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NIRS IN ANIMAL SCIENCES

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Abstract: The standard chemical method of analysis of the most important quality parameters of raw materials and finished products takes a long time and cost when compared to production process. Therefore, the application of the NIRS method, as a rapid method, enables that the analysis of the content of important ingredients in feed production is completely in line with the production process. NIRS is, in fact, an empirical and secondary analytical technique that requires previous calibration by using samples of known composition and properties determined by certain standard (laboratory) methods of analysis. (Givens and Deaville, 1999). Today the NIRS technology is very compatible with the internet technology to transfer electronic data in both directions, thereby reducing the cost of NIRS data interpretation and report distribution.

INTRODUCTION

Increased competition within the animal feed industry and narrow profit margins, have increased the need for improved production process efficiency, as well as the reduction of waste. To achieve these objectives, rapid analytical methods need to be used in order to react faster in case of deviation in the product specifications. Consequently, a huge amount of money could be saved and a product with more consistent quality could be offered to the customers. NIRS method is certainly a good solution because it has a great potential for improvement of the monitoring and control of production processes in animal feed factories. NIRS method has a very wide range of applications so that it is now used for testing a large number of foods of different origin: cereals and cereal-based products, oilseeds, animal feed, various intermediate products of animal origin, as well as for the analysis of the samples with various consistency: liquid, pasty, granular and powdery. A number of techniques of this analytical method have been developed, which use different areas of the spectrum, different methods of recording and collecting the spectrum, as well as various statistical methods

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for calibration of NIRS devices. (Osborne and Fearn, 1986; Baeten andi Dardenne, 2002; Murray, 2004; Flinn, 2005).

Principles of application

All types of spectroscopy are based on the interaction of electromagnetic radiation with a sample to be analyzed. The NIR region of the electromagnetic spectrum lies between the visible and infrared region and is usually defined by a wavelength range **700-3000 nm.** However, most analytical application of this technique is between ***1100 to 2500 nm.*** (Deaville i Flinn, 2002). The basic principles of NIR spectroscopy involve the production, recording and interpretation of spectra arising from the interaction of electromagnetic radiation with the organic matter (Manley *et al*., 2008). NIR radiation interacting with a sample may be absorbed, transmitted or reflected. Thus, there are different mode of measurements in NIR spectroscopy fitting different applications. In practise the common modes are ***transmittance, interactance, transflectance, diffuse transmittance, and diffuse reflectance,*** with the last two being the most frequently used (Huang et al., 2008). The obtained NIR spectrum looks like a smooth, wavy line with some not clearly defined characteristics, as at the same wavelength occurs the absorption of the radiation by a number of different organic compounds present in the examined material, and the NIR spectrum is actually composed of many overlapping bands which makes it very complex and inhibit the determination of the direct connection between the concentration of important constituents and energy absorption (Osborne Fearn, 1986; Murray Williams, 1987; Wiedemann *et al*., 1998; Deaville Flinn, 2002; Cen He, 2007).

Recording the response of certain molecular bonds (for example, ***O-H; N-H; C-H)*** to NIR radiation, generates a spectrum that may be characteristic of a sample and may act as a ***"fingerprint"*** (Woodcock *et al*., 2008). This spectrum is rich in chemical and physical information about organic molecules, and may therefore yield valuable information about the composition of a product (Katsumoto *et al*., 2001). By carrying all of this information, spectra allow us to evaluate, explore and select a population of samples before we determine what we should measure by classical technique. This is an important research characteristic of spectroscopic techniques (Murray, 1999).

Instrumentation

A NIR spectrometer instrument mainly consists of light source, beam splitter system (wavelength selector), sample holder, optical detector, and data processing analysed system (Manley *et al*., 2008). NIR radiation sources can be thermal or non-thermal.

In the thermal group the included sources are

- the quartz halogen lamps and
- the Nernst filament.

In the second group

- light-emitting diodes (LED);
- laser diodes and
- lasers are the main source of light, which consist of discharge lamps.

According to the wavelength selection, spectrophotometers can be distinguished in

(I) discrete-wavelength spectrophotometers and

(II) continuous spectrum NIR instruments.

