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Energy and Protein Requirements for Maintenance, Production

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Methods Adopted for Arriving at Nutrient Requirements of Livestock and Poultry; Energy and Protein Requirements for Maintenance, Production and Reproduction.

Defination-

1. 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 eliminated through the various paths of excretion.

2. Basal Metabolism-

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. Relaxation on bed prior to and during measurement
4. Postabsorptive state.

It has been reported that basal metabolism is 10 to 15% greater when animals are standing than while they are lying down, the horse being an exception.

The fourth condition, postabsorptive state, implies a state of fasting in which a long enough time has elapsed since the ingestion of food to make sure that the heat increment due to its digestion and assimilation has been dissipated.

Such a condition is readily obtainable in animals with simple stomachs in overnight fast, while in ruminants it cannot be obtained except after a prolonged period of fasting.

To determine if an animal has been reached a postabsorptive 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 nonprotein RQ of fat (0.7) is reached also indicates that a postabsorptive state has been attained. In ruminants a decline in methane excretion to a minimum level indicates a postabsorptive 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.

3. Respiratory ratio (RQ)- is defined as the volume of carbon dioxide released over the volume of oxygen absorbed during respiration

Fat RQ- 0.7

Protein – 0.8

Carbohydrate- 1

However, RQ can rise above 1 when CO_2 is released without oxygen consumption.

4. 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. To avoid some of the problems associated with a four-day fast in ruminants, some workers have determined heat production over a specific time period after the last feeding and have referred this **value as standard metabolism**.

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.

Units of Expressing Fasting Metabolism/Basal Metabolism-

The NRC committee on Animal Nutrition had adopted, finally, the 0.75 power of weight as defining the metabolic body size of an animal.

Brody's original formula for basal metabolism (BM)-

$$BM = 70.5\ W^{0.734}$$

Kleiber's original formula-

$$BM = 67.6W^{0.756}$$

Both authorities agreed that the basal metabolism per day for adult homeotherms may be represented by the general formula: **BM (Kcal) = 70 W** $^{0.75}$. The coefficient 70 represents an average value for the kilo calories of basal heat produced per unit of metabolic size in experiments with groups of adult mammals.

5. BMR- factors

- Basal metabolism is highest in the newborn and gradually drops during the growth period to the figure for the adult animal, and even during adult life.
- BMR declined about **8%** per year of age.
- Basal metabolism is lowered by undernutrition but increased by emotional stimuli.
- Thyroid secretions augment heat production by increasing the heart rate, the respiration, etc.
- BMR declines with castration. It is quite variable among species, with sheep and swine being notably lower than cattle and poultry.

Methods Adopted to Estimate Energy Requirements for Maintenance-

The energy requirement for maintenance is the minimum amount needed to keep the animal in energy equilibrium. Energy requirements are best determined by measurement of energy expenditure.

