UNIT-IV: ANIMAL NUTRITION

• Nutritional terms, proximate analysis, Classification and composition of feed and fodders, antinutritional factors, feeding standards, nutrient requirements of animals and computation of rations

. • Evaluation of feeds for energy and protein in animals.

• Role of minerals, vitamins and their deficiency disorders. Feed supplements and feed additives, conservation and preservation of feed and fodders.

• Feeding of infants and growing animals, thumb rule of feeding, feeding and care of pregnant and lactating animals.

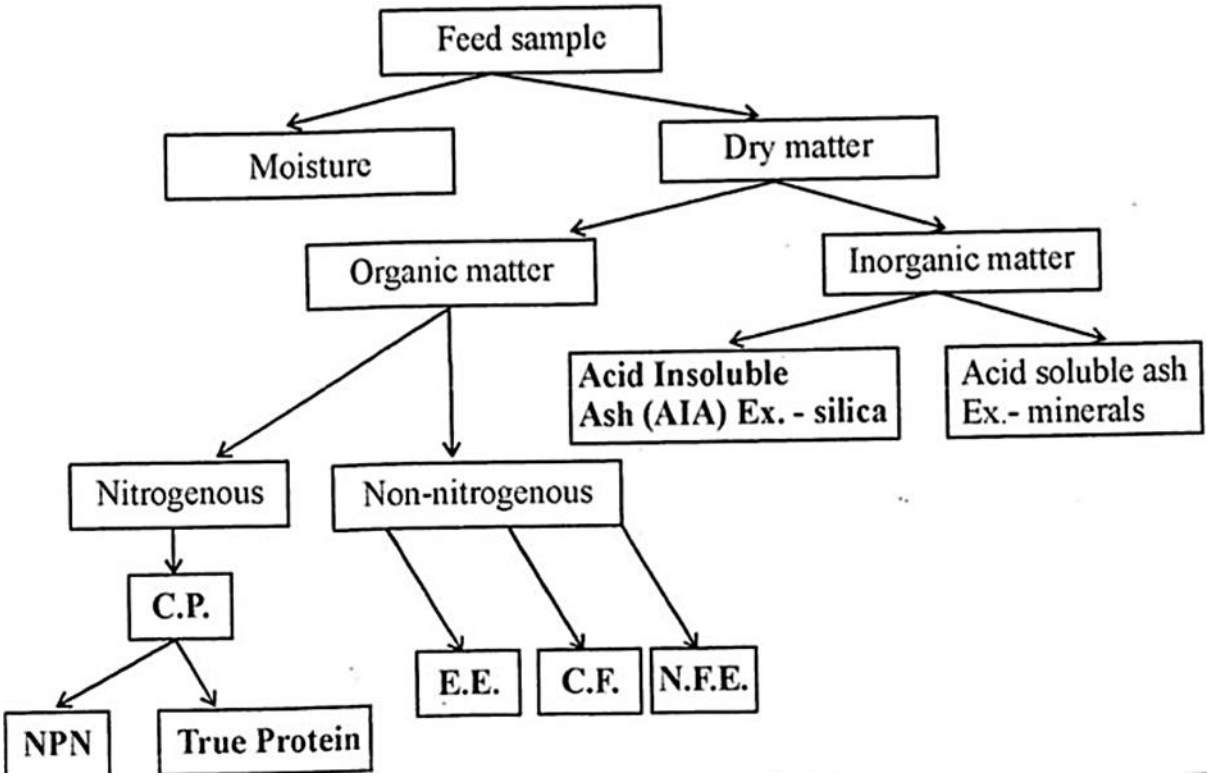
• Feeding of livestock during scarcity, metabolic disorders, processing of feeds and forage, quality control of feedstuffs.

Nutritional terms, proximate analysis, Classification and composition of feed and fodders, antinutritional factors, feeding standards, nutrient requirements of animals and computation of rations

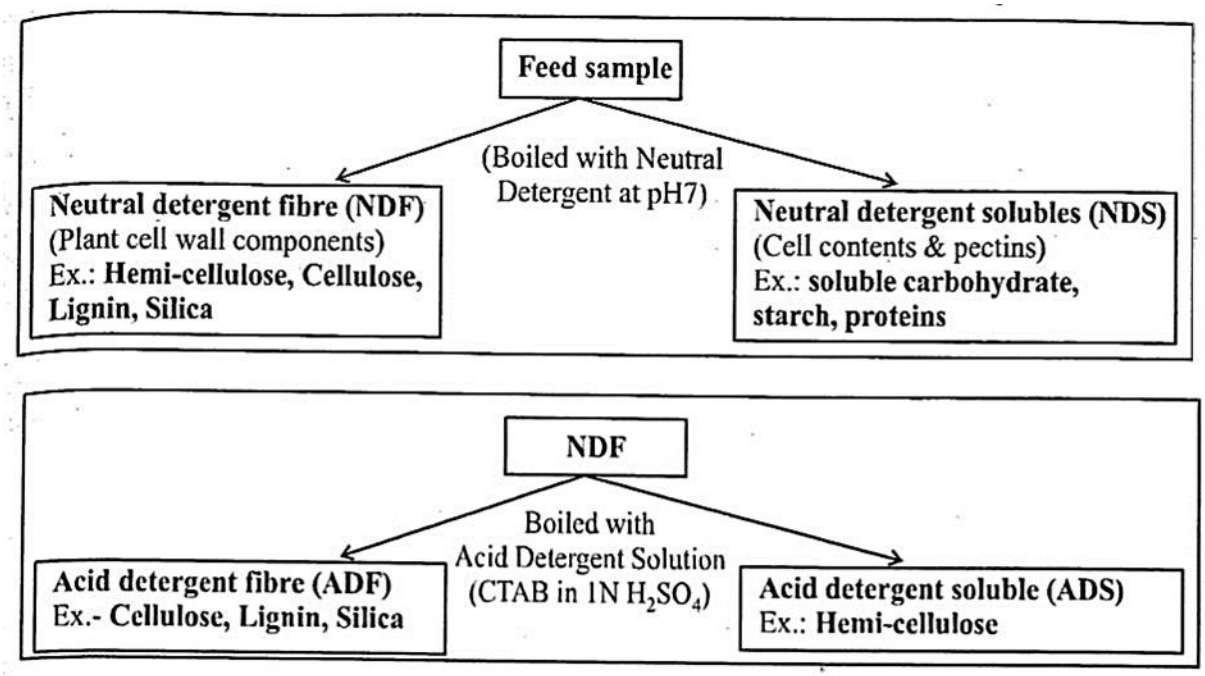
Nutritional Terms and Their Definitions

- **Dry Matter (DM)**: The portion of feed remaining after removing water content.
- **Crude Protein (CP)**: Measure of protein content in feed, calculated from nitrogen content.
- **Crude Fibre (CF):** Indigestible cellulose, lignin, and hemicellulose.
- **Ether Extract (EE):** Portion of feed soluble in ether, representing fat content.
- **Nitrogen-Free Extract (NFE):** Readily digestible carbohydrates such as sugars and starches.
- **Ash:** Inorganic residue after burning feed, representing total mineral content.
- **Acid Detergent Fibre (ADF):** Measures cellulose and lignin, indicating the less digestible portion of the feed. Higher ADF = Lower digestibility.
- **Neutral Detergent Fibre (NDF)**: Measures hemicellulose, cellulose, and lignin, indicating the total fibre content. Higher NDF = Lower feed intake potential, but necessary for rumen health.
- **NDF-ADF=Hemicellulose**
- **Total Digestible Nutrients (TDN)**: Sum of digestible fibre, protein, lipid, and carbohydrate components of feed.
- Proximate principles (6): Moisture, Crude Protein (CP), Crude Fiber (CF), Ether Extract (EE), Total Ash, Nitrogen-Free Extract (NFE) (calculated)

Proximate composition: By Henneberg and Friedrich Stohmann at Weende (Germany) in 1865.



Detergent method of forage analysis: By Van Soest in 1960



Role and Requirement of Water, Metabolic Water

- Vital for digestion, nutrient transport, waste excretion, and temperature regulation.
- Metabolic water is produced internally during the metabolism of nutrients, particularly carbohydrates, proteins, and fats.

- **Energy Metabolism:** For every gram of carbohydrate, protein, and fat metabolised, approximately 0.6, 0.4, and 1.1 grams of water are produced, respectively.

Proximate Analysis

Proximate analysis is a chemical method used to determine the composition of feed, food, and other organic materials. It provides an estimation of the **six major components** of a sample:

1. **Moisture**
2. **Crude Protein**
3. **Ether Extract (Crude Fat)**
4. **Crude Fiber**
5. **Ash (Total Mineral Content)**
6. **Nitrogen-Free Extract (NFE)**

2. Significance of Proximate Analysis

- Helps in **formulating balanced diets** for livestock.
- Assists in **quality control** of feedstuffs.
- Provides **energy estimation** of feed.
- Useful for **economic evaluation** of feeds.
- Essential for **nutritional labeling** of food products.

3. Components of Proximate Analysis

3.1 Moisture Content

- Moisture represents the **water content** in the sample.
- Determined by **drying the sample** at **105°C** in a hot air oven until a constant weight is achieved.
- Formula: Moisture %=Initial weight - Final weight/Initial weight×100
- High moisture reduces **shelf life** and increases **microbial spoilage**.

3.2 Crude Protein (CP)

- Crude protein is estimated using **Kjeldahl's method**, which determines the **total nitrogen (N)** content.
- Assumption: **Protein contains 16% nitrogen**, so a conversion factor of **6.25** is used.
- Formula: Crude Protein %=Nitrogen %×6.25\CP
- Overestimates protein because it includes **non-protein nitrogen** (NPN) compounds.

3.3 Ether Extract (Crude Fat)

- Measures **fat and fat-soluble components** using **solvent extraction** (typically **ether**).
- Important for **energy value**, as fats provide **2.25 times more energy** than carbohydrates.
- Low fat content can indicate **poor energy supply** in feeds.

3.4 Crude Fiber (CF)

- Represents **structural carbohydrates** like cellulose, hemicellulose, and lignin.
- Determined by **successive digestion** with **acid (H_2SO_4) and alkali (NaOH)**, followed by drying and weighing.
- Important for **gut motility and digestion** in ruminants.

3.5 Ash (Total Mineral Content)

- Represents **total inorganic matter** in the sample.
- Determined by **incinerating the sample at 550-600°C** in a muffle furnace.
- High ash content indicates **high mineral content**, but excessive ash may indicate contamination.

3.6 Nitrogen-Free Extract (NFE)

- Represents **soluble carbohydrates** (sugars and starches).
- **Primary energy source** for monogastric animals.

$$\text{NFE \%} = 100 - (\text{Moisture} + \text{CP} + \text{EE} + \text{CF} + \text{Ash})$$

4. Limitations of Proximate Analysis

- **Crude Fiber underestimates** total fiber content, as some fiber components are lost.
- **NFE is indirectly estimated**, leading to possible errors.
- **Non-protein nitrogen (NPN) is included** in crude protein, which may misrepresent actual protein content.
- **Ash does not provide individual mineral values**, requiring further analysis.

Classification of Feed and fodder

4.1 Why Classify?

- Grouping of similar feedstuffs
- Facilitates ration formulation
- Allows for substitution based on price/availability

4.2 Base for Classification:

1. Physical characteristics (Bulkiness)- Roughages & Concentrates
2. Chemical characteristics-

SN	Item	Roughage	Concentrate
1	Crude Fibre	CF>18%	CF<18%
2	TDN	TDN<60%	TDN>60%
3	Energy Content	Low	High
4	Digestibility	Low	High
5	Function	Bulk	Energy
6	Example	Straw, hay, silage	Grains, meal, cake

4. 3 Crampton and Harris Classification (NRC):

1. Dry forage, roughages and Hay
2. Green/succulent forage and pasture
3. Silage
4. Energy feeds
5. Protein supplements
6. Mineral supplements
7. Vitamin supplements
8. Additives

1. Dry forage, roughages and Hay

Classification of Roughages

They are classified on the basis of:

A. By Moisture Content

1. Dry Roughages: Contain less than 15% moisture.
   - Examples: Hay, straw, and chaff dry fodder.
2. Green/Succulent Roughages: Contain 80-85% moisture.
   - Examples: Fresh pasture grasses, tree leaves, silages, roots, and tubers.

B. By Type

1. Legume Roughages: High in protein and often used for production purposes.
   - Examples: Berseem, Lucerne (Alfalfa), Cowpea.
2. Non-Legume Roughages: Lower in protein compared to legumes.
   - Examples: Maize, Bajra (Pearl Millet), Sorghum, Oat.

C. By Nutritional Value

1. Non-Maintenance Type: Contain less than 3% Digestible Crude Protein (DCP). Examples: Straw, stover.
2. Maintenance Type: Contain 3-5% DCP. Examples: Non-leguminous cereal fodder.
3. Production Type: Contain more than 5% DCP. Examples: Legume fodders.

D. By Season

1. Rabi Season Roughages: Grown during the winter season.
   - Examples-Oats, lucerne (alfalfa, known as the "queen" of forages), berseem (known as the "king" of forages).

2. Kharif Season Roughages: Grown during the summer season.
   - Examples: Maize, Cowpea, Bajra, Sorghum.

- Annual Forages:Examples-Maize, sorghum, berseem, cowpea.
- Perennial Forages:Examples-Hybrid napier, para grass, desmanthes.

Examples & Common Terms Related to Dry Feeds

- **Forages:** Plant materials that are fresh or preserved and used for feeding animals.Examples: Hay, straw, silage, and pasture.
- **Roughages:** Feedstuffs with higher fibre content.Examples: Husk, shells.
- **Hay:** Dried product of thin-stemmed crops.Examples: Alfalfa hay, Timothy hay.
- **Straw:** Byproduct of cereals/legumes left after the removal of grains/pulses.Examples: Wheat straw (0% DCP), gram straw.
- **Fodder:** Aerial parts including ears/heads.Examples: Corn fodder.
- **Stover:** Aerial parts without ears/heads.Examples: Corn stover (Kadbi).
- **Bagasse:** Leftover of sugarcane after the extraction of juice.Examples: Sugarcane bagasse.
- **Hull:** Outer covering of beans/peas.Examples: Cottonseed hull, soybean hull.
- **Husk:** Outer covering of grains and legumes.Examples: Rice husk, gram husk.
- **Shell:** Hard covering of nuts.Examples: Groundnut shell.

Advantages of Dry Roughages

- Hunger Satiety: Helps in satisfying the hunger of animals.
- Moisture Control: Maintains dry matter intake (DMI).
- Cost-Effective: Cheaper source of dry matter.

Disadvantages of Dry Roughages

- Poor Digestibility: High lignin content leads to low intake.

- Low Nutritional Value: Except for hay, most dry roughages have low crude protein (CP) and digestible crude protein (DCP).CP: 3%
- Hay: Higher nutritional value with 15-17% CP.

2. Green/Succulent Forage and Pasture: They have high moisture content(80-85%).

Types of Green/Succulent Forages

1. Pasture: Plants that are either natural or cultivated and used for grazing Examples: Various grasses and legumes that are grown in fields and consumed directly by grazing animals.

2. **Fodder:**Crops harvested and used for stall feeding. Examples: Maize, sorghum, and other cereal crops that are cut and brought to the animals.

3. **Top Feeds:**Tree leaves, top cuttings of plants, and agricultural crops.

Energy Feed

1. Characteristics of Energy Feeds:

- Crude Protein (CP): <20%
- Crude Fibre (CF): <18%
- Total Digestible Nutrients (TDN): 75-80%

2. Main Types of Energy Feeds:

a) Cereal Grains:

- Main component: Starch (60-65%)
- CP: 8-12%
- Fat: 2-5% (mostly unsaturated fatty acids)
- Deficient in essential amino acids (lysine and methionine)
- Calcium deficient, phosphorus rich (but in phytate form)
- Deficient in vitamins D and A (except maize)
- Risk of causing Subacute Ruminal Acidosis (SARA)

Key Cereals:

- Maize: High in metabolizable energy, contains cryptoxanthin (vitamin A precursor)
- Barley: Higher fiber, lower oil content, preferred in summer
- Oats: High crude fiber (10-18%), lower TDN, preferred in summer
- Wheat: Easily digestible starch, higher risk of SARA
- Millets (e.g. Sorghum, Bajra): Small grains, higher fiber, preferred in winter

b) Molasses:

- Instant energy source (sugar)
- Rich in minerals
- CP: up to 5-6%
- Used with urea in ruminant diets
- Can be included up to 10% in concentrate mixture
- Higher levels may cause digestive disturbances

c) Fat:

- Highest energy yield (2.25 times that of carbohydrates)
- Limitations in ruminants:Not more than 6% of dry matter intake
- May be given in bypass form for high-yielding animals
- No major digestive issues in monogastric animals

Protein supplements

Characteristics of Protein Supplements

- Crude Protein (CP): Greater than 20%
- Crude Fiber (CF): Less than 18%
- Protein Types: Can be true protein or Non-Protein Nitrogen (NPN)

A. Plant Origin Protein Supplements

1. Cottonseed Cake (CSC) CP
2. Groundnut Cake (GNC) CP
3. Soybean Meal (SBM) CP
4. Mustard Cake CP
5. Guar Meal CP
6. Sesame/Til Cake CP
7. Gram CP
8. Guar CP

B. Animal Origin Protein Supplements

1. Fishmeal CP
2. Meat and Bone Meal (MBM) CP
3. Blood Meal (BM) CP
4. Feather Meal CP

5. Hatchery Byproducts CP

C. Single Cell Protein (SCP)

- Bacteria: *Methanomonas methanica*.
- Yeast: *Spirulina*.
- Algae: *Torulopsis utilis*.

