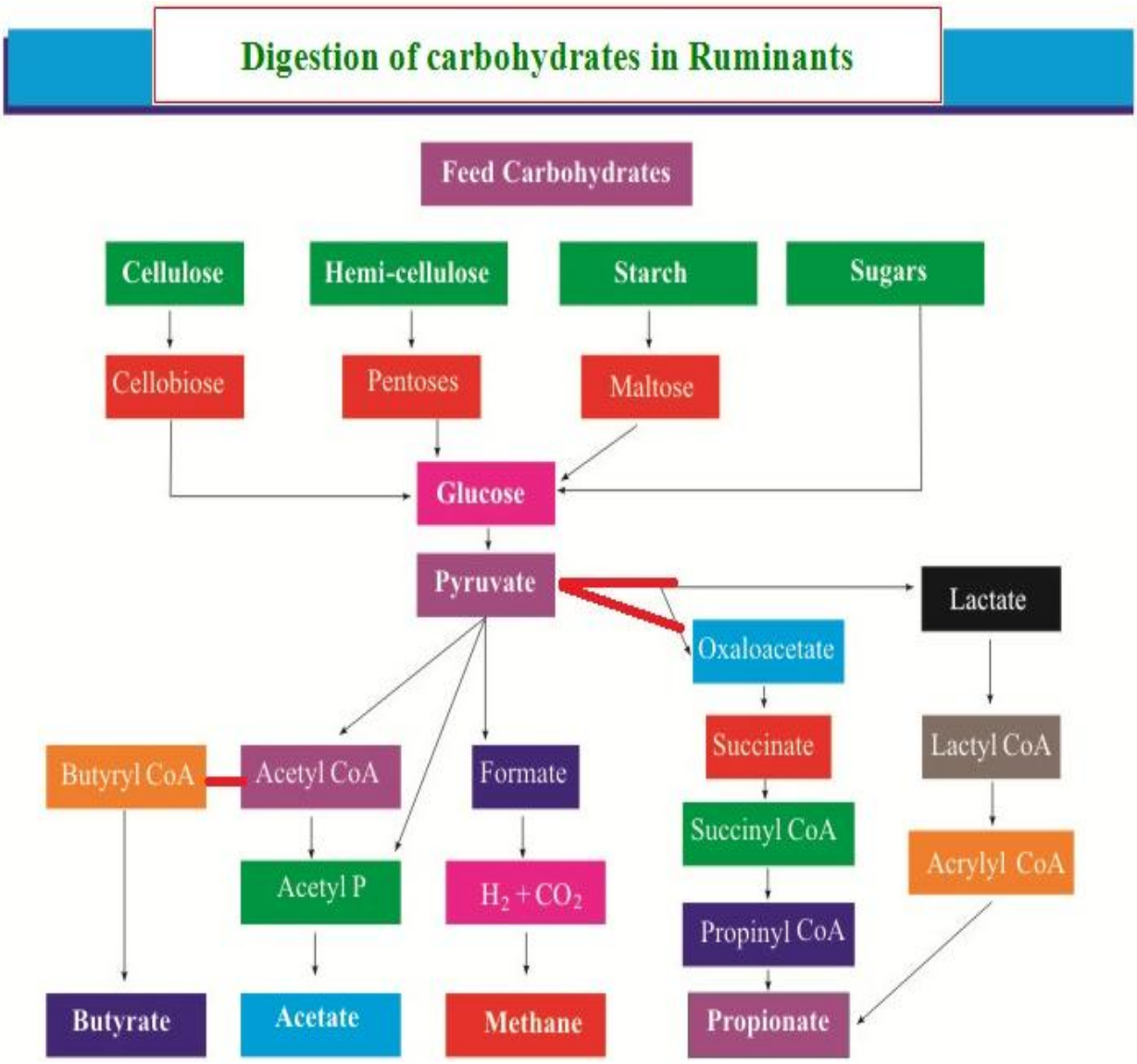


End product of carbohydrate digestion in Non-ruminants/Mono-gastric/simple stomach Animals: Glucose

ATP production:

1 glucose molecule = 38 ATP

Digestion of carbohydrates in ruminant animals



End product of carbohydrate digestion in ruminant animals: Volatile fatty acids (VFA)

VFAs:

1) Acetic acid
2) Propionic acid
3) Butyric acid

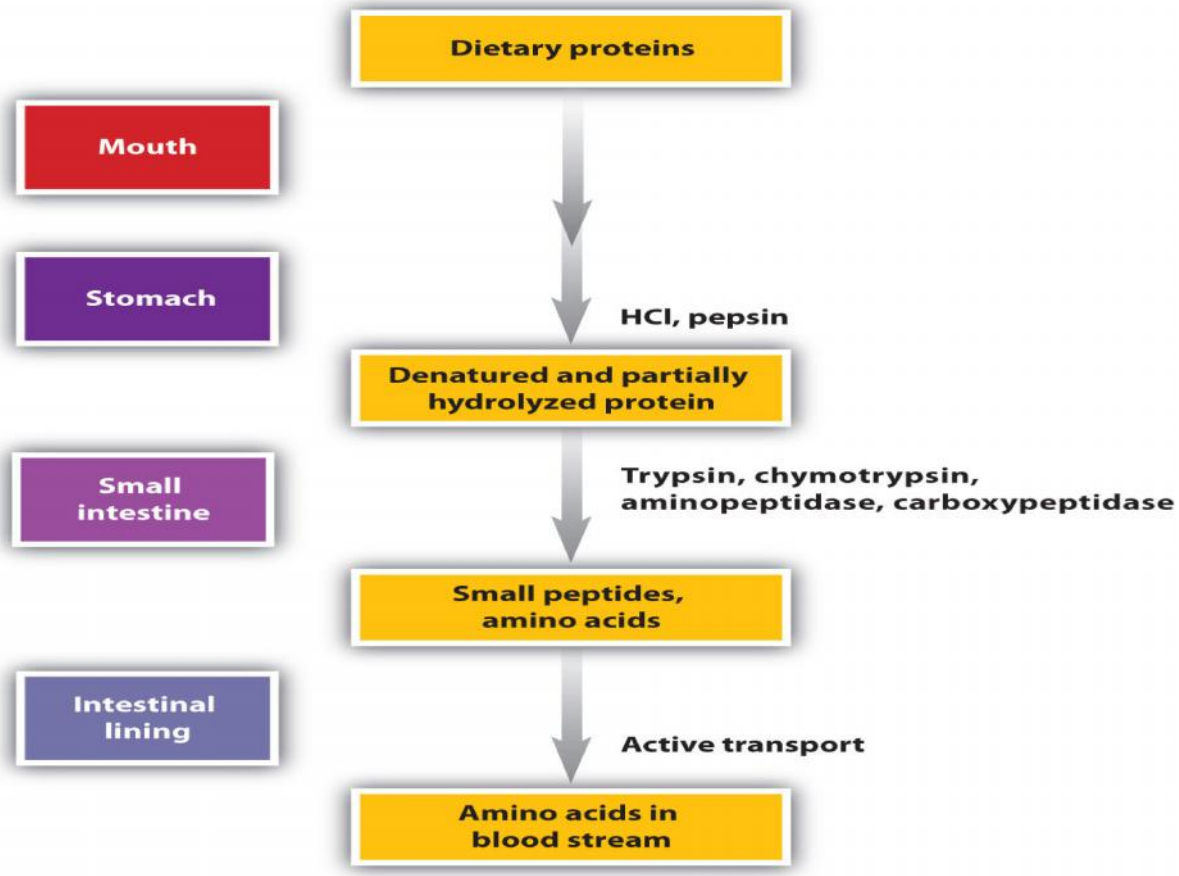
Nutritional aspect of protein

Proteins are large bio-molecules, consisting of one or more long chains of amino acids.

Functions of proteins

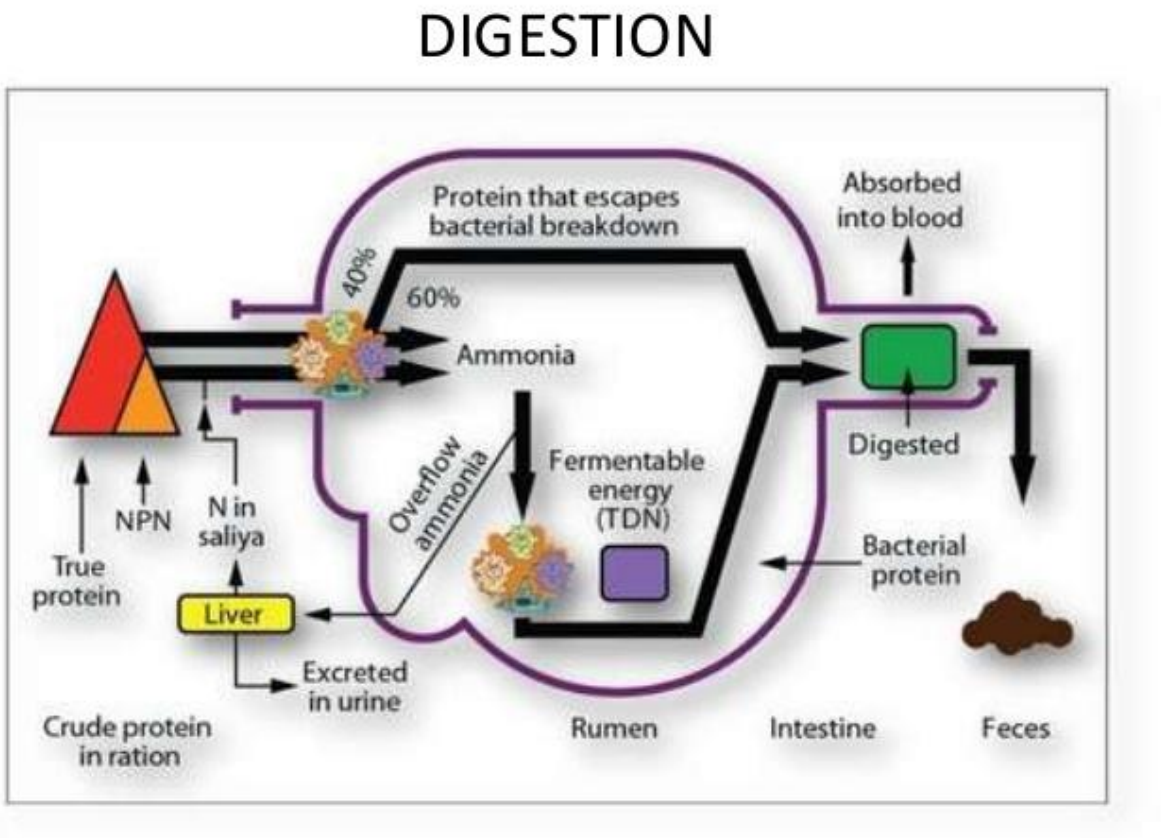
- Fundamental basis of cell structure & function.
- All the enzymes, several hormones, transport carriers, immunoglobulins etc., are proteins.
- Involved in the maintenance of osmotic pressure, clotting of blood, muscle contraction.
- During starvation, proteins (amino acids) serve as the major suppliers of energy.

Digestion of proteins in simple stomach animals



End product of protein digestion in Non-ruminants: **Amino acids**

Digestion of proteins in ruminant animals



End product of protein digestion in rumen: **Ammonia**

Amino Acids

- There are about 20 amino acids found in the animal body. All the 20 amino acids are metabolically essential but not all are dietary essential.
- W.C. Rose classified 10 amino acids as essential and others as non-essential amino acids

Essential Amino Acids

Essential amino acids are defined as the amino acids, which cannot be synthesized in the body at a rate required for normal growth.

Ten essential amino acids are –

1. Valine,
2. Iso-leucine,
3. Leucine,
4. Lysine,
5. Methionine,
6. Histidine,
7. Phenylalanine,
8. Arginine,
9. Threonine
10. Tryptophan

In poultry **glycine** is eleventh essential amino acid.

Non-essential Amino Acids

Non-essential amino acids are defined as the amino acids, which can be synthesized in the body at a rate required for normal growth.

Non-essential amino acids are –

1. Alanine
2. Asparagine
3. Aspartate
4. Cysteine
5. Glutamate
6. Glutamine
7. Glycine
8. Proline
9. Serine
10. Tyrosine

Difference between Essential amino acids and Non-essential amino acids

	Essential amino acids (EAA)	**Non-essential amino acids**
1.	Essential amino acids cannot be synthesized in the body at a rate required for normal growth.	Non-essential amino acids can be synthesized in the body at a rate required for normal growth.
2.	They are dietary as well as metabolically essential.	They are metabolically essential but not dietary essential.
3.	Essential amino acids cannot be synthesized from non-essential amino acids.	Non-essential amino acids can be synthesized from essential amino acids.
4.	Ex. Lysine, Methionine	Ex. Alanine, Cysteine

Limiting Amino Acids

Among the essential amino acids, the amino acid in a feed that is most deficient relative to animal's requirement is called as limiting amino acid.

First liming amino acids:

Ruminants – Methionine

Poultry – Methionine

Pigs – Lysine

Nutritional aspect of fat/lipids

The tri-esters of fatty acids with glycerol (1,2,3-trihydroxypropane) compose the class of lipids known as fats and oils.

It comprises a group of naturally occurring molecules that include fats, waxes, sterols, fat-soluble vitamins (such as vitamins A, D, E, and K), monoglycerides, diglycerides, triglycerides, phospholipids, and others.

Functions of Fats:

1. To provide energy: 9 Kcal/g
2. Fats can also be stored in body for subsequent use.
3. Fats form structural material of cells and tissues such as the cell membrane.
4. Fats also carry the fats soluble vitamins A, D, E and K into the body and help in the absorption of these vitamins in the intestines.
5. Some fats supply essential fatty acids.

