Feedstuff Evaluation

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PREFACE

This volume represents the proceedings of the 50th University of Nottingham Easter School in Agricultural Sciences held at Sutton Bonington in July 1989. The accurate evaluation of feedstuffs for livestock is of fundamental importance to the overall efficiency of animal production. Initially, systems of expressing the nutritive value of feeds were considered, as such an approach is essential if comparative estimates are to have any meaning. Modifications to feeding value as influenced by animal factors including intake and palatability, were discussed as, ultimately, the nutritive value of ingested food may be viewed in terms of animal responses. Specific dietary ingredients, being plant polysaccharides, fats, minerals and vitamins, were considered subsequently. Prediction of the nutritive value of compound feeds and individual feeds through classical wet chemistry and the more recent NIR is assuming considerable importance in the rapid evaluation of diets. Associated with these developments is an appreciation of the relevance of both inter- and intra-laboratory variation in determinations. Finally, the need to collate information into an interactive data-base is being actively pursued. It is evident that safety of animal feeds is becoming an increasingly topical issue and the last session considered the relevance of naturally-occurring toxic factors, residues, mycotoxins and, finally, animal pathogens.

It is hoped that the contents of the proceedings will have a wide appeal to all those involved in every aspect of nutrient supply to animals.

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CONTENTS

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COMPARISON OF ENERGY EVALUATION SYSTEMS OF FEEDS FOR RUMINANTS

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Abbreviations used in the text

CH_4 = methane energy
DE = digestible energy
dE = energy digestibility
dO = digestibility of organic matter
DXL = digestible lipids
DXP = digestible crude protein
DXF = digestible crude fibre
DXX = digestible N-free extract
FCM = fat-corrected milk (4%)
FL = level of feeding
FRG = Federal Republic of Germany
FU = fodder unit
GB = Great Britain
GDR = German Democratic Republic
IE = gross energy
k_f = efficiency of utilization of ME for fattening
k_g = efficiency of utilization of ME for growth
k_m = efficiency of utilization of ME for maintenance
k_{mg} = overall efficiency of utilization of ME
k_l = for lactation
ME = gross energy minus losses of faeces, methane and urine
NE_g = net energy for growth
NE_l = net energy for lactation
NE_m = net energy for maintenance
rse = residual standard error
SE_K = starch equivalent
TDN = total digestible nutrients (digestible organic matter plus 1.25 digestible ether extract)
UFL = Unité fourragère lait
XP = crude protein

Introduction

To describe or predict the performance of farm animals effective feed evaluation systems are required, which generate information necessary to formulate diets of optimum quality. Haecker (1914) described the necessary knowledge as follows:

> 'In order to determine the actual net nutrients required to produce a given animal product, the composition of the product should be known as well as the composition and the available nutrients in food which is to be fed for its production, so that the nutrients in the ration might be provided in the proportions needed by the animal'.

Feed evaluation systems should be simple. This requirement is in great conflict with accuracy of prediction of responses over a wide range of variation of rations and a correct modelling of the underlying physiological processes in the farm animals. Most systems applied on a large scale in practice are a reasonable compromise between simplicity and accuracy of prediction.

Animal production is very much dependent on the quantity of energy consumed. Systems have been developed for animal nutrition in practice and have been in use since the beginning of this century (Breirem, 1969, pp. 656–677).

Current energy evaluation systems are simplified models to describe the nutrient requirement of animals for a target production on one hand and to indicate the potential of the feeds to those requirements on the other.

Recently, alternative approaches (for example those based upon mechanistic modelling) to overcome the weakness of our current systems has been given increasing attention in research studies (Webster, Dewhurst and Waters, 1988; Baldwin and Miller, 1988). Because the practical application of these alternatives is not likely in the forseeable future a detailed comparison between the current energy evaluation systems is still useful.

It should be emphasized that feed evaluation systems have a much wider significance than the formulation of adequate rations to achieve the desired animal performance. They contribute to the farmer and feed industry and also to the management of least-cost strategy of feeding of farm animals and the purchase-policy of feedstuffs for least-cost formulation of concentrate mixtures. Moreover, they play a role in finding the best systems of grassland management and fodder conservation. In addition wider issues of agricultural policy on, for example, utilizing national feed resources in an efficient way, reducing adverse side-effects to the environment and planning future alternatives in animal production as a result of changing public opinion and development of consumer markets is partly dependent on a correct feed evaluation.

Characteristic features of current energy evaluation systems for ruminants will be discussed briefly and some information on interrelationships between systems given. Different ways of comparison will be discussed.

The demands to have one common system of feed evaluation in several countries will increase substantially with developments in Europe as planned for 1992 and onwards. Some aspects of the future trends will also be given attention in this paper.

Some historical aspects of energy evaluation of feeds and feeding standards

In the history of feed evaluation, since Albert Thaer (1752–1828) introduced the concept of hay equivalents as measures of relative value based on determining the materials in feed extractable with water (and other solvents), the Weende analysis of feedstuffs, developed by Henneberg and Stohmann (1864) in the nineteenth century, has been important in the description of feedstuffs. Within the last 40 years new methods of analysis have improved the description of fibrous components, carbohydrates, proteins and lipids. However, in the previous century scientists had already realized that information from feeding trials and chemical analysis of feeds was not sufficient to understand energy metabolism and that energy losses should be measured more accurately.