Note: SCP is a sustainable protein source but can be expensive to produce.

Important Notes on Specific Supplements

- Sesame/Til Cake: Very rich in calcium, making it a valuable supplement for balancing mineral content.
- Soybean Meal (SBM): Low in methionine, often requiring supplementation with synthetic amino acids.
- Meat and Bone Meal (MBM): Banned in some regions due to the risk of BSE (mad cow disease) caused by prions.
- Mustard Cake: Contains erucic acid, limiting its inclusion to 10-12% of the concentrate mix.
- Blood Meal: Poor digestibility, palatability, and low in calcium and phosphorus.

Methods of Making Vegetable Protein Supplements

1. Hydraulic/Ghani Method: Produces cake with about 8% fat.
2. Expeller Method: Produces cake with about 6% fat, with some bypass protein.
3. Solvent Extraction: Uses ether or benzene to produce meals with less than 1% fat.

Note: Cake has higher oil content and lower protein, while meals have lower oil and higher protein content.

D. Non-Protein Nitrogen (NPN) Sources

- Definition: Nitrogen in forms other than true protein and peptide.
- Examples: Urea (46% N), Biuret (35% N).
- Function: Increases microbial growth in the rumen.

Issues with Urea Supplementation

- Rapid Hydrolysis: which can lead to toxicity.
- Source of Nitrogen Only: Requires energy (e.g., starch) for effective utilization.
- Optimal Ratio: Starch to urea ratio should be 10:1 (1 kg starch per 100 g urea).
- N:S Ratio: For optimal rumen microbial function, the nitrogen to sulfur ratio should be 10:1.

Urea/NPN Supplementation Guidelines

- Concentrate Mix: Up to 3% of the mix.
- Total Dry Matter Intake (DMI): Up to 1%.
- Total Nitrogen/Protein Need: Up to 33% (one-third).
- Salt: 0.5% of the mix.
- Straw Treatment: 4% for treating straw.
- Not Beneficial: If Total Mixed Ration (TMR) CP is greater than 13%.
- Maximum Permissible Level (MPL): 27 g/100 kg body weight or 100 g/day for an adult cow, and not more than 10 g/day for goats.
- Toxicity Treatment: Administer 45 liters of cold water followed by 2-6 liters of 5% acetic acid (vinegar).

Urea Products

- Examples: Uromol, Urea-Molasses Mineral Block (UMMB), Urea-Molasses Liquid Feed.

E. Agro-Industrial By Products

They are derived from the processing of agricultural products. cheaper than primary feed ingredients, & Rich in Fiber and Minerals

- Protein Content: 12-14% Crude Protein (CP).
- Energy Value: Moderate

Examples of Agro-Industrial Byproducts

- Flour: Finely ground grains used as a feed ingredient.
- Bran: The outer covering of grains such as rice and wheat, rich in phosphorus and fibre.
- Rice Polish: A byproduct of rice milling, rich in energy and B-complex vitamins.
- De-Oiled Rice Bran (DORB): Used as a filler in feed formulations.
- Hulls: Outer coverings of beans and peas, such as soybean hulls.
- Chunni: Broken grains with husk, such as gram or dal chunni.
- Distillers Dried Grains with Solubles (DDGS): Byproduct of ethanol production, rich in protein and fibre.
- Gluten: Protein-rich byproduct from starch extraction in grains.

3. Mineral Supplements

Mineral supplements are essential for maintaining the health and productivity of livestock. They are categorised into macro-minerals and micro-minerals based on the quantities required by animals.

- Mineral Mixture (MM): Typically, 2% of the concentrate mix.

- Salt: Usually 1% of the concentrate mix. Salt acts as a condiment, encourages water intake, and helps manage heat stress.

4. Vitamin Supplements

Vitamins are organic compounds required in small quantities for various physiological functions. They are categorised based on their solubility:

Water-Soluble Vitamins

- B-Complex Vitamins: Includes B1 (Thiamine), B2 (Riboflavin), B3 (Niacin), B6 (Pyridoxine), B12 (Cobalamin), Folic acid, Pantothenic acid, Biotin, and Choline.
- Vitamin C (Ascorbic Acid): Regular supply is essential as it is not stored in the body.

Fat-Soluble Vitamins

- Vitamin A,D,E,K

Note: Vitamin B is synthesised by rumen microbes, and green fodder is a good source of vitamins.

5. Additives

Additives are non-nutritive substances added to feed to improve body weight gain, feed efficiency, and control or prevent diseases. They include:

- Antibiotics: Used to prevent subclinical infections and promote growth.
- Antioxidants: Prevent oxidative rancidity of fats and improve feed stability.
- Buffers: Help maintain optimal pH in the rumen.
- Colors & Flavors: Enhance the palatability and attractiveness of feed.
- Enzymes: Improve the digestibility of feed components.
- Hormones: Used to enhance growth and production.
- Medicines: Added to feed to prevent or treat disease

Anti-Nutritional Factors (ANF) in Feeds

Substances present in the diet, which by themselves or their metabolic products interfere with the feed utilization, reduce production or affect the health of animals.

- Different adulterants, produced by plants to protect themselves (tannins, lignin)
-

A. Anti-nutritive substances according to their chemical properties:

Proteins	Glycosides	Phenols	Miscellaneou
Protease inhibitors	Saponins	Gossypol	Antimetals

Haemagglutinin	Cyanogens	Tannins	Antivitamin
Enzymes Lipo-oxidase Amino acids Glyco-protein	Glucosinolate		Carbohydrate & fat

B. Anti-nutritive substances according to their Mechanism of Action (MOA):

1. Substances Depressing Digestion or Metabolic Utilization of Protein:

ANF	Source	Action	Others	Treatment
Protease inhibitors	Soybean and other beans	ıibit ›teolytic ivity	2 types; Kunitz: anti-trypsin and Bowman-Birk: trypsin-chymotrypsin inhibitors	Heat treatment
Haem-agglutinin (Lectin/Ricin)	Soybean, castor bean (ricin) and other legumes	Agglutinate RBC	Disrupt cell membrane	Heat treatment
Tannin (Polyphenolic compounds)	Fodder tree, Sorghum, sal seed meal, sunflower meal, mango seed	ıibit ›teolytic ivity	Astringent in nature, decrease lubrication nature of saliva, decrease fiber digestibility	›etannification (PEG), Physical and chemical methods
Saponin	Legume fodder; Lucerne, soybean, berseem	Decrease surface tension in rumen, hemolysis, protein inhibitor	Tympany/Bloat	Water soaking, Add cottonseed oil in diet

2. Substances Depressing Carbohydrate Metabolism

ANF	Source	Action
Amylase inhibitors	Cereal grains and legumes	Inhibit amylases and reduced starch digestion
Phenolic compound (Lignin)	Mature forage	Reduced CHO digestibility
Flatulence factors	Chickpea	Flatulence and digestive discomfort when in excess amount only

3. Substances Reducing Solubility or Interfering With Utilization of Mineral Elements

ANF	Action	Source	Others	Treatment
Phytic acid	Impairing absorption of minerals like phosphorus, zinc, iron, etc	Cereals, Legumes seeds, oilseeds and nuts	Form complex with minerals and decrease their absorption	Phytase enzyme
Oxalic acid	Form insoluble salts of calcium and magnesium	Beet, spinach, millet, paddy straw, napier grass	Oxalate poisoning	Ruminal degradation, water soaking , calcium treatment
Glucosinolates (goitrogenic)	Depress the synthesis of thyroid hormone	Genus Brassica, Cruciferae family (cabbage, turnips, rapeseed and mustard seed)	Ruminants are less susceptible, Iodine deficiency	Iodine supplementation
Gossypol	Bind with Iron Appetite and weight loss, death due to cardiac failure	Cotton seed	Toxic to simple stomached animals	Addition of calcium and iron salts Heat treatment

4. Substances Inactivating or Increasing Requirements of Certain Vitamins

ANF	Action	Source	Others	Treatment
i-vitamin A	Reduces activity of Vitamin A	Raw soybean	Lipoxygenase enzyme destroy carotene, precursor of vitamin A	Heat treatment for 15 minutes
Anti-vitamin D	Depress Vit D synthesis	Soy protein	Increases vit D requirement by 10 folds	Autoclaving
Anti-vitamin E	Reduces plasma Vitamin E	Raw kidney bean	Deficiency disease due to Vit E	Autoclaving
i-vitamin K	Interfere blood clotting mechanism	Sweet clover (Dicoumarol)	Reduce prothrombin	Water soaking and Autoclaving

Anti-pyridoxine	epress activity of Vitamin B6	Linseed		Water soaking and autoclaving
Anti-niacin	Niacytin, antagonist to niacin	laize, wheat bran	Perosis and growth depression	Autoclaving

5. Substances That Stimulate Immune System Antigenic proteins:

- Macromolecular proteins or glycoproteins capable of inducing a humoral response
- Polyclonal antibodies are secreted in body fluids for eliminating the antigenic protein.
- Feed antigens are exposed continuously to increase the chance that the immune system develops into an acute/chronic hypersensitivity reaction.
- Antigenic globulins of soyabean are glycinin and β – conglycinin.

Effect of Feed Antigens

- Increased protein secretion with lowered protein digestibility
- Increased maintenance requirement due to activation of the immune system

Inactivation of feed antigens:

- Chemical or enzymatic treatments
- Hydrolysis of proteins by means of acid or proteases results in products apparently free of antigenic proteins.

6. Miscellaneous

ANF	Action	Source	Other	Treatment
Mimosine (tyrosine analogue)	Inhibits thyroxine hormone synthesis	Subabul (leucaena)	Monogastrics are more susceptible	Ferrous sulfate supplementation
Cyanogen (Amygdalin, linamarin)	Hydrolysed into hydrogen cyanide or prussic acid	Sorghum, sudan grass, linseed, cassava root	Ruminants are more susceptible Death due to anoxia	Sodium nitrate and sodium thiosulphate
Nitrates and nitrites	Form met-hemoglobin (brown color)	Contaminated water, hay or straw	Ruminants are more susceptible	High dose of vitamin A supplementation

Anti-nutritional factors according to feed source

Plant/Product	ANF
Soybean	Protease inhibitor, lectin, glycinin, conglycinin, urease, saponin
Subabul/ leucaena	Mimosin
Neem cake	Nimbin

Kidney bean	Protease inhibitor, amylase inhibitor, Anti-vit E
Castor bean	Ricin
Paddy straw, napier	Oxalate
Rubber seed cake	HCN
Mahua seed cake	Saponin, Tannin
Sesame cake	Phytic acid, Oxalic acid, Aflatoxin
Sunflower seed meal	Polyphenol
Cottonseed	Gossypol
Sesbania grandiflora	Saponin, Tannin, Alkaloids, Amine
Egg	Avidin
Astragalus spp.	Nitropropanol
Raw fish, bracken fern	Thiaminase
Berseem, Lucerne	Saponins
Jowar	Dhurrin (Cyanogen)
Oat hay	Nitrate
Linseed, cassawa	Linamarin (Cyanogen)
Mustard, rapeseed, cabbage	Glucosinolates

Feeding Standards

Feeding standards are statements or quantitative descriptions of the amounts of one or more nutrients needed by animals.
Requirement is expressed in quantities of nutrients required per day or as a percentage of diet.

Objectives of feeding standards:

- To guide farmers to formulate properly balanced rations for their livestock.
- Estimate the adequacy of feed/ nutrient intake for various spp. of animals.
- To classify the nutrient requirement according to different physiological functions like growth, maintenance, lactation, egg production and wool growth.

Limitation of feeding standard:

- No standard can be a complete guide to feeding because some other factors like palatability and physical nature of ration can play significant roles.
- Environmental conditions

Expressions of nutrients requirements in different standards are DE, ME, NE, TDN, CP, DCP, MP.

Classification of feeding standards

Feeding standards		
A. *Comparative type*	**B. *Digestible- Nutrient system***	**C. *Production-value type***

Compare different feeds to a standard one	Feeding based upon digestible portions of nutrients in different feed.	Based upon efficiency of feed to increase productivity.
1. Hay standard 2. Scandinavian feed Unit" Standard	1. Grouven's Feeding standard 2. Wolff's feeding standard 3. Wolff's Lehmann feeding standard 4. Haeckers's Feeding standard 5. Savage feeding standard 6. Morrison standard 7. National Research Council standard 8. Indian standard	1. Kellner-feeding standard 2. Armsby feeding standard 3. Agricultural and Food Research Council standard.

A. COMPARATIVE TYPE

1. **Hay standard:** suggested by Thaer In 1810
   - Different feeds should be compared using **meadow hay** as a unit.
   - The only measure was the practical feeding experience.
   - Nothing was known of the chemical value of feeds and the physiological requirements of the animals.
2. **Scandinavian "feed unit" standard: By** Professor Fjord In 1884
   - only the feed **unit** was taken.
   - The value of one pound of common grain such as corn, barley or wheat, is given as one unit value and the value of all other foods is based upon this.
   - According to this standard, one feed unit is required for each 150 lbs. of body weight and an additional unit for every three pounds of milk production.

B. DIGESTIBLE NUTRIENT SYSTEM

1. Grouven's feeding standard

- Feeding standard with **crude protein, carbohydrates and fat** contained in the feed as the basis of the standard.
- According to this standard, a cow weighing 1,000 lbs. should be fed 28.7 lbs. of dry matter containing 2.67 lbs. of crude protein 0.6 lb. of crude fat and 14.55 lbs. of crude carbohydrates.

2. Wolff's feeding standard: by Dr. Emil Von Wolff In 1864

- Based on **digestible protein, digestible carbohydrates and digestible fats**.
- This standard is an improvement over the standard of Grouven,

- It does not consider the quantity and quality of milk produced.

3. Wolff's Lehmann feeding standard:

- Dr. G. Lehmann of Berlin modified Wolff's standard in 1896.
- He took into account the **quantity of milk** produced, but he failed to take into account the quality of milk.

4. Haecker's feeding standard

- First time considered the **quantity as well as the quality of milk** produced in formulating a milk standard.
- First to separate the requirements for maintenance from the requirements of production.
- His standards included digestible crude protein, carbohydrates and fats.
- Later it was expressed in digestible crude protein and total digestible nutrients.

5. Savage feeding standard

- Based on nutritive ration
- The **nutritive ratio** should not be wider than 1:6 or narrow than 1:4.5.
- About two-thirds of the dry matter should be from the roughages and one-third from the concentrates.
- Therefore, the **protein requirement increased** about 20 percent above the standard of Haecker.

Nutritive ratio:

ratio of dig. Protein to the sum of digestible Carbohydrates (CF & NFE) and dig. Fat. Also called as albuminoid ratio.

NV = DCF + DNFE + (DEEx2.25) / DCP = TDN – DCP/ DCP

Where, TDN= DCF+DCP+DNFE+ (DEEx2.25)

- Protein rich feeds: Narrow NV e.g. protein cakes.
- Poor protein feeds: wider nutritive ratio e.g. roughages.

6. Morrison feeding standard

- First presented in the 15th edition of "Feeds and Feeding" published in 1915
- Also called "Modified Wolff and Lehmann standard".
- These standards were expressed in terms of **Dry Matter (D.M.), Digestible crude Protein (DCP) and Total Digestible Nutrients (TDN).**
- After revision, **net energy values instead of TDN** in computing rations were also included.
- In the year 1956, Morrison included in the standard the allowances for calcium, Phosphorus and Carotene
- The average of Morrison standards has been accepted for Indian livestock.

6. National Research Council (NRC) standard:

First published in 1945

- The standard includes **digestible protein and total digestible nutrients (TDN)**
- Also includes the recommended **requirements for calcium, phosphorus, carotene and vitamin D** for most animals.
- They use ME for poultry, DE for swine and horses, DE, ME and TDN for sheep, ME, TDN and NE*m* and NE*g* for beef cattle and for dairy cattle, values are given for DE, ME, TDN, NE*m* and NE*g* for growing animals with additional values as NE*l* for lactating cows.

8. **Indian standards**

- Sen and Ray standards**:** he adopted the **average of maximum and minimum values recommended by Morrison**.
- **Indian Council of Agricultural Research:** considered the fact that nutrient needs of livestock and poultry breeds under tropical environments are different from those developed in temperate climate.

C. PRODUCTION VALUE TYPE

1. Kellner feeding standard

Based upon **"Starch" as a standard unit of measurement (Starch equivalent)**.

- **Starch equivalent:**
- Fat producing power of feed (A production type/ NE system).
- SE of a feed is the number of Kg of starch that produces the same amount of fat as 100 kg of the test feed.
- This starch equivalent in turn can be converted into energy by a method worked out by Armsby and Kellner.

2. Armsby feeding standard

- Based on **true protein and net energy** values.

3. Agricultural Research Council (ARC) standard

- Followed in the United Kingdom.
- Give requirements of poultry, ruminants and pigs.

British Feeding Standards is that the unit of energy requirements has been expressed in terms of **Starch equivalent** instead of TDN or ME or NE as in Morrison and in N.R.C. standards.

Balanced Ration and Its Characteristics

Ration

- The total amount of feed provided to an animal in a 24-hour period to meet its dietary needs.

