DEPARTMENT OF ANIMAL NUTRITION

CLASS-NOTES

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

THEORY

UNIT-2

APPLIED RUMINANT NUTRITION-I

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SYLLABUS

UNIT-2 (APPLIED RUMINANT NUTRITION-I)

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

INTRODUCTION

Applied Animal Nutrition (Ruminants) course deals with practical application of basic knowledge we learned from course Principles of Animal Nutrition and Feed Technology in day to day feeding of ruminants.

Difference between Ruminants and Non-ruminants

Ruminants	Non-ruminants
1. Ruminants have compartmental stomach (Rumen, Reticulum, Omasum & Abomasum)	1. Non-ruminants have simple stomach (Abomasum only)
2. Ruminants can utilize fibrous feed efficiently.	2. Non-ruminants cannot utilize fibrous feed efficiently.
3. Ruminants are also called as Foregut fermenter. Fermentation of feed takes place in foregut (rumen & reticulum).	3. Non-ruminants are also called as hindgut fermenter. Fermentation of feed takes place in hindgut (caecum & colon).
4. Microbial digestion	4. Enzymatic digestion
5. Ruminants can utilize non-protein nitrogen sources.	5. Non-ruminants cannot utilize non-protein nitrogen sources.
Ex. Cattle, Buffalo, Sheep, Goat	Ex. Horse, Pig, Rabbit, Dog, Elephant

PHYSIOLOGICAL PHASES IN LIVESTOCK PRODUCTION

The science of livestock production divides itself into several different physiological phases. Every animal should be fed so that the nutritive requirements of each physiological phase of production with which it is involved are met.

The physiological phases are –

- Maintenance
- Growth
- Pregnancy
- Lactation
- Work
- Wool production

Maintenance:

Maintenance requirement is the amount of the nutrients required to maintain an animal in equilibrium state without any gain or loss of body weight.

- ✓ Maintaining an animal in a state of well-being or good health from day to day, makes no growth, develops no fetus or yields no product.
- ✓ While formulating rations, the maintenance nutrient requirements are satisfied first and the requirements for other purposes are in addition to maintenance.
- ✓ On an average, about one-half of all feed fed to livestock goes for maintenance.
- ✓ The requirements for maintenance are as follows:
    a. Energy for the vital functions: heartbeat, respiration, body temperature, blood circulation and for voluntary activity.
    b. Protein for the repair of body tissues.
    c. Minerals to replace mineral losses.
    d. All of the vitamins are essential for maintenance.
    e. Water is required for essentially all body functions.

Growth

- ✓ Growth is increase in muscle, bone, organs, and connective tissue.
- ✓ Growth is essential for animal to produce meat or to attain mature body size.
- ✓ The daily growth rate of animals increases up to puberty and then gradually declines.
- ✓ The nutritive requirements for growth are in addition to that required for maintenance.
- ✓ The primary nutrients required for growth:
    a. Protein: Formation of muscle and connective tissue and to a considerable degree of bone is primarily protein. Hence, protein is one of the major nutritive requirements of growth.
    b. Energy in the form of net energy must be provided to meet this need in addition to that in the protein of tissue.
    c. Minerals: Since bone formation is a primary activity of growth and since bone is high in calcium and phosphorus content, these two minerals are very essential for growth.
    d. Vitamins: Certain vitamins function in various metabolic processes related to nutrient utilization for growth.
    e. Water: Fat-free muscle tissue is about 75% to 80% water.

Pregnancy

- ✓ Nutritive requirements for development of foetus are energy, protein, calcium, phosphorus, and vitamin D in particular and other minerals and vitamins.
- ✓ More than 2/3rd of the foetus growth occurs during the last trimester of pregnancy.
- ✓ Proper feeding during pregnancy is essential to avoid birth of dead foetus or weak foetus, to build up body reserves lost during early lactation and at the same time the animal should not become obese.

Lactation (Milk Production)

- ✓ Milk is produced and secreted by the mammary glands.
- ✓ Nutrients for milk production are carried by the blood to the mammary glands.
- ✓ The nutrients are removed from the blood by the mammary glands, converted into milk, and secreted into the udder more or less throughout the day.
- ✓ Nutritive requirements for milk production are in proportion to the amount of milk produced.

The major nutritive requirements for lactation are:

a. Protein: Must be of good quality at the glandular level. If ration is deficient in protein, tissue reserves of protein may be used for milk production
b. Energy: Energy over and above that for milk protein is required for the formation of milk fat and sugar. Must be in the form of net energy.
c. Minerals and vitamins

Wool production

- ✓ Wool is practically pure protein and contains Sulphur containing amino acids.
- ✓ **The primary nutritive requirements for wool production are :**

a. Protein: Must be sulfur-containing as fed or as synthesized in the rumen.
b. Energy: This must be in the form of net energy and can come from any feed energy source.
c. Potassium: This mineral is an essential component of the suint in wool.
d. Other minerals and vitamins

Work

- ✓ Energy, protein, minerals and vitamins are required to carry out work.

IMPORTANCE OF SCIENTIFIC FEEDING IN RUMINANTS

Present status of feeding ruminants in India

Cattle and Buffalo

- Non-descript cows and buffaloes with low milk production ability are allowed for grazing after morning milking till evening milking time.
- Medium and high yielding animals are maintained in house and fed with cultivated fodder/grasses. In addition concentrate feeds comprising of grains, oil cakes; bran's and mineral supplements are fed.
- In organized farms, the body weight of the animals are measured and the nutrient requirement of the animal for maintenance and production are calculated and accordingly fed as a balanced ration containing green fodder, dry fodder and concentrates.

Sheep and Goats

- Nearly 80 to 90 % of the sheep and goats in India are reared under free range system.
- They are allowed for 6–8 hours grazing on pastures, cultivated lands, and village pond bunds. Occasionally tree leaves are lopped and fed.
- In few parts of India, intensive goat farming through deep litter system or slatted floor housing system where the sheep and goats are stall fed with cultivated fodders and concentrates.

What is Scientific Feeding

Scientific feeding involves:

- An understanding of the various nutrients required by livestock animals for different physiological functions such as maintenance, growth, reproduction, milk production, wool production, work, etc.
- An understanding of the physical, chemical and nutrient composition of different feed and fodder resources available, the nutrients contained in them and how efficiently they are utilized by the animals.
- Formulating balanced and economic rations by combination of different feed and fodder resources to supply the nutrients to livestock for different physiological functions.

Why scientific feeding should be practiced?

- To explore the genetic potential of livestock animals by feeding a balanced ration to meet the daily nutrient requirements for better animal performance.
- India possesses a huge livestock population. There is a deficiency of 11% of dry fodder, 28% of concentrates and 35 % of green fodder. So a judicious use of available feed resources is possible only through scientific feeding.

BALANCED RATION

Ration: The amount of feed supplied to an animal for a period of 24 hour.

Diet: Feed ingredients including water, which is consumed by animals at a time.

Balanced ration: A ration which provides proper amounts and proportions of all the required nutrients needed to keep the animal healthy and productive.

