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SYMPOSIUM ON 'THE LIMITS TO CLASSICAL ASSESSMENT OF NUTRITIONAL ADEQUACY'

Evaluation of feeds for ration formulation

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In order to predict animal performance with some degree of accuracy, the feed compounder needs an extensive knowledge of the raw materials that he is to use in the manufacture of those feeds. It is then necessary to assume additivity of the individual raw material values providing there is no evidence to the contrary. This evaluation of raw materials is carried out primarily by laboratory assay and animal bioassays. However, there have been many attempts to develop means of prediction, particularly of the energy content of raw materials and finished products. The present paper will review the three approaches, concentrating mainly in the ruminant area, for this is where there is most doubt about current methods of evaluation. Certain aspects of evaluation of ingredients for use in non-ruminant feeds will be covered.

Laboratory evaluation

The evaluation of a raw ingredient normally starts in the laboratory with an extensive assessment of the various nutrients present. Thus the oil fraction will be analysed into its constituent fatty acids together with measurements of the proportions of saturated and unsaturated fats. The protein fraction will be identified as constituent amino acids; for the ruminant, measurements will be taken of the quickly-degradable nitrogen, pepsin digestibility and acid-detergent-insoluble N. The carbohydrate fraction will be split into the various starches, sugars and fibre fractions present. Extensive analysis is carried out on the content of major and trace minerals. Quite often digestibility measurements such as Invitro D, neutral cellulose digestibility, together with possible measurements using the rumen simulation technique (Rusitec) will be undertaken to give some guide as to the nutritional value of the ingredient to the animal. An area of prime importance with many raw materials is anti-nutritive factors which may be present. If a proper laboratory study is to be carried out, tests must be undertaken for trypsin inhibitor, glucosinolates, tannins and other factors which might adversely affect animal performance. These studies would often include tests for the presence of mycotoxin.

From these studies in the laboratory the nutritionist will then make his best estimate as to the nutritive value of the raw material. At this stage an economic evaluation will then normally be carried out in order to ascertain whether the ingredient is likely to be of economic use in various products. Obviously if the price is considerably higher than the economic value of the nutrients then it is unlikely that the evaluation would proceed any

Table 1. *The importance of defining the source of a raw material (nine samples of maize-gluten feed)*

Sample	GE (MJ/kg DM)	DE (MJ/kg DM)	18 h RDP (mg/g protein)	Digestibility of UDP
1	18·9	13·9	813	0·20
2	20·0	13·4	657	0·40
3	20·5	13·6	752	0·45
4	19·9	12·1	676	0·38
5	19·6	14·5	620	0·68
6	20·2	13·6	723	0·27
7	19·3	14·4	803	0·70
8	18·7	13·2	714	0·47
9	19·6	13·8	731	0·51

GE, gross energy; DE, digestible energy; DM, dry matter; RDP rumen-degradable protein; UDP, rumen-undegradable protein.

further. However, if the raw material did appear to be economically valuable, the normal procedure would then be to proceed to animal bioassays. In the case of raw materials for ruminants, these bioassays would concentrate mainly on evaluation of metabolizable energy (ME) content and of the various protein fractions.

Energy evaluation for ruminants

Traditionally ME has been measured in either calorimetric chambers or metabolism crates. The latter suffers from the fact that methane losses are not measured. Reports from the Rowett Research Institute (1976) and Wainman *et al.* (1979) clearly indicate that these methane losses vary between different raw materials and can be quite significant in terms of energy that is lost, e.g. values ranging from 1·1 to 2·5 MJ/kg dry matter. The current economic value of 1 MJ ME in high-energy dairy diets is approximately £7/tonne. Thus if due to methane loss an inaccuracy in excess of ±0·5 MJ is present in the evaluation then an ingredient which may look attractive may in fact prove to be uneconomic. Therefore it is always better to carry out measurements in calorimetric chambers if possible rather than metabolism crates.