Balanced Ration

- A balanced ration is specifically designed to include all essential nutrients in the right proportions and quantities, ensuring proper nourishment of an animal over 24 hours.
- It supports all physiological activities, including maintenance, growth, reproduction, lactation, egg and wool production, and work.

Characteristics of a Balanced Ration

1. **Nutritional Adequacy:**
    - The ration must provide all required nutrients (carbohydrates, proteins, fats, minerals, vitamins, and water) within the amount of dry matter (DM) the animal can consume in a day.
2. **Digestibility:**

- Ingredients should be easily digested, ensuring maximum nutrient absorption and minimal wastage.

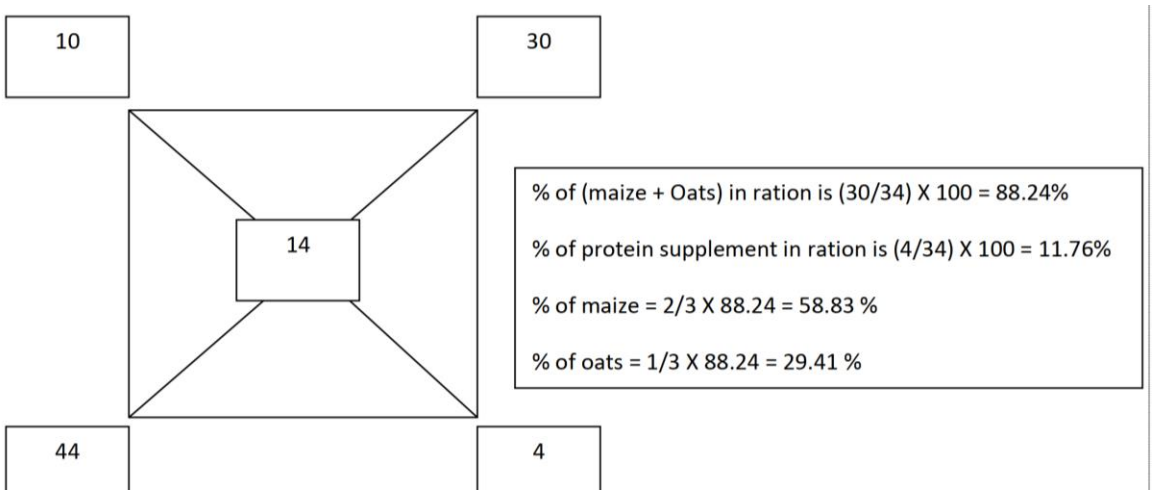
3. **Palatability:**
    - The feed must be tasty and appealing to encourage consistent intake.
4. **Laxative Properties:**
    - The ration should include components that prevent constipation, promoting healthy digestion.
5. **Bulkiness:**
    - Adequate bulk is necessary to satisfy the animal's hunger while preventing overconsumption of nutrients.
6. **Green Fodder Inclusion:**
    - Incorporating green fodder ensures a rich supply of vitamins, minerals, and roughage for proper gut function.
7. **Gradual Changes in Feeding Pattern:**
    - Sudden changes in feed can disrupt digestion. New feeding patterns should be introduced slowly.
8. **Consistent Feeding Schedule:**
    - Feed should be provided at evenly spaced intervals to maintain a stable digestive rhythm.
9. **Proper Preparation:**
    - Chopping, soaking, or grinding feed enhances its digestibility and palatability.

Ration Formulation

- The process of combining different feed ingredients in specific proportions to provide a diet that meets the animal's nutrient requirements during various stages of life.

Methods of Ration Formulation

A. Pearson Square Method



A graphical method for balancing rations using feeds with different nutrient concentrations.

1. **For Two Feeds:**
    - Example: Yellow maize (9% CP) and protein supplement (44% CP) to create a ration with 16% CP.
        - Calculation:
            - Subtract 16 from each feed's CP value: $44-16=28 \text{and} 16-9=7$ $44 - 16 = 28 \quad \text{and} \quad 16 - 9 = 7$ $44-16=28 \text{and} 16-9=7$
            - Percentages:

$$\% \text{ Maize } = \frac{28}{35} \times 100 = 80\%$$

$$\% \text{ Protein supplement } = \frac{7}{35} \times 100 = 20\%$$

2. **For Multiple Feeds:**
    - Includes ingredients like maize and oats in fixed ratios.
    - Example: A 14% CP ration with maize and oats in a 2:1 ratio.
        - Average CP: $(2\times9)+(1\times12)3=10\%$
3. **Fixed Percentages of Certain Ingredients:**
    - Example: 20% oats and 2% mineral mix. Calculate remaining components to meet 14% CP.

B. Algebraic Method

- Uses equations to balance multiple feed ingredients for required nutrient levels.

- Example: Corn-soybean meal ration with 16% CP, including 10% bran and 2% vitamins/minerals.
    - Equations:
        1. Total: X+Y+10+2=100X + Y + 10 + 2 = 100X+Y+10+2=100
        2. CP: 0.09X+0.44Y+10×0.12+0=160.09X + 0.44Y + 10 \times 0.12 + 0 = 160.09X+0.44Y+10×0.12+0=16
    - Solving:

- Corn: $X = 68.34\%$, Soybean meal: $Y = 19.66\%$, Bran: 10%, Vitamins/Minerals: 2%.

C. Trial and Error Method

- Iterative adjustment of feed ingredients until nutrient requirements are met.
- Widely used due to simplicity and flexibility.

D. Computer Software

- Allows quick calculations considering multiple ingredients and nutrients simultaneously.
- Can optimize for cost using **linear programming**, minimizing ration cost while meeting nutrient requirements.

Total Mixed Ration (TMR)

- **Definition:** A complete ration that combines concentrate and roughage in correct proportions.
- **Forms:**
    - Mash, pellets, cubes, or blocks.
- **Preparation:**
    - Roughages chopped into 1–2 cm particles before mixing.
- **Advantages:**
- Prevents selective feeding; each bite contains all required nutrients.
- Facilitates automation in feeding processes.
- Allows ad libitum feeding without nutrient imbalances.
- Incorporates unconventional or less palatable feed items.
- Less dusty, easier to store and transport.

Concentrate Mixture for Cattle

- A standard concentrate mixture for cattle typically contains:

- **DCP:** 14–16%, **TDN:** 68–70%.
- **Ingredients:**
  - Cereals: 25–35 parts.
  - Oil cakes: 25–35 parts.
  - Cereal by-products: 10–25 parts.
  - Pulses: 5–15 parts.
  - Fortification: 2% mineral mixture, 1% salt, and 20–30 g of Vitamin AD_3 per 100 kg (if required).

Limitations of a Balanced Ration

1. **Individual Differences:**
   - Cannot account for genetic variations among animals.
2. **Feed Palatability:**
   - May fail if animals reject the ration due to taste or texture.
3. **Environmental Factors:**
   - Climate and stress can alter nutrient metabolism, making static recommendations less effective.
4. **Nutrient Bioavailability:**
   - Does not always consider the biological value or availability of vitamins and minerals.

Energy Requirements of Livestock for Maintenance

Energy is essential for supporting life processes, including:

- **Maintenance:** Sustains vital functions without nutrient gain or loss.
- Growth, reproduction, production, and work.

Maintenance

- A physiological state where nutrient input equals output, maintaining a balance without gain or loss.

Fasting Catabolism

- Occurs when energy intake is insufficient, causing body tissue breakdown to meet life-essential activities.

Basal Metabolism

- The minimal energy expenditure required for basic physiological functions during fasting and rest.
- **Purpose:**
    - Provides a direct estimate of the net energy required for maintenance.
- **Basal Metabolic Rate (BMR):**
    - **Newborns:** Highest at birth.
    - **Declines with age:** Approximately 8% annually.
    - **Influencing Factors:**
        - **Under-nutrition:** Reduces BMR.
        - **Emotional Stimuli:** Increases BMR.
        - **Castration:** Lowers BMR.

Conditions for Measuring Basal Metabolism

1. **Good Nutritive Condition:**
    - Poor nutrition decreases heat production during fasting.
2. **Thermo-Neutral Environment:**
    - Range of environmental temperatures where no extra energy is needed for thermoregulation (around 25°C).
        - **Lower Critical Temperature:** Below this, heat production increases to maintain body temperature.
        - **Upper Critical Temperature:** Above this, heat production decreases to prevent overheating.
    - **Species Differences:**
        - Ruminants: Wider thermo-neutral zone and lower critical temperatures compared to pigs and poultry.
3. **Post-Absorptive State:**
    - The phase where digestion and assimilation-related heat production subsides.
        - **Non-Ruminants:** Reached overnight.
        - **Ruminants:** Requires prolonged fasting (~4 days) due to microbial digestion.
        - **Pigs:** Also require ~4 days.
        - **Fowl:** Achieves post-absorptive state within 2 days of fasting.

4. **Relaxation or Rest:**
    - Resting minimizes energy expenditure.
    - **Activity Increment:**
        - Energy required for activity.
        - Cattle, sheep, swine: 20–30% of basal metabolism.
        - Poultry: 50% of basal metabolism.
    - Standing animals: 10–15% higher energy needs than lying animals.
    - Grazing animals: Maintenance energy requirements are 25–50% greater than housed animals.

Related Metabolic Terms

1. **Fasting Metabolism:**
    - Specific to ruminants; measures heat production at designated times after feeding.
2. **Standard Metabolism:**
    - Heat production measured within a specific period after feeding to avoid prolonged fasting issues.
3. **Resting Metabolism:**
    - Heat production in animals lying at rest but not in a thermo-neutral or post-absorptive state.

Surface Area Law (Rubner's Law)

- **Principle:** Heat production in warm-blooded animals is directly proportional to body surface area.
- **Metabolic Body Size Formula:**
    - Surface area ∝W0.67

$$\text{Surface area} \propto W^{0.67}, \text{ where } W \text{ is body weight.}$$

    - where WWW is body weight.
    - **Implication:** Smaller animals produce more heat per kilogram of body weight than larger animals.

Basal Metabolism Equations

1. **Brody's Equation:**
    - Basal metabolism (kcal)=70.5×W0.734

$$\text{Basal metabolism (kcal)} = 70.5 \times W^{0.734}$$

    - Adjustments:
        - Cattle: 15% higher than interspecies mean.
        - Sheep: 15% lower than interspecies mean.
2. **Kleiber's Modification:**
    - $67.6 \times W^{0.756}$.
3. **NRC General Formula:**

$$70 \times W^{0.75}.$$

4. **Lusk's Suggestion:**
    - Basal metabolism equals 1000 kcal per square meter of body surface per 24 hours, regardless of animal size.

2. Evaluation of feeds for energy and protein in animals

Methods for Estimation of Energy Requirements for Maintenance

A. Direct Calorimetry

- **Description:**
    - Involves placing a healthy, non-producing animal in a calorimeter during the post-absorptive state.
    - Measures:
        - **Sensible heat loss:** Heat radiated or conducted.
        - **Evaporative heat loss:** Heat lost through evaporation from the lungs and skin.
    - **Outputs collected:** Feces, urine, and gases for analysis.
- **Advantages:**
    - Provides a precise measurement of total heat production.
- **Limitations:**

- Expensive and technically complex.

B. Indirect Calorimetry

- **Description:** Estimates heat production indirectly by assessing respiratory gas exchange and nitrogen excretion.

1. Factorial Method:

- Adds components like **activity increment** to the basal (fasting) metabolism to estimate maintenance energy.

2. Feeding Trial Method:

a) **Short-Term Feeding Experiments:**
- Measures heat loss using:
- Carbon-nitrogen balance.
- Respiration calorimetry (gas exchange and urinary nitrogen excretion).
- Used to determine **net energy requirement**.

b) **Long-Term Feeding Experiments:**
- Assumes energy equilibrium when body weight changes are negligible.
- Used to assess energy requirements over extended periods.

C. Regression Equations (Most Common Method Recently)

- Conduct feeding experiments at different feed intake levels.
- Extrapolate the **maintenance energy requirement** by plotting feed intake against production levels and extending the curve to zero production.
- **Advantages:**
  - Efficient and widely applicable.

D. Comparative Slaughter Experiments (Lofgreen and Garrett Method)

- **Description:**
  - More accurate than other methods.
  - Estimates fasting heat production by comparing body composition changes in animals before and after slaughter.
- **Fasting Heat Production (FHP):**
  - In beef cattle, ranges from **72–82 kcal/kg$W^{0.75}$/day**, with a mean of **77 kcal/kg$W^{0.75}$/day**.
- **Advantages:**

- Provides precise energy values for maintenance.

Maintenance Energy Requirements of Various Species

A. Dairy Cattle

1. **Net Energy (NE):**
   - 80 kcal/kg$W^{0.75}$/day.
2. **Metabolizable Energy (ME):**
   - 133 kcal/kg$W^{0.75}$/day.
   - **For Indian cattle and buffaloes:**
     - Proposed by Sen and Ranjhan: **122 kcal/kg$W^{0.75}$/day**.
3. **Digestible Energy (DE):**
   - 155 kcal/kg$W^{0.75}$/day.
4. **Total Digestible Nutrients (TDN):**
   - 35.2 g/kg$W^{0.75}$/day.
5. **Net Energy (MJ/day) (ARC):**

Net Energy (MJ/day) (ARC):

- Formula:

$$\text{NE (MJ/day)} = 0.53 \times (W/1.08)^{0.67} + \text{Activity increment.}$$

   - **Activity Increment:**
     - Growing cattle: 0.0071×W0.0071 \times W0.0071×W.
     - Dairy cows: 0.0091×W0.0091 \times W0.0091×W.
     - WWW is the body weight in kilograms.

B. Sheep

1. **Metabolizable Energy (ME):**
   - 98 kcal/kg$W^{0.75}$/day (NRC, 1981).
2. **Total Digestible Nutrients (TDN):**
   - 27.3 g/kg$W^{0.75}$/day.
3. **Net Energy (MJ/day) (ARC):**

Formula:

$$\text{NE (MJ/day)} = 0.226 \times (W/1.08)^{0.75} + \text{Activity increment.}$$

- **Activity Increment:**
  - 0.007×W0.007 \times W0.007×W.

C. Goat

1. **Metabolizable Energy (ME):**
   - 119 kcal/kg$W^{0.75}$/day.
2. **Total Digestible Nutrients (TDN):**
   - 30 g/kg$W^{0.75}$/day.

Protein Requirements for Maintenance – Methods of Estimation

- Protein maintenance requirements represent the amount of protein lost through:
  - **Urine:** Includes urea, creatinine, ammonia, uric acid, allantoin, amino acids.
  - **Feces:** Includes undigested nitrogen, bacterial nitrogen, and metabolic fecal nitrogen (MFN).
  - **Other losses:** Hair, skin (scurf), and hooves.

Estimating protein requirements is complex due to:

- **Energy-protein interplay:** Protein can be used as an energy source during energy shortages.
- **Excessive protein intake:** Deamination converts excess protein into nitrogen-free substances for energy.
- **Adult growth:** Renewal of tissues like wool, feathers, hooves must be considered.

Nitrogen Components

Endogenous Urinary Nitrogen (EUN)

- Defined as the minimal nitrogen excreted in urine when an animal consumes a nitrogen-free, energy-adequate diet.
- Indicative of nitrogen catabolism required for maintaining life processes.
- **Common Values:**
  - 2 mg EUN/kcal basal metabolism (500 mg/MJ)2

- **Ruminants:** 350 mg/MJ fasting metabolism due to urea recycling to the rumen or large intestine.
- **Species-Specific Values:**
  - Indian cattle: 0.02 g/kg body weight/day
  - Bos taurus: 0.289 g/kg body weight/day

Exogenous Urinary Nitrogen

- Nitrogen excreted in urine beyond the endogenous portion.

Fecal Nitrogen

- **Components:**
  - Undigested nitrogen.
  - **Metabolic Fecal Nitrogen (MFN):** Excreted on a nitrogen-free, energy-adequate diet.
    - Includes:
      - Unused digestive enzymes.
      - Abraded mucosal cells.
      - Bacterial nitrogen.
- **Proportional to DM Intake (DMI):**
  - European cattle: 5 g/kg DMI
  - Indian cattle: 3.5 g/kg DMI
  - Buffalo: 3.4 g/kg DMI

Protein Estimation Methods

A. Nitrogen Balance Method

- **Principle:**
  - The minimum protein intake at which nitrogen equilibrium is achieved (nitrogen intake = nitrogen excretion).
- **Indications of Nitrogen Equilibrium:**
  - Animal has stopped growing.
  - Protein is adequate in quality and quantity.
  - Energy, mineral, and vitamin needs are met.
  - No wasting diseases present.
- **Types of Nitrogen Balance:**
  - **Negative:** Excretion > intake (e.g., fasting, illness, protein deficiency).

- **Positive:** Intake > excretion (e.g., growth, pregnancy, recovery).

B. Feeding Trial Method

- **Principle:**
  - Maintenance protein requirement is the level at which the animal maintains body weight over an extended feeding period with a diet adequate in energy, minerals, and vitamins.