Essential Fatty Acids

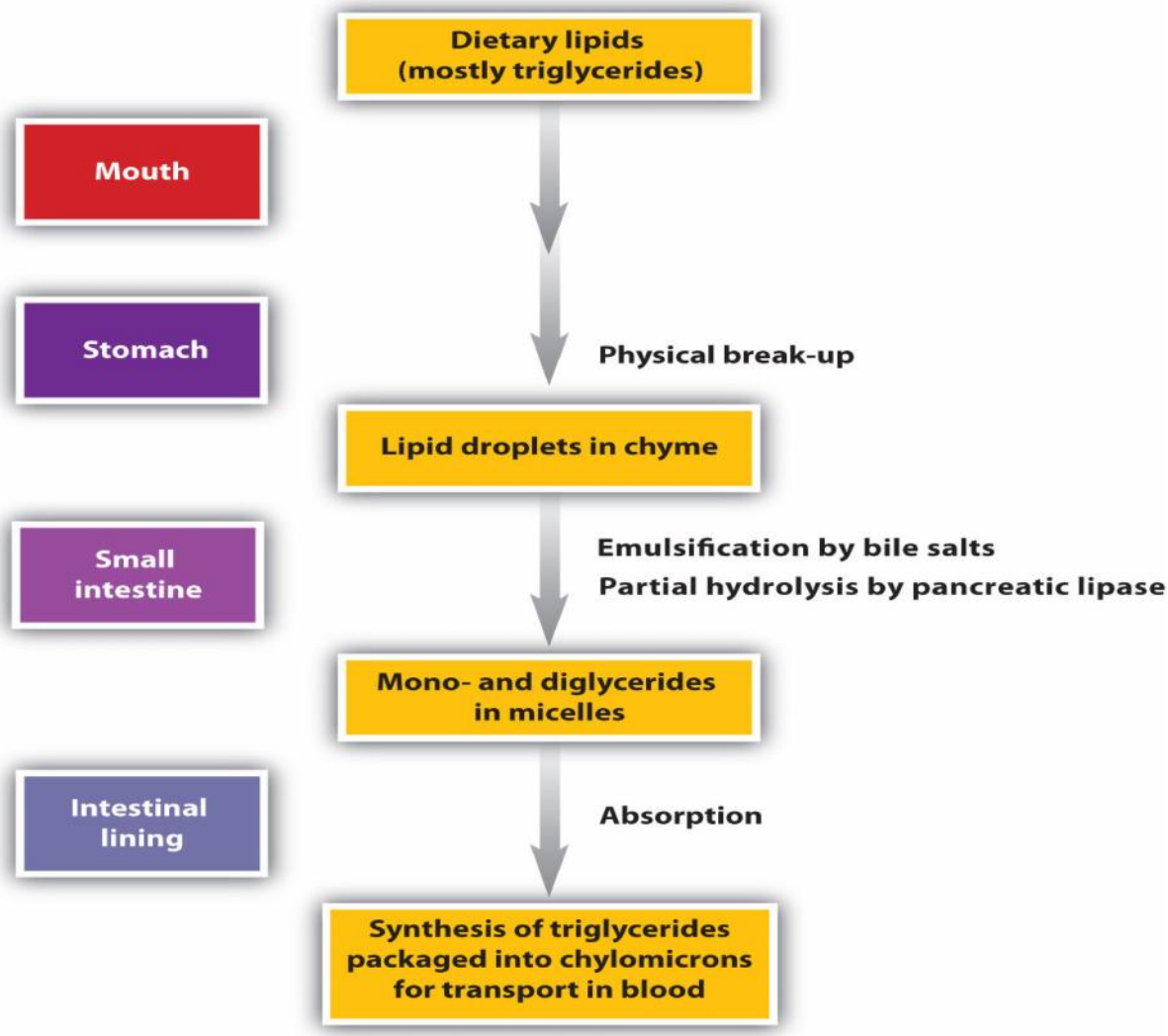
Essential fatty acids are defined as the fatty acids, which cannot be synthesized in the body at a rate required for normal growth.

Essential fatty acids are –

1. Arachidonic acid
2. Linoleic acid
3. Linolenic acid

- The omega-6 series is derived from Arachidonic acid and Linoleic acid
- The omega-3 series is derived from Linolenic acid
- Members of omega-6 and omega-3 families are considered essential fatty acids for mammals because of their inability to introduce double bonds between the ninth carbon atom and the terminal methyl group of the fatty acid chain.

Digestion of fats in simple stomach animals



ATP production:

1 Stearic acid molecule = 153 ATP

Digestion of fats in ruminant animals

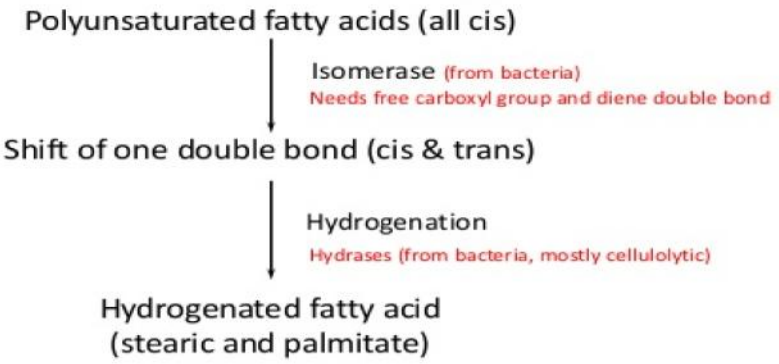
Fat Digestion and Absorption in Ruminants

- Most of the cattle diets predominantly contains **PUFA** as part of plant triglycerides and glycolipids.
- Bacteria in the rumen split off the fatty acids (and sugars) from the glycerol backbone called as **lipolysis or Hydrolysis.**
- Then the released fatty acids undergo hydrogenation called as **Biohydrogenation.**

Biohydrogenation

- As unsaturated fatty acids are released from the glycerol backbone in lipolysis, they are quickly hydrogenated to **saturated fatty acids.**
- In cows fed most typical diets, more than **90%** of the unsaturated fatty acids will be biohydrogenated to produce saturated fatty acids that flow to the small intestine.
- Lipolysis occurs **more rapidly** than the biohydrogenation thus large amounts of **unsaturated oils** can "overwhelm" the biohydrogenation process and result in undesirable effects on the rumen microbial population.

Hydrogenation of fatty acids in the rumen



IMPORTANCE OF WATER IN ANIMAL PRODUCTION AND HEALTH

- Life cannot be sustained without water.
- Animals may live for more days without food but die in fewer days if deprived of water.

FUNCTIONS OF WATER

1. As a major factor in body temperature regulation.
2. All the biochemical reactions that take place in an animal require water.
3. Act as solvent for a wide variety of compounds.
4. It serves as a carrier of digestive juices, enzymes and hormones.
5. It is a medium for hydrolysis of nutrients in the system.
6. It provides cell rigidity, fluidity and elasticity.
7. It serves as lubrication fluid in the synovial cavities.
8. It serves as a medium for transportation of semisolid digest in the gastrointestinal (GI) tract; medium for various solutions like blood, tissue fluids and cell secretions and excretory fluids such as urine and sweat.

WATER REQUIREMENT

- Water requirements for any class or species of animals depends on dietary and environmental factors:

Animal	**Litres/day**	**Animal**	**Litres/day**
Cattle & buffalo	30-50	Swine	10 - 20
Sheep and goat	4-5	Chickens	0.2-0.4
Horses	30-40	Turkey	0.4-0.6

- All environmental temperature that do not result in heat stress, there is a good linear relationship between dry matter consumption and water consumption.
- Water consumption may increase by 12% or more of body weight per day during heat stress.
    - Animals will consume 2 to 5 kg of water for every 1 kg of dry feed consumed when they are not heat stressed.

- Birds require less than mammalian species.
- Young animals generally require more water than adult per unit of body weight.

WATER SOURCES

1. Drinking water
2. Water contained in feed
3. Metabolic water or oxidation water: Water that is provided to the animal by metabolic processes is called as metabolic water or oxidation water. Oxidation of carbohydrates yield 60% of its weight as water, protein yields 42% and fats yield 100%. Metabolic water plays important role under certain physiological conditions of the animal. 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.

Metabolic Water

Metabolic water refers to water created by oxidation of organic material inside a living organism through their metabolism.

Metabolic Water Production

- 107 grams of water per 100 grams of fat
- 42 grams of water per 100 g of protein
- 60 grams of water per 100 g of carbohydrate

Importance of Metabolic Water

- Metabolic water meets 100 % water requirement in hibernating animals.
- Metabolic water meets 15-25 % water requirement in desert animals.
- Metabolic water meets 5-10 % water requirement in domestic animals.

FACTORS MODIFYING WATER REQUIREMENT

- Physiological status of animal
  - Young calves consume more water
  - Pregnant and lactating animals consume more water.
- Ambient temperature, Relative humidity, Wind velocity, Rain fall
- Dry matter intake
- Composition of feed:
  - ✓ Feed with high level of salt increases the water intake.

- ✓ Feed with high protein leads to higher production of uric acid / urea which in turn increasses water requirement
- ✓ High fibrous feed also leads to increase in water requirement.
- Variation of species
- Frequency of watering the animal
- ✓ Diurnal and seasonal variation

EFFECT OF WATER RESTRICTION

- Moderate water restriction decreases
    - ✓ feed intake
    - ✓ productivity
    - ✓ urine and faecal water excretion
- Severe water restriction leads to

✓ rapid weight loss, increase in blood concentration

✓ increased renal excretion of sodium, potassium and nitrogen

✓ Increased pulse rate and rectal temperature

✓ Nausea, difficulty in muscular movements and death.

IMPORTANCE OF MINERALS IN ANIMAL PRODUCTION AND HEALTH

CLASSIFICATION OF MINERALS

- In animal tissues and feeds, minerals are present in varying amounts and concentrations.
- Depending upon the mineral concentration in body they are classified as:

A) Macro Minerals:

The concentrations of these minerals in body are more than 70 mg/kg live weight.

1. Calcium (Ca)
2. Phosphorus (P)
3. Magnesium (Mg)
4. Sodium (Na)
5. Potassium (K)
6. Chlorine (Cl)
7. Sulphur (S)

B) Micro minerals or Trace elements:

The concentrations of these minerals in body are less than 70 mg/kg live weight but are physiologically equally important.

- The following fifteen micro minerals are essential to fulfill physiological functions in the body

Iron (Fe)	Zinc (Zn)	Chromium (Cr)	Silicon (Si)
Copper (Cu)	Iodine (I)	Fluorine (F)	Nickel (Ni)
Cobalt (Co)	Molybdenum (Mo)	Tin (Su)	Arsenic (As)
Manganese (Mg)	Selenium (Se)	Vanadium (V)	

IMPORTANCE OF MACRO MINERALS IN ANIMAL PRODUCTION AND HEALTH

General functions of minerals

The general function of minerals and trace elements can be summarized as follows:

1. Minerals are essential constituents of skeletal structures such as bones and teeth.
2. Minerals play a key role in the maintenance of osmotic pressure.
3. Minerals serve as structural constituents of soft tissues.
4. Minerals are essential for the transmission of nerve impulses and muscle contraction.
5. Minerals play a vital role in the acid-base equilibrium of the body.
6. Minerals serve as essential components of many enzymes, vitamins, hormones, and as cofactors in metabolism, catalysts and enzyme activators.

CALCIUM

FUNCTIONS

1. Structural component of body (Skeleton and teeth): 99% of the calcium in the body is present in the bones and teeth.
2. Calcium is essential for the transmission of nerve impulses and muscle contraction.
3. Calcium is required for clotting of blood.

REGULATION OF CALCIUM METABOLISM

- Whenever blood calcium level decreases below the normal, parathyroid gland is stimulated to secrete parathormone. 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 dihydroxy 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 parathormone.

DEFICIENCY SYMPTOMS -

1) Rickets and Osteomalacia

- 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.
- 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.

2) Milk Fever / Parturient Paresis

- Milk fever (parturient paresis) is a condition, which 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 parathyroid gland is unable to respond rapidly enough to increase calcium absorption from the intestine to meet the extra demand.

Prevention and Treatment

1. Normal levels of blood calcium can be restored by intravenous injections of calcium gluconate, but this may not always have a permanent effect.
2. 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.
3. Feeding acidified diet during the later part of dry period also suggested to prevent milk fever.
4. Deliberate use of low calcium diets during dry period to increase calcium absorption in the practical prevention of milk fever requires a good estimate of calving date, otherwise calcium deficiency may occur.
5. Administration of large doses of vitamin D_3 for a short period prior to parturition has also proved beneficial.

DEFICIENCY SYMPTOMS IN POULTRY

- ✓ soft beak and rubbery bones,

- ✓ retarded growth and bowed legs,
- ✓ The eggs have thin shells or there is production of leathery eggs.

Calcium Requirement

- Dairy cattle : 0.34 % DM
- Pig : 0.9 % DM
- Poultry – Broiler : 1.0 % DM
- Poultry – Layer : 3.5 % DM

Calcium Supplementation

- Bone meal, Fish meal, Limestone (Calcium carbonate), Di-calcium phosphate
- Legumes are good sources of calcium.

PHOSPHORUS

FUNCTIONS

1. Phosphorus occurs in close association with calcium in bone (85%).
2. Phosphorus plays a vital role in energy metabolism in the formation of sugar-phosphates and adenosine di- and triphosphates.
3. Phosphorus plays a key role in metabolic reaction of carbohydrate, protein and lipids which occurs through phosphorylated intermediate compounds.
4. Phosphorus is the component of phospholipids, which are important in lipid transport and metabolism as constituent of cell membranes.
5. Phosphorus is constituent of RNA and DNA.
6. Phosphorus is a component of many enzyme systems.

DEFICIENCY SYMPTOMS

1) Rickets and Osteomalacia

- Like calcium, phosphorus is also required for bone formation and a deficiency can also cause rickets or osteomalacia.

2) Pica / Depraved Appetite

- '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.

3) Poor Fertility

- 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.

CALCIUM : PHOSPHORUS RATIO – 2 : 1

Nutritional Secondary Hyperparathyroidism (Miller's disease or bran disease or big head disease)

- The optimum calcium : phosphorus ratio in diet must be **2 : 1.**

✓ An excess of dietary phosphorus in relation to calcium may result in a bone disorder called Nutritional Secondary Hyperparathyroidism (NSH).

✓ 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 de-mineralized bone is replaced by fibrous connective tissue.

- Nutritional secondary hyperparathyroidism occurs in horses that are 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.

Requirement

- Dairy cattle : 0.29 % DM
- Pig : 0.7 % DM
- Poultry – Broiler : 0.7 % DM
- Poultry – Layer : 0.5 % DM

Supplementation

- Cereal grains, fish meal and meat products are good sources of phosphorus.

- Much of the phosphorus present in cereal grains is in the form of phytates, which are not digested and utilised in monogastrics.
- In ruminants, hydrolysis of phytates by bacterial phytases occurs in the rumen and therefore well utilised.

MAGNESIUM

FUNCTIONS

1. Magnesium is closely associated with calcium and phosphorus.
2. Essential constituent of bone and teeth
3. Magnesium is the commonest enzyme activator
4. Magnesium plays a role in oxidative phosphorylation leading to ATP formation

DEFICIENCY SYMPTOMS

1. Hypomagnesaemia Tetany (Lactation Tetany, Grass staggers)

- In adult ruminants a condition known as hypomagnesaemic tetany associated with low blood levels of magnesium (hypomagnesaemia) has been known under a variety of names including lactation tetany and grass staggers.
- Typical symptoms of tetany are
    - Nervousness, Tremors, Twitching of the facial muscles,
    - Staggering gait, Convulsions.