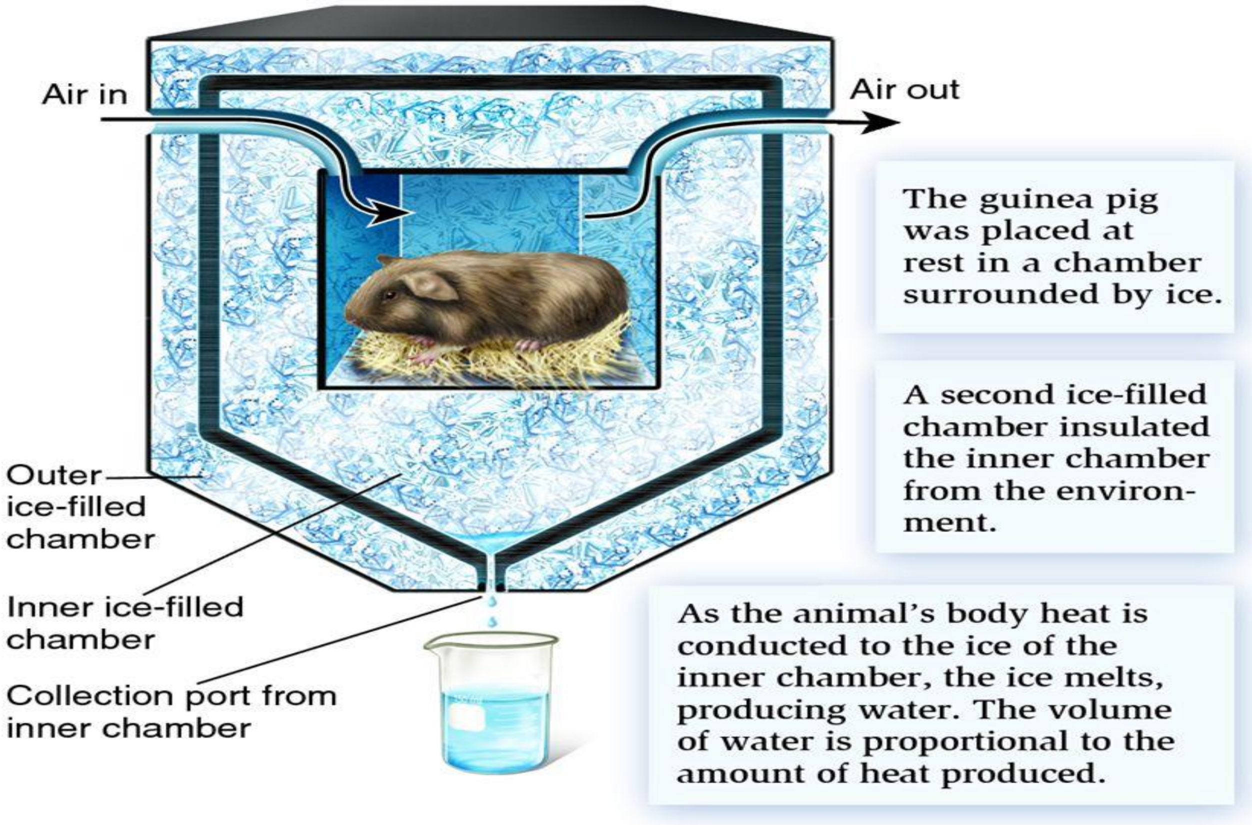
Energy expended for maintenance of an animal is converted into heat and leaves the body. Thus an intake sufficient to offset the loss represented by the fasting metabolism would be the requirement if the animal is maintained under basal conditions.

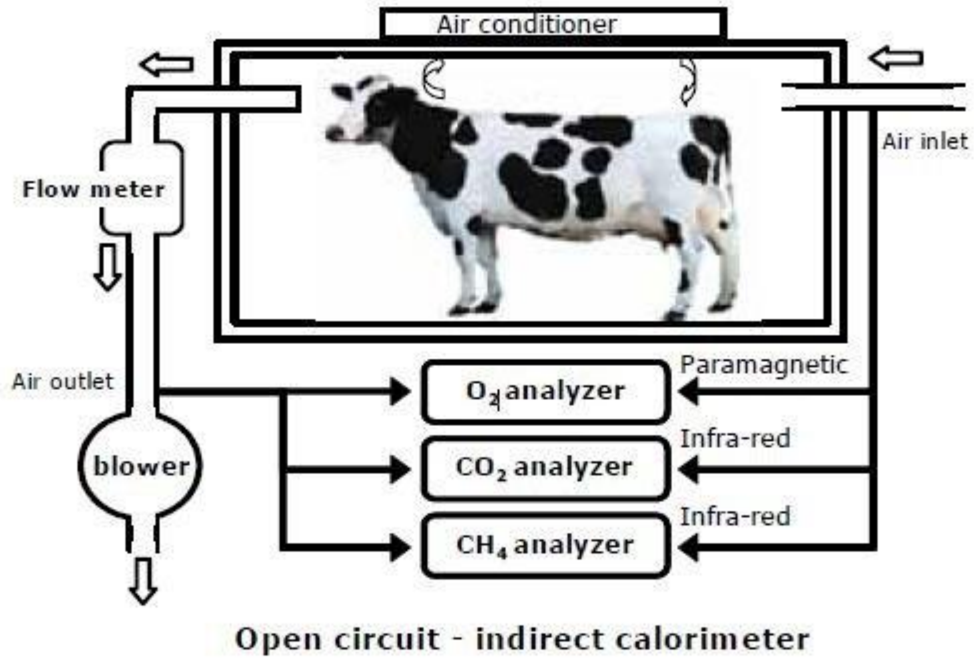
Data on maintenance requirements of energy have mainly been obtained in four ways-