C. Factorial Method

- **Components Included:**
  - EUN, MFN, and dermal nitrogen losses (hair and scurf).
    - Cattle: 2.2 g N/day
    - Sheep: 0.6–1 g N/day
- **Biological Value (BV) of Protein:**
  - Indicates protein quality (Cattle: 70%, Sheep: 65%).
- **Truly Digestible Protein (TP):**

$$\text{TP (g/day)} = \frac{(\text{EUN} + \text{MFN} + \text{S1 or S2}) \times 6.25 \times 100}{\text{BV}}$$

    - **EUN:** Endogenous urinary nitrogen (g/day).
    - **MFN:** Metabolic fecal nitrogen (g/day).
    - **S1:** N loss via scurf (Cattle).
    - **S2:** N loss via fleece (Sheep).
- **DCP Requirement (g/day):**
  - Formula: DCP Requirement (g/day)=TP−(MFN×6.25)

Protein Maintenance Requirements (DCP)

1. **Cattle:** $2.84\,\text{g DCP/kg}\,W^{0.75}\text{/day}$.
2. **Sheep:** $2.73\,\text{g DCP/kg}\,W^{0.75}\text{/day}$.
3. **Goats:** $3\,\text{g DCP/kg}\,W^{0.75}\text{/day}$.
4. **Horses:** $3\,\text{g DCP/kg}\,W^{0.75}\text{/day}$.

BIS (Bureau of Indian Standards) Protein Specifications for Cattle Feed

- **Type I:** Minimum 22% CP.
- **Type II:** Minimum 20% CP.

New Systems for Expressing Protein Requirements of Ruminants

The protein requirement of ruminants is viewed as:

1. **Rumen Microorganism Needs:** Nitrogen requirements for microbial protein synthesis in the rumen.
2. **Host Animal Needs:** Protein requirements for the ruminant itself, absorbed and utilized at the tissue level.

New Systems for Protein Expression

1. **Metabolizable Protein (NRC System):**
    - **Definition:** The sum of:
        - Dietary protein that escapes degradation in the rumen (undegraded protein).
        - Microbial protein synthesized in the rumen and absorbed by the host animal.
    - **Key Insight:**
        - Maintenance protein needs can be entirely met by microbial protein.
        - **Microbial Protein Synthesis:**
            - For every **1 MJ of ME (Metabolizable Energy)** intake, **7.8 g of microbial protein** is synthesized, provided there is sufficient nitrogen in the diet.
2. **RDP/UDP (UK Metabolizable Protein System):**
    - **Proposed by:** ARC (Agricultural Research Council).
    - **Components:**
        - **RDP (Rumen Degradable Protein):** Protein degraded in the rumen for microbial use.
        - **UDP (Undegraded Protein):** Protein that bypasses rumen degradation and is available for absorption in the small intestine.
3. **French PDI System:**
    - **Definition:** Based on the true protein digested and absorbed in the small intestine.

Non-Protein Nitrogen (NPN) Substances in Ruminant Diets

- Ruminant feeds naturally contain about **30% of nitrogen as NPN**, including amino acids, amides, and amines.

2. **Feeding NPN Compounds:**
    - Up to **30% of protein requirements** of dairy cattle and buffaloes can be met using NPN compounds like urea and biuret.
    - **Urea:**
        - Contains **46% nitrogen**.
        - Fully degradable in the rumen.
    - **Efficient Utilization:**
        - Requires simultaneous feeding of soluble carbohydrates (1 kg of soluble carbohydrate for every 100 g of urea) to provide the necessary energy for microbial growth.
    - **Urea Inclusion Rates:**
        - Concentrate mixture: Up to **3%** (BIS specifies **1%**).
        - Total ration: **1%**.
3. **Urea Recycling:**
    - **Mechanism:**
        - Blood urea re-enters the rumen:
            - **Directly:** Through the rumen wall.
            - **Indirectly:** Via saliva.
        - Approximately **20% of absorbed ammonia-N** is recycled in sheep (Blaxter's estimate).

Protein Reserves in Ruminants

1. **Characteristics:**
    - Comprise **5–7%** of total body protein.
    - Labile reserves used during:
        - Starvation.
        - Periods of reduced protein intake.
    - Restored during periods of adequate protein availability.
2. **Tissue Impact:**
    - Depleted first in the **liver**, followed by kidneys, heart, and skeletal muscles.
    - Reserves contribute to the **free amino acid pool** during depletion.

3. **Metabolic Importance:**
    - Protein reserves are less significant than energy reserves, which are stored in larger amounts and specific organs.

Bypass Protein/Protected Protein

1. **Definition:**
    - **Bypass protein** refers to dietary protein that escapes rumen degradation (undegraded protein, UDP).
2. **Proportion in Normal Diet:**
    - Typically, **60% of dietary protein** is degraded in the rumen, while **40% remains as UDP**.
3. **Benefits of Protected Protein:**
    - Provides a higher supply of essential amino acids to the host animal.
    - Improves efficiency of protein utilization by the host animal.
4. **Methods for Protecting Protein:**
    - **Heat Treatment:** Denatures proteins to resist rumen degradation.
    - **Tannin Treatment:** Binds proteins to protect them from microbial degradation.
    - **Formaldehyde Treatment:** Cross-links proteins, making them resistant to breakdown in the rumen.

3.Role of minerals, vitamins and their deficiency disorders. Feed supplements and feed additives, conservation and preservation of feed and fodders.

Classification of Minerals:

Two type

Major (Macro) Minerals

- Calcium (Ca)
- Phosphorus (P)
- Sodium (Na)
- Chlorine (Cl)
- Potassium (K)
- Magnesium (Mg)
- Sulphur (S)

Minor (micro) Minerals

- Zinc (Zn)
- Copper (Cu)

- Cobalt (Co)
- Iron (Fe)
- Iodine (I)
- Manganese (Mn)
- Selenium (Se)
- Molybdenum (Mo)

Newer Trace Minerals

- Chromium (Cr)
- Fluorine (F)
- Nickel (Ni)
- Arsenic (Ar)

Minerals as Enzyme Components

Mineral	Enzyme	Function
Iron	Cytochromes	Electron transport and energy production
Copper	Cytochrome oxidase, Ceruloplasmin	Electron transport, iron metabolism
Zinc	Carbonic anhydrase, Carboxypeptidase	CO2 transport, protein digestion
Manganese	Pyruvate carboxylase	Gluconeogenesis
Molybdenum	Xanthine oxidase (uric acid)	Purine metabolism
Selenium	Glutathione peroxidase	Antioxidant defence

Key Points

- **Calcium and Phosphorus:** Vital for bone structure and metabolic processes.
- **Sodium, Potassium, and Chlorine:** Crucial for maintaining fluid balance and nerve function.
- **Zinc, Copper, and Iron:** Essential for enzyme function and metabolic processes.
- **Selenium and Vitamin E:** Work together as antioxidants to protect cells from oxidative damage.

1. Macrominerals and their deficiency system

1.1 Calcium (Ca)

Importance and Functions of Calcium
Approximately 99% of the calcium is found in bones and teeth, where it provides structural integrity. The remaining 1% is involved in vital metabolic functions.

Structural Role: Bones and Teeth-Provides strength and structure.

- **Metabolic Functions:**
  - Blood Coagulation: Essential for the clotting process.
  - Nerve Impulse Transmission: Facilitates the transmission of nerve impulses.
  - Muscle Contraction: Crucial for muscle function.
- **Blood Calcium Levels:**
  - Normal Blood Concentration: 9-11 mg/dl.
  - Layers (Egg-Laying Birds): Higher concentration, around 30-40 mg/dl.
- **Hormonal Regulation:**
  - Parathormone (PTH): Increases blood calcium levels by mobilizing calcium from bones and enhancing the activation of vitamin D (1,25 di-hydroxy cholecalciferol) in the kidneys.
  - Calcitonin: Decreases blood calcium levels by inhibiting bone resorption.

Deficiency Symptoms

- **Young Animals:**
  - Rickets-weak and deformed bones due to inadequate mineralization.
- **Adult Animals:**
  - Osteomalacia-Softening of the bones caused by defective bone mineralization.
  - Milk Fever (Parturient Paresis)- In lactating animals characterized by low blood calcium levels, leading to muscle weakness and paralysis.

1.2 Phosphorus (P)

It is a component of phosphoproteins, nucleic acids (nucleotides), and phospholipids, which are essential for various physiological functions.

Key Functions

Structural Role:

Phosphoproteins, Nucleic Acids, and Phospholipids-Integral components of cell membranes and genetic material.

Metabolic Functions:

Energy Metabolism-Vital for the formation of ATP (adenosine triphosphate), the primary energy carrier in cells.

Form in Feed:

Phytate/Phytic Acid-The primary storage form of phosphorus in cereal grains, which is less available to non-ruminant animals.

Environmental Impact:

High Levels of Phosphorus-Can contribute to environmental pollution by promoting the growth of algae in water bodies.

Health Issues:

High Phosphorus Intake-In combination with magnesium, can lead to urolithiasis (urinary stones).

Blood Concentration: Normal Levels-4-8 mg/dl.

Deficiency Symptoms

- **Pica (Depraved Appetite/Allotriophagy):**
  - Abnormal cravings and eating non-food items such as wood, soil, and bones.
- **Post-Parturient Hemoglobinuria (PPH)**:
  - A condition in cows characterized by the breakdown of red blood cells after calving, leading to hemoglobinuria (presence of hemoglobin in urine).
- **Ca:P Ratio:**
  - The optimal calcium to phosphorus ratio is 2:1. An imbalance can lead to conditions such as "**Big Head Disease**" in horses, where excessive phosphorus intake relative to calcium causes bone deformities.

1.3 Potassium (K)

Chief Intracellular Cation: Potassium is the primary cation inside cells, playing a crucial role in maintaining cellular function.

Functions:

- Nerve and Muscle Activity: Essential for normal nerve impulse transmission and muscle contraction.
- Enzyme Activation: Activates various enzymes involved in carbohydrate and protein metabolism.

Sources:

Natural Conditions: Grass and green fodder are rich sources of potassium.

Deficiency Symptoms

Synthetic Milk: Potassium deficiency can occur in animals fed synthetic milk, leading to reduced nerve and muscle activity, and in severe cases, paralysis.

1.4 Sodium (Na)

Chief Extracellular Cation: Sodium is the primary cation outside cells, crucial for maintaining fluid balance and nerve function.

Functions:

Water Intake Increases water intake, which is particularly important during heat stress.

Acid-Base Balance: Helps maintain acid-base balance in the body.

Sources:

Common Salt (NaCl): The primary source of sodium in animal diets.

Deficiency Symptoms

- General: Slow growth, keratinization of corneal epithelium, impotency in males, delayed sexual maturity, and impaired estrus.
- Poultry: Feather picking and cannibalism.
- Salt Poisoning: Common in pigs and poultry when excessive salt is consumed.

1.5 Chlorine (Cl)

Importance and Functions

Functions:

Acid-Base Balance: Helps maintain the acid-base balance in body fluids.

Electrolyte Balance: Works with sodium to regulate osmotic pressure and fluid balance.

Sources

Common Salt (NaCl): The primary source of chlorine in animal diets.

Deficiency Symptoms

- General: Deficiency of chlorine can lead to an abnormal increase in the alkali reserve, resulting in alkalosis.
- Poultry: Deficiency can lead to feather picking and cannibalism.

1.6 Sulphur (S)

- Amino Acids: Integral component of sulphur-containing amino acids such as cystine, cysteine, and methionine.
- Vitamins: Essential for the synthesis of vitamins like biotin and thiamin.
- Hormones: Part of important hormones like insulin and oxytocin.
- Wool: Rich in cysteine, wool contains about 4% sulphur. The nitrogen to sulphur (N:S) ratio in wool is typically 5:1.
- NPN Supplementation: For non-protein nitrogen supplementation in ruminants, the N:S ratio should be 10:1 (or up to 15:1).

Deficiency Symptoms

- Reduced Feed Intake: Lowered appetite and feed intake.
- Poor Wool Quality: Reduced wool growth and quality due to insufficient sulphur for cystine synthesis.

1.7 Magnesium (Mg)

- Enzyme Activation: Acts as a cofactor for enzymes such as pyruvate carboxylase and pyruvate oxidase.
- Energy Metabolism: Essential for the tricarboxylic acid (TCA) cycle, which is crucial for carbohydrate and lipid metabolism.
- ATP Synthesis: Necessary for the production and utilisation of ATP.
- Normal Blood Levels: 2-4 mg/dl.

Deficiency Symptoms

- Hypomagnesemic Tetany: Also known as grass tetany or lactation tetany, characterised by muscle spasms, convulsions, and potentially death due to respiratory failure.
- Lactation Tetany: Occurs in lactating animals.
- Grass Staggers: A condition in grazing animals, particularly ruminants, due to low magnesium levels in lush, fast-growing pastures.

Microminerals and their deficiency system

2.1 Iron (Fe)

- Transport: Iron is transported in the body by transferrin.
- Storage: Stored in the form of ferritin and hemosiderin.
- Enzyme Component: Integral part of various enzymes and proteins involved in oxygen transport and metabolism.

Deficiency Symptoms

- Piglet Anaemia: Known as "thumps," characterised by laboured breathing due to iron deficiency in young pigs.
- Iron Absorption: Governed by the mucosal block theory, where ferritin saturation in the intestinal mucosa regulates iron absorption.

2.2 Copper (Cu)

- Essential for normal pigmentation of hair, fur, and wool
- Component of turacin, a pigment found in feathers
- Involved in various enzyme systems and oxidation-reduction reactions

Deficiency Symptoms:

1. Lambs: Muscular incoordination leading to sway back condition (enzootic ataxia)
2. Wool: Loss of crimp, resulting in stringy or steely wool due to disruption of disulfide linkages between cysteine molecules

3. Falling disease: Degeneration of heart muscle (myocardium)
4. Microcytic anaemia in pigs, poultry, and calves

2.3 Cobalt (Co)

- Essential component of cyanocobalamin (vitamin B12)
- Required by rumen microbes for the synthesis of vitamin B12

Deficiency:

- "Pining" condition in ruminants, characterised by:Loss of appetite
    - Loss of appetite
    - Wasting
    - Anaemia
    - Reduced growth and milk production

2.4 Iodine (I)

- Essential component of thyroid hormones (thyroxine and triiodothyronine)
- Increases basal metabolic rate, accelerating growth

Deficiency:

- Goiter (enlarged thyroid gland)
- Reduced growth rate
- Reproductive problems
- Hairless, weak, or stillborn offspring

Note on Goitrogenic Compounds:

- Found in Brassica genus plants (e.g., cabbage)
- Inhibit iodination of tyrosine, interfering with thyroid hormone synthesis

2.5 Manganese (Mn)

- Activates glycosyl transferases, important for bone formation
- Component of various enzyme systems

Deficiency Symptoms:

1. Poultry:
    - Perosis (slipped tendon) - malformation of leg bones Reduced hatchability and eggshell thickness
    - Head retraction in chicks
2. Other animals:
    - Impaired growth
    - Skeletal abnormalities
    - Reproductive problems

2.6 Zinc (Zn)

- Component of numerous enzymes:Carbonic anhydrase
- Pancreatic carboxypeptidase
- Lactate dehydrogenase
- Alcohol dehydrogenase
- Alkaline phosphatase
- Thymidine kinase

Deficiency Symptoms:

1. Skin disorders:

   Parakeratosis in pigs (thickening and hardening of skin) Bone abnormalities:'Swollen hock syndrome' in poultry

2. Bone abnormalities:'Swollen hock syndrome' in poultry

2.7 Molybdenum (Mo)

- Known for its interaction with copper (Cu)
- Acts as an antagonist to Cu, Zn, and sulphur (S)

Toxicity/Deficiency:

- Teartness or peat scour: Can be caused by either Mo toxicity or acute Cu deficiency

2.8 Selenium (Se)

- Considered one of the most toxic minerals when in excess
- Component of glutathione peroxidase enzyme
- Works synergistically with Vitamin E as an antioxidant

Toxicity Symptoms:

1. Alkali disease
2. Blind staggers
3. Degnala disease
4. Hoof deformity

2.9 Fluorine (F): Bureau of Indian Standards (BIS) recommends that F concentration in mineral mixtures should not exceed 0.06%.
Functions:Prevention of dental caries

2.10 Chromium (Cr)

- Acts as a glucose tolerance factor
- Functions similar to insulin-like growth factor (IGF-1)
- Carcass modifying effects:Enhances nitrogen (N) retention
- Helps reduce stress and metabolic disorders

2.11 Nickel (Ni)

- Important for urease activity in the rumen

Fat Soluble vitamin and their role

1. **Vitamin A**
2. **Vitamin D**
3. **Vitamin E**
4. **Vitamin K**

Vitamin A (Retinol)

Vitamin A, also known as retinol. It is derived from carotenoids, such as carotenes and xanthophylls, which are precursors of vitamin A.

Sources

- Carotenoids: Found in plant-based foods, including carotenes (e.g., beta-carotene) and xanthophylls.
- Animal-Based Sources: Liver, fish oils, egg yolk, and dairy products.

Conversion in the Body

- Intestinal Mucosa: Carotenoids are converted into retinol in the intestinal mucosa.
- 1 Molecule of Beta-Carotene: Yields 2 molecules of Vitamin A (Retinol).

Functions

- Anti-Infective Vitamin: Enhances immune function and helps in the maintenance of epithelial tissues.
- Vision: Essential for the synthesis of rhodopsin, a pigment in the retina that is necessary for night vision.