Requirement

- Ruminants – 0.2% in dry matter.
- Monogastrics – 0.05% in dry matter.

Supplementation

- 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.

SODIUM, POTASSIUM AND CHLORIDE

- Nutritionally sodium, potassium and chloride are considered together because of the similarity of their functions and distribution in the body.
- Sodium, potassium and chloride are stored largely in body fluids and soft tissues.
- Nutritionally sodium, potassium and chloride are considered to be of minor importance because they are present in sufficient quantity in the diet.

FUNCTIONS

1. They maintain osmotic pressure
2. They regulate acid base equilibrium
3. They control water metabolism in the tissue
4. They are essential for the function of enzyme systems
5. They are essential for neural and muscular conduction and transmission
6. Sodium is the main cation of extracellular fluids, while potassium is the main cation of intracellular fluid.
7. Chlorine (anion) plays an important part in the gastric secretion, where it occurs as hydrochloric acid as well as chloride salts.

DEFICIENCY SYMPTOMS - POTASSIUM

- Deficiency is rare in farm animals kept under natural conditions.

DEFICIENCY SYMPTOMS - SODIUM

- 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.

DEFICIENCY SYMPTOMS - CHLORIDE

- A dietary deficiency of chlorine is rare. If it occurs it may lead to an abnormal increase of the alkali reserve of the blood (alkalosis) caused by an excess of bicarbonate.

EXCESS OF SODIUM CHLORIDE (Salt; NaCl)

Excess of sodium chloride in the diet leads to **salt toxicity**

- Symptoms are excessive thirst, muscular weakness and oedema.
- Salt poisoning is quite common in pigs and poultry, especially where fresh drinking water is limited.

SULPHUR

FUNCTIONS

1. Sulphur is a component of:
   - ✓ Vitamins: Thiamine and Biotin
   - ✓ Amino acids: Methionine and Cysteine
   - ✓ Hormone: Insulin
   - ✓ Glutathione
   - ✓ Coenzyme A
   - ✓ Chondroitin sulphate
2. Rumen microbes require sulphur for synthesis of sulphur containing amino acids

Requirement

- 0.1 % of dry matter in ruminants
- Sulphur requirement may be met by inorganic sulphates in ruminants which are not possible in monogastrics.

IMPORTANCE OF MICRO MINERALS IN ANIMAL PRODUCTION AND HEALTH

IRON

FUNCTIONS

- More than 90 per cent of the iron in the body is combined with proteins, the most important being **haemoglobin and myoglobin**.
- 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. It 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 electron transport chain (**cytochromes**).
- Enzymes containing or activated by iron are **catalase, peroxidases, phenylalanine hydroxylase** etc.,

ABSORPTION OF IRON - MUCOSAL BLOCK THEORY

- The efficiency of absorption is increased during periods of iron need and decreased during periods of iron overload.
- According to Mucosal block theory the mucosal cells of the gastrointestinal 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 DEFICIENCY

Microcytic Anaemia (Piglet Anaemia / Thumps)

- **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 1 mg per day.
- Anemia in piglets is characterized by poor appetite and growth. Breathing becomes labored and spasmodic-hence the descriptive term **'thumps'** for the condition.

Requirement

- Because of efficient recycling, requirement of iron for most of the farm animals is very low @ 25 –100 mg kg^{-1} dietary dry matter.
- In laying hens the iron requirement is more, since egg production represents a considerable drain on the body reserves.
- Increased during pregnancy, haemorrhages, young one when they are maintained on milk diet. Higher growth rate demands 125 ppm in piglet diet and 40 ppm to calves

Supplementation

- Feeds of animal origin, such as meat, blood and fish meals, are excellent sources of iron
- Legume and oil seed meal are rich in iron.
- Cereals straw and bran are rich in iron
- Ferrous sulphate salts and iron dextran

COPPER

FUNCTIONS

- Copper is the integral component of following enzyme
  - **Ceruloplasmin (ferrooxidase) -** conversion of iron into transferrin.
  - **Erythrocuprein -** occurs in erythrocytes where it plays a role in oxygen metabolism.
  - **Cytochrome oxidase**, which is important in oxidative phosphorylation and myelin synthesis.
  - **Lysyl oxidase** is needed for the conversion of lysine to desmosine which forms crosslinks in elastin and collagen fibres.

- **Tyrosinase** is necessary for the conversion of the amino acid tyrosine to melanin which is necessary for the normal pigmentation of hair, fur and wool.

- Copper is the integral component of **Turacin, a pigment of feathers**.
- Copper is required for maintenance of **crimp of wool**.

COPPER - DEFICIENCY

- A deficiency of copper impairs the animal's ability to absorb iron leading to anemia,
- Deficiency of copper causes
  1. Loss **of 'crimp' in wool - 'stringy' or 'steely' wool.**
  2. Depigmentation of hair and wool,
  3. 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.** The signs range from complete paralysis of the newborn lamb to a swaying staggering gait, which affects, in particular, the hind limbs.
  4. **'falling disease'** – sudden death due to rupture of major blood vessels

Requirement

- Dietary requirement and supply of copper
  - Dairy cattle - 10 ppm on DM basis
  - Beef cattle, sheep - 5 ppm
  - Pigs and poultry - 5-6 ppm

Supplementation

- Seeds and seed byproducts are usually rich in copper
- Application of copper containing fertilizer
- Provision of copper containing salt licks
- Ingestion of organic complexes of Copper

COPPER POISONING

- Continuous ingestion of copper in excess of nutritional requirements leads to an accumulation of the element in the body tissues, especially in the liver. Hence copper can be regarded as a cumulative poison.
- 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.

COPPER – MOLYBDENUM – SULPHUR INTERRELATIONSHIP / 'TEART'

- 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.

ZINC

FUNCTIONS

- Higher concentrations of zinc are present 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

PARAKERATOSIS

- Zinc deficiency in pigs causes **parakeratosis**, a skin disorder.
- Reddening of the skin followed by eruptions, which develop, into scabs.

- Parakeratosis 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.
- Subnormal growth, depressed appetite, poor feed conversion and leads to reproductive disorders in farm animals.
- Gross signs of zinc deficiency in chicks are
    - retarded growth,
    - foot abnormalities,
    - 'frizzled' feathers,
    - bone abnormality referred to as the **'swollen hock syndrome' in poultry**.

Requirement

- Poultry 40 mg.kg feed
- Pig 40 mg/kg feed
- Cattle 30 mg/ kg feed

Supplementation

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

MANGANESE

FUNCTIONS

- Manganese is important in the animal body as

1. An activator of many enzymes such as hydrolases and kinases
2. As a constituent of enzymes such as **arginase, pyruvate carboxylase and manganese superoxide dismutase**.
3. Manganese through its activation of **glycosyl transferases**, is required for the formation of the mucopolysaccharide which forms the organic matrix of bone.

4. Manganese containing superoxide dismutase catalyses the reactions that promote immunity in animals.

DEFICIENCY SYMPTOMS

1) Perosis / Slipped Tendon

- 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 the 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.

2) Nutritional Chondrodystrophy

- 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.**

Requirement

- Poultry: 50 mg/Kg of feed
- Pig: 40 mg/Kg of feed
- Cattle: 25 mg/Kg of feed
- Sheep: 40 mg/Kg of feed

Supplementation

- Rich sources are rice bran and wheat bran, offals. Most green foods contain adequate amounts. Manganese salts: oxide, chloride, carbonate.

COBALT

FUNCTIONS

- Cobalt is required by microorganisms in the rumen for the **synthesis of vitamin B_{12}**
- Cobalt acts as an activating ion in certain enzyme reactions

DEFICIENCY SYMPTOMS

Wasting disease or coast disease or Pining or Enzootic marasmus

- Cobalt deficiency causes vitamin B_{12} deficiency in ruminants
- Wasting disease or coast disease or Pining or Enzootic marasmus
  - ✓ Decreased feed intake
  - ✓ Emaciation - Loss of body weight due to wasting of skeletal muscles
  - ✓ Decreased growth rate
  - ✓ Fatty degeneration of liver

Requirement

- 0.07 ppm in the DM – dairy cattle, sheep
- 0.1 ppm – beef cattle and lambs

Supplementation

- Cobalt can be supplemented either through
  - ✓ salt licks
  - ✓ mineral mixtures or
  - ✓ by placing cobalt oxide bullet in the ventral sac of rumen using a cobalt gun.

SELENIUM

FUNCTIONS

- Selenium is a **component of gluthathione peroxidase,** an enzyme which catalyses the removal of hydrogen peroxide, thereby protecting cell membrances from oxidative damage.
- 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.

DEFICIENCY SYMPTOMS

Nutritional myopathy / white muscle disease / stiff lamb disease / mulberry heart disease

- The most frequent and the most important manifestation of Selenium deficiency in farm animals is muscle degeneration (myopathy).

- **Nutritional myopathy,** also known as muscular dystrophy, frequently occurs in cattle, particularly 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**.

SELENIUM TOXICITY

Alkali Disease and Blind Staggers

- Some species of plants (*Astragalus racemosa*) that grow in seleniferous areas contain very high levels of selenium.
- **Alkali disease** (chronic diseases) **and blind staggers** (acute diseases) selenium toxicity 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 deforrmities.
- Acute poisoning, which results in death from respiratory failure, can arise from sudden exposure to high selenium intakes.

Requirement

- Calves and lambs : 0.1 mg / kg feed
- Growing pigs : 0.05 mg / kg feed

- Poultry : 0.1 mg / kg feed

Supplementation

- Fish meal is a good source of selenium.
- Seleno-methionine, seleno-cysteine and sodium selenite are supplemental sources for selenium.

IODINE

FUNCTIONS

- Iodine plays an important role in the synthesis of the two hormones, **triiodothyronine (T_3)** and **tetraiodothyronine (thyroxine; T_4)** produced in the thyroid gland.
- The 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

Goitre

- 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.**
- 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.

Requirement

- Pig: 80-160 micro gram /day
- Poultry 5-9 micro gram /day
- Sheep 50 -100 micro gram /day

- Cattle 400- 800 micro gram /day

Supplementation

- The richest sources of this element are foods of marine origin like seaweed's, fish meal etc,.
- In areas where goiter is endemic, precautions are generally taken by supplementing the diet with the element, usually in the form of iodized salt.

MOLYBDENUM

FUNCTIONS

- The biological functions of Molybdenum, apart from its reactions with copper, are concerned with the formation and activities of the following enzymes.
  - **xanthine oxidase,**
  - **cytochrome C oxidase**
  - **aldehyde oxidase.**

MOLYBDENUM - DEFICIENCY

- Molybdenum deficiency has not been observed under natural conditions in any species.

MOLYBDENUM - TOXICITY

Teart

- The prominent manifestations of molybdenum toxicity in cattle are diarrhoea, scouring, harsh, staring coats and weight loss. This condition is termed as '**teart**' or **'peat scours'.** This condition may be counteracted by oral or intravenous administration of copper.

Requirement

- Since the requirement is very low, it is met from the usual diet

Supplementation

- Not warranted. (Not required)

CHROMIUM

- 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 is a component of **glucose tolerance factor** (GTF)
- Chromium may also play a role in **lipid synthesis**.

FLUORINE

- Fluorine is integral part of **bone and teeth**.
- Fluorine is necessary for **prevention of tooth decay/dental caries**.

FLUORINE - DEFICIENCY

Dental Caries

FLUORINE - TOXICITY

Fluorosis

- Fluorine is a very toxic element, with ruminants being more susceptible than non-ruminants. It causes a condition called as **fluorosis**.
- There is dental pitting and wear, leading to exposed pulp cavities. Further increases in fluorine cause depression of appetite, 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.

Prevention of mineral deficiencies and imbalances

- Supplementation with concentrated source of one or more mineral elements
  - Suitable mineral mixture
  - Suitable licks
  - Treatment of drinking water with soluble salts
  - Injection of slowly absorbed organic compounds
- Appropriate fertilizer treatment of the soil to improve mineral composition of herbage.

IMPORTANCE OF VITAMINS IN ANIMAL PRODUCTION AND HEALTH

VITAMINS (definition)

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

CLASSIFICATION

- Vitamins may be classified based on their solubility as fat soluble vitamins and water soluble vitamins.
    - **Fat-soluble vitamins** includes:
        1. Vitamin A (Retinol)
        2. Vitamin D (Cholecalciferol)
        3. Vitamin E (Tocopherol)
        4. Vitamin K (Phylloquinone)

    - **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. Niacin/Nicotinic acid
        4. Vitamin B6 (Pyridoxine)
        5. Panthothenic acid
        6. Folic acid
        7. Vitamin B12 (Cyano cobalamine)
        8. Biotin
        9. Choline

DIFFERENCES BETWEEN FAT SOLUBLE AND WATER SOLUBLE VITAMINS

Differences	Fat Soluble Vitamins	Water Soluble Vitamins
Names	Vitamin A, D, E, K	Vitamin C Vitamins B group
Solubility	Soluble in fats and organic solvents	Water soluble
Digestion & 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 B12
Toxicity	An over dosage can lead to toxicity	Usually not toxic as it is readily excreted when given in excess

VITAMIN A (Retinol)

- Discovered by **McCollum & Davis and Osborne & Mendel** in 1913.
- Vitamin A (Retinol) only exists in Animal Kingdom.
- Vitamin A does not exists as such in Plant Kingdom.
- In plants exist pro-vitamins of Vitamin A such as:

1. **Carotene (α, β, γ) – β carotene is most active form**
2. **Xanthophyll**

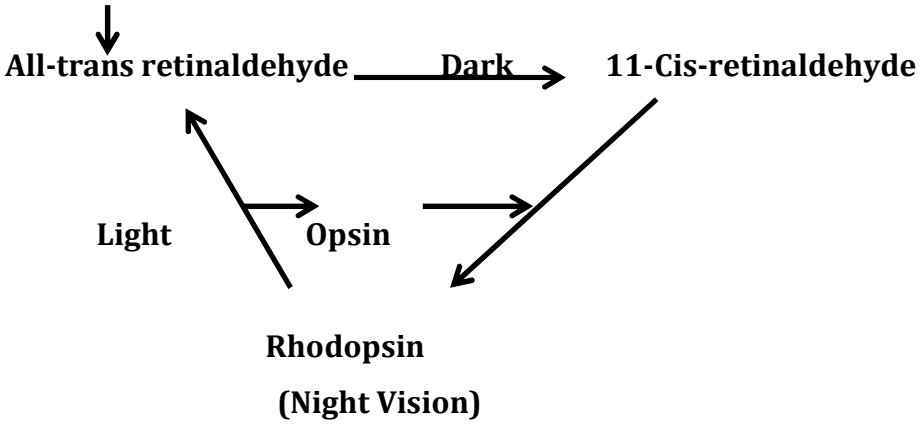
FUNCTIONS

1. Synthesis of glycoprotein **to maintain integrity of epithelial cells**.
2. **In bone formation and growth** (synthesis of mucopolysacharides).
3. **Synthesis of the visual pigment Rhodopsin**
4. Retinol and retinoic acid (RA) are essential for embryonic development during fetal development.