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

Dry non-producing, mature animals were fasted, kept in a thermoneutral environment and their heat production was determined (fasting metabolism). 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: A non-producing, adult, healthy animal in a postabsorptive state (3-5 days after the last feeding) is kept at 25°C in the animal calorimeter where there is an arrangement for the collection of faeces, urine, gases and the 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. Open circuit respiration chamber is available at IVRI, Izatnagar. 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.

Activity increment- Energy required for consumption and digestion of food, energy required for the increased respiration and heart rate due to walking and other movements, and that due to low or high environmental temperatures are not accounted for in the determination of basal heat production. The amount needed for activity is referred to as activity increment and obviously depends upon the activity.

Mitchell (1931) proposed that the net energy requirement for maintenance of poultry could be obtained by increasing basal metabolism by **50%.** In case of cattle sheep and swine the activity increments may be of the order of **20- 30%.**

2. **Both short and long-term trials were performed with mature, non- producing animals fed at the maintenance level (if the energy content of their food is known).** In the short-term trials energy or nitrogen and carbon balances were determined to assess whether the animals were in energy equilibrium. In the long-term trials energy equilibrium was assumed to be the case if the body weight changes were absent or negligible (animals are not kept in calorimeters). The use of feeding experiments to estimate the maintenance energy requirements under practical conditions has a greater problem of determining energy equilibrium than is true of measurements in a calorimeter.

3. Data on maintenance requirements were obtained (*by conducting feeding trials with different levels of feed intakes*) by extrapolation of intake of feed towards zero level of production.

This can be done by **comparative slaughter experiments**.

Methodology of Comparative Slaughter Method. The Comparative Slaughter Method is used in this test to conduct live animal feeding studies by administering a standard meal of known energy over a two-week adaptation period. A group of animals is slaughtered after the adaptation period, and their body composition and gross energy are assessed to get baseline data. The remaining animals are given the same feed for a set amount of time before being slaughtered, and their body composition is calculated. The difference in body energy content between the initial baseline animals and the animals after the experiment is used to calculate energy retention.

Plotting the data of daily heat produced per unit metabolic body size versus daily ME intake per unit metabolic body size and then extrapolation to zero energy intake it was estimated that fasting heat production of beef cattle lies between 72 and 82 Kcal per unit metabolic body size with a mean of 77.

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 (MER). Hence the animal can be given varying amounts of dietary energy and the response data can be measured.

Protein Requirements for Maintenance-

The amount of protein (N×6.25) lost in the urine and faeces of animals, and additional losses, such as hair, skin, and hooves represent the amount of protein required for maintenance.

Endogenous-nitrogen metabolism: -There is a **minimum essential nitrogen catabolism** incident to the maintenance of the vital processes of the body, even as is the case for energy. This catabolism is measured as the minimum urinary nitrogen excretion on a nitrogen-free, energy adequate diet and is called **endogenous urinary nitrogen (EUN or UNe).**

Later in 1934 Brody and coworkers confirmed that relationship and is indicated by the following formula.

$$\textbf{EUN mg/d} = \textbf{146 } W^{0.72} \textbf{ Kg}$$

EUN-
Minimum EUN excreted by mature animals of different species, ranging in weight from **0.02 to 500 kg.**
It was suggested that mammals excrete **2 mg** of EUN per kilocalorie of basal metabolism, or **140 mg** N /kg$^{0.75}$/day.
EUN is **highest** in young animals and **lowest** during hibernation since EUN tends to reflect energy metabolism.
EUN of Indian cattle was **0.02 g/kg** BW while that of *Bos taurus* was **0.0289** g/kg BW.

