Unit-III

- Common feeds and fodders of Rajasthan and their nutritional importance.
- Feeding standards and nutritional requirements of domestic animals.
- Importance of nutrients in animal production and health.
- Proximate and detergent system of analysis.
- Digestion, absorption and metabolism of carbohydrates, fat and Protein in ruminants and non-ruminants.
- Balanced ration, computation of ration and feeding of dairy cattle, buffaloes for various physiological phases of life.
- Formulation and feeding of sheep and goat during different phases of life.
- Formulation and Feeding of poultry, swine and eqines for various categories.
- Conservation and preservation of fodders, improvement of poor quality roughages and processing of feed and fodders for improvement of nutritive value.
- Anti-nutrtitional factors and common adulterants in feeds and fodders.
- Feed additives, supplements and growth stimulants in the ration of livestock and poultry.

.Fodder Production and Classification

Definition

- **Fodder**: Cultivated crops harvested and used for stall feeding of livestock.
- **Forage**: Vegetative matter, either fresh or preserved, utilized as animal feed, including grasses, legumes, and other plants for hay, pasture, fodder, and silage.

Classification of Forages

A. Based on Season of Cultivation

Season	Examples
Kharif (June - October)	Cowpea, Guar, Field bean, Bajra, Jowar, Maize
Rabi (October - March)	Berseem, Oats, Barley, Lucerne
Summer (April - June)	Cowpea, Guar, Field bean, Maize, Bajra

B. Based on Plant Types

a)Non-Legumes (Graminaceous)

Common Name	Local Name	Scientific Name	Type
Sorghum	Cholam	*Sorghum bicolor*	Annual (Summer)
Sudan Grass	-	*Sorghum sudanense*	

Common Name	Local Name	Scientific Name	Type
Maize	Makkacholam	*Zea mays L.*	
Cumbu / Bajra / Pearl Millet	Cumbu	*Pennisetum glacum*	
Teosinte	-	*Euchlaena mexicana*	
Finger Millet / Ragi	Kelvaragu	*Eleusine corocana*	
Little Millet / Samai	Samai	*Panicum miliare*	
Proso Millet	-	*Panicum miliaceum*	
Oats	-	*Avena sativa*	Annual (Winter)
Barley	-	*Hordeum vulgare*	
Rye	-	*Sicale cereal*	
Hybrid Napier	-	*Pennisetum purpureum x Pennisetum americanum*	Perennial
Guinea Grass	Guinea Pull	*Panicum maximum*	
Para Grass	Neerpull	*Brachiaria mutica*	
Doop / Bermuda Grass	Arugampullu	*Cynodon dactylon*	
Anjan Grass (Buffel)	Kollukkattai Pullu	*Cenchrus ciliaris*	
Black Anjan Grass	Karuppu Kolukkatti Pullu	*Cenchrus setigerus*	

Common Name	Local Name	Scientific Name	Type
Rhodes Grass	Mayil Kondaipullu	*Chloris gayana*	
Signal Grass	-	*Brachiaria decumbens*	

Legumes

Common Name	Local Name	Scientific Name	Type
Cowpea	Karamani	*Vigna unguiculata*	Annual Legume
Rice Bean	-	*Vigna umbellata*	
Moth Bean	Naripayaru	*Phaseolus aconitifolius*	
Gaur / Cluster Bean	Kothavarai	*Cyamopsis tetragonaloba*	
Field Bean / Lab Lab	Mochai	*Lablab purpureus*	
Sun Hemp	Sannappai	*Crotolaria juncea*	
Pillipesara	-	*Dolichos trilobus*	
Berseem / Egyptian Clover	-	*Trifolium alexandrinum*	
Fenugreek (Winter)	Vendiyam	*Trigonella foenum-graecum*	
Senji (Winter)	-	*Melilotus parviflora*	
Lucerne / Alfalfa	Kudiraimasal	*Medicago sativa*	Perenial Legume
Hedge Lucerne	Velimasal	*Desmanthus virgatus*	

Common Name	Local Name	Scientific Name	Type
Stylo	-	*Stylosanthes hamata*	
Schofield Stylo	-	*Stylosanthes guinensis*	
Siratro	-	*Macroptilium atropurpureum*	
Clitoria / Butterfly Pea	Sangupushpam	*Clitoria ternatea*	
Perennial Groundnut	-	*Arachis glabrata*	
Centro	-	*Centrosema sp.*	
Desmodium	-	*Desmodium uncinatum*	

Tree Fodders

Common Name	Local Name	Scientific Name
Soobabul	Soundal	*Leucaena leucocephala*
Catechu	Karungali	*Acacia catechu*
Gum Arabic / Babool	Karuvelam	*Acacia nilotica*
Israeli Babool	-	*Acacia tortilis*
Umbrella Tree	Kudaivel	*Acacia planifrons*
Siris	Vagai	*Albizia lebbeck*
Sisoo	Yette	*Dalbergia sissoo*

Common Name	Local Name	Scientific Name
Karun Dumbi	-	*Diospyros melanoxylon*
Sesbania	Agathi	*Sesbania grandiflora*
Banyan Tree	Alamram	*Ficus bengalensis*
Malai Icchi	-	*Ficus lacor*
Peepal Tree	Arasamaram	*Ficus religiosa*
Anjan	Achamaram	*Hardwickia binata*
Uthimaram	-	*Lannea coromandelica*
Mohwa	Illupai	*Madhuca longifolia*
Neem	Vembu	*Azadirachta indica*