Vitamin A and Vision

Rhodopsin synthesis – Visual cycle

Vit. A (Retinol)



VITAMIN A – DEFICIENCY SYMPTOMS

1) **Night Blindness**

- Inadequate retinol available to the retina results in impaired dark adaptation, known as "**night blindness**."

2) **Bitot's Spots**

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

3) **Xerophthalmia (Dry Eye)**

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

4) **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.

5) 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.

6) Nutritional Roup

- In poultry Vitamin A deficiency leads to high mortality rate.
- 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 shut with thick exudates.

VITAMIN A - DEFICIENCY – EFFECT ON REPRODUCTION

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

VITAMIN A - DEFICIENCY – EFFECT ON CEREBROSPINAL FLUID PRESSURE

- One of the initial effects of vitamin A deficiency is elevated cerebrospinal fluid (CSF) pressure.
- The mechanism whereby the increase in CSF pressure is brought by thickened duramater leading to under absorption of CSF.

VITAMIN A - TOXICITY

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

Requirement

- Growing Cattle :80 IU/ kg body weight
- Dry cow :76 IU/ kg body weight
- Lactating cow: 110 IU/ kg body weigh
- Piglet :500 – 1000 IU / kg feed
- Pig : 2000 – 3000 IU / kg feed
- Poultry
    - ✓ Broiler : 1500 IU / kg feed
    - ✓ Layer : 4000 IU / kg feed

Supplementation

- Animal source: Cod liver oil, egg yolk, milk fat.
- Plant source: All green leaves are rich in provitamin A**, beta-carotene**.
- 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 seen in chicken and rat.
- **Vitamin A value is expressed as International Unit (IU).**
- One IU = 0.3 micro gram of crystalline retinol.

VITAMIN D

Vitamin	Chemical Name	Pro-vitamin
D_2	**Ergocalciferol**	Ergosterol - plant
D_3	**Cholecalciferol**	7-dehydrocholestrol – skin of animals

- ✓ Also called as **Anti-rachitic factor**
- ✓ **Vit. D3** ⟶ **25-hydroxy Vit. D3** (in Liver)

- ✓ **Vit. D3** ⟶ **1, 25 di-hydroxy Vit. D3** (in kidney) --- active form of Vit. D

FUNCTIONS

1. Synthesis of **Calcium binding protein** (necessary for absorption of calcium)

2. Regulation of calcium metabolism and skeletal remodeling.

VITAMIN D - DEFICIENCY SYMPTOMS

1) Ricket

- 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.

2) Osteomalacia

- Resorption of calcium and phosphorus from the bone.
- 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.

3) In Poultry

- In poultry bones and beak become **soft and rubbery**; legs become weak.
- Egg production is reduced and **leathery eggshell**.

Requirement

- Lactating cow :30 IU/ kg body weight
- Piglet :100-200 IU / kg feed
- Pig : 200 – 400 IU / kg feed
- Poultry
    - Broiler : 200 ICU / kg feed
    - Layer : 600 ICU / kg feed

Supplementation

- Exposure to sunlight
- Egg yolk and Cod liver oils
- Sun dried roughage's/grains

VITAMIN E (Tocopherol)

FUNCTIONS

- Vitamin E functions in the animal mainly as **biological/natural 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.
- Firstly, radicals are scavenged by vitamin E as a first line of defense and secondly, glutathione peroxidase destroys any peroxide formed before they can damage the cell.
- Vitamin E also plays an important role in the **development and function of the immune system.**

VITAMIN E – DEFICIENCY SYMPTOMS

1. Nutritional myopathy

2. White muscle disease/Stiff lamb disease

3. Mulberry heart disease

4. Exudative diathesis

5. Encephalomalacia/Crazy chick disease

- The most frequent and the most important manifestation of **Selenium deficiency** in farm animals is muscle degeneration (myopathy).
- **Nutritional myopathy**, also known as muscular dystrophy, frequently occurs in cattle, particularly 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.
- A popular descriptive name for this condition is **white muscle disease**.
- 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, 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**.

- **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 nutrition myopathy and in exudative diathesis but selenium does not seem to be important in **encephalomacia**.

Requirement

- Lactating cow : 2.5 IU/ kg body weight
- Piglet : 5- 10 IU / kg feed
- Pig : 20 - 30 IU / kg feed
- Poultry
    - Broiler : 5 - 10 IU / kg feed
    - Layer : 5 IU / kg feed

Supplementation

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

VITAMIN K

- ✓ Vitamin K identified by Henric Dam & designated as K for word Koagulation.

Vit. K1 – Phylloquinone (Green Plants)
Vit. K2 – Menaquinone (Synthesized by intestinal bacteria)
Vit. K3 – Menadione (Synthetic Vit. K)

FUNCTIONS

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

VITAMIN K – DEFICIENCY

Sweet Clover Disease / Bleeding Disease

- Low prothrombin level in blood leads to haemorrhagic conditions.
- In cattle **sweet clover disease** is associated with Vitamin K.
- Sweet clover when it gets mould infested contains a compound **dicoumarol**, which lowers prothrombin content of blood leading to haemorrhagic disease and hence vitamin K is also called as anti haemorrhagic vitamin.
- In chicks Vitamin K deficiency causes anaemia and delayed clotting time of blood.

Requirement

- Piglet : 0.25 – 0.50 mg / kg feed
- Pig : 1.0 – 1.5 mg / kg feed
- Poultry
    - Broiler : 0.50 mg / kg feed
    - Layer : 0.50 mg / kg feed

Supplementation

- Green leafy vegetables, egg yolk, liver, fish and synthesized by bacteria in gastro intestinal tract.

WATER SOLUBLE VITAMINS

Vitamin C (Ascorbic acid)

FUNCTIONS

- Plays an important role in the **formation of collagen** and intercellular cement substance (Capillaries, teeth, bone)
- Plays an important role in the oxidative reduction reaction of living cells.
- Plays an important role in the absorption of iron and incorporation of plasma iron into ferritin.
- Plays an important role in the hydroxylation of deoxycorticosterone, tryptophan, phenylalanine

VITAMIN C – DEFICIENCY

Scurvy

- *Scurvy in adults:* Weakness, bleeding, loosens teeth, swollen joints, hemorrhages.
- *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.

Requirement

- Vitamin C is dietary essential **only in man, guinea pig and other primates, red vented bulbul and fruit eating bat** as these species lack the enzyme ***L-gulonolactone oxidase***.
- Stress increases the requirement of this vitamin.
- Other species synthesise vitamin C from glucose.

Supplementation

- Citrus fruits and green leafy vegetables are rich sources.

VITAMIN B_1 (Thiamin)

FUNCTIONS

- **Thiamine pyrophosphate** is a coenzyme involved in oxidative decarboxylation of pyruvate to acetyl coenzyme A and of alpha ketoglutarate to succinyl COA in TCA cycle.

VITAMIN B1 – DEFICIENCY SYMPTOMS

1. Star Gazing in poultry

In Chicks deficiency of thiamine leads to anorexia, emaciation, **polyneuritis** characterized by head retraction, nerve degeneration and paralysis which otherwise called as ***star gazing posture***

2. Cerebrocortical necrosis in ruminants

Anorexia, Emaciation, Muscular weakness and progressive dysfunction of the nervous system

3. Polyneuritis in pigeon

4. Beriberi in human

5. Chastek paralysis in foxes

Requirement

- Lactating Cow : 41 mg / day Pig : 2 - 3 mg / kg feed
- Poultry – Broiler : 1.5 mg / kg feed Poultry – Layer : 0.8 mg / kg feed

Supplementation

- Yeast, germ and bran of cereal grains.
- Pork is rich in thiamine.

VITAMIN B_2 (Riboflavin)

FUNCTIONS

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

- In sows riboflavin is necessary to maintain normal oestrous activity and prevent premature parturition.

DEFICIENCY SYMPTOMS

Curled Toe Paralysis / Clubbed Down Condition

- Poor appetite, retarded growth, vomiting, skin eruptions and eye abnormalities.
- 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.

Requirement

- Lactating Cow : 156 mg / day Pig : 4 – 5 mg / kg feed
- Broiler : 2 - 3 mg / kg feed Layer : 2 mg / kg feed

Supplementation

- Synthesized by yeast, bacteria and fungi. Rich sources are liver, yeast, milk and green leafy vegetables.

NIACIN (Nicotinamide)

Tryptophan ----------(Vit. B6)----------> Niacin

FUNCTIONS

- 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

1. Pellagra

- In pigs, deficiency symptoms include poor growth, anorexia, enteritis, vomiting and dermatitis.
- Deficiency symptoms are particularly likely in pigs and poultry if diets with a **high maize content are used, since maize is poor source of Niacin or of tryptophan.**

2. Black tongue in dogs

Requirement

- Lactating Cow : 289 mg / day Pig : 15 – 20 mg / kg feed
- Poultry – Broiler : 27 mg / kg feed Poultry – Layer : 10 mg / kg feed

Supplementation

- 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.

VITAMIN B_6 (Pyridoxine)

FUNCTIONS

- Of the three related compounds (pyridoxine, the corresponding aldehyde derivative as pyridoxal and the amine as pyridoxamine.) 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**.
- Necessary for conversion of **Tryptophan** to **Niacin.**
- The 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**.**
- Chicks on a deficient diet show jerky movements, while in adult birds hatchability and egg production are adversely affected.

Requirement

- Lactating Cow : 48 mg / day Pig : 2 – 3 mg / kg feed
- Poultry – Broiler : 3mg / kg feed Poultry – Layer : 3 mg / kg feed

Supplementation

- 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.

PANTOTHENIC ACID

FUNCTIONS

- R.J. Williams named this vitamin as Pantothenic acid means "From Everywhere".
- Pantothenic acid acts through **Coenzyme A** and **Acyl Carrier Protein**.
- Play role in **transfer of two carbon units** and **acyl group.**

DEFICIENCY SYMPTOMS

- ✓ **Goose Stepping in Pigs**

Supplementation

- Pantothenic acid is widely distributed in nature; green leafy materials, cereals, yeast and extracted oilseed meals are good sources of the vitamin.

FOLIC ACID

FUNCTIONS

- 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.**

- **Maturation of RBCs**

DEFICIENCY SYMPTOMS

- ✓ poor growth**,**
- ✓ **Macrocytic anaemia**

Supplementation

- Folic acid is widely distributed in nature; green leafy materials, cereals and extracted oilseed meals are good sources of the vitamin.

BIOTIN

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,**
  - **accetyl coenzyme A carboxylase,**
  - **propionyl coenzyme A carboxylase.**
- **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.

DEFICIENCY SYMPTOMS

Fatty Liver and Kidney Syndrome

- In poultry, biotin deficiency causes reduced growth, dermatitis, leg bone abnormalities, cracked feet, poor feathering and **fatty liver and kidney syndrome (FLKS)**.
- In pigs, biotin deficiency causes foot lesions, **alopecia** (hair loss) and a dry scaly skin.
- **Spectacle eye condition**

Supplementation

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

CHOLINE

FUNCTIONS

- It is a component of **lecithins** which play 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 trans methylation reactions.
- It 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

Perosis / Slipped Tendon

- Chorine is also concerned with the prevention of **perosis or slipped tendon in chicks**.

Fatty Liver

- Deficiency symptoms, including slow growth and fatty infiltration of the liver, have been produced in chicks and pigs.

Supplementation

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

VITAMIN B12 (Cyanocobalamine)

- Also called as **Anti-pernicious anaemia factor, Chick growth factor, Cow manure factor, Animal protein factor.**

- Microorganisms in the rumen synthesize B_{12}, if **cobalt** is supplied adequately in the diet.
- **Vitamin B12 is only metabolic essential but not dietary essential in ruminants.**
- **Vitamin B12 is metabolic essential as well as dietary essential in monogastric animals**

FUNCTIONS

- Coenzyme of vitamin B_{12} is **methylcobalamin**, function include **isomerases**, **dehydrases**.
- **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
- Maturation of RBCs
- Synthesis of DNA & RNA

DEFICIENCY SYMPTOMS

Pernicious anaemia (Megaloblastic / Macrocytic anaemia)

- Poor growth, Poor feathering, Decreased hatchability**,** Dermatitis and rough coat.
- Defect in synthesis of DNA

Requirement

- Piglet : 5 – 8 µg / kg feed
- Pig : 15 µg / kg feed
- Poultry – Broiler: 9 µg / kg feed
- Poultry – Layer : 3 µg / kg feed

Supplementation

- Vitamin B_{12} 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.

MEASURES OF FEED ENERGY AND THEIR APPLICATIONS

Energy: Energy is capacity to do work.

Various types of energy: chemical, electrical, mechanical, nuclear and radiation energy can be converted from one form to the other.

- The plants trap energy from sun (solar energy) to synthesize complex constituents (chemical energy) that are broken to yield energy for maintenance of life in the animal for performance of work /production.
- **Energy required for maintenance of life includes:**
  - Mechanical energy for essential muscular activities like heart-beat, respiration
  - Chemical energy like movement of dissolved substance against concentration gradient, synthesis of enzymes & hormones.
- **Energy required for performance of work / production includes:**
  - Growth
  - Muscular work
  - Milk production
  - Wool production
  - Egg production

Basic unit of energy:

Calorie:

One calorie is the amount of energy required to raise the temperature of 1g of water by 1°C from 14.5°C to 15.5°C.

(1000 calories = 1 Kcal; 1000 Kcal = 1 Mcal or Therm)

Joule:

The International Union of Pure and Applied Chemistry (IUPAC) advocates to use the term Joule as against Calorie.

