

## FEEDING STANDARDS: AN OUTMODED CONCEPT IN RUMINANT NUTRITION

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**SUMMARY**

Efficient use of feed resources is recognized to be an important component of livestock management. However, traditional feeding standards and systems are shown to have been an inconsistent and unreliable medium for applications of modern nutritional knowledge. Their continued use is admitted to be expedient but it is suggested that effort should be diverted from "patching up" these **fundamentally** unsatisfactory systems towards development of new ones. The principles and problems of alternative concepts are outlined and a few simulation models listed which meet some of the desirable criteria.

## INTRODUCTION

Probably Noah (Anon BC) was the first person to really need access to feeding standards for livestock but it was not until the 19th century that records appear of systematic attempts to provide them (Tyler 1975). Modern systems differ little from the pioneering ones; they attempt to list the biological values of feeds together with the nutrient or energy requirements of animals and to explain how to use this information (compare Jarrige 1978 with Henry 1898). Unfortunately the complexities of feeding, digestion and metabolism cannot be adequately expressed in tables of finite size so, in attempts to make the systems "work", the operating instructions multiply and the incidence of subjective elements increases. The sophisticated nutritional knowledge that has accumulated is relevant to animal production but its full utilization will be **possible** only when there is matching sophistication in its use. Attainment of this goal should have high priority in applied animal nutrition. Indeed, failure to accept this challenge must undermine the rationale for much current research in nutritional physiology.

## WHAT NUTRITIONAL INFORMATION IS NEEDED AND BY WHOM?

First, data on the energy requirements of livestock for different types of production and on the energy values of feeds are needed to plan feed supplies for regions or large enterprises through cropping programmes, importation of feedstuffs and utilization of crop residues and industrial by-products. Information of a general nature is satisfactory for this purpose.

Secondly, by contrast with pastoral industries, pig and poultry production is so intensive and competitive that the survival of an enterprise depends on attaining the highest possible efficiency in utilization of feed, because feed accounts for a large **fraction** of the operating costs. In these industries a level of animal performance is prescribed - for example, to realise the genetic potential of the stock or to guarantee a product with desired characteristics - and a diet is chosen that, **at** minimum cost, supplies the necessary energy and nutrients under ad libitum feeding. Thus, accurate detailed information is needed about the nutrient content of feeds and the requirements of the animals.

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Thirdly, efficient use of feed is also an economic necessity with intensively managed **ruminants** (high-yielding dairy cows, goats or sheep; growing/fattening animals in feedlots). However, knowledge of the specific nutrient requirements of ruminants is not extensive and is complicated by the fact that nutrient supply is drastically modified by the **rumen** microbes,

Whether and how nutritional information could be used to improve the productivity of pastoral enterprises is a matter of opinion. It would be useful to be able to determine the level of supplementary hand feeding needed to sustain a desired level of production. This question is posed daily-for dairy cows in Australia, annually in some regions (Mediterranean climate) for **weaners** and breeding females, and during inclement weather or **prolonged drought** in other regions. However, grazing animals are presented with a **variable** menu from which they select a diet whose composition and amount cannot be readily assessed, and their energy expenditure responds to an array of environmental factors. If menu, diet and animal performance from time to time could be foreseen or assessed, it would facilitate choice of efficient management strategies for each situation, but **an** acceptable method of making such an assessment has not yet been devised.

Evidence will now be cited that traditional feeding standards and systems **are** neither consistent nor reliable; and therefore do not satisfy these needs for information about animal nutrition.

