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Animal and Poultry Nutrition

- DIGESTIBILITY AND NUTRIENT REQUIREMENTS
- EEDING OF DIFFERENT SPECIES

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Digestibility and Nutrient Requirements

CONTENTS

DIGESTION AND ABSORPTION

This chapter has been studied in the course of physiology but the following are some knowledges of interest in nutrition, which should be reviewed.

Animals differ behaivourly and anatomically according to the kind of feeds consumed. In order to maximize the use of feeds these differences in digestion and absorption must be understood.

Appetite and its control

The hypothalamus in brain has been implicated as one of the major control centers of appetite regulation. It is believed that there is a chronic activity of its “feeding area” (the lateral hypothalamus) which is kept in check by the “satiety center” (the ventro-medial area). The hypothalamus is sensitive to circulating blood nutrients, as sugars and lipids, (chemostatic hypothesis), or to temperature (thermostatic hypothesis) in its work with appetite. Receptors in the rumen sensitive to the acetate and propionate levels affect feed intake. When the gastrointestinal tract is distended, there is a cessation of feeding. If an animal eats bulky or succulent feed, it may become satiated before fulfilling its energy requirement.

Types of feeding behavior

Based on the kind of feed, animals are classified as follows:

1. Carnivores: The food is readily digestible, mostly fats and protein, and have short and relatively simple digestive tract (1:6 for dogs and 1:4 for cats, body length to intestine length). Cats, which are true carnivores, require certain nutrients, such as preformed vitamin A and Taurine, which in the wild can be obtained only from consumption of meat.
2. Herbivores: The GI tract tends to be long (1:10 for rabbit to 1:27 for sheep) and there are modifications which enable the animals to digest plants efficiently. The large intestine in horse is voluminous (cecum 15.9% and colon 45.4%-relative capacity - cecum in ox & sheep 2.8-2.3 % and colon and rectum 8-10.5%). In ruminants stomach forms 66-71% and 66 gallons capacity in mature cow (less than 10% in horses and rabbits, capacity 5 gallon in horse).
3. Omnivores: The GI is generally longer than carnivore but shorter than herbivore. Humans, swine, and poultry are examples. They are not fastidious in their feeding behavior and consume a wide variety of animal and plant foods.

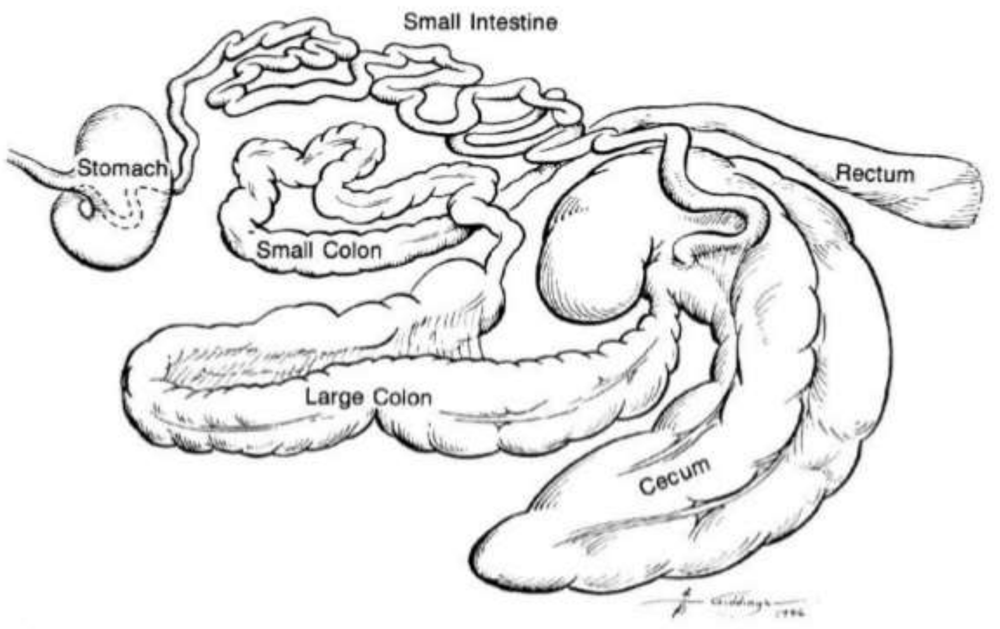
Based on the anatomy of the digestive tract animals may be grouped as:

1- Nonruminants are two subgroups, either with nonfunctional cecum (pig, dog, fish, monkey, man) or with functional cecum, or called the nonruminant herbivores (horse, rabbit, g. pigs and hamster). The last are capable of digesting fiber and synthesizing a number of vitamins. The horse stomach is designed for constant intake of small quantities of feed, rather than large quantities at any one time (quick tiring and labored breathing). Horse breaks not more than 30% of cellulose (ruminants 60 - 70%), synthesizes limited amount of B vitamins and vitamin K. Thus B vitamins along with A & D additions are good insurance especially with stress and low quality feeds. Small intestine never get a chance at the ingesta from cecum and colon so horse should be fed less roughage, higher quality proteins (and not such NPN as urea) and added B vitamins and K. The requirements are more parallel to pigs more than cows.

2- Ruminants: In the stomach compartments there is enormous population of microorganisms (25 – 50 billion bacteria and 200,000 to 500,000 protozoa/ml) & enormous amount of energy is expended (42000 jaw movements daily of which 26400 in rumination) and large amount of gases (primarily CO_2 and methane) results and must be eliminated. Young calves are more like that of simple stomach and the milk bypasses the first two compartments to the fourth stomach. If the calf gorges itself, the milk may go into the rumen where it is not digested properly and may cause upsets of the calf's digestive system.

3- Avian: Digestion in the fowl is rapid (2.5 h in laying & 8-12 h in nonlaying for the feed to pass from the mouth to coloaca).

Figure 16.2 Digestive system of the horse. The posterior view shows the colon or large intestine proportionally larger than the rest of the digestive tract. Note particularly the location of the cecum at the anterior end of the colon.



Digestive system of horse (source: google.com)

DIGESTION

Digestion in mouth

- In herbivore an enormous amount of energy is expended in mastication, 74 – 98 jaw movement per minute (and remastication in ruminants, 55 jaw movements per minute).

- As to the saliva, in the horse the parotid secretion is not continuous but occurs only when the animal eating food (mechanical, but little chemical). In ruminants the parotid secretion is continuous, ensures adequate moisture, buffer alkali, and phosphate for the functioning of the first three stomach compartments.

- In ruminants a reflex evoked by mechanical stimulation (by roughage) of the cardiac region of the stomach, causes copious secretion of saliva which prevents frothiness in the rumen ingesta. High in grain diets cause a number of nutritional or metabolic problems including acidosis and many other complications secondary to the acute acidosis.

The saliva (may reach 130 - 180 liter in cattle) has a high bicarbonate (4 times as serum) and phosphate (15 times) contents which make it a good buffer in the rumen and the pH is maintained at 5.5 - 6.5. The phosphate might be also related to the growth of rumen microflora, and its concentration is maintained even when cattle and sheep are on phosphorus - deficient diet.

- Horse and cat lack salivary amylase. Some might classify the dog with pig as having saliva containing enough ptyalin (amylase) to be of significance in digestion. The saliva of rabbit has a weak amylolytic action. Generally ptyalin is not of great significance in domestic animals.

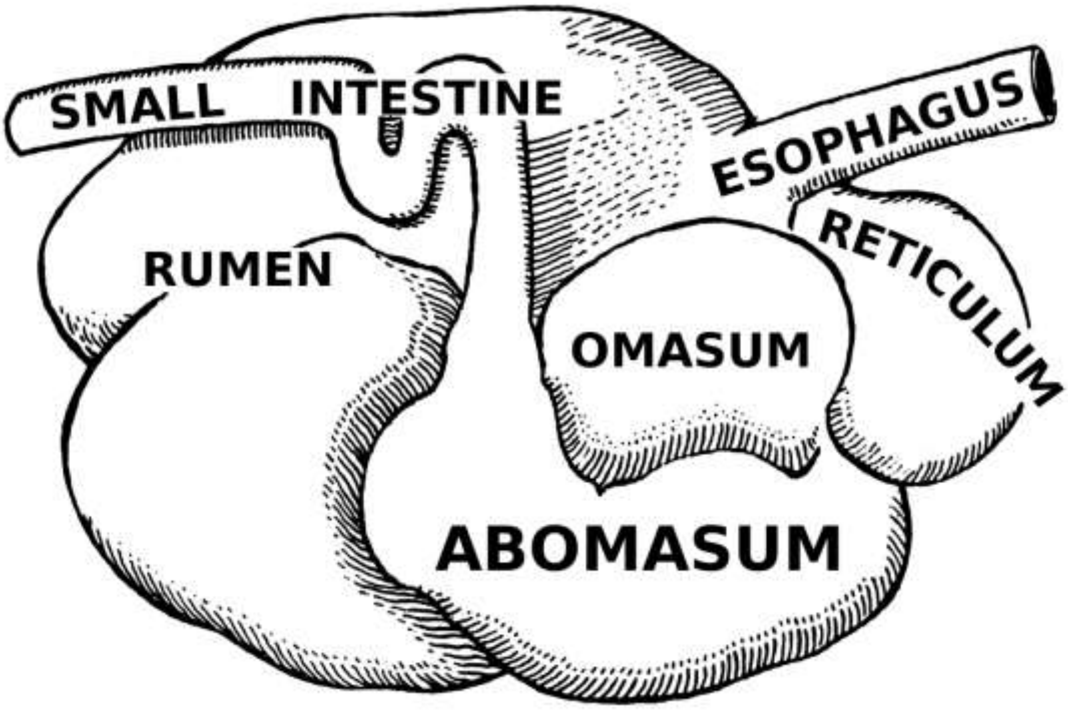
The $\propto$– amylase enzyme hydrolyses the $\propto$– 1, 4 glucan links in polysaccharides containing 3 or more $\propto$ – 1, 4 linked D-glucose units.

Digestion in simple stomach

- Among the simple-stomached animals are found carnivores, herbivores, and omnivores.
- Stomach also produces an "intrinsic factor" concerned in the absorption of vitamin B_{12}.
- Pepsinogen is activated by HCl to pepsin and converts proteins into proteoses and peptones.
- Rennin is the milk coagulating enzyme in the calf and probably other young mammals. It changes casein to paracasein (soluble). Calcium ions then react with paracasein to form the gel calcium paracaseinate.
- Gastric lipase is most abundant in carnivores and rodents, almost absent in fish and birds, and particularly absent in ruminants. The amount of the enzyme is too small and its action is doubtful to extend beyond emulsification.
- As for the other biochemical processes in the stomach salivary digestion of starch is continued for 15-30 minutes or more (man & somewhat in pig), and in herbivorous animals bacteria and plant enzymes begin their activity.

Digestion in ruminant stomach

- Contents of rumen contribute 10-20% of the live weight of ruminants.
- At the age of about 1.5 year old, the four compartments have reached their permenant relative sizes. At birth rumen is much smaller than abomasum and by 2-3 weeks calf begins to ruminate.
- Rumen contents contain 85 - 93% water on average, so ruminants should have abundance of water.
- As to the rate of passage of food residue, it may be completely excreted after 7 - 10 days.
- When the ration contains no roughage, rumination is slow and listless.
- The highest total counts, of bacteria and protozoa, have been recorded with diets largely composed of concentrates, and diets rich in soluble carbohydrates encourage the growth of lactobacilli. A normal rumen flora is established as early as six weeks of age in calves.
- In animals given concentrate diets, acid production may be unusually rapid and saliva secretion unusually low and pH as low as 5.0 and transiently 4.5. Protozoa cannot tolerate a pH less than 5.5 and it is normally absent from rumens of cattle fed high-concentrate diets.
- About 70% of the DM entering the rumen is converted by the microorganisms to soluble and gaseous compounds.



Ruminant stomach (source: google.com)

Digestion of Carbohydrates in the Rumen

The main end products are acetic, propionic and butyric acids and CO_2& methane. Pyruvic, succinic and lactic acids are important intermediates. The total concentration of VFA varies between 0.2 and 1.5 g/100 ml according to the diet and time elapsed since previous meal. The total weight may reach 3 kg/day in a cow. With all - concentrate diets propionic may even exceed acetic. Methanogenesis is a complicated process involves folic acid and vitamin B_{12}. About 4.5 g of methane is formed for every 100 g carbohydrate digested and ruminant loses about 7% of its food energy as methane.

It was shown that absorption of VFA_S occurs from the rumen, reticulum and omasum and caecum (large intestine) but not from abomasum. Some may pass through the abomasum and be absorbed in the small intestine.

The ratio of acetic acid to propionic was significantly higher at the lower level of feeding, and increased concentration of the total VFA_S were observed when high protein diets were fed although the relative proportions of acetic acid decreased and of butyric acid increased.

Digestion of Protein in the Rumen

The rumen microbes have a "levelling" effect on the protein supply of ruminants; they supplement both quantitatively and qualitatively the protein of food but has a deleterious effect on protein rich concentrates.

A more recent development is the protection of good quality proteins either by treating them chemically (with formaline for example) to reduce their solubility, or by giving them liquid suspensions that can be made to bypass the rumen via the oesophageal groove.

Ruminants receive 30% of the diet nitrogen in the form of non-protein nitrogenous compounds in the form of amino acids, amides and amines. Now it is a common practice to supplement diets with urea or less commonly biuret, ammonium salts and other nitrogen compounds.

Digestion of Fat in the Rumen

The food fats in ruminants are soft and contain a high proportion of C_{18} polyunsaturated acids, linoleic and linolenic. Although there is considerable hydrolysis of lipids in rumen, there is hydrogenation or hardening of unsaturated fatty acids. So the animal body fat is rich in the saturated C_{18} acid stearic.

Synthesis of vitamins

1) Rumen microorganisms synthesize members of B-complex and vitamin K.
2) The synthesis increases when the animals receive diets low in vitamins.
3) Adequate synthesis of B_{12} will take place only if there is sufficient cobalt in the diet.

Digestion in the small intestine

The Factors of Digestion in the Small Intestine are:

1) Duodenal juice (lubricant and protects against the HCl of the stomach).
2) Pancreatic juice. 3) Intestinal juice. 4) Bile. 5) Certain movements of the intestinal wall.

1-Pancreatic juice

The juice shows the presence of several proteolytic enzymes, a lipolytic and an amylolytic one.

Proteolytic enzymes (at least 3 are present)

- ***Trypsinogen:*** It is activated by the enterokinase, found in the intestine, into trypsin. Trypsin acts upon peptide linkages involving the carboxyl groups of lysine and arginine. Trypsin appears to be present in all animals. The optimum pH for its action is about 8.

- ***Chymotrypsinogen:*** It is changed to chymotrypsin by the action of trypsin in the intestine and has specificity towards peptide bonds involving the carboxyl groups of the aromatic amino acids (Phe, Tyr). Chymotrypsin shows a powerful coagulating action on milk.

- ***Carboxypeptidase:*** It acts on peptides (containing free carboxylic group) from the end of the chain and splits off an end amino acid.

Pancreatic Lipase (Steapsin): It hydrolyses fats to fatty acids & glycerol. As already been stated, the amount of fat digestion in the stomach is slight. Liquified fat upon entering the intestine, encounters alkaline juices in the upper part of the intestine where any free fatty acid in the fat is converted to soap. This, aided by the churning action of the intestinal movements, emulsifies the neutral fat. Emulsification hastens fat hydrolysis. The fatty acids released from the hydrolysis are themselves insoluble in the medium present in the intestine. They combine with bile salts to form water- soluble diffusible compounds, and also the bile salts have an activating effect on lipase. Their action in this respect is believed to be nonspecific.

Fats are absorbed in the form of fatty acids & glycerol. There is a possibility that fat in unhydrolyzed form is absorbed, perhaps in a state of molecular fineness.

- ***Lecithinase:*** An enzyme capable of hydrolyzing the phospholipid lecithin is said to be found wherever lipase is found.

Pancreatic Amylase (Amylopsin): It is found in the pancreas & pancreatic juice of all vertebrates. Resembles salivary amylase in many respects & hydrolyzes starch and the dextrin to maltose. It is claimed that it is composed of amylase proper hydrolyzing starch into dextrin, and one or more dextrinases hydrolyzing dextrins into maltose.

Bile probably has a slight accelerating influence on the amylolytic action of the pancreatic juice. Certain ions particularly Cl is necessary for the action of pancreatic amylase.

Other enzymes (Electrophoretic components)

Sucrase (invertase) and maltase enzymes have been found in the pancreas, but the amounts not large. These enzymes and lactase are found more abundantly in the small intestine.

2. Intestinal juice

The following enzymes have been described in intestinal juice or in extract from the mucosa:

1- Enterokinase: activates trypsinogen of the pancreas.

2- Peptidase (Erepsin): converts peptides to amino acids.

3- Maltase, Sucrase, Lactase:

- Maltose $\xrightarrow{\textit{maltase}}$ 2 glucose (enzyme, found also in pancreatic juice in small amount).
- Sucrose $\xrightarrow{\textit{saccharase}}$ glucose + fructose.
- Lactose $\xrightarrow{\textit{lactase}}$ glucose + galactose (it is present in the intestine of all young mammals but may be lacking in mature mammals that do not receive milk in their food).

4- Amylase: found in significant amount.

5- Polynucleotidase, nucleotidase and nucleosidase :

Under the influence of gastric and pancreatic digestion nucleoproteins are split into protein and nucleic acid. The protein is digested in the usual manner; the nucleic acid is digested by enzymes of the intestinal juice and mucosa into mononucleotides.

A mononucleotide is a combination of phosphoric acid, pentose and purine or pyrimidine base. When the phosphoric acid is split off from a nucleotide, a nucleoside is left.

- Polynucleotidase splits nucleic acid in its constituent mononucleotides.
- Nucleotidase, a phosphatase hydrolyzes mononucleotides into nucleosides and phosphoric acid.
- Nucleosides are hydrolyzed to purine and pentose by nucleosidase.

3. Bile

Bile obtained from the gall bladder contains several times as much total solids as that obtained from the hepatic ducts directly (liver bile) and has lower pH. The following constituents occur in the bile:

1- Bile pigments	6- Lecithin
2- Bile acids or bile salts	7- Mucin-like substance
3-Cholesterol	8-Fats
4- Soaps	9-Urea
5- Inorganic salts	10-Other substances

Bile salts, Bile as a digestive secretion

Bile salts are the sodium and to a lesser extent the potassium salts of glycocholic and taurocholic acids, formed in the liver and found in the bile.

Glycocholic acid is a compound of glycine and cholic acid .Taurocholic is a compound of taurine and cholic acid. Glycine and taurine are of protein origin.

Bile is both an excretion and a digestive secretion. It is chiefly because of the presence of bile salts that is able to function in the latter way. By means of its bile salts it is of use in digestion and absorption in the following ways:

1- Bile activates pancreatic lipase.
2- Bile probably accelerates slightly the action of pancreatic amylase.
3- Bile assists in fat emulsification.

4- The higher fatty acids are nearly insoluble in H_2O but in the presence of bile, their solubility increases thus their absorption is aided. During fat absorption, bile salts are also absorbed, in combination with the fatty acids. The reabsorbed salts thus enter the portal blood and are carried back to the liver, where they are again excreted. During their reelimination, they act as cholagogues or stimulants to the flow of the bile. Small amount of the bile salts are lost from the body in the feces.

5- Bile assists the absorption of fat-soluble vitamins. Bile has some important functions as a digestive secretion aside from its content of bile salts:

a- It is a reservoir of alkali and thus assists in maintaining an optimal reaction in the intestine.
b- The mucin or mucin like constituent of bile and the protein of pancreatic and intestinal juices, act as stabilizers of the fat emulsion in intestine.

6- Bile was formerly believed to have a marked antiseptic properties and thus to regulate the bacterial growth in the bowel.

The liver

From the stomach and small intestine, most of the absorbed nutrients travel through the portal vein to the liver- the largest gland in the body. The liver not only plays an important part in nutrient metabolism and storage, but also forms bile, a fluid essential for lipid absorption in the small intestine. The numerous physiological functions are:

1- Secretion of bile.
2- Formation and storage of glycogen and regulation of glucose in the blood.
3- Deamination of AA_S & formation of urea.
4- Destruction of uric acid.
5- Synthesis of FA_S from CHO and protein, phosphorylation of fats, interconvertion of FA_S, partial oxidation of FA_S and formation of ketone bodies.
6- Storage of vitamin A.
7- Detoxication of harmful compounds.
8- Aiding in destruction of RBC_S.
9- Formation of plasma proteins.
10- Inactivation of polypeptide hormones.
11- Storage and distribution of B_{12}.
12- Formation of prothrombin.
13- Destruction of estrogens.

Digestion in the large intestine

- The time food has reached the entrance of the colon most of the hydrolyzed nutrients will have been absorbed.
- Cellulose and many of the hemicelluloses are not attacked by any of the enzymes present in the digestive tract. Lignin is known to be completely unaffected.
- Digestion in large intestine is brought about by enzymes carried with food or as a result of microbial activity.
- The bacteria present are mainly of the proteolytic type producing skatole, indole, phenol, FA_S, H_2S, and AA_S. The digestion of cellulose and other higher polysaccharides is small in pig compared with horse and ruminants.
- There is a synthesis of B vitamins which may be absorbed by the host. In horse the B vitamins synthesized are not always produced or absorbed in quantities sufficient to meet the requirements.
- In comparison with ruminants horses suffer from the disadvantage that the products of microbial digestion have less opportunity of being absorbed and no opportunity of being further broken down by its own digestive enzymes.

Digestion in the fowl

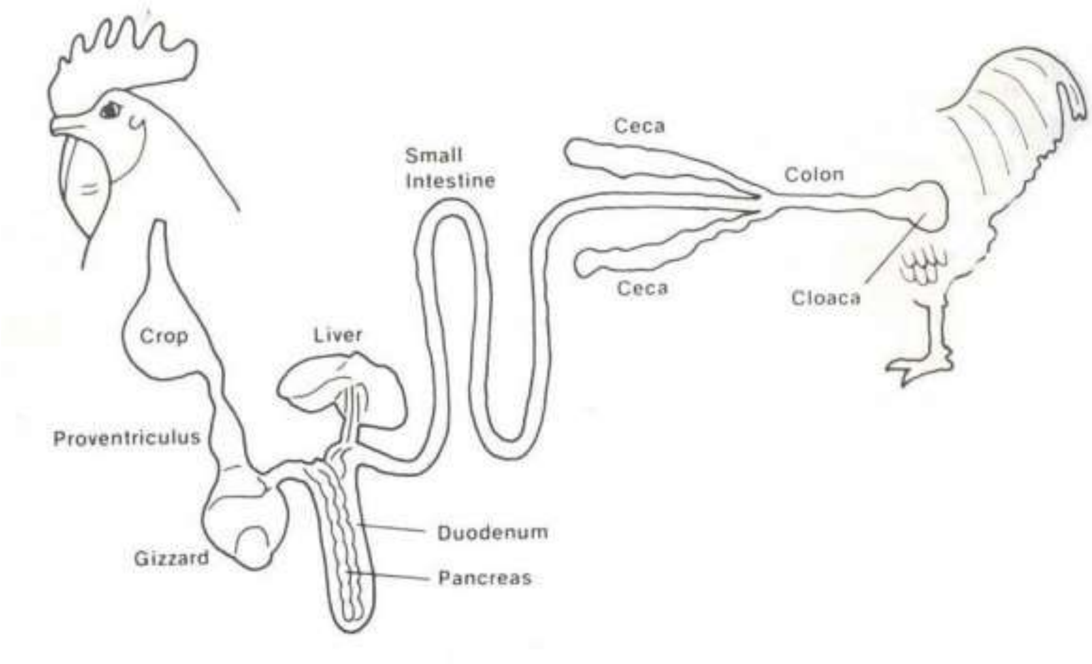
Birds have no teeth and there is no chewing. In the crop the feed is stored and soaked. Then to proventriculus, where it is stored temporarily, while digestive juice secreted and mixed with it. The food passes to the gizzard containing stones or grit where it is crushed and ground. Then the feed moves through the small intestine, the caeca, and the large intestine (colon) to the cloaca.

The enzymes present in the digestive secretions of the fowl are similar to those in the secretions of mammals, although lactase has not been detected. Salivary-amylase is known to occur in the fowl, and the action of this enzyme on starch continues in the crop.

The presence of grit in the gizzard, although not essential, has been shown to increase the breakdown of whole grains by about 10%.

The pancreatic juice of fowls contains the same enzymes as the mammalian secretion, and the digestion of proteins, fats and carbohydrates in the small intestine is believed to be similar to that occurring in the pigs. The intestinal secretion contains mucin, & amylase, maltase, sucrase and proteolytic enzymes.

The caeca, which function mainly as absorptive organs, are not essential to the fowl. Only some hemicellulose breakdown occurs.



Digestive system of chicken (source: google.com)

Microbial digestion in the horse

The horse has a simple stomach but a greatly enlarged caecum and colon, and those organs are inhabited by microorganisms with activities very similar to those of rumen organisms. Cellulose is digested and fatty acids are produced and absorbed, although the digestion of cellulose in roughages is less efficiently performed in the horse than the ruminants. Vitamins of the B complex are synthesized, but are not always produced or absorbed in quantities sufficient to meet requirements. Microbial digestion of soluble carbohydrates and of proteins and lipids is limited, because they are mainly digested and absorbed before the digesta reach the caecum.

Comparison of Horse and Ruminant:

- Stomach capacity is less than 5 gallons for the horse but 66 for the mature cows. If the horse is fed too much roughage, labored breathing and quick tiring may result. The horse stomach is designed for constant intake of small quantities of feed.
- There is less microbial activity in the horse. Horses break not more than 30 % of the cellulose, while ruminants from 60 -70 %; horses synthesize limited amount of B vitamins and K, so additional B vitamins along with A & D is good insurance especially with stress and low quality feeds.
- Small intestine never gets a chance at the ingesta from cecum and colon. So the horse should be fed less roughages, higher quality proteins (and not such NPN as urea) and added B vitamins and K. The requirements are more parallel to pig more than cows.

ABSORPTION

It is the process whereby foods, properly prepared by the organs of digestion are transferred from the lumen of the gut to the blood or lymph. By this means get to the tissues for utilization and for storage.

Place of Absorption

1) Mouth and Esophagus: No food absorption takes place in them.
2) Stomach: Contrary to what might be supposed, absorption is very limited under normal conditions. On the whole the food substances are not ready for absorption, proteins are not split below the peptone stage, fats are hydrolyzed to a slight extent, and carbohydrate digestion is in most animals, far from complete.

There is little reason to believe that inorganic salts are ordinarily absorbed from the stomach in significant amounts. Certain drugs may be absorbed from the stomach of some animals.

3) The small intestine: is the chief seat of absorption in carnivores and omnivores and is doubtless of great importance as an organ of absorption in herbivores as well.

4) Large intestine: as an organ of absorption is of limited importance in man and carnivores, except in the initial part of the colon where water absorption occurs. The large intestine of all herbivores, on the contrary must be well adapted for absorption. This would seem to be especially true in the simple stomached herbivores where such extensive digestive changes are reserved for the large bowl. It is probably less true of ruminants, where stomach digestion and absorption are so important. In the intestine, digestion and absorption proceed side by side.

Routes for Absorbed Foodstuffs

There are two routes by which absorbed food-stuffs may enter the general circulation, the lymph and the blood of the portal system.

Proteins and carbohydrates digestion products, water, and inorganic salts are absorbed largely by the blood.

Mechanism of Absorption

It is held that absorption is due in part to some special property of the epithelial cells. These structures expend energy in absorption, at least in certain phases of the process. The descriptive terms "Active transfer" and "Passive penetration" have been suggested for the two aspects of the mechanism of absorption.

Carbohydrates digested and the simple sugars are actively transported across the cell and carried by the portal blood system to the liver. The pentose sugars have a much slower rate of absorption than hexoses.

The end products of lipase activity on fats (mono and diglycerides and fatty acids) are absorbed by diffusion across the villi. Within the cells the mono and diglycerides are reesterified with the acids (from food and blood). The triglycerides pass into the thoracic duct and join the general circulation as chylomicrons. Amino acids from proteins pass into the portal blood and so to the liver.

In case of Ca and P, an excess of either interferes with the absorption of the other. Vitamin D promotes both. Phytic acid forms insoluble Ca and Mg salts which are broken down with difficulty especially in chicks. Oxalic acid renders Ca insoluble. Phytates and oxalates are broken down in the rumen. Mg is poorly absorbed by ruminants and about 90 % may be unavailable. The absorption of Fe is to large extent independent of the dietary source.

Vitamin C is one of the naturally occurring reducing agents which favours iron absorption by reducing the ferric iron to the ferrous. Zinc resembles iron in being poorly absorbed. Ca is believed to inhibit the absorption of zinc. Iodine is present mainly as inorganic iodide in plants and in organic form in foods of animal origin. In organic combination it is thought to be less well absorbed than the inorganic form.

Vitamin A is more readily absorbed than carotene, although it is thought that vitamin A esters must be hydrolyzed to the alcohol form before absorption. B_{12} absorption depends on the "intrinsic factor" secreted by the stomach.

THE DIGESTIBILITY OF FOODS

The potential value of a food for supplying a particular nutrient can be determined by chemical analysis, but the actual value of the food to the animal can be arrived at only after making allowances for the inevitable losses that occur during digestion, absorption and metabolism. The first tax imposed on a food is that represented by the part of it which is not absorbed and is excreted in the feces.

The digestibility of a food is defined as that portion which is not excreted in the feces and assumed to be absorbed by the animal. It is commonly expressed in terms of DM and as a percentage, the digestibility coefficient. In a digestibility trial, the food under investigation is given to the animal in known amounts and the output of feces measured.

So only a certain percentage of feed is utilized by the animal body and the part of feed so utilized is known as the digested nutrient and the remaining part passes through the animal undigested. The digestibility can be determined by one of the following methods.

A- Direct or conventional methods

The digestibility of a particular feed for any class of stock is determined by means of digestion experiment with that kind of animal. The chemist first finds by analysis the percentage of each nutrient the feed contains. The animal is then fed weighed quantities of the feed for a preliminary period of a few days, so that all residues of former feed may pass out of the digestive tract. Ruminants and horses are usually allowed 10-15 days, pigs 5 days and sheep at least 15 days. This period is to accustom the animals to the diet and to clear from the tract the residues of previous foods. Also food intake levels can be noted.

More than one animal is used, firstly because animals, even when of the same species, age, and sex, differ slightly in their digestive ability, and secondly because replication allows more opportunity for detecting errors.

Male animals are preferred to females because it is easier to collect feces and urine separately. Small animals are confined in metabolism cages which separate feces and urine by an arrangement of sieves, but larger animals are fitted with harness and feces collection bags made of rubber (impervious material).

Owing to the differences in the composition of the feces, even when the supply and quality of the food is constant, it is essential to collect them for at least 10 to 12 days when experimenting with horses or ruminants and at least 6 days for pigs. Longer periods are giving greater accuracy.

With simple stomached animals (omnivora and carnivora) the feces resulting from a particular input of food can be identified by adding an indigestible coloured substance, called a marker, such as ferric oxide, carmine or chromic oxide to the first and last meals of the experimental period (or just before the beginning of the ingestion of the ration and again at its close), the beginning and end of the fecal collection are then delayed until the first marker appears in and the second disappears from the excreta. With ruminants this method is not successful because the dyed meal mixes with others in the rumen, and instead an arbitrary time-lag of 24-48 hours is normally allowed for the passage of food residues, i.e. the measurement of fecal output begins 1 to 2 days after that of food intake, and continues for the same period after measurement of food intake has ended.

During the digestion experiment, the same amount of the feed is given to the animal each day and at the same time. The feces are carefully collected and weighed and samples are analyzed. Each day one tenth or one fifth of the well- mixed feces is taken, at once dried and then after being left exposed to the air to render it "air dry ",it is analyzed in exactly the same way as the food.

The differences between the amount of each nutrient fed daily and the amount found in the feces is the amount of the nutrient that is digested.

For poultry the determination of the digestibility is complicated. This can be solved either chemically (most of the urine N is in the form of uric acid and most of the fecal N is presented as true protein) or surgically to separate the urine and feces.

Metabolism cage (source: google.com)

B- "*By difference" methods*

This method is used in case of feeds which cannot be fed alone. Thus horses or ruminants are not fed concentrates alone without hay or other roughages. Again, while pigs may be fed on grain only, such feeds as tankage, and L.S.M. are too rich in protein to be fed alone. Thus hay for herbivores and grains for pigs and poultry can be used as basal diets.

C- Indicator or index methods

For reducing the cost and time required in digestion experiments, other methods in which feces are not collected and weighed, but are merely sampled and analyzed. Sometimes it is impractical to measure directly either food intake or feces output, or both, for instance, when animals are fed as a group. These methods are called the indicator methods, in which the digestibility is calculated as follows:

$$\text{Digestibility of DM} = \frac{\text{\% indicator in feces - \% indicator in food}}{\text{\% indicator in feces}} \times 100$$

$$\text{Or} \quad = 100 - \left(\frac{\%\ \text{Indicator in food}}{\%\ \text{indicator in feces}} \right) 100$$

$$\text{Digestibility of a nutrient} = 100 - \left(100 \times \frac{\%\ \text{indicator in food}}{\%\ \text{indicator in feces}} \times \frac{\%\ \text{nutrient in feces}}{\%\ \text{nutrient in food}} \right)$$

The problem of measuring how much feed an animal obtains from pasture or range, the indicator method can be used as follows:

$$\text{DM consumption (g/day)} = \frac{\text{Units indicator/g dry feces x g DM in feces/day}}{\text{Units indicator / g DM of forage}}$$

The indicator may be natural constituent of the food (as lignin, chromogen, nitrogen) or be added to it, as chromic oxide. Digestibility can be determined as follows:

1) Determination of the lignin content of the forage or ration as the lignin is not digested to any appreciable extent even by ruminants. The digestibility of the various nutrients can then be determined. It was found that a small percentage of lignin can be digested by ruminants and an average correction can be made for this. Lignin methods is less reliable as the animal usually consumes the leaves than stems and young plant than old and so the lignin content of the food sample differs from that actually consumed.
2) By using a naturally occurring plant pigments or chromogen in forage plants as an indicator in digestion experiments. This pigment is entirely indigestible and entirely recovered in the feces. This method is proved especially useful in determining the digestibility in forage eaten by animals on pasture.
3) From the nitrogen content of the forage and the feces as it was found that there is a positive relationship between the concentration of nitrogen in feces and the digestibility of forage dry matter. Herbages higher in digestibility are commonly richer in N and thus give rise to feces high in N concentration, in addition, metabolic fecal N becomes concentrated in a smaller weight of feces.
4) A carefully weighed amount of chromic oxide, an inert indigestible compound, is administered to the animal each day, and the amount in the feces determined.

D- The Chemical in vitro methods

A chemical method in which samples of feed is digested within the laboratory gives approximate information on the digestibility of such feeds as meats and fish by-products. In ruminants the digestibility can be measured by the "two stage in vitro" method in which a finely ground sample of food is incubated for 48 hours with buffered rumen liquor in a tube under anaerobic condition in the first stage. In the second stage the bacteria are killed by acidifying with HCl to pH2 and are then digested by incubating them with pepsin for further 48 hours. The insoluble residue is filtered off, dried and ignited, and its organic matter subtracted from that present in the feed to provide an estimate of digestible organic matter. The coefficient determined in vitro is generally 1-2% units lower than that measured in vivo.

The validity of digestibility coefficients

The assumption that the proportion of food digested and absorbed can be determined by subtracting the part excreted in the feces is open to question on two counts. The first is that methane lost by eructation in the ruminants leads to over estimation of digestible CHO and digestible energy. In addition not all the feces are actual undigested food residues, part is contributed by enzymes, and other substances secreted into the gut and not absorbed, and abraded cellular material. Since this N is derived from the body, it is known as the metabolic fecal N- the amounts excreted are approximately proportional to the DM intake. Feces also contain appreciable quantities of ether-extractable substances and minerals (particularly Ca). The values obtained in digestibility trials are therefore called apparent digestibility coefficients to distinguish them from coefficients of true digestibility.

Factors influencing digestibility

Digestion coefficients are not constants for a given feed or species. They are influenced by several variable factors.

I-The Animal factors

- Animals of different species do not always digest the same quantity of any given food. The greatest digestive power is, undoubtedly, possessed by the ruminants, but foods of low fiber content are equally digested by ruminants and non-ruminants. Differences in digestibility ability of sheep and cattle are small and of no practical importance. Apparent digestibility for proteins is higher in swine as metabolic fecal nitrogen is smaller than ruminants (0.1 g MFN for rats, pigs & man per 100 g DM consumed while it is 0.5 for ruminants).
- Different breeds of the same animal species possess a nearly equal digestive power.
- Between individual members of the same breed, small variations, usually traceable to some slight physical weakness on the part of the animal, may occasionally be noted.
- The age of the animal does not influence the digestibility except in very old age when the digestibility is lowered.
- Whether the animal is working or at rest seems to have little effect upon the digestion of the food, even at hard work, but the quicker the rate the lower the digestibility. Ruminants must get rest intervals for their rumination.
- Alteration in conditions under which the animals are placed, are also without influence upon the digestibility of the food, provided violent excitement and disturbance of health are avoided.

II- Food factors

- ***Level of feeding***
  - If coarse food is the only foodstuff given then smaller or larger quantities do not affect digestion.
  - Large rations, in which the ratio between roughage and concentrates kept constant, seem, to be digested to a lesser degree than small ones as it has a faster rate of passage.
  - Increasing the concentrate intake alone causes the reduction in digestibility to be greater. It is due partly to the associative effect of foods.

- ***Ration composition***

The digestibility of a food is influenced not only by its own composition, but also by the composition of other foods consumed with it. This associative effect of foods represents a serious objection to the determination of digestibility of concentrates by difference. The digestion in the rumen depends very much on the balance of nutrients and that for example:

- The one-sided addition of digestible-carbohydrate to a food causes, under certain circumstances, a depression of digestibility.

- The addition of fat or oil does not alter the digestion of food, provided the added material is in a finely divided form and in moderate amounts, if however, large quantities of oil or melted fat are poured over the food, its digestibility is diminished.
- The increase of crude protein in a food causes not only no depression of digestibility of other components but, on the contrary, minimizes the depressing effect of large quantities of nitrogen- free substances.

- ***Preparation of foods***
  - Crushing of grain for cattle and grinding for pigs increase its digestibility.
  - Chaffing of roughages has little effect but may reduce it by preventing the selection of finer parts.
  - Pelleting of roughages has little effect.
  - Grinding of roughages reduces the digestibility of their crude fibre as much as 20% units and the dry matter as a whole by 5-15%, because of the faster rate of passage and the less complete fermentation of the finer parts.
  - Chemical treatment of cereal straws which contain a high proportion of lignin, in order to separate the cellulose from the lignin, increases the DM digestibility from 40% to 60-70%. Treatment is either by 2-3% Na OH soaking for 1-2 days and then washing to remove the alkali, or by the recent method of spraying the straw with a small volume of concentrated alkali and neutralizing the excess with acetic or propionic acid.
  - Cooking does little improvement for digestibility especially that of some vegetable protein by destroying an enzyme inhibitor present in the feed. Excessive heating may cause the amino group of lysine to react with the aldehyde group of sugar to form indigestible complex.
- ***Food composition***

  - An increase of crude fiber content of many feeds by 1% reduces digestibility by 0.7-1% unit for ruminants, and twice this value for pigs.

  - Digestibility of crude protein is particularly dependent upon the proportion of protein in the food. The output of metabolic fecal N in ruminants is equivalent to about 3 g of crude protein per 100 g of food DM eaten. So food containing less than 3%of CP reduces the digestible protein supply of the animal.

NUTRIENT REQUIREMENTS OF ANIMALS-FEEDING STANDARDS

Feeding standards are statements of the amounts of nutrients required by animals while the allowances are greater than these amounts by a safety margin designed principally to allow for variations in requirements between individual animals. Safety factors have been criticized.

Feeding standards may be expressed in quantities of nutrients, mainly for animals given exact quantities of food, or in dietary proportions, mainly for animals fed to appetite. In some cases the requirements for single functions are not known, this is particularly true for vitamin and trace element requirements.

Standards may be given separately for each function (as in dairy cattle) or as overall figures for the combined functions (growing chickens).

In the following chapters the nutrient requirements for maintenance, growth & wool, fattening, work, reproduction and lactation will be discussed.

REQUIREMENTS FOR MAINTENANCE

The animal is in a state of maintenance when its body composition remains constant, when it gives rise to no product such as milk & when it performs no work on its surroundings.

Animals deprived of food are forced to draw upon their body reserves to meet their requirements for maintenance and the purpose of the maintenance ration is to prevent this drain. To maintain an animal at rest without losing or gaining in weight it must have the minimum quantity of the following and which promote zero balance:

1- **Energy** to maintain the body temperature and to carry on the vital function.

2- **Protein** to repair the small daily waste of protein.

3- **Minerals** to replace the small but continuous loss of minerals.

4- **Vitamins** especially vitamin A & D.

5- At least for young calves, lambs, pigs, chicks, dogs, rats, and mice, a very small amount of **fat or of certain fatty acids** are needed for health.

These are in addition to **water, air, exercise and sunlight**.

Energy requirements

Maintenance and heat production

The energy expended for maintenance of an animal is converted into heat and leaves the body in this form. The quantity of heat arising in this way is known as the animal's basal metabolism, and its measurement provides a direct estimate of the quantity of net energy needed to meet the requirements for maintenance. The measurement is complicated by the fact that heat also comes from the digestion and metabolism of food (the heat increment of feeding or the specific dynamic action). Considerable heat is produced especially in case of ruminants in the fermentation of carbohydrates in the digestive tract. The heat generated helps to warm the body.

The effect of food, on the measurement of the basal metabolism, is removed by depriving the animal of food (overnight in man to several days in ruminants).

Net energy required and vital functions

The energy expended even when an animal is not eating, is for the work of the heart, lungs and other internal organs. Nutrients are also constantly being oxidized in the muscles to keep them in a state of tension and more nutrients are oxidized in standing and moving.

While about one third of the total energy in the digested nutrients is unavoidably converted into the aforementioned "heat increment", even in easily digested feed as corn, and with roughage about two-thirds, the amount of energy needed for the vital processes is relatively small. For example to maintain a horse at rest only one third of the total energy of the ration is needed to be supplied in the form of net energy, the remainder being used solely to warm the body.

Maintenance ration for livestock except swine and poultry may therefore consist largely of roughage, but not of wheat straw alone, which furnishes nearly no net energy to horses and little to ruminants.

The sum of the energy lost as heat plus that required for the activity at maintenance living is the maintenance energy requirement.

Maintenance energy requirements not proportional to body weight

It was concluded that values for fasting metabolism as TDN or energy of mature animals of various sizes are closely proportional to the 0.73 or the 0.75 power of the live weight which is called the metabolic weight (the basis of these figures is that the body surfaces of animals of various sizes are proportional to the 0.67 power of their live weight). The fasting metabolism of adult animal of species ranging in size from mice to elephants has an average value of 70 kcal per kg $w^{0.75}$ per day, but there are considerable variations from species to species.

Protein requirements

There must be a supply of protein to replace the daily breakdown or the wear of the protein tissues of the body. The nitrogen lost in the feces **(5g N/kg DM in cow)** arises from the enzyme and cell residues of the digestive tract. While the nitrogen in the urine **(0.12g N/kg$^{0.75}$ in ruminants)** represents that of materials expended, and which cannot be recovered for reuse. Likewise for the growth of hair or wool and of skin and hooves.

Approximately the DCP needed equals EUN x3 to 3.5 x 6.25.

But for the practical requirement a cow can be maintained on 80 – 60 g CP /100kg live weight, NRC (1988), for a cow of 400 or 800 kg respectively (3.56/kg$^{0.75}$). It is believed that this allowance will safely cover the variations in the composition of feeds, and the development of the unborn calf until the last few weeks of pregnancy, when an additional allowance is advised.

When stock is fed rations exceedingly low in protein, the digestibility of the protein and other nutrients is often seriously decreased (wastage of feed). A supply of protein somewhat above the minimum promotes the health of animals, and animals with a good protein reserve are better able to resist infection (the antibodies are produced from the serum proteins). For maintenance the food must provide not only a certain amount of protein but also the protein must be of proper quality for the particular class of animal.

Protein requirement is not proportional to body weight

The protein needs are proportional to the 0.73 or 0.75 power of the live weight, the same as in the case of requirements for energy.

Mineral requirements

From mineral starvation, the end will come sooner than if no food at all is given. The requirement is relatively small in comparison with those for growth or for milk production. However, even when livestock are not being fed for production common salt should ordinarily be supplied and also small amount of Ca and P. In most regions other necessary minerals are usually furnished in sufficient amounts by ordinary feeds. It is known that for animals which finished their growth, rations contain plenty of good quality roughage will usually furnish sufficient mineral matter except common salt.

Vitamin requirements

All vitamins are needed for the wellbeing of the animal especially vitamin A and D. Requirements for the fat-soluble vitamins, in older animals at least, are considered to be proportional to body weight.

Requirements vary also according to the extent to which B vitamins are synthesized in the alimentary tract. Horses obtain adequate amounts of the B vitamins from natural feeds and from synthesis by intestinal microflora for maintenance. Hardworking horses may need a dietary supplement of B vitamins under some conditions.

Other requirements: Air, water, exercise, and sunlight.

Inanition

Inanition (malnutrition) or incomplete starvation is a more field condition than complete starvation. The diet is insufficient in quantity and all essential nutrients are present but in suboptimal amounts. In addition there is mental depression, lack of sexual desire and increased susceptibility to infection.

A deficiency of one or more specific dietary essentials is more appropriately described as partial starvation.

REQUIREMENS FOR GROWTH

Importance of thrifty growth and characteristics

1. **Thrifty growth** is important as it is one of the most important forms of livestock production.
2. For the animal to reach its **full production capacity** it should be fed properly in addition to inherited characteristics.
3. **Conception** is the starting point for growth. The longer the percentage of the total growth period spent in utero, the more advanced are the young at birth. Rats born with eyes closed, has no hair, legs not used for considerable period, nourished on milk for relatively long period, while in guinea pigs eyes opened, full coat of hair and within a few hours it is running around nibbling leafy material. Pregnancy period in rats is 21-23 days compared with 58-75 days in g. pig. The calf, lamb, and foal resemble the guinea pig as regards their stage of development of birth, while the pig and the human baby are more like the rat.
4. The **rate of growth** is not constant; there are periods of acceleration and retardation. Thus growth tends to cease earlier in the female than in male.
5. Pregnancy, by the action of progesterone in inhibiting estrogens, causes a resumption of growth (**pregnancy anabolism**).
6. As to the **growth of body parts**, bone develops earlier than muscle, which in turn develops earlier than fat. Also markedly different rates are exhibited by certain organs and chemical constituents.
7. **As an animal ages** the general tendency is for there to be a progressive decline in the water content of its gains, a slight fall in protein, and a marked rise in fat. It is generally assumed that the gains made by faster-growing animals contain greater concentrations of fat and energy, and lesser concentrations of water, protein and ash.
8. ***Measures of growth:*** a- Increase in weight (in gram/day or as percentage of the mass at the start). It is crude because changes in weight include changes in the weight of intestinal contents which in ruminants may reach 20% of the gain. b- Size measures (as height, length, heart girth or circumference). c- A combination of weight and size measures is more useful, d- The growth in tissues, viz., protein and the skeletal minerals, can be obtained by a balance experiment or by the slaughter procedure.

Certain hormones have proved effective as growth stimulants, but hormones are neither permitted nor used to any extent as feed additives in many countries. Also some other compounds may be used to increase the rate of growth of animals under some conditions.

10. ***Retardation of growth:*** Severe retardation (results from a failure of glandular secretions) is rare. It was noted; however, that severe and prolonged undernutrition at an early age may result in permanent stunting.

11. ***Accelerated growth performance:*** Today's methods of feeding result in more rapid rates of gain of broilers, pigs, and cattle and they reach slaughter weights at younger ages on less feed. This is due to improvement in breeding, management and feeding practices. Fat deposition does not constitute an acceleration of growth rate.

Utilization of food by young animals

1- Young animals make decidedly **more rapid gains** considering their size than do older animals, even when the latter are fed on liberal ration e.g. a month old calf fed liberally on milk will gain about 1 kg/100 kg live body weight while a daily gain of 0.3 kg/ 100kg body weight is large for 2- years- old fattening steer.

2- Youngs can **build into their protein tissues** and skeleton a large part of the proteins and minerals in their rations. The growing animal possesses an extraordinary power of incorporating the proteins which are offered to it.

3- Generally speaking, the young animals require considerably **less feed** per 100 kg of gain in body weight and, therefore, make much cheaper gains than animals which are older. Because of this, young animals have a marked economic superiority in the production of meat.

These are the following reasons for the rapid gains and the more economical meat production of young animals:

a- Their gains are more watery than those of older animals and also contain more protein and less fat which has a decidedly higher energy value than protein. Much more net energy is therefore required to make a pound of gain on a mature fattening animal than on one which is young and growing.

b- Food eaten is ordinarily lower in fiber and hence digestible and higher in NE.

c- Youngs eat more food in proportion to live weight and leave for tissue building a much large part of their feed after their maintenance has been met.

Requirements for growth

The skin, muscles, ligaments, and internal organs of animals are almost wholly protein, as a large part of the nervous system and the organic portion of the bones. During youth, all these parts steadily increase in size, and at the same time much mineral matter is built into the skeleton or is retained in the vital parts of the body cells.

The nutritive requirements for growth are very different from those for mere maintenance. Not only are for greater amounts of certain nutrients required but also a young growing animal suffers sooner and much more seriously from nutritive deficiencies than does a mature animal. It needs in comparison with maintenance decidedly more protein & protein of better quality, much more TDN as growth consists largely of an increase in muscle and other protein tissues, and a more liberal supply of minerals and large amounts of vitamins. Maintenance rations consist chiefly of roughages which furnish little net energy. On the other hand, for thrifty growth, the ration must be more concentrated.

In practice it is usually found that only one or two amino acids are very markedly deficient (the limiting A A_s). For pigs the acid likely to be the most deficient is lysine and for chicks the "first limiting" acid is commonly methionine although lysine and perhaps arginine may also be deficient.

Treating of protein feeds with heat, aldehydes, or tannins to reduce the solubility of the protein reduces ammonia production in the rumen and apparent digestibility, but increases growth rate and nitrogen retention.

Wool production needs substantial amount of protein

Since wool fiber is practically pure protein, a substantial amount of food protein is required for its production. There are two aspects of wool growth which distinguish it from the growth of muscle. 1-Despite, a negative nitrogen and energy balance, wool growth continues at the expense of the breakdown of other protein tissues. 2-Wool protein has an AA distribution quite different from that found in muscle. It contains, on a percentage basis, over 10 times as much cystine as does muscle protein, a difference which is only partially balanced by the higher content of methionine in muscle. The microorganisms in the rumen can utilize inorganic sulfur and nonspecific sources of N to form these essential AAs.

Wool growth is clearly influenced by NE intake and the pattern of AA_S absorbed. Methionine and cystine supplements also increased wool growth in some tests but not in the others. It was found that methionine, lysine, and thereonine were the limiting AA_S for growing lambs receiving urea.

Wool quality is influenced by the nutrition of the sheep. High levels of nutrition increase the diameter of the fibres, and it is significant that the finer wools come from the nutritionally less favourable areas of land. Periods of starvation may cause an abrupt reduction in wool growth; this leaves a weak point in each fibre and is responsible for the fault in fleeces with the self-explanatory name of "break". An early sign of Cu deficiency in sheep is a loss of "crimp" or waviness in wool; this is accompanied by a general deterioration in quality, the wool losing its elasticity and its affinity for dyes being reduced.

Mineral elements

1. **Ca & P** (with vit. D) and others as F, Cu, Zn, I & Mn are important for bone growth in addition to the electrolytes Na, K & Cl.
2. **K** and **Fe** are least apt to be deficient in the diets of farm animals (plants and most fertilizers contain K). Higher need values for K are for cattle, horses and sheep.
3. On a salt **(NaCl)** - free diet the values in urine may fall to zero and Na is the most critical in all animals. Common salt should be added to the grain mixture at the rate of 1%.
4. **Mg** is required for normal growth, feeds and most forages contain sufficient, except during lactation when the requirements are highest and its utilization may be reduced. Milk is an exception. Calves limited to milk as the only food, with no access to forages or concentrates, will suffer from Mg deficiency after several months.
5. When NPN provides an important part of the N for ruminants **S** should be provided at a N-S ratio of 1:10 (for synthesis of AA_S, thiamin & biotin). Ca sulfate, Na sulfate, DL-methionine, or hydroxy analog could be used (supplied 0.13 to 0.15% of S) but wool growth and S retention was slightly higher on methionine hydroxy analog.
6. Weight gain and energy utilization was reduced when Hb levels of calves fell below 7 g/100 ml blood. Ferric oxide is much less available for calves and sheep than ferrous sulfate, ferrous carbonate, or ferric chloride. Anemia frequently occurs in suckling pigs.
7. **Copper** is required, along with iron, for Hb formation. It also plays many other important roles in the body. Cu deficiency in cattle and sheep has caused serious losses in several countries. Adding copper sulfate to mineral mixtures or concentrate feeds is effective in preventing the losses.
8. **Iodine** prevents goiter in animals and people alike. Soybean meal and some other feeds are goitrogenic and more iodine is needed if they are included in the diet. Iodine is usually supplied to farm animals along with common salt (0.007% iodine).
9. All calves from cows fed a low-**Mn** diet, had enlarged joints, twisted legs, stiffness, and a general physical weakness. Most forages and cereals contain at least 20 ppm which is sufficient to meet the requirements of the cow.
10. **Cobalt** deficiency is an area problem which occurs in ruminants, but not in horse or other nonruminants on the same pasture.
11. **Zinc** is a critical nutrient for growth of animals and to prevent dermatosis.
12. **Se** requirement is about 0.1 mg/kg dry feed for most animals.