A further problem with measurements of ME of raw materials is that the value may change quite markedly between one source of that material and another. Values presented in Table 1 indicate that in nine different sources of maize-gluten feed the digestible energy (DE) ranged from 12·1 to 14·5 MJ/kg dry matter and the digestibility of the undegraded protein ranged from 0·20 to 0·70. Thus it is very important to ensure that different sources of supposedly the same ingredient are evaluated and that when applying values for formulation purposes the correct source is ascribed to a raw material.

Recent evidence from work supported by or carried out under the auspices of Dalgety Agriculture Ltd have raised doubt as to the value of ME in predicting animal performance. Values presented in Table 2 indicate that cows produced more milk on diets formulated to a constant ME level when that energy was primarily obtained from digestible fibre and fat sources as opposed to starch sources. Part of this finding in fact was undoubtedly due to increased silage intake, but there was also clear evidence of improved efficiency of energy utilization (Thomas *et al.* 1986). Similar results have been obtained from other trials, often with an increased milk-fat output when highly-digestible-fibre diets were fed. Over all the trial work carried out, it was quite evident that milk and solids output was as good or better with a highly-digestible-fibre diet than

Table 2. *The effect of composition of concentrate on voluntary intake of silage and milk output by cows at weeks 3–10 of lactation (from Thomas* et al. *1986)*

Type of concentrate . . .	High-fibre	High-starch
Silage intake (kg dry matter/d)	7·45	6·55
Concentrate intake (kg dry matter/d)	8·55	8·40
Digestible energy intake (MJ/d)	218	215
Average milk yield (kg/d)	28·4	26·9
Average butterfat (%)	3·93	4·23
Average fat yield (kg/d)	1·12	1·13
Average protein yield (kg/d)	0·80	0·78
Average lactose yield (kg/d)	1·35	1·27
Compound feed cost/cow in experimental period (£)	69·83	77·10

with one high in starch. Commercially these high-fibre diets can be produced at a raw material cost of about £4–£10/tonne less than the normal high-starch diet and therefore there is an economic benefit to the dairy farmer in using this type of compound dairy feed.

Obviously this type of diet with a highly-digestible-fibre content also carries a high crude-fibre content, i.e. approximately 120 g/kg compared with 60 or 70 g/kg for the more traditional type of diet. Therefore it does not lend itself to the prediction of its ME content by equations such as 'U1' which was recommended in a report of the UK Agricultural Supply Trade Association/Agriculture Development and Advisory Services/Council of Scottish Agricultural Colleges Working Party (Alderman, 1985). The findings on which the recommendations for prediction equations in the latter report were derived were from a study carried out at the Rowett Research Institute on 'Compound feedingstuffs for ruminants' (Wainman *et al.* 1981). Because of concern about the ability of these recommended equations to predict the energy value of high-oil and highly-digestible-fibre compounds, further work has been undertaken at the Rowett Research Institute using wether sheep at maintenance and at the Hannah Research Institute using lactating dairy cows. The diets studied in this work involve five different fats at levels of 0, 30, 60 and 90 g/kg and three different fibre sources, untreated straw, sodium-hydroxide-treated straw and a combination of sugar-beet pulp and citrus pulp at 0, 200 or 400 g/kg of the compound part of the diet. Full results of this work are not yet available but the initial results indicate that equation 'U1' underestimates the energy content of diets with variable levels of oil by 0·85 MJ/kg, and equation 'U2' by 0·32 MJ/kg. In the case of NaOH-treated straw, 'U1' underestimated the energy content by 1·0 MJ and 'U2' by 0·26 MJ, whereas in the case of untreated straw the underestimation was similar with both equations at about 0·8 MJ. With sugar-beet and citrus pulps the 'U2' prediction was extremely close to the animal measurement but 'U1' again showed a marked underprediction. Thus it would certainly appear that an equation of the 'U1' type, which includes no estimation of digestibility, particularly of fibre, is unsuitable for general application for predicting the energy value of individual parts or the total diet. However, it does appear that an equation of the 'U2' type which includes neutral-cellulose digestibility might be derived as a reasonable means of predicting the ME of a complete compound and thus also in predicting the value of individual ingredients within that compound. The use of these equations, however, only gives an estimation of ME which, as has been suggested earlier in the present paper, may not in itself be a very good guide towards animal performance. Indeed there is a great deal of current debate in Europe as to whether a system for declaring the ME or net energy of a compound should be introduced.