Desirable characteristics of a balanced ration

The ration should be properly balanced

- With a correct and balanced ration a cow can get the best out of all the constituents present in her feed resulting in production of milk at cheaper cost.
- In improperly balanced ration, much of the feed is wasted. What is eaten by the cow is not important but what she digests is important.
- Because the feed digested alone goes for milk production and maintenance of the body. A balanced ration is thus more purposeful and beneficial.

The ration must be palatable

- Whatever feed given to an animal must be to its liking.
- Evil smelling, mouldy, musty, spoiled and inferior feeds are unpalatable and must not be given to the animals.
- If some excellent feed is not good in taste, they should be improved by special preparations like addition of salt or other feed additives.

The combination of variety of feed in the ration

- By combining many feeds in a ration, a better and balanced mixture of proteins, vitamins and other nutrients are furnished than by depending on only a few.
- Variety of feeds in the ration makes it more palatable.

The ration should contain enough of mineral matter

- Every litre of milk yielded by a cow contains a little more than 0.7% of mineral matter.
- If the amount of mineral matter in the ration is not sufficient to meet the demand in the milk yield, the cow shall have to draw upon her own body supplies or fall down in milk yield.
- At the end of her lactation, the cow will be left as an extremely weak animal and her milk yield in subsequent lactation will go down considerably.

The ration should be fairly laxative

- Constipation is often the cause of most of the digestive troubles.
- It is, therefore, necessary to give such feeds, which are laxative in character.

The ration should be fairly bulky

- The stomach of cattle is very capacious and they do not feel satisfied unless their bellies are properly filled up.
- From the point of providing energy, indigestible fibre is not of any great importance but it plays an important role in giving a feeling of fullness to cattle.
- If the bulk of the ration supplied is small, however rich it might be in its nourishing constituents, cattle may fall a victim to the depraved habits of eating earth, rags, dirty refuses, etc., for filling up stomachs.

The ration should contain sufficient green fodder

- Green succulent fodders are of great importance in feeding of milch animals because of their cooling and slightly laxative action.
- They aid in the appetite and keep the animal in good condition.
- Green fodders are bulky, easily digestible, laxative and contain enough of necessary vitamins.
- Leguminous green fodders are very rich in proteins.

The ration should be economic

Feedstuffs used in ruminant nutrition

- Balanced rations for ruminants are made up of five basic types of feed.

The five types of feed are:

I) Bulky forages for energy

- ✓ They include fresh materials, such as green grass, cereal crops as well as dry materials, such as hay.
- ✓ They provide most of the energy ruminants needs and some minerals and will make up most of the ration – they are what fills the animal and stops it feeling hungry.
- ✓ Most bulk forages contain low levels of protein.
- ✓ **For example:**

  Green forage of maize, jowar, oat

  Grasses (Para grass, Guinea grass, Anjan grass, Napier grass, Rhodes grass)

  Hay of grasses, maize, jowar, oat

  Straws of maize, jowar, wheat or rice

II) Supplementary forages for energy and protein

- ✓ Supplementary forages provide both energy and protein and some minerals.
- ✓ These are especially grown on the farm as feed for cattle and contain higher protein and/or energy levels than bulk forages.
- ✓ They are fed in addition to the bulk forages, usually in smaller amounts.
- ✓ **For example:**

  Lucerne, Berseem, Cowpea, Subabul, Stylo

III) Concentrates for energy and protein

- ✓ They contain high levels of protein or energy or the both & some minerals.
- ✓ They are also low in fibre and easy to digest.
- ✓ Concentrates are expensive and are therefore fed in small amounts in addition to forages and generally fed to growing, pregnant and lactating animals.
- ✓ **For example:**

  A) Energy sources

  Cereal grains (maize, jowar, oat, barley and wheat)

  Cereal by-products (wheat bran, rice bran, maize germ)

  Molasses

B) Protein sources

Oil seed cakes (soybean meal, groundnut oil cake, sun flower oil cake, cotton seed cake, sesame oil cake, mustard oil cake)

Animal protein sources (fish meal, meat meal)

Commercially prepared concentrate mixture/compound feed

Commercial feed: Compound feed which is produced for sale.

Compound feed: A mixture of different dietary feed ingredients blended together to form a complete feed for non-ruminants, or a supplementary feed to complement forage for ruminants.

- Compound feeds contain carbohydrate sources such as cereals and protein sources such as oilseeds or fish meal, with mineral and vitamin supplements.
- The ingredients are usually milled to reduce particle size and aid mixing.
- Most compound feeds are pelleted for ease of handling and use on farms.
- Compound feeds are colloquially referred to as concentrates.

Complete feed: A mixture of dietary feed ingredients designed to meet all the nutrient requirements of an animal.

- For pigs and poultry, complete feeds are usually blended from cereals and protein sources, with added oil, minerals and vitamins to meet requirements.
- For ruminants, complete feeds (often referred to as total mixed rations) contain a mixture of forages, by-products, cereals, protein sources, fats, minerals and vitamins.

BIS (Bureau of Indian Standards) specifications:

Characteristic requirement (%)	**Type I**	**Type II**	**Calf starter**
Moisture (max)	11.0	11.0	10.0
Crude protein (min)	22.0	20.0	23-26
Crude fat (min)	3.0	2.5	4.0
Crude fibre (max)	7.0	12.0	7.0
Acid insoluble ash (max)	3.0	4.0	2.5

Model Feed Formula of Compound Feeds

Feed Ingredient (%)	Type I	Type II
Maize	20.0	10.0
Rice polish	15.0	15.0
Mustard cake	15.0	18.0
Groundnut cake	19.0	12.0
De-oiled Rice bran	15.0	30.0
Molasses	10.0	10.0
Calcite powder	1.5	1.5
Common salt	1.5	1.5
Mineral mixture (type II)	2.0	2.0
Urea	1.0	-

CLFMA (Compound Livestock Feed Manufactures Association) specifications:

Requirement (%)	Dairy special feed	Type 1	Type 2	Type 3
Moisture (max)	12.0	12.0	12.0	12.0
Crude protein (min)	22.0	20.0	18.0	16.0
Undegradable protein (min)	8.0	--	--	--
Crude fat (min)	3.0	2.5	2.5	2.0
Crude fibre (max)	7.0	7.0	12.0	14.0
Acid insoluble ash (max)	3.5	4.0	4.5	5.0

IV) Mineral supplements

- ✓ Although some minerals are naturally present in bulk and supplementary forages and concentrates, dairy cows also need to be regularly fed additional minerals.
- ✓ This is most easily done by regularly offering access to a commercially manufactured mineral supplement.

BIS SPCIFICATIONS (%) FOR MINERAL MIXTURES FOR CATTLE

Characteristic	Requirement (%)	
	Type I (with salt)	Type II (without salt)
Moisture (max)	5	5
Calcium (min)	18	23
Phosphorus (min)	9	12
Magnesium (min)	5	6.5
Salt (Sodium chloride, min)	22	-
Iron (min)	0.4	0.5
Iodine (min)	0.02	0.026
Copper (min)	0.06	0.077
Manganese (min)	0.10	0.12
Cobalt (min)	0.009	0.012
Fluorine (max)	0.05	0.07
Zinc (min)	0.30	0.38
Sulphur (max)	0.4	0.5
Acid Insoluble ash (max)	3.0	2.5

V) Vitamin supplements:

- ✓ *Not a problem with practical dairy cow rations:* some vitamins are made by the micro-organisms in the rumen and others are naturally present in feeds, such as leafy green forages.

