

Chapter 12

Guidelines for the evaluation of feed resources

The proposals in this chapter are intended to assist researchers in allocating priorities to the activities needed to arrive at decisions concerning the potential role of a feed resource in the farming system. The categories into which resources should normally be allocated are indicated, namely: basal feeds or supplements for monogastric or ruminant animals; biomass for fuel or as soil conditioner.

Evaluation procedures begin with discussions with farmers and processors and lead on to simple tests (in sacco or in vitro estimates of degradability) to assess availability to micro-organisms (and gastric enzymes) terminating with feeding trials with target animals to define surface response functions to major supplementary nutrients.

INTRODUCTION

What is the minimum information required in order to identify and classify feed resources for the functions set out in Chapters 3 to 6? It seems that the classical system of proximate analysis and even the more sophisticated methods for identifying the components of plant cell walls (i.e., ADF and NDF) contribute little information for the development of feeding systems which aim to efficiently utilize tropical feed resources.

In the industrial countries, livestock nutritionists have had as their final goal the determination of absolute requirements for nutrients for the diverse production functions of livestock: growth, fattening, milk production, reproduction etc. These goals are less relevant to the less-developed countries, especially those in the tropics, partly because of ecological differences, but to a greater extent because the economic climate is completely reversed. In all industrial countries, with the exception of New Zealand and to some degree Australia, state subsidies provide a large proportion of the revenue received by farmers. This leads

to a situation where fixed costs are high (e.g., opportunity price of land and of labour) which obliges farmers to maximize individual animal productivity and feed conversion efficiency. The support price for animal products (or indirect subsidies such as cheap irrigation water and fossil fuel) further encourage the farmer to aim for maximum productivity. A highly evolved marketing system presents a range of feeds to the producer, many of them imported, and encourages the use of least cost formulations that require decisions about both cost and nutrient availability. The consequence is that nutrient requirements reflect mainly biological rather than economic criteria.

In almost all less-developed countries, agriculture is not subsidized and the producer must manage the farm enterprise to secure optimal economic returns to inputs. Because of the law of diminishing returns, the levels of animal productivity where economic response is optimized are lower than those where biological response is maximized. The outcome of this change of emphasis is that farmers in the less-developed countries need production function criteria (production response to change in nutrient supply) rather than the absolute levels of nutrients for a given level of production.

The range of feeds available to smallholder farmers is mainly restricted to what can be grown on the farm, and distance from formal markets means that few of the available alternatives have an opportunity price. Socio-economic criteria at family level also strongly influence the choice of crops and methods of processing.

To provide the kind of information that is required in this complex socio-economic environment demands a more pragmatic approach to feed evaluation which emphasizes acquiring knowledge about a resource (usually from the farmers themselves) and finally establishing the basis of the feeding system by means of practical feeding trials.

DEFINITION OF CROP RESIDUES, Agro-industrial BY-PRODUCTS AND PRIMARY PLANT PRODUCTS

Crop residues are invariably fibrous, of low digestibility, and low in nitrogen. They are produced on the farm and therefore widely spread geographically. On small farms in developing countries they form the principal feed of ruminant livestock during the dry seasons.

Agro-industrial by-products result from the processing of crops such as oilseeds, sugar cane, oil palm, sisal, citrus, pineapple and bananas; or the slaughter and processing of livestock and fish. They are geographically restricted to the factory sites, are usually marketed and frequently exported to earn foreign exchange. They are rich in protein (oilseeds and meals of animal origin) or sugar (molasses, citrus and pineapple pulps) and occasionally in starch (reject bananas, cassava peels) and usually low in fibre. Exceptions are sugar cane bagasse, palm-press fibre, coffee pulp and cocoa pods.

Primary plant products of interest in tropical countries, especially as alternatives to cereal grains, are the juice from sugar cane and sugar palm, the oil and the fresh fruit from the African oil palm, and the roots from cassava and sweet potato. Leaves and foliage from multi-purpose trees and shrubs, from certain crop plants and from water plants are also in this category.

CATEGORIES OF BY-PRODUCTS

It is convenient, when establishing principles for evaluating new feed resources, to allocate them to one of five categories:

Category 1:

Feed resources high in fibre and low in nitrogen: these include the most important crop residues, namely cereal straws and stalks, legume haulms and straws and cereal stovers.

Category 2:

Feed resources high in fibre and relatively high in nitrogen: in this category are animal excreta, brewers' grains and leaves and foliages from trees, shrubs and water plants.

Category 3:

Products and by-products low in fibre and low in nitrogen. This category includes products and by-products from processing of: sugarcane and sugarpalm (e.g., juice and molasses), cassava (roots, peel, bran and fines), citrus and pineapples (pulp), bananas (rejected fruit) and other products from food processing plants (e.g., broken biscuits).