Metabolic faecal nitrogen (MFN or FNm).-
It consists principally of 'spent' digestive enzymes, abraded mucosa and bacterial nitrogen. It is difficult to obtain MFN using a nitrogen-free diet in ruminants.

- MFN is proportional to feed intake and it is about **2 mg per g** DMI in rats.
- The MFN values determined in Indian cattle **were 0.35 g / 100 g** DMI and in buffaloes **0.34 g / 100 g DM intake**. These values are lower than the values determined in Bos taurus.
- Endogenous urinary nitrogen and metabolic faecal nitrogen put together has come to **350 mg N/kg** metabolic body size per day in ruminants. It is two to three times as great as in nonruminants.

Protein requirements have been calculated by conducting **nitrogen balance trials, feeding trials and factorial method** where endogenous urinary nitrogen(EUN), metabolic faecal nitrogen(MFN), nitrogen loss through skin and biological values (BV) of proteins are estimated to assess the protein requirements.

1. **Nitrogen balance method**: -

Various rations containing different levels of protein are fed to the various groups of non-producing, adult, healthy animals. The rations are otherwise adequate in energy, minerals and vitamins required by the animals. Nitrogen balance is determined in the experimental animals. The **minimum protein intake at which nitrogen equilibrium** is achieved is the maintenance requirement. The experimental animals chosen for the studies must be in adequate protein nutrition at the start of the experiment.

Disadvantage: It is a short-term measurement carried out under closely controlled conditions, and thus the question always arises as to how accurately the results apply to the long-term feeding.

2. Feeding trial method:-

Long-term feeding trials are conducted with non-producing, adult, healthy animals which are kept on different levels of protein with adequate intake of energy, minerals and vitamins. The **level of protein at which the animal maintains its body weight without loss or gain** over an extended period is considered the maintenance requirement of protein.

3. Factorial method:-

Protein requirements can be determined accurately by factorial method. Mostly this method has been followed throughout the world. In India many workers have followed factorial method where EUN and MFN are estimated to assess protein requirement (Kehar, 1944). Dermal losses of hair and scurf (2.2 g N/day) are also included. The net requirement, however, only covered replacing these losses, and the efficiency with which the absorbed protein is utilized (i.e., its BV) also must be considered. ARC assumed BV values of **70%** for cattle and **65%** for sheep.

Energy for growth and fattening: Energy requirements can be obtained by using
1. feeding trials and 2. factorial calculations.

- Based on **factorial calculations**: The factors involved in the total net energy needs for growth and fattening include the needs for maintenance (basal metabolism, plus that for activity) and that deposited in the tissue gained.

The NRC standards on energy requirements for growing and fattening beef cattle were established from NE values. They include a multiple net energy system whereby the daily requirements for maintenance were based on **NEm = 77 Kcal per W Kg$^{0.75}$** . Based on growth studies with steers and heifers, the NE requirements for gain of steers and heifers were calculated as NEgain.

The NRC established the NE requirements for growth of dairy cattle on the same basis as was done for beef cattle. Requirements were also expressed in terms of DE, ME and TDN.

- **Based on feeding trials:-**

Estimating energy requirements from feeding trials is based merely on feeding different groups of animals with different levels of energy and determining the energy level that promotes the growth or fattening desired. Much of the earlier recommendations for beef and dairy cattle, swine, and sheep were on this basis. The energy requirements of growing and fattening swine in current NRC standards (1998) were based on feeding trials. Although these were expressed in terms of DE and ME, some of the value converted from TDN

Factors that can alter nutrient requirements-

1. **Individual animal variation**: Individual animals vary in their requirements of nutrients. Hence some margin of safety is desirable in formulating diets and especially with nutrients that are not very stable and may be slowly and gradually destroyed by long storage.