1 calorie = 4.184 joules

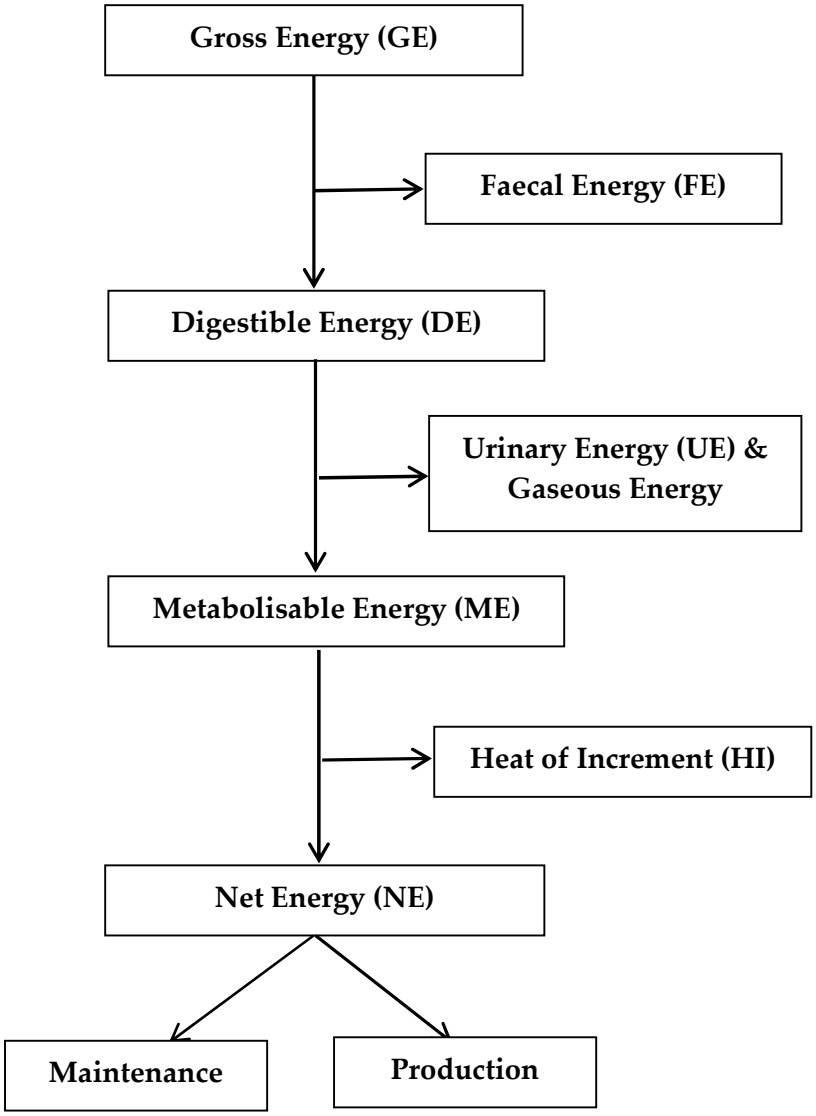
SYSTEMS OF EXPRESSING ENERGY VALUE OF FEEDSTUFFS

1. Gross Energy
2. Digestible Energy

3. Metabolisable Energy
4. Net Energy
5. Atwater's Goss Energy Value
6. Atwater's Physiological Fuel Value
7. Total Digestible Nutrients (TDN)
8. Starch Equivalent (SE)
9. Armsby's Net Energy System

Energy Partitioning:

Feed energy partitioning in animal body is given below



1. GROSS ENERGY

It is defined as the energy liberated as heat when feed, faeces or any other substance is fully oxidised by burning a sample completely in a bomb calorimeter.

2. DIGESTIBLE ENERGY

Digestible Energy (DE) = Gross Energy (GE) – Faecal Energy (FE)

It is the energy of the feed less the faecal energy.

Energy lost in faeces accounts for the largest loss of energy, which ranges between 20 to 40%.

3. METABOLISABLE ENERGY

Metabolisable Energy (ME) = Digestible Energy (DE) – Urinary Energy (FE) – Gaseous Energy

- It is the digestible energy less the energy lost in urine and combustible gases leaving the digestive tract, chiefly methane.
- It can also be defined as ingested gross energy minus faecal energy minus urinary energy minus gaseous energy.
- It is the portion of energy available for metabolism.
- ME is commonly used to evaluate feedstuffs for poultry because the birds void urinary and faecal losses together.
- Urinary losses of energy are quite stable in a given species and are usually 2-3% of GE.
- The losses are more in ruminants.

4. NET ENERGY (NE)

Net Energy (NE) = Metabolisable Energy (ME) – Heat of Increment (HI)

- Net energy is obtained from ME by subtraction of heat increment.
- NE is that portion of energy that is completely useful to the animal for maintenance and production purpose.
- The portion of NE used for maintenance is the energy required to sustain life processes.

- The other portion of NE is used for tissue gain or milk or egg production.

HEAT INCREMENT (HI)

- Heat increment is the amount of energy lost as a result of chemical and physical processes associated with digestion and metabolism.
- **HI** increases with the amount of feed consumed and may be used in animals reared in cold environment to warm the body otherwise.
- HI is a wasteful process.
- HI is also called as *specific dynamic effect* it consists of the following
    - Heat of nutrient metabolism.
    - Heat of fermentation.
- HI is greater in ruminants compared to monogastrics.

5. TOTAL DIGESTIBLE NUTRIENTS (TDN)

- This is the simplest form of energy evaluation.
- The digestibility of nutrients is determined by digestibility trials.
- TDN is simply a figure, which indicates the relative energy value of a feed to animals.
- It is ordinarily expressed in Kg or in percent.
- It can be calculated by the formula

TDN (%) = % digestible crude protein + % digestible crude fibre + % digestible N-free extract + (2.25 x % digestible ether extract)

% TDN = % DCP + % DCF + % DNFE +(2.25 x % DEE)

- 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.
- The principle of determining the TDN of feed is essentially the same as proposed by Henneberg and Stohmann at the Weende's experiment station.

- The feed and faeces are subjected to the proximate analysis namely, CP, EE, CF and NFE.
- The amounts of these nutrients not recovered in the faeces are considered to be digested.

FACTORS AFFECTING TDN VALUE OF FEED

% Dry matter:

In high moisture feed the nutrient concentration is less and so the TDN value on fresh matter basis will be less.

% Digestibility of dry matter:

The presence of indigestible substances like lignin, acid insoluble ash will interfere the digestibility of other useful nutrients.

Hence feeds with high lignin and/or acid insoluble ash will have low TDN values.

Presence of minerals:

Since minerals as such contribute no energy, high mineral containing feeds will have low TDN.

% Digestible fat 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%.

Advantages:

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 the ruminant were in TDN values.

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 Eg. 1 kg of TDN in low-grade roughage contains only 50% of the net energy present in 1 kg of TDN in maize grain. Thus, low quality feeds are over estimated by the TDN system.
3. If feeds are high in fat content, the TDN value some time exceeds 100 in percentage (Eg.) Pure fat which has 100% digestibility would theoretically have a TDN value of 225% (100 x 2.25 = 225). Animal fat – 175%, maize oil – 172%.
4. The term total digestible nutrients consider only the energy giving nutrients whereas the micronutrients like minerals have not been included.

6. STARCH EQUIVALENT

- The classical method developed by **Kellner** in 1907 in Germany.
- Kellner's system was based on the determination of carbon nitrogen balance by respiration experiments.

Definition:

Starch equivalent is defined as the number of Kg of starch required to produces the same amount of fat as that of 100 kg of the respective feed.

SE = (Weight of fat stored per unit of food/ Weight of fat stored per unit weight of starch) X 100

- NE value of 1 kg of starch for fattening is 2360 Kcal.
- 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.

Golden number (0.95) for concentrate:

- 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.
- **Actual SE of concentrates = Calculated production value x 0.95 Golden number**

Advantages:

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 in some.
3. It is a productive type system, which considers all the energy losses including faecal, urinary, gaseous and heat losses.

Limitations:

1. The starch value of the ration is not constant at different levels of feeding, but decreases with increasing levels.
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.

7. ARMSBY'S NET ENERGY SYSTEM

- Armsby used calorimeter for his NE determination.
- Kellner compared two levels above maintenance and measured energy values of foods for fattening.
- Armsby, however, compared two levels below maintenance – the higher level was close to maintenance – and calculated the NE value of feed by relating the addition of more food to the resultant saving in body tissues.
- As the utilization of ME for maintenance is markedly higher than for fattening the evaluation of the same feedstuff according to Kellner and Armsby leads to different results.
- Armsby expressed the NE value in therms (1 therm = 1 Mcal = 1000 Kcal).

8. ATWATER 'S GROSS ENERGY VALUE

Average gross energy value can be worked out based on composition of carbohydrate, fat and protein using appropriate value.

Atwater 's average gross energy value factors

1. Carbohydrate: 4.15 Kcal/g
2. Protein: 5.65 Kcal/g
3. Fat: 9.4 Kcal/g

9. ATWATER PHYSIOLOGICAL FUEL VALUES

- To calculate physiological fuel values, the calorific values of the three nutrients are multiplied by the corresponding digestible coefficients to get the digestible values.
- The digestibility coefficient of 98% to carbohydrate, 95% to fat and 92% protein are applied to monogastric animals.

Atwater physiological fuel value factors

1. Carbohydrate:– 4.15 x 0.98 = 4 Kcal/g
2. Protein:– (5.65 – 1.25) x 0.92 = 4 Kcal/g
3. Fat:– 9.40 x 0.95 = 9 Kcal/g

CALORIMETRY

- Antoine Laurent Lavoisier stated that heat in the animal body is produced by oxidation of nutrients.
- Antoine Laurent Lavoisier referred as founder/father of science of nutrition.
- Heat produced by animal is measured by using calorimetry.

Difference between Direct and Indirect calorimetry

	Direct calorimetry	**Indirect calorimetry**
1	The insensible heat loss is estimated directly	The insensible heat loss is estimated indirectly
2	No need to measure exchange of respiratory gases	There is need to measure exchange of respiratory gases
3	Very accurate	Less accurate
4	Very complicated and expensive	Relatively easy technique

A) DIRECT CALORIMETRY

- The insensible heat loss (latent heat of water vaporized from the skin and the respiratory passages) is estimated by determining 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.
- There are two kind of direct calorimeters
    1. Adiabatic calorimeter
    2. Gradient calorimeter

i) ADIABATIC CALORIMETER

- In this type an animal is confined in a chamber constructed in such away 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 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.

ii) GRADIENT CALORIMETER

- 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 amount of water vapour added to the air is measured by assessing the rate of airflow and change in humidity.
- The main advantage of this type of calorimeter is also the accuracy in measurement.
- The disadvantage is very expensive to construct and complicated to operate.

B) 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.
- Varieties of techniques are available for measuring the respiratory exchange; all ultimately seek to measure oxygen consumption and CO_2 production per unit of time.
- There are two kind of indirect calorimeters
    - Open circuit system
    - Closed circuit system

i) Open circuit system:

- Ingoing air is metered and sampled continuously for O_2, CO_2 and methane content.
- Similarly, outgoing air is metered and sampled for O_2, CO_2 and methane content.
- Analysis of gases has been accomplished with chemical and volumetric or manometric techniques.

ii) Closed circuit system:

- Devices require the animal to rebreathe the same air.
- CO_2 is removed with a suitable absorbent (soda lime) which may be weighed before and after use to determine its rate of production.
- The water vapour is removed with a suitable absorbent (silica gel).
- 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 O_2 consumption and CO_2 production must be corrected for any difference 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.

Respiratory Quotient (RQ)

RQ is the ratio between the volume of carbon dioxide produced by the animal and the volume of oxygen used.

Respiratory Quotient (RQ) = volume of carbon dioxide produced / volume of oxygen used

RQ for Carbohydrate = 1 RQ for Fat = 0.7 RQ for Protein = 0.82

CARBON AND NITROGEN BALANCE TECHNIQUE

Carbon and Nitrogen balance technique is used to measure energy retention

- 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 9.4 Kcal per g for fat and 4.0 Kcal per g for protein.

PROTEIN EVALUATION OF FEEDS

IN SIMPLE-STOMACHED ANIMALS:

Nutritive value of protein can be determined either by

1. Chemical evaluation
2. Biological experiments

CHEMICAL EVALUATION

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

A) 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 other amino acids than the amino acid in greatest deficit.

B) Essential amino acid Index: (EAAI)

- Is defined as the geometric mean of the egg ratios of essential amino acids.
- 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.

BIOLOGICAL EXPERIMENTS

1. Digestibility Co-efficient.
2. Protein efficiency ratio (PER)
3. Net protein retention (NPR)
4. Gross protein value (GPV)

5. Nitrogen Balance Experiments
6. Biological value
7. Net protein utilization (NPU)
8. Protein replacement value (PRV)

DIGESTIBILITY COEFFICIENT

- The term digestibility Coefficient 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.

Digestibility Coefficient = (Protein Intake – Protein in faeces)/100

PROTEIN EFFICIENCY RATIO (PER)

- It is defined as the weight gain per unit weight of protein eaten and may be calculated by using the following formula.

PER = Gain in body weight / Protein consumed

NET PROTEIN RETENTION (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 = (Weight gain by test protein group – weight loss of non-protein group)/Weight of protein consumed

GROSS PROTEIN VALUE (GPV)

- The live weight gains of chicks receiving a basal diet containing 80g crude protein/kg are compared with those of chicks receiving the basal diet plus 30g/kg of a test protein, and of others receiving the basal diet plus 30g/kg of casein.
- The extra live weight gain per unit of supplementary test protein, stated as a proportion of the extra live weight gain per unit of supplementary casein, is the gross protein value of the test protein, i.e.

GPV = A /A^o

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

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 in the food is measured as well as that voided in faeces, urine and any other 'N' containing products such as milk, wool or eggs. When the 'N' intake is equal to the output the animal is in 'N' equilibrium.
- When the intake exceeded the out go, it is in positive value, when the out go exceed the intake the animal is in negative value.

BIOLOGICAL VALUE

- It is a direct measure of the proportion of the food protein which can be utilised by the animal for synthesizing 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 on albino rats in which nitrogen intake and urinary and faecal excretion of nitrogen are measured and the results are used to calculate the biological value as follows.

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

- 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 lossses to arrive at a more precise BV.

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

- 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.

NET PROTEIN UTILISATION (NPU)

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

$$NPU = \frac{(\text{Digestibility co-efficient x Biological value})}{100}$$

PROTEIN REPLACEMENT VALUE (PRV)

- This value measures the extent to which a test protein will give the same 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 = (A – B) / N intake

- Where A = N balance for standard protein

  B = N balance for test protein

PROTEIN EVALUATION OF FEEDS – RUMINANTS

1. Crude protein
2. Digestible crude protein
3. Rumen degradable and un-degradable protein
4. Metabolisable protein

CRUDE PROTEIN

- The proximate composition of the feed provides this information.
- Nitrogen content in feed is estimated by using Kjeldhal Method.
- Crude Protein (%) = N x 6.25
- 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

- Digestible crude protein calculated as

  DCP = Crude Protein x Digestible coefficient
- This holds good for concentrates, but not for roughage which has relatively constant composition and digestibility coefficient.