FEEDING EXPERIMENTS IN LIVESTOCK ANIMALS

A knowledge of the quantitative needs of the body for the nutrients and the relative value of feeds as source of these nutrients is the basis of scientific feeding, which has been gained gradually by feeding trials/experiments over many years. Feeding experiments have been carried out with farm animals during the past two centuries to compare the value of different feeds or combination of feeds. The feed given to animals are first chemically analyzed for its composition and later to find out its utilization in the animals, feeding experiments are conducted. The qualitative value of feed is expressed as digestibility, metabolizability or its effect on production like weight gain, milk production, egg production etc.

Guidelines for the design of feeding experiments

- Diets: The experimental diets must be similar in terms of ingredients, except for the ingredient which is to be tested.
- Animals: Should be of similar age, size and sex.
- Statistical design:
    - Randomization of animals of same age and size into different groups.
    - Whenever group feeding is done, replication of the group is important.

The different feeding experiments are:

1. Comparative feeding trials
2. Feeding trials with laboratory animals
3. Purified diet method
4. Germ-free technique
5. Group feeding versus Individual feeding
6. Controlled feeding versus *Ad libitum* feeding
7. Equalized Paired feeding or Paired feeding
8. Slaughter experiments

1. COMPARATIVE FEEDING TRAILS

- It is the simplest form of feeding trial.
- Two or more rations may be compared with each other on this basis.

- The feed eaten provides a comparison of the relative amounts of the ration required to produce a unit of product and by the use of cost figures, the results may be put on a money basis.

Feed conversion ratio (FCR)/Feed efficiency:

- ✓ The ratio expressing the number of units of feed required for one unit of production (meat, milk, eggs) by an animals.
- ✓ In growing animals:

$$\mathbf{FCR} = \frac{\textbf{Feed intake (kg)}}{\textbf{Body weight (kg)}}$$

- ✓ In milking animals:

$$\mathbf{FCR} = \frac{\textbf{Feed intake (kg)}}{\textbf{Milk production (kg)}}$$

An example to show soya meal is better protein than sunflower cake

Rations	FCR
1: Maize fodder + Soybean meal	6.1
2: Maize fodder + Sunflower cake	6.8

Disadvantage: This experiment tells us that comparatively, soybean meal diet was better than sunflower oil cake diet. But it tells nothing as to why the soybean meal was better. Was it due to better quality protein? or the presence of higher lysine? etc. which cannot be found out by just comparison.

2. FEEDING TRIALS WITH LABORATORY ANIMALS

- The feeding trials can be conducted with laboratory animals viz. rat, mice, guinea pig, rabbit, hamster, etc.
- Today many of the problems in nutrition are being studied with laboratory animals.
- The processes of growth, reproduction and lactation can be effectively investigated and the value of various feeds for the different functions can be determined.

Advantages

1) Low cost in terms of animals, feed and labour and the shorter time involved for a given experiment in view of the shorter lifecycle of the lab animal.

2) The influence of individual variability can be reduced to a minimum by the use of animals of similar genetic and nutritional history by using large number of animals and by close environmental control.
3) It is very easy to slaughter lab animals for chemical and histological examinations compared to large animals.
4) Useful for studying various fundamental principles of nutrition.
5) Serve as a pilot experiment, by means of which much preliminary information can be obtained more quickly and at much less cost than with large animals.

Disadvantages

The results obtained in feeding trials with small animals cannot be considered to have direct application to the various species of farm animals because of the differences in physiology and other considerations.

3. PURIFIED DIET METHOD

- ✓ Purified diets were used in conducting feeding trials with lab animals.
- ✓ Purified diets consist of purified sources of the various nutrients.

  Carbohydrates are supplied as starch, glucose or sucrose;

  Protein is supplied as casein, purified soya protein;

  Fat as lard or oil;

  Minerals as chemically pure salts;

  Vitamins as pure crystalline compounds;
- ✓ Such a diet makes it possible to include or withdraw a given nutrient with a minimum disturbance to other nutrients.
- ✓ In 1816, Magendie fed diets of pure sugar and of pure fat to dogs to ascertain whether or not N was required in the food.
- ✓ J.B.Boussinggault, McCollum and Davis, Osborne and Mendel carried on nutritional studies with various species, involving the use of diets consisting in part of purified nutrients.

Advantages

1) This method was responsible for much of our modern knowledge of nutrition, especially poultry nutrition including the physiology of vitamins, the establishment of differences in protein quality and more exact information regarding many of the minerals.

2) This method is the only method by which the role of individual mineral needed by the body in small amounts can be effectively carried out only with basal diets where the element can be added in known amounts.

Disadvantages

1) The ingredients of these diets cannot be considered pure in the absolute sense. For example, starch cannot be entirely free from mineral elements. Some of the vitamins were identified as “impurities”.
2) Some of the constituents, notably protein, in purified diets may be altered from their natural state in the process of purification.
3) All the nutrient requirements of the species should be known to prepare a completely purified diet.
4) The diet must be of suitable physical nature and palatable so that it will be consumed as per the need.
5) Purified nutrients are costly.

4. GERM FREE TECHNIQUE

- ✓ Germ free means, free of contamination by bacteria, yeasts, moulds, fungi, protozoa and parasites in general, that is, free of all other life.
- ✓ It is evident that various vitamins are synthesized in the intestinal tract and contribute to the host's nutrition and complicate the interpretation of the data on dietary requirements obtained in feeding trials.
- ✓ Thus nutritionist has special interest in the techniques which have been developed for obtaining animals which are germfree at birth and for rearing them in an uncontaminated environment thereafter.
- ✓ The new born are obtained by Caesarian section and reared in specially designed apparatus in an uncontaminated environment and are fed sterilized diet.
- ✓ Success has been reported with rats, rabbits, hamsters, mice, chickens, turkeys and monkeys. Rats, mice and chickens have been bred through successive generations.
- ✓ Techniques have been developed for obtaining “Specific Pathogen free" baby pigs by hysterectomy and using them for nutrition experiments.
- ✓ Specific Pathogen Free (SPF) animals are developed to avoid the multiplication of intestinal organisms and used in nutrition experiments.

Disadvantages

- ✓ It is expensive method and needs sophisticated technique as well as germ free diet.

5. GROUP FEEDING VERSUS INDIVIDUAL FEEDING

GROUP FEEDING	INDIVIDUAL FEEDING
1) Animals are fed in a group during the feeding experiment.	1) Animals are fed individually during the feeding experiment.
2) This is cheaper in terms of equipment and labour cost.	2) This is costly in terms of equipment and labour cost.
3) The data on feed consumption and the individual performance of the animal can-not be maintained in group feeding.	3) The data on feed consumption and the individual performance of the animal can be maintained in individual feeding.
4) Interpretation of the results is complicated and not accurate, if there is wide variation in the individual behaviour within the group like in feed consumption, production, etc.	4) Interpretation of the results is easy and accurate, as record of individual animal is kept.