Vitamins

There are still many instances in which the data are less precise than desirable, and excesses of some nutrients, especially vitamins may be added to insure that a deficiency will not occur.

Milk is the natural food for young animals

Milk is practically indispensible for young animals as a food during the entire suckling period. Whole milk containing the fat has the following virtues:

1- It is easily digested and assimilated and has a very high nutritive value per pound of dry matter.
2- It has an abundance of high quality protein.
3- It is rich in Ca and P.
4- It provides plenty of energy in the fat and milk sugar.
5- It is high in vitamin A value; if produced by animals fed good rations.
6- It is rich in riboflavin and is a good source of niacin, vitamin B_{12} and other B complex vitamins
7- The milk sugar tends to increase the assimilation of Ca and P and to prevent putrefaction in the digestive tract.

Milk is not a perfect food for exclusive feeding to animals over long periods. It has but little of iron, the content of vitamin D is rather low, and it is not rich in ascorbic acid. In livestock feeding the lack of iron is important only in the case of young pigs not on pasture. The relatively low content of vitamin D can readily be made good by allowing the young animals access to sunlight, or by including in the ration well-cured legume hay or some other sources of vitamin D. The fact that milk has but little ascorbic acid is not of importance in feeding farm animals.

There is a definite relation between the composition of the milk and the rate of growth of the young.

REQUIREMENTS FOR FATTENING

The object of fattening: we all know that the lean meat from a well- fattened animal is better flavored and more juicy than that from a lean one. This improvement in the quality of the lean meat, and not the storage of thick masses of fat, is the main object in fattening animals before they are slaughtered for meat.

. This storage of fat, which forms the so-called "marbling" of meat, adds to the juiciness and flavor, besides increasing the digestibility and nutritive value. During fattening there is also some increase in soluble material of the muscles, which adds to the flavor of the meat.

Beef becomes decidedly more tender, as well as better- flavored, when it is aged for a few days at the proper temperature in a cooler. This is also the case with mutton from older sheep. The increase in tenderness is due to enzyme action on the tough and resistant protein in the connective tissue of the meat. Unless a carcass has a sufficient covering of external fat, it will tend to spoil before it has been sufficiently aged.

What fattening is? In the fattening of mature animals or those which have nearly completed their growth, the gain consists primarily of fatty tissue. In the case of such animals there is little storage of protein and mineral matter. For example, the gains made by steers which are fattened when nearly full grown will be about two-thirds fat, and will have only about 8 per cent protein, less than 2 per cent mineral matter, and somewhat over 20 per cent water.

Most of the animals raised for meat in this country are now fattened for market at relatively young ages. For instance, but few steers are older than 3 years when slaughtered, and a large proportion are only 1 to 2 years old. Likewise, practically all the lambs not retained for breeding are fattened and marketed before they are a year old. Most of the pigs reach the market when much less than a year of age. Since such animals are still growing rapidly in muscle and skeleton while they are being fattened, the proportion of protein and mineral matter will be much higher in their gains than in those of older animals.

The fact that the proportion of fat in the gain made by an animal steadily increases during the fattening period is of much practical importance. It is the chief reason why the feed cost per pound of gain increases rapidly after an animal has become fairly well fattened. Such flesh contains much more fat and less water, and it is correspondingly more expensive to produce.

Also, when an animal has become fairly fat, it eats less feed per 1,000 lbs live weight. Consequently, it has less nutrients left for meat production after the maintenance requirements have been met. In addition, the actual maintenance requirements of a fat animal per 1,000 lbs. live weight may be higher than for one in moderate flesh.

Any excess fat beyond that which is required to make beef or mutton attractive, juicy, and well-flavored is therefore largely waste, though it has been a heavy expense to the producer. Years ago, when cattle were usually fattened after they were well grown, it was necessary to carry them to a high finish to make the meat tender and juicy. Now, however, with our changed methods of beef production in which cattle are fattened while yet young and growing, such extreme fattening is no longer needed to produce beef of good quality.

So the source of fat which the animals store in their bodies has been conclusively shown to be mainly from the fats and carbohydrates, and to a much less extent from the proteins contained in the feeds.

The relative values of different feeds for the formation of body fat depend on the amounts of net energy or of total digestible nutrients that they furnish. For this reason, such a feed as corn grain is unexcelled for the fattening of stock.

Effect of food fat on body fat: At least in the case of swine and chickens, if the feed contains considerable fat the kind of fat in the food may have a pronounced effect upon the character of fat stored in the body. This is because the fatty acids in the food fats are to some extent deposited unchanged in the fatty tissues. If the feed contains considerable fat that is liquid at ordinary temperatures, the body fat may become so soft as to injure the quality of the carcass.

The kind of fat in feeds also affects the character of the milk fat produced by cows. On the other hand, the character of the body fat formed by ruminants (including cattle, sheep, and goats) is apparently not changed appreciably by the kind of fat in the feed.

Nutrient requirements for fattening

The first requirement of a ration for fattening animals is an abundance of total digestible nutrients or net energy. The amount of protein needed and also of vitamins and minerals will depend chiefly on the age of the animals, the requirements being much greater for young animals than for those that are well grown when fattening begins.

Mineral and vitamin requirements for fattening: Mature fattening animals do not require a much greater amount of minerals than they need for mere maintenance, and their vitamin requirements are also low. On the other hand, young fattening animals have even greater needs for minerals and vitamins than those that are merely making normal growth. Particular care must therefore be taken that they have an ample supply of these nutrients, or the gains will be unsatisfactory, and the animals may even become decidedly unthrifty.

Factors influencing fattening

In addition to the **suitability** and the **liberality** of the ration, certain other factors have a great influence on the rapidity, and economy of gains during fattening.

Unthrifty animals make slow and expensive gains. **Young** animals that are thin and even somewhat small for their age, due to a previous scanty supply of feed, may make rapid and cheap gains when fed a liberal fattening ration. It will, of course, require considerably longer for them to reach a desired market condition than for animals which are in better flesh at the start of fattening. If young animals have been stunted by a lack of minerals or vitamins, they are apt to be unthrifty and therefore unprofitable in the feedlot.

The ability of an animal to make economical gains and reach a good finish also depends upon **temperament**. While a wild animal, nervous and active, can be fattened only with extreme difficulty farm animals are more quiet and usually fatten readily.

REQUIREMENTS FOR WORK PRODUCTION

Many different kinds of animals, such as elephant, camel, mule, donkey, water buffalo, dog, horse, and human, are used for work in various countries. Horses are used, for example, as race, police, and draft horses, and dogs as race, pleasure, guard and police dogs.

The source of muscular energy

Carbohydrates are the primary and most efficient source of energy for muscular work. However, fat and protein can also be used indirectly, probably through previous formation of carbohydrates from these nutrients. Under normal conditions, the carbohydrates and the fat of food are first used, and little more or no more protein is broken down than during rest. Should the carbohydrates and fats of the food not furnish enough energy, the body fat is next used. Finally, as a last resort, the muscles or other protein tissues can be called upon, if the energy can be secured from no other source.

Although energy is by far the principal food need for muscular performance, protein and various other nutrients are also concerned. Phosphorus compounds and calcium and magnesium ions are minerals directly involved. Various B-vitamins serve as cofactors in the metabolic reactions which take place.

Nutrient requirements for work animals:

Feeding standards serve only as general guides. A suitable ration should be fed to keep the horse in good working condition rather than an arbitrarily specified allowance. Estimates of the energy requirements for various human activities are available more than horses which are limited where some values are listed by NRC (1973) and (1989).

The nutrient concentrations for working horses (NRC, 1989) on dry matter basis are as follows:

Stage	Mcal/Kg DE	DM intake % B.Wt.	Diet proportions		CP %	Ca %	P %
			Conc. %	Hay %			
Maintenance	**2.00**	**1.35-1.80**	**0**	**100**	**8.0**	**0.24**	**0.17**
Light work	**2.45**	**1.35-2.25**	**35**	**65**	**9.8**	**0.30**	**0.22**
Moderate work	**2.65**	**1.58-2.25**	**50**	**50**	**10.4**	**0.31**	**0.23**
Intense work	**2.85**	**1.80-2.70**	**65**	**35**	**11.4**	**0.35**	**0.25**

NRC (1973) recommended 2.75 Mcal of DE per Kg of 100% dry feed, and 10% CP of which about 50% is digestible for maintenance, light (2 hr/d), and medium (4 hr/d) work (feed intake is 1.1 -1.5, 1.5-1.9, and 2-2.4 % B. Wt. respectively).

Protein requirements:

The chief need in rations for work animals is a sufficient supply of feeds rich in TDN or net energy. A mature animal needs during work but little more protein, minerals, and vitamins than are required for satisfactory maintenance at rest.

A young work animal that is still growing needs more feed than a mature animal doing the same work. Also, the requirements of a brood mare are increased during pregnancy and specially when suckling her foal. It is important that both these classes of work animals have plentiful supplies of protein, minerals, and vitamins.

It is agreed, at least, that even during hard work there is no marked increase in the amount of protein used in the body, if the amounts of other nutrients are ample. For this reason, a mature animal needs during work but little more protein than is required for satisfactory maintenance at rest. However, the digestibility of a ration is usually decreased when the proportion of protein is too low. Also, it is believed that a supply of protein somewhat above the minimum requirements tends to give work animals better life and spirit. The protein requirement should be increased as the work becomes harder.

Protein intakes appear to be adequate for mature working horses and humans when 10 % of the gross energy in the diet is in the form of protein.

Minerals and exercise

Sodium: The kidney can regulate the urinary sodium losses but significant amounts of sodium are lost in sweat. It is assumed that the salt requirements of horses can easily be met allowing free choice access to salt. Even in humans, most losses can easily be recovered in a single meal. But frequent intake of small amounts of saline solutions is recommended for individuals doing prolonged work under heat stress. Saline solutions (0.3 to 0.4 percent salt) appear to be superior to salt tablets as gastrointestinal disturbances have been reported due to the consumption of the latter.

Potassium:Potassium deficiency results in decreased endurance times in swimming rats and disruption of carbohydrate metabolism in the muscle. Severe muscular dystrophy has been reported in potassium-deficient rabbits.

Calcium: The increased need for calcium due to sweat losses will be corrected by the increased intake of the diet due to the greater energy needs.

Phosphorus: Phosphorus is lost in sweat but at least in the horse the quantities are probably not as great as those of Ca.

Iron: There may be significant amounts of iron lost in human sweat, but most diets contain enough iron to compensate for the loss.

Vitamins

There is no doubt that the exercise increases the total requirements of many vitamins. The need for the B-vitamins in energy metabolism is increased because of the greater energy intake.

Water

Dehydration is probably one of the most common problems of athletes working in hot, humid environments. The simplest and most obvious way to prevent dehydration is to allow horses to drink whenever they wise. There is no danger in allowing horses water when they are hot providing that they are offered water frequently and not allowed to become too thirsty. It is recommended that horses be given the opportunity to drink every hour or so. Cold water can be given without harmful effects. If a horse is extremely thirsty, the water should be rationed initially, perhaps gallon or so every 15 -20minutes.

Conclusion

From the foregoing it is clear that the primary need is rations for work animals is for a sufficient supply of feeds rich in easily digested carbohydrates, and which consequently yield a large amounts of net energy . Hence the most common ration for horses at hard work are made up of only moderate amount of hay or other roughage, with a liberal supply of farm grains, such as corn or barley which are rich in net energy. If the rest of the ration is very low in protein, a small amount of protein rich feeds should be added to compensate for the wear and tear of the body tissues occurring during work and to balance the ration according to the recommendation of the feeding standards. The harder the labour performed, the larger should be the proportion of grain to roughage in the ration.

The mature animal when at work does not need a much greater amount of minerals or vitamins than when nearly being maintained at rest. However, since a long life of usefulness is important, it is wise to be sure that there is a plentiful supply of these nutrients in the ration.

REQUIREMENTS FOR REPRODUCTION

It has long been appreciated that regular and normal reproduction is the essential basis of successful animal industry including milk production. The reproductive function is conditioned by a long series of distinct but interrelated physiological events in which the body as a whole, as well as the sex organs, are concerned.

A failure of any one event to take place normally can result in temporary or permanent failure of the function as a whole. Low fertility or sterility of temporary nature, because of their prevalence are the cause of much greater loss, than infertility of a more permanent kind, which occurs less frequently but attracts most attention.

Introduction to the general role of nutrition

Nutrition plays at least a general role but its significance is larger than this. The development, composition, and normal functioning of the reproductive system is dependent on adequate nutrition. Nutritional factors play vital roles in the various physiological events which occur in the attainment of sexual maturity and in the course of the reproductive process.

The nutrient supply influences the process in **early ages** either by delaying the sexual development and puberty, or the female animals never reach the normal size.

In mature animals it affects:

a- the production of ova (so the animal fails to conceive or gives fewer offsprings),

b- the production of sperms,

c- the protection of the mother,

d- the protection of the unborn young, and

e- the milk may be scanty or of low vitamin content.

f- if the mother is fed inadequately the offspring are apt to be weak or undersized.

Mother is able to protect the unborn young against deficiencies **on the expense of her body** and to a **certain extent** and against **temporary** or **small deficiencies**. It can sacrifice her bones for Ca & P and other tissues for proteins (muscles). Thus the nutrition of pregnant animal must have a double object-producing a normal offspring and protecting her own tissues.

How the effects of nutrition are mediated?

The effects of nutrition are mediated either directly or indirectly.

Direct mediation as in:

a- phosphorus deficiency suppresses estrus.

b- digestible undegradable proteins (DUP) increase ovulation and used to flush ewes, while rumen degradable proteins (RDP) increase leads to ammonia toxicity and reduction of fertility.

c- protein deficiency of long term in pigs causes reproductive failure.

d- calcium, P, Fe, I, Cu & Co deficiencies may cause reproductive disaster.

e- Zn deficiency prevents spermatogenesis as it is a component of thymidine kinase.

f- Cu deficiency reduces the secretion of LH.

Indirect mediation through:

a- the endocrine system particularly anterior pituitary by reduced hormone production, change in rate of destruction or alteration of organ sensitivity.

b- the effect on general metabolism and eventually the feed intake (as in protein, mineral and vitamin deficiencies).

How to trace the effects?

Effect of nutrition is difficult to be carried out as the response needs:

- many animals due to the large random individual variability in reproduction which causes statistical problems (80 sows are needed to demonstrate a 5 % increase in litter size, and a tested bull should mate 10-20 cows).
- the animals should be tested for several generations.

Reproductive function is more resistant than other bodily activities.

Signs of a deficiency appear before reproductive abilities are seriously affected, and the underfeeding or deficiency has to be severe to exert its full effect. On the other hand neither growth nor sexual activity takes precedence over the other. The following are examples:

Phases of the reproductive cycle and their relative needs

The cycle consists of three phases

1- **The production of ova and sperms:** the needs in mammals are small compared with requirements for egg production in birds.

2- **Pregnancy:** in early stages of pregnancy the amounts of nutrients deposited are small and it is only the last third that it becomes necessary to make special provision in the diet for the growth of the fetus.

In addition to the nutrients deposited in the uterus, pregnancy increases appetite and the animal tends to gain in weight.

3- **Lactation:** in the lactation phase the needs are large.

So in intensive husbandry feeding standards must be applied more exactly and less reliance placed on reserves (as cycle follows closely or overlaps the previous one). Mostly the troubles are from multiple deficiencies which reflect general undernutrition, rather than single deficiencies.

The first phase - the production of ova and sperms

The effect of nutrition on the initiation and maintenance of reproductive ability

I- Plane of nutrition

Effect on puberty

Puberty occurs in cattle at a particular weight or body size than at a fixed age (species, breed & nutrition).

a- Undernutrition delays puberty in both sexes in most species.

b- Overfeeding hastens puberty but causes breeding troubles & shorter productive life.

Effects after puberty

a- Immediately after puberty **undernutrition** reduces the production of eggs (swine & sheep), and of sperms (cattle, sheep & swine). But potential fertility in the three species was not greatly affected, however.

Undernutrition may decrease the number and vigor of sperms or secretion of accessory organs or cause cessation of spermatogenesis. In females continued underfeeding causes cessation of ovarian function. Half- starved animals are relatively infertile.

Undernutrition has to be severe and prolonged to exert its full effect. Bull losing 0.9 kg /day, was at the end of 14 weeks capable of producing semen containing normal spermatozoa but the production of fructose and citric acid in the accessory secretion was much reduced. If severe, it causes retrogressive changes in sex organs after they are fully developed.

b- **Overfeeding** causes extreme fatness and endocrine disturbance which leads to sterility.

In males extreme fatness interferes with the production of fertile sperms and lessens his desire to mate.

In females estrogens responsible for estrus may be absorbed in the fat depots (sows). The ovaries may become so infiltrated with fat as to hinder the development of the follicles with irregularity or cessation of estrus which result in delay or failure in breeding. The animal will be unable to conceive.

There may be also such an excessive amount of fat in the reproductive tract that, even if the egg is matured and fertilized, it may fail to reach the uterus and become implanted properly.

Flushing

Flushing is the high - plane feeding of the female for several weeks before mating.Ewes gaining weight or fat reserves in the 3-4 weeks before mating are more likely to conceive and more likely to have twins or triplets than those in poor condition. This has led to the practice of flushing which is transferring the animal from low to high plane before mating. Also animals kept continuously on higher plane will also have a high fertility and high fecundity.

After mating the flushing plane should be reduced to about the maintenance level (some suggested to feed the high plane 4-6wk beginning 2-3 wk before the start of breeding). Higher levels of feeding are claimed to cause losses of ova by stimulating the destruction of progesterone (the hormone required for the establishment and maintenance of pregnancy).

Value of flushing for the different animals

In sheep, there is a period of several months between weaning and remating during which ewes may be on a low plane of nutrition, the transfer to higher level will be of value.

In sows, flushing seems to have little effect, however flushing the maiden gilt 10 days before mating can increase litter size.

In cattle, the main problem of fertility is that of obtaining reconception in cow two months after calving, at a time the nutritional demands of lactation are high and must be met partly from body fat reserves. .

The second reproductive phase –pregnancy

Fetal growth

Needs are small and progressively increase to become several times as large towards the close of the period. Only in the last third it becomes necessary to make special provision and the last quarter is the time of critical importance (2/3 of the energy and protein deposited in the last ¼ of gestation and larger proportion for Ca & P towards the end - sow). In the mammary gland 80% of protein in the last pregnancy quarter.

Meeting these needs is reflected in:

a. more vigorous young,
b. higher potential level of milk secretion - it is in the last part that the formation of the secretory cells of the udder is most active.

The needs of pregnancy in relation to other needs

a. Even the needs for energy in the last 2 months are small (2.34 NEl) in relation to that for maintenance (7.82 NEl) of the mother cow, but the requirements for protein (632 g CP) and for Ca (12 g) & P (6 g) are quite appreciable (maintenance 341, 18 and 13 respectively-NRC (1988) for a cow of 450 kg). Refer to page 106 for the daily nutrient requirements table 7.
b. A 500 kg cow gains 0.8 kg / day over the last 6 weeks of pregnancy representing gain in fetus and its associated structures.
c. In the products of conception (newborn of about 30 kg) there are no greater than nutrients

in 182 - 227 kg milk (after the addition of fetal fluids &membranes). So pregnant animals do not require such great amounts of nutrients even during the last part of pregnancy.

Extra uterine growth during pregnancy

Live weight gain was found to be greater in pregnant animals than that can be accounted for by the products of conception alone (sow). This is called the pregnancy anabolism, maternal growth, or maternal regrowth. It occurs in immature animals, which are still growing so it is a necessary function, and occurs also in older ones. In the last frequently much of the weight gained is lost in the ensuing of lactation.

Effects of nutrition on pregnancy-general

It should be noted that the fetus has a high priority and is able to maintain its nutrient supplies by drawing on the reserves of the mother. In case of feeding inadequate ration the mother sacrifices her bones for Ca & P and other tissues for protein to nourish the fetus, and so the mother is the more severely affected (as in case of Fe, fetus adequately supplied while the mother is anemic). But the protection is not absolute, as in severe & prolonged deficiencies both fetus and mother will suffer.

Factors affecting the degree of protection

The protection afforded the fetus is not absolute but:

a- It varies from one nutrient to another.

- In ewes as a result of insufficient supply of energy may lose 15 kg of body substance during pregnancy and still give birth to normal lambs.
- An avitaminosis A which is without an apparent effect on the ewe can lead to serious abnormalities in the young.
- Fetus can be adequately supplied with iron when the mother herself is anemic. This is unusual in farm animals because their diets are normally rich in iron.

b- Mother reserves, as the effect of underfeeding in pregnancy depends on the body reserves.
c- The stage of pregnancy at which the deficiency occurs. In general the more serious the latter it occurs but this rule is not invariable- vitamin A deficiency in early pregnancy can lead to abnormalities and even fetal death.

The malnutrition (meaning both inadequate and excessive intakes of nutrients) may affect pregnancy in several ways.

1 - Severe malnutrition may cause the death of the fertilized egg:
at an early stage - resorbed in the uterus
later in pregnancy developed incorrectly and die-expelled before full-term (abortion), or carried to full - term (stillbirth).

2- Less severe malnutrition may:

a- reduce birth weight of the young, or
b- diminish viability either due to:

- lack of strength
- lack of reserves (e. g. fat) or the reserves being inadequate for the critical first days of life.
- lack of size
- congenital deformities
- prematurity

3- In some circumstances it is the mother not the fetus that suffers. Also dam's milk yield may be affected and so affect the young.
4-In severe and prolonged deficiencies both fetus & mother are affected.

The effect of nutrition on pregnancy

I-Plane of nutrition

- ***Mother***

  •***Underfeeding***

  a- Inadequate nutrition causes incomplete skeletal development which is particularly dangerous and may lead to difficulties in parturition. Stunted heifers show twice as many difficult first calving. Following refeeding of the low plane heifers they performed normally.

  b- Severely undernourished pregnant females may show permanent damage (drainage on her body). Mother's bone may be depleted - if the depletion only involves the reserves in bones so no structural injury, but if the depletion is severe and continued it will result in osteomalacia, spontaneous fractures, parturient paresis, or lameness (sows).

  c- Inadequate nutrition limits the formation of secretory cells in the udder and lessens milk secretion. It is during the last part of gestation period that the process is most active.

  d- Underfeeding causes also impairment of subsequent reproductive potential of the cow.

  e- Ewes may be affected by "pregnancy toxemia".

Pregnancy toxemia in ewes

The fetus has a high requirement for CHO and it is able to maintain the sugar concentration of its own blood at a level higher than that of the mother (also the Ca). If the glucose supply is insufficient the nerve tissues which rely on CHO for energy are affected.

Occurrence

This is prevalent in sheep in the last month of pregnancy. The disease occurs in ewes with more than one fetus, so the other name "twin" lamb disease and is most prevalent in times of food shortage and when the ewes are subjected to stress as inclement weather or transportation.

Refer to page 143 in " Sheep feeding " chapter

- **Overfeeding**

High planes cause obesity, deposition of fat in birth canal reducing pelvic opening and causing dystocia.

- ***Fetus***
  - ***Underfeeding***
    a- Stunted heifers gave claves only slightly less than animals offered the recommended planes. Following refeeding they performed normally.

The result of underfeeding may be the death, prematurity, or reduced viability (refer to "effect of nutrition on pregnancy").

b- The nutritional deficiencies must be severe to causes death.

- ***Overfeeding***

It causes fetal deaths (sows).

The effect of deficiencies of the different nutrients on the young can be summarized in the following:

a- Death in the uterus (reduced litter size, abortion or stillbirth).

b- Reduced viability at birth due to either congenital deformities, to a lack of size and strength, or to reserve being inadequate for the critical first days of life.

Nutrient deficiencies must be severe to cause the death of fetuses. Death is caused by deficiency of protein and vitamin A, also through deficiency of I, Ca, B_2 and pantothenic acid. In sows overfeeding causes fetal deaths. Congenital deformities of nutritional origin often arise from vitamin A (eye and bone malformations in particular), I (goiter in the unborn & complete lack of hair in the young), B_2 (hairlessness) & Cu (swayback in lambs).

Variations in birth weight due to nutrition are a reflection of the energy intake of the mother during the later stages of pregnancy. Young animals should be born with reserves of mineral elements particularly Fe & Cu, and of vitamins A, D and E, because the milk is frequently poorly supplied with these nutrients. Extra iron to mother not anemic has no influence on the reserves of the newborn. If the mother is anemic these reserves, though not Hb, may be reduced, Cu and fat-soluble vitamin reserves are more susceptible to improvement through the nutrition of the mother

The effect on the mother is discussed before where pregnancy toxemia in sheep has been mentioned.

Feeding of the male animals

The requirements for the production of spermatozoa are likely to be inappreciable. There is insufficient experimental evidence on which to base feeding standards for breeding males. In practice males are given food well in excess than that required for maintenance of females of the same weight. Males have higher BMR and maintenance needs than females and as the feeding standards are based on females or castrates, underestimate the requirement of males. Males should be kept in thrifty condition to retain their breeding powers. The requirements of sires in ordinary service are not far different from the needs for mere thrifty maintenance.

Experimentally nutritive deficiency of vitamin A, usually produces visible symptoms of deficiency in the sires, before it impairs his breeding potency.

Young sires should be fed so that they grow normally and develop vigorous bodies and strong skeleton. So ample amounts of protein, minerals, and vitamins.

The third phase – lactation

The metabolism of lactation is tremendous and the cow is a very hard working animal because:

1. A high yielding cow 600 kg body weight secretes about 10.000 kg milk.
2. It may produce 8 times DM as in body.
3. A cow secreting about 27 kg milk needs 400 kg blood/kg milk to flow through the udder, a total of about 10.000 kg (300 times that in the body of a cow weighing about 450 kg). Thus so many great times the blood passes through the udder, and too large amount of energy needed which is a small part of the requirement.
4. Needs depend upon amount & composition of milk which is similar in composition but its detailed constitution of the various fractions vary from species to species.

The course of milk secretion

1- The time involved in reaching the peak depends upon inherited factors and upon the condition of the cow prior to calving and how she is fed and managed thereafter. Milk yield increases from parturition to about 45 days and in practice peak is earlier and falling after peak is much sharper.

2- The rise in secretion following parturition increases faster than food intakes. The animal readily draws on her own reserves for a short time to produce milk. However unless current nutrition balances milk outputs, the maximum yields cannot be sustained more than a few weeks, on body reserves. Previous nutrition, which determines the cow's reserves at calving, is thus concerned.

3- ***Weight loss in early lactation presents no problem*** in otherwise healthy cows unless the loss becomes excessive, and if the losses are replaced in later lactation and the dry period.

4 - Following the peak, there is a regular decline such that ***each month's yield being a constant percentage of the peak***. Persistency is the term used to denote the measure of this rate of decline, which is accelerated at the 22^{nd} week after a new conception. The onset of new pregnancy is thus a determining factor in the length of the lactation of the cow, both because of this accelerated decline

and because of the necessity of giving her a rest period before another lactation.

5- The fact that many cows will continue to secrete some milk right up to parturition if milked regularly shows that there is no physiological mechanism for absolutely stopping the process before the event.

6- Cows which remain unbred may continue to secrete milk at a decreasing rate for two or three years or even longer.

7- Failure to remove the milk regularly and completely from the gland lessens its activity and brings about cessation, a fact which finds practical application in the drying off the animals. The onset of new pregnancy during lactation results, after a period, in a more rapid decline in the secretion than otherwise occurs.

8- Underfeeding during the declining period of secretion has an immediate effect in lowering the output, in contrast to its lesser influence at the start of lactation, but no system of feeding will counteract in any way the normal decline.

9- With lactations of substantially equal length, the yield of the cow generally increases during the first four or five. The growth of the body as a whole is a factor during the first three (markedly greater hypertrophy of the gland during the second pregnancy than during the first and smaller increases during the succeeding pregnancies). Persistency decreases in succeeding lactations. Expressed another way it may be said that the level at which secretion begins increases to maturity but that the total yield for the lactation is not proportional to this rise because of a declining persistency factor.

10- The longer the dry period, the greater the persistency in the next lactation. Shortening the dry period before a second lactation lowers yields to a much greater extent than shortening it before a later lactation (the greater growth of body and gland before the second lactation). The importance of an adequate dry period to build up nutrient reserves is well understood.

The composition of blood and milk

1- Milk has a quantitative composition very different from that of blood plasma and that there are qualitative differences as well. The two fluids are isotonic. Certain variations in composition are inevitable and factors are breed, strain, individuality, age and stage of lactation.

2- Certain milk constituents, including lactose, casein, and some of the fatty acids, are clearly synthetic products of the gland, while others, such as the minerals and vitamins, pass in directly from the blood stream. There are various organic constituents for which there is a lack of information.

3- With the normal decline in the yield, the percentage of fat rises, and so does the protein to a lesser degree. In contrast, the lactose declines slightly, and for the maintenance of osmotic relations, its decline is balanced by a rise in chlorides. These same changes tend to occur when the yield is subjected to an abnormal drop as the result of sickness, off-feed, or other disturbing factors. Fat content is relatively constant for the first four lactations, and then decreases gradually with age.

Effect of various factors upon the composition of milk

In general there is a strong tendency for a lactating animal to produce milk of normal composition under widely varying conditions. Any inadequacy in the ration or fault in the methods of care and management will generally manifest itself by a reduction in the yield of milk, rather than by a change in its chemical composition. However, certain factors have an effect on the fat %. The content of certain trace minerals in milk can be increased by a very liberal amount in the feed. A very important fact is that the vitamin A value of the milk depends on the vitamin A or carotene content of the ration.

Limitation of energy has a greater effect than protein limitation on the SNF which is reduced in both cases. Lactose shows little change. The lowered protein is probably due to increased gluconeognesis from amino acids owing to a reduced propionate supply.

Effect on protein

A deficiency or an excess of protein in the ration does not appreciably change the composition of milk. However, a lack of protein, greatly decreases the yield (the only significant difference was that milk from the high protein feeding contained more of the non-protein nitrogenous compounds, including urea which are found in traces in milk & also this milk was slightly higher in vitamin B-complex).

Effect on fat

1. If the ration of dairy cows does not have a certain minimum amount of fat, the yield of milk will be reduced. Experimentally it was shown that the richness of the milk can be considerably increased for a few days by adding fat or fat-rich feed to the ration. The fat content however, tend to fall back to normal later even though the feeding of fat is continued. In an experiment on cows in Beni-Suef University (Abdel-Hafeez et al, 2002) the increase in milk fat continued even though the feeding of fat (dried fat) discontinued.
2. Certain feeds especially coconut meal & palm-kernel oil meal may cause a very slight increase in the fat content of milk over a long period.
3. On the other hand, cod liver oil and certain fish oils decidedly at levels of 200 g /day decrease the percentage of fat in milk of cows by about 25%.
4. When fed in considerable amounts feeds that are rich in fat may have a marked effect on the character of milk fat just as they do on the body fat produced by swine. Soybeans and peanuts cause soft butter. C.S. meal & coconut oil meal cause hard butter with high melting point.
5. Milk fat depression occurs when the acetate to propionate ratio falls below 3. This needs a fine balance between roughage and concentrates.
6. Rations low in fiber causes digestive disorders, production problems & low milk fat.
7. A certain roughage in the long state is essential to maintain fat and must be enough to ensure 17% CF in the DM.
8. Diets rich in saturated and monoene acids increase the concentration of these acids in milk fat. The extensive hydrogenation in rumen precludes a similar effect with polyunsaturated acids. Addition of saturated acids causes slight temporary increase in milk fat while unsaturated acids as low as 250 ml depresses fat %. The depression was greatest when high in 18:2 or more highly unsaturated. Feeding the same amount in its natural feeds eliminates the effect or decreasing it.

Effect on lactose:

Lactose in milk cannot be changed by any ordinary method.

Effect on minerals:

Calcium & Phosphorus: are not changed to any appreciable extent by increasing the percentage in feed. Though a ration seriously deficient in P or Ca will reduce milk production and may cause injury to the animal.

It is essential to keep in mind that the animal is able to reduce skeletal Ca reserves over long periods of time before growth & milk production are adversely affected.

Iron: Milk is very low in iron and it is impossible to increase it.

Iodine & Cobalt The amount of them in milk can be increased decidedly by adding to the ration a supplement supplying the minerals. However, the cow is very inefficient in transferring iodine into her milk.

Effect of nutrition on milk yield

Yield of milk may be decreased due to the following factors

1. **Underfeeding** during the declining period of secretion has an immediate effect in lowering the output but lesser influence at the start of lactation. But no system of feeding can counteract the normal decline. Deficiency of energy also decreases SNF (in addition to yield). Yield drops to a very low level if no food and within 3 days, and SNF & fat rise to twice.

Severely undernourished animal loses more weight than usual in early lactation and will not gain weight normally in late lactation.

2. A certain minimum amount of **fat** is needed for maximum milk production (NRC, 1978 recommends 2% and a maximum of 5%) at least with high producing animals & milk goats. Diets having 5-7% ether extract produce more milk than diets containing 4%. Some add fat to the diet at the start of lactation, so concentrating the energy content, and increasing the amount of roughage allowed.

3. **Protein** deficiency decreases the yield, lowers immune & transport protein, and if it is for a long period decreases the hormone secretion. The animal becomes liable to be affected by infectious diseases and metabolic ones which would not normally appear.

4. Deficiency of **minerals** decreases the yield (Ca, P, Salt, Cu, Co, Zn) especially Ca & P where it is greatly reduced.

Feeding of Different Species

Contents

I. Feeding of Dairy Cattle

Contents

Introduction

1. Dairy animal is arranged in different classes from the maturation and nutrition points of view:

- Calves
  - From birth to weaning
  - From weaning to 12 mo.
  - Heifers from 12 mo. to breeding at 15 mo.
- Pregnant and dairy cows
  - Pregnant heifers from 15 mo. to 3 or 4 mo. before calving
  - Pregnant heifers 3 – 4 mo. before calving
  - First and second calf heifers
  - Cows in early, mid, or late lactation
  - Dry cows

2. Modern dairies have a high replacement rate of cows. It is attributable to culling for low production or health problems.
3. Cows are served at 15 mo., but it is better to delay the first service to 18 – 21 mo. of age. Gestation lasts 40 wks.
4. After parturition heat recurs not sooner than about 5 wks and mostly before the 10^{th} one. Cows are rebred within 30 to 90 days postparturition. Heat lasts 4 – 24 h and recurs every 3 weeks.
5. Peak of milk production is at 2 – 6 to 4 – 10 wks (milk is 30 – 40% more than the start), maintains for from few days to 14 d or more, and then declines.
6. Cows giving less than 2 gallons per day, in the first third of lactation, do not worth keeping, so fattened or put to a beef bull. Lactation lasts 305 d, suitable for yearly calving, and milking is 2 – 4 times/d at regular times.
7. Fat percentage in milk can be corrected to 4% by using special formula which differs according to the breed. The most well-known is that of Holstein, FCM = [(0.4) (kg milk yield)] + [(15) (kg fat yield)].

Example1- Milk fat correction to 4%

A. Using the formula, 30 kg milk 5% fat are equivalent to:
[(0.4) (30)] + [(15) (30 × 0.05)] = 12 + 22.5 = 34.5 kg 4% FCM
The factor "0.4" is 0.6 for 3% FCM and 0.8 for 2%.

8. Persistents or stayers are cows of:
   a- high peaks,
   b- peaks staying for as long as possible,
   c- milk production showing slow gradual fall, and
   d- giving considerable amount of milk when due to be dried.
9. There are complications in meeting the needs for high- producing animals; as it needs: high feed intake (FI), optimal ratio of VFAs, optimal fermentable nitrogen – to – bypass protein ratio, avoiding metabolic diseases or problems as milk fever, ketosis, displaced abomasum, “downer

cow syndrome”, milk fat depression, or retained placenta and dystocia, etc. Downer cow syndrome is the recumbent cases of milk fever which fail to rise following treatment with calcium.

10. The body uses nutrients in priority basis, with maintenance; growth and pregnancy have higher priority than milk production (some produce milk at the expense of maintenance and growth).
11. Within a herd, approximately 25% of difference in milk production among cows is due to heredity; the remaining 75% is determined by environmental factors, with feed making up the largest portion. Feed accounts for about 55% (45 – 65%) of the cost of milk production. So a good feeding program is necessary for a profitable milk production.
12. Changes in feed composition should be gradually, as marked changes in feed composition lead to simple indigestion that in turn may result in metabolic diseases such as parturient hypocalcemia and primary acetonemia. So feeding must be consistent and according to needs.
13. In developing countries the dairy industry is much different, herd sizes are small, productivity is low and dual purpose animals are often used. Feeding programs may involve low quality roughage – based diets. Ammoniation of low – quality roughages, supplementation with bypass protein, and use of high energy agricultural by-products, supplements as molasses, sugar cane, bananas and cassava are examples.

Nutrient needs of dairy cattle

The nutritive requirements have been established by the National Academy of Sciences – National Research Council (NRC). In NRC (1988) the requirements do not allow for any margin of safety, so do not provide for animal differences, feed differences, and losses of certain nutrients in storage. Accordingly in the formulation of rations, margins of safety should be provided.

I. Energy

Researchers have developed several net energy systems.TDN still, in some cases, interchangeable with the term energy, but caloric values are more accurate.

Energy (DE and ME) is used with different degrees of efficiency for maintenance and body gain in non-lactating animals, so NEM and NEG. But lactating animals use energy for maintenance, pregnancy, milk production and weight change with similar degrees of efficiency, so single net energy value NEL is adequate to calculate rations.

Dairy Calves

- In calves before weaning, rumen is not well developed; it must be fed chiefly on milk or concentrates high in TDN and low in fiber (in a calf rearing system milk or milk replacer to 50 kg of body weight(12% in large breeds & 13% in small ones) and milk (14%) plus starter (1%) and hay till 75 kg, and a month for the withdrawal of milk and starter and introduction of growing mixture till a weight of 100 kg and age of about 4 mo. in large breeds and 6 mo. in small ones.
- As the calf grows older, it can utilize more and more roughages, until after the age of about a year the ration may consist entirely of roughages.
- Even when well – fed, many cows are unable to develop their full inherited capacity for milk production if they were stunted during growth by a lack of feed or by nutritive deficiencies.
- A calf needs 86 kcal/ $kg^{0.75}$ for maintenance (NEM) and for NEG the gain in kg is multiplied by the total average for both breeds (large and small) and both sexes is 2.05 at 100 kg BW +

0.25/ 50 kg increase in B wt. The needs are calculated using four equations so complicated, and no need here to mention.

- In NRC (1988) the main system of feeding calves depends on making a ration at 100 kg body weight and at every 50 kg increase in weight with a total of 11 diets to a body weight of 600 kg (in large breed heifers -75% of mature size) and we called it the "10-phase weight" system. NRC has extracted a 3-phase system which includes only 3 nominated diets, one for each phase. A third system imitating the NRC 10 – phase, depends on feeding calves ad libitum, was suggested and we called it the "10 – phase ad libitum" one. The last system is not only a simple increase in the amount of food intake but also includes a change in diet composition to satisfy the needs for NEM and NEG in the maximum amount of food. The ad libitum system could be applied on 3 phases the same as that with NRC, by nominating three diets, but with ad libitum feeding and decreased dietary energy density (refer to table 1).
- The growth stage is divided by NRC (1988) for the 3- phase system for feeding, into three age – phases (3 – 6 mo., 6 – 12 mo., &> 12 mo., for 12-15 or 18 mo.), with three growing diets instead of mixing so many diets for the different age periods. After reaching a weight of about 400 kg the density of energy can be decreased till a weight of about650 kg in NRC, and 500 with "ad lib" where no concentrates are needed with fair quality hay (at about the age of about 2 years – large breeds).
- The density of energies (NEM & NEG) in the growing diets differs according to the energy needed and the DM intake relative to each age period.

Table 1 Energy density (Mcal/kg DM diet) in the 3-phase systems

3- phase systems				
	NRC		**Ad libitum**	
	NEM	**NEG**	**NEM**	**NEG**
I) 3-6mo. (100-150kg)	1.70	1.08	1.55	0.94
II) 6- 12 mo. (150-250kg)	1.58	0.98	1.49	0.90
III) > 12 mo. (200–400 kg)	1.40	0.82	1.40	0.82

The approximate weights for the growing heifers and bulls are 150, 250 and 400 kg at the end of the three phases respectively, and the approximate average daily gain is 700 and on maximum is 800 in large breed females, 600 in small breed, 1000 in large breed males and 700 in small breed.

The densities of energies are translated into diets in the following table with roughage either hay(1.14NEM& 0.58NEG) or tibn (1.0NEM & 0.22NEG), while the concentrate mixture is considered to have 2.0 NEM and 1.35 NEG.

Table 2 The CM percentage in the diets of the two systems

Phase	NRC		Ad libitum	
	W.H	**W.T**	**W.H**	**W.T**
I	65	76.2	47.5	64.3
II	55	69.4	41.0	59.9
III	30	52.4	30.0	52.4

- When a bull calf gets mature (reaches 75% of its mature weight) it needs only 86 kcal/ $kg^{0.75}$ NEM for maintenance.

Gestation

- NEL is 104 kcal/ $kg^{0.75}$ in the last 2 months of gestation of mature dry cow, 30% more than that required for maintenance (for only maintenance 80 kcal/ $kg^{0.75}$ NEL is required).
- Energy density in rations is 1.25 Mcal/ kg DM and protein 12% for the last two months of gestation, and the energy density may be increased to 1.35 for animal conditioning and replenishment (and CP to 12.96).
- Very high and very low planes of nutrition in late gestation are undesirable. High planes cause obesity, deposition of fat in birth canal reducing pelvic opening and causing dystocia. The low levels result in weak, less active calves and impairment of subsequent reproductive potential of the cow. Lack of energy is the most common deficiency in dairy rations. Disorders of grain overload should be avoided as a large quantity of concentrates fed too quickly may cause one of the several digestive disorders.
- Dry cow in good condition should be fed medium – quality forages as the primary constituent of their diets. Concentrate feeding should be increased gradually to about 0.5% of live weight the last 2 – 3 weeks prior to calving to allow the cow and the ruminal microorganisms to become adapted to the larger amount of concentrates required in early lactation. The amount of concentrates should not exceed 40% of the total DM intake, however (the roughage is hay).

Lactation

Cows cannot produce milk at peak levels if their rations are too low in energy. All cows, except low – producing ones (less than 6.5 – 9 kg) need some grain if they are to yield at top levels. It becomes increasingly difficult to provide sufficient energy as milk production increases. Rumen inert fat and full-fat oilseeds and high – energy feedstuffs are useful, noting that a minimum amount of fiber should be satisfied.

Early lactation

- DMI may not exceed 1.5% of the body weight immediately after calving and there is inability to consume sufficient energy during the first 6 – 8 weeks of lactation even when fed high quality roughage.
- High – producing cows are often unable to consume enough feeding early lactation to prevent some loss of body energy, Ca, P and perhaps protein. Yet such losses can be minimized by

feeding as much of a properly balanced diet as the cow can safely use during the first 6 – 8 weeks after calving. Adequate feeding immediately after calving also helps to prevent ketosis. Thereafter milk yields should be used to calculate the allowance for energy. So high-producing cows are in negative balance in the first few weeks of lactation and experience body weight loss because: a- highest milk production. b- maximum DMI is not achieved until 10 – 14 wks postpartum.

- Energy stored as body fat during the dry period is mobilized during early lactation. Lipotropic agents such as choline facilitate lipid mobilization.
- In a feeding program replenishment of body reserves was considered by increasing the energy allowance, in late lactation, by an amount equivalent to about 3 – 5 kg milk NEL per day for a cow of 600 kg body weight.
- The cow may go off food and reduced milk fat when concentrates increased above 55-60%, in addition to metabolic and digestive disorders, and impaired ability to mobilize body tissue reserves to supplement dietary energy.
- Body stores can supply only a limited amount of the needs and if the cow have to rely too heavily on body stores of energy and protein, either milk production will be held to the level of nutrients available or metabolic disease such as ketosis will develop.
- If the cow is not able to consume sufficient food and the loss becomes excessive, initiation of estrus cycle may not occur. Effect could be mediated by blood glucose level, which in turn influences the release of gonadotropins, which control the estrus cycle, and the energy deficit and the low insulin limit ovary responsiveness to hormones, thus excessive weight loss lowered conception rates and prolonged calving intervals.
- The level of body fat at calving may have a negative effect on feed intake after calving (release of excessive quantities of free FAs).
- The feeding program in this period should include: a- maximizing the intake of high-energy concentrate, while, b- avoiding digestive upset by giving a sufficient level of fiber to obtain optimum rumen function:
    - Note that the intake of food reaches to about 85% of the requirement, during the first 3 weeks relative to latter lactation, and the use of a diet with NEL density of 1.67 Mcal/kg DM (using rumen inert fat, full fat oilseeds and high energy feeds), is useful.
    - In early lactation the animal is not fed according to production but through using the early lactation diet or a certain other system.
    - As a general from parturition until peak, and to avoid severe metabolic problems, properly balanced diet (high in energy and contains at least 17% CF) should be fed ad libitum.

Mid and late lactation

In mid and late lactation the animal is fed according to production needs. Energy need for maintenance is 80 kcal / $kg^{0.75}$NEL and for one kg 4% FCM is 0.74 Mcal NEL. For the energy of milk in Mcal/ kg an addition or subtraction of 0.05 Mcal is applied for each 0.5 percent change in fat content from 4 percent.

In practice most cows lose some weight during the first few weeks of lactation and then shift to a relatively small but positive energy balance for the rest of lactation. Cows past the point of energy equilibrium, gain a small amount each day reaching 0.055 percent of its live weight.

The amount of NEL required for one kg of tissue gain during lactation is 5.12 Mcal and the amount of NEL spared by the loss of 1 kg of body tissue is 4.92 Mcal.

For calculating the amount of energy needed by a lactating cow follow this example:

Example 2- Lactating cow energy

Calculate the energy requirements for a cow of 600 kg bodyweight and producing 40 kg milk of 4% fat.

I - Milk energy

$40 \times 0.74 = 29.6$ Mcal

II - Maintenance energy

$600^3 \sqrt{\ } \sqrt{\ } \times 80 = 9698$ kcal or 9.698 Mcal ($600^{0.75}$can be calculated directly)

III- Weight gain energy

Gain = $(600 \div 100)\ 0.055 = 0.33$ kg/ day

Energy needed = $5.12 \times 0.33 = 1.69$ Mcal

Total energy = $9.698 + 29.6 + 1.69 = 40.988$ Mcal

To allow for the growth of young heifers, the maintenance requirements should be increased by 20 & 10% for the first and second lactation respectively, reaching 96 and 88 kcal/ $kg^{0.75}$.

A challenge with high producing cows is to get sufficient energy intake to support the amount of milk synthesized which they are capable. Rumen inert fat and full fat oilseeds and high energy feeds are useful. Whole cottonseed is a very valuable feedstuff because it is a good source of energy (from the oil), protein, and fiber. It contains approximately 20% fat and 24% CP (23% CF). However there are numerous reports of gossypol toxicity in dairy cattle. Whole cottonseeds should be limited to 2.5 – 3 kg per cow per day (4 kg in another source). Toxicity includes liver lesions, anemia (as it reacts with iron), ascites, edema, heart lesions, lung damage, and cardiac failure. Gossypol damage is cumulative, and adverse effects may not be observed until after many weeks or months of feeding livestock cottonseed.

Recommended energy content of diets for lactating cows

- The NEL density in rations for lactating cows differs according to milk yield and body weight.
- A cow of 600 kg, producing milk of 4% fat, is assumed to be basic or reference cow for calculating the NEL/ kg DM diet, for all other cows. The concentration of energy in the diet for the reference cow is 1.42 Mcal, NEL/kg DM for milk yields equal to or less than 10 kg/day. The energy increases linearly to 1.72 for milk yields equal to or greater than 40 kg/d.
- NRC gave five dietary NEL densities 1.42, 1.52, 1.62, 1.72 (17% CP), and 1.72 (18% CP) Mcal / kg DM diet for the five classes of milk production starting by 10 kg or less, 20, 30, 40 & 50 kg milk 4% fat (10, 10 x2, x3, x4, x5).
- The energy concentrations in the diets of all other cows, than the 600 kg cow, is assumed to change linearly as their energy requirement for milk production relative to energy requirements for maintenance, or the milk production in kg relative to the metabolic body size, change in a manner identical to that of the 600 kg –cow.

  Example:

  In a cow of class I (600 Kg) producing 10 kg milk the two calculations are:

  a- E requirement for milk(7.4) ÷ Maintenance E (9.698) = 0.763

b- Milk production (10) ÷ Metabolic body weight(121.23) = 0.0825

- As a rule of thumb, the amount of milk including approximation is to deduct or add 1, 2, 3, 4, or 5 for every 100 kg body weight less or more than 600 kg, in the five classes respectively.

Table 3 Amount of milk in different classes and body weights

Body Wt. Kg	Milk 4% fat – kg				
	I	**II**	**III**	**IV**	**V**
400	8 (7.38)	16	24	32	40
500	9 (8.72)	18	27	36	45
600	10	20	30	40	50
700	11 (11.23)	22	33	44	55
800	12 (12.41)	24	36	48	60

The figures in parentheses are the real amounts before approximation.
The figures are calculated as maintenance in Kcal × 0.763= milk energy in Kcal or metabolic body weight in kg × 0.0825 = milk in kg. The same end result.

- The total NEL needed is divided by the DM to get the energy density of the diet (using the standard animal figures) as follows:

Maintenance = $600^{0.75}$ x 0.080 = 9.698 Mcal

For gain = 600 x 0.055 ÷ 100 x 5.12= 1.690 Mcal

For milk = 0.74 x 10 = 7.4 x 2, x3, x4& x 5

Total energy 18.788, 26.188, 33.588, 40.988&48.388

Energy density

18.788 ÷ (2.2 DM x 6(wt.÷100)) = 1.423 NRC recommends 1.42

26.188 ÷ (2.9 DM x 6) = 1.505 NRC recommends 1.52

33.588 ÷ (3.5 DM x 6) = 1.599NRC recommends 1.62

40.988÷ (4.0DM x 6) = 1.708NRC recommends 1.72

48.388÷ (4.7 DM x 6) = 1.716 NRC recommends 1.72

From NRC, (1988) the animal consumes 2.2, 2.9, 3.5, 4.0 & 4.7% of its body weight DM at the start of the five milk groups respectively.

II- Dry matter

The data for DMI (dry matter intake) are not requirements per se, unlike the requirements for NEM, NEG and CP. They are not intended to be estimates of voluntary intake but are consistent with the specified dietary energy concentration. The use of diets with decreased energy concentration will increase DMI needs and the use of diets with increased energy concentrations will have an opposite effect.

Growing calves

- In growing calves from birth to 100 kg body weight it is a system of feeding on several diets, more than a fixed DMI, where milk, calf starter and hay are fed according to a special feeding strategy. Any way it is 1.2% to 50kgbody weight, and 2.6% to 75kg and after.
- The DMI of growing calves (> 100 to 75% of mature weight) differs according to the dietary energy density (as also other classes or species of animals). DMI also differs according to the growing phase and body weight.
- In NRC (1988) mature sizes were assumed to be 800 kg for large – breed females, 600 kg for small – breed females, 1000 for large – breed males, and 800 for small – breed males.
- The DMI values in NRC weight requirement table should not be considered to be maximum intake amounts, for a stated gain, and can be increased by 17% to reach the ad libitum level as indicated by research in 1986, for large-breed heifers. For every 100 g-lesser gains than maximum DMI in the weight systems should be decreased by 6% in NRC and & 7% in ad libitum.
- The rate of DMI increase will be assumed to be applicable for both the large and small breeds and both sexes.
- In ad libitum system, the DMI in phases I & II is also increased by 17% instead of 4 &9.4 respectively, as shown in the following table.

Table 4 Dry matter % of body weight in NRC and ad libitum systems

	NRC-3 phase	Ad libitum3 phase
100	**3.14** (65.0) ⟵	**3.53** (47.5)
150	**2.91** (55.0) ⟵	**3.11** (41.0)
250	**2.81** (30.0) ⟵	**2.81** (30.0)
400	2.35 (30.0)	2.35 (30.0)

DMI is calculated in relative to the concentration of CM and eventually the energy.
The figures in parentheses are the CM% in diets fed with hay.

Dry pregnant cows and breeding bulls

- In the dry period the animal consumes 1.7 – 2.5% DM according to milk produced and ration composition. In NRC it is 1.86 – 1.56 % according to body weight (400 – 800 kg),calculated on basis of energy needs without consideration to conditioning.
- In breeding bull it is 1.6 – 1.33% (500 – 1000 kg body weight) - NRC.

Lactating cows

- As to NRC (1988) a lactating animal of 400 kg body weight consumes 2.7% DM with a base production of 10 kg milk 4% fat decreased by about 0.2 units for every 100 kg increase in weight up to 800 kg. For every 5 kg milk in excess of the base 10 kg, DM increased by about 2 kg.
- DM needed = Total amount of energy ÷ dietary energy density.
- The total amount of DM needed for a cow of 400 kg at the start of each of the five milk classes is 9.68, 12.63, 15.22, 17.51, and 20.69 kg respectively, while it is 16.53, 21.48, 25.82, 29.65 and 34.99 for a cow of 800 kg. The figures are needed to establish the "thumb rules" for feeding either for TMRs or separate feeding, especially that of the 400 kg cow.

Example 4 - Lactating cow DMI

Estimate the DM requirement of a cow of 600 kg and producing 40 kg milk 4% fat.