#### THE PROPERTIES OF TRADITIONAL FEEDING STANDARD SYSTEMS

##### Consistency amongst extant systems

Some authors have implied that consistency amongst systems is a substitute for validation against observations. For example, in ARC (1980) the requirements of cattle for maintenance, growth and fattening were estimated using the current scheme and earlier ones (ARC 1965; NRC 1970, 1971; Schiemann *et al.* 1971; MAFF 1975) and appreciable discrepancies were found. Maintenance requirement for **metabolizable** energy (ME) was **42-48** MJ/d for 400 kg cattle and 4.7-5.9 MJ/d for 30 kg sheep; requirement for gain of 1 kg/d in cattle varied from 46 to 65 MJ/d at 200 kg live weight and from 73 to **110** MJ/d at 400 kg; for 200 g/d, sheep needed 10.9 - 13.9 MJ/d. It was concluded that the energy value of liveweight **gain** was not being set correctly in relation to rate of gain and age and that further research was needed to rectify this fault. Alleged causes of variation in estimated **ME** requirement for milk production. (e.g. **146-177** MJ/d for 20 kg milk/d in a 500 kg cow at weight maintenance) were that **MAFF** estimates uniquely included a "safety margin" and only some systems corrected for level of feeding (ARC, NRC) and "diet quality" (ARC). The systems also gave different estimates of requirements for pregnancy, for example a total of 12.7-18.9 MJ/d for a 75 kg ewe 2 weeks **pre partum** and **20-37** MJ/day extra for a "standard" cow near term. **No** action was suggested to resolve the discrepancies for the ewe and cow so the implication was that the ARC estimates should be preferred.

Under the aegis of the Commission of the European Communities, growth rates in cattle given specified rations were predicted by the authors of several new systems in use in Europe (Beranger 1980). Co-efficients of variation between the estimates were as **high** as 40% and

the respondents offered a variety of "explanations": "The discrepancies between the different systems can be considered as large or small; it depends on your philosophy" (R. Jarrige); "I don't think the situation is as bad as one might suppose from the variations" (A.J.H. van Es); "it is not clear to me exactly what was done" (A. Neimann-Sørensen); "a number of us have used feeding trials to adjust the requirements to be correct" (G. Alderman).

De Brabander et al. (1982) found appreciable variation between five **extant schemes** for dairy cows. Estimated requirement for maintenance of a 600 kg cow was **4.69-5.24** kg concentrates/d or **5.40-6.27** kg roughage/d and production of 15 kg fat-corrected milk was estimated to need **6.00-6.41** kg concentrates or **7.12-8.09** kg roughage. These authors commented that the most complex system (Jarrige 1978) was not better than the others (Schiemann et al. 1971 and Hoffmann et al. 1974; MAFF 1975; Buysse et al. 1977 and van Es 1978; NRC 1978) and that it compensated an **underevaluation** of roughages by an underestimation of the requirements for **bodyweight** change.

Even if various systems **gave** the same answer (which in fact they do not), they could all be wrong. Comparisons without validation are immaterial and indeed they can give quite a misleading impression of reliability.

### Reliability

Before any predictive apparatus can be judged reliable, it has to be tested against an appropriate range of data not used in its construction, and be shown to have consistent bias, preferably small.

Knox and Handley (1973) described application of the system of NRC (1970, 1971) to 95278 cattle receiving, in feed-lots, rations that contained **40-85%** concentrates. On average, liveweight gain was overestimated by  $8 \pm 2\%$ . Errors were higher for the summer period (150 kg gain underestimated by c. 30 kg in 1969 and by 10 kg in 1970) than for winter (gain **overestimated** by **10-20** kg). Overestimation was explained as an overlooked effect of weather on maintenance requirements but the cause of underestimation could not be identified.

Joyce et al. (1975) tested the systems of **ARC** (1965) and NRC (1970) **against data** from feeding trials with both grazing and stall-fed cattle. Average errors of predicting ME intake were only a few percent but the between-trial standard deviation of the errors was **10-15%** and there were substantial discrepancies between the two systems, for example 22% for a 400 kg animal gaining 1 kg/d.

A working party of 'the British. Agricultural Development and Advisory Service (Alderman 1972) studied systems based on ARC (1965). Differences between **predicted** (P) and observed (O) growth rates (P-O) were **-0.16** to **+0.30** kg/d for cattle gaining **0.7-1.9** kg/d on concentrates and 0 to **+0.24** kg/d for gains of **0.5-1.2** kg/d on forages; errors became more positive at high live weights. For dairy cows, errors in estimating milk yields of **14-22** kg/d were **-4** to **+6** kg/d when **liveweight** changes were known and taken into account. There was comparable information for sheep. Many reasons for error were advanced and it was concluded that **"The modifications and approximations necessary to evolve an energy system for ruminants capable of rapid manipulation by nutrition advisers may be suspected of introducing errors or bias when tested against recorded animal**

performance. In view of both the measured errors of animal feeding trials recorded in this report, and of the larger errors of practical application on farms, the Working Party believe that their proposals will meet the needs of advisers". The proposed new system (MAFF 1975) was considered to give "more accurate predictions" than older systems, which is indeed faint praise.

