Variability in feed composition and its impact on animal production

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Knowledge of feedstuff composition is vital for the nutritionist, in order to meet precisely the nutrient requirements of livestock; the feed manufacturer, in order to produce balanced compound feeds; the farmer, in order to plan forage production; and the policy-maker, in order to direct strategies that guarantee a competitive, sustainable, environmentally friendly and food-safe agriculture. Feed tables and databases of feed composition and the nutritional value of feedstuffs can provide this information. However, such collections of data are valuable only as long as they provide reliable and up-to-date information. Data on feedstuff characteristics may be affected by different types of variability. The use of imprecise feedstuffs data, characterized by low intrinsic and high extrinsic variability, is deleterious to animal production from the nutritional, economical and environmental points of view.

1. INTRODUCTION
In order to meet the nutritional requirements of livestock a precise knowledge of feedstuffs composition is necessary. Such information is particularly vital when trying to achieve the high levels of production required in today’s competitive markets (where there is growing interest in quality, efficiency and the environment) through the preparation of balanced diets for the animals. Knowledge is also essential in order to mix the right proportions of various ingredients
for the manufacture of valuable compound feeds. Ultimately, knowing the chemical characteristics and the nutritional value of raw materials is fundamental in the planning of forage production on the farm so that crop yields can be balanced with the animals’ requirements. The general aspects of this have been reviewed by Topps (1989).

From a political point of view, data on feedstuff composition and nutritional value provide essential information to policy-makers that allows them to develop competitive and sustainable agriculture.

Feedstuffs are usually described by their chemical composition as well as by their nutritional value. Information on the composition of a feedstuff is acquired through chemical analysis, and most commonly includes such parameters as dry matter, protein, fiber fractions, organic matter and fat contents. The nutritional value of a feedstuff is assessed from experiments with animals (in vivo digestibility/in situ degradability, etc.) and provides information on how feedstuffs are digested and metabolized by the animal, mainly through interpreting differences between the input and the output of a series of components. Among these, the digestible/degradable organic matter and the digestible or metabolizable energy values are the ones most frequently represented in databases and used to predict energy supply from feeds and diets.

To provide both chemical and nutritional information, feedstuffs have been analysed in laboratories and animal-based studies and the resulting data collected in tables of feed composition for more than 200 years. The first recorded publication was that of Thaer (1809). More recently, collections of data have been organized into computer programs, creating databases of feedstuffs composition. The first database available on a computer was produced in 1963 at Utah State University in the United States (Harris, Asplund and Crampton, 1968). Today, modern databases are powerful tools with which information can be rapidly retrieved, sorted, updated and printed.

2. SOURCES OF DATA
Information on feedstuffs composition and nutritional value plays a fundamental role at the farm, feed manufacturer and government
levels, so the data inserted into databases need to be reliable and of high quality. The quality of the data depends, in the first place, on the origin of the information, which may have been extracted from the literature, collected from laboratories, obtained from other databases or generated specifically from animal studies and analyses of feeds.

**Data assembled from the literature**

Feedstuff information in the literature usually concentrates more on the data value obtained and does not give a full description of the feedstuffs concerned (Leche, 1983). When feedstuffs are insufficiently or inappropriately described there is a risk of confusing their real origin. A typical example of this occurs when publications generally refer to the product “distillers’ dark grains”, which is a by-product of the whisky distilling industry that, depending on the type of distilling process, may be derived from barley (in the malt distilling process) or wheat and/or maize (in the grain distilling process). In this case a true and existing genetic variability is ignored. It is evident that the compositions of the two products will differ, so the provision of additional information on the origin of the feedstuff is essential; it is not enough merely to refer to it as “distillers’ dark grains”. In the absence of additional information, when trying to obtain information on the protein content specifically of barley distillers’ dark grains, a value obtained from the average protein content of samples of both barley dark grains and wheat/maize dark grains would be retrieved from the database, and this value would be meaningless. Data obtained from the literature can therefore often be inappropriate, particularly when they use averaged data which may incorrectly merge different feedstuffs. Data from the literature are recommended only when no other sources are available.