RUMEN DEGRADABLE AND UNDEGRADABLE PROTEIN

- Proposed by the Agricultural Research Council (ARC) for the UK.
- The dietary proteins which is degraded in rumen is called as Rumen degradable protein (RDP)
- The dietary proteins which bypass the rumen without degradation is called as Rumen undegradable protein (RUDP).

METABOLISABLE PROTEIN

- 'Metabolisable protein' system is used in the USA.
- 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 consist 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.
- Microbial protein, synthesised in the rumen, similarly contributes to metabolisable protein.

Calorie Protein Ratio

It is defined as the metabolizable energy (Kcal/kg) divided by the percentage of crude protein in the ration.

$$\text{Calorie : Protein} = \frac{\text{ME (Kcal/kg)}}{\text{\% CP}}$$

Nutritive Ratio

It is the ratio of the digestible protein to the sum of digestible carbohydrates and fat, the latter being multiplied by 2.25.

$$\textbf{Nutritive ratio (\%)} = \frac{\textbf{\% DCF + \% DNFE + (\% DEE x 2.25)}}{\textbf{\% DCP}}$$

$$\textbf{Nutritive ratio (\%)} - \frac{\textbf{\% TDN} \quad \textbf{\% DCP}}{\textbf{\% DCP}}$$

- It is also called albuminoid ratio.
- Feeds richer in protein have narrow nutritive ratios (1 : 0.7)
- Feeds poor in protein content have wide nutritive ratio (1 : 9)

METHODS OF FEED PROCESSING FOR IMPROVING THE NUTRITIVE VALUE OF INFERIOR QUALITY ROUGHAGES

Physical	Chemical	Biological	Combination
1. Chopping 2. Soaking 3. Grinding 4. Steam pressure 5. Explosion 6. Irradiation 7. Pelleting	1. Acid treatment 2. Alkali treatment 3. Use of other chemicals - ozone, H_2O_2.	1. SCP production 2. Use of cellulolytic organisms 3. Mushroom Growth	1. Physio-chemical process 2. Karnal process

PHYSICAL TREATMENT

1. **Chopping:**

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

2. Soaking:

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

3. Grinding:

- Particle size is 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.

4. Steam pressure:

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

5. 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 celluosic bonds to a certain extent and makes cellulose available for microbial action.

6. Irradiation:

- Straw is treated with γ (gamma) irradiation.
- Causes rupture of ligno celluosic bonds and makes cellulose available for microbial action.

7. Pelleting:

- Particle size is 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.

CHEMICAL TREATMENT

1. 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 celluosic bonds and makes cellulose available for microbial action.

2. Alkali treatment:

- Straw is treated with NaOH, NH_4OH, 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.

A. NaOH treatment:

a. 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.

b. Dry method:

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

B. Ammonia treatment:

- Anhydrous form or concentrated solution is 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 digestability of the straw it also increases the nitrogen content of it.

- Disadvantage – On opening the stack most of the ammonia is lost by volatilization.

C. Urea Treatment

Procedure for preparing Urea Enriched Paddy Straw:

Required Materials:

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

To enrich 100 kg of paddy straw

- Dissolve 4 kg urea in 65 litres of water
- Spread a polythene sheet/Gunny bag on the floor. Initially spread 5 kg of paddy straw in layers.
- Using the sprinkler, sprinkle the prepared urea solution over the paddy straw ensuing that all the paddy straw is wet by it.
- Similarly spread another layer of paddy straw over the first layer and repeat the sprinkling of urea solution.
- 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 liberated from urea. This step facilitates the breakage of lignocellulose bond by ammonia thereby releasing cellulose from lingin bondage for digestion and utilisation.
- After 21 days the urea treated paddy straw is ready for feeding.

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

- Growing cellulolytic microorganisms such as white rot fungi *Trichoderma viridae, 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

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 fimeratius* culture.
- Allowed to remain for 5 days then used for feeding.
- Main advantage of this process is that free ammonia is converted into microbial protein and ligno cellulose bond is degraded.

Advantage:

1. Increases palatability.
2. Increases digestability.
3. Certain treatments increase nitrogen or protein content.
4. Improves animal performance.

Disadvantage:

1. Increase feed cost.
2. Technology or methodology involved.

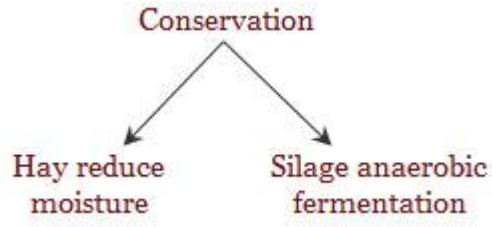
INTRODUCTION TO FEED TECHNOLOGY:

FEED INDUSTRY; PROCESSING OF CONCENTRATES AND ROUGHAGES.

Refer text-book “Principles of Animal Nutrition and Feed Technology” (Second Edition) by D.V. Reddy (Chapter 16. Feed Technology; Page no. 308 to 346)

CONSERVATION OF FORAGE CROPS

- Seasonal variation creates surplus forages at one point of time, that would be wasted if not conserved.
- There are two methods of conserving forages, the simple method is to drive off moisture in forages, while in the other method, natural fermentation is facilitated to retain succulence in the preserved forage.
- The driving off moisture from forage forms the basis in hay making while retaing forage's succulence forms the basis for silage making.



HAY

- In hay making forage is conserved by reducing the moisture content of the green crop to a level low enough (12-14%) to inhibit the action of plant and microbial enzymes.
- The harvested crop can be dried either by natural drying or through artificial drying, but natural drying is preferred as there it can be done without incurring expenditure towards electricity.
- Hay can be stored satisfactorily in a stack or bale.

REQUISITES FOR GOOD HAY

Good quality hay can be produced by considering the following points.

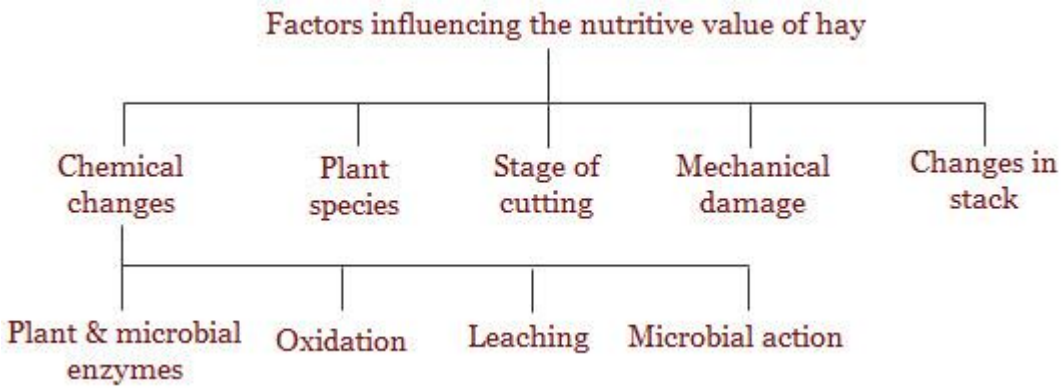
1. **Selection of crop** – The crop to be made as hay should have soft pliable stem.
2. **Harvesting of crop** – The crop should be harvested at 2/3rd flowering stage as it is at that time the plant will have the maximum nutrient in it. Delaying the harvesting further would divert the nutrients from the plant to seed production resulting in low nutritive value of the harvested crop.
3. Hay should be leafy and green in colour as they reflect the nutritive value of hay.
4. Hay should be free from moulds and weeds.

5. Hay should have the characteristic aroma of the crop.

SCHEDULE FOR HARVESTING AND CURING OF HAY

- Good quality hay can be produced by harvesting the crop early in the morning and left in the field as such for curring.
- The harvested crop should be allowed to dry in the field until the moisture content is reduced to about 40%.
- Frequent turning is necessary to facilitate uniform drying.
- On sunny days field drying of harvested crop for two days is sufficient to make hay.
- The air dried crop may be turned with the rake and made into small feathery windrows at the end of first day.
- The windrows may be baled at the end of second day and if further drying is required inspite of two days of sun drying, they may be placed over tripods or tetrapods or over the fence to facilitate airation during drying.
- Hay should always be stored in well ventilated place as they catch fire easily.
- Average quality hay will have 25-30 per cent crude fibre and 45-60 per cent TDN.

FACTORS INFLUENCING THE NUTRITIVE VALUE OF HAY



A. CHEMICAL CHANGES

1. **Plant & microbial enzymes:**

- Plant continues to respire even after harvest and during respiration, the sugars are oxidised to CO_2 and H_2O leading to increase in concentration of cell wall constituents like cellulose and lignin.
- Plant enzymes proteolyse the protein resulting in formation of free amino acids that could be lost due to leaching.

2. Oxidation:

- During drying, oxidation occurs leading to reduction in the carotene concentration and that is why sun drying should be stopped when greenery starts fading.
- But sun drying enhances the vitamin D content in the hay due to irradiation of ergosterol present in green plant.

3. Leaching:

- Leaching causes loss of soluble minerals, sugars and nitrogenous constituents in addition to facilitating mould growth.

4. Microbial action:

- Microbes flourish during drying for prolonged period under bad weather leading to moldy hay that are unpalatable & harmful to farm animals & man.
- Such hay may cause allergic diseases affecting man known as hay fever or farmer's lung.

B. PLANT SPECIES

- Legume hays are rich in protein & minerals than grass hay.
- Non-legume hay has more carbohydrate but less palatable.

C. STAGE OF GROWTH/CUTTING

- The nutritive value of hay depends on the stage of growth of the crop at the time of cutting.
- Harvesting matured crop results in hay with lower digestibility, lower net energy value and lower palatability but with larger yield.

D. MECHANICAL DAMAGE

- Since leaves lose moisture more quickly than the stems, they become brittle and easily crushed by handling.
- Handling hay during early morning minimize loss of leaves.
- Flattening of herbage facilitates uniform drying and thereby reduces shattering.

CHANGES DURING STORAGE

Brown Hay

- Dark brown colour observed in over heated hay stored at higher moisture level during stacking is due to oxidative degradation of sugars combining with amino acids or proteins.
- Plant respiration ceases at about 40^{o}C, but thermophillic bacteria continue to be active until 72^{o}C and therefore oxidative degradation continues in hay containing thermophilic bacteria.
- The heat tends to accumulate in hay stored in bulk and eventually combustion may occur.

LOSSES IN NUTRITIVE VALUE OF HAY ARE DUE TO:

- Losses due to late cutting.
- Losses of leaves by shattering.
- Losses due fermentation.
- Losses due to leaching.

Sun drying enhances the vitamin D content in the hay due to irradiation of ergosterol present in green plant.

ARTIFICIALLY DRIED FORAGES

- Artificial drying is very efficient process but expensive method of conserving forage crops.
- Drying is brought about by allowing hot gas (150^{o}C) to pass through herbages for about 20 to 50 minutes depending upon the drier design and the moisture content of the crop.
- There are driers wherein gases in the range of 500-1000^{o}C are allowed to pass through to dry herbages within 0.5 to 2 minutes.

SILAGE

- Silage is the preserved material produced by the controlled fermentation of crop under anaerobic conditions in a structure known as silo.
- Ensilage is the name given to the silage making process.
- The main purpose of silage making is to preserve succulent fodders for usage at the time of scarcity.
- Silage making involves natural fermentation in anaerobic condition with due care to discourage activities of undesirable bacteria.

Advantages of Silage Making:

1. Silage can be made even on weather that does not permit hay making.
2. More number of animals can be reared per unit of land.
3. Year round supply of high quality succulent fodder is possible.
4. Satisfactory silage can be produced in spite of weeds, as ensiling process kills many kinds of weed seeds.
5. Silage making converts stem forage crops to soft that are better utilized by the livestock.

FACTORS TO BE CONSIDERED IN SILAGE MAKING

- Selection of crop:
    - Crop with soft and pliable stem is most suitable for silage making.
- Time of harvest:
    - Crop should be harvested when 50% of the crop are in ear emergence stage as at this stage crop will be nutritious as well as with high biomass yield.
- Wilting of the crop:
    - Crops with high moisture (85%) will produce more effluents that would go as waste.
    - To reduce effluent loss, crops with high moisture content are wilted for few hours, until moisture level is reduced to 65 %.
- Chaffing of the crop:
    - The success of silage depends on the ability to provide anaerobic condition in silo.

    - Anaerobic condition prevents oxidation of nutrients in crop and promotes conducive environment for desirable organisms to survive and produce lactic acid.
    - Thus in order to prevent the development of air pockets in silo, compression of ensiling materials is important.
    - Compression can be achieved better by chaffing the crop.
- Preparation of the silo:
    - Several type of containers are used as silo.
    - The silo should be cleaned and re plastered to make the silo walls smooth and strong.
- Additives:
    - Molasses at the rate of 2% (Weight of forage) provides readily available carbohydrate necessary for increasing the lactic acid production by lactobacillus.
    - Further Molasses increases palatability and nutritive value of silage.
    - Molasses is sprayed over the forages to facilitate uniform distribution.
    - Salt at the rate of 1% (Weight of forage) is also added to improve palatability of silage.
- Filling up of the silo:
    - Rapid filling of silo is desired for anaerobic condition.
    - Silage making should not be undertaken during rainy days.
- Compaction:
    - Compaction of chaffed material can be brought about by manual trampling or by engaging tractor.
    - Compaction is the key step in silage as it removes the air pockets to promote anaerobic fermentation.
- Sealing of the silo to prevent the entry of air or water:
    - To sustain anaerobic condition and to prevent entry of atmospheric air / rain into silo, the silo should be sealed as soon as the silo is filled.
    - It is advisable to fill the silo pit to form a dome shape and cover it with insulators like tarpaulin sheet or plaster it with mud.
    - Dome shape filling will facilitate rainwater to run off and prevents seepage.

- Silage will be ready in four weeks time.
- Upon opening the silo, the silage should be taken out daily to feed animals.