C. Based on Duration of Crop

Type	Examples
Annual Cereal	Maize, Sorghum
Perennial Grass	Hybrid Napier, Guinea Grass
Legumes	Annual: Cowpea, Berseem Perennial: Lucerne, Stylo
Tree	Soobabul, Agathi

D. Based on Nutrient Density in Dry Matter

Category	Examples
Non-Maintenance	Wheat Bhusa, Paddy Straw, Ragi Straw

Maintenance	Jowar, Maize, Bajra
Low Protein	Maize, Oats, Barley
High Protein	Berseem, Lucerne, Cowpea, Subabul leaves

E. Based on Plant Family and Duration

Family	Examples
Legumes	Berseem, Cowpea, Stylo
Non-Legumes	Hybrid Napier, Guinea Grass, Fodder Sorghum

Plant Parts/Residues and By-products Used for Feeding

Category	Description
Straw	Dried remains of crops like wheat, oats, barley
Leguminous Straws	Residues from leguminous crops like cowpea, groundnut
Hay	Entire herbage dried for storage
Silage	Fermented green plant material
Stovers	Byproducts after harvesting grains like maize, jowar
Haulms	Plant material harvested and dried for feed (e.g., groundnut plants)
Bhusa	Refuse collected from threshing pulse crops like Bengal gram

Types of Grasslands in India

Grasslands can be classified into tropical, temperate, and steppe regions. In India, five major types of grasslands have been identified:

Grassland Type	Species	Climate Region
Dicanthium-Cenchrus-Elyonurus	*Dicanthium annulatum*, *Cenchrus ciliaris*, *C. setigerus*	Arid and semi-arid, Northern Gujarat, Rajasthan, Punjab

Sehima-Dicanthium	*Sehima nervosum*, *Chrysopogon montonus*, *Heteropogon contortus*	Semi-arid, Deccan plateau, Chota Nagpur, Aravallis
Phragmites-Saccharum	*Phragmites karka*, *Saccharum spp.*, *Imperata spp.*	Dry-sub-humid, Semi-arid, Gangetic plains, Brahmaputra Valley
Themeda-Arundinella	*Themeda anathera*, *Arundinella spp.*, *Chrysopogon spp.*	Humid, moist sub-humid, Manipur, Assam, West Bengal
Temperate and Alpine	*Agrostis*, *Calamagrostis*, *Dactylis*, *Oryzopis*	Temperate and cold, Himalayan States, Western Ghats

Crops and Fodder

Crop Type	Examples
Annual Crops	Maize, Cumbu, Sorghum.
Cereal Forage	Cereal crops harvested immature for hay, silage, green feed, or pasturage.
Catch Crop	Crop inserted between two principal crops to provide quick livestock feed or improve the soil.
Cover Crop	Annual crops sown to improve soil microclimate and reduce erosion.
Fodder Crops	Cultivated species used for livestock feed in the form of silage, soilage, or hay.
Forage Crops	Crops grown primarily for livestock feed, either harvested or grazed directly by animals.

Nutritional Terms

Term	Definition
Anti-Quality Constituents	Toxic substances in forage that may cause harm or interfere with digestion.
Crude Fibre	Insoluble carbohydrates in feed, including cellulose and lignin, which represent tough plant parts.
Crude Protein	All nitrogenous substances in feed, including true proteins and non-protein nitrogen compounds.

Roughage	Plant materials high in crude fibre and low in digestible nutrients (e.g., straw, stover).

Farming and Grazing Systems

System	Definition
Dairy Husbandry	Care, breeding, feeding, and milking of dairy cattle, as well as milk production and sales.
Integrated Farming	Combination of cropping systems with livestock, poultry, fisheries, and forestry for profitability.
Ley Farming	Alternation of food crops and pasture on the same land.
Intercropping	Growing two or more crops simultaneously on the same land.
Mixed Cropping	Seeds of two or more crops mixed and sown without distinct spacing.

Pasture and Grazing Terms

Term	Definition
Grazing	Partial or complete defoliation of vegetation by livestock.
Grazing Capacity	Number of animals a given pasture can support without overgrazing.
Rotational Grazing	Dividing a pasture into smaller sections and grazing each in rotation to avoid overgrazing.
Silvipasture	An agroforestry system where livestock feed on forage produced by trees and shrubs, as well as grasses.
Strip Grazing	Confining animals to a small area of pasture for a short time using movable fences.
Permanent Pasture	Pasture of perennial plants maintained for several years for grazing.

Crop and Livestock Systems

Term	Definition

Monoculture	Growing the same crop season after season or year after year.
Sequential Cropping	Growing two or more crops in a sequence on the same land.
Row Intercropping	Sowing two or more crops in distinct rows (e.g., 1:1, 1:2, etc.).
Relay Cropping	Sowing seeds of one crop into a standing crop before its harvest.

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.

7. 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.

Nutritional Aspect of Carbohydrates, Proteins, and Fats

Primary Energy Source: essential for maintaining bodily functions, growth, and reproduction.