Category 4:

By-products low in fibre and high in nitrogen: this group comprises mostly oil seed cakes and meals and slaughter offal.

Category 5:

By-products high in oil and in fibre and low in nitrogen; the fruit, palm press fibre and "mud" from the processing of the African oil palm are in this category.

ASSESSING NUTRITIVE VALUE

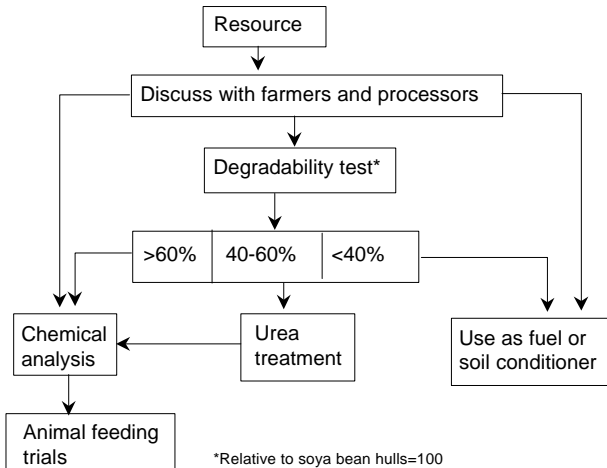
In discussing guidelines for research on tropical feed resources, it is convenient to consider the different objectives relating to their use. To a major extent the role of the resource in the farming system will depend on its chemical and physical properties. Answers are thus required to the following questions:

- What will be the likely role in the farming system of a relatively unknown resource?
 - As the basal diet of monogastric or ruminant animals?
 - As a supplement to the basal diet of either of these major species?
 - As a source of fuel?
 - As a source of soil nutrients including carbon?
- How can tests be done quickly and cheaply to assess the value as feed, fuel or soil conditioner of the resource?
 - The digestibility of the organic matter (categories 1, 2 and 5)
 - The availability of the nitrogen for micro-organisms (category 2)
 - The "by-pass" or "escape" properties of the protein for ruminants (category 3)
 - The amino acid balance (relative to the 'ideal' protein for monogastric species (category 3)
 - How to protect the protein or the oil for feeding to ruminants (categories 4 and 5)
 - Does the product contain secondary plant compounds and how can these be neutralized?
- How can the resource, if suitable as a feed, be used best in feeding systems with other locally produced resources?

HOW TO CATEGORIZE THE RESOURCE

In order to establish a framework for evaluation procedures, it is convenient to make the approach in an iterative fashion as illustrated in Figures 12.1 and 12.2.

Figure 12.1. The first steps in evaluating a new feed resource are: discussions with farmers/processors; assess degradability (digestibility); decide on end use (feed or fuel or soil conditioner or suitability for ammoniation); analyze for N and lipids.



The role of the resource in the farming system

The first step is to learn about the origin of the resource: whether it is a primary plant product, a residue or a by-product. To learn about primary plant products, it is best to talk to farmers in the area where the plant, shrub or tree is grown. The same applies to crop residues. Much valuable information can be gained by understanding harvest procedures, seasonal and soil effects and the nature of the farming system where the resource is produced.

In the case of agro-industrial by-products, it is advisable to visit the factory, farm or household, where the processing is carried out. Certain agro-industrial processes vary little among countries and continents (e.g.,

industrial processing of sugarcane, solvent extraction of oilseeds). However, at artisan level, processing methods vary widely even for the same product. In this case it is essential to talk with the owner/operator of the equipment used for the processing in order to understand fully the procedures that are being used.

The information gained in this informal survey will facilitate making the initial decision as to the potential role of the resource in the farming system and, in many cases, will permit the allocation of the resource to one or other of the above categories.

Assessing relative degradability

There are two ways of assessing the potential rate of degradability of the resource by micro-organisms:

- Rate of loss of organic matter from either: nylon bags incubated in the rumen of fistulated animals (*in sacco*) or: from an incubation medium (*in vitro*).
- Rate of gas production in an *in vitro* system

Choice of one or other of these methods will be determined by many factors. The use of rumen-fistulated animals as incubators has the advantages of low cost and independence of power supplies and expensive equipment (e.g., electrical incubators and *in vitro* apparatus). The environment in the rumen can be varied easily by manipulating the animal's diet, which enables a wider range of studies to be done than is possible with *in vitro* systems. On the negative side is the ethical question of (unnecessary) surgical manipulation of the animals. Most *in vitro* systems also require a fistulated animal as a source of inoculum although there are alternatives (the rumen from a recently slaughtered animal), fresh faeces or rumen liquor obtained with a stomach tube).