The amount of DM with a base of 10 kg milk = 2.7– ($\frac{600-400}{100}$ x 0.2)

= 2.3% of body weight (NRC, 2.2)

Amount of DM for the basal production (10 kg milk) and maintenance of its body = (600 ÷ 100) 2.3 = 13.8 kg

Amount of DM added for the extra milk = $\frac{40-10}{5}$ x 2 = 12 (NRC estimated it to be 10.8 kg)

Total amount of DM needed by the cow = 13.8 + 12 = 25.8 kg (NRC estimated the total DM requirement to be 24 kg)

- The lag of maximum DMI behind peak milk yield causes negative energy balance in early lactation (weight loss).
- In lactating cows the total DMI is influenced by the ratio of forage to concentrate in the ration. A minimum of 30% roughage is essential for maintenance of normal fermentation and prevents the depression of milk fat. When the concentrates in a ration exceed 70%, forage intake is inadequate for normal ruminal fermentation, and a drastic reduction in milk fat percent often occurs. Frequently this reduction is also accompanied by lower milk production and typical "fat cow syndrome" problems.
- When cows are fed very liberally on roughage of excellent quality and the allowance of grain is restricted to their needs they will consume 2.5% of the hay equivalent. When the roughage

is scanty or of poor quality it may consume 1.5%. The rate of 2% is the most common rate of feeding roughage, considered in the ration formulation. So it can be considered that the rate 2.5% is for excellent hay or its equivalent of berseem, 2% for say fair amount of berseem or good alfalfa hay and 1.5% for low quality hay or wheat straw(Abdel-Hafeez).

Example 5 - Roughage consumption (liberal feeding)

The three kinds of roughage are berseem hay which is considered the standard, the low quality – wheat straw, and the excellent quality – fresh berseem. The DM in hay and straw is 90% and in berseem 15% on average.

Estimate the amount of roughage a cow of 600 kg can consume.

Method 1

- Fresh hay = 600 ÷ 100 × 2 = 12 DM hay = 12 x 0.9 = 10.8
  Fresh straw = 600 ÷ 100 × 1.5 = 9 DM straw = 9 x 0.9 = 8.1
  Fresh hay equivalent of berseem = 600 ÷ 100 × 2.5 = 15
  DM hay equivalent of berseem = 15 x 0.9 = 13.5
  The amount of fresh berseem = 13.5 ÷ 0.15 (DM of berseem) = 90 kg

Method 2

- Amount of DM roughage rate of consumption:
  Hay = 2 x 0.9 = 1.8 straw = 1.5 x 0.9 = 1.35 Berseem = 2.5 x0.9 = 2.25
  DM the cow consumes
  Hay = 1.8 X 6 = 10.8 Fresh = 10.8 ÷ 0.9 = 12
  Straw = 1.35 x 6 = 8.1 Fresh = 8.1 ÷ 0.9 = 9
  Berseem = 2.25 x 6 = 13.5 Fresh = 13.5 ÷ 0.15 = 90

III- Crude fiber

- In high producing cows fed rations low in fiber they show digestive disorders and production problems, among them displaced abomasum, acidosis, rumen parakeratosis, and low milk fat.
- Digestible fiber increases the production of acetic acid, precursor of milk fat, in the rumen. Additionally when fed in the right form, roughages promote cud – chewing and salivary secretion (buffer, favors acetic than propionic, which the last is characteristically produced on highly acid rations). For this reason many dairymen like to feed long – stemmed hay.
- It is generally recommended to feed long – stemmed hay, or its equivalent of silage or other coarse roughage, fed at least 1 – 1.5% of LB wt. (of roughage DM –in low and high production respectively). In most operations, 1/3 of ration DM should be derived from roughage (hay – at high production) and at least 1/3 from grain (at low production).The remaining 1/3 DM is derived from roughage or grain, determined by the level of production. High quality hay has approximately 16% CP and the higher the protein and the lower the fiber fraction, the better the quality. In the ration examples at the end of "ration formulation" chapter we used the hay of medium quality 13.8% CP, 1.23 Mcal, NEL and 0.58 NEG/kg DM.
- The crude fiber should not be less than 17% of the DM in lactation rations except in very high producing animals it is 15% as well as in the growing calves (except at 3-6 mo. 13%) and mature bulls and 22 in pregnant animals.

IV- Protein

Dairy calves

- At birth the calf is actually not a ruminant; the requirements are amply met when fed a normal amount of milk for at least 6-9 weeks and supplied with good quality roughage.
- By time, rumen will have developed and needs for protein quality and B vitamins are largely satisfied if good ample roughage and a starter, containing good quality protein, are fed to the age of 3-4 mo.
- In milk replacer high quality protein and B-vitamins must be provided.
- Rumen develops more rapidly if supplied with plenty of good hay as soon as the animal will eat. Calves ruminate at 2-3 weeks and usually at 3-4 weeks.
- When calves are fed a reasonable amount of whole milk or skimmilk until they are 4 to 5 mo. of age no special attention need to be paid to the quality of protein furnished by the rest of the ration. Thus an excellent ration after 3-4weeks is merely skimmilk, cereal grains and good legume hay.
- When milk feeding is discontinued at 6-9 weeks as in the calf starter methods, the quality of protein in the starter is of importance till the age of 3-4 mo. However good results are secured with starter having no animal protein but considerable part of the protein is supplied by SBM which furnishes protein of high quality.

Needs

- NRC (1988) recommends 16, 12 & 12% CP in dietary DM in the three phases but it is appropriate to be 16, 15 and 12 as that calculated from the NRC need table. On ad libitum feeding the levels will be 13.68 (16÷1.17), 12.82 (15÷1.17) and phase III is kept as it is 12%. Growing calves need 15.25, 15.00 & 11.75g / $kg^{0.75}$ in the three phases. For fattening calves refer to table (3) in ration formulation chapter (it is 15-16% in I, 13-13.5% in II, and 11-12% in III according to the level of fattening).

Pregnant cows and mature bulls

- It needs 10 g CP/ $kg^{0.75}$ in the last two months of pregnancy (three fold as needed for maintenance). In the dietary dry matter it needs for gestation 12% CP.
- A mature bull needs about 7.5 g/$kg^{0.75}$ and a diet of 10% CP in DM.

Heifers and cows

- In heifers and dry or low -producing cows, the quality of protein has no real meaning.
- In high-producing cows bacterial synthesis is insufficient to fulfill the needs-the use of methionine hydroxyl analog (MHA) and ways to protect dietary protein from ruminal degradation may be beneficial.
- NPN should not be fed for high - producing cows, but after the peak can supply a portion of the nitrogen (urea 1.5% of concentrate plus sulfur supplementation).
- SBM can be replaced by a mixture of corn, urea and fat as 1 SBM ≡ 0.760 fat +0.151 urea+ 0.773 corn.

- The protein requirement is divided into degradable intake protein (DIP) and undegradable intake protein (UIP).
- The lactating animal needs 3.56 – 3.23 g CP/kg$^{0.75}$ for maintenance, of a cow from 400 – 800 kg, and 90g for 1 kg 4%FCM (NRC, 1988) plus or minus 6 g for every increase or decrease of 0.5% fat unit. For the body change each kg gain needs 320 g CP.
- The total CP needed is divided by the DM to get the CP% in diet (using the standard animal figures) as follows:

  Maintenance = $600^{0.75}$× 3.4(maintenance) = 406.12 g

  For gain = 600 x 0.055 ÷ 100 x 320= 105.6g

  For milk 10 x 90 = 900 x 2, x3, x4&x 5 g

  Total CP in kg 1.418, 2.318, 3.218, 4.118 & 5.018

  Crude protein percentage in diet DM =

  1.418 ÷ (2.2x 6) x 100 = 10.74 NRC recommends 12

  2.318 ÷ (2.9x 6) x 100 = 13.32 NRC recommends 15

  3.218 ÷ (3.5 x 6) x 100 = 15.32 NRC recommends 16

  4.118 ÷ (4.0 x 6) x 100 = 17.16 NRC recommends 17

  5.018 ÷ (4.7 x 6) x 100 = 17.79 NRC recommends 18
- The need for the first and second calf heifers should be increased by 20 and 10% respectively for maintenance reaching 4.27 and 3.92 g/ kg$^{0.75}$.
- In a feeding program, the protein intake increased to meet the needs of 1.25 times the milk produced in early lactation, 1.1 times in mid lactation, while in late lactation replenishment of body reserves was considered by increasing the energy. Mobilization of total body protein in early lactation is minimal and rapid depletion of mobilizable protein occurs during periods of negative nitrogen balance.
- Milk rations contain 12, 15, 16, 17 & 18 % crude protein in the five groups of production respectively.

V- Minerals

Dairy calves

As soon as the calves begin to eat concentrates, salt should be provided where they eat what they wish. Under certain conditions there may also be a deficiency of P or Ca. Milk for calves and plenty of legume hay or even grass hay for heifers provides ample amounts of Ca and P for calves &Ca for heifers respectively.

There will no lack of P after calves are weaned from milk, if they are fed 0.75 to 1.33 kg (1.5 – 3.0 lb) per head daily of concentrate mix containing 10 – 20% wheat bran, LSM or CSM (it is supposed to be with high quality roughage). If any calves show evidence of goiter, this should be prevented in the future by the use of iodized salt.

Dairy cows and general notes

In one lactation (300 days) a cow secretes in her milk nearly as many minerals as three 18 -month –old steers store in their bodies. Additionally, a milk cow needs minerals for maintenance, development of unborn calf, and for growth if she is young.

Next to salt, dairy cattle of all ages and stages of production are more apt to suffer from a lack of P than any other mineral. Also Ca is important because of the high Ca content of milk and its relationship to milk fever.

Within relatively wide limits, cattle are able to avoid toxicity from high dietary Ca through excretion of excessive via feces. Excessive Ca has an antagonistic effect on the metabolism of P, Mn and possibly Zn; this is in laboratory animals but not quantitatively evaluated in cattle. But bulls fed 3 – 5 times the Ca recommended; show a high incidence of osteopetrosis, vertebral ankylosis and degenerative osteoarthritis. Under conditions of heat stress, K should be increased from 0.65% to 1.2%.

Salt is added at the rate of 1% of the concentrate mix, in addition they should always be available free – choice. If high levels of grains are fed 0.5% is added (to minimize high levels of salt in the manure which can pose pollution problems).

It is also good to guard against any trace mineral deficiency by providing Co, Cu, I, Mn and Zn (in mineral mix, in trace mineralized salt, or in the ration itself).

As to the mineral requirements of dairy animals refer to the requirement table in which it is stressed on Ca and P.

VI –Vitamins

Calves

- **Vitamin A supplement** must be given if whole milk is discontinued earlier or hay not of good quality.
- Whole milk is not rich in **vitamin D** so good quality legume hay as soon as the calves will eat it must be offered; in addition to exposure of calves to sufficient direct sunlight prevent rickets. Vitamin D must be added to calf starter and milk replacer, and to most calf rations.
- **B vitamins** are supplied by the milk, and synthesized in the rumen, and there is no deficiency when dairy calves are raised by one of the usual methods. If calves are weaned from milk at only a few days of age, vitamin supplement should be included in the milk replacer if it does not contain a considerable proportion of dried skimmilk and other dairy by-products.
- In the dairy rations vitamin A can be added at the rate of 2200-4000 lU/kg diet DM (NRC, 1988).
- To guard against deficiencies, newborn calves are sometimes given an injection of vitamin A with D and E, soon after birth.

Cows

- Some dairymen regularly inject **vitamin A** into all cows when they go dry (decreases calving difficulties and gives stronger, healthier calves).
- Results are disastrous when cows are fed for long periods on rations seriously deficient in vitamin A. During pregnancy it is important to feed a ration with plenty of carotene- sometimes a concentrated supplement is fed for some weeks previous to calving.

- **β- Carotene** has been suggested to have a role in reproduction and a possible effect in reducing mastitis.
- **Vitamin D** is of value in preventing milk fever.
- **Vitamin E** in combination with Se has been effective in reducing the incidence of retained placenta and clinical mastitis in cows.
- There is evidence that high-producing cows respond to dietary supplementation with **niacin**, and it may require **choline** supplementation to facilitate lipid mobilization from liver to mammary gland, in spite choline chloride is rapidly degraded in the rumen. The practicality of its supplementation is questionable.

VII- Water

Calves over 8 wks and cows are watered twice daily. Large amounts of water are essential if a cow is to produce to her maximum capacity. Cows produce more milk if have available drinking cups than if they are watered twice daily.

Special requirements of dairy cattle

Fat

- The newborn dairy calf requires some fat in the diet until the rumen becomes functional. Adult ruminant may not require dietary lipids for normal rumen function or for growth.
- Ruminal microorganisms can suffice a source of lipid constituents for the host animal. A minimum of 2% is being suggested for older animals (forages <3%, grains 3-4%).
- Levels of added fats or oils above 5% can have adverse effects (decrease in cellulose digestion, decrease intake, increase fecal soaps).
- When dairy cattle are fed unprotected long-chain FAs, caution must be taken to provide supplemental Ca& Mg, because added fat increases Ca& Mg soap formation in the rumen and excretion of these elements in the feces.
- Whole seeds as cottonseeds, soybeans and sunflower seeds have been used successfully with the principle of feeding a maximum of 0.5 kg added fat should be followed. Whole used cottonseeds should be limited to 2.5-3.0 kg/cow/day out of concern for gossypol toxicity and perhaps effects of cyclopropene FAs.
- There are recent interests on the part of producers in "dry" fats that can be easily handled and that have minimal effects on rumen fermentation. Ca salts of FAs(82% fat) and the so called prilled fat are insoluble or inert with regard to their effects on fiber digestion; yet hydrogenated normally, solubilized and absorbed satisfactorily.

Fiber or roughage factor

Adequate coarse roughage before and after calving appears to prevent displaced abomasum, which occurs most often in early lactation. Grinding or fine chopping reduces the effectiveness. Refer to the title "crude fiber".

Additives

- **Antibiotic**

No reason for recommending their use in rations for lactating animals, but included in milk replacers and calf starters to increase rate of gain and lessen incidence of disease and diarrhea.

- **Sodium propionate, sodium and calcium lactate, and propylene glycol**

  Na propionate and Na &Ca lactate powder ¼ to ½ lb/cow/d beginning a week before calving and extending 6 wk after calving are recommended for preventing ketosis. Propylene ¼ to ½ pint/ cow can be used in similar manner. They are not palatable so used gradually or as a drench.

- **Buffers**

Prevent ruminal environment from becoming too acid. The mostly widely used are Na bicarbonate (baking soda), Mg O, dolomitic limestone, and Ca $(OH)_2$. Results are variable with regard to rumen function and/or butterfat test. Buffers are potentially of greatest benefit for lactating dairy cows under the following conditions.

- During early lactation.
- When large amounts of readily fermentable concentrates are fed, especially at frequent intervals.
- When silage is the major or only forage.
- When concentrate and forage are fed separately.
- When feed ingredients are chopped, ground, or pelleted (increases rate of fermentation and decreases salivary secretions of buffers).
- When cows are abruptly switched from a high- forage diet (dry period) to a high- concentrate diet (onset of lactation).
- When milk- fat depression has occurred.
- When off- feed problems occur from use of highly fermentable diets.
-

Feeding systems

I - Group feeding

It is advantageous to divide the herd (more than 200 milking cows) into corrals or groups of cows producing at about the same level, with each corral of 50 – 100 cows managed as a unit, and fed differently according to their production potential. The corral concept led to changes in feeding practices including group feeding, and complete rations, with a different combination of feeds for each corral. Group feeding can be easily adapted to the use of complete feeds where the concentrates, roughages, and supplements are mixed in one feed rather than being fed separately.

One of the main disadvantages of this program is that mismanagement can result into the so called "fat cow syndrome" and related health problems such as calving difficulties, poor reproduction, low dry matter consumption, and metabolic disorders. The disorders may take many months to develop.

It is uneconomical to divide small herds into groups to feed separate rations and is difficult in sometimes to group animals in some barn design.

II- Feeding according to need (traditional individual feeding)

It is possible to feed each cow according to its optimal nutritional need. Grain allocation can be controlled while the cow is in the milking parlor or stanchioned barns, and intake of silage, hay, and other feed can be regulated by the use of electronic sensors on neck chains which control cow access to individual feeders, or fed ad libitum a controlled amount.

III- Phase feeding

The lactation of a cow can be divided into four periods, or phases, (early, middle and late lactation-and the dry period) each of which requires a different type of feeding program.

Phase 1, is the period covering the first 10 weeks after calving. During this period the cow will rapidly reach peak milk production. Throughout this period, the cow will be in a negative energy balance. This means that the cow cannot ingest enough energy to sustain production and must therefore, draw upon body reserves to make up the energy difference (DM intakes may not exceed 1.5 % of body weight immediately after calving but can reach 4.25 – 5.5% by 12-15 weeks of lactation in cows fed high quality forage). It is essential that a diet properly balanced in all nutrients be fed ad libitum.

Phase 2, is the second 10 weeks after calving. The cow will reach her maximum level of feed intake during this period.

Phase 3 is the last half of lactation (24 weeks). Milk production is on a steady decline throughout this period; and feeding with a high level of grain will be largely wasted on low producers. However, the excess energy can serve to recondition high producers. An increase in the energy needs for the milk produced by 30 % is helpful.

Phase 4 is the dry period following lactation (7-8 weeks depending on production and state of flesh). It allows the cow to divert many of the ingested nutrients to her rapidly developing calf and to restore depleted body reserves. Also it is necessary for the recuperation and development of the secreting tissues of the mammary gland. Only during the dry period and last weeks of lactation can a high producing cow regain the Ca& P drawn from her body stores. At the end of the dry period, the cow must be gradually changed from one ration to another to prepare her for the new lactation. Failure to allow for this adaptation period can create numerous health problems.

Dry cow have three important jobs: 1- Recovering from a heavy milk- producing period and resting the mammary glands, 2- Developing the unborn calf (more than half the fetal growth occurs during the last 2 months of lactation), 3- Storing up body reserves for the next milking period. This necessitates that they be properly fed. The following routine is recommended for dry cows:

1. Turn 1st and 2nd lactation heifers dry 60-65 days. Cows more than 4 years of age dry 50-60 days before freshening. Many high – producing cows require as long as 1st and 2nd lactation heifers. If the cow is to be medicated the medication should be introduced once milking is abruptly halted.
2. Concentrate feeds put considerable stress on the rumen, thus roughage is very important during the dry period to promote healthy rumens. Dry cows will not have to gain much weight (more efficiently during the latter stages of lactation). Under proper dry cow management, grain should only be required during the last 2 weeks for rumen acclimation.
3. The last 2 weeks are to prepare the cow for parturition. If milk fever is a problem, the cow is desirable to ingest less than 100g Ca and a minimum of 45 g P/ day, also vitamin D should be provided. Feed grains for rumen acclimation (the same lactation ration) which should not exceed 5.5 kg. Dry cows should not be in a fat condition at calving. On the ^{1st}day after calving cows should be fed the same amount of grain that they were getting before calving, followed by an increase of 2-3 lb (0.9-1.35 kg) per day, according to the cow's appetite. If insufficient fiber is fed, displaced abomasum may be a problem.

Health disorders

Displaced abomasum

In this condition the abomasum is shifted upward and to the left of its normal position. The relatively new practice of feeding dry cows liberal amounts of grain has been pointed to as one contributing factor (lack of bulk and rumen fill promotes flabby muscle tone of rumen, permitting abomasum to become displaced). The displacement may cause a twisting (torsion), interfering with movement of digesta through the gut. There is a marked decrease in feed intake and milk production. Surgical intervention may be necessary.

Milk fever

The incidence of milk fever or parturient paresis is highest in high – producing cows 5 to 10 years old, and Jerseys are more susceptible than other breeds. The best cows, except heifers, are about to have milk fever at parturition or shortly after (within 48 to 72 hours). First calf heifers are rarely affected.

This is caused by a lack of calcium in the blood, produced by the heavy drain on the supply of this mineral when the cow begins to secrete a large amount of milk. At the outset of lactation the parathyroid gland seems to be unable in some cases to meet the demand for calcium, and milk fever results. Parathyroid hormone acts on the kidney tubules to increase renal reabsorption of Ca and stimulates the development and activity of bone eosteoclasts, the cells that resorb bone matrix and release Ca into the blood. PTH stimulates the synthesis of 1, 25–OH vitamin D which stimulates intestinal Ca absorption. Its major roles are to regulate synthesis of Ca transport proteins in the intestinal mucosa, and in conjunction with PTH, to stimulate bone resorption. As levels of PTH and 1, 25 – OHD_3 appear to be adequate, susceptible cows may have fewer or defective PTH and 1, 25 – OHD_3 receptors in intestine, bone and kidney. The receptor activity may decline with age, explaining why heifers almost never develop milk fever, and the problem becomes progressively more severe as cows age.

Symptoms

Signs of milk fever include loss of appetite, dull and listless attitude, cold ears, and a wobbling, incoordinated gait. The animal goes down and is unable to rise. Commonly the head is twisted to the side. The name milk fever is a misnomer. Body temperature is not elevated and is usually depressed. Major changes in blood constituents are a drop in Ca and P and an increase in Mg. The symptoms are due to impairment of neuromuscular function caused by a deficiency of Ca ions which function in impulse transmission.

Preventive measures

Feeding a high – Ca diet during the dry period promotes milk fever. Feeding susceptible cows an extremely low – Ca diet during the last few weeks (a month) of gestation will prime the endocrine systems and forces the parathyroid to increase its activity that promoting Ca absorption and mobilization. Ca intake should be increased as soon as parturition occurs. This method of prevention was effective in most cases. However, it has the disadvantage that high – producing cows can regain their store of Ca, lost during the height of milk production, only during the dry period and the last part of the lactation.

Another method is to feed susceptible cows a ration very high in phosphorus and extremely low in Ca for a month before calving (15 g/ day), high in energy. It is believed that this method of feeding forces the parathyroid gland to increase its activity and draw on the Ca store in the skeleton. But it was found that prepartal diets high in P inhibit 1,25 – OH – D3 formation and increase the incidence of milk fever and hypocalcaemia.

Experimentally milk fever has been prevented in susceptible cows by giving in the feed extremely large doses of vitamin D daily for at least 3 days and preferably not more than 7 days before calving and 1 day after calving. Vitamin D metabolites are effective at lower levels. They function in Ca absorption and mobilization from bone.

Electrolyte balance and alkalinity or acidity of the diet may influence milk fever. Thus diets high in Na and K tend to induce milk fever (may reduce Ca availability), whereas those high in anions such as chloride and sulfate reduce milk fever. It is suggested that reducing the dietary cation– anion balance induces a metabolic acidotic condition influencing the resorptive ability of the kidney and bone resorption.

Treatment

The usual treatment for milk fever is the injection of solution of Ca gluconate or other Ca salt into the jugular vein or mammary veins, to raise the Ca content of the blood. The older method of treatment was to inflate the udder with air. The last method is still used in cases which are not cured by the injection of calcium salt.

Ketosis or acetonemia

Is a serious disease in some dairy herds, especially of high-producing cows, some of the symptoms resemble milk fever but it does not usually occur until several weeks after calving. In ketosis there is a rapid fall in milk yield, a loss in weight, digestive disorders, drowsiness, and sometimes pronounced nervous symptoms. It develops within the first 30 days of lactation.

Ketosis is apparently caused by insufficient supply or faulty utilization of carbohydrates in the body, resulting in a serious deficiency of glucose in the blood. The trouble may be brought on by various causes or stresses, but the chief cause is the drain on the glucose supply of the blood in high production. The lack of carbohydrates causes an increased metabolism of fat, and an accumulation of certain normal products of fat metabolism (called ketone bodies) which are toxic when present in excess. The disease has usually been treated by the injection of a glucose solution into a vein, generally combined with the feeding of molasses or sugars. If a cow comes down with ketosis, a glucose solution can be administered intravenously to promote rapid recovery.

Other treatments

Feeding sodium propionate or propylene glycol for 3 to 10 days at the rate of one-quarter pound daily, divided into two doses, mixed with the grain. In severe cases where the cow is eating little or no grain, one-half pound of the salt is administered by capsule or drench.

Insufficient feed before calving may tend to produce ketosis. It is therefore, not advisable to reduce the amount of concentrates too much before calving, and it is best to increase the feed intake after calving as rapidly as is safe. Some feed molasses or another form of sugar for 2-3 weeks after calving but this is of doubtful value as a preventive of ketosis. Additionally starting challenge feeding during the latter part of the dry period is helpful in preventing ketosis.

Laminitis (founder)

Hoof inflammation is a problem in high – producing, confined dairy cows. It results in reduced ability to obtain feed, lowered milk production and reduced fertility. Its incidence increases as concentrate intake increased. Also increasing the dietary protein level from 16 to 20% increased the incidence and severity of lameness. High protein intake may cause a histamine allergenic reaction in capillaries, causing thromboses that reduce blood supply to the hoof. This may prevent adequate sulfur amino acids from reaching the keratin – synthesizing cells, causing poor hoof formation. The thromboses and capillary damage may cause inflammation and tenderness. High protein intakes cause elevated rumen ammonia. Prolonged elevation of ammonia in blood entering the liver may cause liver damage and impaired detoxication of ammonia. The excess ammonia may induce laminitis as in silage.

Lactic acidosis occurs when there is an abrupt increase in intake of readily fermentable carbohydrates (grain overload). The accumulation of lactic acid in the rumen increases the osmolality of the rumen contents, drawing water from blood and causing dehydration and hemoconcentration. Absorbed acid may cause systemic acidosis with a lowered blood pH, electrolyte imbalance, and kidney failure. Hemoconcentration may cause arterioles in the extremities to rupture causing laminitis, or founder.

Fat cow syndrome

It is caused by an excessive intake of energy during late lactation and the dry period. Within a few days after calving they are inappetent or totally anorexic. Those that are only inappetent require about one week to begin eating and milking normally. The prognosis is poor in totally anorexic and fatality rate is high.

The most useful sign of fat cow syndrome is the sight of very fat cows in the dry cow group. Other general signs may include evidence of a decreased resistance to infection syndrome and increased incidence of metabolic diseases such as ketosis. The syndrome is characterized by inappetence, reduced milk output, and extensive loss of condition, some are totally anorexic.

In early lactation the mobilization of tissue in response to the negative energy balance, releases fatty acids and amino acids into the blood, the fatty acids are transported in the blood to various organs, such as the liver, kidney, and muscle, in which they are deposited as intracellular triglycerides. The extent of organ fat deposition is determined by predisposing factors, such as the amount of excessive fat, presence of disease, or stress complications during calving, which lead to tissue mobilization. The amount of fat in the liver is normally quite low (i.e. 1 to 2 percent) although depending on conditions it may increase precalving to 4 to 10% percent of fresh liver weight. The mobilization of the adipose tissue after calving may result in fat accumulation in the liver of more than 20 percent. Severely ketotic cows had a greater percentage of fat in the liver than healthy cows and showed a positive correlation between fatty infiltration and blood ketone concentrations. To reduce the incidence of fatty liver, it is necessary to avoid the over conditioning of cows during late lactation and the dry period and to formulate rations that maximize feed intake after calving.

Grass tetany

It is observed in lactating cows feeding on the lush, rapidly growing pasture that most common in spring (USA). It is caused by inadequate Mg in critical extracellular fluids. Only 1 percent of the body’s total supply of Mg is found in these fluids, and this level can drop very quickly when inadequate Mg absorption and mobilization of bone and tissue supply occur. Affected animals are restless, stop grazing and run for no apparent reason and walk with a high – stepping action, legs stiff, animal is subject to fall. When recumbent, they experience tetanic spasms interspersed with bouts of chronic convulsions. The case may be improved by appropriate soil management and by direct diet supplementation.

Calf scours

It is sometimes difficult to distinguish the infectious disease from diarrhea caused by other factors – such as overfeeding, irregular feeding, use of unclean utensils, too rapid changes in feed, or exposure to drafts and cold, damp floors. With the infectious type of scours, however, several calves are usually affected; and some animals may die quickly. In herds with calf morbidity and mortality problems, the use of antibiotics, vaccines, hyperimmune serums should be considered only as one part of general calf health management - not as a remedy to overcome all kinds of unsound management practices.

Feeding calves

Since milk is the primary product of dairy production, it is necessary to switch the young calf to cheaper feeds as soon as possible. The following are the feeds which are routinely fed to calves.

I- Liquid feeds

a- Colostrum

The ingestion of liberal quantities of colostrum by the newborn calf within the first 6 hours after birth is the most important requirement. Approximately 25% of the calves may not voluntarily ingest sufficient colostrum even when left with their dams. This may necessitate the forced feeding of colostrum to all calves as a routine procedure (calves can be fed using a pail). Colostrum should be fed for at least 3 days (antibodies, high protein, minerals and vitamins).

Absorption of colostral immunoglobulins ceases by 24 hours after birth, but the continued ingestion of colostrum will provide local intestinal immunity against acute undifferentiated diarrhea. Without the absorption of antibodies (first 24 hr) mortality may reach 90%.

Colostrum is very high in vitamin A, which is of great importance for the calf is born with a very small store. It has also a laxative effect in removing the muconium.

If for any reason, the calf cannot receive the colostrum a vitamin A supplement should be administered and a colostrum substitute should be used (an egg-white emulsion with fresh cow's milk, 6 eggs in the 1st feeding and one less egg for the following feedings each time).

Surplus colostrum may be considered a cost-free liquid feed for calves, because unmarketable for human consumption, and can be stored frozen for 1 year without losing its antibody values

b- Whole milk

Following the three-day colostral feeding period, dairy calves may be fed whole milk, a milk replacer, or a combination of these, depending on availability and economics.

Calves can be fed whole milk either naturally or artificially. Artificial feeding is needed especially when the mother is high lactating and feeding calves on extra amount causes digestive disturbances which retard growth and may lead to death.

In artificial feeding mammary gland can be milked down for all milk and milk production recorded. Feeding is through a pail, bottle or a funnel and teat. In the funnel put a ping- pong to prevent calf from suckling air. Calves get accustomed to artificial feeding in about 2 weeks (can drink milk from the pail without using the attendant finger).

Whole milk (10-14%) is excellent especially for calves raised as heifer replacements. It is usually fed, twice daily, at a rate of about 10% of body weight. Calves may be fed solely on whole milk, until weaning at 35-56 days of age. A calf starter diet containing 16-20% protein should be made available in small quantities (100 to 250 g/day) beginning the second week of life. This could be increased every several days so that the calf is consuming about 750 g/day before weaning in addition to small quantities of good-quality hay.

Early weaning at 3-4 weeks may cause some calves do not adjust effectively (transition from a preruminant to ruminant) and are unthrifty for up to several weeks. They may also develop a chronic dietary diarrhea.

The allowance of milk should be divided between 2 or 3 feedings (3 in weak calves) and the amount of each should be measured or weighed and not estimated. The milk should be as fresh as possible and at 35 – 38℃.

The allowance of milk should be gradually increased as the calf grows older, if it is thriving. Overfeeding is the cause of much trouble in calf rearing and should be avoided at all times. A safe plan is to keep the calf in a little hungry. A good rule is to feed 1 lb of whole milk, daily per 10 lb live weight. Weak or sickly calves should be fed less, and even a large and vigorous calf should not be fed more than 12 lbs a day. In case of indigestion or scours, the allowance should immediately be cut in half until the calf recovers. This rate of feeding (1/10 of B. Wt.) continues up to the first three weeks, then 1/15 next two weeks then 1/20 with gradual tapering up to 60 days, in systems designed to wean at this age.

Natural feeding is performed by leaving the calf with his mother, after birth, to get the colostrum for the first 3 days. Then it continues feeding milk from his mother from the four mammary quarters and after it takes its needs the cow is milked, this is in the first month of age. In the second month the calf suckles half and in the third month just one quarter. At the end of the third month the calf is weaned. Calves (2 – 4 in number) of about the same age and vigor can be kept in a box stall with a cow (nurse cow) competing for the milk. Dry calf meal and hay are given as soon as possible and weaning at 2 – 3 months of age.

c- Milk replacers

Good milk replacers are composed of sizable amounts of milk byproducts (the newborn calf lacks sufficient enzymes to utilize efficiently nondairy feedstuffs, such as grains, sugars, vegetables, forages, etc.) as skim milk, butter milk, or whey; and they are generally reinforced with animal or vegetable fats, antibiotics, vitamins and minerals. They can be used as the only feed following colostrum or used with a calf starter. Replacers are commercially produced as they are difficult to formulate and mix.

Milk replacers are used extensively to raise calves for replacements and to fatten calves in vealing operations. It is assumed that they are cheaper than cow's whole milk because they consist of skim milk powder and other milk by-products and added fats of animal or vegetable origin, added carbohydrate of vegetable origin, and more recently, added nonmilk proteins. Whereas many of the replacers are of good quality, some are nutritionally inadequate and predispose to digestive disturbances, resulting in chronic diarrhea, poor growth rates, secondary starvation, and high morbidity and mortality rates, usually owing to enteric disease.

The digestibility of young calves under 10 days of age for the DM, nitrogen and fat of cow's whole milk are high- 95, 94 and 95% respectively. So the ideal milk replacer for calves up to 3 weeks of age, approximating the quality of whole milk would contain, skim milk 75-80%, source of digestible fat homogenized with the skimmilk (at 15-20%), vitamins A,D,E, $B_{12}$and B vitamins, cobalt-iodized salt, copper, iron and zinc and other trace minerals. Attempts are also being made to replace the high quality milk protein with less expensive vegetable and animal proteins. Also energy is increased by using cereal starches and animal and vegetable fats. The quality of milk replacer for calves under three weeks of age depends upon the digestibility of each ingredient and the relative amount of each in the total mixture.

Ministry of agriculture, Egypt (1961), had recommended that whole milk can be replaced by milk replacer at the age of 10 – 14 days and the calves weaned at 6 – 7 weeks, and then fed on the starter. Replacer may be composed of 38.5% skimmilk, 5% whey, 35% SB flour, 5% ground barley, 7% dextrose, 5% yeast, 2.5%dicalcuim phosphate, 0.5% vitamins A & D, 0.5% mineral mixture, and 1% antibiotic(aureomycin).

d- Skimmilk

Whenever skim milk is available, the calves should be changed from whole milk to this by-product as soon as they have a good start. After the calf is 2 to 4 months old, it can usually be accustomed to cool milk, if the temperature is reasonably uniform.

In raising calves on skim milk, the change from whole milk to skim milk may begin when the calf is 2 to 4 weeks old, the exact age depending on the vigor of the calf. The change should be made at the rate of about 1lb a day over a period of 7 to 10 days. In the case of very valuable calves, some whole milk is often fed for 2 months or longer. At the other extreme, in an experiment, the calves were changed from colostrum to skim milk on the fourth day of age with fair results.

After the calf has been changed entirely to skim milk, the allowance may be increased very gradually, if the calf is doing well. Not over 14 to 16 lbs of skim milk daily are needed, but if an excess is available after any pigs or poultry have been provided for, large vigorous calves maybe fed somewhat more. Not more than 18 lbs daily should be fed until the calf is 6 weeks old, but after this, vigorous calves may have as much as they wish. If but a small amount of skim milk is available, good gains should be secured on only 10 lb of skim milk per calf daily along with plenty of concentrates and good hay.

If the supply is sufficient, skim milk feeding should be continued for at least 6 months, but when the supply is scanty, thrifty calves can be weaned at 2 to 3 months and then be fed a calf starter. For feeding with skim milk any of the grain mixtures are satisfactory that are suggested for feeding with milk.

e- Butter Milk, Whey or Reconstituted Milk

Butter milk is a good substitute for skim milk. It is best not to begin changing calves from whole milk to butter milk until they are 4 weeks old, as butter milk sometimes has a more laxative effect than skim milk. Whey or reconstituted whey from dried whey can be used. If the calf, tend to scour, this can be prevented by mixing one-quarter teaspoonful of slacked lime with each feeding.

Dried skim milk, dried whey or butter milk are also common ingredients in dry calf starters, or calf meals.

II- Dry feeds and pasture

a- Calf Starters

Where no or insufficient skim milk, butter milk or whey is available, the calf starter method of raising calves is widely used. In this method, the calves are given a good start on normal amounts of whole milk and are taught to eat a dry calf starter or calf meal, and good hay as soon as possible (at the 10th day of age). Then, if they are thrifty, the amount of milk is soon reduced and they are weaned entirely from fluid milk at 7 to 10 weeks of age. After this, they are fed only the calf starter with plenty of first-class hay and with water to drink.

In this method there is less labor (as warming, washing, sterilizing utensils, …. etc.) . To secure the best results, the calves must be well started on the dry calf meal and hay before they are weaned from milk. Excellent quality legume hay or mixed hay high in legumes must be fed and if a calf is delicate or sickly, whole milk feeding must be continued, until it is strong.

Until the calf is 3 months old, let it have all the dry calf meal it will eat, up to a maximum of 4 or possibly 6 lbs a day, along with plenty of good hay. When the calf is about 3 months old, supply a simple "Growing mixture" in addition to the more expensive calf starter. Any of the mixtures suggested for milk-fed calves will be satisfactory, which contain L.S.M., or wheat bran, or other protein supplements. When the calf is 4 months old, the calf starter can be discontinued and the cheaper mixture fed, along with the hay.

In this method, not over about 350 lbs of whole milk need be fed in addition to the colostrum during the first 3 days, which is not marketable. To reduce the amount of whole milk used, the feeding of milk in this method is sometimes discontinued at an earlier age than stated.

Calf starters are produced commercially as they are difficult to formulate and mix. They contain several grains, animal and vegetable proteins, and vitamin and mineral mixes. A high energy satisfactory more economical simple one (for feeding first 45 days along with skim milk) is composed of 50% barley, 27.5% SBM or CSM, 10% molasses (to encourage consumption), 10% bran, 1% dicalcium phosphate, 1% trace mineralized salt, 0.5% antibiotics, vitamin A 22000 lU/kg and vitamin D 4500 /kg (if calf is not exposed to sunlight) should be added. The proximate analysis is 20% CP, 5.3% CF, 2.6% fat, 0.47 % Ca, 0.68% P, 69.4% TDN. Starters should be either coarsely ground, or pelleted. The primary purpose of the calf starter is to speed the transition of the calf's diet from an all-liquid feed to a solid feed.

b- Grains and other concentrates

When a calf is 1-2 weeks old, it should be taught to eat concentrates. Any mixtures of the farm grains are satisfactory, or even a single grain. If the calf gets plenty of whole milk, skim milk or butter milk, it will receive sufficient protein in the milk. Adding a small amount of such a feed as wheat bran or linseed meal to grain will usually make the mixture more palatable to calves, and therefore may be advisable, merely from this stand point. Such mixtures are excellent for calves fed milk:

	I %	II %	III %	IV %
Corn	39	66	66	80
Barley	33	-	-	-
Bran	17	-	22	-
LSM or SBM	11	34	12	20

Molasses can be used gradually from 1-2 oz. If the amount of milk is limited and especially if calves are weaned at an early age and raised on concentrates and hay alone, the mixture must contain much more protein. Also, a larger proportion of protein supplements is required when calves are raised on whey.

Calves chew corn or oats thoroughly up to an age of 6 to 9 months and after they have learned to eat concentrates, show a preference for the whole grain. After 6-9 months, the calves chew grain less thoroughly and corn and oats should then be ground and also wheat, barley, sorghums. Coarse grinding is preferable. The calf can be taught to eat the grain mixture by putting a handful or less in the bottom of the pail after it has finished drinking its milk. Until the calf is 2 to 3 months old, it may eat as much of the mixture as it desires, a supply being kept before it in a feed box. Care should be taken to clean the box out regularly.

Older calves fed a liberal allowance of skim milk may be allowed up to 4 lbs of the grain mixture a day and those raised on calf meal, up to 5 lbs a day. If the calves begin to eat more than the proper amount should be hand-fed twice daily, instead of letting them have all they will eat. Otherwise, they will not eat enough hay, and also the feed cost will be too high. It is recently advised to mix hay with the concentrates, at the rate of about 25 – 30%, as a total mixed ration.

c- Hay

It is very important that calves have hay of first rate quality as soon as they will eat it. At about 2 weeks of age, a handful of the hay should be placed each day where the calf can get it. Little will be eaten at first, but even this may be important in preventing rickets and other troubles. As the calf grows and its rumen develops, more hay will be eaten, until at 6 months of age it should be eating 3-5 lbs a day. The amount of hay eaten per 100 lbs live weight usually increases up to about a year of age.

d- Pasture

Where internal parasites are less serious, thrifty calves do well, on clean pasture after they are 2- 4 months old, if accustomed to it gradually and if they are fed plenty of other feed and are supplied with shade, shelter, salt and fresh water. Some start to feed calves on berseem at the second week starting with 0.25 – 0.5 kg and the amount increased gradually to reach about 6 kg at weaning (4 months).

If calves, much under a year of age, are pastured with older cattle, they may become badly infected with internal parasites from older cattle. If calves are pastured when too young, there is more trouble from scours, and they may suffer from heat and flies. Many dairymen therefore prefer not to turn calves on pasture until they are 5-6 months old. Instead calves are kept in the stable where they are more sure to receive proper feed and attention.

During warm weather it is therefore well to let calves over 2 months of age have access to clean outside pens, if they are on pasture.

A feeding system for a dairy calf from birth to weaning

The first several days of the newborn calf's life are extremely critical. Its immunity system is low, and it must, therefore, depend on colostrum to provide the essential antibodies for protection from stress and disease. After about 3 days the colostrum gradually changes its composition to milk.

– Calves are routinely separated from their dams, after 12-24 hours, and are subsequently fed colostrum by bucket until day 4 postpartum. The calf nurses 4-5 times the first day, for about 5 minutes each time.
– From day 4 until weaning (generally at about 8 weeks of age), whole milk or milk replacer can be fed. A mixture of whole milk and replacer may be used; but its use must be consistent from day to day.

– At about 10 days of age, a once-a-day feeding routine may be used (but nutrient intake must remain the same as when a twice-a-day routine is used).
– If it is designed to wean at an early age follow the following:
  a) By 2 to 3 weeks (or even one week) of age, the calf should begin to consume a palatable starter diet and leafy good quality hay. Note that for about the first 3 week of life, the calf should be fed milk or a high quality milk replacer because milk or milk replacer bypass the rumen via the oesephygeal groove, consumption of solid feed is necessary to stimulate rumen function.
  b) As the calf eats more and more calf starter, milk replacer should be withdrawn.
  c) By the time the calf, is consuming 0.5 – 0.7 kg calf starter per day in addition to good quality hay (25 – 30% of the DM), milk replacer can be withdrawn completely.
  d) During this period, hay should be available free-choice, and dicalcium phosphate should be mixed with the calf starter at levels of 1 – 2%. Adequate vitamins should be supplied along with trace minerals.
  e) From weaning to 3 months, the level of calf starter can be gradually raised to 2.75 kg. Hay should be available free-choice and the calf can start getting a limited exposure to greenage (excessive levels limit the nutrient intake because of the high moisture resulting in poor growth, scours, and "pot-bellied" calves).
  f) By 3 months of age, the rumen should be almost fully developed and the calf starter can be replaced by traditional feeds (simple growing mixture).

Feeding of Dairy heifers

It is entirely unnecessary to feed heifers expensively to secure good growth and development. All that is necessary is plenty of first-class roughage in summer and good pasture in winter with only a minimum amount of a suitable concentrate mixture when needed.

Under 12 months of age

The feeding of milk or special calf meals is usually discontinued by the time heifers are 6 months of age, or even before. They should have an abundance of other feeds at this time, so that their growth will not be checked.

Experimentally it was shown that if heifers are fed an abundance of excellent legume hay, they may make normal growth when fed no concentrates after 8 months of age.

The amount of concentrates needed by heifers less than 12 months of age will, of course, depend on the quality and amount of roughage.

Over one year age

After heifers are a year of age, they may be fed satisfactorily, up to 3 or 4 months before calving, without concentrates, if fed either an abundance of good legume or mixed hay and silage, or else all the well-cured legume hay they will eat. They will not carry as much flesh as some breeders desire, but if well fed before calving and during their first lactation period, they will reach normal size and weight.

With roughages of ordinary quality it is necessary to feed a small amount of concentrates to keep heifers growing properly. They should be fed more liberally, so as to supply nutrients for the development of fetus and also so the heifer will be in good condition for high production in their first lactation. With plenty of good roughage, 4 to 5 1bs of concentrates are sufficient at this time.

Yearling heifers do well on good pasture without any concentrates, if they can actually secure plenty of forage. If the pasture gets scanty, it should be supplemented with enough other feed, concentrates, hay or silage to keep them growing satisfactorily. The same concentrate mixtures may be used for heifers of this age as for those up to a year of age. If desired, the proportion of protein supplement in the mixture may be reduced slightly, as heifers needed somewhat less protein as they become older.

Feeding dairy bulls

The young bull

The same principles apply in the rearing of the young bull as with heifers, and the same methods of feeding can be used, except that it is wise not to limit the amount of milk so much as to check his growth.

After 5 to 6 months of age, when a bull calf should be separated from the heifers, he should have somewhat larger amount of concentrates (roughage is ad-libitum) than a heifer. This is because a young bull makes more rapid gains than a heifer and consequently needs more nutrients. If well grown, a bull should be sufficiently mature for very light service at 10 to 12 months of age, but not more than 1 or 2 services in any one week should be permitted until he is 2 years old.

Bulls in service

The bull in service should be fed good roughage and sufficient concentrates to keep him in thrifty condition, but not fat.

Time and frequency of feeding and watering

Cows are generally fed twice or three times daily from the complete rations. Hay provided free – choice at all times, silage once or twice daily, and feed concentrates twice daily – this is when the forage and grain are fed separately. Hay may be put out in large amounts once daily or in small amounts several times a day. At least twice-a-day feeding of hay is desirable to reduce wastage. If wastage exceeds 10% improve the manner of feeding or the quality of the hay. Silage is usually fed once daily. Cow should not have access to silage or other feeds that cause off – flavored milk, for at least 2 – 3 hours prior to milking.

Grain should be fed twice daily. It may be fed individually in the milk barn according to the level of production. Part of the concentrate of high producers is generally fed in the manger along with the hay and/ or silage.

Under the system of grouping or corral feeding, grain are fed twice daily in the manger, right after milking, as a top dressing on the silage and/or hay, or mixed with the silage and/or hay.

Calves should be fed milk or milk replacer once or twice daily at regular intervals. It is more harmful to overfeed than to underfeed a young calf.

Water should be available at all times. If there is too little water or if the cows must stand in line to get it, milk production will suffer.

Ration formulation for dairy cattle

Contents

Introduction

- A dairy ration is mostly composed of roughage (tibn, T; hay, H; or berseem, B) and a concentrate mixture, estimation of each's proportion is the basis of ration formulation.
- There are several kinds of rations (33 kinds with a total of 104 diets) can be formulated in a dairy farm. The diet requirements for energy, CP, Ca & Na should be always kept in mind.
- The diet or CM composition or nutrient content are all on DM basis.
- The CM is composed of corn, bran, fat, SBM, LS, salt and premix. The bran is 33% in lactation and breeding diets while it is 10% in growing and fattening. Salt is 0.5 to 1 % in all diets T, H, or B.

Kinds of dairy rations

I- Lactation rations

In lactation diets the proportion of roughage can be estimated by the "square" method using the diet energy density, in diets containing no fat, where CM energy can be estimated. Diets are mixed on crude fiber-basis in diets containing fat, where CM energy could not be estimated, and the amount of roughage is just to satisfy minimum CF needs. In order to satisfy the minimum CF needs tibn should not be less than 30.6% for 17% CF and 25% for 15%. The respective percentages for hay are 45.8 & 37.5, and for berseem 55 & 45. The amount of H is 1.5 times the amount of T, in all diets, and the amount of B is 1.8 only with minimum CF and about 2.0 or 2.1 in others (I & II starting NEL diets). With "maximum roughage" the proportions are estimated in different way and it is 1.33 for H and 1.67 for B. In using energy-basis the CM-NEL should be considered 1.78 with T and 1.82 with B or hay (with B or H usually CM contains no LS but only 1% salt on the average, and so of higher NEL). The CM in lactation contains 33% bran, to cover P needs, and assumed to contain 6% CF, while hay contains 30 and berseem 26.

Table 1 The amount of H& B, DM as compared to T in diets

Diet	Starting NEL		Maximum roughage and starting NEL	
	H	B	H	B
I	1.5	2.06*	1.33	1.67
II	"	2.14*	"	"
III	"	1.8	"	"
IV	"	"	-	-
V	"	"	-	-

*Diets are formulated using the diet energy density.

The lactation rations could be formulated are:

A-Lactation rations with ''group starting-NEL'', and normal amount of roughage, for the five milk groups

The rations are needed to contain at least 17% CF in the groups I, II & III and 15% in IV & V. The last three groups are needed to be supplemented with a large amount of fat and the T proportion is 30.6 % in III and 25 % in IV and V, satisfying the minimum needs for CF. The diets NEL/kg DM are 1.42, 1.52, 1.62, 1.72 (17% CP) & 1.72 (18% CP) respectively, for each group start.

Roughage and CM proportions:

NEL/kg DM Diet I

CM 1.78 — 1.42 — 0.42

Tibn 1 — 0.36

0.78

T= 46.15 % **(more than 30.60)**

Diet II

1.78 — 1.52

1 — 0.26

0.78

T=33.33% **(more than 30.60)**

Diet III

CM 1.78 — 1.62

Tibn 1 — 1

0.78 0.16

T= 20.5 % **(less than 30.60)**

Diet IV & V

1.78 — 1.72

1

0.78 0.06

T= 7.69 % **(less than 25.00)**

In 1.42 and 1.52 diets the T % is more than that needed to satisfy the minimum CF. In 1.62 & 1.72 T does not satisfy the minimum CF, and proportions should be estimated on CF-basis where CM must be supplemented with fat to leave a more space for T. T % should be 30.6% in 1.62 and 25 % in 1.72.

CF% of DM Diet III

CM 6 — 17 CF — 25 69.4%

T 42 — 11 30.6%

36 36

T= 30.6 %

Diets IV&V

CM 6 — 15 CF — 27 75%

T 42 — 9 25%

36 36

T= 25 %

The fat, in the CM, is estimated as follows:

1.62 NEL diet:

Needed NEL of CM in 1.62 diets = (1.62 of diet - 0.306 of T) ÷ 0.694 CM in diet = 1.893 Mcal, NEL / kg DM.

Fat % in CM = (1.893 – 1.781) ÷ 3.88 X 100 = 2.89 (3.88 is the difference between NEL fat-5.84 and corn-1.96; 1.781 is the basal CM energy)

1.72 NEL diet:

NEL of CM in 1.72 diet = (1.72 - 0.25 of T) ÷ 0.75 = 1.96

Fat % in CM = (1.96 – 1.781) ÷ 3.88 X 100 = 4.61

At the end of production in each of the first three groups the feed intake should be increased by about 6 % to satisfy the energy needs of the animal.

Example

At the end of group I the energy should be 1.51. The animal consumes 1.51 ÷ 1.42 = 1.063 times from the 1.42 one, with an increase of 6%.

B- Lactation rations with a maximum amount of roughage and starting NEL

It can cope with linearity of energy and can be fed as TMR (according to milk production), dressed roughage, or in separate roughage and concentrate. The linearity is needed in the first 3 groups I, II & III (1.42, 1.52 & 1.62), which have an end energy density different from the start one, but not in 1.72.

To get the proportion of the roughage in the diets, the maximum amount consumed is divided by the total DM of the diet. For a cow of 400 kg the dietary DM needed in the first three groups is 9.68, 12.63 & 15.22 kg respectively calculated from total E needed ÷ diet E , and the maximum amount of tibn, for example, consumed equals 1.35 "maximum T, DM for every 100 kg body wt." X 4 "400 body weight /100" = 5.4 kg DM, T / day. So the proportion of T in the diets is:

5.4 ÷ 9.68 = **0.5579,** 5.4 ÷ 12.63 = **0.4276**& 5.4 ÷ 15.22 = **0.3548** in the three groups respectively.

As the amount of roughage is the maximum, the CM in the three diets is needed to be supplemented with a large amount of fat especially if fed with tibn and hay. The roughage is fed at its maximum and CM added according to the amount of milk secreted, giving diets different in NEL density according to milk production.

C- Early lactation diet

The diet has 1.67NEL/kg DM, 19% crude protein, and 17% CF. The proportions of roughage and CM are estimated using the square method on CF-basis. The CM contains a large amount of fat.

II Breeding rations

a- A ration for dry pregnant animals, NEL, 1.25 but could be increased to 1.35 for reconditioning (CP increased to 12.96). T proportion is estimated by square method on E- basis where it is 53.95% and H is 1.48 times and B is fed with T.

e- A ration for breeding bulls 1.15 NEM, equivalent to 1.25 NEL and 10% CP. It contains 67.1% T, estimated on E- basis, and H is 1.49 times and B is fed with T.

III Rations for growing calves (after weaning, 100 to 400 kg)

Rations for growing calves are formulated according the 3- phase systems, either according to NRC and high concentration of CM, or according to the ad lib feeding and lower concentrations. In NRC system the calves still have an allowance to increase feed intake for extra growth, while in the ad lib system no more room to increase feed intake. Refer to table 1 for energy density and table 2 for CM percentages page 68.

The figures of NEG can be used in ration formulation by the square method, giving ingredient proportions not greatly different from that when NEM is used with.

The H contains 1.14 and 0.58, T 0.75 and 0.22, and CM 2.0 and 1.35,Mcal/Kg DM in all for NEM and NEG respectively.CM contains 10% bran.
Hay is 1.47 T and B 1.96.

IV Rations for fattening calves (100 or 150 kg to about 400)

The calves can be fattened at three levels depending on the CM % in the diet. The diet composition is fixed along the fattening period but differs in the CP content according to the phase and level of feeding. The CP decreases as the body weight increases. The CP % of the CM in the three phases in the three levels is 19.5, 16.25 &14 % respectively (with T). The following are the characteristics of the three levels in the three phases of feeding.

Table 3 The characteristics of fattening diets, fed with T

	Level											
Phase	A				B				C			
	NEG	T %	Diet CP %	CM CP%	NEG	T %	Diet CP %	CM CP%	NEG	T %	Diet CP %	CM CP%
I (100 or 150 to 200 kg)	1.12	20	16	19.5	1.07	25	15.63	The same as "A"	1.01	30	14.85	The same as "A"
II (200 to 250 kg)	〃	〃	13.5	16.25	〃	〃	13.19		〃	〃	12.58	
III (>250kg)	〃	〃	12	14.0	〃	〃	11.5		〃	〃	11.0	

Hay is also 1.47 times the amount of T and B is 1.95. Estimation of H or B allows the estimation of CM, CP% and eventually the percentage of SBM.CM contains 10%bran. The SBM% in CM is about 23,15and 9.