Classification of Carbohydrates

1. **Monosaccharides-**

- Trioses, Tetroses, Pentoses (e.g. Ribose, Xylose, Arabinose), Hexoses (Glucose, Galactose, Fructose)

2. **Disaccharides-**

- Lactose (Galactose and Glucose by beta 1-4 linkage)/ Milk sugar
- Maltose (Glucose and Glucose by alfa 1-4 linkage)/ Malt sugar
- Sucrose (Glucose and Fructose by alfa 1-4 linkage)/ Table sugar/ Non reducing sugar
- Cellobiose (Glucose and Glucose by beta 1-4 linkage)

3. **Trisaccharide-**

- Raffinose (Galactose, Glucose and Fructose)

4. **Polysaccharide-**

- Glycogen (alfa 1-4 & alfa 1-6 glucose), Starch, Cellulose (beta 1-4 glucose), Dextrin, Inulin
- Mix Polysaccharide- Hemicellulose (beta 1-4 xylose), chitin, Pectin, Mucilage
- Complex polysaccharide- Glycolipids, Glycoproteins

Classification of Amino acid

1. Aliphatic amino acid

Monoamine- Monocarboxylic (Neutral): Glycine, Alanine. Serine, Valine, Leucine, Isoleucine

- Monoamine-Dicarboxylic(acidic): Aspartic acid, Glutamic acid
- Diamino-Monocarboxylic (Basic): Lysine, Arginine,

- Sulphur containing: Methionine, Cystine, Cysteine

2. Aromatic Amino acid: Phenylalanine, Tyrosine

3. **Heterocyclic:** Proline, Histidine, Tryptophan

- Ketogenic amino acid: Leucine, Lysine
- Glucogenic & Ketogenic amino acid: Isoleucine, Phenylalanine, Tyrosine, Tryptophan
- Glucogenic amino acid: Rest all other

Essential amino acid: (By W.C. rose)- Can not synthesised in body

- Pig: Lysine
- Poultry: Glycine
- Sheep: Methionine
- Cat: Taurine

Critical amino acid: Low in practical diet e.g.- Lysine, Methionine

Classification of Fatty acid

- Saturated Fatty acid- butyric acid, caproic acid, lauric acid, Palmitic acid
- Unsaturated Fatty acid- Palmitoleic acid, Oleic, linoleic, Linolenic, Arachidonic acid
- Essential fatty acid in cat- Arachidonic acid and in pig & Poultry- linoleic acid

Classification of Feed and fodder

1.

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

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 diseases.

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.

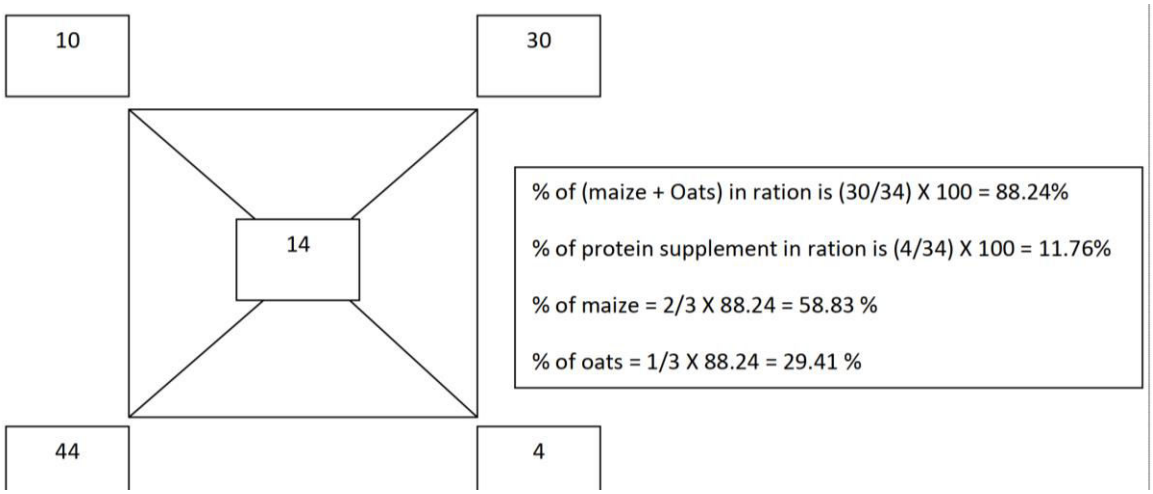
7. **Gradual Changes in Feeding Pattern:**
    - Sudden changes in feed can disrupt digestion. New feeding patterns should be introduced slowly.
8. **Consistent Feeding Schedule:**
    - Feed should be provided at evenly spaced intervals to maintain a stable digestive rhythm.
9. **Proper Preparation:**
    - 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=28and16−9=744 - 16 = 28 \quad \text{and} \quad 16 - 9 = 744−16=28and16−9=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: (2×9)+(1×12)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 $\propto W^{0.67}$

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

- 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/kgW$^{0.75}$/day**, with a mean of **77 kcal/kgW$^{0.75}$/day**.
- **Advantages:**
    - Provides precise energy values for maintenance.

Maintenance Energy Requirements of Various Species

A. Dairy Cattle

1. **Net Energy (NE):**
    - 80 kcal/kgW$^{0.75}$/day.
2. **Metabolizable Energy (ME):**
    - 133 kcal/kgW$^{0.75}$/day.
    - **For Indian cattle and buffaloes:**
        - Proposed by Sen and Ranjhan: **122 kcal/kgW$^{0.75}$/day**.
3. **Digestible Energy (DE):**
    - 155 kcal/kgW$^{0.75}$/day.
4. **Total Digestible Nutrients (TDN):**
    - 35.2 g/kgW$^{0.75}$/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/kgW$^{0.75}$/day (NRC, 1981).
2. **Total Digestible Nutrients (TDN):**
    - 27.3 g/kgW$^{0.75}$/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 g DCP/kg $W^{0.75}$/day.
2. Sheep: 2.73 g DCP/kg $W^{0.75}$/day.
3. Goats: 3 g DCP/kg $W^{0.75}$/day.
4. Horses: 3 g DCP/kg $W^{0.75}$/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

