CANADA

IDRC-134e

Standardization of Analytical Methodology for Feeds

Proceedings of a workshop held in Ottawa, Canada, 12–14 March 1979

Editors: W.J. Pigden, C.C. Balch, and Michael Graham

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IDRC-134e

Standardization of analytical methodology for feeds : proceedings of a workshop held in Ottawa, Canada, 12-14 March 1979. Ottawa, Ont. IDRC, 1980. 128 p. : ill.

/IDRC publication/. Compilation on /animal nutrition/ /nutrition research/ applied to the /evaluation/ of energy values of /feed/s and the /standardization/ of analytical /methodology/ — discusses /biochemistry/ aspects, practical rationing systems, /nitrogen/ evaluation, /sugar cane/ feeds /classification/, /trade/ and /legal aspect/s of /technique/s. /List of participants/.

UDC: 636.085.2.001 ISBN: 0-88936-217-3

Microfiche edition available

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Cosponsored by the
International Development Research Centre
and the
International Union of Nutritional Sciences

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Problems of Standardization of Units to Describe the Energy Value of Feedstuffs

P. W. Moe[1]

The most important considerations in selecting units to describe the energy values of individual feeds are whether they are reproducible and whether they account for the major proportion of variation in energy value. Digestible (DE) or metabolizable energy (ME) values as measured at maintenance intake are the most suitable units for compiling data on a large number of feeds from many sources. Additional data on chemical composition are needed to estimate efficiency of use of DE or ME in the producing animal and to estimate change in DE and ME value with change in intake level.

Net energy (NE) values may be derived from tabulated DE, ME, and/or chemical composition for specified feeding conditions. NE values derived in this manner are useful in applied feeding systems, but are not suitable for compilation in large data banks.

Nearly all energy units are based on digestible energy (DE), metabolizable energy (ME), or some form of net energy (NE). These terms are thoroughly discussed in the preceding paper by van Es (1979); therefore, I will only comment on the use of these energy units to develop specific recommendations for feeding animals in practice.

Digestible Energy

Because only the measurement of energy intake and feces energy is required, DE has been measured for many feeds, usually at maintenance intake. Measurement of DE alone accounts for a very large proportion of the variation in efficiency of use of ingested feeds. Limitations to the use of DE include variation in DE value with plane of nutrition and variation in use of DE from different diets.

Metabolizable Energy

Measurement of ME requires the measurement of energy losses in feces, urine, and methane. Because methane is a gaseous loss, its measurement requires relatively expensive apparatus. Therefore, most tabulated ME values have been calculated from DE using an estimate of methane loss. Directly measured ME values have been effectively used in research to characterize energy requirements and efficiency of energy use. Relatively few data, however, are available from directly measured ME values of a large number of feeds. Limitations to use of ME include variation in ME value with plane of nutrition and variation in use of ME from different diets. The latter is of considerably greater importance with growing than with lactating ruminants.

Net Energy

Net energy is defined as the energy recovered in the animal product. NE systems or variations in the form of feed-unit systems have become quite popular because of the relative certainty with which NE requirements for production can be described. NE values of feeds are easy to describe in theoretical terms but very difficult to measure. Measurement of NE whether by calorimetry or slaughter balance is generally by one of three methods: (1) by difference between measurements at two levels of production; (2) by difference between a measured point and another point that is an assumed value chosen to represent either maintenance or fasting; and (3) by regression analysis of measurements at several levels of production. By any of these methods, the magnitude of NE values for production is greatly influenced by the magnitude of the maintenance values that are either estimated or assumed. Correct use of NE values, therefore, requires an exact description of all of the assumptions involved in their derivation.

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Source of Data on Feeds

All of the information obtained about a specific feed falls into two distinct categories. The first consists of direct determinations by chemical analyses. These analyses are repeatable measurements of specific components or classes of components by rigidly defined methodology. Determination of the amount of specific minerals, amino acids, total nitrogen, cell walls, lignin, ash, etc., are examples. Procedures, of course, must be adequately defined or referenced to ensure uniformity of procedures, but in general, the measurements are repeatable for a particular sample material. The important point is that the results are influenced only by the sample material itself and not by how it is used or incorporated into animal diets.

The second category of measurement is biological in nature and is intended to provide a measure of how well a particular feed is used by animals. This introduces a totally new source of error in the measurements, i.e. biological variation. Measurements of digestible, metabolizable, or net energy values are such measurements. These measurements, while influenced by the nature of the test feed, are also influenced by normal biological variation of animals, the design of the experiment, and the interpretation of the data. The measurement of net energy value, for example, includes a sizeable element of "interpretation."

Application of Feed Composition Data

A second consideration in the suitability of attributes of feeds is the question of how the information will be used. I will identify two extremes, although a number of intermediate applications also exist.

The first extreme is the feed composition data bank, especially that maintained on an international basis. The objective of the data bank is to provide a very accessible source of valuable information on a wide variety of feeds. Because the data are used for a wide variety of situations in widely varying geographic locations with differing climatic and management factors, it is essential that the data be as objective as possible. Data derived chemically certainly fit this requirement; data derived biologically, however, are more subjective in nature because they may be influenced by management or interpretation. Some biological measure is necessary, however, as chemical measures alone do not adequately describe the potential biologically available energy in a feedstuff. The question which arises then is: which of the biological measures are suitable for incorporation in data banks? Digestibility as measured at a maintenance intake is undoubtedly the most effective measure for this purpose because it directly accounts for the largest source of variation in feed value. Digestibility is also a useful predictor of efficiency of use of digested energy and is therefore useful for estimating ME or NE values in feeding systems. It is my belief that net energy values are not suited to compilation in data banks because they cannot be measured independent of some assumptions. The assumptions may refer to net energy values of some diet components or net energy requirements for maintenance, for production, or for both. Net energy value may be derived by difference, which may yield a totally different value related to the last increment of feed consumed.

