Estimation of Nutrient Requirements for Various Body Functions

Nutrient requirement for maintenance: When an adult and dry animal is neither losing nor gaining in body weight with constant body composition, their nutrient requirements are called the maintenance requirement.

Nutrient requirement for gain: It is the amount of nutrient required per unit gain in body weight.

Fasting Catabolism: In the absence of feed, the nutrients required to support the activities essential to life (viz. respiration, circulation, maintenance of muscular tonus, manufacture of internal secretions, etc.) come from the breakdown of body tissue itself. This destruction of body tissue is referred to as the fasting catabolism, and it can be measured in terms of the waste products eliminate through the various paths of excretion. Most of the tissue breakdown occurs to meet the demand of the fasting organism for energy for its vital processes.

Energy Metabolism of Fasting: The energy expended in the fasting animal is represented by the fasting heat production and this can be measured in the respiration calorimeter (Direct calorimetry), or can be obtained by one of the methods of indirect calorimetry. Its measurement provides a useful basis of reference for other phases of energy metabolism. Fasting catabolism of a given species provides a basis for studying the factors which affect it and for comparing the metabolism in different species.

Basal Metabolism: It's the baseline for calorie needs. The minimum energy the body requires to sustain vital functions in complete rest and without any food intake. Fasting catabolism has to be measured at its minimum value just required for the maintenance of life. Such a minimum value is called basal metabolism, or basal metabolic rate (BMR). It has its most exact meaning in the case of humans, because it is with this species that the conditions which are essential for a true minimum value can most nearly be attained. The conditions for its measurement in man are

1. Good nutritive condition
2. Environmental temperature of approximately 25°C (thermoneutral environment)
3. The body is at complete rest during measurement.
4. Postabsorptive state.

To determine if an animal has been reached a post absorptive state, measurement of heat production to the point of a constant minimum level can be made. Measurement of the respiratory quotient (RQ) to the point that the non protein RQ of fat (0.7) is reached also indicates that a post absorptive state has been attained. In ruminants a decline in methane excretion to a minimum level indicates a post absorptive state. By third day of fasting it declines to 0.5 litre from 30 L in sheep and in cattle to 2 litres from 200 L per day. So the measurement of basal metabolism in the ruminant cannot have the exact significance as it has in humans.

Fasting Metabolism: In ruminants the value determined is referred as fasting metabolism rather than of the basal metabolism. Fasting metabolism refers to heat production at specified times after the last feeding. This should not be confused with the term fasting catabolism, which also includes energy voided in the urine of fasting animals. The term resting metabolism has been used to denote the heat eliminated when an animal is lying at rest, though not strictly in a thermoneutral environment or in the postabsorptive state.

UNIT OF REFERENCE IN FASTING METABOLISM/ BASAL METABOLISM

- Heat production or basal metabolism rate varies with body size.
- Rubner developed the concept, referred to as the surface area law.
- Acc. To this law, the heat given off by all warm blooded animals is directly proportional to their body surface and that, expressed on this basis, heat production is constant to body surface for all species.
- The surface area on the other hand is very difficult to measure, and methods were therefore devised for predicting it from their fractional or decimal power of body weight.
- Scientists decided to standardize the expression of fasting metabolism on ¾ power of body weight i.e., Kg. $W^{0.75}$because of the close relationship between metabolism and metabolic body weight.
- The fasting metabolism of adult animals of various species ranging in size from rat to cow has an average value of 70 kcal per Kg. $W^{0.75}$ per day, but there are considerable variations from species to species.
- Basal metabolism of various body weights are now a days determined from the formula

  B.M (Kcal) = $70W^{0.75}$ Kg

- The coefficient 70 represents an average value for the kilocalories of basal heat produced per unit of metabolic size in experiments with groups of adult mammals.
- It should be noted that the above formula applies only in case of adult animals whose growth is complete.

Protein requirements for maintenance: When the animal is kept on the nitrogen free diet otherwise adequate in all other nutrients, the animal excretes nitrogen in faeces and urine. In the beginning the losses of nitrogen in faeces (metabolic faecal nitrogen) and urine (endogenous urinary nitrogen) are more which go on reducing every day on a nitrogen free diet but after few days when protein reserve of the body are depleted the endogenous urinary losses and metabolic faecal losses become constant. If these animals are given the graded level of nitrogen, the nitrogen excretion would increase which is due to metabolism of protein from the exogenous sources. The nitrogen requirement for maintenance is calculated on the basis of protein/ nitrogen required to balance the MFN and EUN losses. The MFN depends upon the amount of DM intake.