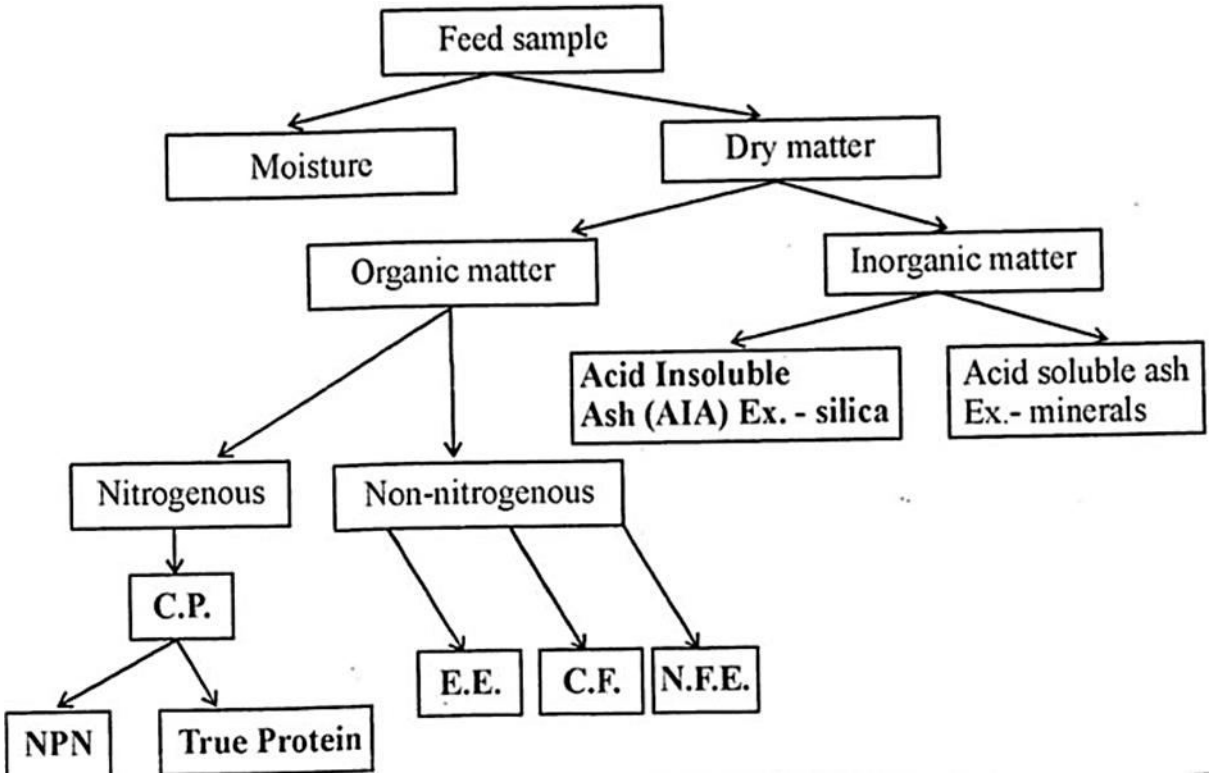
1. **Characteristics:**
   - Comprise **5–7%** of total body protein.
   - Labile reserves used during:
     - Starvation.
     - Periods of reduced protein intake.
   - Restored during periods of adequate protein availability.
2. **Tissue Impact:**
   - Depleted first in the **liver**, followed by kidneys, 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

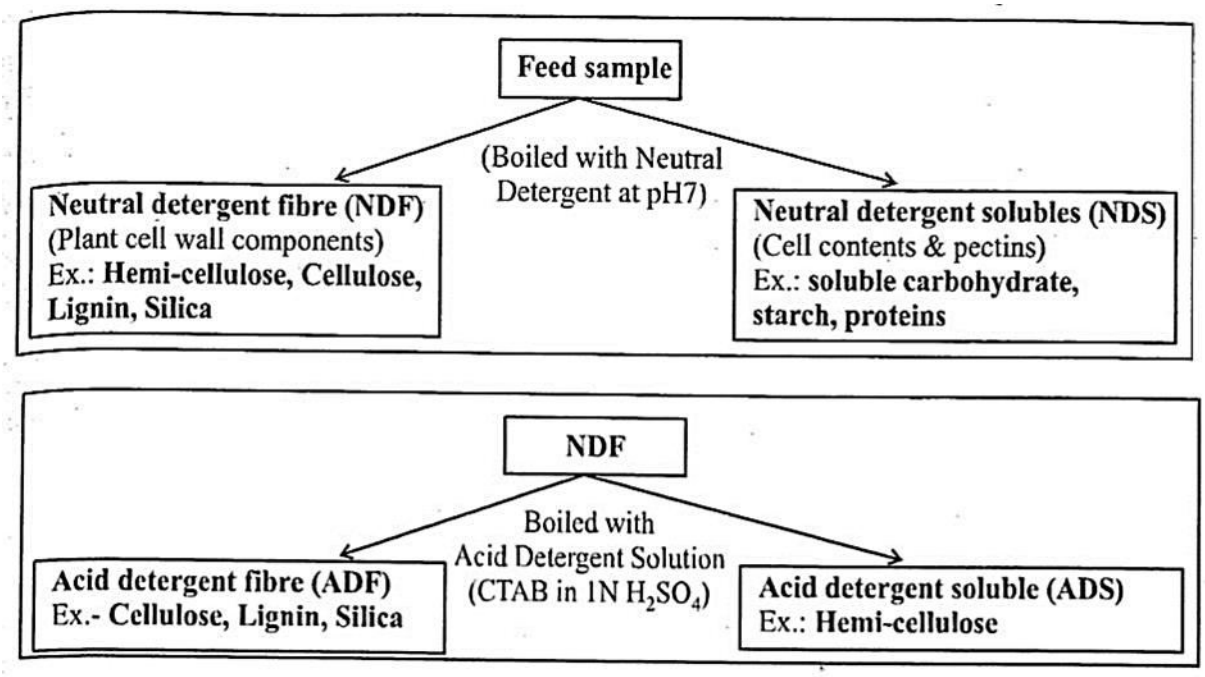
1. **Definition:**
   - **Bypass protein** refers to dietary protein that escapes rumen degradation (undegraded protein, UDP).
2. **Proportion in Normal Diet:**
   - Typically, **60% of dietary protein** is degraded in the rumen, while **40% remains as UDP**.