**Data collected from laboratories**

When compiling databases of feedstuffs information, the data used have usually been produced in a number of different laboratories. When assembling collections of data, it is necessary to have specific information regarding the analytical procedures used to obtain
the data, in order to guarantee that those used to create a database have been obtained through standardized methods, are expressed in standardized units and can, therefore, be compared.

The standardization issue is particularly important for data on the nutritional value of feedstuffs, obtained through in vivo digestibility or in situ degradability studies. In this case, together with the strictly analytical issue, the laboratories and research institutes involved should have standardized procedures for conducting animal studies. These relate to the numbers of animals and the species used (sheep, cattle, pigs, etc.) and to the feeding and collection protocols employed. However, when conducting in vivo/in situ studies, results will always be substantially influenced by variability among individual animals, no matter what level of standardization is achieved.

The standardized analytical procedures used to collect data from laboratories need to be monitored continuously, and the data they produce checked for accuracy and relevance. For this purpose, ring tests among participating laboratories should be carried out in order to evaluate the precision of standard or newly developed techniques (Barber, 1983; Fisher, 1983).

**Merging of new and old data**

It is common practice to merge new databases with old ones. In these cases it is important that the analytical procedures used to obtain all the data are understood in order to generate information that is expressed on a common basis and is, therefore, comparable. The evolution of analytical methodology is a substantial issue. Old data may have been obtained with obsolete methods or with surviving analytical procedures that, in the past, produced data that were less accurate than those produced today. Thus, the merging of old data with new may be inappropriate and may reduce the overall quality of the information.

**Data produced specifically for use in databases**

The data generated specifically for use in databases are likely to be those of the highest quality as all the necessary information will be included and the methods standardized and checked. The chemical composition of feeds can be analysed using the most up-to-date and
standard methods and animal studies can be designed appropriately, by deciding which animal species to use and in which physiological state the animals studied should be. Both feeding and collection protocols can also be set with the aim of meeting the specific requirements of the database.

Ideally, an entire database would be produced by analysing specifically the composition of feedstuffs and studying their nutritional value through animal studies. In this way the variability arising from extrinsic factors such as analysis methods and animal protocols would be reduced to the minimum. On the other hand, when using data from a single source it is critical that the techniques and procedures used have been certified for precision and are representative. However, if it is to contain representative information, the database has to be established with an appropriate number of samples. The costs involved in analyzing feedstuffs and, particularly, performing animal measurements are so prohibitive that it is rare for feedstuff information to be produced specifically for the purpose of assembling a database. Moreover, much time is required to obtain the data, particularly those derived from animal studies. Therefore, the data are usually extracted from the different sources listed previously. Ultimately, it is the responsibility of the database manager to judge which information to include in order to generate a meaningful database.

3. SOURCES OF DATA VARIABILITY

Information on feedstuffs may be associated with different sources and types of variability. Variability can be “intrinsic” and caused by real differences among feedstuffs, such as the genetic origin of the feed or the processes that have been applied to it. Variability can also be “extrinsic” that is caused by differences in sampling and analysis procedures.

Intrinsic variability of data

Each feed has particular chemical and nutritional characteristics which distinguish it from other feeds. However, the same feed can also be derived from different cultivars or influenced by its geographical
origin. Moreover, an identical raw material may have been processed in a variety of ways to produce very different products. The wide range of diverse wheat-related materials provides a clear illustration of the need to distinguish among different feedstuffs derived from the same raw material. Terms for wheat-based materials include wheat, durum wheat, winter wheat, spring wheat, processed wheat meal and wheat distillers’ dark grains. All of these products and by-products are wheat-based, but they vary substantially in terms of both chemical composition and nutritional attributes and it is therefore expected that they will have different effects when fed to animals.

When assembling a database it is necessary to make sure that the real variability arising from the intrinsic characteristics of the feedstuffs is correctly recognized in order not to affect the quality of the data. Information from feedstuffs databases is most commonly retrieved in the form of averages (or “consolidated data”), so the feeds have to be merged judiciously in order to obtain meaningful information. To achieve reliability, a precise description and the correct naming of feedstuffs are essential, and for this purpose all available information on the type, origin, processing, etc. of the feedstuffs is needed.