6. CONTROLLED VERSUS AD LIBITUM FEEDING

Controlled feeding	*Ad libitum* feeding
1) In controlled feeding experiments limited feed is given to animals.	1) In *ad libitum* feeding experiments free choice feed is given to animals.
2) This method provides controlled conditions required for certain purposes like the determination of digestibility.	2) This method does not provide controlled conditions required for certain purposes like the determination of digestibility.
4) It gives biased results for direct practical application.	4) It gives unbiased results for direct practical application.
5) Controlled feeding frequently gives rise to consistent results.	5) *Ad libitum* feeding frequently gives rise to variable results.
6) The cost of feeding is less.	6) The cost of feeding is more.

7. EQUALIZED PAIRED/PAIRED FEEDING

- ✓ In paired feeding, the feed intakes are completely controlled.
- ✓ In this method of comparing two rations, the animals are fed alike in a preliminary period.

- ✓ Then animals are selected by pairs and are kept on ration A and ration B and are fed same quantity of feed limiting the intakes of both to that of the animal consuming the lesser amount.
- ✓ The two animals of the pair are similar in size, age and previous history.
- ✓ But such equalities are not essential from pair to pair.
- ✓ The equalization of feed intake is also limited to within the pair.
- ✓ Minimum of four pairs of animals are to be used to carry out statistical analysis.

Advantages

1) Properly conducted equalized paired feeding experiments have a distinct advantage over *ad libitum* method as regards to the adaptability of the results to statistical treatment.
2) The larger the number of pairs, the greater is the reliability of the results.

Disadvantages

1) The faster-growing animal is penalized because of restricted feeding.
2) As the animal on the superior ration increases in weight over its mate, its maintenance requirement becomes greater than that of its mate.
3) The frequent effect of a nutritionally deficient ration is to decrease feed consumption.
4) By limiting feed intake, the full effect of the better ration cannot express itself.
5) The method is not suitable for finding out how much superior one ration is to another for growth.

8. SLAUGHTER EXPERIMENTS

- ✓ Slaughter experiments involve the analysis of certain specific tissues or of the body as a whole.
- ✓ In studies of the protein requirement for growth or the value of different protein sources, it is important to know the specific effect in terms of protein tissue formed, since the increase in the body as a whole is due to water, fat and minerals as well as protein, the relationship may vary.
- ✓ To study the effect of a given diet on changes in body composition, a group of like animals are selected and a part of them are slaughtered and analyzed at the start of the experiment.

- ✓ The others are fed different experimental diets for a given period and then slaughtered and analyzed.
- ✓ The difference in their composition from the animals slaughtered at the start reveals the effect of the diet fed.
- ✓ In general, small laboratory animals are much easier to work with than the larger farm animals.

Advantages

1) The slaughter method has greatest application in studying the nutrition of beef cattle, sheep and swine.
2) Slaughter diets may also include various measures of market value, such as dressing percentages and quality of the carcass and such measures are frequently used in meat production experiments
3) To study the influence of a given ration, upon the quality of the product and upon its selling price.

Disadvantages

1) It requires much more time and labour than is involved in merely weighing feed and animals.
2) Problems in the selection of representative samples of tissues and in their preparation for analysis.

Overall Conclusion on feeding experiments:

- ❖ No single method is suitable for the solution of all types of nutrition problems.
- ❖ The investigator must select his method in accordance with his problem, frequently employing more than one method.
- ❖ He must interpret his results with a full advantages and limitations of the methods used.

MEASUREMENT OF DIGESTIBILITY

DIGESTIBILITY

Digestibility is the portion of the feed or nutrient present in the feed that is not excreted in feces by the animal.

- Digestibility can be determined by feeding experiments. It is usually expressed as:
    - Digestible nutrient
    - Digestibility coefficient (%)
- When the digestibility is expressed in percentage it is known as digestibility coefficient.

$$\textbf{Digestibility}\ (\%) = \frac{\textbf{Nutrient Intake} - \textbf{Nutrient Voided}}{\textbf{Nutrient Intake}}\ \textbf{x 100}$$

Apparent digestibility:

- This digestibility estimated is called as apparent digestibility, since the faeces contains undigested feed as well as metabolic losses (mucosal debris, unspent enzymes, undigested microorganisms).

- For example, if a cow consumed 10 kg of hay containing 9 kg of dry matter (DM) and excreted 4 kg of dry matter in its faeces, the digestibility of the hay dry matter would be:

$$\textbf{Apparent digestibility} = \frac{\textbf{DM Intake} - \textbf{DM Voided}}{\textbf{DM Intake}}\ \textbf{x 100}$$

$$\textbf{Apparent digestibility} = \frac{\textbf{9} - \textbf{4}}{\textbf{9}}\ \textbf{x 100} = \textbf{55.6\%}$$

True digestibility

- As these feces contain undigested feed as well as metabolic losses; the digestibility determined called as apparent digestibility.
- For example, these faeces contain 3.7 kg of undigested feed and 0.3 kg metabolic losses.
- True digestibility is calculated as:

$$\textbf{True digestibility } (\%) = \frac{\textbf{Nutrient Intake} - (\textbf{Nutrient Voided} - \textbf{Metabolic losse}}{\textbf{Nutrient Intake}} \text{x 1x } \mathbf{100}$$

$$\textbf{True digestibility} = \frac{\mathbf{9 - (4 - 0.3)}}{\mathbf{9}} \textbf{x 100} = \mathbf{58.9\%}$$

- Thus the apparent digestibility of feed is less than the true digestibility.

- Digestibility coefficients are estimated for all organic nutrients.
- For ash or minerals it is not estimated, because it does not contribute to energy to the feed, and most of the absorbed minerals are excreted through the gut.

DIGESTION TRIAL versus METABOLISM TRIAL

Particulars	Digestion trial	Metabolism trial
Purpose	Gives information on portion of the feed or nutrient present in the feed that is not excreted in feces by the animal, which is absorbed from the gastro intestinal tract.	Similar to digestion trials but gives more information on utilization of nutrient after absorption from the gastro intestinal tract.
Information obtained	Information on digestibility co-efficient of nutrients. Hence, digestion trials provide information about only nutrient digestion from feed.	In addition to digestibility co-efficient, one gets information on nutrient balances such as N, Ca, P, energy etc. Hence, metabolism trials provide complete information on nutrient digestion and utilization from feed.
What is collected	Only faeces.	In addition to faeces, urine, milk, etc are also collected.
Result	Apparent digestibility co-efficient of nutrients.	In addition to apparent digestibility co-efficient, the information on positive or negative nutrient balance is obtained.

NORMS ADOPTED IN CONDUCTING DIGESTION AND METABOLISM TRIALS

Selection of animals

- The animals should be of the same breed, sex, age and body weight.
- Generally a minimum of four adult animals are needed.
- Animals should be healthy and free from parasites.
- Male animals are preferred to females because it is easier to collect faeces and urine separately.

Preliminary/Adjustment period

- The test feed has to be fed daily in constant amounts, as per the requirements of the animal, for an extended period. This is called preliminary period.
- The purpose of this period is to remove all the residues of previous feeding regime in the digestive tract and establish a uniform passage rate of faeces as related to feed intake.
- It is essential to have preliminary period of 10–12 days for ruminants and 3–5 days for non-ruminants.
- Water and salt licks are provided at all times.
- Animals are fed individually.

After this preliminary period, animals are transferred to cages or stalls and 2–3 day adaptation period is allowed for their acclimatization. This is followed by collection period.