In level A the expected body gain is 1.3 kg/d (starting with > 1.0 kg at 100 kg weight and ending with > 1.6 at 400 kg), in level B 1.2 (starting with 1.0& ending with > 1.5), and level C 1.1 (starting with 0.9& ending with 1.4).
The DM consumption is considered at the ad libitum rate and to be 3.53 % at 100, 2.91 % at 200, and 2.81 % at 250 (3.92, 3.23 & 3.12 on fresh- basis).

Correction of diet CP %:

In formulating diets with H or B using the square method either on NEL or CF basis, the CP % of the diet may be higher than that needed, and it needs for the H or B to be replaced by T and corn or basal CM. The diets need correction are:

Lactation		
Starting NEL	I H (0.97)	I II B(5.2, 0.71)
Max. roughage	I H (1.04)	I II B (5.06, 0.70)
Breeding		
Dry cow	H (0.3)	B (2.85)
Bull	H (3.8)	B (2.44)
Growing		
NRC-3	III H (0.76)	III B (5.08)
Ad libitum- 3	III H (0.76)	I II III B (1.65, 3.13, 5.02)

The figures in parentheses are the amount of CP units in excess of that needed. The figures less than 1.0 can be left as an allowance (the underlined).

Methods of correction:

The correction method is by replacing H or B with a mixture of corn or CM and T having CP, of course, less than that of H or B. This can be solved using the square method performed on NEL basis or NEG. The figures on the right side of the equations are rounded.

As a general rule for reducing 1 CP replace about 12 units H and 9 B by corn or CM and T.100H = 25 corn and 75 T , 100B = 40 corn and 60T, 100H = 30 CM and 70T, and 100B = 50CM and 50T approximately.

Example

Diet I (ad lib.) growing is 70 % B and 30 % CM and contains 15.34 CP (needed CP is 13.69).

CP needed to be reduced = 15.34 – 13.69 = 1.65

B needed to be reduced = 1.65 × 9 = 14.85 of about 50 % CM and 50 % T .So the diet will be

			CP
B	70 – 14.85 = 55.15	× 0.175	9.65
CM	30 + 7.425 = 37.425	× 0.10	3.74
T	= 7.425	× 0.04	0.30
	100.00		13.69

The CP can also be corrected using double square method on NEL or NEG- basis in one (T & corn or CM having the NEL or NEG of the diet) and CP – basis in the other (between the two mixtures).

Feeding with CCM (1.65 NEL - 1.25 NEG-and 10%CF) or CTMR (about 1.30 NEL):

Some of the dairy diets can be fed with commercial concentrate mixtures (CCMs) or the animal fed commercial total mixed rations (CTMRs). The diets are as follows:

a- Lactation diets

The CCM can be used in formulating diets for up to 1.52 NEL with T, H, or B. There is a waste of CP especially in group I with H & B and slightly with II.

Lactation diets (with CCM)

	w.T		**w. H**		**w.B**	
	I	**II**	**I**	**II**	**I**	**II**
			Starting NEL diets			
Roughage	35.4	20	54.76	30.95	92	52
CCM(17.78CP)	64.6	80	45.24	69.05	8	48
CP %	12.9	15.02	15.6	16.55	17.52	17.63
CF %	21.33	16.4	20.95	16.19	24.72	18.32

So CCM can be used for diets I & II with a waste of protein in H & B.

b- Breeding diets

	w.T	**w. H**
Dry cow		
Roughage	46.15	71.43
CCM(17.78CP)	53.85	28.57
CP %	11.42	14.94
Bull		
Roughage	61.54	Nearly 100% hay
CCM(17.78CP)	38.46	
CP %	9.30	

* With H there is a waste of protein.

Note:

- CCM could not be used with maximum roughage as its NEL should not be less than about 2.0 Mcal.
- The CTMR is suitable for the milk group I(refer to table 6).
- With CCM the CP % could not be corrected. Hay or berseem can be replaced by T and corn to reduce CP, but most of B or H will be needed to be replaced.
- The underlined figures are either do not satisfy CF needs or the CP is high and wasted.

c- Growing diets (ad lib.) with CCM-mixed on NEG-basis

	w. T			**w. H**			**w.B**		
	I	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
Roughage	30.1	33.98	41.75	46.27	52.24	64.18	64.58	72.92	89.58
CCM (16.67 CP)	69.9	66.02	58.25	53.73	47.76	35.82	35.42	27.08	10.42
NEG	0.94	0.90	0.82						
CP %	12.85	12.37	11.38	15.35	15.17	14.83	17.20	17.27	17.42
	Low in CP			High in CP			High in CP		

If CCM is fed with T the lactation mixture (17.78 CP) should be used especially in ad. lib. system where the CM proportion is less than in NRC system. It is better to feed calves at the first phase CCM with hay or berseem.NRC diets are formulated with square method on NEG-basis.

d- Fattening diets

Level		**T**	**H**	**B**
A	Roughage	12.62	19.4	27.08
	CCM (15.56)	87.38	80.6	72.92
	CP %	14 For II&III	15.22 Can be for I	16.09 For I
B	Roughage	17.48	26.87	37.5
	CCM (15.56)	82.52	73.13	62.5
	CP %	13.54 For II&III	15.09 Can be for I	16.29 For I
C	Roughage	23.30	35.82	50.0
	CCM (15.56)	76.70	64.18	50.0
	CP %	12.86 For II & III	14.93 For I	16.53 For 1

- With T the CCM is better to have 17.78 % CP on DMB.
- Feeding with H or B can be used for fattening 100-200 kg calves (I), otherwise there will be a waste of protein. For > 200 T can be used.
- Generally when using CCM the amount is about 1.2 times the CM in the T diets in lactation and breeding, and 1.1 times in growing and fattening.

1.78 + 0.2 of T=1.98 NEL 1.65X1.2=1.98

1.35+0.22X0.1=1.394 NEG 1.25X1.1=1.375

In lactation and breeding (dry cow) CCM is 1.4 times CM with hay and 1.7 with berseem. In growing and fattening it is 1.15 with hay and 1.33 with berseem on the average.

Roughage proportions in dairy diets – summarized

In lactation diets with maximum roughage, the amounts of T, H, or B are estimated on roughage ad libitum feeding – basis and its percentage as a part of the total amount of DM needed calculated. Diets formulated on energy – or CF – basis are fed as TMR each according to its milk group or class, while diets formulated on maximum roughage – basis are fed as separate ingredients , roughage and CM, the amount of roughage is fixed as a percentage of body weight, while that of the CM differs according to milk production. In most farms the roughage is offered dressed with CM. The tibn diets are taken as standard as the roughage is relatively of fixed quality and composition.

Table 4 Roughage proportion in dairy diets

	Roughage		
Diets	**T**	**H**	**B**
Lactation			
I,II,III.IV,V Starting NEL	46,33,31,25,25	68,51,46,37.5,37.5	95,71,55,45, 45
I,II,III Maximum roughage groups	56,43,36	76,57,47	93,71,59
Early lactation	31	46	55
Breeding			
Dry pregnant cow	54	80	87.5 B +12.5 T
Breeding bull	67	100	63B + 37T
Growing calves			
I,II,III ad lib.	36,40,48	53, 59, 70	70, 79, 93
NRC	24,31,48	35,45,70	47,60,93
Fattening calves			
A	20	30	40
B	25	36	48
C	30	44	59

Figures underlined are the percentages satisfying the minimum CF.

Mathematics in feed formulation

I- **Roughage proportion**

The concentrate and roughage proportions are estimated using the following methods:

a) **Square method** performed on energy-basis, in case when the energy density of the CM could be estimated. The method does not guarantee the fibre content of the diet.

- **A diet of 1.42 Mcal, NEL/kg DM**

CM-NEL 1.78 0.42 53.85% CM

1.42

T- NEL 1.0 0.36 46.15 % T

0.78 0.78

CF % = (6 of CM × 0.5385) + (42 of T × 0.4615) = 22.61
CF % is more than the minimum 17% - so it is okey.
(Note: Diets for calves can be mixed on NEG-basis-and CF usually already satisfied.)

- **A diet of 1.52 Mcal**

CM	1.78		0.52	66.67% CM
		1.52		
T	1.0		0.26	33.33% T
	0.78		0.78	

CF% = (6 × 0.667) + (42 × 0.3333) = 18

b- Square method performed on minimum CF-basis but does not guarantee the energy density for the diet.

Diets with more than 1.52 Mcal should be formulated using this method, and usually the CM energy density is increased by the addition of fat or any other high energy feeds.

Proportion of roughage satisfying a minimum of 17 and 15 % CF

CM, CF (Suggested)	6		25	69.4 % CM	6		27	75% CM
		17				15		
T, CF	42		11	30.6 % T	42		9	25% T
	36		36		36		36	

So the roughage should not be less than 30.6 % for diets < 1.72 and 25 % for a diet of 1.72 NEL.

c- By considering the maximum amount of roughage could be consumed and its relation to the total DM.

A cow of 400 kg, for example, consuming 9.68, 12.63&15.22 kg DM in milk groups I, II&III respectively, the roughage proportion will be

	% of T	% of H	% of berseem, DM
I	1.35 X 4÷ 9.68 X 100= 55.79	1.8X4÷9.68X100=74.38	2.25X4÷9.68X100= 92.98
II	1.35 X4÷12.63 X 100= 42.76	1.8X4÷12.63X100=57.01	2.25X4÷12.63X100=71.26
III	1.35X 4÷15.22 X100= 35.48	1.8X4÷15.22X100=47.31	2.25X4÷15.22X100=59.13

The underlined figures are the DM of T, H & B when consumed at 1.5, 2.0 & 2.5 %, of body weight, hay equivalent (on fresh basis).

II - Concentrate mixture composition

The following is an example for estimating the physical composition of a CM.

Diet characteristics (a lactation diet-class I)

T %, 55.8 (maximum amount fed in group I; CM %, 44.2); NEL / kg DM, 1.42; CP%, 12; Ca %, 0.43; Na %, 0.18 ((NEL, CP, Ca & Na are the only nutrients considered).

Steps

- LS % in CM = 0.43 ÷ 0.442 ÷ 0.35 = 2.78 (0.442 = proportion of CM, 35 % = content of Ca in LS)
- Salt % in CM = 0.18 ÷ 0.442 ÷ 0.39 = 1.044 (39 % content of Na in salt)
- Needed CM, NEL = 1.42 – 0.558 (of T) ÷ 0.442 (CM) = 1.95

Basal NEL, CM = 0.528 (of bran) + (67 – [2.78 LS+1.0 Salt]) X 1.96 NEL of corn Mcal/kg DM = 1.767

Fat % = 1.95 – 1.767 ÷ 3.88 (difference between corn and fat energy in kg) X 100 = 4.72

- Needed CM, CP% = (T, CP 4 x 0.558 of T) – 12 (of diet) ÷ 0.442 (CM) = 22.1 %
  CP basal = 5.85 (of corn) + 4.62 (of bran) = 10.47
- SBM % =(22.10 – 10.47) ÷ 0.4 (50 of SBM – 10 of corn ÷ 100) = 29.08%

Note

1- CM for lactation contains 33 % bran, satisfying the need for P.

2- No Ca or Na are considered to be present in T and CM.

3- Basal NEL is the energy in corn and bran [(1.6 of bran X 0.33) + (1.96 of corn X 0.6322)] = 1.767

4- Basal CP is the protein in corn and bran [(14 of bran X 0.33) + (10 of corn X 0.6322)]

The CM composition is:

Corn	balance of 100 units	SBM	29.08
Bran	33.00	LS	2.78
Fat	4.72	Salt	1.00

Premix is added as instructed.

III- How to make a thumb rule for feeding

1- Transfer the amount of DM needed by the given animal to as-fed basis.

2- Calculate the amount of roughage and CM using the already known dietary proportions.

3- Calculate the energy content of the roughage and find whether it is sufficient to cover the needs for maintenance or needs to be supplemented with CM. If it is more than needed, calculate the Kilos of milk covered by the extra energy (Note that the energy is tabulated on a DM- basis).

4- Divide each of the fresh roughage and concentrate mixture, if any, by the body weight and multiply by 100 to get the amount of food per 100 kg body weight fed to cover maintenance.

5- Divide the amount of milk by rest of CM to get the second factor of grain: milk ratio. Another way, you can divide the density of energy in fresh CM over 0.74 the energy in one kg milk.

Note: For breeding animals and growing or fattening calves the same principles are applied, relating the amount of roughage and concentrate to 100 kg of body or 50 kg in fattening as used to be.

Thumb rules for feeding lactating animals

- I, II, III, IV & V starting NEL
- Early lactation

It is usually not supplied in separate roughage and concentrates mixture ingredients. It is fed as TMR according to the feed intake of each group, covering the maintenance & milk produced, for example:

Amount of fresh diet for maintenance =

Energy needed for maintenance ÷ (diet energy in kg DM ×0.9)

Amount of fresh diet needed for secreted 4% FCM= (amount of milk in kg × 0.74) ÷ (diet energy in kg DM × 0.9)

- Maximum roughage groups

Maintenance (for a cow of 400 – 800 kg)

Roughage kg / 100	T **1.5 - 1.28**	H **2 – 1.7**	B, fresh **15 – 12.7**
CM / 100	0.41		
Milk (for a cow of 400- 800 kg)			
Skipped	….	1/kg	6 - 9.5kg

Milk kg / kg CM- in the three groups in T, H & B respectively

2.37, 2.32, 2.38 2.4, 2.32, 2.4 2.21, 2.21, 2.36

As an average it is 2.35 in I &II with T & H and 2.2 in B, and 2.38 in III in T, H, or B.

Dry pregnant cow (400 – 800 kg)

With T About 1 kg CM (0.95 – 0.80) / 100 kg body

About 1.25 kg T (1.11 – 0.93) / 100 kg body or ad libitum

With H About 0.5 kg CM (0.41 – 0.35) / 100 kg body

About 1.75 kg H (1.65 – 1.38) / 100 kg body or ad libitum

With B About 11 kg B (10.93 – 9.13) / 100 kg body

About 0.25 kg T (0.25 – 0.21) / 100 kg body or ad libitum

Bull (500 – 1000 kg)

With T 0.6 kg CM (0.59 – 0.49) / 100 kg body

1.25 kg T (1.19 – 0.99) / 100 kg body or ad libitum

With H 1.75 kg H (1.78 – 1.48) / 100 kg body

With B 7.0 kg B (6.72 – 5.59) / 100 kg body

0.75 kg T (0.66 – 0.55) / 100 kg body or ad libitum

Growing calves (approximated figures)

	NRC-3			Ad libitum- 3		
CM	2.75	2.25	1.75 - 1.5	2.5	2.0	1.75 – 1.5
T	**1.0**	**1.0**	**1.5**	**1.5**	**1.5**	**1.5**
CM	2.25	1.75	1.0-0.75	2.0	1.5	1.0
H	**1.5**	**1.5**	**2.0**	**2.0**	**2.0**	**2.0**
CM	2.0	1.25	0.25	1.25	0.75	0.25
B	**10**	**12**	**16**	**16**	**16**	**16**

• In ad libitum it is the" maximum" amount of roughage in all phases and then CM is the rest of the amount of feed intake (4.0, 3.5 & 3.25% fresh feed intake).

Fattening calves

	Body weight				
	Level	**100**	**150**	**200**	**250 &>**
CM/50 kg fed with tibn	**A**	1.6	1.4	1.3	1.25
	B	1.5	1.3	1.2	1.15
	C	1.4	1.3	1.15	1.1

• It is 1.6, 1.5 & 1.4 at 100 decreasing 0.1 unit/50 kg till a weight of 250 kg then fixed. This is with T.
• Roughages T, H, or B can be fed ad libitum.
• The CM can be decreased when fed with H or B but rather it is left for extra gain.

Information tables

Table 5 Nutrient content of feeding stuffs commonly used in ration formulation (on DMB-NRC, 1988)

Feed	**TDN**	**Energy in Mcal / kg DM**					**CP**	**CF**	**Ca**	**P**
	%	DE	ME	NEM	NEG	NEL	%	%	%	%
Corn	85	3.75	3.34	2.10	1.43	1.96	10			0.29
Bran	70	3.09	2.67	1.63	1.03	1.60	14			1.38
Fat	177	7.30	7.30	5.84	5.84	5.84	----			---
SBM	84	3.70	3.29	2.06	1.40	1.94	50			0.68
Tibn	44	1.94	1.51	0.75	0.22	1.00	4	42		0.05
Hay	55	2.43	2.0	1.14	0.58	1.23	13.8	30	1.25	0.22
Berseem	------	------	2.5	1.30	0.77	1.40	17.5	26	1.82	

Notes

Common salt contains 39% Na.
Berseem and berseem hay may differ greatly in nutrient content from the values mentioned. In this case composition should be considered in the ration formulation. The CM formulated differs in NEL according to the level of fat it contains but, as a basal, it contains1.78 NEL when contains LS to be fed with T (1.76 and 1.77 in breeding), and 1.82 NEL when free from LS to be fed with hay or berseem.
The CM with 10 % bran and fed to growing and fattening animals is estimated to contain 1.35 NEG.
The CM is estimated to contain 6 % CF and a basal CP (without SBM) of 11 with T and 11.22 with H or B in breeding and lactation, 10 with T and 10.33 with H or B in growing and fattening.
NDF in corn, bran, SBM, tibn and hay is 9, 51, -, 85 & 50 respectively and ADF is 3, 15, 10, 54 & 37% - NRC, (1988).

Table 6 Nutrient content of commercial diets and mixtures (on DMB)

	CP%	**CF%**	**TDN%**	**Molasses**	**Roughage**
Diets (CTMR)	(not<)	(not >)	(not<)	(not >)	(not >)
Lactating cows (NEL, 1.30)	14.44	26.67	58	12	50
Fattening calves(1st stage)	12.22	24.44	61	12	40
Fattening calves(2nd stage)	11.11	22.22	67	12	30
Mixtures (CCM)					
Calf starter	**18.89**	**6.67**	**78**		
Growing *(*6-12mo.,NEG, 1.25*)*	**16.67**	**14.44**	**73**		
Fattening (large calves ,NEG, 1.25*)*	**15.56**	**16.67**	**72**		
Lactating cows (NEL, 1.65*)*	**17.78**	**16.67**	**72**		
Breeding bulls(NEL, 1.65*)*	**17.78**	**16.67**	**72**		

Notes

Growing and fattening CCM is estimated to be 1.25 Mcal, NEG /kg DM and lactating cows CCM is 1.65 NEL. TDN in calf starter is not less than 78%, and 72% in the rest of the CCMs. Lactation CCM is estimated to contain 10% CF while that formulated contains 33% bran and contains 6% CF. The lactation CTMR has about 1.30 NEL{(1.65 of CM× 0.5) + (1.0 of T × 0.5 = 1.325)}.

Table 7 Daily nutrient requirements for dairy cattle

	NEM	NEG	NEL	CP	Ca	P	DM	Remarks
	Kcal/kg$^{0.75}$	Mcal/animal	Kcal/k$^{0.75}$ or kcal/kg	g/kg$^{0.75}$ g/kg	g/kg$^{0.75}$ g/kg	g/kg$^{0.75}$ g/kg	% of body weight	
Calves								
Maintenance	*86*							
Gain		*Rule*						
Total				*15.25, 15, 11.75*	*0.65 – 0.30 (acc.to age)*	*0.35 – 0.20*	*Rule*	
Breeding bull (500 - 1000kg)	*86*			*7.5*	*0.20 - 0.25*	*0.10 – 0.15*	*1.6 – 1.33*	
Lactating cow (400 - 800kg)	*Rule*							
Maintenance			*80*	*3.56 – 3.23*	*0.18- 0.21*	*0.12 – 0.15*		
Kg milk 4%fat			*740*	*90*	*3.25*	*1.98*		*Rule*
Kg gain			*5120*	*320*	----	-----		
Heifer								
Maintenance	*As cow x 1.2 or 1.1 (1st& 2nd calving)*							
Dry pregnant cow (400 - 800kg)			*104*	*10*	*0.29 – 0.35*	*0.17 – 0.20*	*1.86 – 1.56 (acc. to wt.)*	

Notes:

- *All needs are in kcal or gram / kg$^{0.75}$ except NEG it is Mcal per animal, and milk is kcal or g / kg milk 4% fat.*
- *Rules are suggested for NEG in calves, for DM in calves & cows and for all the milk nutrients*

- NEG rule: gain in kg x 2 at 100 kg body weight plus o.33 unit every 50 kg more,, in large breed females. In males it is 1.79and 0.21, respectively. So the males are more efficient.

- NEL milk rule: 0.74 Mcal / kg 4% FCM plus or minus 0.05 Mcal for every ± 0.5% fat unit more or less than 4%.

- CP milk rule: 90 g / kg 4% FCM plus or minus 6g for every 0.5% fat unit more or less than 4%.

- Ca and P milk rules: 3.21g Ca / kg 4% FCM ±0.24g for every ±0.5% fat unit.P1.98 and ± 0.15g / ± 0.5% fat.

- NEL, CP, Ca & P needs for first and second calf heifers equal that needed by cow maintenance x 1.2 or 1.1 respectively.

- DM calf rule: 3.53% DM for the first 100kg of body weight and 2.33% for the rest of 250 kg body weight, on ad lib. feeding 3.14% DM for the first 100 kg of body weight and 2.5% for the rest of 250 kg body weight, on NRC feeding. From 250 to 400 kg decrease feed intake by 0.15/50 kg on average. On fresh basis roundly it is 3.5-0.15/50 kg in NRC and 4-0.25/50kg in ad lib.

- DM cow rule : 2.7% at 400 kg with the base of 10 kg milk 4% fat, decrease 0.2 unit for every100 kg more in body weight and give 1.9 (or 2.0) kg DM / 5 kg milk more.

- *For Ca and P it can be approximated to be 0.35g Ca and 0.20g P /kg$^{0.75}$ in all animals except in calves it may increase to 0.65ginCa and 0.35g in P in young ages. The dry pregnant cow is not in Ca balance at the beginning of the last 2 mo. of gestation, then Ca requirement can be increased from 25 to 33 % (to reach 0.39 to 0.47 Ca g/kg$^{0.75}$ at 33%).*

Table 8 Recommended nutrient content of dairy cattle diets (on dry matter- basis)

Mixture or diet		Energy (Mcal/kg DM)			CP	Ca	P	Na	Min. CF
		NEM	NEG	NEL	%	%	%	%	%
Calf starter		1.9	1.2	---	18	0.60	0.40	0.10	
Milk replacer		*2.4*	1.55	---	22	0.70	0.60	0.10	
Growing rations									
3 phase feeding (ad-lib and NRC systems)									
Phase I(3-6mo.)	*Ad lib.*	1.55	0.94		13.68	0.44	0.26	0.10	
(100-150)	*NRC*	1.70	1.08		16	0.52	0.31	〃	
Phase II(6-12mo.)	*Ad lib.*	1.49	0.90		12.82	0.35	0.26	0.10	
(150-250)	*NRC*	1.58	0.98		15	0.41	0.30	〃	
Phase III(>12mo.)	*Ad lib.*	1.40	0.82		12	0.29	0.23	0.10	
(250-400)	*NRC*	1.40	0.82		12	0.29	0.23	〃	
Fattening rations									
Phase I	***A***		1.12		16.40	0.52	0.31	0.10	
(100-200)	***B***		1.07		15.63	〃	〃	〃	
	C		1.01		14.85	〃	〃	〃	
Phase II	***A***		1.12		13.80	0.41	0.30	〃	
(200-250)	***B***		1.07		13.19	〃	〃	〃	
	C		1.01		12.58	〃	〃	〃	
Phase III	***A***		1.12		12.00	0.29	0.23	〃	
(>250)	***B***		1.07		11.50	〃	〃	〃	
	C		1.01		11.00	〃	〃	〃	
Dry pregnant cows		--	---	1.35	12.96	0.52	0.26	0.10	22
Dry breeding bulls		1.15	---	1.25	10.00	0.30	0.19	0.10	15
Milking cows									
Level of production (in a cow of 600 kg)									
10 Kg or less, to 20		---	---	1.42	12	0.43	0.28	0.18	17
20-30		---	---	1.52	15	0.51	0.33	0.18	17
30-40		---	---	1.62	16	0.58	0.37	0.18	17
40-50		---	---	1.72	17	0.64	0.41	0.18	15
50 &>		---	---	1.72	18	0.66	0.41	0.18	15
Early lactation									
(0-3wk postpartum)		---	---	1.67	19	0.77	0.48	0.18	17

Notes:

•The diets may be evaluated for its content of about thirty nutrients, but energy, CP, Ca, Na, and sometimes P are the nutrients used in ration formulation. Vitamins and the rest of mineral elements are supplied as a premix.

• 0.6 – 0.8 Ca and 0.5-0.6 % P are needed for calf starter, milk replacer and early and high (30- > 50) lactating cows. While 0.5% Ca& 0.25 to 0.33 P are needed for the rest of the classes.

• A minimum of 12% CP is suggested to ensure that rumen bacteria needs are satisfied

• The approximate weight for growing heifers and bulls at 6 mo. is about 150 kg and at 12 mo. is about 250 and at 18 mos. is about 400. The approximate average daily gain is 700g, as mentioned in NRC.

• Dry pregnant cows need a diet of 1.25 NEL which should be increased to say 1.35 for body conditioning, and Ca by 33%.

• In lactation Ca increases by 0.07 each class (40 to >50 considered as one class) and P by 0.05, starting with that of 1.42 diet.

•To get the NEL DM the total NEL needed in Mcal is divided by the needed DM in kg. For NEM and NEG DM the calculation is too difficult to be discussed here as it may need special equations.

• To get the CP % of diet DM, the total needed in kg is divided by the DM needed in kg and multiplied by 100. Refer to the calculated examples.

Dairy diets example:

The following are examples of dairy diets formulated using the feeds nominated and the methods and calculation steps mentioned before. Additives should be added to diets as instructed and in fattening graduation in feeding the large amount of concentrates should be followed.

Examples for Diets in a Dairy Farm

Table 9 Lactation diets for a production up to >50 kg with starting NEL density

Concentrate mixture composition	CM with tibn					CM with hay					CM with berseem				
	I	**II**	**III**	**IV**	**V**	**I**	**II**	**III**	**IV**	**V**	I	II	III	IV	V
Corn	44.22	40.45	34.64	32.38	28.96	66	53.52	45.56	39.52	35.40	66	66	56.45	47.81	43.27
Bran	←		33		→	←		33		→	←		33		→
Fat	---	---	2.89	4.61	4.61	---	---	3.2	5.26	5.26	---	---	1. 8	3.97	3.97
SBM	19.64	23.67	26.41	26.95	30.3	---	12.54	17.39	20.7	24.73	---	---	7.75	14.38	18.93
LS	2.28	2.19	2.39	2.44	2.51	---	---	---	0.78	0.87	---	---	---	---	---
Salt	0.86	0.69	0.67	0.62	0.62	1.0	0.94	0.85	0.74	0.74	1.0	1.0	1.0	0.84	0.84
Premix	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Roughage %, diet and CM requirements															
Roughage	46.15	33.33	30.6	25	25	67.8	50.85	45.83	37.5	37.5	95.2	71.4	55	45	45
Times tibn						1.47	1.53	1.50	1.50	1.50	2.06	2.14	1.80	1.80	1.80
Diet NEL	1.42	1.52	1.62	1.72	1.72	1.42	1.52	1.62	1.72	1.72	1.42	1.52	1.62	1.72	1.72
Diet, CP	12	15	16	17	18	12.97	15	16	17	18	17.20	15.71	16	17	18
CM, NEL	1.78	1.78	1.89	1.96	1.96	1.82	1.82	1.949	2.014	2.014	1.82	1.82	1.89	1.982	1.982
CM,CP	18.86	20.5	21.29	21.33	22.67	---	16.24	17.87	18.92	20.52	---	---	14.17	16.59	18.41
Basal															
CM,NEL	1.78	1.78	1.78	1.78	1.78	1.82	1.82	1.825	1.81	1.81	1.822	1.822	1.825	1.828	1.828
Basal, CP	11.01	11.03	10.73	10.55	10.55	11.22	11.22	10.92	10.64	10.63	11.22	11.22	11.07	10.84	10.84

Diet I H corrected to 56.2 H + 8.3 T and the rest is CM. CP increment can be left as an allowance.
Diet I B corrected to 48.4 B + 22.9 T and the rest is CM.
Diet II B corrected to 65.0 B + 3.1 T and the rest is CM. CP increment can be left.
Premix is added as instructed but note that it is added on CM- basis not on diet- basis.

Table 10 Lactation diets for a production up to 40 kg with starting NEL density and maximum roughage

Concentrate mixture composition									
	CM with tibn			**CM with hay**			**CM with berseem**		
	I	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
Corn	29.38	29.67	28.79	62.19	49.91	44.56	66	66	55.73
Bran	←	33	→	←	33	→	←	33	→
Fat	4.72	3.48	4.72	3.81	2.14	3.76	---	---	2.99
SBM	29.08	31.49	30.20	---	13.95	17.8	---	---	7.28
LS	2.78	2.55	2.57	---	---	---	---	---	---
Salt	1.04	0.81	0.72	1.0	1.0	0.88	1.0	1.0	1.0
Premix	+	+	+	+	+	+	+	+	+
Roughage %, diet and CM requirements									
Roughage	55.8	42.8	35.5	74.38	57.01	47.31	93.0	71.26	59.13
Times tibn				←	1.33	→	←	1.67	→
Diet NEL	1.42	1.52	1.62	1.42	1.52	1.62	1.43	1.522	1.62
Diet CP	12	15	16	12.97	15	16	17.20	15.71	16
CM, NEL	1.95	1.91	1.96	1.97	1.905	1.97	1.82	1.82	1.938
CM,CP	22.10	23.23	22.60	---	16.59	17.98	---	---	13.83
Basal CM,NEL	1.77	1.775	1.777	1.822	1.822	1.824	1.822	1.822	1.822
Basal CP	10.47	10.64	10.52	10.84	11.01	10.86	11.22	11.22	10.92

Diet I H corrected to 61.9 H + 8.9 T and the rest is CM.
Diet I B corrected to 29.5 B + 31.1 T and the rest is CM.
Diet II B corrected to 65.0 B + 3.1 T and the rest is CM.

Table 11 Early lactation diets

Concentrate mixture composition

	CM with tibn	CM with hay	CM with berseem
Corn	21.45	28.30	37.33
Bran	←	33	→
Fat	5.03	6.13	4.61
SBM	36.68	30.68	24.03
LS	3.17	1.04	---
Salt	0.67	0.85	1.03
Premix	+	+	+
Roughage %, diet and CM requirements			
Roughage	30.6	45.83	55
Times tibn		1.5	1.8
Diet NEL	1.67	1.67	1.67
Diet, CP	19	19	19
CM, NEL	1.965	2.042	2.0
CM,CP	25.61	23.40	20.83
Basal CM, NEL	1.78	1.804	1.821
Basal, CP	10.94	11.13	11.22

Table 12 Dry cow and bull diets

	Concentrate mixture composition					
	CM with tibn		**CM with hay**		**CM with berseem**	
	Dry	Bull	Dry	Bull	Dry	Bull
Corn	32.12	34.38	66	---	---	---
Bran	33	33	33	---	---	---
Fat	---	---	---	---	---	---
SBM	31.09	29.20	---	---	---	---
LS	3.23	2.63	---	---	---	---
Salt	0.56	0.79	1.0	---	---	---
Premix	+	+	+	---	---	---
	Roughage %, diet and CM requirements					
Roughage %	53.95	67.1	79.73	100	87.5+12.5T	62.5+37.5T
Times tibn			1.48	1.49	----	-----
Diet NEL	1.35	1.25	1.35	1.23	1.35	1.25
Diet CP	12.96	10	13.26	13.8	15.81	12.44
Diet Ca	0.52	0.3	0.98	1.25	1.59	1.14
CM, NEL	1.76	1.77	1.822	---	---	---
CM, CP	23.46	22.24	---	---	---	---
Basal CP	11.02	10.98	11.22	---	---	---

Diet "dry" H- no need for correction.
Diet "dry" B corrected to 61.9 B + 27.3 T+ 10.8 corn.
Diet "bull" H corrected to 54.4 H + 34.7 T+ 10.9 corn.
Diet "bull" B corrected to 40.5 B + 50.2 T+ 9.3 corn.

Table 13 Growing diets (NRC-3 phase system)

Concentrate mixture composition	CM with tibn			CM with hay			CM with berseem		
	I	II	III	I	II	III	I	II	III
Corn	63.76	63.79	65.23	71.96	75.46	89.15	88.67	87.08	89.0
Bran	←	10	→	←	10	→	←	10	→
Fat	---	---	---	---	---	---	---	---	---
SBM	23.95	24.15	22.70	17.3	14.07	---	10.85	2.28	---
LS	1.95	1.69	1.58	0.35	---	---	---	---	---
Salt	0.34	0.37	0.49	0.39	0.47	0.85	0.48	0.64	3.83(1.0)
Premix	+	+	+	+	+	+	+	+	+
Roughage and CM %, diet and CM requirements									
Roughage	23.8	30.6	47.6	35	45	70	46.7	60	93.3
Times tibn				←	1.47	→	←	1.96	→
CM	76.2	69.4	52.4	65	55	30	53.3	40	6.7
Diet NEG	1.08	0.98	0.82						
Diet NEM	1.70	1.58	1.40						
Diet CP	16	15	12	16	15	12.76 (real)	16	15	17.02 (real)
CM, NEG	1.35	1.35	1.35						
CM, CP	19.75	19.85	19.27	17.18	15.98	7.80	14.69	11.25	10.30
Basal CP	10.17	10.19	10.19	10.33	10.35	10.32	10.35	10.34	10.30

Diet III H corrected to H 60.9 + 6.2 T and the rest is CM. CP increment can be left.
Diet III B corrected to B 48.1 + 23.0 T and the rest is CM.

Table 14 Growing diets (ad libitum - 3phase system)

Concentrate mixture composition	CM with tibn			CM with hay			CM with berseem		
	I	II	III	I	II	III	I	II	III
Corn	64.89	66.53	65.23	81.45	86.55	89.15	89	89	89
Bran	←	10	→	←	10	→	←	10	→
Fat	---	---	---	---	---	---	---	---	---
SBM	22.40	21.38	22.70	8.05	2.7	---	---	---	---
LS	2.31	1.67	1.58	---	---	---	---	---	---
Salt	0.4	0.42	0.49	0.54	0.63	0.85	1.0	1.0	1.0
Premix	+	+	+	+	+	+	+	+	+
Roughage %, diet and CM requirements									
Roughage	35.7	40.1	47.6	52.5	59	70	70	78.7	93.3
Times tibn				←	1.47	→	←	1.96	→
CM	64.3	59.9	52.4	47.5	41	30	30	21.3	6.7
Diet NEG	0.94	0.90	0.82						
Diet NEM	1.55	1.49	1.40						
Diet CP	13.68	12.83	12	13.68	12.83	12.76	15.34	15.96	17.02
CM, NEG	1.35	1.35	1.35						
CM, CP	19.07	18.74	19.27	13.57	11.43	10.3	10.3	10.3	10.3
Basal CP	10.13	10.16	10.19	10.35	10.33	10.3	10.3	10.3	10.3

Diet III H corrected to 60.9 H + 6.2 T and the rest is CM. CP increment can be left.
Diet I B corrected to 55.2 B + 7.6 T and the rest is CM.
Diet II B corrected to 50.5 B + 14.4 T and the rest is CM.
Diet III B corrected to 48.1 B + 23.0 T and the rest is CM.

Table 15 Fattening diets

Concentrate mixture composition in the three phases									
	CM with tibn			**CM with hay**			**CM with berseem**		
	I	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
Corn	64.38	73.13	79.13	70.13	81.63	87.38	77.88	87.88	89.5
Bran		← 10 →			← 10 →			← 10 →	
Fat	---	---	---	---	---	---	---	---	---
SBM	22.87	14.62	9.12	18.62	7.62	2.12	11.62	1.62	---
LS	2.25	1.75	1.25	0.75	0.25	---	---	---	---
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Premix	+	+	+	+	+	+	+	+	+
Characteristics in the three levels of fattening A, B, C									
Roughage	20A,	25B,	30C	29.87A,	36.36B,	44.16C	39.66A,	48.30B,	58.60C
Times tibn				1.49	1.45	1.47	1.98	1.93	1.95
CM	80A,	75B,	70C	70.13A,	63.64B,	55.84C	60.34A,	51.70B,	41.40C
Diet NEG	1.12A,	1.07B,	1.01C						
Diet NEL	1.69	1.65	1.60						
CM, NEG	1.35	1.35	1.35						
CM, NEL	1.86	1.86	1.86						
Basal CM, CP	10.3	10.3	10.3						

Note:- The figures are approximated and mostly are the maximum. Roughage% differs according to the fattening level and CM, CP and SBM and diet CP according to phase of fattening. - For the dietary and CM, CP in the three diets, in each of the three levels of fattening, refer to page 37table 3.

I- Feeding of Beef Cattle

Contents

Feeding of Beef Cattle

Beef cattle are treated the same as dairy with the consideration of milk production.

Feeding Stocker (Feeder) Cattle

In USA, animals, both steers and heifers that are intended for eventual finishing and slaughtering, are called stockers, calves or yearlings. They are being fed and cared for in such manner that growth rather than finishing will be realized. They are generally younger and thinner than feeder cattle. Stocker cattle and stocker cattle programs have changed with the passing of time. Until the early 1900s, stockers involved growing purchased or homegrown calves or yearlings on grass and hay until they were 3 or 4 years of age. As calf weaning weights increased and finished slaughter weights decreased, the amount of time and gain required to grow calve from weaning until the beginning of the finishing period was substantially shortened. The stocker cattle industry became a calf yearling industry, usually starting with 150 to 250 kg calves and ending with a yearling sold to a feeder at 275 to 325 kg or less.

Feeders are calves and yearlings, carrying more weight and /or finish than stockers, which are ready to be placed on high- energy rations for finishing and slaughtering

The development of large feedlots and year- round feeding increased the demand for feeders ready to go on high-concentrate nations. The roughage is used more efficiently in growing cattle, whereas it is usually an expensive item to use in large feedlots.

Today, the stocker stage is changing again, as a result of tow forces working in opposite directions, with one force favoring lengthening of the stocker stage and the other favoring shortening it.

1. Scarce and high-priced grains favor more roughage feeding and less grain feeding , resulting in carrying stockers to older ages and heavier weights, followed by a shorter feedlot period
2. Heavier milking cows and heavier weaning weights, coupled with high- priced land, favor shortening the stocker stage, or even eliminating it, as 275 kg, or heavier, weaning weights are achieved. Heavy –weaned calves will likely go directly into the feedlot or for slaughter. Calves with light to average weaning weights will likely be carried as stockers to 320 to 365 kg weights, thereby shortening the feedlot period and lessening grain feeding.

Back grounding is an old practice with a new emphasis and a new name. Actually, back grounding and the stocker stage are one and the same. Both refer to that period in the life of calf from weaning to around 350 kg weight, when it is ready to go on high- energy finishing ration. The term "stocker stage" connotes emphasis on marketing roughages through thin cattle, whereas "back grounding" connotes emphasis on growing out feeder calves ready to go on a high energy finishing ration. At its best, the animals should be in good health, and ready to go on full feed.

The dividing line between stockers and feeders is not always as clear-cut as the above definitions would indicate. That is not all thin cattle are suitable for stockers. For e.g., very large yearlings and most heifers (in USA) are usually sold as feeders, to be placed on high- energy feeds. Also, certain type of cattle (Okie) are usually back grounded for 50 to 60 days, then placed on a finishing ration, Okie-type cattle usually they are animals whose growth has been held back to less than their genetical potential.

Compensatory growth

Compensatory growth is increased growth rate in one time period as a result of growth restriction imposed during an earlier time period.

It is common practice in USA for stocker cattle to be “roughed through “the winter as cheaply as possible with limited daily gains. Then, in the spring, the animal is turned to lush spring pasture or put in a feedlot on a high-energy ration. Animals so managed exhibit the phenomenon of “compensatory growth” that is, on the high- energy diet they gain faster and more efficiently than similar cattle which were fed more liberally during the wintering period. Large compensatory growth usually indicates that the stocker operator has lost money, while the feeder has made money. It is noteworthy that Holsteins and the larger exotics should never be handled so as to exhibit compensatory gains. If they are held back in the winter, they are too heavy when they finish.

Feeding Finishing (Fattening) Cattle

The finishing of cattle is what the name implies, the laying on of fat. Additionally, there is an increase in the total muscle (red meat) mass. The requirements of the consumer is accomplished through an improvement in the flavor, tenderness, and quality of the lean beef which results from marbling

In a general way, there are 2 methods of finishing cattle for market: (1) cattle feedlots, including confinement finishing, and (2) pasture finishing.

The major nutritional requirements of finishing cattle are energy, protein, minerals, vitamins, and water. The greatest need is for energy. Of course, net profit depends on how much of that energy can be converted to pounds of gain – and how efficiently.

About 80 % of the cost of finishing cattle, exclusive of the purchase price of the feeders, is feedstuffs – grain, hay, silage, and miscellaneous wastes and by-products.

Kinds of cattle to feed

The cattle selected for a particular feedlot should match the operator’s available feed, labor, shelter, and credit. Also, it is imperative that there be a suitable market outlet following finishing. For example, it would be unwise to feed lightweight heifers in an area where the strongest slaughter market is for heavy steers. The general guides that follow will be helpful in determining what kind of cattle to feed in a given lot.

Age and weight of cattle

Today, cattle are referred to by ages as calves, yearlings, and 2-year olds. This shift to younger cattle has been brought about primarily by the consumer demand for smaller and lighter cuts of meat and improved feeding and management practices.

The age of cattle to feed is one of the most important questions to be decided upon by every practical cattleman. **The following factors should be considered in reaching an intelligent decision on this poin**t.

- **Rate of gain** - when cattle are fed liberally from the time they are calves, the daily gains will reach their maximum the first year and decline with each succeeding year thereafter. On the other hand when in comparable condition, thin but healthy two- year – old steers will make more rapid gains in the feedlot than yearlings, likewise yearlings will make more rapid gains than calves. In average feedlot the gains are:

Calves	1 kg
Yearlings	1.23 kg
Two-year –olds	1.32 kg

- **Economy of gain**- Calves require less feed to produce 100 pounds of beef than do older cattle. This may be explained as follows:

1. The increase in body weight of older cattle is largely due to the deposition of high – energy fat, whereas the increase in body weight of young animals is due mostly to the growth of muscles, bones, and organs. Thus, the body of a calf at birth usually consists of more than 70 percent water, whereas the body of a fat 2-years –old steer will contain only 45 percent moisture. In the latter case, a considerable part of the water has been replaced by fat. Also, it was found experimentally that fattening of animals too young in age produces 79.4% protein, 17.1% fat and 3.5% ash; while fattening after weaning at the age of 8 mos. to 18 mo. produces 60.6% protein, 35.1% fat and 4.3% ash. Considering that 1 kg of meat contains about 760 g water and 1 kg of body fat contains 100 g water, the kg fat will contain about 6 times that of the same weight of meat in calories. So the addition of 1 kg body gain in young animal costs less than the addition of 1 kg on a mature one.
2. Calves consume a larger proportion of feed in proportion to their body weight than do older cattle.
3. Calves masticate and digest their feed more thoroughly than older cattle. Despite the fact that calves require less feed per 100 pounds gain – because of the high- energy value of fat - older cattle store as much energy in their bodies for each 100 pounds of TDN consumed as do younger animals. From the above the younger the cattle, the greater the feed efficiency.

	Feed/ L1b gain	TDN/ lb gain	Mcal/ lb gain
Calves	8.0	6.0	9.86
Yearlings	8.3	6.2	10.19
Two – year-olds and over	8.5	6.4	10.52

Mcal ME was calculated by assuming 1.6434 Mcal ME = 1 lb TDN

A more accurate of feed efficiency than pounds of feed per pounds of gain can be obtained through the use of energy conversion – the TDN or Mcal required to produce a pound of beef.

- **Length of feeding period –** Calves require a somewhat longer feeding period than older cattle to reach comparable finish. To reach choice condition, steer calves are usually full fed about 8 – 9 months; yearlings, 5 to 6 months; and 2 – year – olds only about 4 months. The longer finishing period of calves is due to the fact that they (1) make smaller daily gains, and (2) are growing as well as finishing.
- **Total gain required to finish** – In terms of initial weight, calves practically double their weight in the feedlot (gain about 250 kg). On the average, yearling increase in weight about 200 kg, and 2-year-olds increase their initial feedlot weight about 150 kg.
- **Total feed consumed** – Because of their smaller size, the daily feed consumption of calves is considerably less than for older cattle. However, as calves must be fed for a longer feeding period, the total feed requirement for the entire finishing period is approximately the same for cattle of different ages.

- **Kind of quality of feed** – Because calves are growing, it is necessary that they have more protein in the ration. Since protein supplements are higher in price than carbonaceous feeds, the younger the cattle, the more expensive the ration. Also because of smaller digestive capacity, calves cannot utilize as much coarse roughage, pasture, or cheap by – product feeds as older cattle.

  Calves also are more likely to develop peculiar eating habits than older cattle. They may reject coarse, stemmy roughages or moldy or damaged feeds that would be eaten readily be older cattle. Calves also require more elaborate preparation of the ration and attention to other small details designed to increase their appetite.

- **Comparative costs and selling price** –Calves generally cost more per 100 pounds as feeders than do older cattle. Also, they generally sell for a higher price per hundred – weight as finished cattle.
- **Dressing percentage and quality of beef** – Older cattle have a slightly higher dressing percentage than calves or baby beef. Moreover, many consumers have a decided preference for the greater flavor of beef obtained from older animals.

From the above discussion, it should be obvious that there is no best age of cattle to feed under any and all conditions. Rather, each situation requires individual study and all factors must be weighted and balanced.

Feedlot Rations

Feedlot rations are usually cereal grains with supplementary protein and a minimum quantity of roughage. The roughage is provided to maintain the health of the rumen and to promote rumination. Because of the negative effect of high- concentrate diets on fiber digestibility, the forage component of high- concentrate diets makes little if any nutritional contribution. With no roughage in the diet, **parakeratosis** or erosion of the rumen wall occurs. The ratio of roughage to concentrate can be important. If the roughage component constitutes more than approximately 20% of the diet, the negative **associative effects** of concentrate on fiber digestion may reduce dietary DE.

When cattle are brought into a feedlot, they should be introduced gradually to the high concentrate diet to avoid lactic acidosis. Wheat is much more likely to induce acidosis than corn. Sorghum grain is less rapidly fermentable than corn, wheat, or barley.

For NEg needed for medium – frame steer calves as an example, it needs 2.5, 3.0, 3.5, 4, 4.5 and 5.5 times the daily gain (1.2 kg /day) starting with 150 kg body weight and ending with 400, values for every 50 kg increment (NRC,1984).

Feedlot Management

Because of their high – energy diet, feedlot cattle have several nutritional problems not usually encountered with beef cows. Feedlot cattle are susceptible to a number of grain overload disorders, including lactic acidosis, rumenities, feedlot bloat, laminitis, liver abscess, polioencephalomalacia, and enterotoxaemia. These disorders are all related to the rapid fermentation of soluble CHO.

Start cattle on a complete , self- fed diet formulated to meet NRC requirements in a " warm- up " or " step – up " program . They should be introduced gradually to a high-concentrate diet. They should begin on a diet of hay, with concentrate introduced in increments of 10% of the diet every 4 to 5 days, beginning with a 50%: 50% concentrate: roughage proportion and work up to a 90:10 ratio. The cattle can continue on the 90:10 diet for the remainder of the feeding period. The feeding of ionophores (e.g. monensin) during the adaptation period to high – concentrate diets can aid in preventing subclinical acidosis, which is characterized by reduction in rumen pH, feed intake , and animal performance. Diets with no supplementing roughage have been successfully used in some instances: an ionophore (to reduce acidosis) should be fed in this case. With no roughage, parakeratosis or erosion of the rumen wall occurs. This program is more successful with grains with a slower rate of rumen fermentation (corn, sorghum) than with a high rate of rumen fermentation (wheat).

Commonly animals are fattened at 1-1.5 years of age till the weight reaches 350 kg for Egyptian animals and 450 kg for foreign breeds

The animals fed balanced rations high in concentrates and low in fiber and at the rate of 2.5-3% of the body weight. Cattle calves are better to be fattened than buffalo calves as the latter are too vigorous and consume too much milk during the suckling period. This is in addition to its slow growth rate compared with that of cattle calves, and the production of meat of coarse fibers.

The animals, in Egypt, may be fattened at different ages as follows:

1. Fattening of suckling calves, as baby beef.
2. Feeding of young calves (6 to 12 mo.), to be used as feeders.
3. Fattening of calves at 8 – 10 or 12 mo. of age and for a year (growing and finishing)
4. Fattening of calves at 1.5 years of age
5. Fattening of mature animals

Fattening of suckling animals

Calves are fed on a plenty of whole milk, and producing good quality meat. This type of fattening is used with foreign breeds and rarely used with Egyptian breeds. In the first week the animal is fed on the colostrum not less than 3 times daily (25.4 % DM and 11.73 % CP in cows and 17.53 % in buffaloes). After the first week the calf is fed on whole milk 4 – 5 times a day decreases gradually to 3 times . Using this method Ghoneim got an increase of 0.94 – 1.12 kg daily in buffalo calves and each kg of gain needed 5.9 – 6.1 kg milk (the calves fed on 15 lb daily for 49 days).

Fattening of suckling calves can also be performed with a limited amount of whole milk and ad libitum feeding of skim milk. Concentrates should be fed as early as the calf can digest, to compensate the energy. The best concentrates are L.S.C, crushed barley, and fine bran. This mixture mixed in equal amounts) can be fed at the third week of age (ad lib).

Fattening using this method stops nearly at a weight of 80-100 kg as the efficiency of food conversion decreases after that and costs too much in comparison with the price of milk and the price of 1 kg.

Vitamin A can be added to the skim milk at the rate of 40-50 g/ calf daily (each gram contains 40 IU vitamin A). In addition mineral mixture and antibiotics can be added to guard against any digestive disturbance and improve the gain.

Fattening of mature animals

In these animals a kg of gain, in a bull, needs about 6.5 Mcal NEG (NRC, 1984) and is more expensive than in case of young animals. Fattening in this case just adds fat, slightly improves the condition of the animal and the quality of its meat so increasing its market price especially if compared with the price of the animal before fattening which is low as it is an animal which finished its production life or it is unprofitable to keep it in the farm.

The following is the fattening system recommended by the Ministry of Agriculture in Egypt since 2000.

Fattening of animals and rations used

(Inspired from Ministry of Agriculture Leaflet 539/ 2000)

Age Class	Weight kg	Fattening Period	Gain	Efficiency of utilization	Feeding regime	Notes
Suckling (as a baby beef)		Stops at a weight of 80-100kg (will be costly)	0.94-1.12 Buffalo Calves	6 kg ration/kg gain	- Colostrum not less than 3 times daily - Whole milk 4-5 times decreased to 3 times - Concentrates fed as early as possible with skim milk (composed of equal parts of SBM, corn, and fine bran).	Rarely used in Egyptian breeds- skim milk can be used
6 mo. (as stockers)	100 kg or 150	6 months (to 200 – 250 kg – one year age)	0.6 kg (Finishing on berseem or berseem and concentrates)		**I.** 5 calves/feddan-22kg berseem/ day increasing about 10 kg/ 50 kg gain (tibn should be fed with) **II.** Morning 0.5 kg concentrates + 0.25 kg tibn - Noon 12 kg berseem (10 calves/ feddan) - Evening 0.5 kg concentrates +0.25 kg tibn. Every dry meal 0.5 kg conc. & 0.25 tibn increased/ 50 kg gain. **III.** Only concentrates – starting with 2.0 kg conc. and 1.0 kg tibn. 1.0 kg conc. and 0.5 kg tibn increased/ 50 kg gain.	Conditions: I. Plenty of berseem, II. less amount is available, III. or no berseem.

Age Class	Weight kg	Fattening Period	Gain	Efficiency of utilization	Feeding regime	Notes
8 – 12 mo. (growing then finishing)	150 – 180	11 months (400 kg – 2 years age)	0.65 – 0.75 kg (0.6 in 6 mo. berseem and 0.8 – 1.0 in 5 mo. dry ration)		I. Berseem: 30 – 35 kg to 50 – 55 kg/day in 6 mo. period (tibn should be fed with). II. Dry ration: 1.75-2.0 tibn and 5-6 kg conc. Ending with 2.5 tibn and 7.75 at 350 kg and reaching a weight of 400 kg	10 kg berseem equals about 1.5 kg derris or about 0.75 tibn and 0.75 high protein conc. mixture.
12 mo.	200	6 mo.	1.1kg (Finishing on dry ration)		First 2 mo: 4.5 kg conc. And 1.5 tibn (25%). Second 2 mo: 5.25 kg conc. And 1.75 tibn. Third 2 mo: 6.75 kg conc. And 2.25 tibn	
	225	5 mo.	1.15		The same rate of feeding mentioned.	
	250	4 mo.	1.25 kg		The same rate of feeding mentioned	
Mature	500	2 mo.	ca 1.0 kg		Dry ration containing about 40% tibn (for a gain of about 1 kg/d give 0.7 conc./ 50 kg body weight)	

- Amount of feeds in leaflet modified.

General Notes in Fattening

Fattening of animals depends firstly on finishing mature animals, dairy animals, or bulls culled. The animals are put to dry lot feeding where at the end of the fattening period the animal does not put except fatty tissue and small amount of protein. Recently fattening starts earlier because of the fact that as the more the animal is young the more meat it puts and the higher is the efficiency of food utilization.

The calves chosen to be fattened should have long deep body, wide ribs, thick legs, large square head, wide back bones and the animals appear healthy. The salesman may force the animals to drink a large amount of water to weigh, by putting large amount of salt in rations or using bottle to force the animal to drink. Others may long fast animals then feed them on green food to give the animals good looking.

Calves can be bought in several seasons, the first after the end of the berseem season at the end of May, the second at the end of September the end of darawa season.