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.

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	ıhibit :oteolytic :tivity	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	ıhibit :oteolytic :tivity	Astringent in nature, decrease lubrication nature of saliva, decrease fiber digestibility	Detannification (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
ıti-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
ıti-vitamin K	Interfere blood clotting mechanis m	Sweet clover (Dicoumarol)	Reduce prothrombin	Water soaking and Autoclavin g
Anti-pyridoxin e	)epress activity of Vitamin B6	Linseed		Water soaking and autoclaving
Anti-niacin	Niacytin, antagonist to niacin	Maize, wheat bran	Perosis and growth	Autoclaving

			depressio n	

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

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

5. **Good Nutritive Condition:**
    - Poor nutrition decreases heat production during fasting.
6. **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.
7. **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.
8. **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

4. **Fasting Metabolism:**
    - Specific to ruminants; measures heat production at designated times after feeding.

5. **Standard Metabolism:**
    - Heat production measured within a specific period after feeding to avoid prolonged fasting issues.
6. **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

5. **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.
6. **Kleiber's Modification:**
    - $67.6 \times W^{0.756}$.
7. **NRC General Formula:**

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

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

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 (NH3 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

conservation 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 KMnO4 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

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.

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

Nutrient Requirements and Methods

A. Energy Requirement For Maintenance

1. BMR = By Direct or Indirect calorimetry
2. Feeding trial: amount of feed energy sufficient to maintain constant weight

• **Basal Metabolic Rate:** Non-ruminants = number of calories required to keep your body just functioning under
following conditions:
1. Good nutritive conditions: Poor state tends to decrease basal heat production.
2. Environmental temperature: Thermo-neutral zone/ temperature of about 25oC.
3. Complete Rest: minimum muscular activity,
4. Post-absorptive state –to make sure that heat increment due to digestion and assimilation has been dissipated.

• **Resting metabolism:** ruminants (because minimum muscular activity is very difficult for animals).
• Activity increment: 50% of basal metabolism in poultry and 20-30% in case of sheep/goat/swine/cattle.
• **Fasting Metabolism:** ruminants (very hard to achieve Post-absorptive state) – so, heat production at specific times after last feeding.

Confirmation of Post-absorptive state:
• Measurement of heat production to a point of a constant minimum level.
• A Respiratory Quotient (RQ) of 0.7 (fat).
• Ruminants: a decline in methane excretion to a minimum level.
• For example, from 30 L of methane to 0.5 L in sheep and from 200 L to 2 L in cattle by 3rd day of fasting.

Unit of Reference in Fasting/Basal Metabolism:
• Rubner: BMR varies with body size = metabolic body size = surface area law
• BMR = 70W 0.75 Kg

For dairy cattle and buffalo:
• NEm = 80 W0.75 (Kcal/day)
• MEm = 133 W0.75 (Kcal/day)
• TDNm = 35.2 W0.75 (g/day)

B. Protein Requirement For Maintenance

1. Feeding trial = minimum dietary protein to maintain body weight
2. Nitrogen balance method- equilibrium = minimum constant N-output
3. Factorial method = EUN+MFN

• Endogenous urinary nitrogen = EUN mg/day = 146 W0.72 kg = Function of Body size
• Indian cattle = 0.020 g/kg BW
• Bos taurus = 0.289 g/kg BW
• Metabolic fecal nitrogen = MFN = Function of DMI
• Indian cattle = 0.35 g/100 g DMI
• Buffaloes = 0.34 g/100 g DMI

Note:
Total or basal endogenous nitrogen excretion of ruminants:- 350mg N/kgW0.75 /day
Dermal losses of nitrogen= 2.2g N/day
• Maintenance requirements of breeds with high milk potential are 20% higher than those with low milk potential

• Maintenance requirements of Bos indicus breeds are 10% lower than Bos Taurus
• Maintenance / NEm requirement of male/ bull is 15% higher than female/cow

C. Energy Requirement For Growth

1. Feeding Trials: different levels of feed energy for optimum/ normal growth
2. Factorial Method: BMR + activity increment + Weight gain (slaughter)

D. Protein Requirement For Growth

1. Feeding trial = minimum dietary protein required to give the maximum growth
2. Nitrogen balance method- minimum dietary protein which provides maximum retention
3. Factorial method = EUN + MFN + Weight Gain (slaughter)

E. Energy and Protein Requirement For Reproduction

• Significant only during last trimester of pregnancy

F. Energy Requirement For lactation

• Depend upon composition of milk, milk yield and efficiency of conversion of dietary energy to milk energy.