Protein evaluation for ruminants

The Agricultural Research Council (ARC, 1980) recommended that protein supply should be described in terms of rumen-degradable protein (RDP) or rumen-undegradable protein (UDP). However, Webster (1985) has seriously questioned whether these descriptions are adequate. He has proposed that the RDP should be broken down into quickly-degradable (QDP) and slowly-degradable (SDP) fractions and that UDP should be broken down into the digestible fraction and the protein bound up in the lignin; the latter he described as acid-detergent-insoluble protein (ADIP). Having suggested four descriptions for protein he then proposed that different utilization values should be given to these fractions. The value 0·8 is suggested for QDP, this value being that given to urea in the ARC (1980) publication, and 1·0 for the SDP, as given to all RDP in the ARC (1980) system. The proposed utilization of 0·8 for QDP must be questioned, for the proportion of this protein which can be trapped by bacteria within the rumen must depend on the amount present at any time. Thus it is suggested that the utilization will fall as the amount of QDP in the diet increases. Webster (1985) suggests that the digestible undegradable fraction (DUDP) is calculated as 0·9 (UDP minus ADIP). Of these four protein fractions, two can be measured in the laboratory, QDP by suspending Dacron bags in a washing machine for a predetermined length of time and measuring N loss, and ADIP by measuring the amount of N in the acid-detergent lignin. The SDP fraction can at this time only be measured by suspending Dacron bags in the rumen of an animal and its value is obviously dependent on the rate of passage. DUDP is then calculated by difference. Having stated that SDP can only be measured by the Dacron-bag technique, there is a great deal of doubt about the repeatability of this technique between centres and thus further work is clearly necessary to define a precise method of carrying out the Dacron-bag technique if repeatable results are to be obtained.

Evaluation of ingredients for ruminant feeds in the future

The proposal by Webster (1985) for a better definition of protein supply is moving in the direction of that proposed by Thomas (1986). Thomas (1986) has suggested that feeds should be described by their ability to act as substrate supplies for the production of acetic, propionic and butyric acids, glucose, amino acids and long-chain fatty acids rather than in the cruder terms of ME or protein. He also suggests that we should move away from describing animals as having specific nutrient requirements, and feeds as supplying these nutrient requirements, towards a means of predicting responses in animals from changes in substrate supplies. A move in this direction would certainly help to explain the discrepancies in milk output obtained when two foods of equivalent ME are formulated from different ingredients. This would appear to be the best approach for the future of feeding dairy cows where the farmer needs to know, not what the requirements of his cows are, but how he can influence total milk yield or the constituent parts of that yield if his milk sales are above or below quota, be that yield or butterfat quota.

Feed evaluation for poultry

In the area of the evaluation of raw materials for poultry, everything appeared to be fairly clear about 2 or 3 years ago with the adoption of techniques for measuring apparent ME or true ME by quick bioassay. However, Fisher & McNab (1987) have again raised some doubts about the methods currently being used. There are basically three types of bioassay:

1. The traditional method which involves the assumption that, because the diet being studied is fed for a prolonged period, measurements of nutrient utilization are taken after a fairly long prefeeding period so that start and end effects will be the same. This method involves complete diets and substitution techniques but suffers with problems of feed wastage and difficulties in measuring the true feed intake.
2. A rapid method which involves starvation of the bird before and after offering the test material. This has the advantage that a known quantity of feed is offered, again involving the use of complete diets and substitution techniques, but suffering from the problem of maintaining feed intake.
3. A modification to this rapid technique, again involving pre- and post-starvation but with tube feeding of the bird. This has the advantage of avoiding substitution, in that single ingredients are fed, but there are problems due to the limit in the amount of feed that can be tube fed.

