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METHODS OF EXPRESSING FEED REQUIREMENTS

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SUMMARY

The partitioning of energy within the animal and the important factors affecting this are outlined. A discussion of the main systems of energy evaluation, their differences and limitations is followed by brief mention of the methods used in deriving the requirements of animals for energy. It is suggested that, in future, the advantages of using metabolizable energy to describe the feed requirements of sheep and cattle in New Zealand should be considered.

FEEDING STANDARDS or nutrient requirements are statements of the amount of nutrient required by animals for optimum performance. Published standards consist of two parts, a statement of animal requirements and an evaluation of the ability of common feeds to meet those requirements. Although modern standards generally include information on all the nutrients required by the important classes of livestock, emphasis is directed here towards the energy requirements of the domestic ruminant.

Nutrients other than energy generally become of practical significance only when the amounts eaten fall below a minimum level. In contrast, animals tend to show a continuous response to changes in the intake of energy. As a result of this, feeding standards for energy are used mainly to predict either production from the quantity and quality of feed eaten or the amount of a given feed required to achieve a desired level of production.

To facilitate an understanding of the various methods of expression that have been used for energy, the present paper first outlines the partitioning of energy within the animal and the important factors that affect this. A discussion of the main systems of energy evaluation, their differences and limitation, is followed by brief mention of the methods used in deriving the requirements of animals for energy. Discussion of the requirements themselves is left to the subsequent papers of this symposium.

PARTITION OF ENERGY IN THE ANIMAL

The unifying feature of the diverse functions undertaken by the animal body is that they all involve a transfer of energy. The nutritive value of a feed is thus largely a measure of its ability to provide useful energy. Energy is measured by the calorie or, as is the case in ruminant nutrition, the multiple forms, the kilo (kcal, 1,000 calories) and mega (Mcal, 1,000 kcal) calorie.

The major constituents of feed may be summarized as:

Food	—————	Water
Dry matter	—————	Ash
Organic matter		
	<i>Energy (kcal/g)</i>	
Fat:	9.4	
Protein:	5.3	
Carbohydrate:	4.2	

Not all the gross energy of a feed is available to the animal, for various losses occur during digestion, absorption and metabolism. These are outlined in Fig. 1.

The gross energy content or heat of combustion of a feed depends on the proportions of water, ash and energy-yielding nutrients present. Since that fraction that is water is very variable and contributes no energy, feeds are usually compared on a dry matter basis. Although the calorific value of fat, protein and carbohydrate are approximately 9.4, 5.3 and 4.2 kcal/g, the great predominance of carbohydrate means that the food of ruminants varies little in gross energy content. It averages 4.4 kcal/g DM with feed rich in fat having higher values and only those high in ash, which has no calorific value, having noticeably lower values.

The first loss is one of major importance and is represented by the undigested energy excreted in the faeces. Digestible energy (DE) refers to energy not excreted in the faeces and is defined as the gross energy of the feed minus gross energy of the faeces. Though largely a reflection of chemical composition, the digestibility of a specific feed is not constant. It is affected by the level of feeding, method of feed preparation, between-animal and species variation, and, in a mixed ration, the nature of the other ration components.

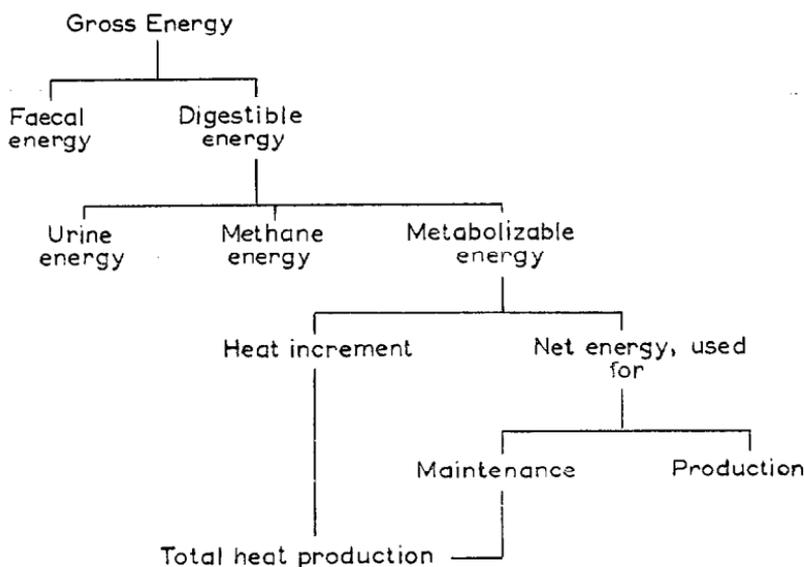


Fig. 1: Partition of feed energy in the animal.