1. Bomb calorimeter – total energy
2. Gaines formula: Fat corrected milk (FCM), kg : 0.4 (Milk yield, kg) + 15 (Total fat yield, kg)

• Example: 750 Kcal of NE is required for one kg of FCM.
• Efficiency of conversion of ME to NE of milk = 62%
• Efficiency of conversion of DE to ME = 82% (ME= DE x 0.82)
• DE requirement for one kg of FCM = 1460 Kcal DE
• The amount of TDN required per kg of FCM = 0.330 kg

G. Protein Requirement For lactation

• Depends upon protein content of milk and efficiency of utilization of digestible protein for making milk protein (generally 60-70%).
• Milk = 3.5% protein = 35 g protein per kg milk
• Dietary Digestible protein required: 50-55 g protein

Energy and protein requirement for egg production

• Energy requirement: maintenance + energy content of egg + efficiency of utilization (68%)
• Daily energy requirement = 314 kcal
• Protein requirement: maintenance + protein content of egg + efficiency of utilization (46-57%) + loss
• Daily protein required:
• Maintenance = 3 g/d
• One egg = 6 g/d
• Feathers = 0.1 g/d
• Total = 9.1 g protein/d
• 46% efficiency = 9.1+ 0.54x9.1= 14g protein.
• From Feeding experiment : 16 g protein /day

Feeding Practices for Cattle and Buffalo

Thumb rule

Feed stuffs	Zebu / indigenous cow	Crossbred cow/ buffaloes
Straw	4.00 kg	4.00-6.00 kg
Concentrates mix		
Maintenance	1.25 kg	2.00 kg
Pregnancy (last trimester)	1.25 kg	1.75 kg
Lactation	1.00 kg/ 2.5 kg MY	1.00 kg/ 2.0 kg MY

- 1 kg Concentrate mix = 10 kg green fodder
- Concentrate mixture = 20% CP, 65% TDN, 0.5-0.7% Ca and 0.3-04% P

3.1 Feeding of calves

Best feeding practice for rearing a calf is to start feeding from the last trimester of pregnancy then in the pre-ruminant period and post ruminant period.

Extra nutrients should be given during the last trimester of gestation to dam with 15- 20 kg green fodder daily to make colostrum rich in vitamin A.

Pre-ruminant period-0-3 month Feeding during pre-ruminant stage can be divided into following steps

1. Colostrum feeding
2. Whole milk feeding
3. Skim milk
4. Calf starter
5. Milk replacer
6. Roughase–hay

- Colostrum: within 2 hours @ 1/10th BW (17% protein, IgM, IgA, IgG)
- Milk replacer:
- Calf starter- Offer fresh lush green fodder free of choice for proper rumen development.

Importance of Colostrum feeding

- Provide passive immunity so calf fed colostrum remain quite healthy Laxative effect hence avoid constipation
- Excellent source of Vit A, D, & E
- Contain antibacterial substances-lactoferrin, lactoperoxidase & lysozyme

FEEDING SCHEDULE OF COW CALVES (0-3 months): WHOLE MILK+ SKIM MILK+ CALF STARTER

Age(days)	Colostrum (lit)	Milk(lit)	Skim milk(lit)	Calf starter(g)
1-3	1/10th B.wt	-	-	-
4-7		1/10th B.wt		-
8-14		1/10th B.wt		-
15-21		1/10th B.wt		Little
22-35	-	1/15th B.wt	-	100
upto 60 days		1/20th B.wt	1/25th B.wt	250

61-90		1/25th B.wt	1/15th B.wt	500

Milk replacer is introduced to cut the feeding cost so that rearing of the calf becomes economical. Achieve comparable weight gain to that of whole milk.

Composition:

Dried skim milk	50
Dried whey	30
Dextrose	8
Oat flour	5
Brewer yeast	5.26
Trace minerals	0.04
Vitamin A	1.7
total	100

Calf starter-

- solid feed consisting of ground grains, oil cakes, animal protein supplement, brans, dried skim milk, soymeal, whey, mineral mix, and butyrate.
- For accelerated growth and early weaning of the calves.
- It should contain 23-26% CP, 18-19.5% DCP and 75% TDN.
- Started at 7-10 days (14 days).
- Calf starter is a crucial link for proper rumen development and reduces the stress of weaning and saves the calf from diarrhea.

Feeding from 3 months to 6 months:

- From 3rd month onward green forages can be given @ 2Kg/day and gradually raising its quantity to 5-6 kg/day at 6 months.

- Concentrate mixture the same as fed to adults should be fed 0.75 kg in 4th, 1kg in 5th and 1.5 kg in 6th months of age.
- After the 6th month, individual feeding of the calf should be stopped. Hay should be fed ad lib to calves.
- For economical raising of calves, they should be maintained on high quality roughage and minimum of concentrate.

3.2 Feeding high yielders:

- Energy: Feeding bypass fat to ruminants
- Protein: Feeding bypass protein to ruminants = UDP = 8% of total diet protein%
- Fiber: 28-32% NDF
- Mineral mixture: 10g MM/ kg of milk production.
- Challenge feeding: steaming up (2 weeks prior to calving)

DCAD salt in pre-partum transition period to maintain a negative dietary cation- anion difference (-100 to -140 meq/kg DMI) for stimulation of parathyroid gland. Activation of parathyroid gland prior to calving, maintain Ca homeostasis and help in avoiding milk fever.

Bypass nutrient technology used in high yielder:

- ✓ Bypass nutrient technology is an important nutritional tool to **increase the productivity** of animals.
- ✓ Bypass nutrients (mainly fat and protein) are protected from hydrolysis in rumen, which gets **absorbed from the lower digestive tract** without altering the rumen environment.
- ✓ It represents a fraction of the nutrient that is **fermented** in the rumen to a comparatively **low degree**.
- ✓ It also has a function to provide the rumen microbes with a **steady supply of nutrients**, rather than with sudden bursts from easily soluble nutrients.