Collection period

- This is the actual experimental period.
- In this period accurate recording of feed offered, residue left out and faeces and urine voided should be done.
- The length of the collection period in general 5–7 days for ruminant.

Test feed

- The test feed should not be deficient in the nutrients because a deficiency of some of them may affect digestion process.
- The test feed should be fed at the level required for meeting the requirements of the animals.
- Normally 90% of the actual feed intake, as measured during the previous week, is offered.

HISTORY OF DIGESTION EXPERIMENTS

The first digestibility trials on farm stock were carried out at the Weende Experimental Station by Henneberg and Stohmann. They began their experiments in 1858 and in I860 published their findings. The digestion experiments were started almost at the same time when the feed stuff was being analyzed chemically at the Weende experiment station.

MEASUREMENT OF DIGESTIBILITY

Digestibility of feed is measured by using following methods.

I. *In vivo* methods

1) Direct method
2) Indirect method
    a. By difference
    b. By using indicator/marker

II. Semi *in vivo* method

1) Nylon bag (*In Sacco*) technique
2) VIVAR technique

III. *In vitro* method

1) Using rumen liquor
2) Using enzymes instead of rumen liquor
3) RUSITEC method

In vivo methods – Direct method

Digestibility of the nutrient is determined by conducting digestion trial in live animals, involving measurement of nutrient consumed and voided.

$$\textbf{Digestibility}\ (\%) = \frac{\textbf{Nutrient Intake} - \textbf{Nutrient Voided}}{\textbf{Nutrient Intake}} \textbf{ x 100}$$

In vivo methods – Indirect method – by difference

In this method, two digestion trials are conducted; first with maintenance type of fodder and the second trial by feeding test concentrate feed along with maintenance type of fodder.

The digestibility coefficients of nutrients present in concentrate feed are determined by subtracting the amount of undigested nutrients in maintenance type of fodder from the total undigested nutrients voided in faeces in the second trial.

In vivo methods – Indirect method – by indicator/marker method

Indicators may be used to measure digestibility of feed under the following circumstances:

1) If metabolism cages and other facilities for direct collection of feces and urine voided are not available
2) If animals are fed in groups, then it is impossible to record the feed consumed and feces voided by each animal in the group but still it is possible to measure digestibility of feed by the indicator method.
3) To know intake of herbage from cultivated or natural pastures and digestibility of nutrients in the pasture consumed by the animal**.**

- In this method indicator is added to feed and if the concentrations of this indicator substance in the feed and in small samples of the faeces of each animal are then determined, the ratio between these concentrations gives an estimate of digestibility.
- For example, if the concentrations of the indicator increased from 1% dry matter to 2% in the faeces, this would mean that 50% of the dry matter had been digested and absorbed.
- The indicator may be a natural constituent of the feed or be a chemical mixed into it. It is difficult to mix chemicals with feeds like hay, but an indigestible constituent such as lignin may be used.
- Other indicators in use are fractions of the feed known as indigestible acid-detergent fibre and acid insoluble ash (silica) and also some naturally occurring n-alkanes of long chain length (C_{25}- C_{35}).
- The indicator most commonly added to feeds is chromium in the form of chromic oxide. Chromic oxide is very insoluble and hence indigestible.
- For non-ruminants, titanium dioxide may be added to feeds as an indicator.
- In this application the marker is given for 10 -15 days in fixed amounts (eg. administered in a gelatin capsule) and once its excretion is assumed to have stabilized its concentration in faeces samples is determined. Faeces dry matter output (kg/day) is calculated as follows:
- Marker dose (g per day)/ Marker concentration in faeces DM (g/kg). For example, if an animal was given 10 g of chromic oxide per day and the concentration of the marker was found to be 4 g/kg faeces DM, faeces output would be calculated as 10/4 =2.5 kg

DM/day. If feed intake was known, dry matter digestibility could be calculated in the usual way.

$$\textbf{Digestibility}\ (\%) = \mathbf{100} - (\mathbf{100\ x}\ \frac{\%\ \textbf{Indicator in Feed}}{\%\ \textbf{Indicator in Feces}}\ \mathbf{x}\ \frac{\%\ \textbf{Nutrient in Feces}}{\%\ \textbf{Nutrient in Feed}})$$

❖ **Examples of an indicator/marker are :**

1) Natural indicators

Lignin,

Acid insoluble ash,

Acid detergent fibre,

n-alkanes of long chain length (C_{25}- C_{35})

2) Chemical indicators

Chromium oxide

Titanium dioxide

Cobalt EDTA

Litium

Strontium

Ytterbium acetate

❖ **The ideal specification of an indicator/marker are :**

- It should be totally indigestible.
- It should not have any pharmacological action on the digestive tract.
- It should be inert to the digestive system.
- It must mix remain uniformly distributed in the digesta.
- It should pass through the tract at a uniform rate and should be voided entirely.
- It can readily be determined chemically, and
- Preferably be a natural constituent of the feed under test.

SEMI *IN VIVO* TECHNIQUE

IN SACCO/*IN SITU* TECHNIQUE / NYLON/DACRON BAG TECHNIQUE

The digestibility/degradability of feeds in the rumen can be determined by keeping the feed sample in bags, which are immersed in rumen contents of fistulated animals for a different period of times. The bags are made up of nylon, Dacron or silk cloth which is indigestible and should be of very fine mesh so that the test feed particles should not pass out of the bag undegraded but at the same time it should allow the rumen microbes to enter into the bag and act on the test feed.

The incubation of nylon bags filled with feedstuff in the rumen for different incubation times yields a measure of the kinetics of feedstuff degradation in the rumen. Although the *in sacco* nylon bag technique is widely used and forms the basis of many feed evaluation systems, this technique requires precise control of procedures and equipment for achieving desirable reproducibility and reliability of the data generated. A number of factors are known to influence the results. Some of these factors are dimensions and pore size of nylon bags, sample weight, washing conditions etc. These factors should be controlled as far as possible.

Procedure

1) The nylon bags of dimensions 9 x 16 cm (pore size: 40-60 micron).
2) The sample should be passed through 2 mm screen.
3) The sample of 3 to 5 g of feeds should be weighed in the bags.
4) In the rumen of sheep, a total of 6-12 bags (depending on size of the sheep) should be incubated (3 bags attached to each plastic tube). The number of the bags can be increased to 24 to 60 for cattle.
5) At least three animals should be used for incubation of the bags. The diet of the animals should be as similar to the feeds under investigation.
6) The incubation time should be 4, 8, 16, 24, 36, 48, 72 and 96 h.
7) Also determine initial water solubility for the samples by immersing a set of bags in triplicate in water (39°C) for 1 h.
8) The bags should be inserted into the rumen at different time intervals so that all bags are taken out at the same time and subjected together to the following washing condition.
9) After incubation, the bags should be immediately placed in cold water to stop fermentation, and to remove the feed particles adhering to the bags.
10) Transfer them to domestic washing machine and wash them for 20 min in water at 22-25°C.

11) Dry the bags to a constant weight at 65°C for 48 hr. Place them in a desiccator kept at room temperature. Weigh the bags after these have come to the room temperature.
12) Calculate percent digestion of feedstuff, and calculate the digestion kinetic parameters using the exponential equation. The bags can be re-used after thorough washing.