An indication of the variation in and magnitude of the energy losses considered so far are illustrated in Table 1, using data obtained at Ruakura.

The metabolizable energy (ME) of a feed is its gross energy less the energy lost in the faeces, urine and fermentation gas. It more accurately represents energy that is of use to the animal than does DE but its determination is more difficult. The main factors that affect the ME content of a feed are those which affect digestibility. Level of feeding is particularly important, for alteration in this alters the amount of energy lost in methane (fermentation gas) and urine as well as in the faeces.

The pasture was autumn growth harvested in July, the silage being derived from maize harvested at a mature stage. The main feature is that, even for the highly digestible pasture, the faecal loss of energy is more than the combined urine and estimated methane losses. It is even more marked for the less digestible maize silage but the compensating effects of a greater gross energy content and smaller urine and methane loss resulted in the two feeds having a similar ME content. The digestibility of the dry matter (DDM) and organic matter (DOM), both analogous to DE, are included for comparison.

TABLE 1: METABOLIZABLE ENERGY VALUES OF TWO FEEDS
(kcal/kg DM)

	<i>Pasture</i>	<i>Maize Silage</i>
Gross energy	4381	4513
Energy losses:		
Faeces	960	1367
Urine	320	161
Methane	389	379
Digestible energy	3421	3146
Metabolizable energy	2712	2606
Digestible dry matter (%)	78.0	69.0
Digestible organic matter (%)	81.4	71.5

A loss of energy to the animal not accounted for by ME is the increase in heat production that occurs during and for some time after the consumption of food. This loss, called the heat increment or specific dynamic effect, arises mainly from the metabolism of the absorbed nutrients and reflects the inefficiency of the biochemical reactions involved. The heat produced in this manner is of no use to the animal except in a cold environment when it helps to maintain body temperature. The total heat production of a fed animal is therefore a combination of heat increment and the energy used for maintenance since the latter is also eventually converted to heat.

The ME of a food less its heat increment gives the net energy (NE) value of that food. NE represents the energy that is available for maintenance and the various forms of production such as growth and lactation. The proportion of ME that becomes available as NE depends on the efficiency of utilization of the ME, defined as the increase in energy retention that results from an increase of 100 kcal in the intake of ME. It ranges from about 25 to 85% and depends primarily on two factors, the purpose for which the NE is used by the animal, and the nature of the diet. The efficiency of utilization of ME for maintenance is about 65 to 80%, body gain 30 to 65%, and lactation 60 to 70% (A.R.C., 1965). The complement of these values represents the heat increment. Feeds high in ME content are used more efficiently than those of low ME content, the differences being most pronounced at feeding levels above maintenance. Thus for maize grain, which is of high ME content, the efficiency of utilization of ME for maintenance is about 80% and for growth about 65%, a ratio of 1.2:1. In contrast, for a feed of low ME content,

such as a poor quality hay, the respective values may be 70 and 35%, a ratio of 2.0:1.

SYSTEMS OF ENERGY EVALUATION

Most of the systems that have been devised may be classified according to whether they are based on DE, ME or NE. Irrespective of the method of expression used, each feeding standard attempts to describe the energy needs of the animal and the energy value of feed by the same unit.

SYSTEMS BASED ON NET ENERGY

The system which has had the greatest influence on animal nutrition is the starch equivalent (SE) system of Kellner. This has been extensively used in the U.K. in the form contained in *Rations for Livestock* (Evans, 1960). The SE of a food is its NE for fattening relative to that of starch. It is defined as the number of pounds of starch that promotes in the adult steer the storage of the same quantity of fat as 100 lb of the feed in question.