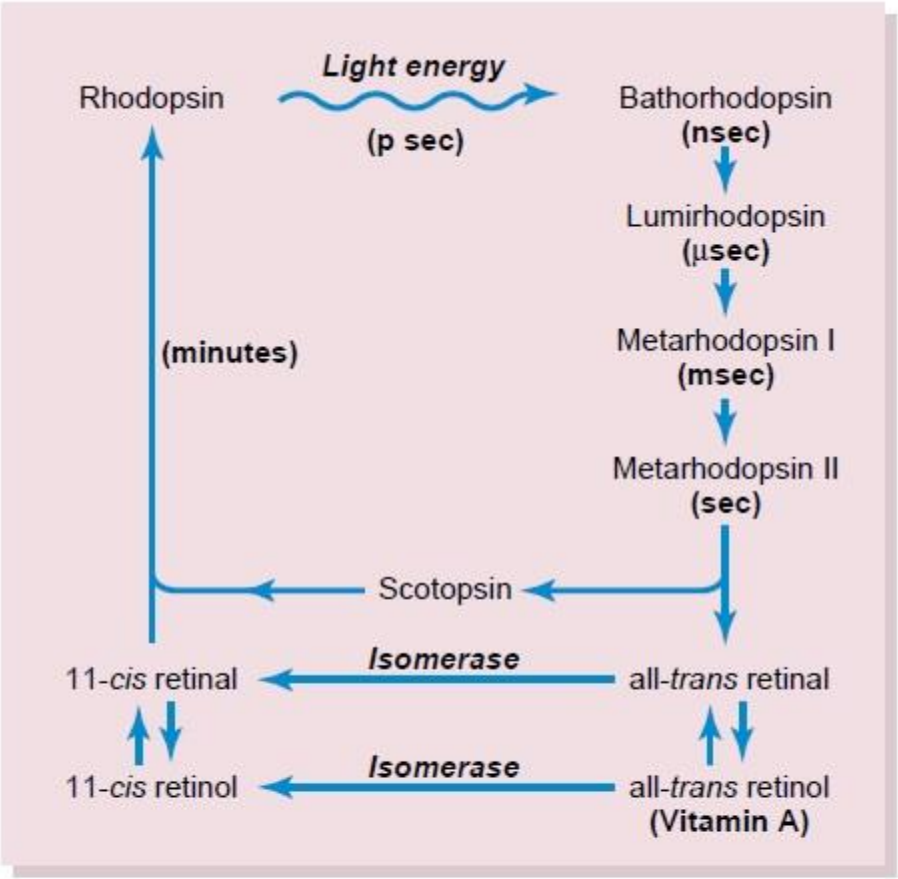


Figure 50–5

Rhodopsin-retinal visual cycle in the rod, showing decomposition of rhodopsin during exposure to light and subsequent slow re-formation of rhodopsin by the chemical processes.

- Reproduction: Supports normal reproduction and embryonic development.
- Growth and Development: Important for bone growth and development.
- Skin Health: Maintains the integrity of skin and mucous membranes.

Deficiency Symptoms

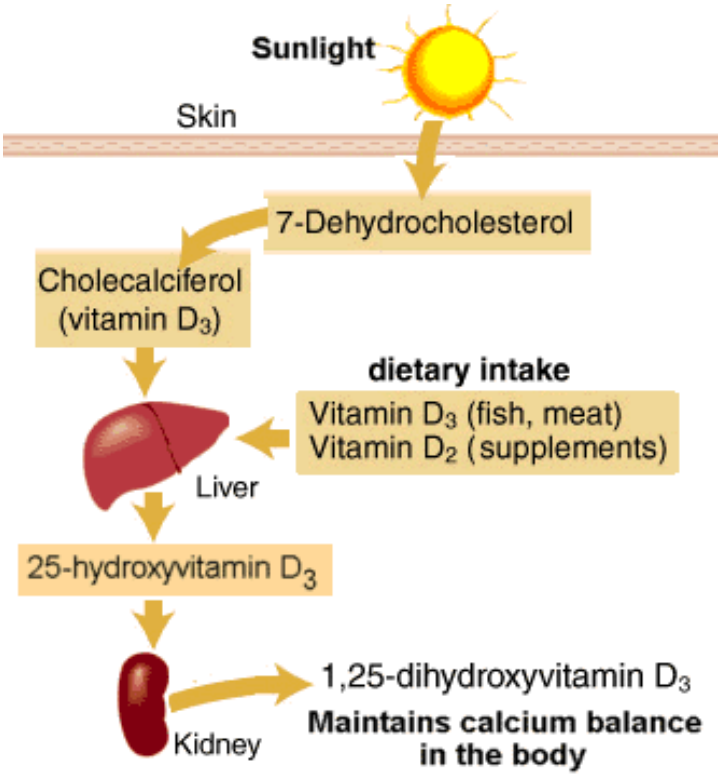
1. Night Blindness: Impaired synthesis of rhodopsin leads to difficulty seeing in low light conditions.
2. Xerophthalmia: Dryness of the conjunctiva and cornea, which can lead to blindness.
3. Infertility: Reproductive issues due to impaired development and function of reproductive organs.

4. Nutritional Roup in Poultry: Respiratory infection characterised by nasal discharge, swollen eyes, and reduced egg production.
5. Bitot's Spots: Foamy patches on the conjunctiva, indicative of severe vitamin A deficiency.

Vitamin D

Types of Vitamin D

1. Vitamin D2 (Ergocalciferol)Source
2. Vitamin D3 (Cholecalciferol)Source



- Hormone-Like Activity: Vitamin D acts like a hormone in the body, regulating calcium and phosphorus metabolism.
- Antirachitic Activity: Prevents rickets, a disease characterised by softening and weakening of bones in young animals.

Deficiency Symptoms

1. Young Animals:Rickets-Characterised by weak and deformed bones due to inadequate mineralization.

2. Adult Animals:Osteomalacia-Softening of the bones caused by defective bone mineralization.

Sources

- Vitamin D2: Found in plants, particularly in fungi and yeast.
- Vitamin D3: Found in animal products such as fish liver oils, egg yolk, and synthesised in the skin upon exposure to sunlight.

Vitamin K

1. Synthesis of Prothrombin: Vitamin K is essential for the synthesis of prothrombin in the liver, a protein and clotting factor that is crucial for blood coagulation.
2. Blood Clotting: It plays a vital role in the blood clotting process by activating clotting factors that help in the conversion of prothrombin to thrombin.
3. Bone Health: Vitamin K is also involved in the regulation of calcium in bones and other tissues.

Deficiency Symptoms

1. Hemorrhagic Conditions: Deficiency in vitamin K can lead to bleeding disorders due to impaired blood clotting. This can manifest as excessive bleeding from wounds, bruising, and internal bleeding.
2. Sweet Clover Poisoning: In cattle, sweet clover poisoning occurs when the plant becomes mouldy and produces dicoumarol, a compound that antagonises vitamin K. This leads to a decrease in prothrombin levels, resulting in hemorrhagic disease.

Sources

- Green Leafy Vegetables: Such as spinach, kale, and broccoli.
- Animal Products: Liver, egg yolk, and fish.
- Synthesised by Gut Bacteria: In the intestines of animals.

Types of Vitamin K

1. Vitamin K1 (Phylloquinone): Found in green plants.
2. Vitamin K2 (Menaquinone): Produced by bacteria in the intestines.
3. Vitamin K3 (Menadione): A synthetic form of vitamin K.

Vitamin E (Tocopherols)

- Antioxidant: Vitamin E acts as a powerful antioxidant, protecting cell membranes from oxidative damage. It works in association with the selenium-containing enzyme glutathione peroxidase.
- Free Radical Scavenging: Vitamin E is the first line of defence against free radicals, neutralising them before they can cause harm.
- Glutathione Peroxidase: This enzyme destroys any remaining peroxides, preventing further oxidative damage.

Deficiency Symptoms

1. **Calves:**

   Nutritional Myopathy: Also known as muscular dystrophy or white muscle disease, characterised by muscle degeneration and weakness.

   Fatal Syncope: Sudden death due to heart failure.

2. **Lambs:**

   Stiff Lamb Disease:Muscle stiffness and weakness due to nutritional myopathy.

3. **Pigs:**

   Mulberry Heart Disease: sudden death due to heart muscle degeneration.

   Fatal Syncope: Similar to calves, sudden death due to heart failure.

4. **Chicks:**

   Encephalomalacia: Also known as "crazy chick disease," characterised by neurological symptoms such as incoordination and convulsions.

   Exudative Diathesis: Edema and haemorrhages due to increased capillary permeability.

5. **Cats:**

   Yellow Fat Disease:Also known as steatitis, characterised by inflammation of fatty tissues.

Sources

- Green Fodders: Rich in vitamin E.
- Cereal Grains: Good sources of tocopherols.
- Vegetable Oils: High in vitamin E.
- Nuts and Oil Seeds: Rich in tocopherols.

Water soluble vitamin and their role

1. **Vitamin B Complex**
   a. **Thiamin (Vitamin B1)**
   b. **Riboflavin (Vitamin B2)**
   c. **Niacin (Vitamin B3)**
   d. **Pyridoxine (Vitamin B6)**
   e. **Pantothenic Acid (Vitamin B5)**
   f. **Folic Acid**
   g. **Cyanocobalamin (Vitamin B12)**
   h. **Biotin (Vitamin B7)**
   i. **Choline**
   j. **P-Amino Benzoic Acid**
   k. **Inositol**
2. **Vitamin C (Ascorbic Acid)**

Vitamin C (Ascorbic Acid)

Sources

- Primary Sources: Citrus fruits and green leafy vegetables are rich sources of vitamin C.
- Synthesis: Most animals can synthesise vitamin C in their bodies from glucose using the enzyme gluconolactone oxidase. However, humans, guinea pigs, and some other species lack this enzyme and must obtain vitamin C from their diet.

Functions

1. Antioxidant: powerful antioxidant, protecting cells from oxidative damage
2. Collagen Synthesis: Protein that helps maintain the integrity of skin, blood vessels, bones, and connective tissues.
3. Intercellular Cement Substance: Plays a crucial role in the formation of intercellular cement substances, which are important for the maintenance of capillaries, teeth, and bone.
4. Immune Function: Enhances the immune response and helps in the absorption of iron from plant-based foods.

Deficiency Symptoms

1. Scurvy: A disease caused by severe vitamin C deficiency, characterised by symptoms such as:
    - Anaemia Dry, rough skin covered with reddish spots
    - Weakness and fatigue
    - Swollen and bleeding gums
    - Loosening of teeth
    - Joint pain and swelling
2. Poor Wound Healing: Due to impaired collagen synthesis, wounds may heal slowly.
3. Increased Susceptibility to Infections: Weakened immune response can lead to a higher risk of infections.

Thiamine (Vitamin B1)

- Energy/Carbohydrate Metabolism: Thiamine is essential for the oxidative decarboxylation of pyruvate to acetyl-CoA and of α-ketoglutarate to succinyl-CoA in the tricarboxylic acid (TCA) cycle. These reactions are crucial for energy production from carbohydrates.

Sources

- Natural Sources: Yeast, bran, rice polish, egg yolk, liver, pork.
- Antithiamine Factors:

  Thiaminase: Found in raw fish and bracken fern, this enzyme breaks down thiamine, leading to deficiency.

Deficiency Symptoms

1. Accumulation of Pyruvic Acid: Without sufficient thiamine, pyruvate cannot be converted to acetyl-CoA, leading to an accumulation of pyruvic acid, which is then converted to lactic acid. This results in muscular weakness.

2. Excess Polished Rice Consumption: Diets high in polished rice, which is low in thiamine, can lead to deficiency.
3. Polyneuritis: Inflammation of multiple nerves leading to paralysis.

   Chastek Paralysis: A specific type of paralysis seen in animals, particularly in those consuming raw fish containing thiaminase.

Riboflavin (Vitamin B2)

- Component of flavoproteins, flavin mononucleotide (FMN), and flavin adenine dinucleotide (FAD)
- Involved in protein and carbohydrate metabolism
- Used by cells to transport hydrogen in metabolic pathways

Sources:

Synthesised by yeast, bacteria and fungi

- Rich sources include liver, yeast, milk, eggs, and green leafy vegetables

Deficiency Symptoms:

1. **Curled Toe Paralysis**
   - Occurs in poultry, especially chicks
   - Caused by peripheral nerve degeneration
   - Characterised by curling of the toes inward, making it difficult for birds to walk

2. **Clubbed Down Syndrome/Condition**
   - Feathers continue to grow within the follicle, leading to curled feathers
   - Affects the appearance and health of the bird's plumage

- Degeneration of myelin sheath in nerves
- Loss of integrity of epithelial tissues
- In swine: stiff legs, nerve degeneration, corneal opacity, cataracts

Importance:

- Essential for proper nervous system function
- Critical for energy metabolism in cells
- Necessary for normal growth and development
- Important for maintaining healthy skin, eyes, and mucous membranes

Niacin (Vitamin B3)/ Nicotinamide

Niacin can be synthesised in the body from the amino acid tryptophan.

- Part of Enzyme Systems: A component of the coenzymes NAD (Nicotinamide Adenine Dinucleotide) and NADP (Nicotinamide Adenine Dinucleotide Phosphate), which are crucial for hydrogen transfer in metabolic reactions.
- Energy Metabolism: Involved in the metabolism of carbohydrates, proteins, and fats.

Deficiency Symptoms

- Dermatitis: Inflammation of the skin.
- Specific to Pigs and Poultry:
- Maize-Rich Diets: Maize is low in tryptophan, leading to niacin deficiency in pigs and poultry.
- Pigs: Symptoms include poor growth and skin lesions.
- Poultry: Symptoms include poor feathering and dermatitis.

Vitamin B6 (Pyridoxine)

- Functions: Protein and Amino Acid Metabolism: Acts as a coenzyme in the metabolism of amino acids and proteins.
- Deficiency Symptoms: Convulsions, anaemia, slow growth, and hatchability issues in poultry.

Pantothenic Acid

Functions: Component of Coenzyme A: Essential for acyl transfer and fatty acid metabolism.

Deficiency Symptoms

- Pigs: Goose-stepping gait, characterised by a peculiar high-stepping walk.
- General: Poor growth and skin lesions.

Biotin (Vitamin B7)

Functions: Carboxylation Reactions: Acts as a coenzyme for carboxylase enzymes involved in fatty acid synthesis and gluconeogenesis.

Deficiency Symptoms

- Raw Eggs: Contain avidin, which binds biotin and leads to deficiency.
- Poultry: Fatty liver and kidney syndrome (FLKS), characterised by fat accumulation in the liver and kidneys.
- General: Dermatitis, poor growth, and cracked feet.

Choline

1. Methyl Donor: Choline acts as a methyl donor in transmethylation reactions, which are crucial for fat mobilisation.
2. Transition Animals: Helps prevent metabolic diseases such as ketosis in transition animals (e.g., dairy cows around calving).
3. Poultry Chicks: Prevents perosis (slipped tendon), a condition also influenced by manganese (Mn).

Deficiency Symptoms

- Perosis in Poultry: Characterised by slipped tendon, where the tendon slips from its normal position, leading to leg deformities.

Vitamin B12 (Cyanocobalamin)

1. Synthesis: Vitamin B12 is synthesised exclusively by microorganisms.
2. Mineral Requirement: Requires cobalt (Co) for synthesis.
3. Absorption: Absorbed in the gut when bound to a glycoprotein called intrinsic factor, which is produced in the stomach.

Sources

- Microbial Synthesis: Synthesised by microorganisms in the gut.
- Animal Products: Found in liver, kidney, and other animal products.
- Not Present in Plants: Vitamin B12 is not found in plant-based foods.

Deficiency Symptoms

- Pernicious Anaemia: A type of anaemia characterised by the inability to absorb vitamin B12 due to the lack of intrinsic factor. Symptoms include weakness, fatigue, and neurological issues.

Perosis in Poultry

- Caused By: Deficiency in manganese (Mn), biotin, choline, and folic acid.

Feed Additives in Livestock Nutrition

Supplement:

- Feedstuffs that are used to improve the value of basal feeds.
- They have their own nutritive value.
- Used in large quantities (protein supplements) or in small quantities (trace minerals).

Feed additive:

Non-nutritive product added to a basic feed in small quantities that affects utilisation of the feed or productive performance of the animal.

Advantages:

- Increase feed quality and feed palatability
- Improve animal performance
- Improve the final product
- Economise the cost of animal protein

Disadvantages:

- May leave their residues
- May favour the proliferation of antibiotic resistant microorganisms

Types of feed additives:

- Additives that promotes growth and production: antibiotic, probiotic, prebiotics
- Additives that alter metabolism: Hormone (estrogens, androgens, progesterone, GH, thyroxine, glucocorticoids)
- Additives that enhance feed intake: antioxidants, flavouring agents
- Additives that enhance the colour: food colour, pigments
- Additives that facilitate digestion and absorption: grits, enzymes
- Additives that affect the health status of livestock: antifungals, Anticoccidials/coccidiostat, acidifiers

Antibiotics:

- bacteriostatic or bactericidal properties.
- Prevent subclinical infections
- Example: penicillin, oxy-tetracycline, chlortetracycline, bacitracin, streptomycin, neomycin, erythromycin

Mechanism of action of antibiotics includes:

- Nutrient sparing effect by increasing growth of vitamin and protein synthesising microorganism
- Reduces the thickness of the intestinal wall of birds, which enhances absorption of nutrients.
- Reduce or eliminate the activity of pathogens causing "subclinical infection."
- Reduce the growth of microorganisms 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 poultry (NH_3 concentration in poultry shed: <25ppm).
- Antibiotics appear to spare the dietary requirement of the chick for unidentified growth factors.