At the opposite end of the spectrum from data banks is the use of information about feeds in the development of practical feeding recommendations. Feeding recommendations to be useful must be as simple as possible for convenience but not so simplified that important sources of variation are ignored. The scope of coverage becomes an important consideration. In the United States, for example, the National Research Council prepares a series of publications on the nutrient requirements of each species of animal and poultry. These are intended for use throughout the country, and are therefore generally broad in application. Each individual state in the United States has extension personnel who are more familiar with specific feeding situations and problems in their geographic location. These groups, as well as private feed companies or nutrition consultants, frequently develop more specific recommendations for their own use. Requirements may be adjusted to include local environmental effects, or the composition and energy value of important feeds may be adjusted for specific management situations or local climatic effects.

For immediate application at the farm level, simplicity is often a very important factor in gaining acceptance of feeding systems. Although the increasing sophistication of managers at the farm level decreases the need for simplicity, it remains an important factor. In this situation, net energy systems have proven very useful. The success of a particular system depends, however, not on whether it is a net energy system or some other system, but whether or not the important variables have been adequately built into the system to account for animal performance. In net energy systems, the burden falls most heavily on the values selected to represent the net energy value of individual feeds. The description of requirements is relatively easy. The description of energy values of feeds is much more difficult.

Feeding Systems

Feeding systems introduced in recent years include an ME system in Great Britain (ARC 1965, MAFF 1977) and NE systems in the United States (NRC 1978), the Netherlands (van Es 1978), France (Vermorel 1978), and Switzerland (Bikel and Landis 1978). These are only examples of many others that have appeared recently. All of these systems have in common the consideration of recent knowledge on the amount of energy required by ruminants for specific physiological functions and the variation that occurs in the ME value of feeds and the efficiency with which ME is used by the animal. Several of the new NE systems use a form of "feed unit" to express the requirements and the energy value of feeds. At first glance, it may appear that these systems revert back to the old feed unit systems in which productive values were directly measured against a standard feed. There is a major difference in the newer systems, however, which should not be overlooked. All of these systems, including those using "feed unit" terminology have defined the feed unit in terms of energy contained in the product formed. They are thus defined in precise energy terms on an absolute basis and not simply on a relative basis in comparison with the reference standard feed. The system described by van Es (1978), for example, defines one "feed-unit-lactation" (VEM) as 1.650 kcal NE_l. Similarly, Vermorel (1978) defines one "unite fourragere lait" (UFL) as 1.730 Mcal NE_l. The systems adopted in the United States and Switzerland use NE_l directly instead of feed units and are expressed as megajoules (Bickel and Landis 1978) or megacalories (NRC 1978). Thus, all of these systems express energy requirements either directly as NE_l or are defined in terms of NE_l.

Differences Among Energy Systems

Although much of the current discussion is about the differences among units for expressing the energy value of feeds and the energy requirements of cattle, a more pertinent consideration in judging the relative worth of one system against another is the manner and extent to which important variables are identified and incorporated either in the establishment of energy requirements or in setting the energy values of individual feeds. In discussions of feeding systems among scientists in the field, there is usually universal agreement on the major factors that can influence the use of energy by animals. There is less agreement on the question of how important each factor is. This is explained in part by personal preference for systems that are extremely broad in application and therefore account for all known sources of variation, or a preference for a system that is narrowly defined for a specific situation. Differences of opinion and preferences have resulted in substantial differences in the way various net energy systems are used. The fact that differences exist does not mean that one system is necessarily better than another. It does mean, however, that values from one system may not be interchangeable with values from another system. It is this point that forms the basis of my concern that net energy values not be tabulated in a central data bank and treated as though they were feed attributes in the same sense that the content of crude protein or cell walls or digestibility is used to identify the attributes of a specific feed.

The following are known to influence the amount of feed required to promote a unit of measurable production such as milk production or body weight gain: (1) reduction in DE value of diet at high intake; (2) reduction in ME value of diet at high intake; (3) variation in efficiency of ME for production; (4) change in distribution of energy between milk and body fat; (5) change in milk composition; (6) change in caloric value of weight gain; and (7) change in ratio between protein and fat in body gain.

All of these effects contribute variation that must be accounted for in either energy requirements or in feed values. Regardless of the energy unit used (DE, ME, or NE) it is possible to incorporate these effects into either the listing of requirements or the energy value of specific feeds. With NE systems, essentially all of these effects need to be incorporated into the NE value of feeds for a specific application. With ME systems, many of these can be incorporated into the listing of requirements. Discussions of the superiority of one system versus another are, therefore, less productive than discussions of ways to improve each of the systems.

Before all of these effects can be used effectively, additional information is needed. With dairy cattle, we cannot yet predict very accurately the rate at which the ME value of feeds declines at high intakes. With growing cattle, clarification is needed of the interactions among weight gain, body composition, and efficiency of ME used for body gain. Research now in progress at many locations will be useful in resolving these problems.

Recommendations:

1. The most useful, informative, and least likely to be misused measure of the biological availability of energy for ruminants is the digestibility of that feed by sheep at a maintenance intake. For very low quality forages and for corn or sorghum grains that have not been ground or steam processed, separate determinations are needed for cattle or buffaloes.
2. Additional chemically derived attributes are needed to allow prediction of ME, rate of change of ME with increased intake, and efficiency with which ME is used for a specific productive process.
3. The feed attributes described above may be effectively used to develop NE values of feeds for use in an applied feeding situation. NE values so derived, however, should not be accumulated in massive data banks and treated as fixed attributes of those feeds.