The approach used by Kellner to allow for differences in the NE value that occur when a feed is used for different forms of production was to weight the NE value of 1 lb SE according to whether it is used for maintenance, growth or lactation. Recommendations as to the requirements for each of these functions were made by assuming that 1 lb SE supplied 1,400, 1,071 and 1,339 kcal of NE for maintenance, fattening and lactation, respectively.

The most serious criticism of the SE system is that it assumes that the relative value of feeds for maintenance and lactation are the same as that for fattening. This is now known to be incorrect for, as has already been indicated, the ME content of the diet also influences efficiency of utilization of ME. This means that the original SE values underestimated the value for maintenance of feeds such as roughages that are relatively low in ME content. In recognition of this, the SE values of hays published in *Rations for Livestock* are an arbitrary 20% higher than Kellner's original values.

The latest feeding standards for beef cattle published by the American National Research Council (N.R.C., 1970) also use NE. An important feature of these standards is that they allow for the effects of feeding level on the NE value of feeds. The method used is to ascribe two NE values to each feed, NE for maintenance (NE_m) and NE for gain (NE_{gain}) both in terms of Mcal/kg. The first repre-

sents the ability of the feed to satisfy maintenance requirements and it is only after these have been met that any remaining NE can be considered available to promote liveweight gain at the rate indicated by the NE_{gain} value. Since the efficiency of utilization of ME for maintenance is higher than that for gain, the NE_m value of a feed is higher than its NE_{gain} value, the ratio of one to the other being dependent on the ME content of the feed. The main criticisms that may be levelled at the SE system are at least partially avoided by the N.R.C. system. It has yet to be established whether the same approach can be adapted to describe dairy cow requirements where the partitioning of NE between maintenance, liveweight change and milk production occur simultaneously.

SYSTEMS BASED ON METABOLIZABLE ENERGY

In the U.K., the recommendations of the Agricultural Research Council (A.R.C., 1965) have replaced the SE system. Animal requirements are calculated on the basis of NE and then transposed into ME. A specific value is not given to each feed. Instead, feeds are defined according to their ME content (Mcal ME/kg DM). The prediction of the animal performance attainable from a given diet requires stepwise calculation during which allowances are made for nearly all the factors known to affect the utilization of feed energy. The method of calculation is complex although some simplification can be achieved by graphical presentation. The apparent improved accuracy of this system is thus achieved at the expense of simplicity.

SYSTEMS BASED ON DIGESTIBLE ENERGY

Included here are DOM and DDM which have been extensively used in this country and DE and Total Digestible Nutrients (TDN) used in North America. TDN is determined as the sum of digested protein and carbohydrate (crude fibre and nitrogen-free extract) together with 2.25 times digested fat in 100 lb of feed. The factor 2.25 is used to allow for the energy value of fat being about 2.25 times that of carbohydrate. Since no allowance is made for the higher energy content of protein, the TDN unit in effect makes an allowance for the energy loss occurring in the urine. It thus may be regarded as being more closely allied to ME than to DE. Although both DE and TDN allow for the higher feeding value of fat, their use has not been extensive in New Zealand since the predominant feed, pasture, is of low fat content.

In regard to DDM and DOM, the latter is the more satisfactory where the feed varies in ash content whether because of natural variation or contamination with soil.

All four systems disregard the variation that occurs in the utilization of digested energy. Foods similar in terms of their digested nutrient content are not necessarily similar in their ME content (Table 1) and the wide variation that occurs in the utilization of ME has already been discussed. As the utilization of digested nutrients is more constant when the feeding level is at or below maintenance than at higher feeding levels, these systems are more satisfactory for describing the value of different foods for maintenance than for production.

A disadvantage of those systems such as DDM, DOM, TDN and SE that indicate the energy value of feeds indirectly is that the units are not of constant calorific value. For example, Hutton (1962a) found that the calorific value of DOM derived from pasture varied from 4.36 to 4.67 kcal/g. This emphasizes that converting these indirect measures of energy to calories by the use of average conversion factors may be quite inaccurate when applied to a particular set of circumstances.

