

## 21st Century Feeds – 19th Century Techniques

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A recent ILRI / ICRISAT workshop [“Approaches to improve the utilization of food-feed crops”] attempted to identify feed quality indicators which could be used by plant breeders in selection programmes. While there are many evaluation methodologies, each with their inherent advantages and limitations, due to our inability to model the animal : feed interface applied studies, where the appropriate class of animal is offered a specific feed and the level of production achieved observed, remain the most precise, albeit often impractical, way of assessing feed quality. Although it is vital to recognize that the ultimate arbitrator of nutritional value will be the host animal and that this consideration should at all times outweigh expediency of laboratory operations in the refinement of current methodologies, a major challenge posed by the increasing global demand for animal products will be for accurate, appropriate and affordable laboratory-based feed evaluation techniques. This paper seeks to identify, the current status of ruminant feed evaluation and where improvements to existing techniques ought to be made or new methodologies developed.

Chemical analysis provides absolute values in contrast to *in sacco* and *in vitro* methods that merely express a ranking of one feed relative to another. However, it offers no estimate of nutritional value, rather this is inferred by statistical association. The Weende or proximate analysis is, despite a number of inherent limitations, still applied after 150 years. It assumes that all nitrogen is present as protein with a nitrogen content of 0.16 which, although not totally correct, is of little consequence to ruminants. The fibre fraction, originally defined the non-degradable portion of the feed, contains few of the components designated as “fibre” using the Van Soest neutral detergent system. The ether extractive contains pigments and indigestible waxes in addition to lipids and the nitrogen-free component, generally considered to estimate only water-soluble carbohydrate, also comprises pectins, hemicellulose and soluble lignin. Separation of the fibre components according to their degradability, rather than defined chemical entities, offers the potential of predicting intake and nutritive value. Of these the NDF component is inversely related to both degradation and intake as it represents the total insoluble fibre matrix, with lignin and associated phenolics most often indicated as the components limiting its digestibility. While NDF equates to cell wall content in grasses and cereals, legumes, citrus pulp and root crops all contain relatively high concentrations of pectins which being readily soluble in neutral detergent solution are, therefore, not included as “cell wall”. Chemical analysis also reveals little about the distribution of components with the feed, e.g. the association of lignin with a particular fibre component. Equally it provides no information regarding changes in digestibility associated with physical or chemical processing, e.g. NaOH application or the occurrence of Maillard reactions following over-heating during processing.

Digestibility studies have been conducted for over 150 years, usually with sheep offered single feeds at maintenance. While this provides a basis of comparison, the results cannot readily be applied to a high producing dairy cow consuming a mixed ration at multiple maintenance levels. Offering feeds at near *ad libitum* levels would be closer to the practical situation, however, variable refusals would interfere with the required steady-state conditions. Intake and digestibility are also non-independent variables. While intake is directly related to digestibility, digestive capacity of animals is inversely related to feeding level with the magnitude of this effect increasing with feed quality. Further the ability of the animal to select will result in the quality of the material consumed exceeding that offered. Dietary components interact [“associative effects”] impacting both positively and negatively on the extent and rate of digestion. Therefore, the digestion of any feed in combination will differ from that identified when examined alone, and vary dependent on the other components with which it is offered. Finally the difference between faecal output and feed consumed provides no indication of the site of digestion or material absorbed. In ruminants dietary protein bears little resemblance to that actually digested, while endogenous protein losses and the degree of hindgut fermentation have such a profound effect on faecal nitrogen values that protein digestibility estimates are difficult to interpret.

The near-infrared reflectance spectroscopy methodology is based on the concept that specific regions of the reflected spectrum, obtained by scanning the feed sample with near-infrared light, can be correlated with feed constituents such as starch or protein. However the accuracy of this correlation, in terms of appropriate samples and suitable laboratory analysis, is a major limitation of the system. A second problem, and one common with many analytical techniques, is that the results tend to be used beyond the scope of the technique. For example, given the complexity of the animal : feed interactions involved can digestibility be estimated using this system ?

The *in sacco* technique was first suggested as a method to evaluate ruminant feedstuffs over 60 years ago, while the procedure on which today’s methodologies are based was defined over 25 years ago. For an assessment of how the rumen environment impacts on degradation there is currently no adequate substitute, however it has two major drawbacks; the relatively large number of surgically modified animals required and the excessive initial particle losses. Equally, and like the Tilley and Terry methodology, it assumes that the substrate lost equates to that potentially available to the host animal. A great deal of research has focussed on aspects of the technique such as substrate preparation, bag material pore size