Robelin and Geay (1976) recorded energy intake, weight gain and changes of body fat and protein in **Limousin** bulls growing from 304 to 646 kg, and Webster (1978) tested the MAFF (1975) and NRC (1970) systems against these data. ME requirements were overestimated by c. 30% and the energy value of gain by more than 100%. Webster's conclusion was that the systems were "not worthless", merely inapplicable to large animals. **Bickel** and Landis (1978) apparently had similar experiences in applying the systems of MAFF (1975) and van Es (1978) to Swiss dual-purpose cattle.

In a symposium on "The Metabolizable Energy System [of MAFF 1975] in Practice", Alderman (1977) modestly claimed that it results in concentrate allocations similar to those used by successful dairy farmers, and Edwards (1977) reported that actual less predicted live-weight gain was  $-72 \pm 67$  g/d for sheep and  $-30 \pm 215$  g/d for cattle (110 groups of each). Edwards suggested that the factors contributing to error were: (i) uncertainty about the energy value of gain, (ii) differences in requirements between the sexes, (iii) effects of activity and climate, (iv) lack of reliable feed values, (v) use of incorrect efficiencies with certain high-energy feeds (fat-fortified materials or silages) and (vi) unsatisfactory estimation of dry matter intake. This list includes virtually all the basic components of the system!

Vermorel (1978) found that the new French scheme (Jarrige 1978) predicted requirements within  $1.1 \pm 4.2\%$  of the observed intakes of lactating cows in 44 feeding trials. However, De Brabander *et al.* (1982), in a similar test, found that intake was **underestimated by 8-11%** by the French and 4 other systems; the bias did not vary much with type of feed but was least near bodyweight maintenance. **Vermorel (1978)**, also showed that predicted feed values for rapidly growing cattle were within **1-9%** of observed values. According to van Es (1978) the contemporaneous Dutch system had also been found "satisfactorily accurate for rations of not too extreme composition".

In summary, none of these systems is reliable in general applications. Errors are unpredictable and the reasons for them are largely a matter of opinion.

#### Conclusions about traditional systems

While precision is not necessary or feasible in ruminant nutritional management, an acceptable system should surely be reasonably free of bias in a wide range of circumstances, should not encourage subjective interference and should allow the consequences of approximations to be traced.

However, the original proposals for the traditional systems were never accompanied by satisfactory evidence of their reliability. Most systems involve a series of predictive steps, and it is impossible to foresee whether the errors of successive steps are

additive or mutually cancelling; overall errors must be determined directly. Furthermore, the systems are empirical rather than mechanistic so their validity in situations appreciably different from those in which they originated cannot be taken for **granted**. Finally, the desire to make schemes that can readily be understood and used by laymen caused adoption of many approximations with obscure consequences individually and collectively. The conclusion is inevitable that the traditional concept of feeding standards is outmoded.

#### IS **THERE** AN ALTERNATIVE TO FEEDING STANDARDS?

No workable and validated alternative is yet available. However, this situation would be speedily changed if research effort were directed to developing and implementing a new concept rather than to "patching up" the fundamentally unsatisfactory traditional systems.

Knowledge of nutritional physiology can be conceptualized to represent quantitatively the processes by which an animal utilizes feed (Black 1983), and the energy exchanges associated with most of these processes are known (Schultz 1978). For the purpose under discussion, a concept should probably be at a whole-animal level, rather than at the extremes of cell or farm. Thus it would be better to partition nutrients correctly amongst alternative products in diverse genotypes (Black 1983; Smith 1983) than to simulate the Krebs cycle (Schultz 1978) or plant growth (but see **Sibbald et al.** 1979). This does not deny the relevance of these matters but merely identifies a manageable module of the whole scene. At the chosen level, the approach should be comprehensive in the first instance though of the least complex form. Contraction can then be contingent upon the results of sensitivity tests of the whole concept and be undertaken with full knowledge of the consequences. Definition of the ability of such a simulation model to predict intermediate and overall responses should be regarded as an essential part of its development. Computer technology should be used freely.