Fattening should be ended when the animal starts to form fat and increased more than a certain degree. Fattening at this time will be too costly and uneconomic. Generally fattening should end economically at 350 kg for cattle calves and 450 kg for buffalo calves. Gain in weight in young calves is composed of 79 % protein , 17 % fat , and in calves of medium age is 61 % protein, 35 % fat, and in full- grown calves 9 % protein and 91% fat . The cost of fattening increases in old animals because of the following:

1. Decrease food utilization efficiency
2. Increase in maintenance ration
3. Water in gains decreases and so protein decreases and fat increases as the animal gets more older because of that fattening should start at the age of 1 year old and weight of about 180 – 200 kg. At this age rapid gains and at the same time feeding can be on roughage cheap in price. As for dentition milky teeth appear in about 4 weeks, permanent centrals after 1.5 -2 years, medials 2 – 2.5 y, laterals 3 – 3.5 y, and corners 3.5 - 4 y. Wearing of teeth , color change , distance between teeth , breakage and dropping of some teeth should be considered.

   Refer to “feeding of dairy cattle “chapter on “ration formulation” for fattening diet examples.

III- Feeding of Sheep and Goats

Contents

Introduction

Sheep and goats share a number of nutritional similarities and are often discussed together as "small ruminants". They are very important in developing countries because of their small size, feeding behavior, and low water requirements.

Sheep and goats are intermediate feeders (share feeding and digestive strategies of both the concentrate selectors and grazers) and thus are more selective in their feeding habits than are cattle and more likely to consume browse. Sheep more than any other class of farm animals are dependent on natural pastures for maintenance and production. Most of the information on nutrient requirements for beef cattle applies as well to the small ruminants.

Sheep and goat production systems include large flocks and herds on the extensive range areas or small flocks and herd that utilize intensive grazing of improved pastures. They are also used to control unwanted vegetation. They arc raised to produce meat, milk, and/or fiber (wool, mohair, and cashmere).

Sheep and goats are merely a tool for harvesting and marketing the forage. The cost of dry feeding may exceed 5 times the green one. The ewes are kept on pasture or hay or silage for most of the year, Supplemental feeds are provided only in periods of nutritional stress (primarily before and after lambing – 4 weeks before and 6 – 8 after). With farm flock, the lambs are usually fed on the farm until market weight is reached. Range lambs are often marketed as feeders (lightweight lambs), which are fattened on concentrates in feedlots or on irrigated pastures and crop residues.

Because their browsing ability allows them to select more nutritious diet, sheep and goats may perform better on "rough" pasture than cattle. However, this should not be construed to mean that they have lower nutrient requirements and can survive on poorer quality food. The opposite is true. These smaller ruminants have higher nutrient requirements and require higher quality feed than cattle, especially when fed mixed or selected feeds which reduce their ability to select the nutritious components. Mature beef cows can be maintained on poorer quality hay than can ewes or goats.

Sheep feeding

- ***Nutrient requirements***

When using NRC (1985) tables, one should be aware of the following:

- Variation among sheep affects the utilization of and the need for nutrients.
- Competition among sheep of different sizes, ages, and breeds may significantly affect the daily intake of individual sheep (excess intake by more aggressive sheep and an inadequate intake by less – aggressive ones).
- DMI is an important consideration in formulating rations. Severely restricted intake results in a 5 -to 10 - fold increase in salt and mineral intake when minerals are offered free-choice, wool picking of self or penmates.
- Feeds excessively high in fiber or water may restrict nutrient intake. This is particularly a problem during: late gestation in twin – and triplet – bearing ewes, early weaned lambs, finishing lambs fed for maximum gains.
- Performance level expected may differ from levels in tables.
- Previous nutritional status may influence requirements.
- Failure to account for wasted food may result in gross underfeeding.
- Except for maintenance and early gestation diets, the amounts of DM indicated are near maximum without resulting in refusal. If higher levels or rates of

production are sought via increased nutrient intake, an increase in the concentration of nutrients in the ration rather than an increase in the amount of feed is necessary.

- Gut fill complicates requirement definitions – 6% of live weight in milk – fed lambs to 30 – 35% in forage fed lambs- higher on forage diets and lower on very high concentrate diets.

The following are informations about the needs of the different classes of sheep from energy, protein, minerals and vitamins from which the daily requirements are estimated. Using the daily DM consumption in the different classes diet characteristics could be identified.

I. Energy

- ME, instead of DE and TDN has important advantages for ruminants.
- Loss of gross energy as methane varies with the type of the diet (high concentrate versus low concentrate) and ranges from 3 – 10%.
- Energy in urine is rather constant 3 – 5% (factors are dietary protein, diet roughage levels, and essential oil content).
- One gram of TDN equals 4.407 kcal DE, 3.594 kcal ME(82%of DE) and 2.022 kcal NE(56% of ME) (from goat's requirements table). This can be considered for hay of average quality.
- Heat increment may be useful in maintaining body temperature. It ranges from 10 to 90% of ME.
- NE for maintenance includes the NE for basal metabolism that relates to muscle activity, tissue repair and replacement, and involuntary metabolic processes such as maintenance of ionic gradients. Also included as NEm is the minimal voluntary activity necessary to sustain life.
- The energy needed to satisfy voluntary activity needs sometimes called activity increment, varies widely depending on the availability of feed, water, and shade. During hot and cold weather, the animal uses ME to cool or heat its body, the energy needed for this is also a part of NEm**.**
- NE is the most refined expression of the value of energy in a feedstuff.
- NE in excess of NEm is NEg, NEl, NEy (reproductive processes, or NE preg) and NEv (production of wool and hair). Efficiency of ME use in these functions differ, milk is the most efficient. Ovine and bovine partial efficiencies of ME use for maintenance and gain can be interchanged.
- Pelleting changes the relationship between NE and ME, particularly when predicting NEg.
- The critical periods for energy needs are the last 4 – 6 weeks of gestation and the first 6 – 8 weeks of lactation. Energy is also a critical nutrient for young, rapidly growing lambs.
- Quite often energy shortages are accompanied by deficiencies of other nutrients (protein, minerals, and vitamins).

Signs of deficiency and Toxicity

- An energy deficiency will manifest itself in a variety of ways depending on its severity.

- In growing animals – reduced rate of gain (an early sign), which progresses to cessation of growth, weight loss, and ultimately death.

- In reproductive females – the early signs are reduced conception rate, reduced reproductive rate (reduced number of multiple births), reduced milk production, with progressively worse deficiencies causing reproductive failure, cessation or lack of initiation of lactation- impaired milk production capability, reduced mothering instinct, and lower birth weights leading to reduced viability in lambs – and death.
- In males –initial reduction and eventual cessation in reproductive activity and performance and finally death.
- In wool - the energy required represents a small fraction of the total energy consumed, but with restriction of energy, wool growth slows, fibers diameter is reduced, total production of wool decreases. In severe cases wool growth ceases creating a "break" (weak spot) in the staple of wool.
- Immune system – lowered resistance to disease and increased susceptibility to parasite infestation.

• In consuming more NE than required, excesses stored as adipose and are valuable reserve until obesity ensues. Signs of NE toxicity are:

- Gross excesses in adipose deposits.
- Ultimately a reduction in reproductive performance in both males and females.
- In pregnant obese females, toxicity manifests itself shortly prior to parturition as ketosis (refer to "pregnancy disease").
- Excessive energy intake may lead to fattening with resultant birth difficulties in single – bearing ewes.

Note that low energy intakes or excessive fattening may result in pregnancy toxemia in the ewe.

Needs

- **Maintenance** need is 56 kcal NEm/ $kg^{0.75}$ and 101.4 kcal ME/ $kg^{0.75}$ (the same NEm& ME for goats).
- **Growth**: NEg ($kcalxd^{-1}$) = 276 $LWGXW^{0.75}$ for medium mature ram weight (115-Kg) genotypes. For every 10 kg mature weight less than 115 kg, the energy requirement increases by 21 kcal X LWG X $W^{0.75}$, or 7.6%. For each 10 kg over 115 kg, a like amount would be subtracted. Rams deposit less energy than ewes of the same genotype at equal live weights. These limited data suggest that caloric densities of energy i gains in rams can be estimated at 0.82 times those for ewes. Castrated males may also have somewhat lower requirements than females, however differences are not well established and no adjustment is recommended at this time.

  Example (NRC)

  A lamb of 30 kg body weight, of medium mature weight, and gaining 200 g daily requires a net energy of: 276 x 0.200 x 12.82 = 708.22 kcal, NEg/d

  So the amount of energy needed depends on the rate of body gain, body weight, and the genotype.

- Separate requirements are presented in NRC tables, for replacement ewes and rams. Ram lambs have the potential to grow at a faster rate, especially after they reach 40 to 50 kg body weight. Mature size for the breed will influence energy requirements. Smaller breeds tend to grow more slowly.
- Ram lambs have a higher feed intake, and use food more efficiently for body weight gain. Gains of intact male are higher in water and protein and lower in fat than in females. Producers breeding ewe lambs should give sufficient additional

feed, during gestation, to meet pregnancy requirements and weight gains of 0.12 (in early gestation) to 0.16 (in late gestation) kg daily. During lactation these ewes still require additional feed to ensure adequate milk production and continued growth, providing 1 kg grain in addition to a full feed of forage.

- **Pregnancy:** a ewe carrying one fetus need 70, 145 & 260 kcal/ day NEpreg at the stages of gestation 100, 120 & 140 days respectively. Ewes carrying 2&3 fetuses need about 177 & 233% of that carrying one, in respective order.

Total feed requirements of pregnant sheep can be obtained by summing the various diet amounts needed to meet each NE requirement (e.g., feed for NEm+ feed for NEg+ feed for NEy for a pregnant ewe lamb or NEm and NEy for pregnant adult ewe). Weight change is + 10 g in maintenance, + 30g in nonlactating – first 15 weeks gestation, + 180 in last 4 weeks of gestation – 130 – 150% expected lambing rate, and +225 in 180-225%expected lambing rate. Fetal growth and pregnancy requirements are substantial in the last 6 weeks of pregnancy and average approximately 0.6 X maintenance DM for single-bearing ewes and 0.7 X maintenance DM for twin-bearing ewes. While total feed energy requirements are 1.7 and 2.0 X maintenance energy for these physiological phases, which needs the ME/ DM to be concentrated to 2.1 Mcal and 2.3 Mcal/ kg DM respectively instead of 2.0 in maintenance.

Note that in NRC tables, in the first 15 to 17 weeks of gestation, no allowance has been made for flushing the ewe to increase lamb production. In early pregnancy fetal growth is very small. The requirements given are intended to provide for maintenance, wool growth, and a small daily gain. The total feed requirement is not significantly different from maintenance. During the last 4 to 6 weeks of gestation, ewes need more energy to meet needs for fetal growth and the development of the potential for high milk production (mammary gland development).

- **Lactation:** sheep have a relatively short lactation period (from 12 to 20 weeks), and the actual quantity and composition of milk produced by animals suckling young are difficult to determine. It has been estimated that 65 to 83 (62 is commonly used) percent of ME is converted to milk energy during 12 weeks of lactation. Higher values were obtained for ewes suckling twins than for ewes with single lambs. The average of these values is slightly above that calculated for dairy cattle. One kg ewe's milk contains 1.1 Mcal and needs (÷0.62) 1.77 Mcal ME, while goat's milk contains 0.781 Mcal and needs 1.25.

In NRC tables the requirement for lactation are estimated for four groups of ewes, suckling singles – first 6 – 8 wk and last 4 – 6 wk, and those suckling twins – first 6 – 8 and last 4 – 6.

A ewe nursing twin lambs produces 25 to 50 percent more milk than a ewe nursing one lamb, the higher yield is probably due to higher frequency of suckling. Within the genetic capability of the ewe, milk production responds to nutrient intake of the ewe and demand for milk by the lamb or lambs.

Requirements for the last 4 – 6 weeks of lactation are based on the assumption that milk production during that period is approximately 30 to 40 percent of the production during the first 8 weeks. McDonald (1973) mentioned that it has been calculated that about 38% of the total yield is obtained in the first four weeks of lactation, 30% in the succeeding four weeks, 21% in the next four weeks and 11% in the final four weeks.

II. Protein

- The rumen develops some degree of functionality by 2 wks of age, primarily as a result of the consumption of dry feed.
- During early rumen development, creep feed should be provided to supplement milk or milk replacer.
- By 6 to 8 wks of age, the functioning rumen has developed into a culture system for anaerobic bacteria, protozoa, and fungi.
- In early gestation a ewe deposits 2.95 g daily and for the last 4 wks 16.75 g (for ewes carrying twins the figures increased proportionally).
- A ewe produces 1.74 kg milk when nursing singles and 2.6 kg when nursing twins. Each kg contains 47.875 g CP, in McDonald (1973) it is mentioned that sheep milk contains 6.1% CP and needs 90 g DP with an efficiency of 0.68.
- Sheep milk needs 126.8 g CP with digestibility of about 71% (goats 3.45% CP and needs 52 DP and 72 CP).
- Ewe lambs produces 75% as much milk as mature ewes.
- In wool 6.8 g CP for ewes and rams per day, assuming an annual 4 kg grease fleece weight.
- Requirement is expressed in CP as in dairy and beef cattle.
- Urea in rations should not exceed 1% or one third of the total dietary protein N (should not be used in young lambs or creep feeder diets), and adaptation takes 2 – 3 weeks. Special emphasis should be given to the supplementation of K, P and S which are absent in urea, especially S as wool contains a high percentage. S can be added at 0.1% to complete diets or by including S in a free – choice loose mineral or block offered to grazing animals.
- Urea should be introduced into the diet gradually to allow for adaptation by rumen microbes, and should be thoroughly mixed to prevent high levels of intake.
- Biuret, triuret, and complexes of urea with formaldehyde or molasses – they have slower ammonia release, and reduce the threat of ammonia toxicity and/ or improve the utilization of ruminal ammonia.
- Deficiency of protein reduces feed intake, and increased feed intake after protein supplementation is a good practical indication that protein was deficient.
- Large excesses of protein can be fed without producing acute toxicity.
- Excesses of NPN or highly soluble protein may produce ammonia toxicity. Affected animals may display nervousness, incoordination, labored breathing, bloating, severe tetany, respiratory collapse, and ultimately death.
- Oilseeds can be used as a source of protein and have the added advantage of providing fat, which increases the energy content of the diet. However, high levels of fat can have a negative effect on fiber digestion in sheep.
- Lambs younger than 8 weeks should not be given access to cottonseeds, and CSMs should be used with caution. All the gossypol in CSM exists in both bound and free forms. Mature sheep can detoxify free gossypol, but young lambs without functional rumens are susceptible to gossypol poisoning and should not be fed CS or CSM until they have been consuming dry feed for several weeks and are 8 to 12 weeks old, but caution should still be used in feeding direct solvent CSM or CS.
- Mature sheep can be fed CSM regardless of the processing method, but CS should probably be restricted to 0.5% of live wt., particularly if fed for extended periods.

III. Minerals

- Salt, the most common form of **Na** and **Cl**, is inexpensive and highly palatable and is usually provided free choice to sheep and goats. Providing it in loose form is preferred over blocks because sheep and goats tend to bite the block (wearing or damaging teeth) rather than licking the block.
- Salt may safely be used to limit free – choice supplement intake if adequate water is available - such mixtures are usually 10 – 50% depending on the desired amount of ration to be consumed. Trace – mineralized salt should not be used for this purpose because of the possibility of excessive intake of various trace minerals, particularly toxic levels of copper.
- In many areas (commonly arid), feed and water may contain enough salt to meet the animals requirements, and supplemental salt need not be offered.
- **Potassium** is generally high in most forages and is seldom deficient in the diet. Supplementation may be needed when animals are on high –grain diets or are grazing mature or drought-stressed pastures. Increased levels (up to 2% K) may also be appropriate when sheep and goats are stressed by transport and placed on new concentrate-based diets.

- Deficiency in either or a Ca: P ratio of less than 1.2:1may cause reduced growth and other possible metabolic problems. Lactating animals have a higher requirement for **Ca** and **P** than nonlactating animals and milk production becomes limited if either Ca or P is deficient. Sheep and goats efficiently reuse P by recycling P through the saliva. In some cases sheep recycle more P per day through the parotid salivary gland than is required in the diet. Calcium and P utilization are influenced by hormones and vitamin D.

- **Sulfur** is an important mineral because it functions in the synthesis of methionine and cysteine (S-containing amino acids). Methionine and cysteine are important for live weight growth but also for wool and hair growth. Methionine is usually the most limiting amino acid for fiber production. Most feeds contain adequate S but some mature hays or drought-stressed pastures may be deficient. A ratio of dietary N to S should be 10:1for both sheep and goats. This becomes particularly important when NPN is being fed because the rumen microbes need a source of S and N available at the same time in order to synthesize methionine and cysteine.

- **Magnesium** deficiency is most commonly associated with sheep and goats grazing lush, fast growing pastures in the spring, when the grass is high in N and K and low in Mg. If blood levels of Mg are low, the animal may suffer from grass tetany. The animal may fall to the ground, froth at the mouth, and rigidly extend and relax the legs. Untreated animals can die. Prevention by feeding adequate levels of Mg is best, but animals can be treated by intravenous administration of Ca and Mg in the gluconate form.

- Of the microminerals, **Cu** and **Se** have the narrowest range between what is required and what is potentially toxic. Sheep are more sensitive than goats to high levels of Cu. Copper is relatively cheap and is added at fairly high levels to beef, dairy, horse, and swine feeds. Feeding sheep these feeds over time can result in Cu toxicity and death; therefore, feeds and minerals formulated for any of these species should be checked for Cu level (needs to be <25 ppm) before they are fed to sheep.

- There is also a relationship between Cu and Mo. In sheep or goats, if a feed has a normal or low level of Cu with a high level Mo, then a Cu deficiency may occur. Adding Mo to the diet of sheep also can be effective in reducing the toxicity of Cu.

- **Selenium** is regulated by the Food and Drug Administration because of potential toxicity. Deficiency in Se results in white muscle disease (stiff lamb disease) in sheep or goats and can also reduce reproductive efficiency. To meet requirements, Se can be purchased as part of the mineral mix or as part of complete feeds. Selenium toxicity can occur if plants high in Se are consumed over a prolonged period. Selenium-accumulating plants are a problem in some range areas.

- **Iron** a major component of hemoglobin, is generally adequate in most feeds and deficiency symptoms are rare in healthy animals; however, blood loss caused by internal parasites can cause anemia. Anemia can also develop in young lambs and kids because of low body stores of Fe and low Fe content of milk. Iron can be given intramuscularly to improve Fe status but management or regular treatment to reduce internal parasites will reduce the chances of iron deficiencies developing in sheep and goats.

- **Iodine** is generally adequate in most feeds. Deficiency is generally exhibited in the newborn by an enlarged thyroid gland clearly visible on the neck (goiter). Some severely deficient lambs are stillborn without any wool. Iodized salt is the most common supplement.

- **Zinc** is not widely stored in the body so the diet should have a continuous supply. Deficiencies are rare but can result in reduced fertility, stiffness of joints, reduced weight gain, and parakeratosis.

- **Manganese** is required by both sheep and goats but precise levels have not been established. Most forages have > 50 ppm Mn and most grains have from 15 to 40 ppm Mn, so deficiencies are rare. Deficiency signs include difficulty in walking, skeletal abnormalities, and reduced reproductive efficiency.
- **Cobalt** is needed by the microbes in the rumen to synthesize vitamin B_{12} but is usually adequate in most feedstuffs.

- In general in ration formulation only **Ca**, **P** & **Na** are considered while the others are supplied in a **premix**. Refer to tables for its dietary percentages, in NRC.

IV. Vitamins

Sheep and goats require dietary sources of fat-soluble vitamins (A, D, and E) but adequate quantities of water soluble vitamins are usually produced by the rumen microbes. Grazing animals generally obtain sufficient vitamin or vitamin precursor to meet requirements but confinement fed or high-producing dairy animals may have to be supplemented.

Vitamin A does not occur in forages but ample amounts of carotene are contained in green vegetation. Carotene is converted to vitamin A. Approximately 1 mg of carotene is equivalent to 400 IU of vitamin A in sheep and goats. Vitamin A and carotene are stored in the body to meet requirements for 3 to 6 months after removal from pasture. Vitamin A can be supplemented to the diet or injected or feeds high in natural sources can be fed (i.e.,green grass or legume hay).

Vitamin D is contained in green forages, and sun-cured hays. Animals exposed to sunlight should obtain sufficient vitamin D to meet requirements; however, animals in confinement, ones with heavy fleeces, or dark pigmented animals may need supplementation. Vitamin D can be fed or injected to prevent deficiencies.

Vitamin E is a biological antioxidant. It is important in its role with Se to prevent white muscle disease (stiff lamb disease) and aids in increasing shelf life of milk. It is not stored in the body in large quantities and is often included in the supplement for fast-growing lambs and kids and for dairy sheep and goats.

Vitamin K is contained in green leafy forages and can also be synthesized by the rumen microbes. Deficiency is not generally seen.

The **water-soluble vitamins** (vitamin B complex) are not stored in the body for very long but are synthesized by the rumen microbes. **Vitamin C** is synthesized by the animals' tissues in sufficient quantities to meet requirements.

Polioencephalomalacia (PEM) is a disorder in sheep in which thiamin (a B vitamin) is destroyed. Treatment with injections of thiamin reverses the symptoms. Under normal conditions, there is not a dietary requirement for water-soluble vitamins. Young milk-fed animals receive sufficient vitamins from the milk.

V- Water

Adequate water is essential for sheep to excrete excess substances such as oxalates, ammonia, and Mg ammonium phosphates that otherwise would cause urinary calculi.

Contamination resulting from industrial activities can be a problem, and in farming areas there are concerns with pesticide, herbicide, and nitrate contaminations of waters. The following are some facts about sheep and water needs:

- Voluntary consumption is 2 – 3 times the DM, and may reach 10 times in late pregnancy with twins, and lactating ewes (first month) and does, and in elevated ambient temperatures. The intake also increases with high-protein and salt-containing feeds. The animal should drink several times and amounts not limited, water should always behind the animal.
- Sheep denied water for more than 24 h ate little or no dry feed (feed 15% CP), and no effect when fed 2% protein hay.
- Sheep may consume 12 times more water in summer than in winter.
- A lack of water accompanied by severe depression in feed intake predisposes ewes to pregnancy toxemia.
- Needs are affected by body metabolism, ambient temperature, stage of production, wool covering, feed intake and composition.
- Heater should be used in winter months. Nutritional needs increase in case of cold water as it needs energy to rise its temperature to body temperature.

- Excessive water in some feeds can adversely affect performance because of limitation of DM intake.
- Nonpregnant, nonlactating sheep may go for weeks without drinking water when consuming feeds of high moisture content.
- In extreme cases the amounts of salt (NaCl) and sulfates contained in water may be sufficient to adversely affect animal performance**.**

Management considerations

I- Ewes

- Mature sheep in reasonable condition can survive a 30% loss in body weight over a 6 month period. Ewe can probably survive on about 60% of the NRC (1985) recommended levels for dry mature ewes.
- Well-grown ewe lamb will usually come in heat at 6 to 9 mo. of age, most prefer to postpone breeding for a year, so that the ewes will have their first lambs when about 2 years old. The breeding season in Egypt is in May and June and lambing at the berseem season.
- When ewes are being bred to lamb more frequently than once a year, lambs are early weaned, and the ewe may not have adequate time to recover body condition. The usual procedure is to breed the ewe to lamb once a year. With this schedule the ewe has a period of 3 to 4 months (dry period) to recover weight lost during lactation (weaning is at 8 weeks). The schedule will be 16 wk dry period, and 4 wk flushing.
- The critical periods during the reproduction cycle are from 2 to 3 weeks prior to breeding to 3 to 4 weeks after breeding and again during the last 4 to 6 weeks of gestation.
- In one time per year lambing, the ewe will be bred during a period of weight gain (flushing) and then will receive slightly over maintenance requirements for the first 3 to 3.5 mo. of gestation. NRC suggests increasing feed intake about 50% over maintenance during the period from 2 week before breeding to the first 3 weeks of breeding. It is recommended that animals be kept at a near maintenance level of feeding in the first month of pregnancy.
- Approximately two thirds of fetal growth occurs in the ewe during ***the last 6-8 weeks of gestation***. For the last third of pregnancy the rapidly increasing size of the fetus and decreased rumen volume necessitate that the nutrient density of the diet be increased. At lambing weight loss is dramatic and nutrient demand is very high because of the onset of lactation.
- ***During lactation*** a gradual decrease in body weight is expected (needs higher than intake - mobilization of body stores).
- ***At weaning*** the demand for milk is reduced resulting in reduction of needs and drying. If the ewe is a dairy breed, the offspring are usually removed 4 to 10 days after birth and dam is milked until production decreases or approximately one month before breeding.
- Generally after weaning, the ewe replenishes body reserves and gains weight before breeding. Such dramatic weight changes are normal but ewes need to be properly fed to avoid metabolic disorders and producing healthy fast-growing lambs.

Flushing

Flushing is the practice of improving the nutrient intake or nutrient utilization to increase body weight and/or condition before breeding, thereby improving the ovulation rate. This can be done by moving ewes to a better pasture, treating with an anthelmintic to reduce internal parasite burden, or feeding supplements.

The period of flushing usually starts 3 to 4 weeks before breeding and continues 1-3 week into the breeding season. Results of flushing are greatest when breeding occurs outside of the normal peak in breeding season (when ovulation rates are already at a high). The key to flushing is to have the ewes gaining weight and/or condition score. Ewes beginning flushing with condition scores of 2.5 or less will have the largest response and generally exhibit increased conception rate, ovulation rate, and therefore higher lambing percentages.

Gestation (length 145 – 147 days)

- The NRC (1985) lists requirements for the first 15 weeks of gestation (energy needs120% maintenance energy) and then higher requirements for the last 4 weeks (170 – 200%).
- Nutrient needs to insure survival of the embryo through implantation (about 40 d after fertilization) are higher than that of mid gestation and are probably closer to the requirements that are listed for flushing (energy170% maintenance & 15% concentrates with hay -NRC).
- Separate requirements are listed for ewe lambs that are bred to lamb at approximately 1 y of age -160% maintenance -15% concentrates with hay-NRC (still growing 50 kg-ewe lamb).
- From implantation until the last 4 to 6 wks of gestation the ewe is essentially fed for requirements that are only slightly above maintenance (120%). It is important to make sure that the ewe does not become fat because this can result in further complications at lambing.
- Two thirds of fetal growth occurs during the last 6 wks of gestation (requirements differ according to the lambing rate and also provide for increasing ewes condition for future milk production needs can be met).
- Inadequate nutrition during this most critical stage of gestation can result in ketosis, low birth weights, low survival rates, low milk production, and low growth rates of the lambs. It is interesting that the fetal growth that occurs during the last 4 weeks effectively reduces the capacity of the GIT right at the time of high nutrient demand. More energy and protein-dense feeding is required to meet this demand.
- Separating ewes that are in less than desired condition and ewes that most likely will have multiple births from ewes in good condition that are expected to have singles is helpful in the proper nutrition of each group.

Milk production

- Directly related to the genetic potential, nutrition and number of lambs suckling.
- Some breeds have been selected for milk production for human use or for cheese making.
- A ewe suckling twins produces 25 to 50% more milk than if she were suckling a single.

- Requirements are separated for the first 6-8 wks (raising singles or twins) and the last 4 to 6 wks (singles or twins).
- Peak milk yield is at about 3 to 4 weeks, and 75% of milk production will occur in 8 wks of lactation.
- It is better to feed ewes with twins separately from ewes with singles.
- Condition and weight loss during lactation is normal.
- In once a year lambing, the ewe has time to regain wt. after weaning and before rebreeding. In accelerated lambing production systems it is desirable to produce a lamb every 6 to 9 mo. and level of nutrition is critical to maintain higher production.

II- Breeding rams:

During most of the year, good roughage alone should be sufficient to keep the ram in proper condition. Pasture should be provided in winter, if possible. In summer, he should be fed legume or mixed hay, and perhaps silage in addition.

For a month before the breeding season, the ram should be given about a pound a day of the same sort of concentrate mixture that is fed for the ewes. It is also a good plan to continue the feeding of the concentrate allowance during the breeding season. The ram should not be allowed to run down seriously at breeding time through insufficient feed or over use. On the other hand, he should never become fat.

A well-built, vigorous purebred ram of good breeding should be selected for the flock, and then be so fed and cared for that he will remain potent. A vigorous ram will serve 40-50 ewes a season, if allowed to run with them all the time during the breeding season, as in the common practice. Where"hand coupling" is practiced or if the ram is turned with the ewes only a short time daily, more ewes can be bred to one ram. A ram is sexually mature at 7 months but used at 1.5 year of age.

III- Feeding lambs

A- Suckling lambs

- Firstly lambs should consume at least 50 to 100 ml of colostrum per one kg of lamb weight (from the mother ewe, another ewe, or colostrum from ewes, or cows can be frozen and later thawing and bottle or stomach tube feeding).
- The lambs rely solely on milk from their mothers for the first 3 to 4 weeks.
- Lambs will begin to nibble at high quality feeds at 3 to 4 weeks of age so providing high-quality hay, water, and concentrate is desirable to ensure that lambs adapt to dry feed.
- During the suckling period of 4 to 5 months; well-fed lambs will make about 2/3 of the growth and the gain in weight that they will make during the entire first year.
- Until pasture is ready, early weaned lambs should be fed both grain and hay in a "creep" beginning when they are about 2- 4 wk old.
- Fresh feed should be put in once or twice a day, and the refuse can be fed to the ewes.
- Good pasture should be provided for ewes and lambs as early as possible.
- The change to pasture should be gradual, the flock being turned on pasture for only 2-4 h at first. Letting them fill up on hay before being turned out to pasture the first time, helps to prevent digestive disturbances.

Creep feeds

To supplement the ewe's milk and to shift the diet of lambs to dry feed, a creep feeder is often set up. A creep feeder is an area where lambs have access to feed without competition from the ewes.

Creep feeders are usually set up at about 10-14 d of age and expected consumption should average 200 to 250 g/d from age 20 days through weaning. Creep rations need to be palatable, contain at least 15% CP and may contain antibiotics.

An example composed of 51.5% corn, 20% hay and 22% SBM, and most creep diets contain 5% molasses, 0.5% trace mineral salt (sheep) and $CaCO_3$ 1%. If the mixture does not contain hay (85%, corn, 13% SBM) the $CaCO_3$ will be 1.5%. Ammonium chloride can be added at the rate of 0.2-0.5%. Vitamin A added at 1200 IU/Kg and vitamin E at 22 IU/Kg.

Initially, lambs prefer ground creep rations and after 4 or 5 wk of age show a preference to pelleted and after 5-6 wk should be fed unground grains.

Early weaning

Lactating ewes normally reach their peak in milk production around 3 to 4 wk postpartum and produce 75% of their total milk yield during the first 8 weeks of lactation. After 6-8 weeks, milk production declines markedly and high nutrient intake fails to stimulate production**.** Early weaning refers to the practice of weaning lambs at 6 to 8 weeks of age.

There is considerable interest in early weaning as it allows:

1- possible early marketing of lambs,
2- out-of-season lambing,
3- multiple lamb crops per year, and
4- use of prolific breeds.

Also it enables higher and more efficient gains while the lambs are young and also reduces ewe cost as it can be maintained on a limited feed allowance for longer periods of time between parturitions.

Lambs to be early weaned should receive creep feed at 7 to 14 d of age. The post-weaning ration should be high in concentrate with a minimum of 16% CP, 0.6% Ca, and 0.3% P.

An example of post-weaning, concentrate diet is composed of corn,59.15%; SBM 25%; hay, 8%; molasses, 5%; dicalcium phosphate 0.4; LS, 1.45%; salt, 0.8%; trace minerals, 0.2%; vitamins (4 million IU vitamin A, 340,000 IU D, 4000 IU E per ton).

Artificial feeding

The practice of removing lambs from their dams, when they are 8 to 24 h old, and rearing them on milk replacer for 3 to 4 weeks, is referred to as artificial feeding. This becomes necessary with orphaned lambs and in cases where the ewe refuses to claim her lambs or is providing an inadequate supply of milk.

Lambs should be allowed to obtain their mother's colostrum within the first 12 to 24 h of life (for a minimum of 8 h at least 50 ml/ kg body weight before being weaned). They should be given 180 to 240 ml of colostrums from another ewe or from a cow. Frozen ewe colostrum is preferred than frozen cow colostrum. It is easier to train a newborn lamb to nurse a nipple than one that has nursed its dam for a period of days.

Lamb milk replacers are recommended to contain 25 to 30% fat and 20 to 25% milk protein on a dry matter basis. Calf high quality milk replacer that contains at least 20% fat and 20% protein can be used (more economical). Cow's milk can be used alone or blended with lamb milk replacer. Gains with whole cow's milk or calf milk replacers are about 90% of those fed high quality lamb milk replacer.

During the first 1 to 2 days, lambs are fed warm milk replacer, subsequently, they can be provided with cool milk on an ad libitum basis. Each lamb consumes 0.9 to 1.4 L of liquid milk replacer per day. Weight gains should approximate 0.25 to 0.30 kg per lamb daily during the period that milk replacer is fed. Lamb weight at 30 days should be about 11.4 to 14 kg. In addition to the milk replacer, clean fresh water should be provided free choice and a palatable creep feed should be started after the first week, to accustom them and minimize weight losses during the transition from a liquid to a solid fed diet at around 3 to 4 weeks. Liquid milk replacer can be discontinued after 4 to 5 weeks and the lambs weaned onto a creep ration. During this period, good quality hay should be provided in limited quantities.

During a 3 to 4 week artificial rearing program, a lamb will consume an average of 400 to 500 g of dry milk replacer per day, (1 replacer with 4 – 5 parts water).The postweaning diet should be high in energy and should contain 18- 20% protein (as-fed basis) for the first 3 wk and then 14-17% thereafter.

Good quality hay should be provided free choice to reduce post-weaning suckling of other lambs, which may cause mortality of male lambs due to urinary tract damage. Lambs should be vaccinated for prevention of enterotoxaemia (overeating or pulpy kidney disease).

B-Growing lambs

Replacement lambs are intended for breeding and, therefore, maximum weight gain and finish is of secondary importance. Finishing lambs are expected to gain weight rapidly and attain the desired finish. In addition, requirements are separate for lambs with moderate as compared to rapid growth potential (in diet nutrient concentration table, in NRC, the two were not separated, so the same diet can be fed).

Lambs can be grown and finished on high quality pasture, on pasture plus supplementation, or in dry lot feeding systems. The type of system used will depend on desired marketing time (faster gains can be made in a dry lot), type of lamb to be sold (lean versus more fat cover), available feed resources, and economics. Lambs usually are placed on grain diets in dry lot for the last 30 to 40 days before marketing.

Dry lot feeding systems usually involve two to three diet changes through the finishing period. Lambs are usually adjusted from pasture - based feeding to concentrates by feeding ground hay (30-50%) mixed with grains (50-60%), molasses (10%; to improve palatability and reduce dust), and possibly an antibiotic premix (1%).

The most common feed lot diets are based on corn and SBM, with molasses and mineral mix and added ammonium sulfate to reduce problems associated with urinary calculi.

Some choose one diet and keep feeding it throughout the feeding period until market. This reduces problems associated with changing diets but will underfeed lambs when they are light and overfeed lambs when they are heavy.

With high grain feeding, all lambs should be vaccinated to prevent enterotoxaemia (overeating disease).

Replacement ewes

Replacement ewes are usually identified at 3 to 4 months of age and removed from the market lambs that are being finished for market. They should not get fat because this can reduce milk production potential. Most producers strive to have replacement ewes lamb at 1 year of age (ewe can be bred at 7 mo. of age).

In ewe lamb breeding the respective ME is increased by 0.1 and CP% by 1.0 (with a maximum of 15) than that in ewes. In ewe lambs there is neither maintenance complete diet, nor a flushing one.

Replacement rams

Should be grown on pasture and supplemented as necessary to obtain 150 - 200 g/day growth. In NRC (1985) the gain in weight reaches 250-330 g starting with 40 kg and ending with 100kg. Once mature, pasture alone will usually meet maintenance requirements.

Nutrition - related metabolic disorders

There are several nutritional and metabolic diseases that affect sheep and goats. Most of these can be prevented or avoided by proper feeding and nutrition.

- **Enterotoxaemia (overeating or pulpy kidney disease)**

Like sheep, goats are susceptible to clostridium perfringens (type C or D) enterotoxaemia. In sheep it afflicts suckling lambs, creep-fed lambs, growing-finishing lambs and ewes fed high levels of grain. It occurs after sudden changes in feeds with access to readily fermentable feeds, and under conditions of calcium insufficiency and acidosis. The disease is a toxic reaction to type C and D, against which antitoxins and vaccination programs with toxoid or bacterins are effective. Under conditions of high CHO, the causative bacteria multiply rapidly and produce a toxin.

Symptoms

Diarrhea, depression, lack of coordination, digestive upsets, coma, and death.

Prevention

Large meals given once a day should be avoided. Changes of concentrates and forages in the ration should be introduced gradually over several days, especially when the protein or E content of the diet is increased.

- **White muscle disease (Refer to minerals)**

It is a nutritional muscular dystrophy. It is a disease of young suckling lambs and kids at 1-5 weeks old. Goats are more susceptible than sheep. For prevention provide adequate Se and vitamin E in the diet or through injection.

- **Pregnancy disease**

It is also known as ketosis, acetonemia, pregnancy toxemia, twin - lamb disease or lambing paralysis. It is somewhat similar to ketosis in cows except that it affects the ewe or doe before parturition.

It is a metabolic disorder defined by increased levels of ketone bodies in blood, milk and urine, and is associated with elevated blood nonesterified FAs.

It occurs at the very end of gestation and is associated with the high demand, by the fetus or fetuses, for CHO (especially glucose or glucose precursors). It usually occurs only in ewes that are underfed during pregnancy, especially during the last month or two and particularly with over fat condition among ewes.

During the trimester of pregnancy, ewes are quite susceptible to ketosis which may result in the disease.

Clinical features

Individuals affected will exhibit labored breathing, lack of energy, staggering, and impaired vision. The breath and urine will often smell sweet.

Prevention

Feeding adequate CHO during late gestation is best, but if detected early, solutions of CHOs can be administered early. Propylene glycol or corn syrup can be drenched two to five times per day till dam recovers.

- **Urinary calculi**

The disease is known as urolithiasis or water belly. It occurs in sheep and goats under range and feedlot conditions. It occurs in all breeds and sexes but blockage of the flow of urine generally only occurs in intact or castrated male sheep. The blockage may rupture the bladder resulting in a condition called "Water belly", and cause death. Goats are known to be susceptible, and serious losses can occur when valuable breeding males are placed on calculogenic rations.

Causes

Nutritional imbalances are generally considered the primary cause but infection is a predisposing factor. Affected animals excrete alkaline urine that has a high P content. Dietary intakes of Ca, P, Mg and K appear to play a major role in the incidence of calculosis in the feedlot lambs.

Prevention

- Feeding NaCl at 4% level increases consumption of water and urine produced.
- K should be maintained, in the dry lot, at an adequate level.
- Ca to P ratio should be maintained at 1.5:1 or greater.
- Use of ammonium chloride as an additive to acidify the urine.

- **Milk fever**

It is not observed frequently in goats as in cows and the treatments are similar.

Poisonous plants and natural toxins

Sheep and goats and other small herbivores tend to be more resistant to poisonous plants than cattle and other grazing animals. Thus both sheep and goats are used in biological control of numerous poisonous plants, including leafy spurge, senecio species, and larkspur.

Sheep and goats are also more tolerant of toxins that affect palatability, so sheep and goats are often used for control of brush and chaparral not consumed by cattle.

Table 1 Nutrient concentration in diets for sheep (expressed on 100 percent DM basis- NRC, 1985)

Body weight (kg)	Weight change/day (g)	Energy[a] TDN[b] (%)	DE (Mcal/kg)	ME (Mcal/kg)	Concentrate (%)	Forage protein (%)	Crude Ca (%)	P (%)	activity (%)	Vitamin A activity (IU/kg)	Vitamin E (IU/kg)
Ewes[d]											
Maintenance											
70	10	55	2.4	2.0	0	100	9.4	0.20	0.20	2,742	15
Flushing - 2 Weeks prebreeding and first 3 weeks of breeding											
70	100	59	2.6	2.1	15	85	9.1	0.32	0.18	1,828	15
Nonlactating - First 15 weeks gestation											
70	30	55	2.4	2.0	0	100	9.3	0.25	0.20	2,350	15
Las 4 weeks gestation (130-150% lambing rate expected) or last 4-6 weeks lactation suckling singles[e]											
70	180 (0.45)	59	2.6	2.1	15	85	10.7	0.35	0.23	3,306	15
Last 4 weeks gestation (180-225% lambing rate expected)											
70	225	65	2.9	2.3	35	65	11.3	0.40	0.24	3,132	15
First 6-8 weeks lactation suckling singles or last 4-6 weeks lactation suckling twins[e]											
70	-25 (90)	65	2.9	2.4	35	65	13.4	0.32	0.26	2,380	15
First 6-8 weeks lactation suckling twins											
70	-60	65	2.9	2.4	35	65	15.0	0.39	0.29	2,500	15
Ewe Lambs											
Nonlactating - First 15 weeks gestation											
55	135	59	2.6	2.1	15	85	10.6	0.35	0.22	1,668	15
Last 4 weeks gestation (100-120% lambing rate expected)											
55	160	63	2.8	2.3	30	70	11.8	0.39	0.22	2,833	15
Last 4 weeks gestation (130-175% lambing rate expected)											
55	225	66	2.9	2.4	40	60	12.8	0.48	0.25	2,833	15
First 6-8 weeks lactation suckling singles (wean by 8 weeks)											
55	-50	66	2.9	2.4	40	60	13.1	0.30	0.22	2,125	15
First 6-8 weeks lactation suckling twins (wean by 8 weeks)											
55	-100	69	3.0	2.5	50	50	13.7	0.37	0.26	2,292	15
Replacement Ewe Lambs[f]											
30	227	65	2.9	2.4	35	65	12.8	0.53	0.22	1,175	15
40	182	65	2.9	2.4	35	65	10.2	0.42	0.18	1,343	15
50-70	115	59	2.6	2.1	15	85	9.1	0.31	0.17	1,567	15
Replacement Ram Lambs[f]											
40	330	63	2.8	2.3	30	70	13.5	0.43	0.21	1,175	15
60	320	63	2.8	2.3	30	70	11.0	0.35	0.18	1,659	15
80-100	270	63	2.8	2.3	30	70	9.6	0.30	0.16	1,979	15
Lambs Finishing - 4 to 7 Months Old[g]											
30	295	72	3.2	2.5	60	40	14.7	0.51	0.24	1,085	15
40	275	76	3.3	2.7	75	25	11.6	0.42	0.21	1,175	15
50	205	77	3.4	2.8	80	20	10.0	0.35	0.19	1,469	15
Early Weaned Lambs - Moderate and Rapid Growth Potential[h]											
10	250	80	3.5	2.9	90	10	26.2	0.82	0.38	940	20
20	300	78	3.4	2.8	85	15	16.9	0.54	0.24	940	20
30	325	78	3.3	2.7	85	15	15.1	0.51	0.24	1,085	15
40-60	400	78	3.3	2.7	85	15	14.5	0.55	0.28	1,253	15

Note: Hay contains 2 Mcal ME/kg DM and concentrate mixture differs, according to the sheep class, from 2.67 to 3.14 ME/kg DM. In "Sheep diet formulation" part the energy density of the CM is fixed at 3 Mcal ME/kg DM with a fixed composition. Molasses or fat can be used in addition to ammonium chloride or sulfate and other supplements or additives.
ME, CM and hay percentages are corrected due to the "daily nutrient requirements for lambs" table of the same NRC.

Sheep diet formulation

Contents

Sheep diet formulation

I-Diet composition

I. Diets are composed of roughage and concentrate mixture.

- The ME for the different ration components is 2.5 Mcal/ kg DM for berseem, 2 for hay, 1.5 for tibn and 3 for concentrate mixture (approximately). ME of corn is 3.15; SBM,3.18 and bran 2.57.
- For the chemical composition and energy density of feeds refer to "ration formulation" chapter in dairy cattle.
- The concentrate mixture is composed of 6 ingredients, corn, bran, SBM, LS, salt and premix- except in fattening we add KCl and Am Cl. Bran in sheep CMs is fixed at 10 %. CM contains no fat except in certain conditions. Basal concentrate mixture contains about 10 % CP with T and 10.3 with H or B.
- Using the DM % of body weight and proportions of roughage and CM, the amounts needed by the animal can be determined (DM ÷ 0.9 = fresh, DM of berseem ÷ 0.15 = fresh).

II-Diet kinds

There are many (22) kinds of diets should be formulated in a sheep farm; having different ME densities.

a- Breeding sheep diets ME, Mcal/ kg DM

- Maintenance (M) 2.0
- Flushing (Fl) 2.1
- First 15 wk or early gestation (FG or EG) 2.0
- Last 4 wk gestation (singles) (LGS) 2.1
- Last 4 wk gestation (twins) (LGT) 2.3

b- Lactation diets

- Singles
  First 6 – 8 wks lactation (FLS) 2.4
  Last 4 – 6 wks lactation (LLS) 2.1 as Fl& LGS in ME and LGS in ME & CP
- Twins
  First 6 – 8 wks lactation (FLT) 2.4
  Last 4 – 6 wks lactation (LLT) 2.4 as FLS in ME and CP

c- Growing lamb diets (for 6.5 mo. to over 70 in ewes and 100 in rams)

Phase	Ewe lambs		Phase	Ram lambs	
	Wt. kg	ME, Mcal/kg DM		Wt. kg	ME, Mcal/kg DM
I	30	2.4	I	40	2.3
II	40	″	II	60	″
III	50 – 70	2.1	III	80 – 100	″

d- Finishing lambs, 4 – 7 mo. old (for 4.0 mo. to over 50 kg)

Phase	Wt. kg	ME, Mcal/kg DM
I	30	2.62
II	40	2.75
III	50	″

e- **Early weaned lambs – moderate and rapid growth (M & R) potentials (feeding for about 5.0 mo. to over 60 kg)**

Phase	wt. kg	ME, Mcal/kg DM
I	10	2.9
II	20	2.8
III	30	2.7
IV	40-60	″

III- Diet requirements

The NRC <u>dietary</u> ME, CP%, Ca and P (diet requirements) can be approximated as follows:

Table 1 Sheep ration requirements

a- Breeding and lactation diets

Class	ME (unified)	ME	CP% (unified)	CP%	Ca% (unified)	Ca%	P% (unified)	P%
M		2.0		9.4	0.25	0.20		0.2
FG		≈		9.3		0.25		≈
Fl	2.1	2.1	9.5	9.4		0.32	0.25	0.18
LGS		≈		10.7		0.35		0.23
LLS		≈		≈		≈		≈
LGT		2.3	11.5	11.3	0.40	0.40		0.24
FLS, LLT	2.4	2.4		13.4 (13.5)		0.32	0.30	0.26
FLT		≈		15		0.39		0.29

ME, CP, Ca and P can be unified in the figures on the left of the brackets.

b- Growing diets

Replacement ewe lambs

	ME	NEG	CP%	Ca%	P% (unified)	P%
I	2.4	0.9	12.8 (13)	0.53 (0.55)		0.22
II	″	0.9	10.2 (10)	0.42 (0.45)	0.25	0.18
III	2.1	0.67	9.1 (9)	0.31 (0.35)		0.17

CP, Ca, and P% are descending with age. In parentheses are the round approximated figures. NEG figures are estimated to allow comparison with calves.

Replacement ram lambs

I	2.3	0.81	13.5 (14)	0.43 (0.45)		0.21
II	″	0.81	11 (11)	0.35	0.20	0.18
III	″	0.81	9.6 (10)	0.30		0.16

The maximum CP%, Ca% and P% in each phase could be used for ewe lambs and ram lambs altogether. CP, Ca and P are descending.

Finishing lambs

	ME	**NEG**	**CP%**	**Ca%**	**P%**	
I	2.62	1.06	14.7 (15)	0.51(0.55)		0.24
II	2.75	1.16	11.6 (12)	0.42(0.45)	0.25	0.21
III	″	1.16	10.0	0.35		0.19

CP, Ca and P% are descending.

Early weaned lambs

I	2.9	26	26.2		0.82	0.40	0.38
II	2.8	17	16.9		0.54		0.24
III	2.7	15	15.1	0.55	0.51	0.30	″
IV	″		14.5		0.55		0.28

CP, Ca and P% are high in phase I, CP in phase II and then the rest of the phases are nearly equal, 15% CP, 0.55% Ca and 0.3% P.

IV-Roughage and concentrate proportion

The proportion of the roughage can be estimated using the "square" method on ME-basis.

The concentrate mixture is suggested to contain 10% bran and about 3% mineral supplement with tibn (of which 0.5% salt), and only 1% salt with hay or berseem (except when feeding a large proportion of CM as in fattening). It will contain 3.0 ME with T and 3.06 with hay or berseem or on the average 3.0.Mcal/kg DM. T is of 1.5, H 2.0, and B 2.5 Mcal, ME/ kg DM.

Roughage and concentrate proportions

●T diets

CM 3 — Diet ME 2 — 0.5
T $\frac{1.5}{1.5}$ — 1.0
∴33.33% CM
66.67% T

CM 3 — Diet ME 2.1 — 0.6
T $\frac{1.5}{1.5}$ — 0.9
∴40% CM
60% T

∴0.1 unit ME over 2 ≡ 6.67 units T replaced by CM with a base of 33.33 CM at 2 ME.

CM 3   0.1   ∴ 10% CM

● H diets   2.1   90% H

H 2   0.9

1.0

∴0.1 unit ME over 2 ≡ 10 units hay replaced by CM.

B 2.5   0.5   B 2.5   0.6

● B diets   2   ∴B 50%   2.1   ∴ B 60%

(From 2 to 2.4 ME) T 1.5   0.5   T 50%   T 1.5   T 40%

1.0   1.0

∴0.1 unit ME over 2≡ 10 units T replaced by berseem (ME 2.0 = 50T&50B)

B 2.5   0.4

● B diets   ∴B 80 %

(From 2.6 to 2.9 ME)   2.6   CM 20 %

CM 3.0   0.1

0.5

∴0.1 unit ME over 2.5 ≡ 20 units B replaced by CM

•Diets are mixtures of roughage (T, H or B) and CM. The proportion of tibn is 66.67 for ME 2 and 6.67 T is replaced by CM for every 0.1 ME increase.

•Hay ME is 2.0 and 10hay are replaced by 10 CM for every 0.1 ME. Berseem ME is 2.5 and for a diet of ME 2.0, it is composed of 50% B, DM and 50% T and for every 0.1 ME replaces 10 T by 10 B, DM. For ME more than 2.5 replace 20 B by 20 CM for every 0.1 ME increase.

•**Substitutions of H and B and correction of CM:**

100H ≡66.67T + 33.33CM 10% CP   (H=1.5 times T)

Replace 19.5 SBM and 3.57LS by corn

(H contains 13.8% CP and 1.25% Ca)

100 B (DM) ≡ 33.33 T +66.67 CM 10% CP   (B=3 times T)

Replace 23.75 SBM and 5.2 LS by corn

(B, DM contains 17.5% CP and 1.82% Ca)

•Formulation should be started with T diets and substitution done if needed. In this case there will be no need to correct the dietary CP if the substitution is made on CM, SBM- basis. The amount of SBM found in the concentrate mixture divided by 19.5 (for hay) or 23.75 (for berseem) gives the amount of H or B replaced, and gives a diet with no extra protein. The equivalency of H or B to T (1.5 &3) for maximum replacement should be considered. Also tibn, hay, or berseem diets can be mixed according to the roughage available making tibn / hay or tibn / berseem diets. The last suggestion is the one nominated to be used.

V-Dry matter intake

Dry matter intake could be displayed in the following table.

Table 2 Dry matter intake percentage of body weight

Breeding (50 – 90 kg ewes)

M	**1st 15**	**Fl, LGS, LLS**	**LGT**
2 – 1.5	2.4 – 1.8	3.2 – 2.2	3.4 – 2.3

Lactation

FLS, LLT	FLT
4.2 – 3.0	4.8 – 3.6

Growing

	I	**II**	**III**	**IV**	**V**	
Ewe lambs	4.0	3.5	3	2.5	2.1	- 0.48/10kg
Ram lambs	4.5	4.0	3.5	3.0		- 0.50/20kg

Finishing

I	**II**	**III**	
4.3	4.0	3.2	-0.55/10kg

M & R

I	**II**	**III**	**IV**	**V**	**VI**	
5.5	5.5	4.5	3.8	3.2	2.8	- 0.54/10kg

Note:

- An animal of 90 kg consumes from 70 to 75% of that consumed by 50 kg animal on body weight – basis.
- The DMI can be related to maintenance.
- Some classes of nutritional stresses need the increase in DMI than maintenance as 1st 15 wk, the other need an increase in DMI in addition to an increase in ME density as in the rest of breeding and lactation classes having from 2.1 to 2.4 ME/ kg DM. To get the amount of fresh food intake the amount should be divided by 0.9 (and 0.15 in case of berseem).
- T as a roughage is poor in CP and in all T diets the CM is supplemented by SBM to potentiate its CP contents.

VI- Crude protein and soybean meal percentages in CMs fed with tibn and hay

Examples for CM, CP and SBM calculations:

- ME 2.0 has 9.4 and 9.3% CP

CM, CP = 4 of T (0.6667) – 9.4 ÷ 0.3333 = 20.20

Or = 4 of T (0.6667) – 9.3 ÷ 0.3333= 19.90

Basal CP = 10%

SBM needed = 20.20 or 19.90 – 10.0 ÷ 0.4 = 25.5 or 24.75

•ME 2.1 has 9.1, 10.7% CP in ewes.