relative to substrate particle size or ratio of the open surface area to the quantity of material incubated in an attempt to improve the accuracy of the degradation profiles. However, little work, outwith attempts by mathematicians, to examine excessive initial particle losses has been conducted. Considering the global usage of this technique with the fact that very few improvements have been achieved, it seems unlikely that this technique will evolve further. Aspects such as the initial excessive losses of fine particulate matter, which is clearly not the result of microbial degradation and leads to erroneous estimates of the two fractions, limit the type of substrates that can be evaluated using short-term incubations. However, as it is often alterations to the degradation kinetics, rather than changes to the absolute value, which produce improvements in animal performance, the ability to accurately estimate these parameters is paramount. Where these data are required alternative methods should be examined. This is especially pertinent when ethical considerations are also included. The surgical modification of experimental animals, for the application of an inappropriate technique resulting in questionable scientific data, cannot be justified.

The two-stage methodology of Tilley and Terry was probably the largest single advance in ruminant feed evaluation. Based on a large number of *in vivo* digestibility studies, it used highly simplified apparatus that allowed large capacity systems to be created, providing values from which *in vivo* digestibility could be predicted with a high degree of accuracy. However, and not a criticism of the system, it generated no information regarding degradation kinetics. Thus two feedstuffs with different rates of degradation but similar end-point values, would be assessed as similar. Slight modifications to the methodology have been made. In one system, a third phase, washing with neutral detergent (ND) solution, has been included to remove microbial contamination and another uses a batch fermentation procedure where feeds are incubated in individual bags within a large fermentation vessel. Recent developments of this latter system have in turn led to degradation kinetic profiles similar to those obtained *in sacco* being achieved.

Gas-based feed evaluation systems, originally used to estimate microbial growth, have attracted renewed research interest. The estimation of fermentation gas release over time is a simple non-destructive measurement, which requires no complex apparatus or chemical analyses, and can provide detailed information regarding the fermentation kinetics. Such evaluation techniques offer considerable potential as screens for the rapid evaluation of large numbers of feedstuffs. Although gas release profiles are similar they are not identical to those of degradation and it is, therefore, vital that degradation profiles are obtained simultaneously to enable fermentation efficiency, that is the proportion of degraded feed partitioned into useful (volatile fatty acid and microbial protein) and waste (gas) end-products to be determined. As this relationship varies over the incubation period, depending on the feed component being sequentially degraded, end-point values cannot be used to achieve this. Equally changes in cumulative gas values alone provide insufficient evidence on which to evaluate feedstuffs. The ability to estimate degradability simultaneously obviates the requirement to predict degradation from mathematical functions, which by necessity have to assume that gas release is directly proportional to degradation, or from stoichiometric calculations on the basis that substrate degraded was entirely composed of hexose sugars. The requirement to model degradation generally arises from either the quantity of substrate fermented providing insufficient residue from which to accurately estimate degradation or the capacity of the system being limited either by initial cost or the rate at which manual measurements can be obtained.

Unlike analytical chemists, ruminant nutritionists do not have a restricted list of methodologies that are applied under highly controlled conditions to evaluate something as esoteric as feed quality. However, the techniques used should be fully described and appropriate to the parameter under investigation. This allows the quality of the results to be assessed and the data obtained compared with other methods or data sets. It is vital to realise that every system has limitations and that these should not be exceeded or the techniques misused. Poor results tend to bring the methodology into disrepute rather than highlighting the inappropriate application by the researcher. To be adopted an evaluation methodology has to be applicable to a specific situation, it has to fulfil the required analytical requirements and it should, to a large degree, be supported by locally sourced resources (including electricity and technological skills), with minimal maintenance and running costs and require only simple repairs.

We have today an extremely rich legacy of feed evaluation techniques created by some of the best nutritional scientists of the last fifty years. Do we even need to question whether these techniques are appropriate today, especially as many of the challenges remain the same? Equally if these systems are deficient what attributes should new systems possess or revised methodologies incorporate, bearing in mind the ultimate role of the host animal? There have been major advances. Increased concern regarding animal welfare issues has, correctly, raised the ethical debate as to whether we should continue to surgically modify animals for routine feed evaluation. This has led to the development of high capacity *in vitro* or enzyme-based systems that have the potential to greatly reduce the number of such animals required. Through automation, micro-techniques, computing and mathematical modelling the capacity and precision of *in vitro* systems have greatly increased. So, however, has the cost, complexity and level of technical expertise required to run and maintain these methodologies, often rendering them inappropriate for many laboratories, even in developed countries. Why haven't these techniques been more widely applied? For instance, we still lack a major feed evaluation database for semi-tropical and tropical feedstuffs where the substrates have been evaluated using similar techniques. Until this is created, the direct

comparison of feeds or ration formulation is impossible. Crucially it is these feeds, and not the temperate grasses of Europe or North America, which will support the global livestock revolution.

#### **References**

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