One important attribute that is often omitted is information on the forage’s stage of maturity. As shown in the example illustrated in the Figure, the content of both neutral detergent fiber (NDF) and starch relate strongly to the stage of maturity of the forage maize, and this is clearly reflected in the dry matter (DM) content of the plant, which increases with maturation. In this case, therefore, it would be incorrect to describe material harvested at different stages simply as forage maize; the different maturity stages should be indicated and, on the basis of these, the different types of product classified.

With respect to the processes applied to the feeds, when introducing data on, for example, rice bran meal, it is necessary to know how the meal was obtained and which processes were involved in its production. In the example shown in Table 1, at least two different types of products (expelled and extracted rice bran meal)
need to be differentiated because they are characterized by different chemical compositions and, consequently, by different nutritional values.

As shown in Table 1, the process that produces the extracted rice bran meal leads to a material with a much lower fat content compared with the expelled one (7.3 g/kg compared with 90.0 g/kg DM), and this produces a direct effect on the metabolizable energy value. It is apparent that if, instead of specifying the type of process used, the values of the two types of rice bran meal had been averaged, the resulting values would have been meaningless.

Another, simpler, example is related to the on-farm processes applied to forages. Hay is obtained by drying the forage, but the drying process may be achieved by “sun curing” or “barn curing” the
The different processes can lead to different compositions; for example, related crude protein content varies from 122 g/kg DM for barn-cured hay to 99 g/kg DM for the sun-cured variety (MAFF, 1986). In this case also, information on the type of process applied to the forage is essential in order to maintain the two feeds as distinct entities and, thus, avoid erroneous mean values.

### Table 1: Extracted and expressed rice bran meal: analytical and nutritional differences

<table>
<thead>
<tr>
<th></th>
<th>Analytical database parameters</th>
<th>Ruminant database parameters</th>
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<tbody>
<tr>
<td></td>
<td>Extracted meal</td>
<td>Expressed meal</td>
</tr>
<tr>
<td>Oven DM (fresh basis)</td>
<td>896</td>
<td>902</td>
</tr>
<tr>
<td>Crude protein (g/kg DM)</td>
<td>54</td>
<td>128</td>
</tr>
<tr>
<td>NDF1 (g/kg DM)</td>
<td>450</td>
<td>370</td>
</tr>
<tr>
<td>Ether extract (g/kg DM)</td>
<td>7.3</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>Source: Van Vuuren and Meijs, 1987</td>
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</table>

Extrinsic variability of data

Differences in analytical procedures may exist among different laboratories and also within the same laboratory. If not identified, differences can compromise the information retrieved from the database as it will compare values provided on different bases. In this respect, an important limitation of databases is related to the type and quality of the data they make available to their users.

In general, the diversity of analysis methods adopted by different laboratories is responsible for most of the extrinsic variability found in databases (Barber, 1983). It is safe to compare or mean parameters only if they have been grouped according to the method of analysis used to obtain them. An example in which incorrect mean values may result is in the estimation of lignin using potassium permanganate,
according to the method of Goering and Van Soest (1970), and using acetyl bromide, according to the method of Morrison (1972). These two procedures for measuring lignin not only give different results but are also expressed in different units and it is therefore incorrect, if not impossible, to merge and compare the two values. Recently, Beever and Mould (2000) highlighted large differences in the crude protein and starch contents of maize silages submitted to nine different laboratories. The values observed for one maize silage ranged from 57 to 119 g/kg DM, for crude protein, and from 165 to 272 g/kg DM, for starch. Investigations uncovered the fact that different methods were being used and that some were predicted by near infrared reflectance spectrophotometry (NIRS).

Variability also often arises in data on the nutritional value of feedstuffs that have been obtained through in vivo/in situ experiments using animals. The animal species may be a source of this inherent data variability. In particular, it is common practice to classify the nutritional value of feedstuffs on the basis of data obtained through measurement among both sheep and cattle under the general definition of “ruminants”. Differences in the passage rate of digesta and, therefore, of feed utilization between these two species are often substantial. Other generalizations commonly made arise from the lack of differentiation among the different physiological states of animals of the same species (dry and lactating cows, for example, or growing and finishing pigs). Such physiological differences may have a great impact on the data obtained, and when not recorded will compromise the quality of those data. Moreover, the use of non-standardized feeding and faecal collection protocols can affect the results obtained substantially.