Theoretical considerations about slowly degradable nutrients: there are 3 type of nutrients that could bypass rumen fermentation to certain degree:

- protein/amino acids,
- fats/fatty acids
- starch
- Minerals (Zn, Cn, Mn) can be chelated, but in that form they entirely bypass the rumen, as they are stable at ruminal.

Objective and importance of bypass nutrient:

- The purpose of feeding "bypass" protein is that a large proportion of the protein is available directly at the lower part of the gastro-intestinal tract, where it is digested and then absorbed as amino acids for utilization at tissue level. The bypass protein provides high quality protein rich in essential amino acids directly at the intestine level.
- Feeding of "bypass" starch reduces excess production of lactic acid in the rumen, which would otherwise result in low rumen pH (acidosis), thereby affecting fibre digestion.
- Bypass fat is generally fed during the early lactation to avoid disturbance to rumen fermentation that is generally encountered when ration is made energy dense with cereals and fat.
- Additionally, it meets the energy requirement of high yielding animals to avoid NEB. Thus, Feeding of "bypass" fat (protected fat) is done primarily to avoid ruminal hydrolysis of bio-hydrogenation of unsaturated fatty acids and increasing energy density of feeds.

Methods of making bypass protein:

1. Natural bypass protein source: Blood meal, Fish meal, Meat meal, cottonseed cake, maize gluten meal, coconut meal, Linseed meal.
2. Formaldehyde treatment: applied @ 1.2 g/100 g CP to reduce the degradability of highly degradable proteins in rumen. However, corrosive nature and carcinogenic effects. Most widely used method.
3. Treatment with metal ions: $ZnCl_2$ and $ZnSO_4$
4. Coating with insoluble protein
5. Acid and alkali treatment: NaOH, HCl, propionic acid – denaturation
6. Heat treatment: groundnut cake and soybean meal at 150°C for 2 hours seems to give sufficient protection.

Note:

✓ During the solvent extraction and expeller method of oil cakes, the temperature reaches only 90- 95 °C and the proteins are only partially protected at this temperature.

Methods of making bypass fat :

1. Naturally protected: cotton seeds
2. Prilled fatty acids
3. Lipids encapsulated by formaldehyde treated protein
4. Ca- salt of long chain fatty acids/ Fusion Method – commercial method/ less rumen degradable + Ca source (CaOH).

Note:

i. Maximal milk production efficiency can be achieved when the supplemental dietary fat provides 15-20% of dietary metabolizable energy or dietary fat @ 6-7% of DMI.

ii. 80-90% FA of unprotected fat are bio-hydrogenated in rumen, but in Ca-LCFA it is 30-40% only.

iii. Unsaturated fat: CLA (conjugated linoleic acid)- health benefits

iv. Supplementation of RPF has no adverse effects on the rumen fermentation even up to 15% of DMI but, Feeding RPF at or above 9% of DMI has no additional benefits in lactating cows

v. During early lactation, maximum response can be achieved at 150– 300 g Ca-LCFA/day/animal.

vi. 3% fat from diet (roughages and concentrate mix) + 3% from Bypass fat.

vii. Bypass fat: 7-8 % Ca, 80 -85 % rumen protected fat.

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 Sheep and Goat

Feeding of Kids

- Birth weight= 1-5 kg
- After birth within 1 hour the kids should get colostrum continued for 3 days.
- After the 3rd day up to weaning, feed them with milk at 2 to 3 times a day (1/6th BW up to 1 month and then 1/8th of BW in the 2nd month and 1/10th-1/12th BW during the 3rd month).
- Milk feeding completely stopped after the 3rd month.
- At about 2 weeks of age: Young ones should be trained to eat green roughages and hay.
- At 1 month of age: Young ones should be provided with concentrate mixture (starter feed).
- Provided @ 100 ml/per kg live weight

Creep Feeding

- Creep feeding means providing supplemental feed for nursing kids for rapid growth
- Essential component of an accelerated growth or early weaning management program
- It is a palatable and easily digestible concentrate mixture
- Also contains antibiotics like oxytetracycline or chlortetracycline @ 15 to 25 mg/kg of feed.
- After one-two weeks, creep feed is given, which contains

- If grasses and cereal fodder—DCP 18% & TDN 75%
- If leguminous fodder –DCP 12% and TDN 70%
- Helps in rapid growth of kid
- Hasten the rumen development
- Offer feed @ 50-100gm/animal/ day, and as gradually they eat more, reduce the milk allowance.
- Creep feed started from 10th day up to 90 days of age or pre-weaning period for faster gain

Advantage of creep feeding

- Increases pre-weaning weight gain. Kids will have greater weight gain per day of age as conversion of creep feed to body weight is very efficient process
- Reach target market weight at very young age
- Reduces the stress associated with weaning
- Transition from milk to dry diet will be much smoother

Feeding Schedule for a Kid from Birth to 90 days

Age of kids	Dam's milk or cow milk (ml)	Creep feed (g)	Forage, green/day (g)
1-3 days	Colostrum 300 ml, 3 feedings	-	-
4-14 days	350 ml, 3 feedings	-	-
15-30 days	350 ml, 3 feedings	A little	A little
31-60 days	400 ml, 2 feedings	100-150	Free choice
61-90 days	200 ml, 2 feedings	200-250	Free choice

Feeding of growing & Finishing:

- Extensive system doesn't fulfill the requirement
- The concentrate mixture/day should be fed as per the following recommendations

B. Wt. (Kg)	Quantity of concentrate mix* (gm/ day)	
	When good quality fodders are available ad. lib. (e.g. green oat, cowpea, maize, Dub and their hays)	When poor quality fodders are available ad. lib. (e.g. mature grasses, straws, stover etc.)
10 to 15	**50**	**300**
16 to 25	100	400
26 to 35	150	600