Probiotics:

direct fed microbials

- Live non-pathogenic microbial feed supplement, which beneficially affects the host animals by improving its intestinal microbial balance, facilitating digestion and absorption.
- Species: Lactobacilli, saccharomyces and Streptococci spp. (30x109 CFU/g)
- Mechanism of action:

• Having a direct effect against undesirable or harmful organisms through production of antibacterial compounds, eliminating or minimising their competition of nutrients.
• Stimulation of the immune system.
• Neutralisation of toxins formed by pathogenic organisms.

Prebiotics:

• Non-digestible food ingredients that benefit the host by selectively stimulating the growth of desirable bacteria in GIT.
• They modify the balance of the microflora population by promoting the growth of beneficial bacteria & thereby provide a healthier intestinal environment.
• Examples:
Oligosaccharides (Mannan-oligosaccharides, fructo- oligosaccharides).
Soya bean meal, rapeseed meal & legumes contain-galactooligosaccharides (GOS)
Cereals contain fructo-oligosaccharides (FOS);
Milk products have trans-galactooligosaccharides (TOS);
Yeast cell walls contain mannan-oligosaccharides (MOS).

Synbiotics: probiotics & prebiotics

Antioxidants:

• Prevent oxidative rancidity of polyunsaturated fats and enhance feed intake
• Example: Vit. E, Se, Ethoxyquin or BHT (butylated hydroxytoluene).

Flavouring Agent:

• Increase palatability and feed intake e.g. Monosodium glutamate (MSG).
• Flavouring agents are needed
- When highly unpalatable medications are being mixed During attacks of diseases.
- When animals are under stress
- With less palatable feedstuffs is being used Food

Colours:

• Make food more attractive and pleasing.
• Examples: acid fuchsin, brilliant blue, β-carotene, saffron, beetroot red, chlorophyll, etc.

Pigments:

• Examples: Carotenoids/ xanthophyll
• Enhance the colour of the marketed product.
• Colour of an egg yolk due to carotenoids
• Carotenoids in alfalfa produce yellow pigmentation of skin and fat of chicken.

• Xanthophylls are not stable compounds and can be lost by oxidation so antioxidants must be added in poultry feed.

Grit:

• Function: facilitates the digestion and absorption in poultry because poultry do not have teeth to grind any hard grain, most grinding takes place in the thick muscular gizzard for increasing the surface area for digestion and subsequent absorption.
• Oyster shells and limestone are used as grit.

Enzymes:

• Enzymes are biological catalyst
• Examples: beta-glucanase and xylanase, cellulose, Phytase.
• Improve the efficiency of the utilisation of the feed.
• Upgrade cereals by-products or feed components that are poorly digested
• Provide additional digestive enzymes to help poultry to withstand stress conditions.

Antifungal additives:

• Mould inhibitors are added to feed liable to be contaminated with various types of fungi such as *Aspergillus* and *Penicillium* spp.
• Propionic, formic acid and acetic acid are added in high moisture grain to inhibit mould growth.
• Antifungals such as Nystatin and copper sulfate preparations are also in use to concentrate feeds to prevent moulds.

Acidifiers:

• As preservative and prevent attaching of microbes with gut walls.
• Organic acids like formic acid, propionic acid, fumaric acid etc. are used as acidifiers

Ionophore antibiotics:

• Ex: monensin, lasalocid, salinomycin
• monensin: *streptomyces cinnamonensis*
• Rumensin: 50-100 mg/head/day
• Active against G +ve bacteria fibrolytic bacteria
• Support G –ve bacteria: concentrate digestion- propionate
• Nutrient partitioning agents: phenylethanolamine towards muscle
• Deodorising agents: Yucca Schidigera (block urease no ammonia)
• Methyl donor: methionine, betaine, choline

• Biopreservatives: Nisin produced by Lactococcus lactic- inhibit G-ve and G+ve bacteria.
• Defauning agent: copper sulfate
• Pellet binder: sepiolite
• Buffer: sod. Bicarbonate, MgO
• Mycotoxin binder: zeolite, mineral clay

onservation of Feed through Silage and Hay

3.1 Storage

• Microbial and insect growth: Temp. 28-30 oC and 65-80% RH
• Insect spp.: Sitophilus oryzae (weevils); Oryzeaphilus (grain beetle); Tribolium (Flour beetle)
• Mould spp.: Aspergillus flavus; Aspergillus ochraceus; Fusarium; Penicillium spp.
• Temp range for fungi: above 25oC = Aspergillus and below 25oC = Fusarium spp.
• Mycotoxin: harmful chemicals produced by fungi.
• Aflatoxin: mutagenic and carcinogenic Aspergillus spp. (B1, B2, G1, G2) B1 (feed)- M1 (milk)
• Zearalenone: oestrogenic activity (pig), abortions Fusarium spp.
• Fumonisins: cardiotoxic Fusarium spp.
• Ochratoxin: nephrotoxic Penicillium spp.
• Safe level of aflatoxin: Poultry/dairy feed 20 ppb
Duck 3 ppb (Duck more sensitive)

• Mycotoxin management:

- Methionine- detoxification
- Ammonia treatment
- Physical treatment sunlight (best method)
- Mould inhibitor: formate and propionate (0.1-1.0%)
- Binders: zeolites, aluminosilicates, bentonite, sepiolite
- Antioxidants: Vit E, C
- Enzymes: epoxidase, esterase

Microbes:

Eubacterium BBSH 797, C. sporogenes and L. viyulinus (Ochratoxin)
Trichosporan yeast (Zearalenone), Flavobacterium & A. repens (aflatoxin)

• Rodent control: warfarin, Comarin (Anticoagulant rodenticides)
• Fumigation:
• Ethylene dibromide
• 40% formalin (35ml) + 17.5 g $KMnO_4$ per m3 for 20 min. = 2:1 (Max Exposure Limit = 2 ppm)

3.2 Conservation of Livestock Feed through Silage and Hay

Silage

Silage is the green succulent fermented material produced by controlled anaerobic fermentation of the green fodder crop retaining the high moisture content. It contains 25-35% DM & 14-16% CP. This process of making silage is called ensiling.

Selection of crops for silage making:

- Thick stems
- High level of fermentable sugar
- Low protein like maize, sorghum, bajra etc.
- **Crop** should have 35 % dry matter or 60-70% moisture at the time of ensiling.
- Legumes are avoided because of containing high amounts of organic acids and anions which resist pH change.
- Crop should be harvested between flowering and milk stage

Method of Silage making

- A silo which is an air tight structure for storage and preservation.
- One cubic meter space is required for 400kg fodder silage making.
- Chopping of forage to a short length (1-3 cm).
- Compact forage as tightly as possible.
- Sprinkle salt at 0.5%, urea 1% and molasses 3% of the material weight to improve sugar content.
- Maintain sealing for 45 days.

Types of fermentation during Silage formation

Lactic acid type- Desirable for making good quality silage and forage is carbohydrate rich. Sugars fermented to VFAs and lactic acid, low pH around 4 which inhibit the growth of undesirable bacteria to grow. It is mediated by Lactobacillus type bacteria .

Butyric acid type- When forage contains more protein and less carbohydrate than clostridium bacteria grow and deteriorate its quality. Butyric acid gives a sharp disagreeable smell which is not liked by animals.

- Flieg index is used to evaluate silage quality which measures butyric acid produced. Lesser the butyric acid better will be silage quality.
- **Very good silage**- greenish brown or golden color with acidic taste and is free from butyric acid with pH 3.5-4.2 and ammoniacal N < 10 % of total N .
- **Good silage**- Brown color with acidic taste with <0.2% butyric acid and pH 4.2-4.5 and ammoniacal-N 10-15% of total N.
- **Fair silage-** pH 4.5-4.8, >0.2 % butyric acid, ammoniacal –N 15-20% of total.

Hay-

Hay is obtained by cutting and curing (sun drying) the fine stemmed grasses or legumes so that moisture content is not more than 12-14%.

Crop-

- Forages like rasses & legumes
- Harvested at 2/3rd flowering stage at early in the morning to minimize loss of leaves

Methods of Hay making

1. **Field curing**- sun drying.
   Steps includes

a. Cutting crop- left as such to dry partially
b. Swath curing to obtain moisture upto 40%
c. Raking –obtained foarge after wilting of foarge to 40% make loose cylindrical bundles
d. Cocking-making bigger heaps of cured hay
e. Baling – by using baler attached to tractor into tightly packed stacked
f. Storing

2. **Barn drying**: using air to reduce moisture to 20-25%. Much greener and leafy
3. **Artificial drying**-hot air-expensive Rapid

drying **Types of hay**

Legume hay: higher TDN and DCP and are rich in protein & minerals. Crops –Lucerne, Cowpea, Berseem. Good quality hay.

Non legume hay: less palatable and less amount of protein, vitamin and nutrients than legume hay but rich in carbohydrates. Crops – Oat, barley, Bajra, sorghum and grasses.

Mixed hay: The nutritive value of mixed hay depends upon the type of legume and non legume crops.

Losses of nutrients during hay making

Losses by shattering- due to shattering of leaves. To avoid this hay should be field cured in morning hours rather than during warm periods of day.

1. **Losses of vitamins due to oxidation**- during drying carotene which is a source of vitamin A in green plants is bleached hence decrease in vitamin A content of hay.
2. **Losses due to fermentation**- after harvesting the crop plant enzymes act on soluble carbohydrates and form co2 and water. Proteins are hydrolysed to amino acids.
3. **Losses due to leaching**- if hay is almost cured and exposed to heavy rains then leaching of nutrients like soluble carbohydrate and protein occurs.

Total loss estimated in hay making

- Loss of DM – 20-30% in legumes and
  10-15% in grasses
- Loss of protein – 28%
- Loss of carotene-
  90%
- Loss of energy -
  25%

Changes during storage- sometime when crops cured for hay making retains higher moisture level during stacking it produces much heat which change the color of hay to dark brown color due to oxidative degradation of sugars combining with amino acids or proteins and is called as Mow Burnt/ brown hay.

Difference in silage and Hay

particular	silage	Hay
DM (%)	30-35	10-15
Type of crop	Non leguminous type. Maize ,jowar,sorghum, bajra	Leguminous type Lucerne, oats berseem
Texture OF CROP	Thick stemmed, carbohydrate rich	Thin stemmed, protein rich
Method utilised	Fermented product	Sun dried product
Losses of nutrients	less	more
Time of harvest of crop	between flowering and milk stage	2/3rd flowering stage
digestibility	Partially digested during fermentation so more digestible	Not digested during drying. Less digestible.
Drying	Crop is not dried and used after cutting only	it is dried first
Air	Complete exclusion of air	Openly dried in air

- **Haylage (hay+silage):** Dry matter in crops used for haylage making is 40- 45%.
- **Wastelage:** Anaerobically fermented animal waste like poultry droppings, poultry litter, swine excreta and bovine dung along with other feed ingredients with the help of lactic acid producing bacteria.
- **Oat hay poisoning/ nitrate poisoning**: Nitrate poisoning can occur in crops like sorghum, lucerne, and Sudan grass. In the rumen, nitrate is reduced to nitrite, which, when absorbed into the bloodstream, oxidizes the ferrous ion in hemoglobin to ferric ion, forming methemoglobin. This causes the blood to become chocolate brown, leading to a brownish discoloration of the mucous membranes and skin.

• Feeding of infants and growing animals, thumb rule of feeding, feeding and care of pregnant and lactating animals.

Nutrient Requirements for Fetal Growth

Determination of Nutrient Deposition

- **Methods**:
    - Nutrient quantities in the fetus are determined by analyzing animals at birth.
    - Time-course analysis during gestation involves examining fetuses and adnexa from slaughtered animals.

Additional Nutrient Requirements (Post 5 Months of Pregnancy)

- Cows in the **last trimester** (after 5 months) require:
    - **DCP**: +0.14 kg/day.
    - **TDN**: +0.67 kg/day.
    - **Calcium**: +12 g/day.
    - **Phosphorus**: +7 g/day.
- **Dietary Management**:
    - Feed an additional **1.5 kg concentrate mixture**.
    - Incorporate **2% calcium carbonate** in the concentrate to meet calcium requirements.

Steaming Up

- **Definition**:
    - A feeding practice where the concentrate allowance for dairy cows is increased **2-3 weeks before calving**.
- **Purpose**:
    - Promotes **mammary development**.
    - Increases **body reserves**.
    - Results in higher **milk production** post-calving.

Nutrient Requirements (Last Two Months of Pregnancy)

For a **400 kg cow** (Ranjhan, 1998):

- **Dry Matter (DM)**: 7.2 kg/day.
- **Digestible Crude Protein (DCP)**: 350 g/day.
- **Total Digestible Nutrients (TDN)**: 4 kg/day.
- **Calcium (Ca)**: 23 g/day.
- **Phosphorus (P)**: 18 g/day.

Nutrient Requirements of Livestock for Lactation

Milk Composition

- **Major Constituents**:
    - Water: **87.5%**.
    - Protein: **3.3%**.
    - Fat: **3.7%**.
    - Lactose: **4.8%**.
    - Ash: **0.72%**.

Milk Protein:

- **95% Nitrogen** in milk is protein, while 5% is Non-Protein Nitrogen (NPN) compounds (e.g., urea, creatinine, glucosamine, ammonia).
- Protein Types:
    - **Casein**: 78% of total milk nitrogen.
    - **β-lactoglobulin**, **α-lactalbumin**, **bovine serum albumin**, **immunoglobulins**.
- Synthesis:
    - Casein, β-lactoglobulin, and α-lactalbumin are synthesized in the **mammary gland** from blood amino acids.
    - Bovine serum albumin and immunoglobulins are directly absorbed from blood.

Lactose:

- Synthesized in the **mammary gland** from glucose and galactose.
- Least variable milk constituent across species.

Milk Fat:

- Synthesized from **plasma lipids** and **blood glucose** (non-ruminants).
- **Ruminants**:
    - Use plasma lipids, acetate, and β-hydroxybutyrate as precursors.

        - Lack key enzymes (ATP citrate lyase and NADP malate dehydrogenase) for glucose-to-fat conversion.
    - Composition:
        - **Triacylglycerols**: 98%.
        - Remaining: phospholipids, cholesterol, fat-soluble vitamins, and pigments.
        - **Saturated Fat**: Predominantly **palmitic acid**.
        - **Unsaturated Fat**: Mainly **oleic acid** with small amounts of **linoleic** and **linolenic acids**.

Solid Not Fat (SNF):

- Includes all milk constituents except water and fat.

Minerals:

- Absorbed selectively from blood.
- Compared to blood, milk contains:
    - **13x calcium**.
    - **10x phosphorus**.
    - **5x potassium**.
    - Only **1/7 sodium** and **1/3 chlorine**.

Vitamins:

- Directly absorbed from blood.
- **Carotene**:
    - Present in bovine milk (from plants).
    - Minimal in milk of sheep, goat, sow, buffalo, camel, and humans.

Pigments:

- **Water-soluble**: Riboflavin.
- **Fat-soluble**: Carotene.

Energy Requirements for Lactation

Importance of Energy in Lactation

- **Highest Nutrient Demand**: Energy is required in the largest quantity for lactating livestock.
- **Proportional to Milk Production**:
    - Additional energy required is directly proportional to the **energy secreted in the milk**.

Energy Content of Milk

- Determined through:
  - **Bomb Calorimetry**.
  - Analysis of milk constituents.
- **Formula for Energy Content (E)**:

  E (kcal/kg) =304.8 + 114.1 F (F is the fat content in g/kg of milk)

  $$\text{ME requirement for lactation} = \text{Maintenance requirement} + \frac{\text{Energy in milk produced}}{\text{Efficiency of utilization of ME for milk production}}$$

- **Efficiency of Utilization**:
  - Average value: **62% (0.62)** for milk production.
  - Suggested by **Van Es**:
    - Efficiency is related to the **metabolizability (qmq_mqm)** of the diet.
    - qmq_mqm: Ratio of **ME (MJ/kg DM)** to **Gross Energy (MJ/kg DM)** at maintenance level.

Maintenance Energy Requirement for Lactating Cows

- Efficiency of utilization of dietary ME for maintenance (k_m) in a lactating dairy cow may be calculatd as

  $k_m = 0.35\ q_m + 0.503$

  and the requirement of ME for maintenance for a lactating dairy cow (ME_m in MJ/d)

$$ME_m\ (MJ/d) = \frac{0.53\ (W/1.08)^{0.67} + 0.0091\ W}{k_m} = \frac{0.53\ (W/1.08)^{0.67} + 0.0091\ W}{0.35\ q_m + 0.503}$$

Feeding of Calves: Pre-Ruminant Growth (Up to 3 Months Age)

1. Colostrum Feeding

- **Definition:**
  - First secretion of the mammary gland post-parturition, designed to provide calves with a strong start in life.
- **Importance:**
  - Rich in **immunoglobulins**, **albumin**, **minerals**, and **vitamins** (especially Vitamin A).

- Lacks **lactose** and has less **fat** compared to normal milk.
- Acts as a **laxative** and confers **passive immunity** to the newborn.

2. Practices for Colostrum Feeding

- **Timing:**
  - Should be fed **soon after birth**, ideally within **30 minutes** or at most within **2-3 hours**.
- **Duration:**
  - Continue for a minimum of **4 days**.
- **Quantity:**
  - Feed at **1/10th of the calf's body weight**.
- **Handling:**
  - Should be fed **fresh**; avoid heating as it causes clotting.

