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# Current and future applications of NIRS technology in the feed industry

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**SUMMARY -** The general purpose of the paper is to show the contribution of Near Infrared Spectroscopy (NIRS) to the quality control in the feed industry. Some arguments to justify the need for analytical quality control in the feed industry together with a list of the main attributes for any actualised and modern QC system are given. Examples on how NIRS gathers those attributes are shown. A number of calibration results are also included and confirm that NIRS has similar or even better accuracy than chemical analyses for the prediction of Weende parameters and metabolisable energy in feed compounds.

**Key words:** NIRS, feed industry, compound feeds.

***RESUME -*** *"Applications actuelles et futures de la technologie NIRS dans l'industrie des aliments pour bétail". L'objectif général de cet article est de montrer la contribution de la spectroscopie infrarouge proche (NIRS) au contrôle de la qualité dans l'industrie des aliments pour bétail. Quelques idées sont présentées pour justifier la nécessité d'un contrôle analytique de la qualité dans l'industrie des aliments pour bétail ainsi qu'une liste des attributs principaux pour des systèmes de contrôle de la qualité actualisés et modernes. Des exemples montrent comment la NIRS recueille ces attributs. Des résultats de calibration sont aussi inclus et confirment que la NIRS a une exactitude similaire ou même meilleure que les analyses chimiques en ce qui concerne la prédiction des paramètres Weende et l'énergie métabolisable dans les composants d'aliments.*

***Mots-clés :*** *NIRS, industrie des aliments pour bétail, aliment composé pour bétail.*

## Introduction

A number of UE Directives and Commission decisions include provisions for circulation of feed materials. According to these regulations information should be given about the content of analytical constituents and declaration of ingredients. At the present situation, there are serious doubts about the existence of a practicably methodology, which can be applied by all the interested partners (industry, consumers, importers). Whereas it is very important to provide the buyers or users of feed materials with accurate and meaningful information such us the quantities of those constituents having a direct effect on the quality of the feed material and also it is necessary to avoid failure on the seller's side to declare analytical constituents with a view of protecting smaller buyers vainly claiming this information, "the costs and timeliness of analysis are consistently limiting factors".

During the past decade a new concept of analysis has evolved using absorption at the Near Infrared region (NIRS). Up-today thousands of NIRS papers, four specific text books (Osborne and Fearn, 1986; Williams and Norris, 1987; Burns and Ciurczak, 1992; Osborne *et al.*, 1993) and the proceeding books of eight International NIRS Conferences (Iwamoto and Kawano, 1990; Biston and Bartiaux-Thill, 1991; Murray and Cowe, 1992; Hildrum *et al.*, 1992; Flinn and Batten, 1995; Davies and Williams, 1996), confirm the suitability of the technique for quantitative and qualitative analysis in the grain, food, feed, pharmaceutical, medical, chemical and textile industries. NIRS technique is a reality which is reaching to different uses, even many of them are still in a research stage.

At present, the competitive abilities of the European feed industry is urgently needing of a strategic action framework for quality control. In the non-far future the feed industry will need to move from the current commercial strategy to a real integral advisory service to farmers. Near Infrared Spectroscopy will allow to make advances in this direction as it will be justified in this paper.

## Some arguments to justify the need of analytical quality control at the feed industry

(i) To scope with national EU and other international legislations including provis ions for circulation, trade and inspection of feeds.

(ii) To provide the customers with accurate and meaningful information such us the quantities of those constituents having a direct effect on the nutritional value of the feeds.

(iii) To have an authorised quantification of the reclaims to the suppliers.

(iv) To provide ration formulation programs with reliable and updated data which allow to dynamically incorporate scientific nutritional knowledge.

(v) To control the production process.

## Main features of an actualised and modern analytical feed QC system

At present any QC system which could make an answer to the above mentioned needs might has the following main attributes:

(i) Speed of response for decision making.

(ii) Low cost per sample.

(iii) Low intra and inter laboratory variation.