An important consideration of the various systems is the ease with which feed values can be determined in terms of the various units. An argument often used in support of those based on digestible nutrients is that feed values can be readily determined by means of digestibility trials involving few chemical analyses. Such is not the case for systems based on ME and NE. The direct determination of ME requires the collection and analysis of urine and fermentation gases in addition to faeces. The measurement of NE is a particularly laborious and expensive undertaking. The energy value of most feeds is therefore predicted rather than measured. Most SE values, for example, have been estimated from the amount of digested nutrients using a formula which incorporates various value numbers and correction factors. The NE values of the N.R.C. (1970) standards have in some cases been estimated from ME which in turn has been estimated from DE or TDN. The A.R.C. (1965) suggest that the ME content of feeds can be calculated by multiplying DE by 0.82 indicating that losses of urine and methane energy constitute 18% of DE.

The various methods of prediction give only average values and the errors of estimate when applied to a specific feed may be high. The errors of prediction, together with

the various inaccuracies inherent in all systems of energy evaluation, emphasize that feeding standards are but guides to those who seek their counsel.

METHODS OF ASSESSING ANIMAL REQUIREMENTS

When assessing the merits and demerits of the various feeding standards, some consideration of the method used in determining the requirement of the animal for energy is necessary. Two basic methods have been used. Although their objective is the same, the manner of achieving it is so divergent that it may account in part for the differences that exist between some of the feeding standards.

The first is a factorial method in which total net energy requirement is considered as the sum of the energy costs of the component parts. The basic component is that of maintenance as estimated by calorimetric procedures. To this are added the energy cost of muscular activity, growth and other forms of production. The essential feature is that the animal's requirements for net energy are first determined, these then being transposed to the desired feed values. This approach has been adopted by the A.R.C. (1965) in formulating their standards. Many of the earlier standards, of which the SE system is an example, were derived by simplified versions of this method although their original recommendations have in most cases been modified by the incorporation of more direct evidence from subsequent feeding trials.

The second method involved the use of multiple regression analysis to partition the variance in energy intake between liveweight and the various forms of production. Both methods assume that maintenance requirements for net energy are proportional to some function of liveweight, generally $LW^{0.75}$. The factorial method also assumes that the maintenance requirement is not influenced by plane of nutrition and the energy cost of maintenance of a fast growing animal or one that is lactating is the same as that of a similar sized non-lactating animal that is merely maintaining weight. Evidence refuting this assumption has been discussed by Preston *et al.* (1969). As Hutton (1962b) has pointed out, the multiple regression technique automatically includes any increase in energy cost owing to an increase in plane of nutrition in the coefficient representing maintenance requirement. This may in part explain why estimates of maintenance requirements of grazing animals made in New Zealand and elsewhere are often higher than values quoted in feeding standards.

There is little doubt that in the last two decades a valuable understanding of the feed requirements of sheep and cattle in this country has been achieved using DOM as the criterion. The inaccuracies of using a system based on digested nutrients are probably outweighed by the uncertainties associated with regulating and estimating the feed intake of grazing animals. In addition, all systems of energy evaluation are satisfactory where only a narrow range of feeds are encountered. The continued use of DOM into the future may be unwise. The present tendency towards the use of an increasing range of feeds and the future improvement to methods of estimating the energy requirements of grazing animals by more direct means than those used at present suggest that the advantages of using metabolizable energy should be considered.

REFERENCES

- A.R.C. [Agricultural Research Council], 1965: *The Nutrient Requirements of Farm Livestock. No. 2. Ruminants*. Tech. Comm. Agric. Res. Council., Lond.: 264 pp.
- Evans, R. E., 1960: Rations for livestock. *Bull. Minist. Agric. Fish Fd., No. 48*.
- Hutton, J. B., 1962a: *N.Z. Jl agric. Res.*, 5: 409.
- , 1962b: *Proc. N.Z. Soc. Anim. Prod.*, 22: 12.
- N.R.C. [National Research Council], 1970: Nutrient requirements of domestic animals, No. 4. Nutrient Requirements of Beef Cattle. *Nat. Acad. Sci., Nat. Res. Council.*, 55 pp.
- Preston, T. R.; Willis, M. B.; Martin, J. L., 1969: *J. Anim. Sci.*, 28: 796.