In any event, the objective in general is to be able to classify the resource relative to a given standard, and not to derive an absolute value. Data derived from *in vitro* and *in sacco* methods are frequently treated as absolute values and used in regression equations to predict parameters of nutritive value, such as digestible and metabolizable energy content and intakes.

In the opinion of this author, the feed value of a resource can only

be measured reliably in a practical feeding trial in the context within which the resource will be used. The purpose of the "degradability" test is to provide additional information to that gleaned in "stage1" so as to classify more precisely the potential of the resource and the category into which it should be put as the basis for future evaluation procedures.

In view of the need to obtain relative data, it is necessary to incubate simultaneously with the unknown feed a product of known degradability which is easily reproducible and of relatively constant composition (e.g., soya bean hulls). Details of recommended methods are in Chapter 9,

On the basis of relative degradability values the following steps will be as indicated in Figure 12.1. If the degradability:

- exceeds 60% of that of soya bean hulls then proceed to chemical analysis and feeding trials with animals;
- is between 40 and 60% of soya bean hulls, then make tests of ammoniation by urea treatment. If this leads to an improvement in degradability then proceed as above; or
- is less than 40% of soya bean hulls, then the resource is best used as fuel or as a soil conditioner (source of carbon for soil micro-organisms).

Chemical analyses

Some simple chemical analyses should be done. The most important are dry matter (DM), nitrogen (N), ash (to estimate organic matter [OM]) and lipids. Other analyses such as for cell wall constituents (Van Soest, 1983) can be carried out if deemed necessary or appropriate. However, the most important information, at this stage, is simply the contents of DM, OM, lipids and N.

Availability of the nitrogen for micro-organisms

The methods used are the same as for degradability. The difference is that a standard substrate, rich in cell walls and low in N is used as the feed/medium, and the test resource is added in graded amounts to the animal's diet (or to the medium for *in vitro* methods). The reference standard in this case will be urea at the same level of N as in the test resource. The result is the rate of degradability of the test feed relative to urea. Ammonia levels in the rumen, or in the media, could also be the basis of the comparison.

The "by-pass" characteristics of the protein for ruminants

Differentiation between N sources which provide amino acids or ammonia can generally be achieved on the basis of knowledge of the source of the feed and on the method of processing. For example, the N in freshly cut grasses is usually highly soluble and therefore available for micro-organisms in the rumen or caecum. The soluble N fraction is less in herbaceous legumes and even more so in leguminous trees and shrubs. The potential of the feed to have appreciable by-pass protein will in general be inversely related with the solubility of the N.

The solubility of the N in water or in an incubation medium containing rumen micro-organisms (or with proteolytic enzymes) will give a chemical assessment of the likely solubility (the inverse of the by-pass property) of the protein.

Measuring the protein-precipitating capacity of secondary plant compounds present in the feed (e.g., for tanniferous plants, shrubs and trees) is another indirect way of measuring potential by-pass characteristics (see Chapter 9).

A more direct way of measuring protein by-pass properties is the wool growth assay (See Chapter 9).

The amino acid balance of the protein for monogastric animals

Equipment for estimating amino acids is expensive to purchase, maintain and operate. It is not recommended under the conditions found in most less-developed tropical countries. For most protein-rich feed resources derived from oilseeds, cereal by-products and animal slaughter, analytical data are available (e.g., Tropical Feeds, 1994) which can serve as a guide as to the likely balance of amino acids.

For new protein-rich feed resources, especially those of foliar origin, a biological chick assay is proposed (Chapter 9) which is simple and easy to carry out even in the absence of laboratory facilities.

How to "protect" protein for ruminants

There is no sure method that can be recommended for use on smallholder farms. Toasting and extrusion of the feed is appropriate for oilseed meals in the feed mill as may be dehydration of foliages. Reacting with formaldehyde has been used commercially in industrial countries but there are doubts as to the safety of the method for more widespread use.

None of these methods is feasible on smallholder farms. Sun-drying will have some positive effect in reducing protein solubility. Research is in progress to investigate the possibility for mixing tannin-rich feeds with those rich in protein but low in tannins. However, no recommendation can be made at this stage, other than to encourage further research in this area.

How to "protect" oil for ruminants

The availability of palm oil, and even fat from animal slaughter, at competitive prices has opened up the possibility of using these resources as supplements in ruminant diets. Too high a concentration of these substances in their "crude" form (more than 4-5% in dry matter) may depress microbial activity in the rumen. Therefore, it is desirable to "protect" them so that they interfere to a minimum extent in rumen metabolism. Reacting the oil/fat with about 20% of its weight as calcium hydroxide, with or without prior saponification, appears to be a simple and effective method. Combining these two elements with protein-rich foliages, in a homogeneous mixture, seems to generate synergistic effects which enhance the efficiency of using both the oil and the protein (Chapter 6).