(iv) Able to produce information on compulsory (e.g. moisture, protein, fat etc.) and non compulsory analytical values (e.g. antinutritional factors, protein damage, energy value, etc.).

Together with the long time needed to obtain the analytical results coming from the traditional wet chemistry, the cost of the analyses prevents the use of data analysis for decision making results. Today, the price of a Weende analysis for one single sample analysed by traditional wet chemistry, could range between £ 60-75. That cost is clearly unaffordable for a routinely quality control. A monochromator NIRS instrument could cost £ 60.000 and one day of NIRS work could produce analytical results for about 360 samples(Shenk and Westerhaus, 1995) that work could save £ 21.000-27.000, which represents 36-45% of the investment. When making comparisons with the classical chemical tests, the cost of NIRS analysis is modest, since it does not require chemical reagents, glassware and consumables, scales, fume extractors, centrifuges etc. If one bears this in mind, NIRS instruments should be viewed as an investment rather than an expense (Williams and Sobering, 1992). NIRS rapidity could be only exploited optimally if the answer given by the instrument is quickly used for decision making. The NIRS data generated during the first hour or before twenty hours from the arrival of the raw material to the industry are of an unmeasurable value for taking actions (Lizaso, 1993). NIRS technology implemented as either on-line or at-line units are very important tools in different points at the industry. Today, there are available different on-line systems (Jensen, 1993).

In the field of animal feeds evaluation, it is well known the existence of high inter and intralaboratory errors, not only for parameters as fibre, digestibility, etc., but also for the most common parameters as moisture, ashes (Argamentería *et al.*, 1993). The traditional application of NIRS in the analysis of agro-food products has focused on the development of predictive equations relating spectral data to nutritional components (e.g. crude protein, crude fat, starch etc.). It is now well known, that when calibrated with accurate reference data, the NIRS prediction errors could be lower than the standard deviation of the conventional/reference data (Williams and Norris, 1987).

One important reason for false expectations of NIRS has been the clear evidence of difficulties for transfer of equations and/or spectra between instruments even from the same manufacturers. Even if NIRS instrument are perfectly set right according to the manufacturers specifications, small differences remaining coming from the source, the optic system, the reference ceramic, the detectors etc. These differences complicate equation and or spectra transfer between instruments (Dardenne *et al.*, 1992). Today it is possible to mathematically match the performance of spectrometers to produce indistinguishable optical responses across a network of cloned instruments (Biston and Dardenne, 1990; Shenk, 1992; Shenk *et al.*, 1992; Moya *et al.*, 1995). Equations and or spectral data can be transferred for a master instruments to a population of satellite instruments. This avoids duplication of efforts at different centres and opens the way for national, European and international harmonisation of analyses (Puigdomenech *et al.*, 1995). Moreover, data collected from a sample can be sent anywhere in the world via telecommunications and an instrument can even be operated remotely by telecommunications (Shenk and Westerhaus, 1995). For instance, spectral data collected by an instrument in a given laboratory in one region/country can be sent to another instrument located in another region/country in minutes and analysed there by the same software.

Please, those interested in NIRS networking should bear in mind, that a technician will not require more than a 2-3 days training course to become a NIRS user and take the job of analysing samples on a satellite instrument. However, the NIRS network setting-up, evaluation and maintenance will need of a scientific and technical design and overall it will need of the existence of a NIRS manager who should have been specifically trained for that purpose. The most important areas of network management are calibration support and instrument monitoring. The key to the operation of a successful network is the system manager and the support staff (Shenk, 1992).

From the beginning of the NIRS feeds analysis thousands of papers have shown the ability of that technique for the prediction of traditional chemical parameters and other useful quality attributes on animal feeds (Garrido *et al.*, 1993). Table 1 gives average values for calibration statistics for compound feeds, which have been reputed as "difficult" to calibrate. The results shown in Table 1, clearly demonstrate that NIRS is able to explain up 90% of the variation existing on the Weende parameters and the accuracy of the calibrations is excellent compared to the normal production tolerances in the animal feed industry (Büchmann, 1995).