Calculation

Empty bag weight (W)

Bag + feed sample before incubation (W_1)

Bag + residue after incubation (W_2)

Per cent dry matter in the feed sample (DM %)

Sample dry matter weight (W_1 -W) x DM % = (W_3)

Residue dry matter weight (W_2 -W) = (W_4)

$$\text{DM disappearance (\%)} = \frac{\text{W3} - \text{W4}}{\text{W3}} \text{ x } 100$$

Advantages/Applications of the technique

- ✓ This technique provides a powerful tool for initial evaluation of feedstuffs and is useful in screening, rapidly, large number of samples developed in forage breeding experiments.
- ✓ This technique is helpful to understand the rumen processes. It is possible to vary the factors within the bag or within the rumen. The animal can be fed a constant diet, and the effect of (treated straw over untreated straw or hay or complete diet) manipulating the feedstuffs incubated in the bag on its degradation kinetics can be studied. Alternatively, the conditions within the rumen i.e.: rumen environment can be varied and a standard material incubated in the bag in order to study the effect of rumen environment on the rate of degradation.

Limitations

- ✓ The technique has certain inherent limitations.
- ✓ The test feed in the bag is not subjected to the total ruminal experience, ie., mastication, rumination and passage. What is actually measured is the breakdown of material to a size small enough to leave the bag and not necessarily a complete degradation to simple chemical compounds.

VIVAR (In Vivo Artificial Rumen) technique

- An in vivo artificial rumen (VIVAR) was developed for studying nutrient utilization by rumen micro-organisms under controlled conditions in the rumen.
- The system consists of a porcelain test tube or stainless steel or glass jars fitted with bacteriological membranes to provide controlled interchange of the VIVAR and rumen contents.
- The rumen microflora passes through the semi permeable membranes and degrades feed samples present inside the VIVAR tube, but the sample particles cannot move outside. After completion of the fermentation period, VIVAR tubes are removed.
- The dry matter disappearance may be recorded by difference in weight of the sample and the residues left in the VIVAR tube.

LABORATORY METHODS OF ESTIMATING DIGESTIBILITY

- Since digestibility trials with live animals are laborious and costly to perform, there have been numerous attempts made to determine the digestibility of feeds by reproducing in the laboratory the reactions which take place in the alimentary tract of the animal.
- Digestion in non-ruminants is not easily simulated in its entirety, but the digestibility of feed protein may be determined from its susceptibility to attack *in vitro* by pepsin and hydrochloric acid.
- It is possible to collect digestive tract secretions via cannulae and to use them to digest feeds *in vitro.*

Tilley and Terry method

- Digestibility of feeds for ruminants can be measured quite accurately in the laboratory by treating them first with rumen liquor and then with pepsin.
- During the first stage a known weight of the finely ground sample of the feed whose organic matter composition is already determined is incubated for 48 hours with buffered rumen liquor in a tube under anaerobic conditions.
- In the second stage the bacteria are killed by acidifying with hydrochloric acid to pH 2 and are then digested by incubating them with pepsin for a further 48 hours.
- The insoluble residue is filtered off, dried and ignited and again weighed.
- The difference between the two weighing gives the organic matter present in the residue.

- The digestibility coefficient determined *in vitro* is generally 1-2 percentage units lower than the coefficient measured *in vivo*.

FACTORS AFFECTING DIGESTIBILITY OF FEED

There are various factors that affect feed digestibility are grouped as:

I. Feed factors
II. Animal factors

I. FEED FACTORS

- The most important feed factors that affect digestibility of feed are feed composition, ration composition and preparation of the feed.

1. ***Feed composition:***
   The digestibility of a feed is closely related to its chemical composition. Other feeds, particularly fresh and conserved herbage show variation in composition and therefore vary more in digestibility. The crude fiber fraction of feed has greater influence on its digestibility and both the amount and chemical composition of the crude fibre are important. If the lignin content in crude fibre is more it reduces the digestibility of the feed. Lignin content of any plant tissue increases with maturity.
2. ***Ration composition:***
   The digestibility of feed is influenced not only by its own composition, but also by the composition of other feeds consumed with it. This is known as associative effect. Associative effect of feeds represents a serious problem on the determination of the digestibility of concentrates by difference method.
3. ***Preparation of feeds:***
   Feed preparation also influences its digestibility. The commonest treatment applied to the feeds are chopping or chaffing, crushing or grinding and cooking, chopping or chaffing roughages increases their surface area and hence increases their digestibility. In order to obtain maximum digestibility cereal grains should be crushed for horses and ground for pigs and poultry: otherwise they may pass through the gut intact. Feed processing such as pelleting and extrusion cooking also enhances feed digestibility.

II. ANIMAL FACTORS

- The most important animal factors that affect digestibility of feed are the species, age, physiological and health status of the animal and level of feeding.

1. ***Species:***

   There is a wide variation in the digestion of feed according to the species of animals. Ruminant animals (cattle, buffalo, sheep, goat) are able to digest fibrous feeds more efficiently than simple stomach animals (poultry and swine).

2. ***Age:***

   Digestibility of same feed is higher in adult animal as compared to young and old animals. In the young animals the digestive system is not fully functional especially with regard to secretion of enzymes, hence they are not able to digest feed as that in adults. In old animals, due to ageing digestion related functions become slow and mal-functioned which lowers the digestibility.

3. ***Physiological and health status of the animal:***

   Animals in advanced stages of pregnancy are not able to digest feed due to the pressure and suffering exerted by the gravid uterus on the gastrointestinal tract. Sick animals especially those suffering from diseases of gastrointestinal tract have reduced capacity to digest feed.

4. ***Level of feeding:***

   An increase in the quantity of feed eaten by an animal generally causes a faster rate of passage of digesta. The food is then exposed to the action of digestive enzymes for a shorter period, so that there may be reduction in its digestibility.

FEEDING STANDARDS

Feeding standards are statements or tables, which indicate the amounts of nutrients required for various classes of livestock for different physiological functions like maintenance, growth, lactation, work, egg production, wool growth, etc.

- ✓ The nutrient requirements are generally expressed in quantities of nutrients required per day or as a percentage of diet.
- ✓ For dairy animals, nutrient requirements are generally expressed as separate body functions but in case of poultry and pigs, combined requirements of maintenance and other body functions are given.

- ✓ There are two terms, which has been used, in the feeding standards.
  - a) Nutrient requirement: gives the nutrient requirement for optimum production and health.
  - b) Nutrient allowance: gives an extra allowance of nutrient over the requirement, which gives a margin of safety.

CLASSIFICATION OF FEEDING STANDARDS

I. Comparative type

1) Hay feeding standard
2) Scandinavian “feed unit” feeding standard

II. Digestible nutrient type

1) Grouven’s feeding standard
2) Wolff’s feeding standard
3) Wolff’s–Lehmann feeding standard
4) Haecker’s feeding standard
5) Savage feeding standard
6) Morrison feeding standard
7) Indian feeding standards
8) National Research Council (NRC) feeding standard

III. Production value type

1) Kellner feeding standard
2) Armsby feeding standard
3) Agricultural Research Council (ARC) feeding standard

I. Comparative type

1) Hay feeding standard

- In 1810 German scientist Thaer, suggested that different feeds should be compared using meadow hay as a unit.
- He published the "HAY EQUIVALENT" as measure of relative value based on determining the materials in feeds extractable with water (and other solvents).
- This standard provided that 100 lbs. of meadow hay was equal in nutritive value to 91 lbs. of clover hay or 200 lbs. of potatoes, 625 lbs. of mangels.