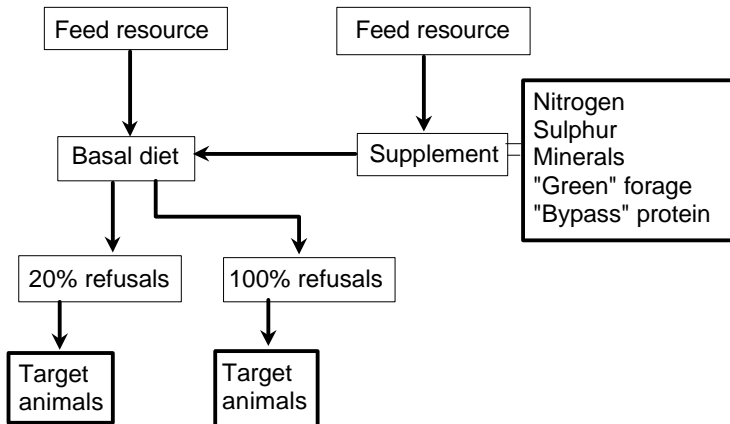
THE TARGET ANIMALS

Once the resource is categorized as either a potential basal diet or a supplement, the next step is to derive surface response curves relating levels of supplement to rate of production and/or efficiency of feed utilization (Figure 12.2).

Ruminants

If the feed resource is to be used as the basal diet for ruminants, then it is useful to evaluate first the advantage or otherwise of offering the resource at a normal (20% refusals) or high (100% refusals) level to facilitate selection. In this test, rumen supplements (sources of ammonia, S and minerals; and some "highly digestible" green forage) should also be given to ensure these are not limiting in the basal diet. These could be free access to a molasses-urea block and legume tree foliage or fresh grass at about 3 kg (fresh basis) per 100 kg live weight.

Figure 12.2. The final steps in evaluation of a feed resource are: determine if suitable for basal diet or as supplement; if basal diet then evaluate at offer levels to give 20% or 100% refusals; if a supplement then add graded levels and determine surface response functions to N, "green" forage and "by-pass" protein.



Having decided on the offer level it may be necessary to assess the need for the rumen supplements. This can be done with a 2 x 2 factorial arrangement of two treatments: access or not to a urea supplement (e.g., the molasses-urea block); and access or not to a source of digestible green foliage. An excellent example of this kind of trial is that reported by Ocen (1992) who evaluated the need for rumen supplements on a basal diet of maize stover (Figure 6.5).

The final step is to derive the surface response relationship between the selected production trait and the source of by-pass protein. The latter may be as a protein-rich oilseed meal (e.g., cottonseed meal) or a tree foliage (e.g., *Gliricidia sepium*). At least five levels should be used with 2 to 3 replications of each level. Examples of this type of evaluation are those with basal diets of molasses in Cuba (Figure 5.1), chopped and derinded sugarcane in Mexico (Figure 5.10) and ammoniated (urea-treated) rice straw in Bangladesh (Figure 5.5) and wheat straw in China (Figure 5.11).

Monogastric animals

The question will usually relate to the suitability of a feed resource (i) to replace cereal grain as the basal diet, or (ii) to serve as a partial or total replacement of the conventional protein supplement which is usually soya bean meal. Knowledge about the feed will usually be sufficient to identify feeds likely to have potential as a replacement for cereal grain as the basal diet. Feed resources such as sugarcane and sugar palm juice, cassava roots, sweet potato tubers, and the fruit of the African oil palm obviously fall into the category of the basal diet of pigs. No prior chemical analysis is necessary in order to make such a decision. Appropriate experimentation may be to evaluate the degree of replacement of the standard cereal grain as was done for pigs in the case of the African oil palm fruit (Table 4.6). Where use of cereal grain is not a viable alternative, it may be more convenient to proceed immediately to on-farm trials as was done in the case of the sugar palm juice in Cambodia (Figure 4.3).

On-station experimentation may be called for to establish surface response curves to a protein supplement. The approach here (Figure 3.2) is similar to that for establishing responses to "by-pass" protein in ruminants. Unconventional sources of protein such as those derived from water plants and tree leaves require a different approach. The problem here may be one of acceptability, often due to the presence of secondary plant compounds. Drying or ensiling are simple ways of neutralizing some of these substances as has been demonstrated for cassava leaves where the toxic glucosides can be reduced to harmless levels by either of these methods (Table 4.8). Simple observation trials are all that is needed to establish the need or otherwise of prior processing. The next step is to assess the effect of degree of replacement of the conventional protein source by the test foliage which calls for a similar experimental design as in assessing surface response functions.