Endogenous urinary nitrogen: It is the minimum nitrogen excreted in urine when a nitrogen free diet which is adequate in energy is fed to animals. This urinary nitrogen is in the form of urea in mammalian urine. Amount of EUN is dependent upon body size of animal and is equal to 0.02-0.03 g per kg body weight or 2 mg EUN per Kcal basal metabolism or

$$\text{EUN (mg/d)} = 146\ W^{0.72}\ \text{kg}.$$

EUN is highest in young animals and lowest in hibernating animals due to different rate of metabolism.

Metabolic faecal nitrogen (MFN): MFN refers to the nitrogen excreted in faeces that is not derived from dietary nitrogen, but from the endogenous losses - such as: residue of bile, digestive enzymes, epithelial cells. MFN is proportional to the amount of dry matter intake and equal to 0.5 g MFN per 100 g of dry matter intake. MFN is not minimum on a nitrogen free diet as it does not contain any food nitrogen.

Estimation of protein requirement for maintenance: Protein requirement for maintenance is calculated by following three methods.

1. Factorial method

2. Nitrogen balance study

3. Feeding trial method

I Factorial method: In this method EUN and MFN are estimated to calculate the protein requirement for maintenance. Dermal losses of nitrogen in hoof, hair and nails are also included which are 2.2 g N per day. To calculate the net maintenance requirement biological value almost must be considered. So total digestible protein requirement for maintenance is:

Total digestible protein = (EUN + MFN + S) x 6.25 x 100/BV

Where S = Loss of nitrogen in hair, hoof etc.

BV = 70 percent for cattle, 65 percent for sheep, 30 percent for wool production

Since MFN is dependent upon dry matter intake and due to variable OM intake, the requirements are expressed in term of available protein instead of true protein by eliminating MFN losses. So

Available protein = (EUN + S) x 6.25 x 100/BV

2. Nitrogen balance study: To estimate the protein requirement for maintenance nitrogen balance study are performed under which different level of nitrogen (protein) are fed to the various groups of non-producing, adult and healthy animals. Nitrogen balance is determined in animals. The minimum protein intake which maintains nitrogen equilibrium is the maintenance requirement for protein. But some time high intake may also result in nitrogen equilibrium. Even in a protein depleted animal equilibrium may also be established by intake level which is not enough for maintaining the needed protein reserves. So the minimum level of protein intake capable of maintaining these reserves is the actual requirement of protein for maintenance. This requirement value must be increased to compensate the individual variation as well as differences in biological value of different feed combination. 0.6 lb digestible protein per 1000 lb. body weight is the maintenance requirement for protein as given by Armsby. The main disadvantage of this method is that it is a short term measurement carried out under controlled conditions and thus question always arises as to how accurately the results apply to the long-term feeding.

3. Feeding trial method: Long term feeding trials are conducted to calculate the protein requirement for maintenance. Different levels of protein are fed. The level of protein at which the animals maintain their body wt. without loss or gain over an extended period of time is the maintenance requirements of protein. The main drawback of the feeding trial method to estimate protein requirements in animals is that it does not reflect the integrity of nitrogenous tissues unless further detailed experiments are conducted.

Protein requirement for growth: Except skeletal growth, the growth is mainly due to deposition of protein and fat in body. But protein requirement for growth is more in younger animals than older animals. In older animals there is more fat deposition than protein. Protein requirement at a particular age will depends upon metabolic body size or live weight, rate of gain and composition of gain whether the growth is fast or slow but animal requires a proper proportion of amino acids for protein synthesis. Protein requirement for growth can be estimated by following methods.

1. Factorial method: The protein requirement for growth includes maintenance requirement as well as requirement for growth. The maintenance requirement can be determined directly by the factorial method. Whereas amount of protein required for growth is estimated from slaughter experiment data or by radioisotopic method.

$$R = \frac{6.25\,[(\text{MFN x DM}) + (\text{EUN x } W^{0.75})]}{\text{BV x T.D}}$$

R = Protein requirement for growth (g/d)

G = Nitrogen retention in body gain (g/d)

B.V. = Biological value

T.D. = True digestibility

2. Nitrogen balance method: In this various rations supplying equal quantities of energy, minerals and vitamins but varying level of protein are compared. The minimum protein level giving maximum nitrogen retention is taken as the protein requirement of animal. But the measurement should be made 2-3 times during the growth period so that data should represent the amount which is adequate during early period, but it is not wasteful later on.