Disadvantage:

Nothing was known of the chemical value of these feeds and the physiological requirements of the animals.

The only measure was the practical feeding experience.

2) Scandinavian “Feed Unit” feeding standard

- ✓ In 1884, Professor Fjord formulated the Scandinavian feeding standard.
- ✓ In this system only one factor, namely, the feed unit was taken into account.
- ✓ The value of one pound of common grain such as corn, barley or wheat, is given as one unit value and the value of all other foods is based upon this.
- ✓ Being simple and easy to calculate, this feeding standard is still continued in a number of Scandinavian countries for formulation of ration for livestock.

Disadvantages:

As the grains are of different types in different countries, the feed units should also be different.

Hence the Scandinavian units are not applicable in our country unless experiments are conducted here with our own grains.

II. Digestible nutrient system

1) Grouven’s Feeding Standard

- In 1859 Grouven, a German chemist published his feeding standard with crude protein, carbohydrates and fat contained in the feed as the basis of the standard.
- According to this standard a cow weighing 1,000 lbs. should be fed 28.7 lbs. of dry matter containing 2.67 lbs. of crude protein 0.6 lb. of crude fat and 14.55 lbs. of crude carbohydrates.

- Very soon after standard of Grouven, Henneberg and Stohmann found that the total nutrient contained in a feed did not form an accurate guide to its value.
- The proportion of digestible parts varied with different feeds and hence the digestible nutrient would be more valuable.
- So due to this defect Grouven's feeding standard was abandoned.

2) Wolff's Feeding Standard

- ✓ In 1864 Dr. Emil von Wolff (German Scientist) proposed a feeding standard based on digestible protein, digestible carbohydrates and digestible fats contained in a feeding stuff.
- ✓ His standard for dairy cows weighing 1,000 lbs. was 24.5 lbs. of dry matter containing 2.5 lbs. of digestible carbohydrates and 0.4 lb. of digestible fats.
- ✓ This has a nutritive ratio 1:5.4.
- ✓ This standard though an improvement over the standard of Grouven.
- ✓ Wolff's standards were published annually without fundamental change until 1897, when they were modified by G. Lehmann (German scientist) to become Wolff-Lehmann standards for various classes of animals.

3) Wolff-Lehmann Feeding Standard

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

4) Haecker's Feeding Standard

- ✓ Keeping in view the demerits of Wolff Lehmann standard, Haecker (1903) an American worker formulated the feeding standard, who for the first time considered the quantity as well as the quality of milk produced in formulating a milk standard.
- ✓ He took into account the allowance for the percentage of fat in the milk in addition to the requirement for maintenance, production and total milk yield.
- ✓ He was also the first to separate the requirements for maintenance from the requirements of production (milk yield).
- ✓ His standards included digestible crude protein, carbohydrates and fats.
- ✓ Later it was expressed as digestible crude protein and total digestible nutrients.

- ✓ According to this standard a cow weighing 800 lbs will require 0.56 lbs DCP and 6.34 lbs TDN for maintenance and 0.054 lbs DCP and 0.341 lbs TDN for every lbs of milk with 4 percent fat in it.

5) Savage Feeding Standard

- An American scientist Savage concluded that the Haecker's standard was too low especially in protein requirement and published his feeding standard in 1912 by increasing 20 percent of protein requirements.
- He expressed his standard in terms of DCP and TDN and further showed that about 2/3 requirement of the dry matter should be met by feeding roughages and the remaining 1/3 from concentrates.
- Fat content of the milk was also considered.
- He suggested that in case of milking cows at least 24 lbs. of dry matter should be provided for an average cow.
- The nutritive ratio should not be wider than 1:6 or narrow than 1:4.5.
- According to this standard a cow weighing 1000 lbs will require 0.70 lbs TDN for maintenance. In addition to this, cow will require 0.065 lbs DCP and 0.350lbs TDN for every lbs of milk produced with 4 percent of fat.

6) Morrison Feeding Standard

- ✓ Morrison F.B. observed that stockmen are spending large sums of money for entirely unnecessary amounts on protein supplement, thus considerably reducing their profits.
- ✓ He therefore, endeavoured to combine in one set of standards what seem in the judgment to be the best guide available in computation of rations for the various classes of livestock.
- ✓ These standards were first presented in the 15th edition of “Feeds and Feeding” published in 1915 under the authorship of Henry and Morrison. They were then called “Modified Wolff and Lehmann standard”.
- ✓ They soon came to be known as the “Morrison Feeding Standard”.
- ✓ These standards were expressed in terms of Dry Matter (D.M.), Digestible Protein (D.P.) and Total Digestible Nutrients (T.D.N.).
- ✓ Morrison indicated the nutrient requirement of animals in a range rather than in one figure.

- ✓ In the year 1956, Morrison included in the standard the allowances for Calcium, Phosphorus and Carotene besides digestible carbohydrates, digestible proteins and net energy in therms.
- ✓ The average of Morrison standards has been accepted for Indian livestock.

7) Indian Feeding Standards

A) Sen and Ray Feeding Standard

- ➢ Dr. K. C. Sen, the first Director, National Dairy Research Institute, Karnal and Ray have compiled the feeding standards for Zebu cattle and buffaloes, based on Morrison's recommendations, where they adopted the average of maximum and minimum values recommended by Morrison.
- ➢ Later on Sen, Ray and Ranjan (1978) revised the Sen and Ray (1964) standard on the basis of experimental trials conducted in Indian animals. These modified values are still functioning in many of our established dairy farms.

B) Indian Council of Agricultural Research Feeding Standard

- ✓ Considering the fact that nutrient needs of livestock and poultry breeds under tropical environments are different from those developed in temperate climate, the Indian Council of Agricultural Research, realizing the necessity of setting up suitable feeding standards for the Indian livestock and poultry.
- ✓ This task was assigned to Late Dr. N. D. Kehar, the then Chairman, I. C. A. R. scientific panel on Animal Nutrition and Physiology, as he had been associated with this type of research activities for about two decades.
- ✓ The scientific panel set up sub-committees for each species by inviting experts from various institutes of the country.
- ✓ On the basis of the scientific information arising from the experimental work carried out in India over the past two decades, nutrient requirement of Indian livestock and poultry ultimately has been published by I. C. A. R. in January 1985 under the able Chairmanship of the panel Dr. K. Pradhan, which formed a strong basis for feeding our livestock and poultry. These standards were updated and were revised in 1998.
- ✓ The feeding standards are based on the experimental results and have been organized to contain information on daily DM, DCP, TDN, Calcium and Phosphorus intake. Since, most of the data on energy and protein value of feed and animals' requirement in India

have been expressed in TDN and DCP. The figure of total digestible nutrient can be converted into digestible and metabolizable energy by taking 4.4 Mcal DE and 3.6 Mcal ME per kg TDN.