PRINCIPLES OF FERMENTATION IN SILO

The fermentation in silo can be regulated by

- Encouraging lactic acid formation by bacteria present on the fresh herbage or
- Addition of preservatives such as sodium meta-bi-sulphite or by direct addition of a weak acid solution.
- The first method the soluble carbohydrates present in the plant material is fermented to lactic acid, resulting in a lowering of pH to within the range of 3.8 – 4.2.
    - Material of this type has lactic acid content (8-12% drymatter) and is described as 'well preserved silage'.
    - As long as the silage mass is kept under anaerobic conditions, its pH will remain stable at 4 and the silage can be stored for 3-4 years.
    - If, however, rain is allowed to enter the silage (or) if lactic acid concentration is scarce, secondary clostridial fermentation take place.
    - There are two types *clostridias*, while one group cause a break down of the lactic acid with the production of butyric acid, the other group of *clostridia* attack amino acids, with the formation of ammonia, organic acids, amines and CO_2.

Either or both of these types of clostridia may become dominant in poorly preserved silage which will have a comparatively high pH value of above 5.

The process of fermentation can be divided into four phases:

- **Phase I:**
    - Aerobic phase, plant enzymes breaks down soluble carbohydrates to carbon dioxide and water.
- **Phase II:**
    - Enterobactor species of bacteria acts on soluble carbohydrates producing acetic acid and lowers the pH slightly.
- **Phase III:**

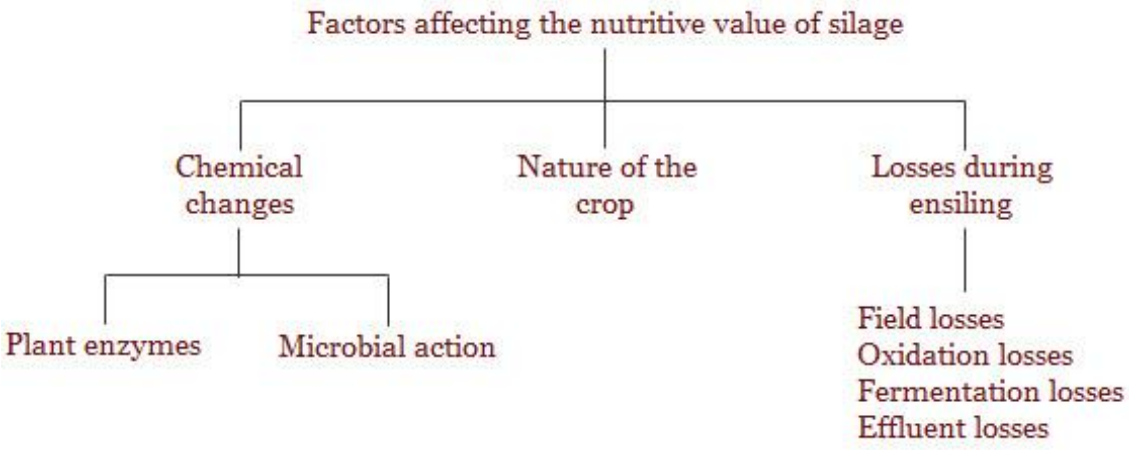
- Lactic acid producing bacteria (Lactobacillus and Streptococcus spp) ferments soluble carbohydrates present in the plant material to lactic acid resulting in a lowering of pH.

- **Phase IV:**
  - Lactic acid production peaks; stabilises to within the range of 3.8 – 4.2. At this pH, crop preservation is good.

A.I.V. silage

- Direct acidification of the crop, is another method of preserving forage; one such system is the A.I.V. process, named after originator A. I. Virtanen.
- The mixture of acids used in this process consists of hydrochloric acid and sulphuric acid.
- These acids are added to material during ensiling in sufficient quantity to lower the pH value below 4.
- A.I.V. silage has been shown to be palatable and harmless to ruminants.

FACTORS AFFECTING THE NUTRITIVE VALUE OF SILAGE



Chemical changes:

- *Plant enzymes:*
  - Plant continues to respire as long as oxygen present or until the plant sugars are used up.

- Sugars are oxidised to carbon dioxide and water, with the production of heat causing rise in temperature of the mass.
- In addition, proteolysis also occurs immediately after the herbage is cut.
- Protein is rapidly broken down to simpler substances mainly amino acids.
- Packing the silo compactly eliminates air pockets and prevents this activity.
- However, if the herbage is not well consolidated, then air may penetrate into the mass and the temperature will continue to rise.

➢ Thus over heated product will be dark brown or black in colour with low feeding value due to excessive loss of soluble carbohydrate and a lowering of the protein digestibility.

Microorganisms:

- In anaerobic condition, the microbes present on the plant surface multiply, using the contents of a cell as medium to produce lactic acid.
- Thus the acidity of the mass drops to about pH 4.0 – 4.2 and at this pH, organisms other than the lactic acid bacteria are inhibited as long as conditions remain anaerobic.
- These lactic acid bacteria are classified into 2 main groups, the homofermentative lactic acid bacteria and the heterofermentative lactic acid bacteria.
- Homofermentative lactic acid bacteria are more efficient at converting hexose into the acid than the heterofermentative organisms.
- During ensilage about 60% of the proteins are broken down to amino acids even in well preserved material.
- Nutritive value - wise break down to amino acids is not a drawback, but in badly preserved material the amino acids are broken down further to produce various amines such as tryptamine, phenyl ethylamine and histamine that could be toxic to animals if absorbed into the blood.
- Though mineral compounds present in herbage such as potassium, calcium, sodium and magnesium may form salts of lactic acid and volatile acids, their bio availability is not impaired in silage making.

NATURE OF CROP

- Legumes have low soluble carbohydrate content with high buffering capacity make them difficult to ensile.
- However, spraying sugar additive, such as molasses on to the crop at the time of filling the silo provides conducive environment for ensiling.
- In order to obtain nutritious as well as maximum yield of crop, they should be harvested when 50% of the crop are in ear emergence stage as digestibility falls rapidly with increasing herbage maturity.
- Chopping or crushing the crop exposes the cell sap which tends to produce more favourable condition for microorganism activity.

LOSSES OF NUTRIENTS DURING ENSILAGE

- Field losses:
    - Harvesting and ensiling on the same day prevents loss of water soluble carbohydrates and protein.
    - Wilting beyond 5 days leads to 6 to 10 % dry matter losses.
- Oxidation losses:
    - In the presence of oxygen, the action of plant and microbial enzymes on substrates such as sugars, leads to the formation of CO2 and water.
    - Rapid filling of silo and compression eliminates air pockets leaving unaerobic condition suitable for ensiling and thereby preventing oxidation losses.
- Fermentation losses:
    - Even though considerable biochemical changes occur during fermentation, the net dry matter loss may not exceed 5% and energy loss may be still lower as high energy compounds like ethanol are formed during ensiling.
- Effluent losses:
    - Effluents are highly nutritious as they contain sugars, soluble nitrogenous compounds, minerals and fermentation acids.
    - The amount of drainage effluent produced depends largely upon the initial moisture content of the crop.

- Crops ensiled with moisture of 85% may result in effluent dry matter losses as high as 10%, whereas crops wilted to about 70% moisture produce little effluent.

SILOS

- The size of the container will generally depend upon the number and kind of animals to be fed.
- The container plays an important role on the nature and quality of silage.

Types of Silos

1. PIT SILO:

- The pit can be excavated in any suitable soil located at non waterlogging area.
- Silo can be cylindrical or rectangular with strong stright and smooth walls.
- The dimension of the pit varies with circumstances and the number of stock to be fed.
- About 10 kg of silage can be accomodated in one cubic feet of silo.

Advantages of pit silo:

- A pit silo is very economical to build & last indefinitely.
- Less power is required for filling.
- The smooth plastered walls allows the silage to settle and retain the juices.

Disadvantage of pit silo:

- Unloading silage from silo pit is difficult process.
- The pit silo occupies farmland that becomes permanently inaccessible for cultivation.
- The main difficulty is ensuring adequate compression.

2. TRENCH SILO

- The process of ensiling using trench silo is more or less similar to pit silo but the only difference is size because trench silo usually have greater length in relation to breadth.

Advantages of trench silo:

- Tractors can be used to pack silage.
- Less power is required for filling the trench silo.
- Well adopted to ensile immature corn etc.,

- There is minimum chance of air getting into the silo as major part of material conserved will settle into the trench below ground level.
- Unloading and carrying of silage are much easier.

Disadvantages of trench silo:

- Once constructed, it is not easy to abandon.
- Relatively more silage is spoilt.
- The trench silo must be trimmed upon the edges & cleaned.

3. TOWER SILO

- Tower silo are round, cylindrical with a varying diameter (6 to 10m), placed above the ground and the height varies from 6 to 10m or more.
- Tower silos are made of wood, reinforced concrete or sheet metal.
- The advantage of using wood is that silage acids do not affect it.
- A chopper blower is necessary for filling up the silo.
- Silage at bottom one third will be over compressed with butyric acid smell emanating from it.
- The silage at the center will be of good quality, whereas it will be often dark and over heated in the top.

Advantages:

- Material can be well preserved with no wastage.
- The mass itself applies pressure & acts as air seal to lower layer.
- Wilting & sealing are not important as in pit silo.
- Minimum dry matter loss.

Disadvantages:

- Very expensive.
- Chopper blower is required to fill silo.
- Emptying is very laborious.
- The silage gets dehydrated, in dry hot places.

4. TUBE SILO

- Grass is filled in plastic cylindrical tubes of varying capacity.
- During ensiling, various additives can be used to regulate the microbial activity and they may be grouped as

- *Fermentation stimulants* - Culture of lactic acid producing bacteria, soluble carbohydrate sources.
- *Fermentation inhibitors* - Inorganic acids, antibiotics, sodium metabisulphite, formaldehyde and formic acids.
- *Others* - Molasses, urea, limestone, poultry manure, salt etc.

Advantages:

- It can be shifted to various locations with ease and it does not occupy permanent location.

Disadvantages:

- Special machinery is required to fill as well as to evacuate silo.

CHARACTERISTIC OF SILAGE

Very good silage:

- Clean pleasant fruity odour.
- Uniformly green or brownish in colour with absence of butyric acid, absence of moulds, absence of sliminess and absence of proteolysis.
- The pH is between 3.8 and 4.2.
- The amount of ammoniacal nitrogen should be less than 10 per cent of the total nitrogen.

Good silage:

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

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.
- Ammoniacal nitrogen is 15-20 per cent of the total nitrogen.
- Colour of silage varies between tobacco brown to dark brown.

Poor silage:

- Due to high butyric acid and high proteolysis, it has a bad smell.
- The silage may be infested with moulds.
- Less acidity, pH is above 4.8.

- The amount of ammoniacal nitrogen is more than 20 per cent.
- Colour tends to be blackish and should not be fed.

Comparison on the Characteristics of Silage

	Very good silage	**Good silage**	**Fair silage**	**Poor silage**
Butyric acid	Absence	Traces	Little	High
pH	3.8 – 4.2	4.2 – 4.5	4.5 – 4.8	> 4.8
Ammonical Nitrogen	< 10 %	10 – 15 %	15 – 20 %	> 20 %
Colour	Greenish brown	Brownish	Tobacco brown	Blackish

HAYLAGES

- Haylages are low moisture silage with characteristics between those of hay and silage.
- It is made from grass and/or legume to a moisture level of about 45-55%.
- To use up the oxygen and to trap and hold the produced CO_2 within the silo, the silos should be as airtight as possible.
- This condition will prevent the forage from spoiling by moulding, oxidising, heating etc.

Advantages:

- Haylage has a pleasant aroma, palatable & high quality feed.
- Partially dried forage can be made into haylage.

Disadvantages:

- Fine chopping, good packing and complete sealing against air entrance inside the silo is more critical than with silage.
- The danger of excessive heating that lowers protein digestibility is more.

HARMFUL NATURAL CONSTITUENTS OF FEEDS AND FODDERS

- Harmful natural constituents are also called as **anti-nutritional factors**.
- **Anti-nutritive factor** is defined as "those generated in natural feedstuffs by the normal metabolism of the species and exerts adverse effects to optimum nutrition".

Type of Anti-nutritive substances/factors

I. Substances depressing digestion or metabolic utilization of protein:

A. Protease inhibitors
B. Ricin or Lectins (Hemagglutinins)
C. Saponins
D. Tannins (Polyphenolic compounds)

II. Substances reducing utilization of minerals:

A. Phytic acid
B. Oxalic acid
C. Glucosinolates
D. Gossypol

III. Substances inactivating or increasing the requirements of vitamins:

Anti-vitamins A, D, E, K and anti-pyridoxine

IV. Mimosine (Anti-hormone)

V. Nitrates and nitrites

VI. Moulds and mycotoxins in animal feedstuffs

I. Substances depressing digestion or metabolic utilization of protein:

A. Protease inhibitors

- Substance that inhibit proteolytic enzymes
- **Trypsin inhibitor** found in raw soyabean, seeds and legumes
- Interferes protein digestion in monogastric animals
- Protein indigestibility reduce growth rate, egg production and feed efficiency
- It leads to hypertrophy of pancreas
- Protease inhibitors are destroyed by proper heat treatment

B. Ricin or Lectins (Hemagglutinins)

- Ricin agglutinates red blood cells
- **Ricin is anti-nutritive factor in castor bean cake**
- Ricin reduces the efficiency of protein absorption
- Ricin is destroyed by proper heat treatment

C. Saponins

- Leguminous fodders such as lucerne, mahua seeds white clover, and red clover contains saponins
- Saponins are bitter in taste, foam forming
- In ruminant saponins results in formation of bloat
- Inhibit the action of proteolytic enzymes and also causes haemolysis of red blood cells
- Saponin poisoning can be avoided by water soaking and rinsing
- Leguminous fodders should always be fed along with some dry fodder

D. Tannins

- Tannins are polyphenolic compounds
- Found in babul seed, tamarind seed
- Chemically tannins may be grouped into:
    - Hydrolysable tannin and Condensed tannins
- Tannins bind to proteins
- The low palatability of some plants and grains is due to their high tannin content
- High tannin content decreases cellulase activity and thereby reduce digestion of crude fibre

II. Substances reducing utilization of minerals:

A. Phytic acid/Phytates

- Phytate forms complexes with mineral elements like zinc, iron, manganese resulting the minerals insoluble in the intestinal tract.
- Thus reduces absorption and utilization of these minerals

B. Oxalic acid

- Plants that are rich in oxalates include beet, spinach and a number of agro-industrial by-products such as rice/paddy straw used as livestock feed ingredient.
- Oxalic acids readily forms insoluble salts with calcium and magnesium leading to impaired absorption.

C. Glucosinolates

- Glucosinolates are found in plants of genus Brassica, which includes cabbage, turnips, rapeseed and mustard seeds, responsible for the pungent flavour
- Glucosinolates are goitrogenic in nature
- They decrease the synthesis of the thyroid hormone (Tryroxine and Tri-iodothyronine), interfering uptake of iodine
- Ruminants are less susceptible to the toxic effect of glucosinolates compared with pigs and poultry
- An adequate supply of iodized salt is a preventive measure to glucosinolates toxicity in simple-stomached animals.