These different techniques tend to give different results and the reason for these differences are not always clear. Obviously any force-feeding technique, as described in bioassay type 3, raises serious questions from the welfare side, but it is extremely useful for not only measuring energy contribution as ME, but also measuring the digestibility of amino acids, lipids, etc. at comparatively low cost per sample tested. Modifications to the technique have been introduced to offer glucose before and after the test period in order to eliminate some of the welfare criticism of the method. It is hoped that the outstanding problems can be resolved, for this is by far the most convenient approach to bioassay techniques for poultry feeding evaluation.

Interpretation of the results from this basic technique is still open to some discussion in that it has become normal to correct ME values to zero N retention. However, as can be seen from Table 3, these corrections change the relative value of high-protein materials compared with wheat. The feed trade is supplying feeds to be given to birds at a positive N balance, therefore it would appear to be wrong to evaluate ingredients at zero N retention for this undervalues the high-protein materials as energy sources. However, clearly to apply no correction is also inaccurate, as this will enhance the energy and the economic value of these high-protein materials to excessive levels. Some compromise between the two extremes would appear to be correct in economic terms, but is hard to define from a scientific basis.

Recently there have been changes in the European feed legislation which have introduced the concept of the declaration of energy in compound feeds for poultry. This

Table 3. *Effect of nitrogen correction on relative value of poultry feed ingredients in terms of metabolizable energy (ME)*

Ingredient	Protein content (g/kg)	Measured ME (MJ/kg) (no N correction)	Value relative to wheat	Measured ME (MJ/kg) (Corrected to zero N)	Value relative to wheat
Wheat	117	13·2	100	12·9	100
Maize	92	14·4	109	14·0	109
Barley	107	12·0	91	11·6	90
Extracted sunflower	280	8·0	61	7·3	57
Full-fat soya bean	370	15·6	118	14·9	116
Extracted soya bean	440	10·7	81	9·9	77
Meat-and-bone meal	480	11·8	89	10·7	83
Fish meal	680	14·2	108	13·2	102
Feather meal	800	14·0	108	13·2	102

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declaration will involve the use of a prediction equation based on the percentage of oil, protein, sugar and starch present in the feed and is intended to predict ME (MJ/kg) corrected to zero N retention as fed. Because of the high content of starch in poultry feeds the predicted ME is very dependent on the accuracy of the starch analysis. There have already been some field problems, where inaccurate analysis has given a low starch and thus a low predicted ME value; it is essential that official methods of analysis are followed very accurately if realistic results are to be obtained. Because of the parameters that are involved in this equation, it is not suitable for predicting the energy content of individual ingredients used in poultry feeds. For instance, it does not differentiate between highly digestible and poorly digestible fats and the use of the equation to obtain individual raw material values would lead to faulty buying decisions by the feed compounder.

Feed evaluation for pigs

With regard to pig feeds a report by Morgan *et al.* (1984) and by French workers at INRA (J.-M. Perez, R. Ramihone and E. Henry, unpublished results presented to the EEC Commission) has led to the derivation of two equations for predicting the DE content of pig feeds. Both these equations rely on oil, crude protein, ash and neutral-detergent fibre and appear to predict the ME of complete pig feeds with a reasonable degree of accuracy. However, as with the poultry equation, they are not suitable for evaluating individual raw materials and resort has to be made to the traditional metabolism-crate measurements in order to derive DE or ME values for the ingredients of pig feeds. It is generally accepted that digestibility of amino acids by pigs will be similar to that of poultry and common matrix values are normally used for both species.

Conclusion

Many problems still exist in the evaluation of raw materials for use in compound animal feeds. In the case of ruminants it would appear that a completely new definition of ingredient values needs to be derived, based on their ability to supply substrates for the production of those chemicals which are essential for the productive processes of the animal. In the case of pigs and poultry, the evaluation of ingredients is more straightforward and outstanding problems mainly lie in the area of accuracy of techniques and the possibilities of deriving prediction equations which could replace the need for bioassay techniques which are obviously more expensive than laboratory analysis.

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