The in situ method used extensively to measure the rumen degradability of feeds is subject to many sources of variability. Huntington and Givens (1995) reviewed many of these, and the in situ method has been the subject of a number of ring tests. For example, Madsen and Hvelplund (1994) reported on the protein degradability of five concentrate feeds evaluated in situ at 23 different
European institutes. Although the mean values obtained were similar to published values, the reproducibility among centres was poor. In particular, the ring test underlined the need to standardize the material used to make the bags and the washing procedures followed.

A last source of variability, in terms of mean data, is related to the number of samples taken of a feedstuff which can vary widely, resulting in consolidated data that are more or less representative.

In conclusion, in order to produce a high-quality database on feedstuff composition and nutritional value, the intrinsic variability generally needs to be recorded and differences among materials need to be clearly identified. This is vital if effectively different feeds are not to be merged and averaged but maintained distinct. On the other hand, extrinsic variability should be kept to a minimum because, when a few standard procedures are each applied to a large number of samples, the resulting data will be more representative and useful than when a large number of different methods have each been applied to only a few samples.

4. EFFECTS OF DATA VARIABILITY

The use of information obtained from feedstuff databases characterized by low-quality data (with high extrinsic variability and low intrinsic variability) may have various effects depending on the end user of the database (e.g. animal nutritionist, compound feed manufacturer, farm manager, policy-maker). In this respect, in general, the quality of the data is more often influenced by the extrinsic than the intrinsic variability.

For the animal nutritionist

Analysis of feedstuffs composition is costly and time-consuming. Nutritional values acquired through studies with animals are particularly labour-intensive. The nutritionist can therefore not normally afford to analyse specifically each of the feedstuffs involved and often needs to base assessments of nutritive value on more readily available and less expensive information.
The animal nutritionist is in charge of designing the animals’ diet. The first consequence of unreliable information on feedstuffs, resulting from high extrinsic variability, may be the formulation of a nutritionally unbalanced diet. This may have different effects, depending on nutritional, environmental and economical factors; these effects are highly interrelated since the optimization of feed utilization leads to the optimization of animal output and financial returns.

**Nutritional effects.** Today, nutritional information on feedstuffs is used to predict animal performance (often with the use of complex models) through estimation of the energy supply to the animal. The incorporation of low-quality data in these models will produce unreliable estimates of animal performance. Furthermore, it is important to maintain the data resulting from in vivo measurement of nutritive value separate from those values predicted from chemical composition.

**Environmental effects.** The most common environmental effect derived from unbalanced diets is caused by nitrogen loss. Particularly for ruminants, the capture of nitrogen depends on the rate of production of microbial protein and is related to the availability of carbohydrates and energy in the rumen. It is therefore important to know the exact amount of degradable nitrogen (together with the carbohydrate and energy availability) when characterizing a feedstuff, in order to capture nitrogen for anabolic purposes and avoid the release of ammonia into the environment.

Table 2 gives an example of how the efficiency of nitrogen conversion in the rumen is affected by the level of nitrogen in the diet. In the Table 2 example, the differences in nitrogen intake are due only to differences in the crude protein content of the grass part of the diet. The balance among nitrogen absorption in the intestine, its conversion into milk protein and its loss in faeces and urine is highly dependent on the capacity of the rumen to capture this nutrient. In the example, increasing the nitrogen intake by approximately 25 percent resulted in nitrogen losses in the urine increasing by 80 percent. It
is therefore evident that even small differences in the concentration of nitrogen in different feedstuffs may give rise to substantial losses of nitrogen to the environment.

**Economic effects.** If, for example, maize gluten is fed at the rate of 5 kg per cow per day to a herd of 100 cows at a metabolizable energy (ME) level of 1.8 MJ/kg DM (as proposed by AFRC, 1993), it would supply the herd with 5 310 MJ ME/day. At a level of 12.8 MJ/kg DM (MAFF, 1986), the daily ME supply to the herd would be 5 760 MJ. Over a 200-day period, the difference in ME supply would be 90 000 MJ, which represents a saving of some 8 tonnes of compound feed, or some US$2 500.