#### Obstacles

Although simulation models can be formulated with the information already available (see next section), lack of data is just as serious a restriction as for traditional systems. There are also conceptual problems that affect both approaches. For example, energy requirements are usually estimated by calculating the maintenance requirement of the particular animal and adding an allowance for each unit of product, on the assumption that the former is independent of the latter. However, it is now apparent that basal metabolism, which is a major fraction of the maintenance requirement, varies with level of production (Graham 1982). Again, negative tissue energy balance is unavoidable in the high-yielding dairy cow in early lactation so there is little merit in providing for maintenance plus milk. Evidently a new concept of energy partition amongst concurrent processes is needed,

**Familiarity** with an extensive array of information may be considered a prerequisite for use of a **complex simulation** model but the complexity should not be evident at the operational level. Experience suggests that few operators are able or willing to supply more than a dozen items of information about the animal, its diet and

the environment. Models should be designed to acquire additional information that they may need from stored tables or equations,

Few systems, ancient or modern, are free of functions that have little factual basis but these are perhaps more numerous in conceptual than in empirical models. While the presence of speculative features at critical points will inhibit general predictive uses, it may facilitate exploration of problems. For example, Black and Mulholland (1983) attempted to identify causes of weight loss in weaned lambs at pasture during summer in a particular region of New South Wales. However, data on the quantity and quality of **herbage** consumed was rudimentary. They resorted to hypotheses about **herbage** intake and **effects** of supplements on it which, as part of an otherwise well-founded model of energy and nitrogen utilization, permitted probable responses to various treatments to be compared. Apparently, only if **high protein** or other supplements were fed ad libitum could normal gains (150g/d or better) be expected, and **this** was confirmed by experiments,

#### Examples

Simulation models for ruminants that satisfy some, but not all, of the criteria discussed above are listed in Table 1. Several deal with the whole animal, and others with a **particular facet** (e.g. digestion) in such a way as to be a potential sub-unit of the whole.

TABLE 1 Ruminant simulation models that offer some alternative concepts to conventional feeding standards

Source	Type
Graham <u>et al.</u> (1976)	Energy and N utilization in sheep
Bywater and Dent (1976)	Nutrient partition in dairy cow
Geisler and Jones (1979)	Energy requirements of pregnant ewe
Geisler and Neal (1979)	Energy nutrition of pregnant ewe
Keener (1979)	Energy utilization of cattle
Graham (1981)	Energy and N utilization by cattle
Black (1983)	Energy and N partition in diverse sheep
Rice <u>et al.</u> (1974)	Ruminants on rangeland
White <u>et al.</u> (1983)	Ewe flock at pasture
Smith (1983)	Flock or herd at pasture
Freer and Christian (1983)	Grazing ruminants
Baldwin <u>et al.</u> (1977)	Ruminant digestion
Black <u>et al.</u> (1980-81)	Rumen function in sheep
Vera <u>et al.</u> (1975)	Thermal exchanges of sheep
Bruce (1980)	Thermal exchanges of cows
Mount and Brown (1982)	Sensible heat loss from sheep
Newton and Edelsten (1976)	Nutritional effects on litter size and weight in sheep
Forbes (1977)	Voluntary intake in lactating cows
Sibbald <u>et al.</u> (1979)	Herbage intake by hill sheep

Several of the models **concentrate** on one productive function such as pregnancy or lactation. The majority are concerned with the responses of an average animal but a few attempt to simulate events in the herd or flock at pasture, which involves consideration of pasture growth.

Of those listed, only the sheep model of **Graham et al.** (1976) and **its** cattle transformation (Graham 1981) are fully described and freely available in **useable** form. These models are mainly empirical, their current versions following the methods of **ARC (1980)** for energy utilization, but they also deal with protein. They are recursive so that values like growth rate or plane of nutrition, which are important determinants of efficiency (**Graham 1982**), can be transferred from early to later cycles of calculation. Also, responses can be accumulated as the animal, diet and environment change over time. These models represent the maximum extension of the **ARC energy system** that is likely to be worthwhile, intractable problems being encountered that are inherent in that system, e.g. the definition of maintenance requirements and efficiency in growing animals (**Graham 1982**).

#### GENERAL CONCLUSIONS

Present-day use of feeding standards and traditional methods are justifiable on **grounds** of expediency; they exist and are within the scope of people educated before the era of computers. While substitution of computers for pencil and paper facilitates the calculations and reduces the need for dubious approximations, it does not change the inherent characteristics of the systems. A fuller application of modern knowledge will depend on the development of new concepts and probably on their implementation through simulation modelling techniques with relatively inexpensive microcomputers.

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