MEASUREMENT OF ENERGY CONVERSION

According to Maynard *et al.* (1979) the first real balance experiment with a dairy cow was conducted by Boussingault in 1839, without however measuring gaseous losses. Knowledge of energy metabolism has been improved by various techniques for example calorimetry. During the late part of the nineteenth and the early part of the twentieth century extensive energy studies were carried out by Rubner, Kuhn, Kellner, Armsby and co-workers in respiration chambers according to the Pettenkofer principles. Møllgaard, Fingerling, Wood, Benedict, Kleiber, Breirem, Crasemann, Nehring, and many others extended these studies.

DEVELOPMENT OF FEEDING STANDARDS

The first standards were based on digestible nutrients, derived from feeding trials described by Wolff in 1864 (Maynard *et al.*, 1979). Atwater brought the Wolff standards to the attention of the American workers, which resulted in the publication by Armsby in 1880 of his book, '*Manual of Cattle Feeding*'. In 1898 tables showing the average composition of American feeds, digestion coefficients for protein, crude fibre, ether extract and nitrogen-free extract and the Wolff–Lehman standards were published by Henry in his book, '*Feeds and Feeding*'. The intakes of digestible nutrients were added, together with digestible ether extract multiplied by 2.25, as a sum of nutrients (TDN).

DEVELOPMENT OF NET ENERGY SYSTEMS

Kellner's work in Germany (Kellner, 1905) based on net energy for fattening resulted in the use of net energy systems in Europe, such as the starch equivalent and the Scandinavian fodder unit, which was modified to be used for dairy cattle by Møllgaard (1929) after evaluation of a great number of feeding trials with lactating cattle.

Since the 1960s the factorial approach as proposed by Blaxter (1962a) of splitting the total requirement into various parts (e.g. for maintenance and physical activity, for milk production, for body gain, for wool growth, etc.) has been adopted by several scientists and used to develop new and revised systems. An EAAP Working Group on Feed Evaluation under the leadership of Van Es attempted to formulate a new European standard system for energy requirements of ruminants in the mid-seventies, but did not succeed. However, Van Es was able to secure a good deal of agreement on the central relationships now in use in the majority of the new and revised systems. In this chapter the comparison of feed evaluation systems will be focussed on these modern systems.

Essential features of current energy feed evaluation systems

TYPE OF INFORMATION REQUIRED

The value of feedstuffs for an animal cannot be assessed from its gross energy value as such. The utilizable portion consists of the absorbable components as only these can be metabolized in the animals' tissues and organs. However, its net effect depends on the efficiency of utilization of these absorbed components in the intermediary metabolism. Accordingly there are two factors arising: (1) the potential of feedstuffs; and (2) the requirements of animals and utilization of feed. Various factors affect one or both aspects of feed conversion.

Knowledge of the potential of feedstuffs and the restrictions to utilizing that potential is important to allow the prediction of the contribution of a given quantity of a feedstuff in a ration. The nutritive value of feeds is measured for example by their voluntary intake, digestibility, chemical composition and presence of anti-nutritional factors. Such data can be assembled to tables of feed composition and nutritive value expressed per kg of feed, as fed to the animal or per kg of dry matter.

Secondly, information is needed on the requirement for energy and nutrients for the various classes of ruminant livestock and for various levels of animal production (meat, milk, wool, reproduction). This requirement should include data about voluntary feed intake and indicate effects of short- or long-term deficits or surpluses of nutrients (Bickel, 1988).

TYPE OF ENERGY LOSSES AND ITS MEASUREMENT

The utilization of feeds from an energetic point of view is accompanied by four kinds of losses: in faeces, in urine, gaseous losses (mainly as methane) and heat (Figure 1.1). The magnitude of all four kinds of losses depends, at least partly, on the type of feed. In general the largest variation is found in faecal and in heat losses.

A large part of the heat losses is dependent to an extent on the feed but is due mainly to the inefficient utilization of absorbed nutrients. Moreover the energy required for maintenance is measured totally as heat. As indicated in Figure 1.1 heat losses also vary in relation to type and level of production and therefore it is difficult to assume that these heat losses are a constant proportion of feedstuffs.