CM, CP = 4 (0.60) – 9.1 or 10.7 ÷ 0.4 = 16.75 or 20.75

SBM needed = 16.88, 26.88

VII- Concentrate mixture composition

Table 3 Concentrate mixture composition in hay and tibn diets

a) Breeding and lactation – Ewes

Hay diets						Tibn diets			
ME group	**CP% needed**	**H%**	**CM CP%**	**SBM %**	**LS %**	**T%**	**CM CP%**	**SBM %**	**LS %**
2.0		100				66.67			
M	9.4		---		-		20.2	25.5	1.71
1st 15	9.3		---		-		19.9	24.75	2.14
2.1		90				60.00			
Fl	9.4		< 10		-		17.5	18.75	2.29
LGS	10.7		< 10		-		20.75	26.88	2.51
LLS	≈		< 10		-		≈	≈	2.23
2.3		70				46.66			
LGT	11.3		< 10		-		17.69	19.23	2.14
2.4		60				39.99			
FLS	13.4		12.8	6.25	-		19.64	24.10	1.51
LLT	≈		≈	≈	-		≈	≈	≈
FLT	15		16.8	16.25	-		22.30	30.75	1.86

b) Growing Lambs

ME group	**CP% needed**	**H%**	**CM CP%**	**SBM %**	**LS %**	**T%**	**CM CP%**	**SBM %**	**LS %**
Ewe lambs									
2.4 I	12.8	60	11.3	2.5	-	39.99	18.64	21.60	2.51
2.4 II	10.2	60	10.3	-	-	≈	14.32	10.80	2.0
2.1 III	9.1	90	≈	-	-	60.00	16.75	16.88	2.23

Ram lambs										
2.3 I	13.5	70	12.8	6.25	-		46.66	21.81	29.53	2.31
2.3 II	11.0	≈	10.3	-	-		≈	17.12	17.8	1.89
2.3 III	9.6	≈	≈	-	-		≈	14.50	11.25	1.60
Finishing lambs										
2.62 I	14.7	38	15.25	12.38	0.16		25.32	18.33	20.83	1.94
2.75 II	11.6	25	10.87	1.43	0.41		16.64	13.12	7.80	1.43
2.75III	10.0	≈	10.30	–	0.14		≈	11.20	3.00	1.20
Early weaning lambs										
2.9 I	26.2	10	27.58	43.20	2.21		6.64	27.78	44.45	2.51
2.8 II	16.9	20	17.68	18.45	1.04		13.31	18.88	22.2	1.77
2.7 III	15.1	30	15.66	13.40	0.55		19.98	17.87	19.68	1.83
2.7 IV	14.5	≈	14.80	11.25	0.70		≈	17.12	17.80	1.97

Note: CM basal CP % is 10.3 % in hay diets and 10% in tibn ones.

The balances of the concentrate mixtures are bran (10%), salt and corn-also do not forget the addition of premix, and other feed additives.

Concentrate mixtures fed with hay have no SBM except in lambs phase I, 6.5 in rams and 2.5 in ewes, finishing I1, 2.5 approximately. In lactation FLS, LLT 6.5 and FLT 17. In early weaned lamb diets, the CM has special descending levels 43.5, 18.5, 13.5 and 11.5 SBM. Salt is 1% in all diets except finishing and fattening it is 0.5%. No LS is needed except in finishing II and fattening.

Concentrate mixtures with tibn differ greatly in SBM levels, LS ranges from 1.25 to 2.5% and salt from 0.5 to 0.75%.

In B diets no SBM or LS are needed in the CM except in early weaning lambs where 46 & 16.25 SBM are needed in I&II and 1.63LS in I.

There is a commercial CM for sheep and goats TDN not < 65 (not < 2.3 Mcal, ME/kg DM), CP 15.56 and CF not > 16.67. Using this CM needs new formulations with T, H, and B- following the square method.

Table 4 SBM % in CMs fed with tibn (approximated)

	SBM % in CM			**Exceptions**	
Breeding and lactation	**25**			**FLT 30, Fl 17, LGT 20**	
Lambs	**Phase**				
Replacement		**I**	**II**	**III**	**IV**
♀	**Irregular**	**22**	**11**	**17**	
♂	**Descending**	**30**	**18**	**11**	

Finishing	**Steep descending**	**21**	**8**	**3**	
Early weaned	**Steep descending**	**45**	**22**	**20**	**18**

IIX-Thumb rules for feeding

Table 5 Thumb rules for feeding with T (figures approximated)

	CM, Kg	T (ad lib), Kg
Breeding & lactation (50 kg ewe)		
Maint.	0.39	0.72] 0.75
	] 0.5	
1st 15	0.47	0.87] 1.0
Fl	0.71	1.07
LGS	0.71] 0.75	1.07] 1.0
LLS	0.71	1.07
LGT	1.04] 1.0	0.85
FLS	1.4	0.93
	] 1.5	] 1.0
LLT	1.4	0.93
FLT	1.6] 1.67	1.07
❖According to the nutritional stress CM increases from 0.5 to 1.67 kg per animal while the T is fed ad libitum		
Growing lambs		
♀ I	0.8	0.53
		] 0.5
II	0.9] 0.8	0.60
III	0.7	1.05] 1.0
A ewe lamb needs 0.8 kg CM in all phases and T fed ad libitum.		
♂ I	1.06] 1.0	0.94] 1.0
II	1.24] 1.25	1. 10

III	1. 45	1.5	1.29	1.5
IV	1.72	1.75	1.53	
A ram lamb needs from 1 to 1.75 kg according to phase and body weight and T fed ad libitum				
Finishing lambs				
I	1.05	1.0	0.35	
II	1. 32	1.25	0.44	0.5
III	1.53	1.5	0.27	
CM is 1to 1.5 kg per animal according to phase, and 0.5 kg T.				
M & R				
I	0.57	0.6	0.04	0.05
II	1.09	1.0	0.17	0.25
III	1.20	1.25	0.30	
IV	1.35	1.33	0.34	
V	1.42	1.5	0.36	0.33
VI	1.55		0.39	
CM is 0.5 to 1.5 kg per animal according to phase, and 0.5 about 0.33 T in phases from II to VI.				

T is given ad libitum.

CM is 0.5 to 1.75 kg / animal, in breeding and lactation, according to stress, and 0.8 for growing ewe lamb. It is from 0.5-1.0 to 1.5-1.75 kg, according to phase or body weight, in growing rams, finishing, and early weaned lambs.

Table 6 Thumb rules for feeding with H

	CM, kg		H(ad lib.), kg	
Breeding & lactation (50 kg ewe)				
Maint.	-		1.15	1.25
1^{st} 15	-		1.35	1.33
Fl	0.175		1.575	
LGS	0.175	0.25	1.575	1.5
LLS	0.175		1.575	
LGT	0.57	0.5	1.33	
FLS	0.93	1.0	1.4	
LLT	0.93		1.4	1.5
FLT	1.10	1.25	1.65	

Growing lambs				
♀ I	0.53		0.8	1.0
II	0.6	0.6	0.9	
III	0.175	0.25	1.58	1.5
♂ I	0.6	0.75	1.4	
II	0.8		1.87	2.0
III	0.93	1.0	2.18	2.33
IV	1.0		2.33	
Finishing lambs				
I	0.93	1.0	0.47	
II	1.31	1.33	0.45	0.5
III	1.31		0.49	
M & R				
I	0.55	0.5	0.061	
II	0.97	1.0	0.25	
III	0.94		0.41	0.5
IV	To		to	
V	1.4	1.5	0.6	0.75
VI	↓		↓	

Table 7 Ration amount for sheep with T, H, or B as roughage - approximated

	T – diets - kg		H – diets – kg		B – diets – kg		
	T	**CM**	**H**	**CM**	**B**	**CM**	**T**
Breeding							
Maint.(M)	0.75	0.5	1.25	-	3.33	-	0.5
1st 15	1.0	≈	1.33	-	4.0	-	0.75
Fl	"	0.75	1.5	0.25	6.5	-	≈
LGS	≈	≈	≈	≈	≈	-	-
LLS	≈	≈	≈	≈	≈	-	-
LGT	"	1.0	≈	0.5	9.0	-	0.5
FLS	≈	1.5	≈	1.0	12.5	-	0.25
LLT	≈	≈	≈	≈	≈	-	≈
FLT	≈	1.67	≈	1.25	14.5	-	≈

Note: Amount is for a sheep of 50 kg body weight.

Growing lambs							
♀ **I**	0.5	0.8	1.0	0.6	7	-	0.25
II	≈	≈	≈	≈	8.5	-	≈

III	1.0	≈	1.5	0.25	6	-	0.75
♂ I	≈	1.0	≈	0.75	9.5	-	0.5
II	≈	1.25	2.0	≈	13	-	≈
III&IV	1.5	1.5-1.75	2.33	1.0	15-16	-	0.5-0.75

Note: Amounts are according to body weight at the start of each phase.

Finishing lambs							
♀ I	0.5	1.0	0.5	1.0	6.5	0.33	-
II	≈	1.25	≈	1.33	5.33	0.9	-
III	≈	1.50	≈	≈	≈	≈	-

M & R	T	CM	H	CM	B	CM	T
I	0.05	0.5	0.06	0.5	0.8	0.55	-
II	0.25	1.0	0.25	1.0	3.25	0.80	-
III	0.33	1.25	0.50	≈	5.75	0.75	-
IV	≈	1.33	to	To	6.0	≈	-
V	≈	1.5	0.75	1.5	≈	≈	-
VI	≈	≈	≈	≈	≈	≈	-

Note: With berseem CM is only fed with finishing and early weaned lambs. No SBM is added except in early weaned lambs I, II & III where the CM has 28.38, 16.5 and 11.5 % CP respectively.

IX- An example for feeding hay with a tibn diet:

A ewe of 50 kg body weight put twins and in the first lactation period allowed 1.5 kg hay DM and tibn ad libitum, formulate a hay / tibn diet calculating the SBM, LS, and salt in the new concentrate mixture.

Informations

- **The animal consumes 4.8 % of body weight DM diet daily.**
- **T diet contains 40% T and 60% CM. The CM contains 30.75% SBM, 1.86% LS, and 0.5% salt.**
- **H diet contains 60% H and 40% CM. The CM contains 6.25% SBM, no LS, and 1% salt.**

Answer I

The amount of H diet =1.5÷0.6=2.5
Percentage of H diet in relation to total DM = 2.5÷ 4.8 ×100=52.1%

∴Formulate hay and tibn diets and mix in the ratio of 1.08 : 1.0 (52÷ 48 = 1.08) or approximately in equal proportions.

Answer II

Percentage of hay in diet = 1.5÷4.8×100 = 31.25% (or 30 %)
H ≡ 0.6667 T + 0.3333 CM (10 % CP)
Replace 0.195 SBM and 0.052 LS by corn

∴ T removed is 20% and CM 10%.

∴ The composition of the diet will be 30 % H, 20 % T, and 50 % CM.

SBM, LS, and salt correction

In T, CM (60)			In CM removed (10)		In CM remained (50)	
SBM	18.54	(30.75%)	– 5.85	(0.195/1H)	= 12.6	(25.2%)
LS	1.12	(1.86%)	– 1.56	(0.052/1H)	=	---------
Salt	0.30	(0.5%)	–		= 0.30	(0.6%)

The rest of the CM composition is 10 % bran and the balance is corn in addition to the premix.

So the diet is composed of:

30 % hay

20 % tibn

50 % concentrate mixture composed of:

Corn 64.2%

Bran 10%

SBM 25.2%

LS -

Salt 0.6%

Premix +

V- Feeding of Poultry

Contents

Introduction

Diverse as they appear to be, species of poultry have much in common in the kinds of feedstuffs and in the manner in which feeds are digested and nutrients are absorbed and metabolized. The major types of poultry are chickens or fowls (layers and broilers) and turkeys. Other poultry, of much less economic importance, include waterfowl (ducks and geese), ostrich, pigeons, and quail.

Poultry nutrition is more critical than that of other farm animals as their digestion is rapid, respiration and circulation are faster, their body temperature is higher 8 to 10° F than four-footed animals, more active, more sensitive to environmental influences, grow at more rapid rate, mature at an earlier age, and egg production is an all or none phenomenon. Metabolically poultry are a well-developed “fast – living” animal.

NRC publishes bulletins giving nutrient requirements of birds on which the formulation of balanced diets depends. Genetic differences among bird strains affect requirements, where each strain has its own standards, as in broiler – type and egg – type strains of chicken. Requirements are presented on the basis of total concentrations in the diet or total consumed per day, and not given separately for each function or on a digestible basis.

Poultry diets are composed primarily of a mixture of several feedstuffs such as cereal grains, soybean meal, animal byproduct meals, fats, Ca-P - and Na supplements, and vitamin and mineral premixes. Diets also can include xanthophylls or other feed additives.

About 55 to 75% of the cost of production may be attributed to feed costs, with the production of egg towards the lower side of this range and the production of broilers and turkeys towards the upper side. Three fourths of this cost is being allotted to maintenance needs and the remainder for productive purposes. As a value for meat, the dressing percentage reaches 65 – 72% while it ranges between 45 and 55 in sheep and cattle.

The following is a functional knowledge of poultry anatomy and physiology before discussing the nutritional requirements.

I- Tissues

- Skin has low sensitivity to the degree that in the condition of cannibalism the weakling bird does not show any reaction to the others pecking at it.
- Feathers make about 20% of their growth in each of the 1st 3 weeks of age.
- Medullary bone provides readily available Ca (25% of Ca used in egg shell).
- Vitamin C is indicated in **“Cage layer fatigue”**

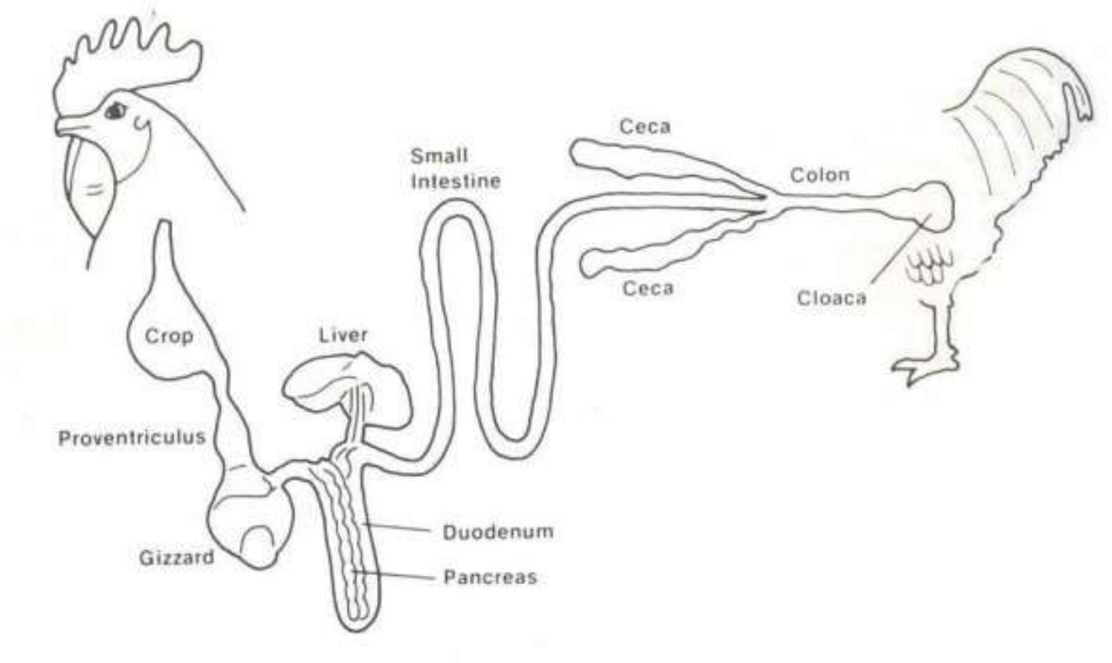
II- Systems

- Uric acid N forms 80% of the daily urinary N, and formation of uric acid needs glycine. Bird uses 1/10 only of the kidney size in normal conditions.
- Hearing is a well-developed sense. Birds do not have selective taste but prefer some colors. Smell is not highly developed.
- The intestine of chicken secretes enterokinase, which changes trypsinogen, secreted by the pancreas, to trypsin. Roasted or treated soya beans are an especially useful protein, but uncooked beans contain a trypsin inhibitor which effectively blocks the work of the pancreas in this particular respect.

Small intestine is a sensitive organ and its sensitive nature continues until the chick is 21 to 28 days of age. A hen can utilize high-Ca uptake, 2 to 4%, without bringing about a trace element deficiency (Mn or Zn), whereas a chick of 2 to 21 days of age fails to absorb or utilize Mn or Zn when over 1.6% Ca is fed.

There is a tremendous outpouring of nitrogenous material by the duodenum. Expressed as crude protein this would amount to about ten times the amount of ingested protein. This recycling phenomenon causes rapid AA depletion which is speeded up because each time the acids pass through liver, some are oxidized and deaminized. In scours reabsorption of endogenous protein may be severely impaired, leading to loss of flesh from the bird.

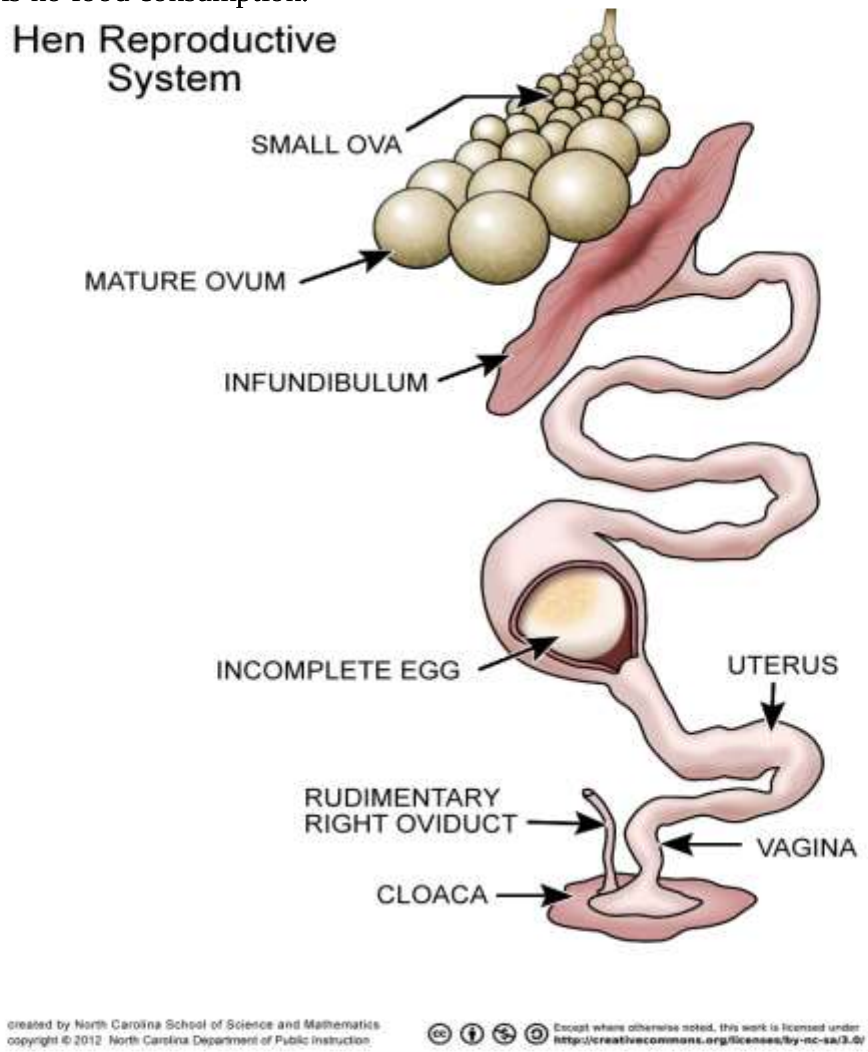
The size and strength of the gizzard are related to the hardness of the food particles and the presence of crushed insoluble stones (grit). When an all-mash diet is supplied the need for insoluble grit is less absolute. Feeding very finely ground food causes abnormal softening, thickening of the lining, hemorrhages and erosion. Coarse food and grit prevent this problem.



Digestive system of chicken (source: google.com)

- Reproductive system and egg production:
  a. The oviduct is divided into five regions, each of which plays a specific role in the completion of the whole egg, funnel or infundibulum, magnum, isthmus, uterus, and vagina.
  b. Magnum is the organ where albumen is secreted and uterus is the part in which the shell is secreted. The shell is formed from calcium carbonate.
  c. There is an enormous range in size among the eggs of the different species ranging from 1400 g in ostrich to 0.5g in humming bird.
  d. An egg needs 25h in its sojourn along the oviduct, and it takes 30 min. for another egg to separate from the ovary.
  e. After peak, production starts to decline by 1 – 2% weekly till the end of the first production season.
  f. Yolk is rich in both fat soluble and water soluble vitamins.

g. Errors in nutrition or management cause a cessation of egg production and when corrected it will take <u>at least 7 – 8 days before production begins</u>, as this length of time is required to produce the yolk.
h. <u>Avidin</u> is a protein which possesses the power of combining with vitamin biotin, rendering it unavailable.
i. In hot weather birds pant to get rid of the extra heat via respiratory system, by this process it loses a great amount of the CO_2 decreasing the level of carbonates in blood, leading to <u>thin shelled eggs in summer season</u>.
j. <u>The source of shell Ca</u> is from the diet and oyster shell kept behind the bird, but the bird may draw some Ca from medullary bone especially at night where there is no food consumption.



Reproductive system of chicken (source: google.com)

Nutrient requirements of poultry-in general

The nutrient requirements of poultry vary according to species, strains (type of production – broilers, layers, and breeders) breeds, age and activity. Requirements for growth of <u>light breeds</u> of pullets for replacement of egg production stocks are different from requirements of <u>heavy breeds</u> of chickens that are grown as broilers.

Recommendations in NRC do not provide any margin of safety (tables for requirements are at the end of the chapter). The nutritionist adds a margin of safety arriving at nutritive allowances to be used in ration formulation. Because of the small size of poultry and feeding in groups, the standards are usually stated in the amounts of the various nutrients required per kg of feed or in percentage, instead of allowance per head daily.

In NRC, the energy level of the diet was first established, under ideal environmental condition, for each species and age of poultry, then the other nutrients were determined based upon the established level of energy. If a higher energy level, than the NRC requirement, is used in the diet, feed consumption will decrease; hence, the minimum level of the other nutrients should be increased in proportion to the energy content. Similarly, if a lower dietary energy level in used, then proportionally lower levels of other nutrients should be used in the diet. When free-choice feeding dietary protein levels that are low in relation to energy, fat deposition is markedly increased; with higher levels of protein, less fat is deposited. Increasing the protein level above that required for maximum growth rate reduces fat deposition still further. A deficiency of a nutrient can be, and often is, a limiting factor in egg production or growth. Broilers fed high energy diets show efficient feed utilization and improved growth rate.

Temperature as a factor affecting the nutritive requirements of poultry

1. As the temperature changes from 20 to 30° C the rate of decline in food consumption was 1.5% per 1° C rise, whereas the fall may be 4 to 5% per 1°C with rise from 30 to 38 °C.
2. In respect of dietary calorie intake, this tend to fall by about 4 kcal/ bird/ day per degree centigrade °C rise in temperature, but the rate is slower at low temperatures and much faster at high temperatures.

As feed consumption decreases, the quantities of essential nutrients, protein, vitamins, and minerals, must be increased accordingly by increasing their concentration in the diet. The margins of safety for vitamins and trace minerals will usually be sufficient to allow for changes in daily food intake but nevertheless the levels should carefully be checked.

3. The optimum temperature for laying birds to allow most efficient food conversion and production would appear to be between 25° and 30°C whilst a minimum of 18 °C and a maximum of 32°C cover the range for good average production.
4. It is seldom practical to make frequent changes in the formulation to match it to the house temperature. One attempt at a practical solution is to prepare two standards of formulations, one for moderate temperatures and one for periods of high temperatures.

Components of poultry diets

I- Energy

The ME values given in the NRC requirement tables are not intended as requirements. Rather, they are provided to give perspective to the other nutrient requirement levels.

The major **energy sources** of poultry feeds are the cereal grains & its by-products and fats.

Animal & vegetable fats are usually added to the feed for meat-type poultry to increase overall energy concentration and improve productivity and feeding efficiency. It increases the intestinal retention time so complete digestion &absorption. The addition of fat improved the productive energy and is particularly valuable during high environmental temperatures. In addition to their high energy value, fats reduce the dustiness of feed mixtures, increase their palatability and improve the texture and appearance of the feed. Rancid fat may, when mixed with other food ingredients, act upon the fat soluble vitamins to such an extent that their value is lost. Vitamin A, D and E may be depleted in this manner. All feed fats should be stabilized by an antioxidant to preserve unsaturated FAs. Fats are carrier for the fat-soluble vitamins and in addition the arachidonic and linoleic are essential nutrients. **Linoleic** is considered the only essential fatty acid. 1 % linoleic is sufficient in growing and adult birds.

Fat can be added to broiler rations at the rate of 3-5 % and in sometimes it may reach 7 %. Hydrogenated fat with a very high melting point is not utilized well by poultry. High levels of fat are not recommended in poultry diets unless they suitably stabilized with antioxidants.

II- Protein

1- Level in diets

The protein requirements of poultry are commonly stated in terms of the percentages of total protein "not digestible protein" which are needed in rations for good results when the protein is of satisfactory quality (refer to the table). The calorie/ protein ratios calculated as kcal ME per kg/percent of CP should be followed in ration formulation. 1% additional large eggs may be anticipated for every 1% increase up to a maximum of 20 % CP.

In poultry rations, it is important to have protein of good quality and to have a sufficient amount of protein. Rations, in which the protein comes entirely from grain and grain by-products, produce poor results, because of poor quality of protein, even if there are ample supplies of minerals and vitamins. Fish meal, meat scrap, tankage and other dairy by-products have a high value as protein supplements in poultry rations. Starting mashes for chicks should generally have at least 5-7 % animal protein supplements or only 4 % good quality fish meal. Now all plant protein diets are formulated with good results.

The application in feeding practice of standards for as many as ten or eleven amino acids is likely to be rather laborious. In practice it is usually found that the amino acid mixtures provided by the diet are out of proportion, and hence inefficiently utilized, because one or two amino acids are very markedly deficient. These are the **"limiting" amino acids**. For pigs the acid likely to be most deficient is lysine while for chicks it is commonly methionine although lysine and perhaps arginine and valine may also be deficient. Also cystine and tryptophan need particular attention. In practice it may be sufficient to ensure that diets for poultry contain adequate amounts of these acids most likely to be deficient, and in laying hens leucine and isoleucine should be also considered.

In the formation of uric acid in birds glycine is required as it contributes part of the uric molecule, and the bird is unable to synthesize arginine. In mammals a final step in urea cycle is a molecule of urea and a molecule of arginine. Methionine is the first limiting amino acid for egg production, and glycine or serine is not essential for layers.
In addition to the essential amino acids there must be sufficient total nitrogen for the chicken to synthesize the other amino acids needed.

Methionine and lysine are manufactured at an economical cost. This allows that the initial balance of the ration can be compounded on the basis of the balance of the less limiting amino acid so the calculated amounts of methionine and lysine can be added at later stage. Only few protein supplements supply more methionine. Fish meal, sesame oil meal and well-hulled sunflower-seed oil meal are good sources of methionine.

A borderline protein deficiency is characterized by poor growth and feathering, reduced **egg size,** poor egg production (but hatchability is not affected), tendency toward greater deposition of carcass and liver fat, poor feed conversion into eggs or meat, and lack of melanin pigment in black- or reddish-colored feathers with low lysine. A severe protein deficiency is marked by-stopping of feed intake, stopping of egg production, loss of body weight, resorption of ova, a tongue deformity with leucine, isoleucine, and phenylalanine deficiency, stasis of the digestive tract, and death.

Protein supplements

Both animal and plant protein supplements are used. Most of that of animal origin contribute minerals and vitamins, but they are more variable in composition than the plant protein supplements. Among the animal sources are the meat meal, fish meal, milk by-products, blood meal, hydrolyzed poultry feathers, and poultry by-product meal.

Fish meals primarily herring, menhaden, and anchovetta are high in protein and extremely well balanced in EAA. However, since FM is high in fat, they tend to create a fishy flavor in meat and eggs when used in large amounts. This, together with the high cost of FM, restricts its use to one of a secondary source of protein supplementation.

The common plant protein supplements are the **oilseed meals** (SBM, CSM, PNM and limited amounts of LSM), corn gluten meal, alfalfa and other legume meals. SBM is the most widely used supplement in poultry rations.

Certain strains of rapeseed meal contain high levels of goitrogenic compounds to be toxic. Even SBM contains harmful substances as trypsin inhibitor, but these are destroyed by proper heating.

In CSM gossypol produces a mottling of egg yolks, or olive-green or dark-brown yolks, even in extremely small amounts. Cyclopropenoic fatty acids-another class of compounds found in CSM-impart a pink colour to egg whites. Because of that CSM is generally not used in laying rations, but it can be used effectively in growing and replacement rations (refer to the practical course). LSM can be used effectively in limited amounts, but it may depress growth and cause diarrhea if fed at high levels (it should not exceed 3-5 % of the ration). Corn gluten meal and alfalfa meal are used extensively for its protein and high content of carotenoids (deep yellow pigmentation to the skin).

III- Minerals

To overcome the possibility of deficiency supplements are added. An excessive amount of Ca supplements interferes with Mn (also excess P as in feeding large quantities of FM), Zn, I & Mg utilization and may reduce **egg production** and lower **hatchability** and with low vitamin D reduces the **egg weight.** Phytin may bind also Ca, Zn, Fe and Mn and render them unavailable. Excess Mg causes **laxation** and iodine has an effect on **egg production, semen production** and **fertility.** Excess Mg interferes with absorption of minerals especially Ca & P. If it is known that a diet contains a high level of Mg, levels of other elements should be increased.

In practice for every formulation the levels of Ca, P and salt should be calculated separately and specific inclusion is arranged. No supplement is needed to be included in rations for K, Mg, Co, F, Mo, and it is not wise to use Se supplements routinely as dietary additives. By contrast the trace minerals are best supplied as a trace mineral supplement. Thus make it unnecessary to consider each of them separately.

1- Calcium and phosphorus

Requirements of layers and breeders for Ca are high and it varies with egg production. Each egg contains 2 g of Ca (2/3 from ingested food and 1/3 from body stores). The convenient supplements for Ca are limestone flour, granular limestone or limestone grit or oyster shell available at choice.

All the phosphorus from animal origin is available. Organic P, in plants, is poorly utilized by growing birds, but is satisfactory for adult birds. Only about 30% of the P in plant products is available to the young chick, poult, or duckling. Wheat bran, rice bran, fish meal, S.B.O.M. and alfalfa meal have a good content especially the first two feeds. In deficiency of phosphorus the results are the same as that in Ca deficiency. Some mobilization of Ca and P from the bones during heavy egg production is a normal physiological process even as is the case for lactation.

For young poultry the Ca: P ratio should be about 1.2: 1, however 1: 1 to 1.5: 1 are well tolerated. For the laying bird, the ratio must be wider (4: 1 or more).

2- ***Salt***

Generally 0.25-0.30 % corresponding to 0.1-0.15 % Na is included. 0.5 % is suggested as the upper desirable limit for the salinity of drinking water. Sodium level is sometimes reduced to minimal to control the moisture level of the faeces.
A proper dietary balance of Na, K and Cl is necessary for growth, bone development, egg shell quality and AA utilization.

3- ***Potassium***

A deficiency of K results in high mortality and retarded growth in chicks, and causes reduced egg production and egg shell thickness in laying hens. It is not deficient in normal rations, due to large amounts of plant products in poultry feeds.

4- Magnesium

Mg is not normally deficient in poultry diets. Mg is not toxic but the inclusion of large amount causes laxation.

5- *Manganese*

There is a special need for manganese by poultry. Choline (0.13 %) in addition to Mn is necessary to prevent perosis and this role has no connection with its role in fat metabolism. A free-flowing Mn supplement should normally be included in all poultry feeds.

6- Iodine

It is included at the rate of 0.5 ppm and if F.M. is included at 5-10 % no need for iodine supplement to be added.

7- Zinc

Zinc is widely distributed amongst poultry feeding-stuffs plus that from food and water receptacles, but zinc from feeds now is clear that it may not be available for the bird and therefore zinc content of feeds should be ignored. The addition of 50 ppm of suitable supplement is all what is necessary.

SBM and sesame meal have some factors (probably phytate) which reduces the availability of Zn. Meat meal and fish meal are the rich sources. Zinc and Ca absorption are interrelated; hence, as the Ca level is increased, the Zn level should be increased also.

8- Copper

Most poultry food mixtures should contain a Cu supplement, especially if the diet has a high content of Zn.

9- Iron

It is normal practice to supplement poultry foods with iron. The normal sources include carbonate, oxide and sulfate. They are all very insoluble (absorption as low as 5.5 - 10 %).

10- Selenium

Requirement for supplementation is needed even in presence of vitamin E. Necrotic liver in rat, exudative diathesis in chick and enzootic muscular dystrophy (also cattle and sheep) can be prevented by either substance, but Se is ineffective in preventing nutritional encephalomalacia (E deficiency) or muscle dystrophy in farm animals induced by feeding dietary fat high in unsaturated FA_S. Fish meal and rapeseed meal are rich sources in Se. Se is very toxic and high levels (10 mg or more/kg diet) cause reduced growth, egg production and impaired hatchability.

Hence care should be taken when adding it to poultry rations. The addition of Se in either Na selenite or selenate at the rate of 0.1 ppm to complete rations for growing chickens to 16 weeks of age, breeder hens; and at the rate of 0.2 ppm in complete rations for turkeys, was approved by FDA. NRC (1994) has recommended 0.1 ppm for growing chickens, 0.15 for broilers, 0.06 for layers, and 0.2 for turkeys.

IV- Vitamins

Vitamin requirements for the insurance of maximum egg production may be insufficient to provide for the normal growth of chicks before and after hatching. For most B vitamins quantities needed for maximum hatchability are appreciably greater than those for egg production alone. This is true for B_2, pantothenic, biotin and folacin. For vitamin A & D this is not so. Rations giving to best production and hatchability provide egg of the highest nutritive value.

1- Vitamin A

A liberal supply of vitamin *A* or carotene is needed for normal growth, also for health. When chicks are fed a ration severely deficient in vitamin A, symptoms of the lack will begin to appear in about 3 weeks. Young chicks are more susceptible to vitamin A deficiency than adults as it takes a relatively long period for adult birds to deplete their body stores.

Laying hens require a higher content of vitamin A in their feed in very hot weather than when it is cooler because they consume then less feed. The amount of vitamin A in eggs depends on the vitamin A value in the ration. In adults, eye problems are prevalent along with decreased egg production and hatchability.

2 - Vitamin D

Relatively short exposure to direct sunlight may provide enough vitamin D for chicks. When poultry do not have ample exposure to direct sunlight, it is essential to include a vitamin D supplement in the ration.

3-*Vitamin E*

Vitamin E is advisable to be supplemented in all specialized poultry rations. Vitamin E in vegetable tissues is not so readily available as with E in oil concentrates. A prolonged vitamin E deficiency causes lowered hatchability and sterility of males. As with vitamins A & D, vitamin E is extremely susceptible to destruction from the oxidation of fats in the feed. To prevent this, antioxidants are commonly added to poultry feeds. Also, vitamin E is often added to feed in an esterified form to protect it from destruction. Reproduction is impaired in deficient adult birds. Degeneration of the testes is observed in deficient males – a condition that can lead to permanent sterility if not corrected in time. Layers do not show a dramatic drop in egg production, but hatchability is severely reduced. In vitamin E deficient chicks, three classical symptoms are observed, encephalomalaia, exudative diathesis, and nutritional muscular dystrophy. In turkey poults, a myopathy of the gizzard can be observed.

4- Vitamin K

All specialized mixtures should be supplemented with K vitamin which passes along egg to young chick. The vitamin should be added to starter rations. Inclusion of 2.5 % high quality dried grass supplies all the vitamin required. Deficiency of the vitamin is not met with in adults as they are able to synthesize sufficient vitamin in their intestine. If laying hens are fed rations deficient in vitamin K, chicks hatched from their eggs may bleed seriously from minor wounds, such as wing banding. Treatment with sulphonamides increases the requirements for the vitamin, as well as parasitic infections such as coccidiosis.

5-*Riboflavin*

Riboflavin is the most important of the B-complex vitamins in feeding poultry. More riboflavin is needed for good hatchability than is required for egg production and maintenance of health.

6 - Thiamin

Thiamin is required by all poultry, but ample amounts are supplied by ordinary rations and deficiency is unlikely under normal conditions.

7- Niacin

Young chicks require more niacin /pound of feed than do older chicks or hens. This is apparently due to some synthesis of niacin by bacterial action in the digestive tract of old birds. Niacin of cereals is bound and unavailable to chicks so it is normal therefore to supply poultry diets with niacin especially if the supply of tryptophan becomes limited.

8- Vitamin B_{12}

Good quality fish meal, fish solubles and other foodstuffs, which are rich in animal protein are usually good sources of vitamin B_{12} and are the standard method of including this vitamin in the ration. If these products do not constitute 5 per cent of the ration, it is advisable to include supplementary vitamin B_{12} in the mixture. In all cases, turkey foods should generally include a vitamin B_{12} supplement. It is always more necessary in diets which are exceptionally rich in protein or fat. Deficiency of B_{12}may cause high mortality in very young chicks.

9- Biotin

Broilers and turkeys may require supplementary biotin in spite of its presence in most food ingredients. Deficiency of biotin causes fatty liver-kidney syndrome (FLKS) in commercial broilers and layers.

10- Others:

Folic acid and **choline** may be needed to be supplemented to breeder's diets. All poultry food mixtures need supplementary **pantothenic acid**. It is found in a wide range of poultry food but it is in a bound form. Cereals are poor in pantothenic acid.

Vitamin C is synthesized by poultry; hence, it is not considered as a required dietary nutrient. There is some evidence, nevertheless, of a favorable response to vitamin C by birds under the stress of high temperature.

Refer to the first semester course for “minerals and vitamins” in poultry.

Nutrient Requirements of chickens

Broilers

- ***Starting and growing market broilers***

Broilers are young, rapidly growing birds raised for meat. The term can apply to all species but commonly taken to refer to young chickens. Broilers are young chickens that are grown to 5 to 7 weeks of age, at which time they are marketed for human consumption. A distinguishing characteristic of modern broiler chickens is their rapid growth, deposition of a large proportion of breast and leg muscles, and their relative inactivity as compared to chickens of lighter breeds that are used for egg production.

The rate of growth decreases with age, resulting in progressively lower nutrient requirements as the broiler approaches market age, so the growth period is divided into intervals.

- The nutrient requirements of broilers are presented in NRC (1994) for three intervals and 42 nutrients. The phases are 0- to 3-, 3 – to 6 -, and 6- to 8 – week. The finisher diet for the last phase has a higher energy to protein ratio to increase the deposition of the subcutaneous fat. The energy density in the three diets is 3200, while the CP % is 23, 20 & 18 in the starter, grower & finisher respectively.
- Requirements are guidelines and must be adjusted to the wide variety of strains of broiler chickens. Thus a special strain catalogue with special requirement levels is usually distributed by the different chick producers.

Feeding programs other than that of NRC

In raising broilers usually two or three different diets, or even one, are used: a “starter”, a “grower”, and a “finisher”. The feeding period is divided into different phases according to the breed and catalogue recommendations. The grower – finisher or finisher rations need to be fed for different intervals depending on desired market size.

Table 1 Broiler feeding programs

Program	Diet	Age period	CP%	ME/Kg
I	Starter	0 to 3 – 4 wk	22 – 24	3100 – 3200
	Grower	till 7– 10 d before marketing, or for about 2 weeks	20 – 21	3000 – 3100
	Finisher	Last 7 -10d or the remainder of the feeding period	18 – 19	3000 – 3100
II •	Starter	0 to 2 wk before marketing		
	Finisher	Last 2 wk		
III	Starter	0 to 7 wk only		
IV ⊙	Grower	0 to 9 wk	20 – 21	3000 – 3100

From 50 days of age till marketing a diet of 16% CP and 3050 ME can be fed (Ministerial decree, 1996). Remove from the diet any animal protein source, antibiotics, coccidiostats and add ½ the needed amount of mineral and vitamin premixes, for cost.

• In this program the change from high protein – starter to a low protein – finisher stresses the bird. Change should be gradual by mixing the two mashes for 2 – 4 d.

⊙ Compensatory growth at the end of the period is expected.

In respect to programs, most are using at least 3 stages (starter, grower, and finisher) to reduce costs and make more efficient use of the nutrients. In the 3 – stage program the starter feed should be used for 3 – 4 weeks, the grower for about 2 weeks and the finisher for the remainder of the feeding period. The birds should be left on the higher nutrient feed formulation until the target weight per age is reached.

NRC 3-stage system was found to be optimal for most of the breeds if the producer has no breed recommendations.

- ***Broiler breeder pullets and hens***

Unlike the laying strains, broiler breeders (the parents of meat-type chicks) do not appear to exert such a rigid regulation of their energy intake and excessive deposition of fat within the adipose tissue results if these birds are allowed food ad libitum. Broiler breeders become excessively fat and heavy, causing leg problems and low egg production, if full – fed on high energy feed. Broiler breeder diets are formulated to provide about 120% of the requirements, for egg-type breeders, for all nutrients (other than energy) and their consumption limited to 80% of what ad libitum intake would be. Meat-type hens may need a diet with 19.5% CP. A bird of the heavier breeds eats 43.2 to 52.3 kg/ year (compared to about 36.4 kg in light breeds producing about 20 dozen eggs), hence they are not as efficient egg producers.

Replacement chicks are usually fed a diet lower in energy than broiler chicks (2900). Also, feed and daily light periods may be restricted, so as to permit the pullets to reach larger body size before they start to lay. They are fed starter feeds to 5 weeks, growing ration to 11, then developer feed until lay. Feed accounts for 60% of the cost of raising replacement pullets.

II Layers

Layers are chickens raised for egg production; most are of the Leghorn breed. They have a slower growth rate and thus lower nutritional requirements than broilers during the early growth stages. Those used as broilers or broiler breeders (meat-type) have rapid growth rates and a large body size.

Because of the high nutrient content of eggs, and the high level of production of the modern layers, the nutritional requirements of birds in full production are very high, particularly for protein, energy and Ca. An 1800g hen at the start of lay contains in her body 20g Ca and 725g DM. The production of 280 eggs will involve the voiding of 560g Ca and 2030g protein (280 X 7.25g CP), so 28 times the Ca content of the body and 2.8 times the initial DM. A laying hen is a hard working animal. The turnover of material during reproduction in domestic avian species is enormous.

Egg composition

In egg production a good flock of layers produce an average of 250 eggs/ year/ hen (average weight 57g/ egg). The yolk forms 31%, albumen 59% and shell 10% of the egg weight.

Egg production characteristics

Egg strains

There are 2 strains, one with white feathers producing egg with white shell, and a strain with brown feathers and producing brown shelled-eggs.

The characteristic of a good egg-laying strain

- Growing period is from hatch to 140 d of age reaching a weight of about 1400g for white strains and about 1700 for brown ones. The bird consumes 8 kg diets for the white & 9 kg for the brown. Mortality rate is 3% for the white and 2% for the brown.
- Sexual maturity starts at 140 d (first egg) and full maturity reaches at 22 week (brown is late by 10 – 15 d).
- 50% production is reached at 155 – 157 d in white and 160 – 162 d in brown.
- Production is starting at 22 wk at low rate then increased rapidly to reach a peak at 30 – 35 wk then declines gradually to end.

Nutrition and egg formation

When the nutritional environment is not suited to optimal egg production, the hen responds in several ways. It could reduce **the size** and/ or **number of eggs** produced, while maintaining the ideal composition, or **could modify the composition** while maintaining the output, alternatively.

Energy

Commercial layer strains appear able to adjust their voluntary food intake to meet their daily energy requirements. Consequently when very high energy diets are fed, voluntary food intake could be reduced as to lead to a deficiency in intake of a specific nutrient in the diet. The calorie/nutrient ratios should be kept as required.

Ultimately, high energy diets will lead to an unbalanced nutrient supply and the general overproduction of lipid material that the liver utilizes to produce yolk lipoproteins. The increased yolk weight relative to the other components of the egg could be a reflection of this, particularly since the composition of the yolk remains unaltered.

Energy deficiencies lead to a reduced egg size and ultimately a reduction in egg numbers but, again, this may simply be a reflection of general dietary deficiencies rather than a specific deficiency of energy per se.

Proteins

It is not surprising that there is a lack of any effect of dietary protein on the composition of egg protein, since the embryo requires certain amino acids for development. Hence an egg deficient or unbalanced in amino acids would be detrimental to embryonic development. Since all the egg proteins are synthesized specifically an unbalanced content is unlikely, although the total amount available may vary and may cause a reduction in egg size. This effect makes it difficult to assess the direct effects of protein and AA intake on hatchability although, surprisingly, in view of the AAs that are apparently essential for embryo development, dietary deficiencies of Try, Lys, or Met did not appear to affect the hatchability of eggs produced.

Lipids

Nearly all the lipid in the egg is present in the yolk. Synthesis of yolk lipoproteins occurs in the liver. The experimental evidence available suggests that the lipid content of the egg is not sensitive to the dietary lipid intake even high-fat diets do not affect total egg lipid, although proportions of egg yolk fatty acids can often be related to the fatty acid composition of the dietary triglycerides.

Despite these last general conclusions there is no doubt that certain FAs are essential in diets for laying hens if they are to produce viable offspring. These acids, e.g. linoleic and arachidonic acids, are derived predominantly from vegetable oils. Dietary deficiencies of linoleic are associated with a marked reduction in egg production, egg size and the proportion of DM and lipid content of the yolk. This is accompanied by a reduction in fertility and an increase in embryo mortality. In severe deficiency of either linoleic or arachidonic acid, the acid could not be detected in the yolk and hatchability was reduced at zero.

High dietary levels of cholesterol bring about high levels in blood plasma and in the yolk, but not all plasma cholesterol is derived from the diet and the type of dietary fat may influence cholesterol production in the bird. Thus a high dietary level of safflower oil results in a high output of cholesterol by the liver. It seems likely that substances such as cholesterol accumulate in the oocyte incidentally with other components because the specific mechanisms for the uptake of the major components are not selective.

Vitamins

The concentration of vitamins A, E and K, pantothenic, nicotinic acid, pyridoxine, folic acid and biotin in the egg have also been shown to be dependent upon their concentration in the diet. This suggests that the bird has no specific mechanism for ensuring that adequate quantities of vitamins are present in the egg, which is surprising in view of the essential nature of the vitamins in normal development of the embryo, hatching and survival of hatched chicks.

Inorganic ions

Their effect on egg production is complicated by the fact that most ions have widespread effects on physiological processes in the body and particularly on these associated with heart, muscle and nerve. In a similar way to the vitamins, it appears that most of the ions in the egg (except those in the shell) are present in concentrations proportional to dietary intake. This is not unexpected since most ions (e.g. Na and K) enter passively into the egg in the large quantities of water present. Furthermore most of the divalent ions (Ca, Mg, Zn, etc.) of the yolk are transported bound to the lipoproteins.

Conclusions

- The bird can apparently maintain the relative composition of the egg irrespective of reasonably wide fluctuations in diet amount and composition.
- In contrast some minor components of the egg (in particular the vitamins and minerals) appear to enter passively as a result of the uptake mechanisms for the major components and for these minor components egg composition tends to depend more directly on the diet.
- In marked deficiency egg production decreased or stopped completely. In less severe deficiency eggs may be smaller or differ somewhat in composition. It is now generally accepted that the composition of egg is, to a certain extent, dependent on the diet of the chicken. Any change in nutrition which affects the composition would be expected to show first in albumen, followed gradually in the next week in the yolk e.g. a change from a breeders mash to a layers mash is followed by a reduction in the B_2 content. The concentration decreases first in the albumen then in the yolk and is accompanied by impairment in hatchability.

Nutrient requirements for layers

- ***Starting and growing pullets***

As to protein requirements, flock replacement chicks are fed a 18% CP all-mash starter diet for the first 6 weeks, followed by a 15 to 16% protein grower feed to 12 wks, and a 15% protein developer feed until sexual maturity (age at first egg - laying, approximately 18 to 20 weeks).

- ***Prelay period****(10-17 days before first egg)*

NRC (1994) recommends the same energy density at 18 weeks to first egg, but 17% CP compared to 15% in 12 – 18 weeks of age period.

Importance of Ca requirement at this time lies in its relation to the metabolism of medullary bone prior to maturity. Since modern egg - strain pullets exhibit a rapid increase in egg production and prolonged first multi egg clutch; it is obvious that a change in the requirements related to calcification must be accommodated before or at time of first egg.

Ca levels of 0.9 to 1.5% at 19 wk of age were detrimental to early shell quality. NRC recommends 2% Ca in the prelaying period.

- ***Hens in egg production***

Energy needs for production

Equations have been developed to predict the energy required by chickens during egg production.

ME per hen daily= $W^{0.75}$ (I73- 1.95 T) + 5.5 Δ W + 2.07 EE (NRC, 1981 - cited from NRC, 1994)

W= body wt in kg, T= ambient temperature (°C), Δ W= change in body weight (g/d) and EE = daily egg mass (g).

The estimated energy requirement can be used to estimate daily feed intake by relating the hen's energy needs to the dietary energy concentration, or to estimate energy density in diet by relating the hens energy to the amount of diet consumed.

Protein needs

A hen producing at a high rate needs 17 or 18 g protein daily (19% in high – energy diet fed in a hot climate or as low as 15% in moderate – energy diet fed in a cool climate). NRC (1994) has recommended 15 % CP, with a consumption of 100 g diet per day, & ambient temperature of 22^{O} C.

Minerals and vitamins

Mineral needs in production for chicken are similar to mineral requirements of other poultry. The onset of egg production creates a need for more Ca to make the egg shell. For maximum egg yield, the choline requirement was about 1050 mg per hen daily.

- ***Brown-egg-laying layers***

Requirements and estimates are listed as 10% greater than those of the white-egg-laying layers (in feed intake & nutrient densities). This is as they have heavier body weights and generally produce more egg mass per hen daily.

- ***Egg-type breeders***

The major nutrient requirements are the same for producing an egg for human consumption, as for producing an egg for hatching; however dietary levels of trace minerals and vitamins that result in maximum egg yield per day may be too low for the developing embryo. Vitamins and trace mineral levels in the egg can be increased by increasing the dietary levels.

Phase feeding

A relatively new concept and term, "phase feeding", refers to changes in the laying hens diets (a) to adjust to age and stage of production (b) to adjust for season of the year and climate changes (c) to account for differences in body weight (d) to adjust one or more nutrients as other nutrients are changed for economic or availability reasons.

Phase feeding programs generally call for:

I- High-protein feed (17 – 18%) from the onset of egg production through the peak production period, then 16% CP for the next 5 or 6 months. Lower level of protein (usually 15%) for the rest of laying period.

II- In phase feeding, NRC (1994) mentioned that phase 1 is designated as the time from the onset of egg production until past the time of the maximum egg mass output. Phase 2 is the period between 36 and approximately 52 wk, a period of high but declining egg production and increasing egg weight. Phase 3 is from 52 wk to the end of the rate of egg production cycle, in some instances to 80 weeks. During phase 3 the rate of egg production continues to decline while egg weight increases only slightly.

On the other hand the amount of nutrient needed each day is assumed in NRC table to remain the same throughout a hen's time of production, and the diet is fixed at 15% CP and 2900 ME.

III- Three diets may be also formulated in the laying period, one (A) from the onset of production to after peak lay and down to 77 – 78% production. The second (B) should be used when production falls in the range of 77 down to 67%, and formula (C) diet should be fed to birds under 67% rate of lay. The CP% is 18.5, 17 and 15.5 respectively.

IV- Two diets may be fed- the first is from 22-40 weeks and the second after 40 weeks. An adjustment is done after approximately 40 weeks of age to increase the Ca level to maintain egg shell quality.

Nutrient requirements of turkeys

Turkeys are raised for meat. Strains have been selected for rapid growth and efficient meat production. Most birds are white, whereas in the past the bronze-colored breeds predominated. Turkey meat has changed from being a seasonal dish (Thanksgiving and Christmas) to having year-round consumption.

Young turkey poults have a higher protein requirement than chickens. Starter diets (0 – 4 weeks) should contain 28% CP. The protein content can be reduced by approximately 2% during each 4–week period, up to a market age of approximately 20 weeks. This is in NRC growing turkey program.

Turkeys are affected by a number of disorders that have a nutritional component. These include:

1. leg weakness: is associated with deficiencies of nutrients involved in bone formation, including Ca, P, D_3, choline, biotin, folic acid, Mn and Zn.
2. enlargement of the hock joint: may occur with deficiencies of niacin, biotin, vitamin E, or zinc.
3. footpad dermatitis: is typical of biotin deficiency. Diets causing sticky droppings, such as with barley or poorly processed SBM may cause droppings to adhere to the feet and cause dermatitis.
4. pendulous crop: caused by yeast proliferation in the crop, may occur with diets high in fermentable CHO. The distention of the crop associated with gas production from the fermentation may interfere with passage of ingesta from the crop to the proventriculus, causing the pendulous crop condition. The disorder can be treated with a fungal inhibiting antibiotic.
5. ascites, or fluid accumulation in body cavities: has been observed with high salt intakes. Se deficiency also causes an edematous condition, exudative diathesis.
6. gizzard myopathy: or degeneration of the gizzard caused by Se deficiency in turkeys.
7. aortic rupture: occasionally occurs in market turkeys. Although aortic aneurysm can be induced experimentally with Cu deficiency and by feeding lathyrogenic substances (lathyrogens are toxic AAs in seeds of lathyrus species), the causes of the problem under field conditions have not been identified. It was suggested that gizzerosine, the gizzard erosion factor, may play a role in aortic aneurysm and rupture.

The following are further pointers pertinent to feeding turkeys:

1. Prevent poult “starve out” upon arrival, poults should be encouraged to consume feed and water as soon as possible. The use of colored feed, or the placing of brightly colored marbles in the feed and waterers, may help. It may be necessary to dip the beaks of some of them in feed and water to start them eating and drinking.