D. Gossypol

- Gossypol pigments are polyphenolic compounds found exclusively in the cottonseed.
- It is toxic to simple-stomached animals
- The symptoms include depressed appetite, loss of weight and even lead to death due to cardiac failure.
- Gossypol toxicity can be reduced by the addition of calcium hydroxide and iron salts.
- Shearing effect of screw press in expeller process is an efficient gossypol in-activator.
- Pigs, rabbits, poultry are more sensitive to gossypol toxicity.

Cyanogens

- Sorghum and sudan grass, linseed and cassava root contains relatively high levels of Cyanide.

Plants	Cyanogens
Sorghum and sudan grass	Dhurrin
Linseed and Cassava	Linamarin
Amygdalin	Almonds

- These cyanogens are hydrolysed to hydrocyanic acid (HCN)
- High level of HCN is found in the young growing plants, during a period of drought, heavy nitrate fertilisation of the soil
- Excess cyanide ion can quickly produce anoxia of the central nervous system through inactivating the cytochrome oxidase system, and death can result within a few seconds.
- Treatment includes intravenous injection of sodium nitrate and sodium thiosulphate.
- Ruminants are more susceptible to HCN poisoning than are horses and pigs.

III. Substances inactivating or increasing the requirements of vitamins:

A. Anti-vitamin A

- Raw soybean contains an enzyme lipoxygenase, which catalysis oxidation of carotene, the precoursor of vitamin A
- The enzyme can be destroyed by heating soyabean for 15 minutes with steam at atmospheric pressure

B. Anti-vitamin D

- Soy protein depresses vitamin D synthesis in chicks and pigs
- The effect could be partially eliminated by increasing the vitamin D in the diet by 10 fold or autoclaving the Soy Protein

C. Anti-vitamin E

- Diets containing raw kidney beans produce muscular dystrophy in lambs by reducing plasma vitamin E
- Autoclaving beans eliminates the anti-vitamin activity

D. Anti-vitamin K

- Dicoumarol produces fatal hemorrhagic condition in cattle called as “Sweet clover disease”.
- Dicoumarol interferes with the blood clothing mechanism by reducing the prothrombin level of the blood.
- The effect is due to reducing vitamin K utilization in the production of thrombin.

E. Anti-pyridoxine:

- An antagonist of pyridoxine (Vitamins B_6) occurs in linseed which can be reduced by water soaking and autoclaving.

F. Biotin:

- Raw egg contain anti-nutritional factor **avidin**, which anti-vitamin of biotin

IV. Mimosine

- Mimosine found in the plants belonging to the genus Leucaena like subabul is a toxic non-protein free amino acid.
- Mimosine is degraded to Dihydroxy pyridone (DHP) in the rumen.
- DHP reaches thyroid gland and inhibits biosynthesis of the hormone thyroxine.
- Symptoms include reduced growth, excessive salivation, loss of hair, eroded gums, enlarged thyroid gland and poor reproductive efficiency.
- Ferrous sulphate supplementation also reduces the mimosine toxicity, by forming insoluble red iron complex.

V. Nitrate and Nitrite

- Nitrate is a non-protein nitrogenous fraction (NPN) present in forages.
- Recently fertilized plants have higher nitrate levels.
- Nitrate itself is not toxic to animals.
- The toxic effect on ruminants is caused by the reduction of nitrate to nitrite in the rumen.
- Nitrites cause an acute toxicosis in cattle
- Nitrite is absorbed into red blood cells and combines with hemoglobin (oxygen carrying molecule) to form brown pigment called methemoglobin.
- Methemoglobin cannot transport oxygen and hence the animal's heart rate and respiration increases, the blood and tissues of the animal take on a blue to

chocolate brown tinge, muscle tremors can develop, staggering occurs, and the animal eventually suffocates and die.

VI. Moulds and mycotoxins in animal feedstuffs

- A mycotoxin is a fungal metabolite causing pathological or physiological changes in man or animal.
- In rainy season it is specifically labile to contain a toxic factor – Aflatoxins, a secondary metabolite of *Aspergillus flavus*.
- Presence of oxygen, conducive temperature (10 – 40ºC) and high humidity favours the mould growth.
- Aflatoxins are the most potent toxic, mutagenic, teratogenic and carcinogenic metabolities produced by the species of *Aspergillus flavus* and *A. parasiticus* on food and feed materials.
- There are four Aflatoxins, B1, G1, B2, G2 out of which B1 is most toxic.
- The susceptibility to these toxins differs among the species,

Poultry and Ducks – Highly susceptible

Cattles and pigs – Susceptible

Sheep are resistant

- In the same species, young animals are more susceptible than adults.
- The most common symptoms in the affected animals are liver damage
- Other fungal toxins include T2 toxin, Ochratoxin A and Zearalenone.

COMMON ADULTERANTS OF FEEDS AND FODDERS

DEFINITION

Adulteration is defined as the admixture of pure substance with some cheaper low quality substance.

- It is done intentionally usually to make money although unintentionally it can happen.

COMMON ADULTERANTS

- The common adulterants in feed ingredients are a follows:

Feed ingredients	**Adulterants**
Groundnut cake	Groundnut husk, urea, non-edible oil cakes
Mustard cake	*Argimona maxicana* seeds, fibrous feed ingredients, Urea
Soybean meal	Urea, non-edible oil cakes, Hulls, Sand
Rice bran, Wheat bran	Ground rice Husk, Saw dust, Sand
Fish meal	Common salt, sand, urea, NPN, other marine
Molasses	Water
Maize	Cobs, Cob dust
Broken rice	Marble grit
Mineral mixture	Common salt, sand, limestone, marble powder

RECENT ADULTERANT: MELAMINE

- Melamine is a metabolite of cyromazine, a pesticide.
- Melamine is rich in nitrogen (66%). It raises the nitrogen level of feed to appear to be higher in protein, and can lead to higher prices for feed.
- Routine chemical analysis cannot deduct melamine, but special techniques are available.

FIELD TESTING METHODS

1. ORGANOLEPTIC EVALUATION - TOUCH

- Insert hand deep into a bag of grains, if you didn't find any temperature difference between inside and outside the bag it means that grains are properly dried.
- Take a pinch of rice polishing, rice bran or deoiled rice bran and rub between fingers. If it is too coarse & rough, it indicates adulteration with paddy husk.
- Fish meal with more moisture level will be dark in colour, hot and will not break easily.

ORGANOLEPTIC EVALUATION - TASTE

- Fresh feedstuff will have a desirable taste while old feeds will have undesirable musty taste.
- Biting and tasting oilcakes will give idea about its freshness, rancidity, mould and moistures and also some adulteration.
- Licking a fish or tasting small piece of it can help in identifying the level of salt.
- Rice bran and rice polish adulterated with paddy husk will have a bland or throat burning taste with feeling to spit the fibrous portion.

ORGANOLEPTIC EVALUATION - VISION

- Examine the feedstuffs for the natural colours, consistency, presence of foreign materials, mould growth, cake and clump formation and any other abnormalities.
- Mouldy grains will have greenish, grayish or blackish discolouration especially at the germinal tip.
- Adulteration of groundnut oil cake with rice bran or any other cheaper oil cakes & fish with prawn heads, crabs, squilla, sheels, etc. can be detected by careful visual examination.

ORGANOLEPTIC EVALUATION - SMELL

- Musty odour indicate fungal contamination or boring insects.
- Odour of petroleum product is suggestive of pesticides/fungicides.
- Leathery smell of meat meal is indicative of adulteration with leather meal.

FEED MICROSCOPY

- Feed and feedstuffs are examined under a wide field microscope.

- **Microscopic observation of fish meal:** The feed microscopic details of fish meal as well as the possible adulterants in them are furnished below. The adulterants can be easily identified by trained eye.
- **Muscle fibre:** Fibre bundles which separate, under pressure, yellowish to brown in colour & greasy
- **Scales:** Transparent, round with concentric rings, flat or curled
- **Sand:** Granular, crystalline or bead like, Light brown to translucent, do not break under pressure.

SPOT TESTS

- Some feed supplements can be identified by using simple chemical reagents

Reagents	**Reaction**	**Compounds identified**
2.5% Ammonium molybdate solution	Effervescence and no precipitate	Carbonates, viz., calcium carbonate sodium bicarbonate
2.5% Ammonium molybdate solution	Yellow precipitate and no effervescence	Phosphates, viz. disodium phosphate, monosodium phosphate, bone meal
2.5% Ammonium molybdate solution	Effervescence & Yellow precipitate	Dicalcium phosphate

CHEMICAL TESTS TO DETECT ADULTERANTS

- In addition to the above tests, specific tests to identify the adulterants have been described by BIS.
    - Detection of castor cake in feedstuffs
    - Detection of neem seed cake in feedstuffs
    - Detection of linseed meal in feedstuffs
    - Detection of common salt in feed stuffs
    - Detection of urea in feedstuffs
    - Detection of hoof or horn in feedstuffs
    - Detection of leather meal in feedstuffs
    - Detection of feather meal in feedstuffs

FEED ADDITIVES

The term "feed additive" refers to a non-nutritive product that is added to a basic feed, which improves utilization of the feed or productive performance of the animal.

Classification

- Additives that influence feed stability, feed manufacturing and properties of feeds
  - Antifungals, Antioxidants, Pellet binders
- Additives that modify animal growth, feed efficiency, metabolism and performance
  - Feed flavors
  - Digestion modifiers (Enzymes, Prebiotics, Buffers, Acidifiers, Ionophores, Anti-bloat compound, Probiotics)
  - Metabolism modifiers (Hormones)
  - Growth promoters (Antibiotics)
- Additives that modify animal health
  - Drugs
  - Immuno-modulators
- Additives that modify consumer acceptance
  - Xanthophylls

Advantages:

1. To improve feed stability, feed manufacturing and properties of feeds.
2. To improve animal growth, feed efficiency, metabolism and performance.
3. To improve animal immunity and health
4. To modify consumer acceptance

Disadvantages:

1. Feed additives add to the cost of animal production
2. Feed additives like antibiotics, hormone may appear in animal product and may harmful to consumers

Difference between feed additives and feed supplements

	Feed additives	**Feed supplements**
1	Feed additives are non-nutritive substances	Feed supplements are nutritive substances
2	Added to basic feed in small quantities	Added to basic feed in small or large quantities
3	They affect utilization of the feed or productive performance of the animal.	Added to balance the ration
4	Ex. Antibiotics, Probiotics, Enzymes	Ex. Vitamins, Minerals, Amino acids

ADDITIVES THAT PROMOTES GROWTH AND PRODUCTION

Antibiotics

- Antibiotics are substances which are produced by living organisms (mould, bacteria or green plants) and which in small concentration have bacteriostatic or bactericidal properties.
- Mainly used for young pigs and chicks
- Antibiotics should not be used in the feed of ruminant animals (cattle, sheep and goats), breeding pigs and breeding and laying poultry stock.
- Ex. penicillin, oxytetracycline (Terramycin), chlortetracycline, bacitracin, streptomycin, tyrothricin, gramicidin, neomycin, erythromycin and flavomycin.

Mode of action of antibiotics

- Antibiotics have sparing action on protein, amino acids and vitamins.
- 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 synthesize known or unidentified nutrients.

Probiotics

- It is defined as a "live microbial culture, 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 many contain yeast.
- They benefit the host by:
    - By inhibiting undesirable or harmful organism and minimizing their competition of nutrients.
    - Altering the pattern of microbial metabolism in the gastro intentional tract.
    - Stimulation of immunity.
    - Neutralisation of enterotoxins formed by pathegenic organism.
- Thus resulting in increased growth rate, improved feed efficiency

Choice of Probiotics

- The probiotics must be active at the low pH
- They must be non-pathogenic and non-toxic
- It must be stable both before and after incorporation into the feed or pre-mix
- The probiotics must be capable of surviving normal pelleting conditions

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.
- Ex. estrogens, androgens, progestogens, growth hormones and thyroxine or thyroprotein (iodinated casein) used 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.

Antioxidants (Ex. **Ethoxyquine or BHT (butylated hydroxyl-toluene)**

- 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.

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 medicants are being mixed
    - During attacks of diseases, When animals are under stress, and
    - When a less palatable feedstuffs is being fed either as such or being incorporated in the ration.

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.

Grit (Ex. Oyster shells, coquina shells and limestone)

- 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.

Buffers and Neutralizers (Ex. carbonates, bicarbonates)

- 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.
- 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.

Chelates

- The word "Chelates" is derived from the Greek word "Chele" meaning "claw" which is a good descriptive term for the manner in which polyvalent cations are held by the metal binding agents. Prior to union with the metal these organic substances are termed as "ligands".
- Ligand + mineral = chelate element.
- Organic chelates of mineral elements, which are cyclic compounds, are the most important factors controlling absorption of a number of mineral elements.
- Chelates may be of naturally occurring substances such as chlorophyll, cytochromes, haemoglobin, vitamin B_{12}, some amino acids, etc., or may be of synthetic substances like ethylenediaminetetracetic acid (EDTA.)

Enzymes (Ex. Phytase, glucanase, cellulase)

- Enzymes are proteins which have the property of catalysing specific biochemical reactions.
- 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 byproducts or feed components that are poorly digested
    - By providing additional digestive enzymes to help poultry to withstand stress conditions

Choice of enzyme

- The enzymes must be active at the low pH
- They must be in a physical form in which they can be safely and easily mixed into all forms of animal feed
- The products should be of a high standarised activity that will remain stable both before and after incorporation into the feed or pre-mix
- The enzymes must be capable of surviving normal pelleting conditions

ADDITIVES THAT AFFECT THE HEALTH STATUS OF LIVESTOCK

- Anti-bloat compounds: (Ex. poloxalene)
    - Surfactants such as poloxalene is used to prevent bloat
- Antifungal additives:
    - Mould inhibitors are added to feed liable to be contaminated with various types of fungi such as *Aspergillus flavus, Penicillium cyclopium* etc.
    - 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.
- Anti-coccidials: (Ex. Amprolium)
    - To prevent the growth of coccidian, which are protozoa and live inside the cells of the intestinal lining of livestock.
- Anti-helmintics: (Ex. Albendazole)
    - The compounds act by reducing parasitic infections.

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.
- Ex: Calcium phosphate, Magnesium oxide, Sodium aluminium silicate

Sweeteners (Ex. Sugar, Saccharin)

It is common constitution of food but yet used as additive.