3. Composition of Colostrum vs. Normal Milk

Nutrient	Colostrum	Normal Milk
Water	77.5%	~87-88%
Fat	3.6%	~4%
Lactose	3.1%	~4.8-5%
Protein	14.3%	~3-4%
Minerals	1.5%	~0.7%

Calf Starter

1. Definition

- **Calf Starter:** A specially formulated concentrate feed designed to support the growth and development of calves, starting from the **15th day of life**.
- **Composition:** Made of ground grains, oilcakes, animal protein supplements, and brans, fortified with **vitamins, minerals, and antibiotics**.

2. Nutritional Composition

- **Crude Protein (CP):** 23-26%.
- **Total Digestible Nutrients (TDN):** 72-75%.

3. Feeding Practices

- **Introduction:**
  - Begin with small quantities from the **15th day of age**.
  - Feed alongside **milk** and **good quality hay**.
- **Purpose:**
  - Promotes rumen development.
  - Provides essential nutrients for growth.

4. Common Formulations

Ingredients	**Formulation 1 (%)**	**Formulation 2 (%)**
Finely ground maize	45	-
Groundnut cake	35	32
Fish meal	8	10
Wheat bran	10	25
Dried tapioca chips	-	15
Ragi	-	10
Molasses	-	6
Mineral mixture	2	2

- Add **0.5 kg common salt** and **25-30 g Vitamin AB2D3 supplement** per **100 kg** of feed.

5. BIS Standards for Calf Starter

Characteristics	**Requirement**
Moisture (%)	Max. 10
Crude Protein (CP) (%)	23-26
Crude Fat (%)	Min. 4
Crude Fibre (%)	Max. 7.0
Total Ash (%)	Max. 5.0
Acid Insoluble Ash (%)	Max. 2.5
Common Salt (Dry Basis, %)	Max. 1.0

Calcium (Dry Basis, %)	Min. 1.2
Phosphorus (Dry Basis, %)	Min. 0.8
Vitamin A (IU/kg)	10,000

Feeding of Calves and Bull Calves

A. Feeding Schedule for Calves (Up to 3 Months of Age)

1. Feeding Components

- **Milk:** Main feed for early nutrition, provided in specific quantities based on body weight.
- **Calf Starter:** Introduced gradually after the 15th day for rumen development.
- **Hay:** Offered in small amounts to stimulate rumination.

2. Feeding Schedule

Age (Days)	Milk	Calf Starter	Hay
1-4	Colostrum: 1/10th body weight (3 feeds/day)	-	-
5-14	Milk: 1/10th body weight (3 feeds/day)	-	-
15-21	Milk: 1/10th body weight	A little	A little
22-42	Milk: 1/10th body weight	100 g	Ad libitum
Up to 2 months	Milk: 1/15th body weight	250 g	Ad libitum
2-3 months	Milk: 1/20th body weight	500 g	Ad libitum

3. Vitamin A Supplementation

- **If green fodder is not available to the dam:**
  - **Immediately after birth:** 10,000 IU.
  - **Next 7 days:** 5,000 IU/day.
  - **Later:** 1,000 IU/day.

B. Feeding Schedule for Calves (4 Months to 1 Year)

Age (Months)	Concentrate Mixture (16% DCP, 70% TDN)	Green Fodder
4	0.75 kg	2-3 kg
5	1 kg	3-5 kg
6-9	1.5-2 kg	5-10 kg
9-15	2-2.1 kg	10-15 kg
15-20	2.1-2.25 kg	15 kg
Above 20	2.25-2.5 kg	15-20 kg

C. Feeding of Bull Calves

1. Future Breeding Bulls

- **Milk Feeding:**
    - Liberal milk feeding for the first **6 months**.
- **Supplementation:**
    - **Calf Starter** and **good quality hay** introduced from the **2nd week of age**.
- **Concentrate Mixture:**
    - **6-12 months:** 2.5 kg/day.
    - **1-2 years:** 3 kg/day.

Feeding of Kids and Different Categories of Goats

1. Feeding of Kids (Up to 3 Months of Age)

Milk Feeding

- **First Month:**
    - Milk fed at **1/6th of body weight**.
- **Second Month:**
    - Milk fed at **1/8th of body weight**.
- **Third Month:**
    - Milk fed at **1/10th to 1/15th of body weight**.

Introduction of Solid Feed

- **From 2nd Week Onwards:**
    - Introduce **kid starter** and **good quality fodder** in small quantities.

Feeding Schedule for Kids

Age of Kid	Body Weight (kg)	Milk (g)	Kid Starter (g)	Green Fodder (g)
Birth to 4 days	1.5 – 2.0	Colostrum	-	-
5 – 30 days	2.0 – 3.0	300 – 500	Small quantity	Small quantity
30 – 60 days	3.0 – 5.0	400 – 600	50 – 100	Small quantity
60 – 90 days	5.0 – 7.5	500 – 750	100 – 200	250 – 500
90 – 120 days	7.5 – 10.0	-	200 – 250	500 – 750
5th and 6th Month	10.0 – 15.0	-	250 – 300	750 – 1000

Example of a Kid Starter

Ingredients	Parts
Deoiled groundnut cake	12
Horse gram	30
Wheat/Maize/Jowar	30

Rice polish/Wheat bran	15
Dried unsalted fish	10
Mineral mixture	2
Common salt	1
Vitamin AB2D3 (25 g/100 kg)	-

2. Feeding Schedule for Different Categories of Goats

Category of Goat	Body Weight (kg)	Concentrate (g)	Green Fodder (kg)
Growing (6-12 months)	15 – 20	300 – 400	1 – 2
Adult Goats	25 – 30	200 – 300	2 – 3
Breeding Bucks	30 – 40	400 – 500	3 – 5

Nutritional Requirements for Reproduction in goat

Advanced Pregnancy

- **Nutritional Demands:** To support the growth of the fetus in the later stages of gestation, additional nutrients are required over maintenance levels.
- **Extra Allowance (Per Day):**
  - **DCP:** 55 g
  - **TDN:** 400 g
  - **Calcium (Ca):** 2 g
  - **Phosphorus (P):** 1.4 g
- **Feeding Strategy During the Last 6 Weeks of Gestation:**
  - Liberal feeding of high-quality fodder.
  - **Concentrate Mixture:** 400–500 g/day.
  - **Few Days Before Kidding:** Reduce concentrate to half and add bran to provide bulk and prevent digestive disorders.

Post-Kidding Feeding

- **Initial Diet:**
  - Feed a **bran mash** for the first few days to aid digestion and recovery.
- **Gradual Transition:**
  - Gradually increase feed to meet milk production needs, ensuring adequate protein, energy, and minerals.

2. Feeding of Breeding Males (Bucks)

During Breeding Period:

- **Additional Nutritional Support:**

    - Required for **spermatogenesis** and mating activity.
    - Provide:
        - **DCP:** 55 g
        - **TDN:** 400 g
        - **Calcium:** 2 g
        - **Phosphorus:** 1.4 g
- **Concentrate Mixture:**
    - Should be included along with high-quality forage.

Non-Breeding Period:

- **Maintenance Diet:**
    - No additional concentrate required.
    - Can be maintained on a **good quality grass-legume mixture** alone.

Feeding Practices for swine

- Hind gut fermenter
- Fermentation- caecum and Colon
- VFA- 35-45% maintenance requirements (60% in ruminants)
- Weaning- 8 weeks.
- Crude Fibre- growing- 6-7% and 10-12% adult pig.
- Pigs less than 2 to 3 weeks old have insufficient pancreatic amylase and intestinal
- disaccharidases. Hence after 2 weeks of age only, pigs are to be fed starch-or
- cereal-based diets.
- Feed efficiency- 30-40% heritable. Best feed efficiency
- ME = 0.96 DE
- Pig- 1st limiting AA- lysine
- Birth weight: 0.7 – 1 kg
- Essential amino acid in pigs: 9 (arginine not essential)
- Iron dextran injection (i/m) is to be given on 4th and 14th day of age to prevent piglet anemia.
- FeSO4 2% of feed

Creep feed:

- Creep (pre-starter) feeding system is essential for **sucking piglets** for faster growth and attain their satisfactory weaning weight.
- Piglets are weaned at 6 weeks of age in western countries and at **8 weeks of age** in India under an intensive feeding system.
- Creep mixtures are introduced at **7-14 days** of age and are fed till weaning.
- Piglets fed on creep ration attain **12-15 kg body weight at 8 weeks** of age.

- During the suckling period piglets are more prone to piglet anemia, creep feed is generally mixed with **ferrous sulfate at the ratio of 9:1 to prevent anemia**.
- Composition of creep feed (BIS, 1986): **CP, min = 20%** and ME (kcal/kg), min = 3265

Grower ration:

- After creep feed on attainment of 12-15 kg of body weight at 8 weeks of age piglets are shifted on grower ration.
- At this stage, pigs consume considerably more feed and attain around 35 kg in indigenous and 50kg BW in exotic breeds.
- Grower ration should have **18% CP** and 3170 kcal/kg ME value.

Finisher/breeder ration:

- On attainment of grower bodyweight pigs are switched over to finisher ration.
- Finisher ration should contain **16% CP** and 3170 kcal/kg ME value.
- For the indigenous pigs, slaughter at about 45-50 kg is recommended (IVRI, 1993).
- Pigs grow around 700 g/day so they can attain 100 kg of body weight in 143 days.
- Breeder pig required a finisher ration with a higher level of vitamins.

Feeding of pregnant sow:

- Feeding of pregnant sows is recommended as breeder pigs but feed offered needs to be restricted to 2-2.5 kg/day, because higher quantity of feed may lead to embryonic mortality.
- Ration should contain **16% CP** and 3000 kcal/kg ME value with 0.7% lysine.

Feeding of lactating sows:

- It should be offered additional feed for early recovery of the body condition (body weight loss) and for milk production.
- For a lactating gilt **2.0 kg of meal with 200g meal per piglet** in the litter may be sufficient to meet nutrient requirement.

Flushing ration:

- A well-balanced **high protein ration before breeding** is required for flushing to obtain greater litter size & body weight.
- This ration is given to gilt or sows, **15 days before mating** to proper conceiving.
- During gestation period, sows are fed on **restricted feeding** (2-3 kg) without getting overweight.
- On the day of farrowing, 250g of wheat bran could be offered for proper lactation.

Feeding of piglets:

1. Colostrum feeding
   - It is the first milk and an essential source of energy, nutrients & immunity for the piglets.
   - It is important to maximize colostrum intake in the first six hours after birth (**150-280 ml/kg of birth BW**)
2. Milk replacer:

- A milk replacer for piglets is a good solution to supply piglets with **extra nutrients** and energy, when sow milk supply is not sufficient.
- The ingredient of milk replacer should be of higher quality and easily digestible since we are feeding a young one.

Use of unconventional feedstuff in pig ration:

- Feed cost of pig production usually accounts for nearly **60-70%** of the total production cost.
- It is extremely important that an economical **as well nutritionally balanced** diet be provided during all stages of production.

Common available unconventional feedstuff:

- Sweet potato- fed as an energy source in pig ration.
- Pineapple waste- waste obtained after squeezing juice contains 5% CP and also fed as an energy source.
- Tapioca waste/ cassava root - it can be used as an energy source in ration up to 5-10%.
- Decaffeinated tea waste - It contains about 7.5% DCP and can be used up to 10% in concentrate feed.
- Garbage waste- wastes from hotel, hostels, kitchen & agricultural wastes can be used in pig ration, before feeding waste should be boiled properly.

Feeding Practices for poultry

General Principal/ guidelines/ facts for Poultry feeding:

- Feed must contain all essential nutrients in the right amounts & proportion required.
- Different standards per age should be followed.
- Palatability of the ingredients, which are used.
- Unlike ruminants, poultry completely depend upon the dietary sources for all nutrients (essential AA., Vit. B groups and K).
- Include agro-industrial by-products to minimize cost of the ration,
- Optimum level of ingredient inclusion as many of ingredients have a deleterious effect at higher levels.
- Optimum Ca:P ratio for different purposes.

Factors affecting feed intake in poultry:

- Energy levels in the ration:
- Increase in energy level → decrease in feed intake and vice versa.
- Environmental temperature: (16-24◦C): Increase in Temp. = decrease in feed intake and vice versa.
- Health of the bird
- Genetics
- Form of the feed
- Nutritive balance of the diet

- Stress
- Body size
- Rate of growth & egg production

Nutrients requirements of poultry:

Energy requirement:

- Ration for poultry calculated based on ME.
- Poultry eat to satisfy their energy needs when fed free choice, thus must control the intake of all nutrients by including them in a definite proportion to available energy level.
- High-energy cereal grains are the principal energy sources.
- Fat may be added at levels of 3-8% to increase dietary energy concentrations.

Protein requirement:

- The amount of protein required is proportional to the energy level in the ration.
- Poultry requires the 11 essential AAs.
- Increase in Temp. = decrease in feed intake = increase in protein requirement and vice versa.
- Some AAs can be met by other AAs: Cystine = methionine, Tyrosine → phenylalanine, Glycine = Serine.
- Overheating or under-heating during processing can affect the availability of some amino acids.

Mineral requirements:

- The major minerals needed in poultry diets are Ca, P, Na & Cl. Trace minerals are added to diets deficient in them.
- The recommended ratio P: Ca in the diet of poultry is 1:1.2 (range 1:1 to 1:1.5). For laying hen 1:4 (Ca important for bone & shell formation)
- Inorganic P have a higher availability than organic P. All P from animal origin & 40% from plant origin (wheat bran & rice bran) is available.
- The amount of Salt (NaCI) added depends upon the feed ingredients. The recommended level in the ration 0.5-1% of the ration. Adult poultry can tolerate much higher inclusion but the water consumption increased. Manganese is required to avoid slipped tendon disease in poultry.

Vitamin requirements:

- All the vitamins have their specific role in the health of the poultry birds. Liberal amount of each vitamin is required to avoid specific disease conditions related to them.

Nutrients requirement in Broilers feeds as per BIS (2007)

.	Characteristic	Requirement for broiler feed		
		Pre-starter	Starter	Finisher

1	Moisture % by mass, Max.	11	11	11
2	CP % by mass, Min.	23	22	20
3	EE % by mass, Min.	3.0	3.5	4.0
4	CF % by mass, Max.	5.0	5.0	5.0
5	AIA % by mass, Max.	2.5	2.5	2.5
6	Salt (NaCl) % by mass, Max.	0.5	0.5	0.5
7	Ca % by mass, Min.	1.0	1.0	1.0
8	Total P % by mass, Min.	0.7	0.7	0.7
10	Available P % by mass, Min.	0.45	0.45	0.45
11	Lysine % by mass, Min.	1.3	1.2	1.0
12	Methionine % by mass, Min.	0.5	0.5	0.45
13	ME (kcal/kg), Min.	3000	3100	3200
14	Aflatoxin B1 (ppb)	20	20	20

Phase feeding in layers

Purpose: To adjust nutrient intake in accordance with the rate of egg production

- In egg production hen usually cover a period of 15 months
- Egg production commences at 20-22 weeks of age, peak at 28-30 weeks of age gradually decline to 65% after 60 weeks and nearly cease at around 72 weeks of age.
- Effect of light exposure: lighted period = increase feed intake & increased stimulation of pituitary gland = increase in egg laid.

Phase I (from 22-42 week of age): Most critical period

- Increase in egg production from zero to peak (85-90% production).

- Increase in body weight from 1300 to 1900g.
- Increase in egg size from 40g/egg at 22 weeks to over 56g/egg at 42 weeks of age.
- Protein and ME are comparatively lower than chick stage (up to 8 weeks) but higher than grower stage (8 to 20 weeks).
- Calcium requirement increases three times to support egg production.

Phase II (from 42-72 week of age):

- Period after 42 wk of age when the hens attained mature body weight to about 72 wks of age.
- Protein and ME requirement during Stage II is comparatively lower than Stage I.
- Calcium requirement increases further to 3.5% of feed.

Nutrients requirement in Layer feeds as per BIS (2007)

.	**Characteristic**	**Requirement for laying birds feed**			
		Chick	Grower	Layer Phase I	Layer Phase II
1	Moisture % by mass, Max.	11	11	11	11
2	CP % by mass, Min.	20	16	18	16
3	EE % by mass, Min.	2.0	2.0	2.0	2.0
4	CF % by mass, Max.	7.0	9.0	9.0	10.0
5	AIA % by mass, Max.	4.0	4.0	4.0	4.5
6	Salt (NaCl) % by mass, Max.	0.5	0.5	0.5	0.5
7	Ca % by mass, Min.	1.0	1.0	3.0	3.5
8	Total P % by mass, Min.	0.65	0.65	0.65	0.65
9	Available P % by mass, Min.	0.40	0.40	0.40	0.40
10	Lysine % by mass, Min.	0.6	0.7	0.7	0.65

11	Methionine % by mass, Min.	0.40	0.35	0.35	0.30
12	ME (kcal/kg), Min.	2800	2500	2600	2400

Feeding of livestock during scarcity, metabolic disorders, processing of feeds and forage, quality control of feedstuffs.

Metabolic Disorder and Symptom

• Metabolism is sum of Physical and Chemical Metabolic processes relating to absorbance and breakdown or synthesis of necessary organic molecules in body
• Disturbance of one or more metabolic processes related to regulation of a certain metabolites in the body fluids is known as metabolic disorders
• Nutritional diseases -» deficiency, excess or imbalance of specific nutrients -» metabolic disturbances -» metabolic disorder
• Mostly occur after parturition
• Transition period---Dry lactation

Influencing factors are

1. Hormonal changes
2. Moving from non-lactating to lactating stage- lactation stress
3. Changing of diet from roughages to highly fermentable CHO.