2. Turkeys grow faster than chickens; hence, they have relatively higher feed and protein requirements.
3. Younger turkeys use feed efficiently.
4. There is a tendency among turkey breeders to provide a high-fiber holding ration for use beginning at 16 weeks of age. This type of ration retards sexual maturing and may result in some desirable effects upon later reproductive performance. The holding ration limits energy intake, but should not limit protein, vitamins, and minerals. Where a holding ration is used, the birds should be switched to the breeder 2 weeks prior to egg production.
5. Good range provides green feed and tends to reduce feed costs. However, it may make for higher losses from blackhead and other diseases, and predators.
6. As they approach maturity, turkeys fed for market purposes should be fed rations that are quite different from those that are fed to turkey breeders.
7. Turkeys are classified according to feather color or bird weight. There are the white, bronze, grey, brown or copper. Most birds are of the heavy weight bronze and the Holland white medium weight strains. Producers prefer the white strains especially if the birds are marketed slaughtered. The presence of black down on carcass decreases its marketing value. In immature birds more down could not be removed and waiting till the bird matures represents an economical loss and high feed conversion index.

Raising for meat production

According to body weight turkeys are divided into three classes, light, medium and heavy. This classification is related to the age of marketing for meat and feed conversion rate.

The heavy breeds for marketing birds of more than 10 kg are the most economical as it has a low FC even at an age of 20 – 24 weeks. On the other hand the FC rises greatly after the age of 12 – 16 weeks in light and medium breeds. In heavy breeds cocks can be fattened till the age of 24 weeks to reach a weight of about 13 kg, and hens fattened till the age of 18 – 20 weeks to reach a weight of 9 kg.

				Body weight, kg	
	Marketed in wks	Av. B. wt., kg	FC	Cocks	Hens
Light	9 12	2.6 4.2	2.1 2.4	10	5.5
Medium	12 14 16	4.5 5.5 7.5	2.2 2.5 2.6	15	8
Heavy	12 16 20 24	4.8 7.2 9.3 13.6	2.3 2.7 3.1 3.5	20-22	8-10

In meat production the fattening period is divided into 3 phases in which diets starter, grower, and finisher are fed. The following is the composition of the three diets:

	Starter	**Grower**	**Finisher**
ME	2800	2900	3100
CP%	26 – 28	18 – 22	15 – 18
Ca	1.4	1.2	1.0
Av.P	0.6	0.5	0.4

Salt	0.5	0.5	0.5
Met	0.56	0.48	0.48
Lys	1.8	1.4	1.0

	Breeds		
Starter diet	**Light**	**Medium**	**Heavy**
Age	0 – 4	0 – 4	0 – 4
CP%	28	26	26
Grower diet			
Age	4 – 8	4 – 12	4 – 9 9 – 16
CP%	22	20	20 & 18
Finisher diet			
Age	8 – 12	♀ 12 – 14 ♂ 12 – 16	♀ 16 – 20 ♂ 16 – 24
CP%	18	16	15

According to the Ministerial decree (1498 on 1996) 5- phase and 3- phase programs were suggested for meat production.

	5- phase program				
	Starter 1	Starter 2	Grower 1	Grower 2	Finisher
Age (wk)	0 - 2	2 – 4	4 - 8	8 – 10	10 to marketing
CP %	29	26.5	23	19	17
ME	2900	3000	3200	3250	3275
	3- phase program				
	Starter	Grower	Finisher		
Age (wk)	0 - 4	4 – 10	10 to marketing		
CP %	29	23.5	19.5		
ME	2900	3050	3150		

It appears that the ministerial programs are suitable for the light breeds.

Daily food intake in heavy breeds

Week	**FI, g**	**Week**	**FI, g**	**Week**	**FI, g**
1	15 (10)	8	140 (100)	20	280
2	25 (20)	9	160 (120)	22	300
3	40 (30)			24	320
4	60 (40)	10	180 (140)	26	340
		12	200 (160)	28	360
5	80 (55)	14	220 (180)	The food intake is about 1.5 times that consumed by light or medium to 18 weeks.	
6	100 (70)	16	240 (200)		
7	120 (85)	18	260 (220)		

The figures in parentheses are for light and medium breeds. Females are not usually marketed after 20 weeks of age.

Breeding

In a program for raising breeding hens the period can be divided into three phases:

1. Incubation period from 4 – 6 weeks.
2. Growing period from 6 weeks till the start of production at 32 weeks. In this period there is a special program of feeding and lighting. The programs limits growth rate and retards sexual maturity.
3. Production period starts at about 32 weeks and extends for 20 – 24 weeks according to the breed when production stops and molting starts. Some prefer to keep the flock for another season, while the others get rid of the flock at the age 12 – 13 month.

The feeding program includes

Starter diet 0 – 6 weeks 26% CP (with boiled eggs)

Pullet diet 6 – 28 weeks (6 – 12 wk 18 – 20% CP, 12 – 28 wk 16% CP)

Breeder diet from 28 till the end of production period

With the pullet diet there is limited feed intake and lighting (12 – 28 wk)to retard sexual maturity till full body maturity.

The breeder diet 17 – 18% CP for heavy breeds and 18 – 19 for light ones, offered at the age 29 weeks making the period from 29 to 32 as transitory (gradually increasing feed intake and lighting).

NRC feeding program

NRC (1994) suggested another feeding program in which a starter diet is fed from 0-4 weeks (28% CP) then five grower diets are used in which CP decreases from 26 to 14 (2% during each 4- week period) while ME increases from 2900 to 3300. The growing period extends to 24 in males and 20 weeks in females. A holding ration of 2900 ME and 12% CP is fed till the start of laying where 2900 ME and 14 CP% - diet is fed. Males are fed a diet with 12% CP and 2900 ME. NRC program is the best to be used with the consideration of age of marketing.

Nutrient requirements of waterfowls and game birds

As related to ducks the white Pekin duck breed is the principal meat producer. In China and Southeast Asian countries, ducks are raised extensively for meat and eggs. Egg – producing breeds, such as the Indian Runner, can achieve egg – production rates equal to or greater than those of chickens. Geese are raised to produce meat, feathers, down, and in France, liver pate. Fatty livers are produced by force feeding the birds with a high – energy diet. Ducks and geese can be fed diets similar to those for chickens.

Leg weakness is a major problem in waterfowl because of their rapid growth rate; adequate choline and niacin are necessary to prevent this disorder.

Geese are grazing birds and can be fed on range. The amount of concentrate for geese can be limited to 1 to 2 pounds of feed per bird per week. If full fed on grain, they will reduce their forage intake. For several weeks prior to marketing, they should have free access to concentrate feed to develop adequate finish. Although goslings have a very rapid growth rate, a large amount of the gain is skin, fat, and feathers. They are less efficient than chickens in the accretion of lean tissue. Their ability to utilize forage may be of value in some countries where feed grains are expensive. Although geese are herbivorous and accept high-fiber diets, the digestibility of fiber is low in this species. The ability to utilize fibrous feeds results from a fast passage time that allows a high-feed intake, plus efficient manner in which the gizzard breaks down plant cell walls, which allows digestion of the cell contents. Growth on fibrous diets was improved when the diets were pelleted. Geese are sensitive to bitter substances in the diet-they prefer grasses and weeds to alfalfa (contain bitter substances such as saponins).

Refer to the nutrient requirements table at the end of the chapter for ducks, geese, game birds and the quails.

The pointers pertinent to feeding ducks

1. Ducks should be fed pellets rather than mash. Pellets will make for a saving of 15 to 20% in the feed required to produce a market duck.
2. Ducks are nearly good foragers as geese.
3. Ducks should be ready for market between 7 and 8 weeks of age.
4. The holding rations are designed to maintain breeding ducks from about 8 weeks of age until the breeding season commences, without their getting too fat. Also the food is limited to about 1/2 pound per bird per day.
5. The breeding diet should be substituted for the holding diet about 4 weeks before eggs are desired for hatching purpose.
6. There are three breeds, one for meat production, the other for egg production and the third is for hoppy.

Meat production

Usually the Pekin ducks are used as it has a rapid rate of growth, also a mix between Muscovy or Suadani with Pekin to produce the “duck mule”. The last has many problems in conception as the males are larger in size than females, so low hatchability.

Feeding for meat production

The feeding for meat production is for a period of 8 weeks, consuming 8 kg diets, at 1: 3 FC, and reaching about 2.6 kg body weight. Don’t extend the period more than 8 wks as the ducks are inclined to store fat and the FC rises to 1: 5 or 1: 6. Also after 8 weeks ducks start molting which continues to the age of 13 weeks, which affects growth rate and feed consumption.

In the feeding period chick weight increases 50 times. The program of feeding includes a starter and a grower diet, and no finisher is given lest the increase in fat precipitation. For energy and CP and other nutrients refer to NRC (1994). According to the Ministerial decree, chicks are fed a starter diet (22, 2900) and a finisher one (17, 3000), in the 2- phase program, and starter (22, 2900) grower (18, 2900) & finisher (16, 3000) in the 3- phase one.

Breeding

The growing period extends till the age of 22 – 24 wk in which limited feeding and lighting till the start of egg production (otherwise inverted uterus a condition could not be rectified as long as it appears).

In incubation period	**Feed ad libitum, 20% CP**
From 2 – 7 weeks	**Pullet feed 16% CP, ad libitum**
From 7 to 21 weeks	**Feed 70% of normal consumption (about 170g) and with limited lighting, CP 13%.**

The program of limited feeding ends at the start of the 22nd week and breeding diet offered (17% CP). Egg production starts at 25 week of age and continues for 9 – 10 months (150 eggs), production can be continued for 12 months (180 – 200 eggs). No more than one season as ducks are inclined to be too fat at the end of the production season and start of molting, so the production in the subsequent seasons will be low except in egg breeds as in Indian Runner. The last can be kept for 4 seasons.

Laying bird consumes about 250g feed containing 16 – 18% CP (NRC- 15%) and containing not less than 6% animal proteins of which 4% fish meal (for high hatchability).

The pointers pertinent to feeding geese

1. They can live almost entirely on good pasture.
2. Weeder geese are used with great success to control and eradicate troublesome grass and certain weeds in a great variety of crops and plantings, including cotton, onions, garlic, corn … etc. At the end of the weeding season the geese are generally brought from the field and placed in pens for fattening for 3 or 4 weeks, until they weigh 10 – 12 pounds or more. Markets are highest during the 4 to 6 weeks prior to Thanksgiving and Christmas.
3. Rations should be in pellet form. Crumbles cause too much feed wastage and should not be used.
4. Geese should be ready for market at about 15 weeks of age.

Notes on feeding geese

Geese usually tend to precipitate a large amount of fat as body fat reaches 31% of the carcass, while it is 5.6% in chickens, 11.7% in turkeys and 17.2% in ducks. The geese liver is of large size and fat could be precipitated in it, liver pate (pate de foie gras). Liver is sold at a high price to the degree that it covers the cost of geese raising and meat production is considered a subsidiary product. Feathers also are a valuable product.

Greenages should be used to decrease the cost of feeding. Light breeds are fed for 8 – 10 weeks for meat production where a concentrated diet is offered. This method is called the early or rapid fattening. The fact that geese are grazers could be used and the birds are left in range till near maturity where it is moved to fattening and given a finisher. This is the “late fattening”.

- **Fattening, early**

Period 8 – 10 weeks: End weight 4 – 6 kg

Feed consumed : 15 – 16 kg

Starter : 20% CP for 4 weeks.

Rest of period : 15% CP.

- **Fattening, late**

Incubation 3 weeks then left in range till near age of maturity without any additional diets.

30 days before slaughter follow the following:

- The bird is gradually moved to the concentrated feed and the 30 days are divided into 3 periods:
  a. The first 10 days : Graduation in feeding but less than satiety level.
  b. The second 10 days : Full-feeding.
  c. The third 10 days : A diet high in energy and low in protein.

Bird should be slaughtered only when the sternum completely disappears.

- **Fattening by forced feeding to produce liver pate:**

Forced feeding is performed either by hand or mechanically before slaughter by one month. The goose is forced fed 800 – 1000g corn divided on 2 – 4 times per day. In the forced feeding goose gains 3 – 5 kg and liver increases in weight by 500 – 800g with the increase in fat% in liver to 60%.

Feeding in egg production

In egg production feed a diet of 2900 ME and 15 % CP as recommended by NRC (1994).

Egg production

- Produce egg efficiently for successive 10 years.
- Can reach to the age of 20 years and still laying.
- 40 – 50 egg/ season.
- 20 – 30 egg/ season in some light breeds.

Laying most of it is in winter (January to April) in one group or two groups. The best rate of laying is in 2 – 6 years of age and decreases till the age of 10 – 12 years. The first season is less in hatchability by 20% than the second season. Males can be used for mating starting at 1 year of age till 6 – 8 years.

Nutrient requirements of Ostriches

Ostriches and other ratite birds (emu, kiwi, cassowary, and rhea) are large flightless birds that have been separated from the main lines of avian evolution for 80 to 90 million years, since the Middle Cretaceous period. Their occurrence in Africa, South America, and an Australia stems from having common ancestors that lived when these continents were joined. These birds have enlarged ceca and microbial fermentation and utilize fibrous vegetation to a considerable extent. There is evidence of nitrogen recycling from the cloaca to the cecum, increasing the efficiency of protein utilization. The metabolic rate is lower than for other avian species, thus contributing to their ability to survive on low – quality diets.

In Ostrich young chicks can be started on turkey or game bird starter ration containing at least 26% CP. They should have continuous access to the starter diet for the first 3 weeks, after which they can be fed all the starter diet they will consume in two 30 – minute feeding periods per day. At this time they should have free access to alfalfa pellets. This feeding program will help to prevent excessive weight gain which causes leg weakness problems. At 8 weeks of age the ostrich chicks can be fed a game bird or turkey grower ration for two feeding periods daily, with continuous access to alfalfa pellets. If good-quality pasture is available, they can be ranged on pasture with the supplemental ration provided twice daily. Forages should be young and succulent. Adult birds can be kept on pasture, with daily supplements of a turkey breeder diet during the breeding season. Birds in dry lots can be fed alfalfa pellets or good quality hay.

Special nutritional disorders in poultry

(Refer to deficiency diseases in minerals and vitamins)

I- Leg Disorders

Leg abnormalities are a problem in poultry, especially in birds kept on wire. Perosis or slipped tendon is caused by deficiencies of choline and manganese. Perosis is due to an abnormality of the joint in the long bones of the leg causing the tendon to slip and pull the leg sideways. Cage layer fatigue is a type of osteoporosis that involves excessive mobilization of calcium from the leg bones, which causes the birds to have difficulty in standing. Insufficient dietary calcium is a causative factor.

Another leg disorder seen in broilers is tibial dyschondroplasia (TD) in which there is abnormal formation of cartilage in the long bones. The cartilage forms a thickened layer below the epiphyseal plate. Dietary electrolyte balance and dietary alterations that affect acid-base or cation-anion balance have a role in TD. High dietary chloride levels provoke an increased incidence. Dietary zeolite has been shown to reduce the incidence and severity of TD, apparently by facilitating calcium utilization. High levels of vitamin A were reported to increase leg disorders, but this result was not confirmed. It was found that a diet low in calcium and high in phosphorus and chloride produced a high incidence of TD in broilers. Supplementation of high phosphorus diets with calcium reduces the incidence of TD.

II- Anemia

Deficiency of iron or copper can cause anemia. Iron is needed for the formation of hemoglobin. It is also a constituent of cytochrome and other respiratory enzymes. If there is insufficient iron in the diet, anemia results because hemoglobin cannot be formed. Copper is essential for normal utilization of the iron. In either case (deficiency of iron or copper), there is a reduction in the hemoglobin content of the blood and in the size of the red blood cells.

Other causes anemia: We have already noted that deficiencies of certain water-soluble vitamins can cause anemia. Among these are deficiencies of folacin (folic acid), pyridoxine, and vitamin B_{12}. The type of anemia-as determined by cell counts, hemoglobin, and hematocrit-sometimes helps to identify the cause. Any substantial loss of blood will also cause anemia. This, in turn, can be due to heavy infestation with internal or external parasites, or to hemorrhage due to impaired blood clotting.

III- Fat Disorders

1. **Excessively fat broilers** are a problem in the United states poultry industry. Selection of birds for very rapid growth rate and the use of high-energy diets are implicated. Maintaining a proper balance of protein to ME helps prevent excessive fat deposition.
2. **Fatty liver syndrome:** (also known as fatty liver and kidney syndrome) it affects layers, with the deposition of large amounts of fat in the liver. The cause is not completely understood, but lipotropic agents (substances that reduce fat

deposition in the liver or hasten its removal) such as choline, vitamin B_{12}, and methionine show evidence of protective activity.

3. **Oily bird syndrome** is sometimes a problem with broilers, observable only after the birds have been processed, and involves a greasy appearance of the fat and skin. Nutritional factors such as the protein-to-calorie ratio may have a role in the syndrome.
4. Another nutrition-related problem with broilers is **sudden death syndrome (SDS)** or flip-over disease. This appears to involve a heart failure (heart attack). Birds that develop SDS have altered fatty acid content of tissues, with decreased arachidonic acid levels. This could result in reduced prostaglandin synthesis, leading to imparired heart function. Biotin deficiency has also been implicated in SDS. Biotin is a cofactor for enzymes involved in fatty acid metabolism. Feeding high-energy diets increases incidence of SDS.
5. **Fatty Liver Haemorrhagic Syndrome (FLHS).** This disease occurs sporadically in laying hens, particularly in caged flocks of the heavier breeds during hot weather. Under these conditions they may not reduce their food intake sufficiently to compensate for the raised environmental temperature and lack of exercise. Consequently their carbohydrate intake is excessive and hepatic lipogenesis is increased. Heat stress may also be involved and dietary factors such as the cereal used as the source of the carbohydrate may affect the amount of fat synthesized.
6. **Fatty liver and kidney syndrome (FLKS).** This is a metabolic disorder with a complex aetiology involving a deficiency of biotin, other dietary factors and stress. It affects broiler and layer type chickens, usually at the age of 10-30 days, and tends to be associated with wheat-based diets with low protein and fat contents. Out- breaks are precipitated by an interruption in the food supply, handling, excessive noise, high or low temperatures and lighting failure. In another source it is mentioned that the disease is also known as “Fatty liver syndrome”.

IV-Other Diseases Sometimes Related to Nutrition

Resistance to infectious disease:

As a general rule, a healthy animal is more resistant to infection. Beyond this generalization, it is difficult to cite specific examples. It has been shown, however, that high dietary levels of vitamin A reduce the mortality due to coccidiosis and enable the surviving chicks to make a faster recovery. High dietary vitamin K is also beneficial when the chicks have coccidiosis-probably by minimizing hemorrhage.

Very high levels of all vitamins were helpful in resistance to infection in studies by C. H. Hill and his associates at the North Carolina Experiment Station. On a theoretical basis, high protein diets should help to promote resistance. However, in some instances, high protein diets have made chickens more susceptible to infection.

Enteritis:

Inflammation of the intestine chiefly of the small intestine is frequently observed in chickens that are raised without access to the soil and green growing plants. On autopsy, the intestine is often found to be filled with bits of shavings, straw, or other material that had been used as litter; sometimes large quantities of grit are also found. Attempts to demonstrate that the enteritis is caused by a micro-organism or other causative agent have failed.

Paralysis:

As has been pointed out in preceding pages, a deficiency of vitamin E in the diet of the young growing chicken produces lesions in the brain; of pantothenic acid in the spinal cord; of riboflavin, in the main peripheral nerve trunks; of vitamin A, in the central and peripheral nervous systems. Moreover, a deficiency of thiamine produces a toxicosis. or poisoning, of the nervous system. Accordingly, a deficiency of one or more of these vitamins may produce paralysis or a similar condition.

Paralysis, presumably of nutritional origin, has been observed, however, when adequate quantities of all five of the vitamins just mentioned were supplied. In some instances the supplemental feeding of alfalfa, and in other instances the feeding of large quantities of dried brain, cartilage, wheat middlings, yellow corn, or wheat, prevented the development of the paralysis.

Dermatosis:

From time to time a dermatosis similar to that produced by a deficiency of pantothenic acid or a deficiency of biotin is observed in growing chicks that are receiving supposedly adequate diets. This condition often disappears if a complete change of diet is made, but is not cured by adding rich sources of pantothenic acid to the original diet.

Aortic rupture:

Occasionally, chickens may die from massive hemorrhage caused by rupture of the aorta. This condition is more frequent in turkeys than in chickens. Part of the problem stems from the very high blood pressure of the avian species. Anything which weakens the walls of the blood vessels poses a potential threat. It has been demonstrated that feeding beta amino propionitrile will cause aortic rupture.

Recent work has shown that a deficiency of copper will cause a weakening of the walls of the blood vessels. The condition can be caused by a toxic level of molybdenum in the diet. Copper has an antagonistic action against molybdenum, and may provide some protection against excessive molybdenum.

Feather Picking and Cannibalism

Cannibalism is a term used by some poultrymen in referring to the habit sometimes developed by chickens, other poultry, and game birds of picking one another's feathers, toes, beaks, heads, combs, backs, vents, and other parts of the body. Most poultry men, however, restrict the use of this term to cases in which blood is drawn. Inasmuch as there are many instances in which only the feathers are picked, or pulled, it is desirable to distinguish between feather picking and cannibalism.

Although there is evidence that feather picking and cannibalism are the result, in part, of unsatisfactory diets, there often are other contributing causes, such as overcrowding and overheating-especially in the case of chicks in battery brooders. The exact nature of the nutritional deficiency or deficiencies involved is not known but it has been found that feather picking and cannibalism are less likely to occur if the diet contains about 20 per cent of barley or oats or about 30 per cent of bran and middlings.In any case there is evidence that feather picking and cannibalism are likely to appear if diets of very low fiber content are fed.

A fairly effective method of stopping feather picking and cannibalism is to increase the salt content of the diet for one or two days. If an all-mash diet is being fed, add 2 per cent of salt- but if both mash and grain are being fed, add 4 per cent of salt to the mash. Usually the feather picking or cannibalism stops within a few hours, but in some cases two days may be required. **It is not desirable to feed high salt diets for more than two days.**

Egg Eating

Egg eating is a vice that quickly develops when the chickens do not get enough calcium. The development of the vice appears to be greatly stimulated if there is overcrowding. Also, it has been observed that egg eating is likely to develop when the diet does not contain enough vitamin D.

Gizzard Erosion

Gizzard erosion is a disorder that has been observed in poultry for many years. It is characterized by erosion or necrosis of the gizzard lining, often with ulceration into the muscular gizzard wall. The entire lining of the gizzard may have a dry, scaly, brownish color rather than the normal greenish yellow color. The upper part of the small intestine may be ulcerated as well. The condition is related to dietary ingredients, particularly fish meal or grains contaminated with mycotoxins.

The gizzard erosion factor in fish meal has been identified by Japanese scientists as a dipeptidelike compound composed of histamine and lysine. This compound, called gizzerosine, is formed by a Maillard (browning) reaction when fish meal is heated. Gizzerosine induces an abnormally high secretion of hydrochloric acid in the proventriculus, apparently acting as an analog of histamine, which is the physiological regulator of gastric acid secretion. It is approximately ten times as potent as histamine in stimulating gastric acid secretion. Gizzerosine is metabolized much more slowly than histamine and has a higher affinity than histamine for gastric histamine receptors. A maximum concentration of 0.4 ppm gizzerosine in practical poultry diets is suggested. Higher levels cause retarded growth and mortality.

Ascites Disorders

Ascites is fluid accumulation in body cavities. Significant occurrence of abdominal ascites is noted in broilers in many countries. In most cases, ascites is associated with liver, heart, or lung damage. Fast-growing broilers are most susceptible; the mortality rate in affected flocks can be reduced by restricting feed to reduce growth rate. The problem may be that the extremely rapid rate of muscle growth in modern broilers outgrows the cardiovascular support systems. Another cause of ascites is high altitude, which intensify the condition because of the lower oxygen content of the air. Mycotoxins and other hepatotoxic agents increase susceptibility. Excess sodium in the feed or water also may cause ascites, as do poor-quality dietary fats containing oxidized fatty acids.

Heat Stress

Heat stress is a major problem in poultry production in the southern United States and in tropical countries. Dietary management may aid in minimizing the detrimental effects. Heat stress has various physiological effects; for example, increased respiration rate decreases the blood CO_2 level, which increases blood pH. The consequences of decreased blood CO_2 and elevated pH are not fully known. Increased weight gain in heat-stressed broilers given carbonated water or water supplemented with NH_4Cl and HCL has been noted. On the other hand, it was observed that addition of o.48 percent KCL to drinking water increased the growth rate of heat stressed broilers by 20 percent though the blood had an alkaline pH and blood CO_2 was depressed, indicating that factors other than blood CO_2 and pH arc involved.

Egg Production Disorders

With layers, maintenance of good egg shell quality can be a problem. The major concerns are with shell thickness and shell structure. It is desirable that egg shells not break during handling of eggs and that the shell resists penetration by microorganisms. Shells should be attractive in appearance that is not misshapen, bumpy, or blotchy. The shell is virtually 100 percent calcium carbonate. Thus adequate dietary levels of calcium arc essential for good shell

Quality; adequate vitamin D is necessary for calcium absorption and shell formation. Dietary zeolites improve egg shell quality presumably facilitating calcium utilization, whereas excesses of phosphorus and deficiencies of manganese can cause thin eggshells.

Besides calcium, a source of carbonate ion is needed to form the carbonate in the shell. The blood bicarbonate is the source of carbonate used in shell formation. Blood acid-base and electrolyte balance influence availability of carbonate ion. In hot weather, the respiration rate of birds increases markedly. This can so increase carbon dioxide loss that blood bicarbonate levels are too low to support proper egg shell formation. Providing a dietary source such as sodium bicarbonate, may be useful under these conditions. There is some evidence that feeding ascorbic acid may also improve egg shell quality under stress conditions.

Egg size is another important economic consideration for the poultry producer. Energy intake is a major nutritional determinant of egg size. Some feedstuffs, such as canola meal, may cause a reduction in egg size, probably due to a reduction in feed intake.

Egg size is affected by the lipid content and composition of the diet. Corn and corn oil in the diet stimulate production of maximum egg size, due to their content of linoleic acid. It was concluded that linoleic acid is necessary for the synthesis of lipoproteins in the liver that can be transported to the ovary for uptake by the developing ova. Egg size cannot be maximized if the amount of linoleic acid present is not adequate to support maximal lipoprotein synthesis.

Other Nutritional Problems

Urolithiasis in poultry is a syndrome characterized by mineralization of the kidney (kidney stones), resulting in acute uricemia (elevated blood uric acid), visceral gout. and mortality. The condition may be induced by excessive dietary calcium. Urinary acidification by feeding ammonium chloride may aid in reducing renal urolith formation. Dietary methionine hydroxy analog has also been shown to reduce calcium-induced kidney damage.

Mycotoxins can cause important losses in poultry production. Some of the important mycotoxins such as aflatoxin, zearalenone, trichothecenes, citrinin, and ochratoxin have been mentioned earlier. Moldy feed ingredients may impair performance even when mycotoxins are not detectable. Aflatoxins affect the immune system, increasing susceptibility to disease. Mycotoxins have a role in field hemorrhagic syndromes in which small hemorrhages may blemish the carcass. Aflatoxins can cause pale bird syndrome by impairing pigment absorption.

Feeds and ration ingredients

Before attempting to balance a ration the following should be considered:

1. **Availability and cost of the different feed ingredients:** The cost should be based on delivery after processing. The ingredients should be available for at least 3 month – rations. Formulation should be changed considering any changes in availability of feeds, prices, change of bird weight and productivity. The cost per unit of production is the ultimate determination of what constitutes the best ration.
2. **Feed composition** tables or average analysis, should be considered only as guides. Whenever possible, especially with large operations, it is best to analyze for the more common constituents-protein, fat, fiber, nitrogen free extract, moisture, and often Ca, P. Such ingredients as oil meals and prepared supplements, which must meet specific standards, need not be analyzed so often, except as quality-control measures.
3. **Vitamin and mineral supplements.** Today vitamin supplements (which are in many cases chemically pure sources that need to be used in very minute compounds) are used in feed formulation instead of using a wide variety of crude feedstuffs. In modern poultry feed formulation and production, premixes are used to provide both vitamin and mineral needs for poultry.

Vitamin concentrate must supplement each kilogram of poultry diets by: vitamin A, 10,000 IU; vitamin D, 1000 1U; E, 10 mg; K, 1mg; B_1, 1mg; B_2, 4mg; B_6, l.5 mg; B_5, 20mg; folic, 1mg; pantothenic, 10 mg; choline, 500mg; biotin, 50ug; B_{12},10ug. And the trace mineral concentrate in mg by: Zn 45, Mn 40, Fe 30, Cu 3, I 0.3, Se 0.1. These are the recommendation of the Ministerial Decree No, 554 of June 1984, Egypt. Refer for Decree No.1498 (1996) for different recommendations for the different species.

It is preferred not to add the premix of the trace minerals to vitamin mixtures as in case of unfavorable storage conditions; minerals may affect the activity of the vitamins.

It is well known that the nutritive content of the egg in respect of many of the important trace minerals and vitamins depends upon the level of these nutrients in the diet of the laying hen (e.g. iodine can rapidly be increased by the addition of suitable iodine supplements to the diet, and B_2 in diet is reflected in B_2 in the egg). Sufficient quantities of B_2 impart to the albumen a very slight yellowish-green tinge. Vitamin K and iron salts (and alfalfa) have been implicated from time to time to be the cause of blood spots in eggs.

4. Broiler or layer concentrates

Nowadays these concentrates are used to supply good quality protein (as it contains mostly animal proteins), minerals, especially the trace elements, and vitamins. In addition the concentrates contain coccidiostats, antioxidants, growth promotants and other additives.

5. Addition of **additives** to poultry rations should be routinely considered and they may include antifungals, antioxidants, pellet binder, enzymes, probiotic-prebiotic- or syn-biotic, coccidiostate, and xanthophylls.

Poultry rations

The poultryman has the following alternatives for purchasing and preparing rations:

1. Commercially prepared complete feed.

2. Commercially prepared protein supplement, reinforced with vitamins and minerals (which may be blended with local grains forming what is called poultry concentrate).

3. Commercially prepared vitamin-mineral premix which may be mixed with oil meals and grains.

4. Purchase of individual ingredients, including vitamins and minerals.

Most choose option 3 or 4.

Formulation of poultry diets

The larger commercial feed companies, and the larger poultry producers who do their own mixing and formulations, generally rely on the services of a nutritionist and the use of a computer in formulating their own rations. Even though they are more time-consuming, and fewer factors can be considered simultaneously, a good job can be done in formulating rations by the hand method.

Today, the most up – to – date standards are those of NRC (1994). Statements of NRC are not always directly applicable to poultry not kept in temperate zones, but modifications can be made especially when more informations becoming available from countries with extreme climates (the same with animals). The requirements have not been increased by a "margin of safety". The margins of safety are due to the variable feed composition, inadequate mixing, improper processing, and unfavorable storage conditions, which may reduce effective concentration of nutrients below those calculated to be present. In case of foods have to be transported long distances in hot climates, higher margins still of safety may be required to guard against almost total loss of vitamin value at normal levels of inclusion. The addition for a margin of safety to the stated requirements arrives at what is called nutritive "allowances" which is used in ration formulation. A chick needs 1500 IU vitamin A and 200 IU vitamin D as NRC recommends while premix supplies 10000 A and 1000 D.

The requirements stated in NRC are the minimum so in formulating diets, it is wise to increase the level of nutrients by about 10%. The NRC tables of chickens and other poultry expressed the requirements in 7 main items; ME, CP, fat, macrominerals, microminerals, fat-soluble vitamin, and water soluble ones. In total the required nutrients are 42 in number, 15 for CP and AAs, 1 fat, 12 for minerals and 13 for vitamins, in addition to energy (ME).

In tabulating the list of requirements there is no need to include the nutrients covered by the diet ingredients or premixes. Eventually in diet formulation the more critical needs ME, CP, Met + Cys, Met, Lys, Ca, av.P are considered with the inclusion of 0.5% salt (NaCl) and vitamin-mineral premix, in addition to additives needed to be added. In the following table the nutrients needed to be satisfied when formulating poultry rations are listed, the figures of NRC could be approximated and rounded to be grouped in rules of thumb easy to keep in mind.

Diet formulation is a topic that should be mastered to some degree by anyone concerned with feeding livestock or poultry. Some of commercial animals and the vast majority of poultry are produced in large units, and controlled environment, wherein the maximum science and technology should be applied and density of nutrients in ration is increased to compensate for the lowered feed consumption. Therefore different types of rations may be needed.

Table 2 Nutrient requirements of the different species of poultry (NRC, 1994)

Weeks	Kcal ME/ Kg Diet	Protein and AAs				Lino-leic acid	Ca	Av. P	Na	Cl	C/P ratio approximated
		CP	Lys	Met &Cys	Met						
Broiler chickens											
1d – 3	3200	23	1.1	0.9	0.5	1.0	1.0	0.45	0.20	0.20	140
3 – 6	"	20	1.0	0.72	0.38	"	0.9	0.35	0.15	0.15	160
6 – 8	"	18	0.85	0.60	0.32	"	0.8	0.30	0.12	0.12	180
White egg – laying strains (immature) – chickens											
1 d – 6	2900	18	0.85	0.62	0.30	"	0.9	0.4	0.15	0.15	160
6 – 12	"	16	0.60	0.52	0.25	"	0.8	0.35	"	0.12	180
12 – 18	"	15	0.45	0.42	0.20	"	"	0.30	"	"	195
18–1st egg (5% production)	"	17	0.52	0.47	0.22	"	2.0	0.32	"	0.15	170
Layers	"	15	0.69	0.58	0.30	"	3.25	0.25	"	0.13	195
Growing turkeys											
1 d – 4	2800	28	1.6	1.05	0.55	"	1.2	0.60	0.17	0.15	100
4 – 8	2900	26	1.5	0.95	0.45	"	1.0	0.50	0.15	0.14	110
8 – 12♂ 8 – 11♀	3000	22	1.3	0.80	0.40	0.8	0.85	0.42	0.12	"	140
12 – 16 11 – 14	3100	19	1.0	0.65	0.35	"	0.75	0.38	"	0.12	160
16 – 20 14 – 17	3200	16.5	0.8	0.55	0.25	"	0.65	0.32	"	"	195
20 – 24 17 – 20	3300	14	0.65	0.45	0.25	"	0.55	0.28	"	"	240
Breeder turkeys											
Holding	2900	12	0.5	0.4	0.2	"	0.50	0.25	"	"	240
Laying	"	14	0.6	"	"	1.1	2.25	0.35	"	"	210
Geese											
1 d – 4	2900	20	1.0	0.60	-	-	0.65	0.30	-	-	145
After 4	3000	15	0.85	0.50	-	-	0.60	"	-	-	200
Breeding	2900	15	0.60	0.50	-	-	2.25	"	-	-	195
Ducks											
1 d – 2	2900	22	0.90	0.70	0.40	-	0.65	0.40	0.15	0.12	130
2 – 7	3000	16	0.65	0.55	0.30	-	0.60	0.30	"	"	190
Breeding	2900	15	0.60	0.50	0.27	-	2.75	-	"	"	195

Japanese Quail											
Starting & growing	**2900**	**24**	**1.3**	**0.75**	**0.50**	**1.0**	**0.8**	**0.30**	**0.15**	**0.14**	**121**
Breeding	**2900**	**20**	**1.0**	**0.70**	**0.45**	**1.0**	**2.5**	**0.35**	**"**	**"**	**145**
Bob white Quail											
0 – 6	**2800**	**26**	**-**	**1.0**	**-**	**1.0**	**0.65**	**0.45**	**0.15**	**0.11**	**108**
After 6	**2800**	**20**	**-**	**0.75**	**-**	**1.0**	**0.65**	**0.30**	**"**	**"**	**140**
Breeding	**2800**	**24**	**-**	**0.90**	**-**	**1.0**	**2.4**	**0.70**	**"**	**"**	**117**
Ring – Necked Pheasants											
0 – 4	**2800**	**28**	**1.5**	**1.0**	**-**	**-**	**1**	**0.55**	**-**	**-**	**100**
4 – 8	**"**	**24**	**1.4**	**0.93**	**-**	**-**	**0.85**	**0.50**	**-**	**-**	**120**
9 – 17	**2700**	**18**	**0.8**	**0.6**	**-**	**-**	**0.53**	**0.45**	**-**	**-**	**150**
Breeding	**2800**	**15**	**0.68**	**0.6**	**-**	**-**	**2.5**	**0.40**	**-**	**-**	**190**

Note:

- For values not listed in quails and pheasants see requirements for turkeys.
- ME = metabolizable energy, CP = crude protein, Lys = lysine, Met = methionine, Cys = cystine, Av. P = available phosphorus, C/P ratio= calorie/ protein ratio, d = day.
- The vitamins and rest of mineral elements are supplied by feed ingredients and added premix. As Na is needed at a percentage of 0.12 – 0.20 and as NaCl contains 39% Na so 0.31 to 0.51% salt is needed and it can be considered as an "allover" percentage 0.5% in all diets. If an animal protein source is used its salt content should be considered. The 15 AAs mentioned in NRC tables are satisfied by different diet ingredients, except Met and Lys which are available in the market at a commercial price. The percentage of the commercial AAs added differs according to the content of diet feeds.
- Linoleic acid is supplied by corn, the main source of diet energy.
- No K or Mg are needed to be supplemented.
- The need of the bird for ME is expressed by Kcal / kg diet and the need of the protein by the amount in 100 units diet (in percentage). Energy is used as the basis to which the rest of nutrients are related. If for example a diet is formulated to contain 80% of the optimal ME density, the rest of the nutrients should be decreased in its concentration to the same percentage. If the density of ME is increased to 120% the concentration of the nutrients is also increased. As protein is one of the main nutrients and highly expensive so the C/P ratio stated should be strictly followed in calculating CP%.
- The bird decreases its feed intake when energy density increased, but as the regulation is not precise, so the optimal ME density in NRC tables should be followed (or in the breed catalogue).
- C/P ratio = Amount of energy (ME) in Kcal in 1 kg diet ÷ CP percentage.
  Example = 3200 ÷ 20 = 160
- ME is in Kcal/ kg diet, other nutrients are in percentage except Mg and trace elements in mg/ kg and also the water-soluble vitamins. Fat-soluble vitamins are in international units per kg except vitamin K is in mg.
- Total period before laying: chicken 21 wk, turkey 32 wk, duck 6 mo, geese 24 mo.

Nutrient composition of feeds and extracted semiextensive tables to ease calculations

Table 3 Feed composition (figures are approximated and rounded)*

	ME Kcal/kg	CP %	Met + Cys %	Met %	Lys %	Ca %	Av. P %	Total P
Corn	3330	9	0.36	0.18	0.26	-	0,08	0.28
SBM	2330	44	1.28	0.62	2.69	-	0.27	0.65
FM	3000	72	3.6	2.16	5.50	2.33	1.70	
Bran	1300	14	0.50	0.21	0.55	-	-	1.15
Fat	8500	-	-	-	-	-	-	
Di Ca-P	-	-	-	-	-	22	18	
Mono Ca-P	-	-	-	-	-	16	20	
LS	-	-	-	-	-	35	-	

* The figures are approximated to ease calculations, and corn and SBM and bran are considered to contain no Ca.

The process of ration formulation by hand

The process leads to empirical, rather than a "least cost" formula being prepared. The task may be simplified by using a protein-vitamin –and- trace mineral concentrate, thus reducing task of formulation to the best combination of cereals and perhaps of one vegetable protein rich ingredient.

There are two main methods (mathematical or algebraic and Pearson's square) of balancing diets for one or two nutrients using two or more ingredients, in addition, in some times, to using ingredients at fixed levels. If we want to add more nutrients, we will require more than three squares and will be tedious to formulate by hand.

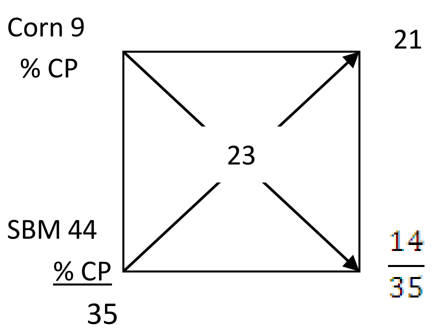
I- Pearson's square method

Some individuals prefer to formulate simple diet using the square method. The amounts of the ingredients are the unknowns. In the square method, diet is balanced for one nutrient, or in double square method, for two nutrients using two or more ingredients respectively.

How to use the square

Place the desired percentage of protein in the center of the square. Place the percentage of protein in each of two main feeds say corn and SBM at the left hand corners of the square (refer to the composition table). Subtract diagonally the smaller percentage from the larger one and place the answer in the right-hand corners of the square. The figures on the right hand corners are called parts. The parts can be totaled and the individual parts are changed to percentage (individual parts ÷ total parts × 100). The following is an example.

An example for ration formulation



Percentage of corn 21 ÷ 35 × 100 = 60

Percentage of SBM 14 ÷ 35 × 100 = 40

Suppose we need to formulate a starter chicken broiler diet having a characteristic of 23% CP, 1.1% lysine, 0.9% Met + Cys, 0.5% Met, 1% Ca, 0.45% P and 0.2% Na. The ingredients nominated to be used are corn, SBM, wheat bran, fat – and for supplements dicalcium phosphate, limestone, salt, vitamin – mineral premix, Met and Lys amino acids.

In spite of being logical to start with the square and CP, some problems should be first solved. The problems are:

1. Neutralizing the diluting effect of the supplements on ME and CP.
2. The amount of ME and CP in the corn/ SBM mixture.
3. Correcting the C/P ratio if no fat is added or increasing or decreasing the ME and CP using fat and wheat bran.

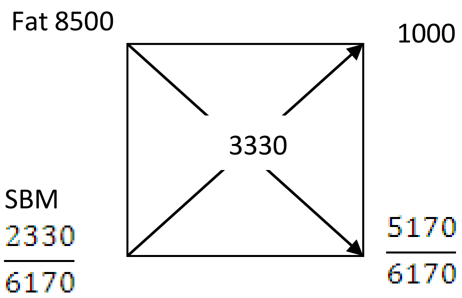
The first step is to calculate the needed supplements.

- Supplements

Na: 0.2 ÷ 0.39 = 0.51 salt (NaCl)
P: 0.45 ÷ 0.18 = 2.5 dicalcium phosphate
(The small amounts of av. P in feeds are not considered)
Ca in dicalcium phosphate = 2.5 × 0.22 = 0.55
The balance of calcium needed = 1.0 – 0.55 = 0.45
Amount of LS for Ca needed = 0.45 ÷ 0.35 = 1.29
Total supplements = 0.51 + 2.5 + 1.29 = 4.30
Corrected CP = 23 ÷ (100 - 4.30) × 100 = 24.033
Corrected ME = 3200 ÷ (100 – 4.30) × 100 = 3343.78
The correction can also be performed by multiplying both of the figures on the left hand corners by the balance of 100 (100 – 4.30 = 95.70).

- The square is then used to make a mixture of corn and SBM satisfying the CP (24.033) then the ME of the mixture is calculated and corrected by substituting a mixture of fat and SBM in place of corn. Generally the mixtures for correction are one of two as follows:

a- Increasing the protein content of the mixture using a mixture of fat and SBM mixed at the ME of corn, when the diet is first balanced for the corrected ME.

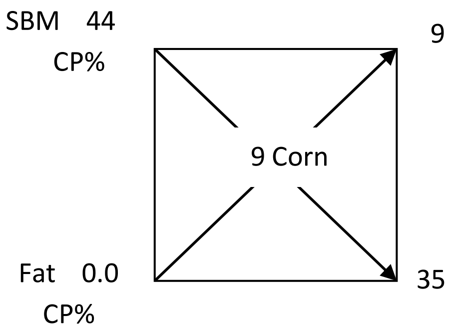


Fat % = 1000 ÷ 6170 × 100 = 16.21

SBM% = 570 ÷ 6170 × 100 = 83.79

Every addition of one unit of the mixture in place of corn will increase CP by 0.2787 or roundly 0.28.

b- Increasing the ME content using a mixture of fat and SBM mixed at the CP% of corn, when the diet is first balanced for the corrected CP.



SBM % = 9 ÷ 44 × 100 = 20.45

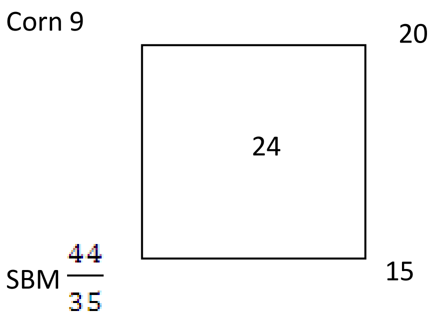
II

Fat% = 35 ÷ 44 × 100 = 79.55

Every addition of one unit of the mixture in place of corn increases ME by 39.08 or roundly 39.

Other formulations may need the CP or the ME to be decreased. The methods are using a mixture of wheat bran and corn mixed at the ME of SBM for decreasing the percentage of CP, and using bran to be added in place of corn and SBM for decreasing the ME content.

The mixtures satisfying the CP (24.033% or 24.0) are:



or 57.14% × 0.957 = 54.68 corn

(in 100 units) (in 95.7 units)

or 42.86 % × 0.957 = 41.02 SBM

The ME content of the mixture 1817.98 for corn plus 957.77 for SBM with a total of 2775.75, so the ME is needed to be increased by SBM/ fat mixture (II) in place of corn.

3200 – 2775.75 ÷ 39 = 10.88 (2.22 SBM and 8.66 fat).

∴ The diet is composed of the following main ingredients:

Corn 54.68 – 10.86 = 43.82

SBM 41.02 + 2.22 = 43.24

Fat 8.64

95.70

•The content for Met + Cys = (43.82× 0.36 ÷ 100) + (43.24 × 1.28 ÷ 100) = 0.158 + 0.556 = 0.714 and containing (43.68×0.18 ÷ 100) + (43.24×0.62 ÷ 100) = 0.347 methionine.

On the basis of Met + Cys calculation it is needed to be supplemented by 0.186 Met (the need is 0.9) and on the basis of Met calculation needs only (0.5 – 0.347) 0.153 so the supplement will be the higher figure 0.186.

•The content for lysine = (43.68×0.26 ÷ 100) + (43.24×2.69 ÷ 100) = 0.114 + 1.166 = 1.28

So there is no need for lysine addition as the need is only 1.1%.

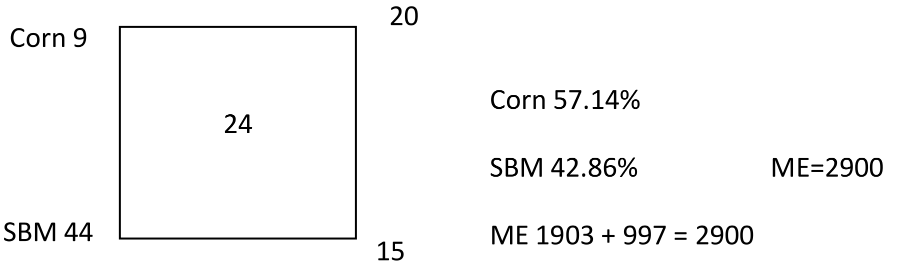
Salt 0.51%, dicalcium phosphate 2.5%, LS 1.29% and kg per ton Met 1.86, Lys 0.0, premix for vitamins and minerals, and additives if needed.

II- Double square method

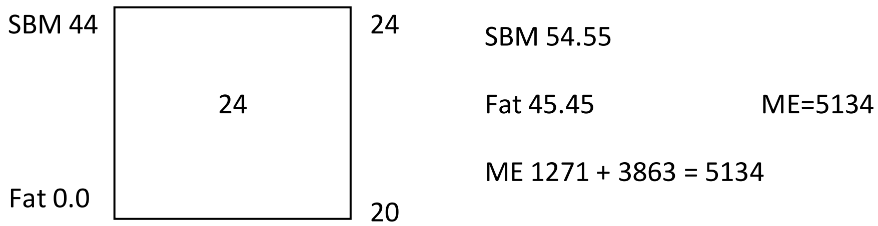
In many situations we need to have exact amounts of the two major nutrients, such as CP and energy. We can accomplish this by going through three squares as shown below.

Suppose we need to formulate a starter diet with 23% CP and 3200 ME. Supplements are calculated as before and CP is corrected to 24% and ME to 3344.

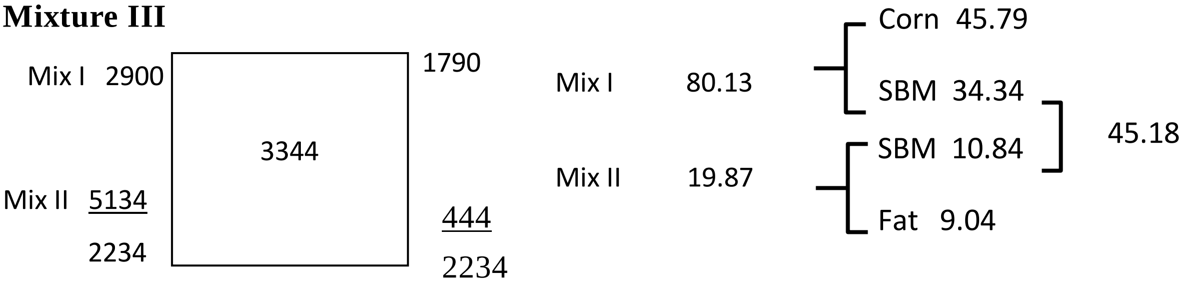
Mixture I



Mixture II



Mixture III



∴ The end mixture is composed of 45.79 corn, 45.18 SBM and 9.04 fat, each should be multiplied by 0.957 to be 43.82 for corn, 43.24 for SBM and 8.65 for fat. The result is the same as in "one square" method and fat/SBM correction.

Of course the CP% and ME/ Kg are determined after calculating the supplements and consider it for the correction.

Introduction of fish meal in the diet formulation

In introducing FM, a certain percentage is designed to be added and after correcting the ME and CP for the amount the FM shares by, the amount of FM is added to the supplements and the balance of ME and CP is only considered. Or FM can be also added by means of substitution as follows:

0.41 FM + 0.59 corn = 0.80 SBM + 0.16 fat + 0.04 diCaP

∴ For every 1 unit FM add 1.45 corn, and remove 1.95 SBM, 0.40 fat and 0.1 dicaP. For one unit FM percent added remove 0.003 LS, and replace it by corn, and from each ton 0.12 kg Met and 0.06 Lys.

III- Trial and error method

Feeds are interchanged by trial - and - error until the right combination is found. This is a time - consuming process. A knowledge about the approximate amounts of the different ingredients is the basis for starting formulation.

IV "Simultaneous equations" method

In our opinion the "simultaneous equations" method, suggested for large animals, is not suitable for formulating poultry diets as it gives the corn and SBM in weight units and it should be transformed into percentage, giving incorrect result.

V- Calorie/ protein ratio method (Abdel-Hafeez, unpublished)

Another method is suggested (unpublished) in which the proportions of corn and SBM are calculated for different calorie/ protein ratios basing on ME and CP and using an unpublished suggested equation.

Establishment of the equation

Suppose Y percent units in a total of 1 kg SBM are replaced with Y of corn, the C/P ratio of the mixture will equal:

C/P ratio of the mixture =

$$\frac{\text{2330 (ME of 1 kg SBM) + 10 (difference between one unit percent corn \& and one unit SBM, ME) Y}}{\text{44 (CP\% of SBM) – 0.35 (difference in CP \%) Y}}$$

From this equation two equal sides are developed

(C/P ratio × 44) – (C/P ratio x 0.35) Y = 2330 + 10 Y

∴ (C/P ratio × 44) – 2330 = [(C/P ratio × 0.35) + 10] Y

$$\therefore \text{Y or units percent corn} = \frac{\text{(C/P ratio x 44) – 2330}}{\text{(C/P ratio x 0.35) + 10}}$$

Using these equations the proportions of corn and SBM could be determined for all the C/P ratios of poultry diets as follows:

Table 4 Corn/ SBM mixtures of certain calorie – protein ratios

C/P ratio	Ingredient Corn	proportion SBM	CP%	Met + Cys%	Met%	Lys%
100	46	54	27.90	0.867	0.418	1.562
110	51.75	48.25	25.89	0.816	0.394	1.423
120	56.73	43.27	24.14	0.771	0.373	1.303

130	61.08	38.92	22.62	0.732	0.354	1.198
140	64.92	35.08	21.28	0.698	0.338	1.106
150	68.32	31.68	20.09	0.667	0.323	1.023
160	71.36	28.64	19.02	0.640	0.310	0.950
170	74.10	25.90	18.06	0.615	0.298	0.884
180	76.58	23.42	17.20	0.593	0.288	0.824
190	78.82	21.18	16.41	0.573	0.278	0.770
200	80.88	19.12	15.69	0.555	0.270	0.720
210	82.75	17.25	15.04	0.538	0.261	0.675
220	84.48	15.52	14.43	0.522	0.254	0.633
230	86.08	13.92	13.87	0.508	0.247	0.595
240	87.55	12.45	13.36	0.495	0.241	0.559
250	88.92	11.08	12.88	0.483	0.235	0.526
260	90.20	9.80	12.43	0.471	0.230	0.495
270	91.39	8.61	12.01	0.461	0.225	0.467
280	92.50	7.50	11.63	0.451	0.220	0.440

The corn and SBM can be corrected and fat added to satisfy a certain amount of CP and ME, using the mixtures previously mentioned. The amounts of the different ingredients are corrected considering the total of the supplements added; in the previous example the amounts are multiplied by 0.957.