3. Feeding trial method: In this method the criteria is body weight gain. Different levels of protein are fed to find out the minimum level which will give maximum growth rate. And that will be the protein requirement for growth.

Estimation of energy requirement for maintenance: Energy requirements are best determined by measurement of energy expenditure. Energy expended for maintenance of an animal is converted into heat and leaves the body. Thus an intake sufficient to offset the loss represented by the fasting metabolism would be the requirement if the animal is maintained under basal conditions.

Data on maintenance requirements of energy have mainly been obtained in four ways.

1. Fasting metabolism as a basis for estimating maintenance requirement.
2. By short and long-term trials with mature, non producing animals fed at the maintenance level.
3. Data on maintenance requirements are obtained by extrapolation of intake of feed towards zero level production.
4. Change in live weight

1. **Fasting metabolism as a basis for estimating maintenance requirement:**

Dry non-producing, mature animals were fasted, kept in a thermo neutral environment and their heat production was determined. This gives an estimate about the minimum quantity of net energy which must be supplied to the animal to keep it in energy equilibrium. This can be estimated by both direct and indirect calorimetry.

Direct calorimetry : Dry non-producing, mature animal in a post absorptive state, kept in a thermo neutral environment in animal calorimeter where there is arrangement for the collection of faeces urine and gases and determination of sensible heat loss as well as heat loss by evaporation of water from lungs and skin surface.

Indirect Calorimetry: Most of the work on energy requirement in India, was conducted using the indirect calorimetry method.

The fasting metabolism is only a portion of the energy required for maintenance, since it is only the energy required in a fasting animal, in a comfortable temperature, without voluntary activity.

Energy required for consumption and digestion of food, energy required for the increased respiration and heart rate due to walking and other movements, varying environmental temperatures are not accounted for in the determination of basal heat production.

The amount needed for activity is known as activity increment.

Mitchell (1931) proposed that the NE requirement for maintenance of poultry could be obtained by increasing basal metabolism by 50%. Cattle under feedlot require less than those under grazing or range system. In case of cattle, sheep and swine the activity increments may be of the order of 20 to 30%. In case of poultry the activity increments may be of the order of 37% for cage system & 50% for deep litter system.

Adding factors such as activity increment to the fasting metabolism to obtain the maintenance energy requirement is called the factorial method of estimating requirements.

Values obtained in this way are not as reliable as those determined under practical conditions in feeding trials.

2. By short and long-term trials with mature, non producing animals fed at the maintenance level. (if energy content of their food is known) - Feeding trial method

In the short term trial carbon nitrogen balance were determined to assess whether the animal were in energy equilibrium. (Measure carbon and nitrogen balance)

In the long term trial energy equilibrium was assumed to be the case if body weight changes are absent or negligible. (Watch body weight)

3. By extrapolation of intake of feed towards zero level of production: Lofgreen and Garrett (1968) measure the net energy requirements of dairy cattle. They calculate the NE requirement for gain and maintenance by determining body composition and empty body weights initially and after a feeding period over the range from maintenance to ad libitum feeding. They plotted the data of daily heat produced per unit metabolic body size versus daily ME intake per unit metabolic body size and then extrapolated to zero energy intake and estimated that fasting heat production of beef cattle is 77 Kcal per unit metabolic size and energy requirement for dairy cattle is as:

NEm = 80 $W^{0.75}$ (Kcal/d)
MEm = 133 $W^{0.75}$ (Kcal/d)
DEm = 155 $W^{0.75}$ (Kcal/d)

TDNm = 35.2 $W^{0.75}$ (g/d)

4. **Change in live weight:**
   Animal will gain or lose body mass according to whether its energy intake is greater or less than its maintenance energy requirement.
   Hence the animal can be given varying amounts of dietary energy and the response data can be measured.

Methods to know energy requirement for growth:

1. Factorial method: In this method total net energy for growth includes energy of tissues formed plus the basal metabolism increased by an activity factor. The requirement of energy is determined at any given period by the expected rate of gain and average body weight during the period. The weight gain plus data from slaughter experiments on the composition of gain provides the figure for calories for expected rate of gain while the body weight data provides the basis for arriving at the required energy for basal metabolism.

NE requirement = BMR + activity increment + tissue growth

BMR + activity increment indicates maintenance requirement. NE can be converted to other forms of energy.

Limitation: Gain in terms of fat and protein vary according to genetic make up and nutritional status of the experimental animal which therefore should be supported by test in feeding trial method before putyng them into actual practices.