2**. Chemical composition of feeds**: Many factors affect the level of nutrients in feeds and these include soil type and level of fertilization; stage of maturity at harvesting; handling and storage methods; processing methods; exposure to varying temperature, humidity and other environmental factors; moisture level; rancidity level; variety of feed; time interval between harvesting, processing, storage and its use, etc.

3. **Variation in availability of nutrients in feeds**: There are differences in the availability of nutrients. For example**, zinc** in soybean meal (SBM) is less available than that in casein. This is due to the **phytic acid** in SBM forming a complex which makes zinc less available.

4**. Effect of higher level of performance**: The level of nutrient that may be satisfactory for the average producer is usually not adequate for the higher level of production. The higher producing animals have increased body metabolic heat from the products they produce. Hence they tend to be more susceptible to heat stress.

5. **Stress conditions**: Higher levels of nutrients are recommended for moderate or severe stress conditions. However, higher levels of nutrients should be used with caution because some can cause harmful effects if used at too high a level. Hence one should be careful when increasing nutrient levels are used to counteract stress. Well-balanced, nutritious diets should be the first line of defense against stress and infectious diseases.

8. **Nutrient interrelationships: Examples of these interrelationships are:**
Choline and methionine
Methionine and cysteine
Phenylalanine and tyrosine
Niacin and tryptophan
Calcium, manganese and copper
Zinc, copper and protein
Copper, zinc and iron
Vitamin D, Ca, P, and Mg
Iron and phosphorus
Molybdenum, copper and sulphur
Sodium and potassium
Biotin and pantothenic acid
Vitamin B_{12} and methionine
Vitamin E, selenium and sulphur amino acids
Because of these interrelationships, the requirement of many nutrients will be modified by the level of other nutrients. Excess calcium may increase the need for phosphorus, Mg, Zn, Cu, Fe and sulphur amino acids.

9. **Quality of water**: Water is a source of minerals and other compounds. Nitrates, sulfites, and other chemicals in the water can destroy certain nutrients. High levels of sulfates and other compounds in water may cause diarrhoea and other digestive disturbances.

10. **Energy content of diet**: The energy content of the diet will definitely affect nutrient needs. For example, amino acid requirements increase as the caloric density increases. The need for other nutrients in the diet may be either increased or decreased depending on the level and kind of fat in the diet.

11. **Variation in deficiency symptoms**: Single nutrient deficiencies are seldom encountered under farm conditions. Conditions such as reduced appetite and growth or unthriftiness are common to malnutrition in general. Nutritional deficiencies may exist without the appearance of definite deficiency symptoms. These may be called borderline deficiencies. Many deficiency symptoms do not appear in an average- or low-producing group of animals.

12. **Nutrient requirements for immunity**: Nutrient levels that are adequate for growth, feed efficiency, gestation, and lactation may not be adequate for normal immunity and for maximizing the animal's resistance to disease.

13. **Moulds in feeds**: Moulds in feeds may affect the availability of biotin. Streptomyces moulds are found in soil, mouldy feeds, manure and litter.

14. **Environmental temperature and humidity affects the nutrient needs**. Destruction of nutrients by rancidity, light or irradiation; feed additives, enzymes, hormones; toxins in feeds; managemental practices affect nutrient needs of the animals.

15. Long term studies involving growth, reproduction, and hematological, histopathological and related data are needed to determine the nutrient requirements more accurately.

16. Some nutrient requirements are worked out using purified diets. This is to be kept in mind while applying this information to the farm animals fed on natural diets because of some difference in the availability of nutrients in the natural diets. For example, **zinc in soybean protein is less available than that in purified casein for pigs**; similarly **vitamin D needs were higher with a soybean protein diet than with a purified casein protein diet.** After perusal of so many factors that affect the nutrient requirements of animals, it is concluded that there are no exact nutritional requirements but only approximate requirements.