Although the variation in losses in urine (3–7% of gross energy, GE) and as methane (5–10%) are small compared with that in faecal losses (15–50%) it has become common practice to rank feedstuffs at least in terms of their content of metabolizable energy (ME = gross energy minus losses in faeces, urine, CH_4),

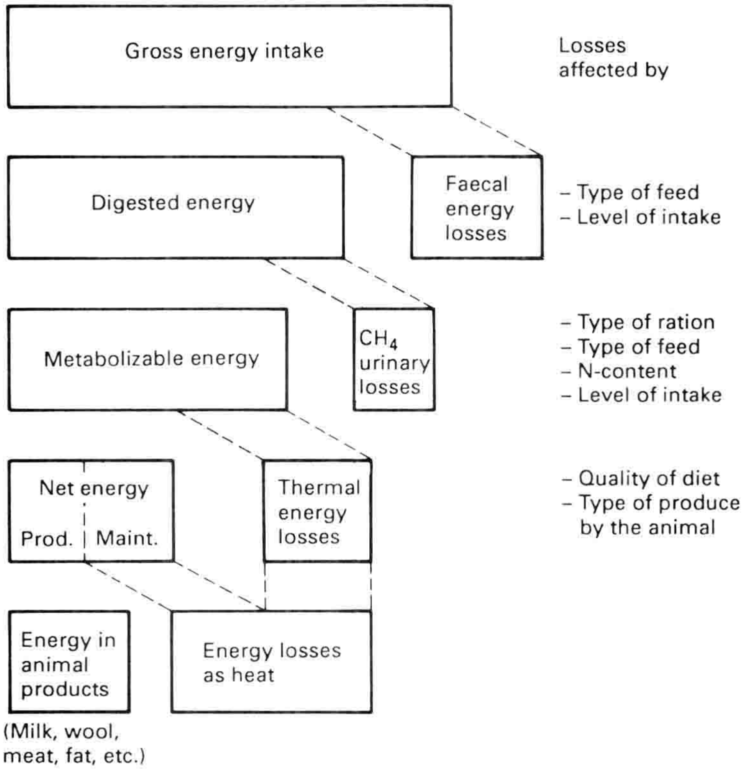

Figure 1.1 Diagram of energy model and factors in energy losses

measured under standard conditions (generally at a maintenance level of feeding). Accordingly ME is a currently accepted measurement of dietary energy evaluation, representing reasonable approximation of the total amount of energy available for metabolism.

Measurement of faecal losses and energy in urine can be undertaken comparatively easily and accurately by collecting of daily excreta. For measurement of methane a respiration chamber is required and measurement of heat losses also need a direct or indirect calorimeter. However, methane losses can be predicted reasonably satisfactory by using the equation presented by Blaxter and Clapperton (1965). This was recently confirmed by Edwards (1988) for grass silages.

The net energy in animal products, such as milk and wool, can be determined accurately by measuring its combustion value. From the difference between energy consumed and the net production total losses can be derived. However, in live animals the energy deposition has to be derived from the energy balance as the difference between input and output of energy. Owing to accumulation of errors, energy balance has a large standard deviation.

STANDARDIZATION OF DIGESTIBILITY MEASUREMENTS

Knowledge of the apparent digestibility of the organic components in feeds is of major importance and the first essential parameter in current energy evaluation systems. Most digestibility coefficients have been derived from trials with sheep, fed at around the maintenance requirement or predictions are made aiming at that level. These data can be converted to cattle because of the great similarities in digestive capacity between cattle and sheep as recently confirmed by Meissner and Roux (1989). However, for a good comparison of values of digestible energy or digestible organic matter, sufficient standardization in the conduct of digestion trials is necessary. Digestibility coefficients should be measured in ruminants under 'normal' conditions, so that rumen fermentation, ruminating and other digestive processes are not disturbed. A minimum amount of 'structure' in the form of long hay is given when deriving the digestibility of feedstuffs, which cannot be fed as a single feedstuff.

An increased feed intake generally depresses digestibility of organic matter with a mean value of approximately 3 units for each incremental increase in intake over maintenance intake (Van der Honing, 1975). This value is in line with the 4% reduction in digestibility as contained in the Nutrient Requirements of Dairy Cattle (NRC, 1978, 1988).

SYSTEMS BASED ON DE AND ME

Few systems are based solely on digestible nutrients or digestible energy. The widely used TDN-system (Total Digestible Nutrients = digestible organic matter plus 1.25 digestible ether extract) is an example of a system based on digestible nutrients. In the USA DE (digestible energy) is also in use and the relationship between both is: 1 kg TDN = 4.40 g Mcal DE (NRC, 1978, 1988).

The current systems in Sweden and Great Britain (GB) are based on metabolizable energy (ME). In this way variation in urinary and methane energy losses are taken into account which provides a more precise basis compared with DE.

In other systems ME is usually used as an intermediary step in the calculation of the net energy value. This intermediary step is a logical approach since the partitioning of metabolizable energy is dependent more on the type of animal and the production level than on the individual feedstuffs.

ME as a percentage of DE is assumed to increase the greater the digestibility. Faecal losses increase at a higher level of feeding, but are partly compensated for by lower losses in urine and combustible gases.

The ME/DE ratio, according to the literature (Van Es and Van der Honing, 1977), increases at a higher level of feeding from 0.81–0.82 at maintenance up to 0.87 at 3–4 times maintenance. This is due mainly to reduction in relative methane and urinary losses. Part of the reduced losses in methane and urine may be attributed to a higher proportion of concentrates in the ration and/or the ground and pelleted form of part of the ration (Van der Honing, 1975). In the French system ME/DE is negatively corrected for crude fibre and crude protein content of the feed (Andrieu and Demarquilly, 1987) and similar effects were calculated from our own data.