Unbalanced diets may also produce an economic loss in terms of animal health, feed conversion efficiency and, ultimately, the output of animal products. The wrong proportion of a nutrient in the diet is reflected in milk production (in terms of both quantity and quality) and has a direct effect on the economics of production. Such effects can be seen extremely rapidly in fast-growing poultry, where even small changes in the nutrient balance can lead to drastic economic consequences.

### For the compound feed manufacturer

Compound feeds are composed of a blend of various raw materials and/or by-products. In designing these products, the feed manufacturer needs to find the balanced combination among different materials that will satisfy the requirements of specific animals in a specific physiological state. In order to achieve this, the manufacturer initially needs to base purchasing decisions on the available information about the chemical composition and nutritional value of feedstuffs. It is therefore very important at this stage that the information available is representative and reliable, not least so that the economic value of the material can be assessed and compared with its market price.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Nitrogen (N) balance of cows fed at different N levels</th>
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<tbody>
<tr>
<td>N intake N excretion (g/day)</td>
<td><strong>N</strong></td>
</tr>
<tr>
<td>(g/day)</td>
<td></td>
</tr>
<tr>
<td>626</td>
<td>107</td>
</tr>
<tr>
<td>494</td>
<td>118</td>
</tr>
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</table>

Subsequently, the composition of the different ingredients will be measured and the nutritional value of the product estimated, but failure to get the initial values correct will ultimately be reflected in a higher cost of production and will reduce sales of compound feeds to farmers.

**For the farm manager**
The farm manager needs to plan crop production in order to meet the animals’ requirements. Managers therefore need to obtain information on the supposed chemical and nutritional characteristics of various ingredients in advance and, based on this information, plan the correct combination and quantity of different forages. If the information is inaccurate, the crops produced will provide unbalanced proportions of nutrients (i.e. too much protein, too few available carbohydrates, etc.). The immediate consequences will be an inappropriate diet for the animals, with direct effects on production, and the necessity to compensate the lack of some nutrients by purchasing from the market.

**For the policy-maker**
The policy-maker needs reliable information in order to be able to direct the policy of the country or region towards competitive and sustainable agriculture. It is evident that, if estimates are based on imprecise information, policy-makers will not be able to make informed or useful decisions.

A further effect of the use of low-quality data by policy-makers is related to the intrinsic variability of feeds, and therefore to real differences in characterizing the materials (genetic differences or differences arising from the processing of raw materials). These differences may be derived from the various ways of describing and naming feedstuffs adopted in different countries. The result is confusion in the trading of feeds, and difficulties in developing and applying export policies.

The lack of harmonization of feed description and naming has been the source of many problems among countries and, in
particular, among the Member States of the European Union (EU). Historically, both linguistic and scientific barriers have produced significant differences in feed identification, feed naming and feed description, and false variability often exists because the same name is attributed to different feeds or different names are attributed to identical feeds. The availability of reliable feed data and information that are uniform among different countries will not only contribute to fair trade in feedstuffs but will also facilitate cooperation in animal nutrition research directed towards feed efficiency, product quality and the environment. Not least, it is indispensable for the correct application of the General Agreement on Tariffs and Trade (GATT) and realization of the EU’s agricultural policy. Within the EU, a number of steps have been taken to produce a common approach to feed description and naming (ENFIC, 1996).

5. CONCLUSIONS
Feedstuffs vary because of their genetic make-up and as a consequence of the processes applied to them (intrinsic variability of feedstuffs). It is important that information about these factors are available and that genetically different feeds and those processed under varying conditions are identified and recorded separately. Failure to do so will produce improperly averaged, generalized data that provide meaningless information. Another source of data variability results from differences in the methodologies used to obtain the information (extrinsic variability of feedstuffs). Chemical analysis procedures and animal study protocols may vary according to the laboratory or institute involved. This type of variability needs to be minimal if reliable information is to be obtained.

To achieve the necessary reliability, information regarding the chemical and nutritional characteristics of a feedstuff needs to be carefully examined before it is incorporated into a database and, once incorporated, it needs to be carefully managed. Failing to do so will produce false variability among feeds, ultimately resulting in errors in predicting animal performance and environmental effects and impairing the economics of animal products.
REFERENCES


ENFIC. 1996. EU concerted action animal feed and nutrition. European Network of Feed Information Centres (ENFIC) at Internet address: home.wxs.nl/~enfic/