- ✓ Recently in 2013 ICAR has published revised feeding standards for Indian livestock animals (Cattle & Buffalo, Sheep & Goat, Swine, Horse, Poultry and Lab animals).

III. Production value type

1) Kellner Feeding Standard

- ➢ In 1907 Kellner, a German scientist investigated a feeding standard based upon "Starch" as the unit of measurement.
- ➢ He took into account not only the digestibility of the feeds as calculated from the amount lost in faeces and urine but also the entire loss from the body including energy expended in digestion and passing the food inside the body (chewing, etc.).
- ➢ For measuring the amount of energy lost from the body as heat, Kellner devised a respiration apparatus.
- ➢ Here heat is determined indirectly by finding the amount of carbon dioxide gas liberated or by measuring the amount of oxygen gas used up in oxidation which takes place in the body.
- ➢ The animal breathes through an airtight mask placed over its nose and mouth.
- ➢ According to this system, a 1,000 lbs. animal needs 0.6 lb. of digestible protein and 6.35 lbs. of starch equivalent.
- ➢ This starch equivalent in turn can be converted into energy by a method worked out by Armsby and Kellner.

➢ For any feed if the composition of it is known it may be converted to starch equivalent by using the following factors:

No.			Factor		SE = (1+2+3)
1	Digestible Protein	x	0.94	=	
2	Digestible Fat	x	2.12	=	
3	Digestible Carbohydrates & fiber	x	1.0	=	

2) Armsby Feeding Standard

- ✓ Armsby standard in U.S.A was based on true protein and net energy values.

- ✓ By means of the respiration calorimeter, Armsby determined the net energy required for mastication, digestion, assimilation and also the amount of heat and gases given off through the excretory channels.
- ✓ Thus after considering the various losses of energy such as in urine, faeces, gases and in the work of digestion, he was able to estimate the amount of net energy available for productive purposes.
- ✓ Armsby expresses his standard in two factors that is true protein and therms of net energy.

Disadvantages:

- ✓ The expense of determining requirements of the animals and the net energy in the various feeds is excessively high.
- ✓ The net energy values of only a very few feeds had actually been determined and most of the values have been computed from the Table of Morrison's digestible nutrients.
- ✓ Armsby standard is not as widely used as are the standards based on digestible nutrients.

3) Agricultural and food research council (A.F.R.C.) standard

- ➢ In United Kingdom a technical committee was set up to develop the standards in 1959, by the Agricultural Research Council (ARC), which later came to be known as Agricultural and Food Research Council (AFRC).
- ➢ In 1983 AFRC set up a single organisation for the UK, Technical committee on Responses to Nutrients (TCORN) and this became responsible for both revising the standards and producing practical manuals.
- ➢ Requirements are set forth in three separate reports dealing with poultry, ruminants and pigs, each of these reports are extensive summaries of the literatures upon which the requirements are based.
- ➢ The unit of energy requirements has been expressed in terms of Starch equivalent instead of T.D.N. or ME or NE as in Morrison and in N.R.C. standards.

The various feeding standards of the world which are available for feeding of different categories of livestock are given below:

Name of the country	Protein	Energy
NRC (USA)	DCP, RDP, RUDP	TDN, DE, NE
ARC (UK)	DCP, MP	DE, ME
SCANDINAVIA	DTP	FEED UNIT
GERMAN	DCP	SE
INDIA	DCP	TDN, ME

Where:

DCP = Digestible crude protein

DTP = Digestible true protein

MP = Metabolisable protein

RDP, RUDP = Rumen degradable & un-degradable protein

TDN = Total digestible nutrient

SE = Starch equivalent

DE = Digestible energy

ME = Metabolisable energy

NE = Net energy

USEFULLNESS AND LIMITATIONS OF FEEDING STANDARDS

- Feeding standards serve as a guide in feeding animals and in estimating the adequacy of feed intakes and of feed supplies for groups of animals.
- In practical feeding operations, it is frequently desirable to take economic factors into account. Thus, modifications (in feeding standards) may be called for in the interest of obtaining the rate of gain or level of milk production that seems the most economical in terms of current feed costs and the market price of the product.
- No standard can be a complete guide to feeding because other factors such as palatability and the physical nature of the ration must also be taken into account.
- Further, environment may change nutrient requirement.

Merits and Demerits of various feeding standards

- The units used in feeding standards should be the same as those used in the evaluation of feeds.

Energy evaluation

- It is not tenable to consider one nutrient more important than another, since all must be available to the animal in adequate amounts if efficient production is to be maintained. However, an animal's requirement for energy is the primary consideration from a quantitative and economic position.
- Energy is the most important factor which limits livestock production and meeting the energy requirement for maintenance and production is the major cost associated with feeding animals.
- The best unit for expressing the energy value is the one which takes into account all the losses incurred by the animal in utilizing the energy present in feeds.

TDN and DE Systems

- The TDN and DE system of feed evaluation have been and continue to be used because these measures are useful as first approximations of a feeds value as a source of energy and a considerable and valuable volume of knowledge exists concerning the proximate composition and the TDN or DE value of feedstuffs.

Merits

1) TDN is a measure of apparent DE but is expressed in units of weight or percent rather than energy per se.
2) TDN value provides a relative measure of the DE content of feed: 1 kg TDN =4.409 Mcal DE.
3) It is easy to determine the TDN content of feedstuffs: proximate composition of feed and faeces and digestion trial are to be done.
4) Digestible energy can readily be determined by using a bomb calorimeter to measure the Gross energy of feed and faeces. No chemical analysis is required.

Demerits

- ✓ TDN systems take into account only the losses of nutrients in the faeces but not the other losses from the body.

- ✓ TDN system over evaluates the energy value of poor quality roughages in relation to concentrates specially so in hot environment because:
  TDN does not consider large amounts of energy wasted in the digestion of fibrous feeds in the form of gases and heat increment and Ether extract of forages largely comprise other than true fat. So a kg of TDN in roughages has less value for productive purpose than a kg of TDN in concentrate.
- ✓ Certain species of forage were found to have high gross energy and high TDN values due to essential oils but low ME values.
- ✓ The measurement of DE takes into account the losses only through faeces.

Starch equivalent and metabolisable energy system

The total digestible nutrients (TDN) system in the USA, Canada and India and Starch Equivalent (SE) system in Europe have been widely used since early 1900s. The SE system was replaced by the ME system devised by Blaxter in the UK. The ARC has adopted the ME system since 1980. ME goes a step beyond DE or TDN (Since energy losses in urine and gasses produced during digestion are corrected) and provides a more accurate measure of the value of a feedstuff. It has been common to use ME as a measure of feed value for poultry because their faeces and urine are excreted through a common orifice; it is actually easier to determine ME than DE for them.

Merits of ME system

1) ME represents a more accurate measure since losses in urinary and gaseous products of digestion are also accounted for.
2) ME provides a more satisfactory measure of nutritive value than do TDN or DE.
3) ME is cheaper and easier to obtain than NE values.
4) The efficiency of utilization of ME takes into consideration the purpose for which it is fed, level of feeding and caloric density of the diet.

Demerits

- ✓ The requirement of the animal and feed value is given in terms of NE and ME, respectively.
- ✓ The large differences in the efficiency of utilization of ME are primarily due to wide variation in the energy losses as heat increment.