The following are, in general, the steps which should be taken in an orderly fashion to formulate an economical ration, for poultry without using computer:

1. Find and list the nutrient requirements and/ or allowances for the particular poultry going to be fed.
2. Choose the most nutritious and cheap protein concentrates if available.
3. Calculate the amount of nutrients (ME, CP, Ca, av. P, salt, methionine and lysine) satisfied by the added percentage of the protein concentrate or fish meal if it is going to be added.
4. Deduct the nutrients in the protein concentrate, or fish meal, from that required to extract the amounts needed to be satisfied by any other feeds available.
5. Meet the needs for Ca & P by using limestone, bone meal or any other supplement. Meet the needs for the common salt.
6. Correct the ME and CP for the FM, protein concentrate, or supplements added.
7. Using for example yellow corn and soybean oil meal to meet the requirements for ME and CP, an algebraic method should be used to calculate the percentage mixed of each of the two feeds. The CP or ME should be corrected using SBM and fat mixtures. The percentages of the ingredients are corrected to make a total of 100 %.
8. Calculate the amount of methionine and lysine the corn / SBM mixture will contain and the balance is supplemented using methionine and lysine amino

acids, available in Kg in the market (in units per ton). Add vitamin/ mineral premix and additives if needed.

9. Check the calculations and the end formula, using the formulation sheet, before mixing.
10. Without the addition of fat, energy density will be lower than optimal and so the amount of Ca, P, salt and AAs can be corrected to keep the calorie or energy/ nutrient ratios as needed.

Chicken Feed formulas

(Supplements approximated)

Phase	Corn %	SBM %	Fat %	Bran %	LS %	DiCaP %	Salt %	Met per ton	Lys per ton	Premix Per ton
Broilers										
0 – 3	42.62	43.58	9.30	-	1.5	2.5	0.5	1.90	-	+
	62.0	33.5	-	-	"	"	"	2.33	0.5	+
3 – 6	55.05	34.21	6.74	-	1.5	2.0	0.5	0.80	-	+
	68.5	27.5	-	-	"	"	"	1.0	1.0	+
6 – 8	62.36	28.09	5.97	-	1.33	1.75	0.5	0.4	-	+
	73.84	22.58	-	-	"	"	"	0.5	0.75	+
Layers										
0 – 6	No need for fat									
	67.25	26.27	-	2.4	1.33	2.25	"	-	-	+
6 – 12	No need for fat									
	70.33	19.16	-	6.76	1.25	2.0	"	-	-	+
12 – 18	No need for fat									
	74.21	16.21		5.60	1.33	1.75	"	-	-	
18-1st	66.5	25.27	1.22	-	4.75	1.75	"	-	-	
	68.91	24.09	-	-	"	"	"	-	-	
Layer	65.64	20.75	3.11	-	8.50	1.5	"	0.78	-	+
	71.48	18.02	-	-	"	"	"	0.5	-	

Turkey feed formulas

(Supplements approximated)

Phase	Corn %	SBM %	Fat %	Bran %	LS %	DiCaP %	Salt %	Met per ton	Lys per ton	Premix Per ton
0 – 4	33.71	56.76	4.20	-	1.5	3.33	0.5	2.0	-	+
	43.55	51.12	-	-	"	"	"	2.25	1.0	+
4 – 8	41.09	50.72	3.69	-	1.25	2.75	"	1.5	0.3	+
	49.42	46.08	-	-	"	"	"	1.75	1.33	+
8 – 12	50.79	39.62	5.51	-	1.25	2.33	"	1.1	1.0	+
	62.27	33.65	-	-	"	"	"	1.33	2.5	+
12-16	63.3	30.25	2.70	-	1.0	2.25	"	0.5	0.2	+
	68.68	27.57	-	-	"	"	"	0.5	1.0	+
16-20	68.76	23.52	4.57	-	0.9	1.75	"	0.2	-	+
	77.35	19.50	-	-	"	"	"	0.10	1.0	+
20-24	75.40	16.36	5.49	-	0.75	1.50	"	0.10	0.14	+
	85.14	12.11	-	-	"	"	"	0.25	1.25	+
Holding	-	-	-	-	-	-	-	-	-	-
	74.78	6.85	-	15.62	"	"	"	-	-	+
Laying	74.74	16.59	0.84	-	5.33	2.0	"	-	-	+
	76.27	15.90	-	-	"	"	"	-	-	+

- The diets were formulated according to the analysis of the ingredients shown in table 3.

- Supplements, except AAs, can be reduced in the diets containing no fat.

- These are the basal diets will be subjected to pelleting and addition of additives as probiotic, prebiotic, and synbiotic and enzymes. The improvement may reach to more than 25% in the bird growth and feed intake. As high live weight gain is at a premium a suitable growth promotant is now induced in the diet as a matter of routine.

V- Feeding of Rabbits

Contents

Feeding of Rabbits

Introduction

The importance of rabbit feeding during a time of food scarcity must be stressed, for the rabbit converts waste products into meat for human food more efficiently than other animals.

The correct nutrition of the domestic rabbit is perhaps the most important aspect of rabbit keeping. The rabbit can be fed on a very wide range of feedingstuffs. The variety means that the feeding - program will be adapted to circumstances of the breeder. Rabbit can be kept on household and garden residues.

Commercial operations must produce at least 6 litters per doe annually to make a profit. To attain that, young rabbits are weaned at 3-4 weeks of age and raised separately from their mother until they reach market weight, generally at 8-9 weeks of age. Intensive breeding programs require that doe be rebred anywhere from 14 to 30 days after kindle, whereby 8 litters per doe are produced annually. Since one doe can produce from 4-6 litters, she has the ability to produce from 130 to 250 pounds of live meat through her reproductive ability. In large operations one buck is kept for 10-15 does (better 5-10) and produces more than 500 offspring annually. From this, it may be concluded that one buck and 4 does producing 4 litters each can produce more meat annually than an average beef cow-and produce it on less feed. Rabbits are also used extensively in biomedical teaching and research.

Economic importance of rabbits

Rabbits compare very favorable in feed conversion with the more traditional animals (rabbit 3:1, broilers 2.2-2:1, while steer 9:1). Protein efficiency in rabbits is 6:1, compared to 1.9:1 in broilers and 10.6: 1 in steers. Since rabbit possesses an enlarged cecum, similar to that of the horse, it can digest and absorb most roughages and forages, to a limited degree (less competition with humans for feedstuffs).The meat of the domestic rabbit is white and contains little fat. Close to 80% of the carcass is edible thus making it an efficient meat-producing 'animal (dressing % is about 55%).

When rabbits are raised for meat production it reaches to a weight of more than 2 kg at 8 weeks or to more than 2.5 kg at 10 weeks. Bucks can be used for breeding at the age of 6 months (better at 8-10 months) and a buck can fertilize 2-3 does in half an hour (bucks better to be used 3 times weekly).

The productive life for bucks or does is 2-3 years. And a doe is ready for fertilization at 5 months and it is better to be at 6-7 months.

Nutritive needs

Rabbits are nonruminant herbivores. The digestive anatomy and physiology closely resemble the horse and in many ways the requirements are similar. Several differences, such as the habit of coprophagy (the ingestion of fecal material) and decreased fiber utilization in rabbits, alter the requirements somewhat. Nevertheless, the types of feeds used for rabbits and horses are very similar.

Coprophagy plays an important role in the modification of their nutritive requirement (as early as 3 weeks of age). This act aids in the absorption of some of the essential amino acids and certain vitamins (K and B complex).By recycling the digesta certain feeds are digested and absorbed that were not utilized the first time. Also some fiber digestion takes place in the cecum.

National Research Council (NRC) Requirements

NRC has established requirements although very little data has been published. For feeding the raising can be divided into several stage periods:

1- The suckling period to the weaning time (30-40 days on maximum).
2- Rabbits raised as a breeding stock from 1 to 5 months.
3- Rabbits raised for meat production to the age of 10 weeks.
5- Nonpregnant does. 5- Pregnant does. 6- Lactating does. 7- Adult bucks.

Refer to Cheeke (1987) requirement table, at the end of the chapter.

Nutrients

Energy

The energy demands of the doe are high if she is to produce 8 litters a year. Likewise growth creates a high energy requirement. Good quality legume hays and supplemental concentrates or commercial pellets are routinely used to supply a high level of energy during peak production periods. The energy requirements for maintaining dry does or young bucks not in service are low with the result that good-quality hay should be sufficient.

The NRC (1977) advised a digestible energy of 2500 Kcal/kg diet for growth, gestation and lactation if the rabbits are fed ad libitum. The density decreased to: 2100 Kcal/kg in case of maintenance.

While no requirement for dietary fat has been established rations routinely contain 2.0- 5.5% fat. Higher fat levels might be feasible, but caution should be exercised to prevent digestive disturbances as scours.

Protein

All production parameters require high levels of good-quality protein. Unlike ruminants, rabbits have been shown to require certain AA in the diet. The EAA profile is very similar to that of the chick and the pig.

Non-protein nitrogen (NPN), such as urea, is of little value in rabbit rations. It is degraded and absorbed in the small intestine and subsequently eliminated as waste products before the NPN ever reaches the cecum where it might be transformed into bacterial protein.

Coprophagy has been shown to increase the biological value of certain low-quality proteins. With the high-quality the increase is not large.

Legumes are excellent sources of protein, and alfalfa is used extensively in rabbit rations. Oilseed meals are widely used as protein supplements when high-protein levels are required. Animal and fish products are seldom included in rabbit diets because of their high costs.

The CP% in rations fed ad libitum is 16% for growth, 12% for maintenance, 15% for gestation and 17% for lactation (NRC, 1977) while it is advised by others to be 18%, 14%, 16-18% & 16-18% respectively.

CSM may contain high levels of gossypol, making the ration unpalatable and toxic. The toxic effects of gossypol can be reduced by the addition of iron salts to the diet. Some raw beans including raw SB as well as SBM have been reported to affect animal performance due to high contents of antitrypsin factors and other growth depressant compounds.

Minerals

Sodium chloride (salt)

Added at the rate of 0.5-1% (in deficiency of I iodized salt is used). Rabbits enjoy salt, and if a salt spool is available; they will satisfy their requirements. The disadvantage of salt spools, especially in all-wire hutches, is that the salt is corrosive to the metal.

Calcium and phosphorus

Excess of Ca affects the requirements of other minerals as Mg and P. When formulating rations the producer should make sure that the Ca/P ratio falls in the range 1:1 to 1.5:1 otherwise imbalances occur.

Rabbits raised on low- P soil- alfalfa showed:

1- Retarded growth.

2 - More matings per conception.

3- Lower breaking strength of bone.

It was found that a large portion of the cereal phosphorus is not readily available. Also almost of the P of the protein-rich supplements of plant origin is found in a bound form.

Potassium

A form of muscular dystrophy which resembles a deficiency of vitamin E occurs in rabbits suffering from K deficiency. Generally a diet consisting of 50% roughage is adequate in fulfilling the K requirement of rabbits.

Cobalt

Since the microorganisms of the cecum have the ability to synthesize vitamin B_{12}, all the precursors-including Co-must be supplied. No quantitative requirement for Co has been established.

Iodine

The needs have not been determined; however it is recommended that iodized salt be used routinely. Rations could contain at least 0.22 mg of iodine /kg.

Iron and Copper

Deficiency causes anemia and requirements are similar to those of the horse.

The rest of minerals

The amounts needed could be reviewed in the NRC and Cheeke tables.

Vitamins

The amount of information, as with minerals, is very limited.

Fat-soluble vitamins

Vitamin A & E are probably the only two vitamins for which there is a serious need for dietary supplementation.

Vitamin A

Requirement for gestation is double that for growth and generally the deficiency affect the reproductive performance of the female before other symptoms can be recognized. Premature degeneration of ova, reduced numbers of fertile ova, abortion, or resorption of fetuses in the latter part of gestation occur in the adult female suffering from" A "-deficiency. Offspring from a .deficient female may be hydrocephalic at birth. 50 ug/kg body weight prevents the symptoms of deficiency.

Vitamin D

Exposure to sunlight supplies the needs for vitamin D. Deficiency (rabbits reared in confinement) causes rickets.

Vitamin E

The NRC suggests a need for a level of 40 mg/kg diet. Unlike other animals Se does not exert a vitamin E-sparing effect. Symptoms of deficiency are muscular dystrophy, reproductive failure, and fatty livers.

Unlike the situation in some other animals, vit.E deficiency does not affect the fertility of the rabbit but produce muscular dystrophy. The feeding of excessive amount of cod liver oil, by destroying the vit.E content of the rations may thus produce this trouble. Vit.E itself is present in fresh green foods, in cereal grains and particularly in the cereal germ.

Vitamin K

Bacterial synthesis and coprophagy should supply the needs. However research has indicated that K is required for reproduction (0.22 mg/Kg diet for pregnant does). If drugs are being used that could reduce the microflora of the gut, supplemental K may be indicated.

Water-soluble vitamins

The requirements for pantothenic, B2, biotin, folic & $B_{12}$are met through bacterial synthesis in the cecum. Research has indicated that some supplementation of niacin, pyridoxine, and choline will aid in production. Cobalt must be supplied for B_{12} synthesis.

In spite of being that the bacterial population of the caecum' manufacture these vitamins, there have, however, been reports of poor growth & reproductive failure due to lack of these vitamins.

Maintenance requirements

In addition to the basal metabolic energy required, if the animal is to move about, digest food, more energy will be required. It is common practice to double the basal metabolic rate to arrive at a figure for the amount of energy which the rabbit requires to maintain itself. The animal eats from 3 to 4% of its weight as a total daily food.

Requirements for growth

The growth of rabbit is extremely rapid and consequently its nutritive requirements are relatively high during the early period of life. Ration should contain about 18% protein. Well-fed animal will develop much more quickly than the poorly fed and maturity in body growth is closely related to maturity in sexual development. Also fertility and good bodily condition are closely related. Excessive fatness and very poor condition both lead to sterility. Improved nutrition is the essential cause of the highest percentage of fertile matings in the green season.

Requirements for pregnancy

For the production of healthy well developed young and a satisfactory milk supply in the doe, her nutrition must be on a rising plane throughout pregnancy. It is particularly during the last half of pregnancy that the main requirements come (1.33 maintenance at the start of pregnancy rising to double the maintenance at the end). We need more protein and more mineral; (protein 16-18% and minerals 5-6%). The size of the mother has the greatest influence which affects the birth size and the litter size.

Requirements for lactation

A satisfactory doe will produce approximately half an ounce of milk per pound body weight each day. The milk contains 13-15% protein, 10-12% fat, and 2.3% minerals. The gross energy is about 1000 Kcalories/Ib compared with 350 Kcalories per Ib of cow's milk and 750 kcal for milk of bitch. The efficiency with which food energy is turned into milk varies but is in the region of 45%. The needs for lactation are approximately on the same level at the end of pregnancy (double maintenance). The total needs of the doe, allowing also a small proportion for her young when they first start eating food, may rise as high as four times maintenance at the end of the fourth week of suckling.

As the quality of the milk protein is very good so if possible animal protein should be incorporated in the first feeds of the young. Mineral requirements for lactation are the same as in pregnancy (except for Ca & P).

Requirements for the stud buck

To remain vigorous and in good health requires more than the normal maintenance ration. Approximately 10-15% above maintenance both of TDN and DCP is satisfactory.

Digestibility of feeding stuffs

There are many factors affecting the digestibility probably the most important is the fiber content. Young animals can digest this matter to a very limited extent. Generally if the fiber content is more than 20% the ration is liable to cause digestive disturbance.

Water requirements for rabbits

The water requirements of rabbits is higher in youngs than in old ones and thus shortage of it in early life has much more serious effect and even a restricted amount of water may seriously retard growth. Thus for medium sized breeds on maintenance ration the requirements would be between 3/4 and 1 pint per day. The requirements for young animals probably in the region of double that of the adults.

The suckling doe will require considerable amounts for the production of an adequate milk supply.

Coprophagy (Pseudo-rumination)

The contents of the caecum is normally a thick fluid and at certain periods contractions of the caecum force some of this material through the colon and rectum thus forming the peculiar type of pellet eaten by the rabbit during coprophagy. The final residue of the twice digested food passes through the colon wherein much of the moisture is removed and the normal faecal pellets formed these latter passing through the rectum and being excreted.

As mentioned above the normal healthy rabbit forms two kinds of faecal pellets. One type is that normally seen on the floor of the hutch, the other type is never normally seen as it is taken directly from the anus by the rabbit and swallowed.

At least half and probably more of the material excreted by the rabbit is reingested as coprophagous pellets.

Several reasons for the peculiar physiological habit have been advanced. On a dry matter basis, the coprophagous pellets contain 3.5 times as much crude protein, as do the normal pellets but only a third of the fiber. In addition it contains a considerable amount of vitamins B-complex. There is little doubt therefore that part at least of the explanation of this process lies in the increased efficiency of digestion and the production of some at least of the animal's vitamin requirements. The habit can be observed at many times of the day.

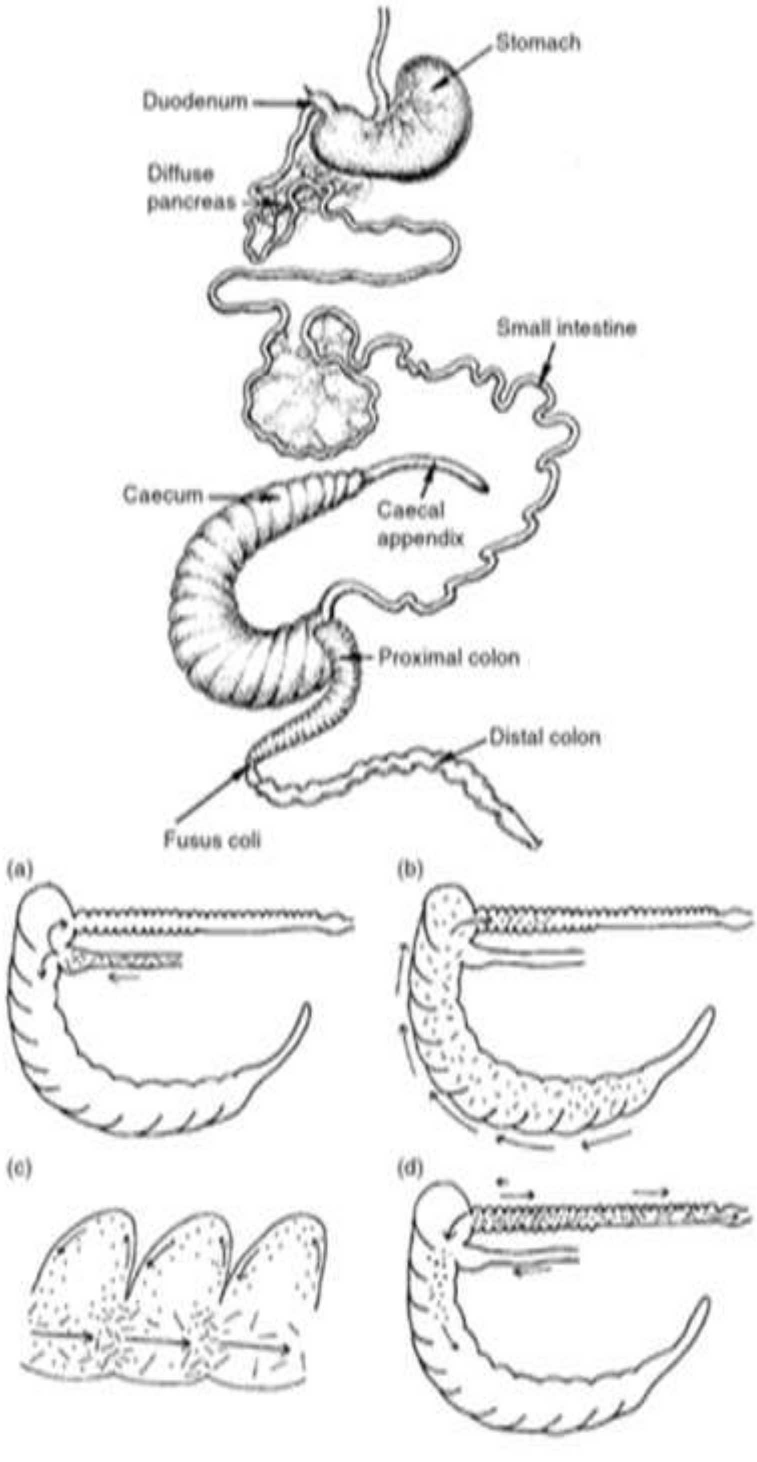


Figure 2 schematic views of parts of the rabbit digestive tract (top) and the mechanism of the selective excretion of fiber and retention of small particles and solubles for fermentation in the cecum of the rabbit. (a) Intestinal contents '"enter the hindgut at the ileocecal-colonic junction and uniformly disperse in the cecum and colon. Dashes represent large fiber particles, and dots represent non-fiber particles; b) Contraction of the cecum moves material into the proximal colon. (c) Peristaltic action moves large fiber particles (dashes) down the colon for excretion as hard feces. Contractions of the haustrae of the colon move small particles (dots) and fluids (backwards into the cecum. (d) Small particles and fluids are thus separated from fiber (Cheeke, 1987-lower part of the figure).

TABLE 1 Nutrient Requirements of Rabbitsof *Ad Libitum* (Percentage or Amount per kg of Diet), NRC (1977)

Nutrients[a]	Growth	Maintenance	Gestation	Lactation
Energy and protein				
Digestible energy (kcal)	2,500	2,100	2,500	2,500
TDN (%)	65	55	58	70
Crude fiber (%)	10-12[b]	14[b]	10-12[b]	10-12[b]
Fat (%)	2[b]	2[b]	2[b]	2[b]
Crude protein (%)	16	12	15	17
Inorganic nutrients				
Calcium(%)	0.4	-[c]	0.45[b]	0.75[b]
Phosphorus (%)	0.22	-[c]	0.37[b]	0.5
Magnesiun(mg)	300-400	300-400	300-400	300-400
Potassium (%)	0.6	0.6	0.6	0.6
Sodium (%)	0.2[b,d]	0.2[b,d]	0.2[b,d]	0.2[b,d]
Chlorine (%)	0.3[b,d]	0.3[b,d]	0.3[b,d]	0.3[b,d]
Copper (mg)	3	3	3	3
Zinc	-[c]	-[c]	-[c]	-[c]
Iron	50	50	50	50
Manganese mg)	8.5[e]	2.5[e]	2.5[e]	2.5[e]
Iodine (mg)	0.2[b]	0.2[b]	0.2[b]	0.2[b]
Vitamins				
Vitamin A(IU)	580	-[c]	>1160	-[c]
Vitamin A as Carotene(mg)	0.83[b,e]	-[f]	0.83[b,e]	-[f]
Vitamin D	-[g]	-[g]	-[g]	-[g]
Vitamin E(mg)	40[h]	-c	40[h]	40[h]
Vitamin K(mg)	-[i]	-[i]	0.2[b]	-[i]
Niacin(mg)	180	-[j]	-[j]	-[j]
Pyridoxine(mg)	39	-[j]	-[j]	-[j]
Choline(g)	1.2[b]	-[j]	-[j]	-[j]
Amino acids (%)				
Lysine	0.65	-[g]	-[g]	-[g]
Methionine+cysteine	0.6	-[g]	-[g]	-[g]
Arginine	0.6	-[g]	-[g]	-[g]
Histidine	0.3[b]	-[g]	-[g]	-[g]
Leucine	1.1[b]	-[g]	-[g]	-[g]
Isoleucine	0.6[b]	-[g]	-[g]	-[g]
Phenylalanine+tyrosine	1.1[b]	-[g]	-[g]	-[g]
Threonine	0.6[b]	-[g]	-[g]	-[g]
tryptophane	0.2[b]	-[g]	-[g]	-[g]
valine	0.7[b]	-[g]	-[g]	-[g]
glycine	-[c]	-[g]	-[g]	-[g]

a Nutrients not listed indicate dietary need unknown or not demonstrated.
b May not be minimum but known to be adequate.
c Quantitative requirement not determined, but dietary need demonstrated.
d May be met with 0.5 percent Nacl.
e Converted from amount per rabbit per day using an air-dry feed intake of 60 g per day for a 1-Kg rabbit.
f Quantitative requirement not determined.
g Probably required, amount unknown.
hEstimated.
i Intestinal synthesis probably adequate.
j Dietary need unknown.

TABLE 2 Nutrient Requirements of Rabbits

Nutrient	Growing 4 to 12 weeks	Lactation	Gestation	Maintenance	Does and Litters Fed One Diet
	Class of Rabbit				
Crude protein, %	15	18	18	13	17
Amino acids, %					
Sulfur amino acids	0.5	0.6	-	-	0.55
Lysine	0.6	0.75	-	-	0.7
Arginine	0.9	0.8	-	-	0.9
Threonine	0.55	0.7	-	-	0.6
Tryptophan	0.18	0.22	-	-	0.2
Histidine	0.35	0.43	-	-	0.4
Isoleucine	0.60	0.70	-	-	0.65
Valine	0.70	0.85	-	-	0.8
Leucine	1.05	1.25	-	-	1.2
Phenylalanine	1.20	1.40	-	-	1.25
Crude fiber, %	14	12	14	15-16	14
Indigestible fiber, %	12	10	12	13	12
Digestible energy, kcal/kg	2,500	2,700	2,500	2,200	2,500
Metabolizable energy, kcal/kg	2,400	2,600	2,400	2,120	2,410
Fat, %	3	5	3	3	3
Minerals					
Calcium, %	0.5	1.1	0.8	0.6	1.1
Phosphorus, %	0.3	0.8	0.5	0.4	0.8
Potassium, %	0.8	0.9	0.9	-	0.9
Sodium, %	0.4	0.4	0.4	-	0.4
Chlorine, %	0.4	0.4	0.4	-	0.4
Magnesium, %	0.03	0.04	0.04	-	0.04
Sulfur, %	0.04	-	-	-	0.04
Cobalt, ppm	1	1	-	-	1
Copper, ppm	5	5	-	-	5
Zinc, ppm	50	70	70	-	70
Iron, ppm	50	50	50	50	50
Manganese, ppm	8.5	2.5	2.5	2.5	8.5
Iodine, ppm	0.2	0.2	0.2	0.2	0.2
Vitamins					
Vitamin A, IU/kg	6,000	12,000	12,000	-	10,000
Carotene, ppm	0.83	0.83	0.83	-	0.83
Vitamin D, IU/kg	900	900	900	-	900
Vitamin E, ppm	50	50	50	50	50
Vitamin K, ppm	0	2	2	0	2
Vitamin C, ppm	0	0	0	0	0
Thiamin, ppm	2	-	0	0	2
Riboflavin, ppm	6	-	0	0	4
Pyridoxine	40	-	0	0	2
Vitamin B_2, ppm	0.01	0	0	0	-
Folic acid, ppm	1	-	0	0	-
Pantothenic acid, ppm	20	-	0	0	-

Adapted from Cheeke (1987).

VI- Feed Additives

Contents

Introduction

Feed additives are nonnutritive substances added to feeds to improve the efficiency of feed utilization and feed acceptance, or to be beneficial to the health or metabolism of the animal in some way. In other words, they are substances other than the known nutrients. Some feed additives, such as antibiotics, are controversial, with claims that their use has adverse effects on human health. There is an increasingly restrictive controls on the use of feed additives for animal production. In the United States, the Food and Drug Administration must approve a feed additive before it can be used commercially. The FDA approval is given only after extensive testing, which establishes the safety of the product and substantiates the claims made for it. Additives are usually included in the feed mixture in very small quantities and require very careful weighing, handling and mixing.

These ”nutritional” additives do not have a part to play in the metabolic processes , what they do is to make the processes more effective in some way , either by counteracting some growth depressant in the system, by modifying hormonal balances or by improving the quality of the food mixture on offer and thereby the birds consumption of it.

Obviously the use of additives should only be considered when there is evidence that their inclusion in the mixture will lead to some such advantage and that the advantage will be economical. Their use should be very carefully controlled at all times in case there should be effects which will be counter-productive.

The mentioned classification of feed additives attempts to categorize them by their principal biological or economic effects. It is not an all-inclusive list, but it includes the most prominent feed additives. Those of special interest in the formulation of poultry food include antioxidant, antibiotics, drugs to prevent or control disease, and pigments. In the case of broilers where high live weight gain is at a premium a suitable growth promotant is now included in the diet as a matter of routine.

Method of use

Additives are included in a food mixture in very small quantities in view of this, special consideration must be given to the manner in which they are mixed , in order to ensure that the additives is evenly distributed throughout the mixture. The most satisfactory method of mixing is to incorporate the additives in "a premix" or " carrier" before they are added to the main bulk of the ingredients in the mixture. The pre-mix might "bulk up" the additive in this way so that it may be added at the rate of, say, 3 kg per tonne of ration. Considerable care is necessary when calculating the actual quantity of the additive that has to be included in the ration. The inclusion of incorrect amounts may lead to unexpected, perhaps, unfortunate results.

In some cases there can be a danger to public health. There may, with some additives, be a build-up of a specific mineral or compound, in the edible tissues of the animal, or in the egg. To guard against this possibility, a number of countries have regulation limiting or prohibiting the inclusion of additives in animal feedstuffs. Inclusions must be detailed on a label supplied to the customer along with the food container. In addition, the manufacturer should give details of any pre-slaughter time during which the drug must be withdrawn from the diet. Where this is necessary the time is usually a period of three to five days.

The poultry farmer who buys food in compound form requires to know the types and the inclusion rates of any additives in the ration that he has purchased. It is also necessary for him to know whether the use of the product requires any special safety precautions, either to protect the attendants handing the food or the stock which may consume the fortified mixture. If he is mixing a purchased concentrate with home-grown ingredients; he must know if the concentrate will cause contamination of the mixing equipment, which could have unfortunate results on other stock consuming diets subsequently mixed in the equipment.

The veterinarian responsible for the disease-prevention programme of the stock also requires to know the type and levels of additives used.

The possible effect of one additive upon another must always be considered. In some cases additives may be antagonistic one to another whereas, in others, may be complementary. The combined value of two additives used at the same time may on occasion be greater than the sum of their individual values, and this phenomenon is known as a synergistic effect.

Classification

The classification of the additives is needed to be displayed in a chart for clarity.

I- Additives that influence feed stability, feed manufacturing, and properties of feeds

A- Antifungals

They are used to prevent fungal growth in stored feeds. Propionic acid, sodium and calcium propionate added as 1 % of grain or diet, also ammonia treatment inhibits growth and inactivates aflatoxin.

B- Antioxidants

They prevent autooxidation of fats. Vitamin E & C are natural antioxidants and ethoxyquin (Santoquin), butylatedhydroxytoluene (BHT), and butylatedhydroxyanisole (BHA) are synthetic. In animal tissues they have a sparing effect on vitamin E and selenium requirements. Synthetic antioxidants help to overcome toxic effects of peroxides. Ethoxyquin added as 125 ppm in broiler diets, prevented the deleterious effects of peroxides on growth performance.

C- Pellet binders

Pelleting increases the density of feed and improves growth and feed efficiency and reduces dust. Bentonite is added as 2 to 3 % of the diet. It improves, in addition, the utilization of urea by ruminants (ion-exchange properties), and absorbs mycotoxins and facilitates their excretion.

II- Additives that modify animal growth, feed efficiency, metabolism, and performance

A- Feed flavors

They are used to increase the acceptance of diets of low palatability, increase the intake of palatable diets, and increase the intake of diets during periods of stress such as weaning. Virtually all animals except carnivores have a “sweet tooth” and prefer diets with added sweeteners (sucrose, saccharin, and glucose) compared to the same diet without sweetener. However, addition of sweetener to the diet does not usually alter feed intake or animal preference. In general, it appears that feed flavors do not improve performance of animals. Stimulating an animal to consume more of a diet than normal, even if possible, would probably not be advantageous.

B- Digestion modifiers

1- Enzymes: The main potential of enzyme addition to feed appears to be for digestion of substances that the animal is intrinsically incapable of digesting. For nonruminants, addition of cellulase provides a means of digesting cellulose but production and delivery has not reached a practical stage.

The primary use of enzymes is to provide sources of B-glucanase to swine and poultry to increase the digestion of B-glucans. Sources of enzymes are available commercially. Glucans are an important source of CHO in barley and oats. The addition of the enzyme to barley – containing poultry diets results in significant improvement in growth rate and feed conversion and reduces or eliminates sticky droppings.

Water soluble pentosans are the major antinutritive factors in rye. Enzyme treatment with fungal enzymes from Trichoderma viride reduces the viscosity of rye in the gut and improves its utilization by poultry, as a result of hydrolysis of the viscous pentosans. The endosperm cell walls of wheat, triticale and rye contain pentosans. Feeding a source of pentosanase to broiler chickens improved growth and reduced the severity of wet litter and sticky droppings when rye or triticales were fed.

2- Buffers: A buffer is a salt of a weak acid or base that resists a pH change, whereas an alkalizing or neutralizing agent neutralizes acid but also increases pH. Na, K, Mg bicarbonate, Ca carborate, and bentonite are true buffers, whereas Na, K carbonate, Mg oxide, NaOH, and $Ca(OH)_2$ are alkalizing agents. Buffers are used extensively for ruminants fed high concentrate diets. The greater rate of fermentation produces more acid, less saliva production (saliva is rich in buffers), and less intrinsic buffering capacity. Forages, especially legumes like alfalfa, have appreciable buffering capacity. Sodium bicarbonate is probably the most frequently used buffer; other widely used buffers and neutralizing agents include MgO, $CaCO_3$, cement kiln dust, and tetrasodium pyrophosphate. Added buffers are particularly useful in the adaptation period from high-roughage to high – concentrate diets and aid in the prevention of lactic acidosis.

Limestone exerts its maximum buffering activity at a pH of less than 5.5, so its major effect is postruminal. MgO functions as a rumen buffer. With high-concentrate diets, the high concentration of VFA produced in the rumen may result in acid overload of the duodenum, lowering the intestinal pH below the optimal level for pancreatic amylase activity, so excretion of a considerable amount of undigested starch in the feces of animals and a lower fecal pH.

3- Ion- exchange compounds: The principal ion-exchange compounds used in feeding are zeolites, which are clay minerals consisting of hydrated aluminosilicates of various cations. They can gain and lose water reversibly and exchange their constituent cations. Besides natural zeolites, there are also synthetic zeolites used as molecular sieves consisting of organic resins or inorganic aluminosilicate gels. One of the major natural zeolites used in feeds is clinoptilolite.

Zeolites are reputed to have beneficial effects on growth , feed efficiency , and incidence of enteric disease. Clinoptilolite is recognized as having the ability to exchange ammonium ions. This property is used to remove ammonia from poultry houses. Zeolites might improve the utilization of NPN by ruminants by complexing with ammonium ions and releasing them gradually over a period of time. Some aluminosilicates are effective absorbants of aflatoxin, and they have been used in poultry to alleviate the effects of toxic levels of dietary aflatoxin.

4- Ionophores and methane inhibitors: Ionophores are a class of antibiotics that are extensively used as feed additives for cattle. Their name is derived from their mode of action in interacting with metal ions and serving as a carrier by which these ions can be transported across membranes. The major ionophores used are produced by various strains of Streptomyces fungi and include monensin (rumensin), lasalocid, salinomycin, lysocellin, and narasin. These compounds are also used as coccidiostats in poultry. Monensin is called monensin when used in poultry feeding and rumensin when used as cattle – feed additive.

The feeding of ionophores to cattle consistently improves feed conversion efficiency and often improves daily gain. The improvement is largely attributed to a change in rumen fermentation resulting in an increased proportion of propionic acid, which is used more efficiently in metabolism than acetate and butyrate, and there is less production of CO_2 and methane during formation of propionate in the rumen. So the animal derives more net energy.

Ionophores may have a favorable influence on CHO metabolism in cattle by stimulating gluconeogenesis. Ionophores inhibit the growth of gram-positive bacteria, so the gram negative population is enriched.

In addition to positive effects on gain and feed efficiency, ionophores reduce lactic acidosis, aid in the control of coccidiosis, feedlot bloat, and acute bovine pulmonary emphysema, and are toxic to the larvae of face and horn flies in the faces. They help to reduce lactic acidosis by inhibiting growth of Streptococcus bovis and Lactobacillus spp. that are the major lactate – producing organisms in grain overload. In a similar manner, ionophores reduce feedlot bloat by inhibiting S. bovis.

Feeding ionophores has favorable effects on reproduction in cattle, because of an elevation in blood glucose due to increased rumen production of the gluconeogenic VFA propionate. Because of their effects on ion transport across membranes, ionophores have an influence on mineral metabolism by animals.

Methane (CH4) production reduces the efficiency of rumen fermentation. Methane is combustible and represents a loss of carbon. Methane formation represents a"hydrogen sink". CO_2 and CH_4 are produced when cellulose is fermented to acetate and butyrate, whereas, when starch is fermented, all the C and H atoms present in glucose are accounted for in the two propionate molecules produced. Inhibition of methane production would increase the efficiency, as well as reducing CH_4 emissions, which has been linked to global warming.

$$\underset{\text{glucose}}{C_6H_{12}O_6} \xrightarrow[\text{fermentation}]{\text{starch}} \underset{\text{propionic acid}}{2CH_3CH_2COOH} \longrightarrow \text{6 absorbed carbons to be metabolized}$$

$$\xrightarrow[\text{fermentation}]{\text{fiber}} 2CH_3COOH + CO_2 + CH_4 \longrightarrow \text{4 absorbed carbons to be metabolized}$$

Various chemicals inhibit methanogenesis. These include chloroform, iodoform, and other halogenated methane analogs. These have not proven to be practical as feed additives. The main methane inhibitors with practical application are the ionophores.

Since monensin is toxic to horses, they should not have access to monensin-containing feed. The levels used as feed additives or in blocks for cattle can be toxic to horses.

5- Isoacids: In addition to the short, straight chain acids, acetic, propionic and butyric; small quantities of branched- chain VFA are produced in rumen fermentation from the degradation of branched – chain amino acids. Under some conditions rumen microbial metabolism may be limited by a deficiency of branched – chain VFA. A feed additive termed isoacids has been produced commercially. Isoacids do not improve the performance of growing animals but may increase milk production. Since isoacids are produced mainly from AAs their concentration in the rumen might be limiting when diets high in NPN or low in rumen degradable protein are fed. A negative factor with isoacids is their pronounced odor. This is very unpleasant for feed mill staff who work with the products.

6- Probiotics: They are defined as live microbial feed supplements which improve the gastrointestinal microbial balance. They are "natural" alternatives to antibiotics, which, ironically, are also "natural". The majority of probiotic products are based on Lactobacillus acidophilus, although other organisms such as Streptococcus faecium, Bacillus subtilis, and yeasts are also used. Probiotics should be viable and capable of growing in the intestinal tract. Responses to nonviable preparations may occur if their activity is due to enzymes that are released, such as B-galactosidase, which digests lactose. The organisms must be able to survive passage through the highly acid stomach. Most lactobacilli meet this criterion .It is very important that they be resistant to bile if they are to survive in the intestine. Several possible modes of action have been suggested as follows:

1 - Change in gut microflora and a reduction in E.coli
2 - Production of antibiotics
3 - Synthesis of lactic acid with consequent reduction in intestinal pH
4 - Adhesion to or colonization to the intestinal mucosa
5 - Prevention of toxic amine synthesis in the gut
6 - Other as yet unidentified modes of action, such as stimulating immune responses in the gut

Attachment of Lactobacilli to the intestinal mucosa, which may assist in the exclusion of pathogens, has been demonstrated. Most enteric pathogens, such as E.coli and Vibrio cholera, cannot produce disease without attachment to the host intestinal cells, so attachment of probiotic organisms to the cells could be very important in increasing disease resistance.

Yeasts (single – celled fungi) and other fungi are also used as probiotics. Administration of yeast culture improved performance of calves subjected to stress from handling and shipping. Also increase in feed intake, favourable effects on palatability, stimulation of rumen fermentation, and improved digestibility were noted. Yeast and fungal probiotics cause changes in rumen fermentation including stimulation of cellulolytic bacteria. Yeast product improved nitrogen retention and fiber digestibility in horses.

7- Oligosaccharides:(2–20 monosaccharide units) have been claimed as beneficial nutritional modifiers for monogastric farm animals. They fall into the group of materials also known as prebiotics, which are defined as compounds other than dietary nutrients that modify the balance of the microfloral population by promoting the growth of beneficial bacteria and thereby provide a healthier intestinal environment.

Oligosaccharides have been suggested that these compounds achieve their beneficial effects in the gut in two ways. First, although they are not easily digested by the host digestive enzymes, compounds such as FOS (fructo-oligosaccharides) can be fermented by the favourable bacteria (e.g. Bifidobacteria and Lactobacilli), giving them a competitive advantage. This shifts the microbial population towards such microorganisms and away from the harmful species.

Second, the gut microbial population may be altered by the oligosaccharide interfering with the attachment of harmful bacteria to the gut wall. As a means of cell recognition, all cell types have a unique configuration of carbohydrate-containing compounds (glycoproteins and glycolipids) on their surface. As described above in the section on probiotics, pathogenic bacterial cells have surface compounds called lectins that recognize these carbohydrates and by which they attach to the gut cells. Once attached, the bacteria are able to multiply and produce their harmful effects. Species such as Salmonella and E. coli have a mannose-specific lectin that binds to mannose residues on the gut mucosal surface. By introducing mannose-containing compounds (MOS) into the diet, the binding by pathogenic bacteria is disrupted and instead they bind to the oligosaccharide and are carried out of the gut with the passage of the digesta.Yeasts have mannans in the cell wall structure and form the basis of some commercial products that are claimed to act in this way. Indeed, the presence of such yeast fragments has been said to be the reason why yeast products are beneficial.

8- Synbiotics: refer to nutritional supplements combining probiotics and prebiotics and in a form of synergism. The main reason for using a synbiotic is that a true probiotic, without its prebiotic food, does not survive well in the digestive system. Without the necessary food source for the probiotic, it will have a greater intolerance for oxygen, low pH, and temperature. Typically, a synbiotic product contains one to ten billion active cells. For instance, yogurts containing live and active cultures produce a synbiotic effect with inulin. Synbiotics work in two ways:

a- by improving the viability of probiotics
b- by delivering specific health benefits .

Examples of common synbiotics are Lactobacilli + lactitol, Lactobacilli+ inulin, Lactobacilli + fructo-oligosaccharides (FOS) or inulin , Lactobacillus rhamnosus+ Galactooligosaccharides (GOS) + inulin, Bifidobacteria + FOS, Bifidobacteria + GOS , Bifidobacteria and Lactobacilli + FOS or inulin.

9- Acidifiers (organic acids): In most animals, the stomach does not become highly acid until after weaning. During the suckling period, fatty acids in milk have antimicrobial activity. After weaning, development of highly acid stomach aids in killing ingested microbes. During a brief period between weaning and the development of highly acid stomach, young animals are susceptible to encroachment of pathogenic organisms into the gut, leading to the well-known phenomenon of postweaning diarrhea (scours). Feeding organic acids in this period may aid in lowering the stomach pH and preventing digestive upset. Citric and fumaric acids have been the primary acidifiers tested. There is a significant increase in growth rate of broiler chicks with 0.5 and 1.0 percent fumaric acid. The beneficial results of citric and fumaric acids may be attributed to their effects on energy metabolism, since they are intermediates in the TCA cycle of cellular energy metabolism.

Some noted an interaction between copper sulfate and organic acids in growth and feed efficiency responses. In calves acidification of milk replacers may improve milk clot formation in the abomasum, which reduces the risk of digestive upsets. Acidified milk replacers help to keep the abomasal pH below 4.2, the minimum pH at which E.coli can survive.

10- Antibloating agents: Surface –active agents such as poloxalene, marketed as Bloat Guard, are effective in preventing frothy bloat. Frothy bloat is associated with consumption of lush legume pasture, and the rapid release of fermentable CHO and soluble protein in the rumen. Surface-active agents prevent the formation of a stable foam by preventing development of bubble membranes. Anti-bloat agents are generally provided as components of blocks.

11- Salivation inducers (sialagogues): They are substances that increase the production and secretion of saliva. Current interest in these substances centers on slaframine. It is a mycotoxin produced by fungi that grow on red clover; consumption of infected clover pasture or hay by livestock causes "slobbers" or profuse salivation. Slaframine might have useful pharmacological properties in ruminants. Inadequate secretion of salvia occurs when low-fiber, high- concentrate diets are fed, leading to metabolic disorders and suboptimal feed utilization. Administration of slaframine increased the salivation rate, the liquid turnover rate in the rumen and the rumen pH, and it increases the efficiency of microbial protein synthesis in the rumen.

12- Defaunating agents: Defaunation is the process of treating a ruminant to eliminate its rumen protozoa. This can be accomplished with a number of chemicals, including copper sulfate and nonionic and anionic detergents. Protozoa feed on rumen bacteria and probably on rumen fungi as well. Defaunation results in an increased population of rumen fungi.

It was hypothesized that the retention of a large population of protozoa in the rumen could reduce availability of microbial protein to the host animal and limit production. With a high-energy molasses or sugar – based diet, growth rates of cattle and sheep were improved by defaunation; wool growth was enhanced also. On conventional diets, there seems to be little effect of defaunation on animal performance. Keeping defaunated animals from becoming refaunated with protozoa is difficult.

Rumen ciliate protozoa increase sulfide production in the rumen via metabolism of S-amino acids, resulting in copper being bound to the sulfide, becoming unavailable for absorption and utilization. Defaunated sheep may be susceptible to copper toxicity.

C- Metabolism modifiers

1- Hormones: Hormones are neither permitted nor used to any extent as feed additives in the United States. At one time, diethylstilbestrol (DES), a synthetic estrogen, was used primarily for cattle, but FDA approval was withdrawn. Estrogens improve growth and feed efficiency in ruminants, particularly in steers. Estrogenic compounds may be administered by implant in the ear; one of the main ones used is zearalenone (Ralgro), a mycotoxin with estrogenic activity. The only hormone permitted in the United States for beef cattle is melengestrolacetate (MGA), a synthetic progesterone, which suppresses estrus and improves weight gain and feed efficiency in feedlot heifers. By suppressing estrus, normal behavior and eating patterns of both steers and heifers are maintained by eliminating the presence of heifers in heat.

2- Beta – adrenergic agents or B – agonists (repartitioning agents): They are norepinephrine (noradrenaline) analogs that stimulate B-adrenergic receptors. They result in repartitioning of nutrients from fat to protein synthesis, causing increased muscle mass and decreased body fat. Clenbuterol, cimaterol, and ractopamine are examples of these compounds. Repartitioning agents are believed to act by increasing fat mobilization (lipolysis) and stimulating protein synthesis. They may also reduce degradation of muscle protein.

D- Growth promotants

1- Antibiotics: Antibiotics are natural metabolites of fungi that inhibit the growth of bacteria. Favorable effects on animal performance were noted, with improvement of growth and feed efficiency and a reduction in health problems such as post- weaning diarrhea. These findings led to the adoption of the practice of feeding subtherapeutic levels of antibiotics to animals, particularly swine and poultry, as growth promotants.
The mechanism of action appears to be due to actions on the gut microflora. Some of the most plausible theories identified are as follows:
(1) Microbes responsible for mild but unrecognized infections are suppressed.
(2) Microbial production of growth – depressing toxins is reduced.
(3) Antibiotics reduce microbial destruction of essential nutrients in the gut or, conversely, improve the synthesis of vitamins or other growth factors.
(4) There is enhanced efficiency of nutrient absorption because the intestinal wall is thinner.

Subtherapeutic levels increase an animals' ability to withstand stress and aid in control of postweaning diarrhea. Broad-spectrum antibiotics, such as chlortetracycline, are usually more effective than narrower spectrum agents such as penicillin and bacitracin.

Animals fed antibiotic have a thinner intestinal wall than controls not receiving them; this could improve nutrient absorption and also reduce maintenance energy and protein requirements. The intestinal mucosa is the most rapidly regenerating tissue in the body. The turnover rate is increased by exposure to bacterial toxins and metabolites, thus substantially increasing endogenous losses of protein and energy. Antibiotics reduce the turnover rate of intestinal mucosal cells. Also it is observed that antibiotics reduce formation of ammonia and amines in the gut; these compounds are irritants that increase the turnover rate of epithelial tissues. Antibiotics may also reduce the intensity of the immune response. The development of microbial resistance to antibiotics, which is well documented, does not alter their growth –promoting activity since it has been used in 1950.

Some of the most commonly used growth –promoting antibiotics are bacitracin, bambermycins, chlortetracycline, erythromycin, lincomycin, neomycin, oxytetracycline, oleandomycin, penicillin, streptomycin, tylosin, flavomycin, and virginiamycin.

Antibiotic use and human health: The widespread use of antibiotics may lead to the development of antibiotic - resistant strains of bacteria, which could make treatment of human diseases more difficult. The worst case is that bacteria resistant to all antibiotics could develop and create life-threatening infections in humans.

Use of antibiotics in feeds does increase the number of antibiotic-resistant organisms in animals. This ability is carried in nonchromosomal pieces of genetic material called plasmids (R-factors). The resistance can be transferred to other bacteria. Although this is theoretically possible, evidence that it has harmed human health, has not yet been found. The committee of the National Academy of Science (1989) believes that there is indirect evidence implicating the use of antibiotics in producing resistance in infectious bacteria that causes a potential human health hazard. Although antibiotics have been used as feed additives since 1950, their effectiveness has not diminished with time. This suggests that the development of microbial resistance, which is well documented, does not alter their growth-promoting activity.

2- **Chemotherapeutic agents:** A variety of compounds that have growth –promoting activity are not antibiotics. These include arsenicals, nitrofurans, and sulfonamides.

Arsenicals are compounds containing arsenic, such as arsanilic acid, sodium arsanilate, and roxarsone. They have a growth- promoting effect similar to that of antibiotics. An antagonism may exist between arsenicals and copper sulfate.

Nitrofurans are synthetic compounds with antimicrobial activity. Chemically they are based on nitrofuran ring (a five membered ring with an NO_2 –group attached). Furazolidone is an example of a commonly used nitrofuran. It has growth –promoting activity in poultry and swine.

Sulfonamides are derivatives of sulfanilic acid. They have broad-spectrum bacteriostatic effects (bacteriostats inhibit bacterial reproduction). They are also effective against protozoa that cause coccidiosis, and some viruses. Sulfaquinoxaline has been extensively used in poultry as a coccidiostat. Sulfonamides are competitive inhibitors of vitamin K.

Carbadox is a synthetic antibacterial compound that is similar in action to antibiotics, and has a growth- promotant effect.

Copper sulfate (needs 10-20 ppm in most species) is a growth promoter for swine and poultry at 125-250 ppm. Copper accumulates in the liver when feed additive levels of the element are fed representing a potential human health hazard. Swine and poultry manure used to fertilize crops or pastureland, make the possibility that crops could take up excessive levels of copper. In addition, broiler litter or dried poultry waste (DPW) is often used as a feedstuff for ruminants; manure from birds fed copper sulfate may cause copper toxicity in ruminants (outbreaks in cows, two cows and 15 steers died of hemolytic crisis – have been described).

3**- Saponins:** Steroid saponins in yucca, a desert plant in United States have been given the trade name sarsaponin and are sold commercially as agents to improve animal performance. They have a role in ammonia metabolism in the rumen, and cause a slight improvement of feed efficiency in finishing pigs.

III. Additives that modify animal health

A- Drugs

A variety of drugs may be added to the feed for the treatment and / or prevention of disease or internal parasites. Some of the drugs commonly used include worming agents (e.g, phenothiazine, piperizine, dichlorovos) and coccidiostats (e.g., monensin, amprolium, sulfaquinoxalene). Regulations involving their use change frequently, and permitted products, dosages, withdrawal times before slaughter, and so on vary from country to country.

B- Environmentally active substances

These products are primarily used for the control of ammonia. Ammonia is an irritating and toxic gas, which is released by bacterial or fungal action on the urea or uric acid excreted by mammals or birds, respectively. In poultry, air ammonia levels above approximately 20 ppm can cause such problems as keratoconjunctivitis (eye damage), damp, matted feathers, and respiratory disease. Animal productivity is reduced when detectable levels of ammonia are present in the environment on a chronic basis and the health of workers in the building is compromised. Zeolites may reduce ammonia to minor extent when fed to poultry, and are more effective when spread directly on the litter or beneath the cages. Sarsaponin in the feed has beneficial effects and is more effective when applied to the excreta directly (in ruminants it has a role in ammonia metabolism in the rumen).

C- Immunomodulators

Instead of using antibiotics and other feed additives to help control microbes that reduce animal performance, an alternative approach is to use compounds to stimulate an animal's immune system, enhancing resistance to microbial effects. Young animals, such as baby pigs at weaning, have an immature immune system and thus are susceptible to postweaning enteritis and morbidity. The concept may offer a viable alternative to antibiotics if effective compounds can be developed.

Immune responses result in a variety of metabolic adjustments that are mediated by cytokines of leukocytic origin. Cytokines are hormone like molecules involved in cell – to – cell communication. Examples are interleukins and interferons. Substances that elicit immune responses (immunogens) result in decreased animal performance.

Antibiotics may act by reducing the microbial burden of the animal and, consequently, the number and intensity of immune responses that result in leukocytic – cytokine release. The synthesis of these substances is metabolically expensive, so the need for lower levels of cytokines provide greater nutrient availability for growth.

IV- Additives that modify consumer acceptance

A-Xanthophylls

They are red and yellow carotenoid pigments that are important in poultry and fish nutrition. They are deposited in egg yolk and body fat and skin and shanks of broilers. Sources include green plants, yellow corn and a variety of yellow or red plants. The richest source is marigold petal meal, which is produced commercially for poultry feeding. It contains 6,000 to 10,000 mg xanthophyll per kg; in comparison, dehydrated alfalfa meal contains approximately 200 mg /kg and corn contains approximately 20 mg /kg. The major xanthophyll in alfalfa is lutein, which is yellow, while in corn and corn gluten meal the major pigment is zeaxanthin, which imparts an orange-red color. Xanthophylls have no known nutritional value other than as a source of pigment, although it is suggested that they may stimulate the immune system. Consumers prefer pigmented poultry products in most parts of the United States.

A number of synthetic carotenoids (e.g., canthaxanthin) have been developed and are marketed for poultry. The use, even of 1 to 3 percent alfalfa meal, as a source of pigments, is considered undesirable by the industry because it reduces feed conversion efficiency. Synthetic xanthophylls increasingly used in poultry diets, are also important in fish nutrition.

B –Saponins

They complex with cholesterol and have been shown to have blood- cholesterol – lowering properties. Its use in poultry failed to lower egg and meat cholesterol. Apparently, synthesis of cholesterol within the bird obviates any dietary effect.

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