2. Feeding trial method: In this method different level of energy containing rations are fed to different group of animals. The level which produces economic growth and development is the energy requirement for growth. This can be expressed in terms of specific feed requirement as TON, NE or DE.

For beef cattle TDN (lbs) = $0.0553\ W^{0.75}\ (1+ 0.805\ G)$
W = body weight in pounds
G = daily gain in pounds
For dairy cattle: TDN (lbs) = $0.036\ W^{0.75}\ (1 +0.57\ G)$
DE = $76\ W^{0.75}\ (1+0.58\ G)$
ME = $62\ W^{0.75}\ (1+0.60)$
NE = $35\ W^{0.75}\ (1 +0.45)$
For sheep
TDN (lbs) = $0.036\ W^{0.75}\ (1+2.3\ G)$
DE = $76\ W^{0.75}\ (1+2.4\ G)$
ME = $62\ W^{0.75}\ (1+2.5\ G)$
NE = $35\ W^{0.75}\ (1+1.8\ G)$
The unit of DE, ME and NE requirements are in Kcal per day.

Requirement of beef cattle is higher as compared to dairy cattle of the same body weight and making similar weight gain because beef cattle store more fat than dairy cattle.

Nutrient requirement for milk production: The production of milk by the lactating females depends upon tile quality of food eaten by the animals. The cow requires additional nutrients for milk production over and above her maintenance requirement. The amount of feed to be offered to milch animals depends upon the quantity as well as quality of milk. About 400 litres blood is circulated through the udder for every litre of milk production.

Energy requirements for milk production: The requirement of energy for milk production depends upon the percentage of fat in milk. Animals yielding milk with high percentage of fat require more energy as compared to low fat producers. This requirement is added to maintenance allowances. Carbohydrate and fats are secreted from the milk as lactose and fat. To compensate this loss, the milch animals should be offered carbohydrate rich feeds with 5 per cent fat. Green feed like berseem, Jowar and maize etc. are good for this purpose. Feeding of good quality hay and silage is also equally effective. 28 g calcium and 2 g phosphorus should be provided per kg milk produced.

How much energy is produced in milk is energy requirement of milk i.e. Gross energy of milk is the NE requirement of animal. Gross energy of milk is 3.13 MJ/Kg of milk. Usually milk is adjusted to a 4 % fat equivalent by Gaines formula. Fat corrected milk (FCM) kg = 0.4 x kg milk + 15 kg fat.

Protein requirements for milk production: The requirement of protein for milk production varies according to the percentage of fat in milk. More than 80% of the protein fed in the ration is secreted out along with the milk as casein. This loss can be overcome by feeding protein rich concentrate and oil cakes to animals. The requirement per kg of milk produced should be added to the maintenance allowances. Since the protein sparing role of NPN compounds by the action of rumen microbes in the ruminants is of great significance, the quality of protein in the ration is not of much importance in such animals.

One kg FCM contains about 35 g protein. The efficiency of utilization of digestible protein for milk production varies from 60 to 70 per cent. So about 50 to 55 gram digestible protein is required in addition to maintenance requirement per kg of milk produced by the animals.

Minerals requirement for milk production: For every 4.5 litre of milk production there is a loss of 5 g chlorine, 8 g calcium oxide and 15 g phosphate salt. Hence, there should be a rich supply of these minerals in the ration of milch animals. Adult and milch cattle require 30-40 g sodium chloride per head. This requirement can be met by mixing common salt in the ration or by providing salt -lick to animals. Leguminous feeds like Lucerne and berseem are good source of calcium. Wheat bran is very rich in phosphorus. Hence such feeds should be offered to milch animal. Milk has low concentration of magnesium. A milk diet provides adequate magnesium for the requirements of a grazing calf up to a body weight of approximately 50 kg but if milk is the sole diet, total intake of magnesium will be inadequate for requirements once his body weight increased.

Vitamin requirement for milk production: Several valuable vitamins are found in milk. Vitamins are important in the production and secretion of milk. The fat soluble vitamin A, D, E and K are especially important for milk production. Green roughages are good source of carotene which is converted into vitamin A inside the animal body. Vitamin D is synthesized by the action of sun rays on the body. Cereal grains are rich in vitamin E. Vitamin of B groups and K and synthesized in the rumen by microbes, hence are not dietary essential for ruminants.