- Under excellent forage condition, lambs may reach slaughter weight early
- Finisher lambs are usually 5-6 month of age and weight 28-40 kg

- Slaughter or market lamb should have weight between 45-65 kg
- Rate of weight gain per day in growing lamb – 50-200 g/day

Flushing

- 25% more nutrients above the maintenance from 2-3 weeks prior to breeding till breeding season.
- Flushing brings ewes/does into heat earlier in the breeding season, ewes/does exhibit heat at same time and increases the lambing/kidding rate and incidence of multiple births.
- Mostly energy component is increased about one month before introduction of the bucks
- Mainly to increase body weight, ovulation rate and thus litter size
- This process should continue throughout the breeding season and for approx. 30-40 days after removing the bucks
- For increasing the ovulation rate and consequently the lambing rate.

FEEDING OF PREGNANT DOES

- Gestation period of ewes is about 143-151 days, on an average 147 days.
- During the first half of gestation period the growth of foetus is not so rapid
- Foetal growth in the last two months of pregnancy is rapid and the metabolic rate of the goat rises rapidly.
- During this period increase ration content to the level of production ration (0.2-0.7kg conc./days/ doe).
- Breeding ram and pregnant ewes (last 6 weeks) should be provided with 50% more nutrients than the maintenance needs.
- Need additional water throughout pregnancy
- Concentrate mixture for pregnant ewe= 150-250 gm/day + 8-9 hrs of grazing
- During last 6 weeks of gestation
    - Excessive energy intake leads to fattening birth difficulty
    - Low energy intake low birth weight, reduced viability & pregnancy toxemia may result in ewes.
- The advantage of extra allowances of feed given during the last half gestation period are as below:
    - It increases the birth weight of lambs.
    - It reduces the number of weak or crippled lambs.
    - It reduces the chance of lambing paralysis which occurs just before lambing.
    - It increases milk of ewes and thereby avoids the tendency for disowning their own lambs.
- For pregnant but lactating goats 300-400 g of concentrate mixture/kg of milk produced should be given in addition to maintenance amount of 150 g/day.

Feeding of lactating ewes/Does

- Nutritional requirement is 2-3 times greater during lactation
- With twin produce 20-40% more milk than with single
- Peak milk yield in early 2-3 weeks
- After lambing plenty of water and light feed should be offered
- By the 3rd day, regular ration can be brought up
- Gradually the feeding of ewes should be increased and start diminishing concentrate feeding by 8th week

- Lactating sheep's need twice the maintenance requirement during the first 2 months and 1.5 times for the remaining period.
- DMI during 1st half of lactating goat is 4-5% and 3-4% of body weight during later half
- For an adult in lactation about 400 g of concentrate mixture or 0.5kg hay or 1kg of good quality green fodder must be given for every ltr of milk produced and over and above that 150 g should be added for maintenance.
- A concentrate mixture for lactating goats should contain about 9-10% DCP and 60-65% TDN.
- A goat weighing 50kg and yielding 2 litres of milk (4% fat) requires 400g of conc. and 5kg of berseem or lucerne.

Conc. mixture for goat:- (Add 2% MM+ 2% Salt)

- 1:2:1 part of wheat bran, maize grain and linseed-cake;
- 2:1:2:2 parts of maize grain, barley, mustard-cake and gram husk;
- 1:2:1 part of wheat bran, barley grain, and groundnut-cake;
- 2:1 parts of gram grain and wheat bran.

Feeding of bucks/Rams

- Breeding males are fed 3-3.5% of total body weight.
- Ration providing 5-6% DCP and 50-60% TDN
- Average breeding buck/ram need 500 g to 1 kg concentrate and yearlings about 25g.
- Avoid excessive weight gain
- If pasture is unavailable, feed hay and concentrate up to 0.7 kg/day

Imp fact

Sheep

• The sulfur containing amino acid, methionine, is the first limiting amino acid for growth of wool and weight gain.
• Feeding habit: grazing
• DMI: 3% both for meat and milk
• Digestion: less efficient than goat
• Maintenance:

DCP: 2.73 g per kg metabolic body size
TDN: 27.3 g per kg metabolic body size
ME: 98 kcal per kg met. Body size

• Weaning age- 90 days
• Colostrum- 100 ml/ kg bwt
• The practice of providing supplemental feed to nursing lambs: creep feeding.
• From 10 days of age to weaning at 90 days to promote growth during early age and rumen development.
• Grower ration: 15% DCP and 72% TDN
• Sheep finisher ration- 13% DCP and 70% TDN
• Reproduction: Breeding rams and pregnant ewes during the last 6 weeks of pregnancy should be provided with 50% more nutrients than the maintenance needs.
• Breeding season Ram- 250-500 g concentrate mix daily
• Milk Production: Sheep are mainly raised for lamb and wool but not for milk production. However, for the nutrition of the lamb, lactating sheep need twice the maintenance

requirements during the first 2 months of lactation followed by 1.5 times the maintenance during the remaining period.
• If good quality pasture is not available: 400 g concentrate mixture

Goat

• Goat: DCP- 3g/ kg metabolic body size
• TDN- 30 g/ kg metabolic body size
• DMI: for meat = 3% BW and milk = 4-6% BW
• Breeding buck- conc. 4-6% DCP, 60% TDN
• Finisher goat, Pregnant and lactating goat- 5-6% DCP and 60% TDN
• Goat grower con. - 12% DCP, 65% TDN
• If good quality pasture not available: 250-500 g concentrate mixture
• Pregnant doe- pasture plus 500 g conc.

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 (NH3 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