Metabolic Diseases

1) Fatty liver

2) Ketosis
3) Acidosis (SARA)
4) Laminitis
5) Milk fever
6) Downer cow
7) Retained placenta
8) Bloat
9) Grass tetany
10) LDA
11) Udder edema

ALL THE METABOLIC DISEASES ARE RELATED TO ONE ANOTHER

Fatty Liver

• Common metabolic disorder during transition period.
• Up to 65% of dairy animals are affected by moderate or severe fatty liver during early lactation
• Reason- Over conditioned animals during dry period (BCS>4.5)
• NEBAL-body fat is mobilized from adipose tissue into the bloodstream in the form of NEFA
• NEFA are taken by the liver in proportion to their supply, but the liver does not have capacity sufficient to oxidize and use all amounts of NEFA for energy.
• Therefore, cows are predisposed to accumulate NEFA as triglycerides within the liver.

Preventatives for fatty liver

- Avoid excessive fattening during dry period by providing relatively low- energy, low-protein forages until the last few weeks of pregnancy.
- Glucogenic sub- glycerol, propylene glycol, monensin.
- B-complex vitamins are sometimes used in cases of fatty liver disease to supply cofactors of metabolism and to help stimulate the animal's appetite.
- Vitamin E and selenium- as their antioxidant effects help protect the liver Lipotropic agents (choline, methionine)- remove fat from liver cells, slow down fat deposition.

Ketosis (Acetonemia)

- In dairy cows, ketosis is a lactation disorder usually associated with intense milk production and NEBAL (6-8 wk postpartum)
- An increase of "ketone bodies" in blood until they eventually begin to spill over into urine and (or) milk.
- Acetone, Acetoacetate, and β-Hydroxybutyrate Acetone: smell from breath

Source of Ketones

1) From butyrate produced in the rumen and converted to beta- hydroxybutyrate by rumen mucosa during absorption
2) From metabolism in liver of LCFA primarily released from adipose tissue during energy deficit

Ketogenesis
• Normally- FFA are oxidized to the normal intermediate acetoacetyl-CoA, which further is oxidized to CO2 and acetyl-CoA in the citric acid cycle
• Ketosis- acetoacetyl-CoA - -» Acetoacetate
1. By Acetoacetyl-CoA deacylase (ruminant liver and kidney)
2. By Hydroxymethylglutaryl- CoA synthase and hydroxymethylglutaryl-CoA lyase pathway (liver and rumen epithelium)
Acetoacetate is converted to other ketone bodies i.e. Acetone or β- hydroxybutyrate

Predisposing factors

• Glucose deficiency (NEBAL)- 60 to 85% of the available glucose drains as lactose in milk. Glucose demand exceeds gluconeogenesis in the liver resulting in increased ketogenesis.
• Excessive fattening/ BCS- pre-partum
• Lactation demand- conducive to excess fat mobilization, which contributes to ketosis.

• Deficiency of ACTH- impaired gluconeogenesis
• Deficiency of OAA- Gluconeogenic

Sign and symptoms

• Loss of appetite, refusing grain and eating only small amounts of roughage, acetone smell in breath.
• A few affected cows will show nervous symptoms.
• Characterized by hypoglycemia- from a normal of 50 to 60 to as little as 25 mg/100 ml.
• Hyperketonemia- from a normal of less than 10 to as high as 50 mg/l00 ml blood
• Other frequently observed changes include increases in NEFA, decrease in liver glycogen and increases in liver lipid that can lead to liver damage.

Treatment

• Intravenous injection of glucose (50% dextrose)
• Intramuscular glucocorticoid (Isoflupredone)
• Gluconeogenic precursor- Sod. Propionate, glycerol, propylene glycol
• Supportive- vitamins

Ruminal Acidosis

• Important nutritional metabolic disorder common in the field especially in high yielding cows with high grain ration.
• Grain engorgement
• Sudden change in diet- Dry cow is fed a high forage ration that is less energy dense and higher in NDF than the lactating animal
• Ruminal populations ill-suited to energy rich ration

Acidosis vs SARA

• Ruminal acidosis (pH<5.5)- when animal consumes excess of grain or due to lactate accumulation
• SARA (pH<6)- excessive VFA production that exceeds ability of rumen papillae to absorb them and is commonly seen at calving when dry cow is switched to grain ration (smaller rumen papillae).

Prevention

• Balancing the diet for starch and effective fibre.
• Sudden changes of feed and slug feeding of grain and/or molasses should be avoided.
• Roughages should be provided with grain/molasses.
• Buffers such as sodium bicarbonate also counteract acidosis

Laminitis

• Pathological disturbance of microstructure of sensitive laminae of hoof.
• Seen in high-production, intensively managed cattle
• Acidosis affects Gram negative bacteria- toxins
• Endotoxins and histamine released as the rumen flora die, are absorbed systemically and affect the microvasculature of the hoof wall and result in clinical laminitis.

Prevention

• Avoid abrupt switch from dry-off ration to high lactation ration
• Foot baths- 2–5% copper sulphate.
• Nutritional supplements- biotin and zinc – help in keratinization.
• Vitamin A and vitamin E- important roles in maintaining claw integrity.
• Other trace minerals that impact claw condition include I, Se, Cu, Mn and Co.

Milk fever/Parturient Paresis (hypocalcemia)

• An afebrile hypocalcemic disease of cattle usually associated with parturition and initiation of lactation in high producing animals when the demand of calcium for milk production exceeds the body's potential to mobilize calcium reserves.
• Low blood calcium level interferes with muscle function causing general weakness, depression and death.

Etiology:

• It is more common in older dairy cows (reduced ability to mobilize calcium from bone and in high milk producing breeds due to exhausted reserves)
• Lactation (usually first 72 hr postpartum)- Ca drain (10 mg/dl to 5 mg/dl)
• Parathyroid inactivity and dietary Ca supplementation during dry period

Clinical Signs

• Body temperature - subnormal (100-101oF)
• Neck curved towards the flank
• Cold extremities
• In-coordination, wobbly and weak
• Occasionally, hyperexcitability

Prevention and treatment

• DCAD- addition of anions to the diet of dairy cows prior to parturition effectively reduced the incidence of milk fever by inducing a metabolic acidosis, which keeps parathyroid hormone in active state thus reducing incidence of fever milk.
• Anionic Min. Mixture during transition period
• Avoid Pre-partum diets high in cations- Na+ and K+
• Restoration of Ca– half i/v and half s.c. in multiple sites - Retreat 8-12 hr later, if needed.
• Ca gel orally 1 day before and I day after calving
• Vit. D- 8 days before calving, s.c.

Downer cow syndrome/complex

• Downer cow syndrome is a complication of periparturient hypocalcemia in cows that do not fully respond to calcium therapy and are unable to rise for >24 hr after initial recumbency.
• The animal may develop a secondary recumbency from pressure damage to muscles and nerves.
• Many peripartum diseases (milk fever, acidosis, fatty liver, displaced abomasum etc.) are interrelated with one another, they have been grouped under the general title "downer cow complex."

Retained placenta

Failure of fetal membranes to be expelled from the uterus within 12 to 24 hours after parturition

Etiology:

• Increased incidence with over conditioning and hypocalcemia
• Dystocia and twinning increases incidence of retained placenta
• Extreme deficiency of dietary energy, protein or both can result in RP.
• The rate of RP is associated with imbalances in Ca and P metabolism.
• Se and vitamin E- important for reducing the incidence of RP
• Deficiency of vitamin A and β-Carotene increase the incidence of RP.

Prevention

o Proper nutrition especially during dry period
o Supplementation with selenium
o Adequate amounts of vitamin A and fiber
o Over-conditioned cows are at an increased risk
o Reduce dystocia– by proper management.

Grass tetany/ Hypomagnesaemia

- It is most often associated with animals in early lactation grazing on lush green pastures
- Rumen is the primary site of absorption of Mg and Low pH enhances Mg absorption while high pH above 6.5 decreases its solubility and rumen absorption.
- Lush green pastures are rich in K+, Na+ and NPN compounds.
- K+, Na+ have positive DCAD thus alkalize the rumen environment resulting in decreased Mg absorbance.
- Further degradation of NPN compounds in lush green pastures exceed the capacity of rumen microbes to incorporate in microbial protein resulting in ammonia build up which increases the rumen pH resulting in decreased Mg absorption
- Disease is more severe if accompanied by hypocalcemia
- Tetanic or paretic type and subclinical types with depression of appetite and milk yield, slight nervousness, anemia.
- **Treatment-** Restoring normal Ca and Mg homeostasis and muscle relaxant
- • Addition of 15-30 g of Mg supplement (MgO) per day usually prevents hypomagnesemic tetany.

Displaced Abomasum

• Dislocation of abomasum to the left (LDA) or to right (RDA) in stomach in relation to normal placing (floor of abdomen)
• Approx. 80-90% of incidences are LDA and most frequent in high producing cows in the first 4 weeks postpartum
• Predisposition- High concentrate, low roughage and diets with smaller particle size, sudden changes in the diet and hypocalcaemia in early lactation

• Transition period- Reduced feed consumption and inadequate filling of the rumen- empty space appears for movement of abomasum which therefore does not reach the ventral abdominal wall
• Low ruminal VFA absorption (papillae)- escape to abomasum, reduce abomasal motility, development of atony and onset of displaced abomasums.

Prevention-
• It can be prevented by maintaining the forage to concentrate ratio of the diet fed in late gestation and early lactation and feeding TMR.
• Grain intake after calving should be increased slowly (0.25 kg/day) until peak grain intake is achieved.

Processing of Concentrates

Objectives of processing feeds are-

- To alter the particle size (most imp factor)
- To change moisture content
- To change the density of feed
- To increase nutrient availability
- To change acceptability (palatability)
- To detoxify/remove harmful ingredients
- To improve keeping qualities
- To make the storage easy and safe
- To make animal production more economical

1. Processing of grains method-

1. Wet processing methods: soaking, steamrolling, reconstitution, exploding, gelatinization, pressure cooking
2. Dry processing methods: grinding, dry rolling, crimping, crumbles, popping, micronizing, roasting, extruding, pelleting, decortication.

Processing of grains/cake

1.1 Wet processing methods:

i. **Soaking:** Grains are soaked in water for 6 to 24 hours prior to feeding. Soaked grains soften, swell and become more palatable. They are easy to mix with roughages and reduce toxic factors.
ii. **Reconstitution:** water is added to dry grain (10%) to raise the moisture content to 25-30% and then stored in an oxygen limiting silo for 2-3 weeks prior to feeding. It increases the solubility of the grain carbohydrates and protein.
iii. **Steam rolling/** Crimping: expose grain to steam for a short period to soften the kernel followed by rolling/compressing. Availability of starch is increased.
iv. **Extrusion:** cooking with the application of adequate pressure to expand the feeds is called extrusion. It results in gelatinization of starch.
v. **Exploding:** swelling of grains subjected to high pressure steam (250 psi) for 20 seconds followed by sudden decrease to atmospheric pressure in steel vessels .

vi. **Pelleting (moist):** Densification of grain with steam or moisture. Pelleting reduces the dustiness of feed, increases the palatability, and makes it easy to handle large particles.

vii. **Gelatinization:** Complete disintegration of starch granules of grains by application of moisture, heat and pressure is known as gelatinization. It improves the digestion of feed by action of amylase on soluble carbohydrates.

1.2 <u>Dry processing methods of grains:</u>

viii. **Grinding:** least expensive method of reducing particle size. It breaks the outer layer exposing the starch and increases the surface area exposed to enzymes. Fine grinding increase dustiness and reduce digestibility. Machine hammer mill which reduces the particle size of grain until it passes through a screen of suitable size (1 or 2 mm).

viii. **Dry Rolling:** compression without adding moisture by passing it between moving rolls. It is a combination of breaking and crushing.

viii. **Crimping:** process of rolling of feed ingredients with the use of corrugated rollers is called crimping.

viii. **Crumbles:** breaking of pelleted feeds is called crumbles.

viii. **Popping/ puffing:** application of dry heat (370-425^{0}C) for 15-30 seconds causing a sudden expansion of the grain which ruptures the endosperm/starch granules making it more available for digestion.

viii. **Micronizing:** popping of grains with the application of infra-red heat energy having wavelengths of $3x10^{8}$to $3x10^{11}$ cycles/second.

viii. **Roasting:** Dry heat processing of the grains with direct flame (300^{0}F) is called roasting. Roasting of whole soybeans inactivates enzymes or inhibitory factors, which improve its nutritive value.

viii. **Decorticating /dehulling:** It is the process of removing the outer coat of grains having high fibre and low digestibility. It improves the energy and protein content of the grains.

viii. **Extruding: T**hermo-mechanical process in which the grains are cooked under high pressure with high temperatures for a short time.

viii. **Pelleting (dry):** It is agglomerating of feed by compacting and forcing it through die opening by a mechanical process without application of steam/moisture.

Advantages of pelleting are:

- Improved handling, storage and other handling characteristics
- Less wastage of feed
- Allows combination of several ingredients or formation of complete ration
- Increases feed density and reduces storage space
- Improving nutritional value through instantaneous heat and pressure.

Processing of Roughages

1. Physical processing of roughages

a. Dry processing methods

b. Wet processing method

2. Chemical treatment/processing

3. Biological processing of roughages

2.1. Physical processing of roughages

a. Dry processing methods

i. **Dehydration:** reduction of moisture content in a dehydrator using a temperature 600-1500°F for 3-5 minutes. carotene content is reduced by 5-15% by it.

ii. **Baling:** forage is cut, dried and then bundled with baler for making storage and handling of forage easy and convenient.

iii. **Chopping/ chafing:** chopping with a chaff cutter for easy handling due to increased bulk density. It also improves ruminal digestion of fiber due to increased surface area. Chopping avoids selective feeding thus wastage of plant material is reduced. Chopping to the average particle size of 0.25- to 0.50 inch appears to be optimum. Too much smaller particle size may adversely affect fat content of milk.

iv. **Grinding:** reduces particle size. Fine grinding of less than (0.25) 1/4th inch, reduces the transit time and decreases rumen contractions, pH, VFA production and salivary secretion.

v. **Pelleting:** ground feed compressed to 1/4 to 3/4' inch in diameter and 1/4 to 1.5 inch in length and a density of 18-20 kg/cft. Finely ground fodder plants are not generally pelleted because the fine particle size affects the normal rumen functions by reducing time of mastication, salivary secretion, lowering of rumen buffering and thereby, decreasing rumen pH. It also increases the rate of fermentation and reduces rate of feed passage through GIT.

vi. **Cubing/block and wafering:** highly compressed forage made from long or coarsely chopped material by heat and pressure. Advantages: increased consumption and production, saving in labor cost, less feed wastage.

b. Wet processing:

Soaking: mixing or spraying water on roughages to soften the stem to improve its palatability and mix the concentrates uniformly which improves the feed intake and digestibility of roughages.

2.2 Chemical treatment of roughages

Treated with chemicals such as sodium or potassium hydroxide and urea to increase the availability of the nutrients to livestock.

i. Urea treatment: Urea treatment is most economical and easiest.

Method: 4 kg urea dissolved in 40 litres of water and sprayed over 100 kg of straw.

- Urea hydrolysis by urease: Ammonia □ breakage of lignocellulose bond by ammonia thereby releasing cellulose from lignin bondage for digestion and utilization.
- After 21 days the urea treated paddy straw is ready for feeding.

Advantages:

- Increase the CP and TDN content from 2% to 10% and 45 to 60%, respectively.
- It improves the palatability.
- Special consideration while feeding urea treated straw:
  - Not advisable to feed the urea treated straw for calves below 6 months of age.
  - Adaptation period is required.
  - **NaOH treatment:** 1.2-1.5% sol.□ Beckmann's method.

ii. $Ca(OH)_2$ + NaOH treatment: both 4%.

iii. 3% Anhydrous NH_3: bind with sugar 4-methylimidazole (cause Bovine bonker)

2.3. Biological processing of roughages

- **Enzyme treatment:** Cellulase improves cellulose digestibility (25 mg/100 kg straw).
- **White-rot fungi, mushrooms and other microbes:** Some of the white-rot fungi like *Phanerochaete chrysosporium* degrade lignin to the extent of 65-75% while other fungi like *Ganoderma applanatum* and *Coriolus versicolor* degrade over 45% of lignin in the lignocellulosic straws.
- Indo-Dutch project on bioconversion of crop residues is a bilateral project of the governments of India and the Netherlands use of fibrous crop residues as animal feed by using on white-rot Basidiomycetes, often belonging to the non-toxic and edible mushrooms.
- **Zadrazil process:** Straw was treated with *Pleurotus spp* (mushroom). This process causes enormous losses of organic matter and therefore is not fit for small level operations.
- **Karnal process:** two-stage technique.
    - In first stage, cereal straws are treated with 4% urea and 40% moisture and ensiled for 30 days followed by
    - second stage in which the urea treated material is mixed thoroughly with 1% single superphosphate, 0.1% calcium oxide and then moisturize to 60-65% before inoculation with 3% *Coprinus fimetarius* (alkali tolerant fungus strain) culture grown on millets.

The solid substrate fermentation is terminated at the mycelial stage of growth of *C. fimetarius*.