Nutrients requirement for pregnancy: The developing foetus inside the uterus gets the supply of nutrients through blood of the mother. This requirement is increased during the last quarter of the gestation period. Hence after 5 months of pregnancy the pregnant cow should be given an additional amount of 0.14 kg DCP, 0.67 kg TDN, 12 g calcium, 7g phosphorus and 30 mg vitamin A daily over and above the maintenance and production requirements for developing foetus. Feeding to such an animal about 1.5 kg of good quality additional concentrate mixture takes care of DCP, TDN and phosphorus requirements. 2% calcium carbonate should therefore be added in the concentrate mixture for this purpose. The milch cow should be dried slowly during this period. One or two weeks before calving the cow should be fed good quality easily digestible additional feeds such as wheat bran, linseed cake. This increase is for the maintenance of proper health and the quality of milk in coming lactation. Therefore, the cow should be given good quality ration during pregnancy in order to maintain good health till and after calving. This process of additional feeding during the last few days of pregnancy is called "steaming up".

Nutrient requirement for work: The nutrient requirement of working bullocks depends on the type of work done by them. When the animal is doing work then the muscular activity is increased and nutrients are oxidized. While doing work there is a expenditure of energy from the body. The energy is obtained from fats and carbohydrates. Depending upon the type of work performed the animals have been divided as light, medium and heavy working bullocks. Hence, the ration of these animals should contain easily digestibility carbohydrates with good quality concentrate mixture. The light and medium working bullocks should be given more roughage and small quantity of concentrate mixture. Protein is not the normal fuel for muscular work and no protein catabolism or extra wear and tear of proteinous tissue occurs during work. So no extra protein is required during hard work but energy requirement is almost doubled.

Nutrient requirement for wool production: The wool fibres consist almost entirely of wool protein keratin, which has high content of the cystine. Thus the wool follicle requires a good supply of sulphur containing amino acids. Wool quality is also influenced by the nutrition of the sheep. High levels of nutrition increases the fibre diameter. The efficiency of food protein can be converted into wool is likely to depend on their respective proportions of cystine and methionine. Keratin protein contains 100-120 g/kg of these sulphur containing amino acids compared with the 20-30 g/kg found in plant proteins, so the biological value of food protein for wool growth is likely to be not greater than 0.3. In the metabolizable protein system, the factor for conversion of metabolizable protein to wool protein is 0.26. The energy requirement for wool growth, a sheep producing a fleece of 4 kg would retain about 0.23 MJ/ day. The efficiency with which metabolizable energy is used for wool production is estimated to be about 0.18. Thus the sheep would require 0.23/0.18 = 1.3 MJ ME/day for wool growth, which may be compared with its maintenance requirement of approximately 6 MJ ME/day. Wool growth in sheep is considerably increased by protein supplements protected from rumen degradation and period of starvation causes abrupt reduction in wool growth. Deficiency of minerals in food items like copper is responsible for loss of crimp or waviness in wool and also restricts melanin formation of wool and hair and zinc for production of brittle wool hair in sheep.

Avian egg production-Estimates of energy and protein requirement

The nutritional requirements for egg production are affected by egg size and breed of hen, percentage of production and composition of egg

Energy requirements for maintenance of layers

Basal Metabolism studies indicate that the

NEm requirement of adult hen = 83 x BW Kg 0.75 Kcal/day

NEm requirement of 1.75 kg adult hen = 83 x 1.75 $^{0.75}$

= 83 x 1.52 = 126 Kcal/day

NEm requirements are approximately 82% of the MEm requirements

MEm requirement = 126/0.82= 154 Kcal/ day

Therefore total ME requirement for non laying hens = 154+57=211 Kcal / day

Energy content of large egg is = 86 Kcal

Then total ME requirement for laying hens = 211+86=297 Kcal / day

Protein requirement for egg production

- For estimating protein requirement for egg production one must consider quantity of protein deposited in the egg as well as protein required for maintenance.
- Maintenance of one hen= 3 g of protein required
- Production of one hen = 6 g of protein required
- Feather Growth = 0.1 g of protein required
- Total requirement at 100% production 9.1 g

Factors that can alter nutrient requirements:-

1. Individual animal variation
2. Chemical composition of feeds
3. Variation in availability of nutrients in fields
4. Effect of higher level of performance
5. Stress condition
6. Intestinal flora
7. Antinutrients/antimetabolites
8. Nutrient interrelationship
9. Quality of water
10. Energy content of diet
11. Variation in deficiency symptoms

12. Nutrient requirement for immunity
13. Moulds in feeds
14. Environmental temperature and humidity