Table 1. Average values (minimum and maximum)[†] for NIR/T calibration statistics in compound feeds for pigs

| Method | Mean % | $R^2$ | SEP % | CV % |
|---|---|---|---|---|
| Moisture | 11.0 | 0.75-0.95 | 0.17-0.48 | 1.5-4.4 |
| Protein | 18.0 | 0.83-0.93 | 0.49-0.62 | 2.8-3.4 |
| Fat | 6.0 | 0.95-0.98 | 0.22-0.44 | 3.6-7.3 |
| Crude fibre | 5.8 | 0.82-0.96 | 0.30-0.70 | 5.2-12.1 |
| Ashes | 6.4 | 0.46-0.92 | 0.40-0.80 | 6.2-12.5 |

[†]From different literature sources and data from author's laboratory

If one can understand that the prediction capacity of the technique or moreso the prediction error (SEP) is a combination of errors of both standard analysis (SEL) and NIR test, and if the high inter and intralaboratory errors found in different ring tests are borne in mind, one ought to be cautious before attributing errors to the method which are not due to the technique. It is theoretically impossible for the SEP of NIRS to be lower than the SEL. The recommendations for the daily control of the equipment, the improvement procedures which allow the detection of sample presentation errors etc., has likewise allowed the minimisation of errors associated with NIRS. The attention paid to the reduction of both errors (standard and NIRS) has been reflected in improved NIRS statistics.

Much effort during the XX century has been spent on devising regression equations to predict digestibility, feed intake and energy value from feed composition. Most of these equations were derived using the results of proximate analyses. The limited predictive capacity of many of the equations generated have been shown in the literature (Barber *et al.*, 1990). In addition, the high time and cost needed to obtain the chemical, in vitro or enzymatic data used as predictors make difficult the use of those equations in practical formulation and rationing at the feed industry or farm. NIRS has also demonstrated that the prediction of animal response could be possible using accurate reference in vivo data and in some cases NIRS can be even more accurate in predicting animal response than any of the current reference methods or combinations of these reference methods. Data in Table 2 has been selected to support the previous argument. The results show that NIRS has similar or even better accuracy than chemical analysis for predicting ME of compound feeds for ruminants.

Table 2. Comparison of NIRS with several laboratory methods for predicting the metabolizable energy (MJ/kg DM) value of compound feeds for ruminants

| Method | Metabolizable energy | Statistics | | |
|---|---|---|---|---|
| | | $R^2$ | SE | N |
| $GE+NDF+ADF_S+ADL_S$ | $ME_{vivo}$[a] | 0.75 | 0.45 | 83 |
| NIRS (M) | $ME_{vivo}$[b] | --- | 0.23 | 80 |
| NIRS (M) | ME (enzym)[c] | 0.86 | 0.29 | 126 |
| NIR (M) | $ME_{vivo}$[d] | 0.84 | 0.37 | 179 |
| NIRS (F) | $ME_{vivo}$[d] | 0.66 | 0.55 | 179 |
| NIRS (M) | ME (enzym)[d] | 0.83 | 0.41 | 179 |
| NIRS (F) | ME (enzym)[d] | 0.60 | 0.69 | 179 |
| NIRS (M) | ME (enzym)[d] | 0.79 | 0.30 | 163 |
| NIRS (F) | ME (enzym)[d] | 0.40 | 0.53 | 163 |

F: Filters instrument; M: monochromator instrument
a: Giger *et al.*, 1994; b: Aufrére and Graviou, 1995; c: Verheggen *et al.*, 1991; d: de Boever *et al.*, 1995

## Conclusions

In the light of the present situation of competitivity in the feed industry, any change from the classical strategy of obtaining information on nutritional value could represent a differential market position.

NIRS could bridge the gap between advanced nutritional scientific knowledge generated and application to practical feed formulation and rationing.

NIRS technology is a reality which sufficiently proved its value as a powerful tool for multiple product/constituent quality control in different points at the feed industry and as an essential support for providing an integral advisory service to farmer.

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