The first one irradiates a sample with only a few wavelengths selected using filters or light-emitting diodes (LEDs). The second one may include a diffraction grating or an interferometer. Infrared detectors can be differentiated according to their spectral response, their speed of response and the minimum amount of radiant power that they can detect. In NIR applications, photon detectors are the main used. The detection devices most widely used for NIR analysis can be divided into single- and multi-channel detectors. Single-channel detectors comprise lead-salt semiconductors. Lead sulphide (PbS) is used over the range 1100-2500nm, indium gallium arsenide (InGaAs) over 800-1700nm (extended range up to 2500nm), and silicon detectors over 400-1100nm. Multi-channel detectors comprise diode arrays or charge-coupled devices (CCDs). NIR instrumentation has evolved dramatically in response to the need for speed in analyses and flexibility in adapting to different samples. Instrument selection must be guided by end application. For instance, low cost instruments, based on filters and LEDs, suffice for many dedicated laboratory and routine in field applications(Paolo Berzaghi., and Roberto Riovanto.,2009)

Advantages of NIRS

Near-Infrared spectroscopy has several advantages over other analytical techniques:

- The spectral measurements is really rapid one sample can be scanned in less than 1min;
- Less expensive because there isn’t any use of chemical reagents and a single operator can analyze a large number of samples;
- Several scans can be made on the same object, which permits to obtain a more representative sample composition and a more accurate result of analysis;

- Sample requires minimal (drying and grinding) or no preparation;
- Several constituents of the same sample can be measured at the same time;
- Easily applicable in different environments (like industry, laboratory, harvesters, etc.); Measurements can also be carried out on/in/at line;
- The opportunity to use optical probes makes it possible to analyse the sample in-situ;
- The availability of portable instruments permits to obtain spectra directly in the field, useful to follow process like ripening.

Disadvantages of NIRS

On the other hand, NIR spectroscopy has some disadvantages to take into account:

- Low sensitivity of the signal which can limit the determination of substances with concentration below 0.1%;
- It is a secondary analytical method, so it requires an accurate chemical an physical analysis as reference samples;
- Development of calibration models require high trained personnel;
- Accurate and robust calibration require a large data set incorporating large variation, which is often difficult to obtain;
- It requires a continuous maintenance of the calibration data set;
- With some hardware it is difficult to transfer calibration between instruments of the same manufacture or between different manufactures (Manley *et al*, 2008);
- Although NIR technique has low measuring cost, the initial high financial investment for the instrumentation represents a important obstacle for the purchase.

Applications

1. **Feed analysis**

The major part of these works aimed to estimate the chemical fractions of feed, such as crude protein (CP), dry matter (DM) and fiber fractions. Nutritive value of a forage depends not only on its chemical composition, but also on its digestive utilization. This is the reason why several authors used NIR as a tool to predict in vivo, in vitro or in situ digestibility of forages and feed.

2. Meat and meat products

Regarding the applications of reflectance spectroscopy, it has been used previously in meat analyses and, recently, numerous studies and applications have been developed for the prediction of meat properties, particularly chemical composition, estimation of tenderness, WHC (Water Holding Capacity), drip loss, colour and pH.

3. Fish

NIRS is a simple and easy technique that can be used to monitor the quality of raw fish but, on the other hand, NIR does not completely replace all reference analytical methods (as, for instance, oil quality assessment) and it is important to maintain skill in reference analysis by lab staff.

4. Milk and dairy products

Application of NIR spectroscopy to evaluate and monitor many properties of milk quality: protein, fat, lactose content. Recently NIR spectroscopy has been used also for developing calibration models on goat milk obtaining good model fitting ($R^2 > 0.87$) for all of the main quality traits (proteins, fat, lactose, total solids, non-fatty solids). Less accurate models were obtained for freezing point and titratable acidity.

5. Eggs

NIRS can be used to determine

- Chemical composition(DM, CP, Lipids, Ash, SFA, MUFA, PUFA) of freeze-dried egg yolk
- pH, Lightness, Redness, Yellowness, TBARS can also be determined

CONCLUSION

The introduction of NIRS technology is a good strategy of plant feed if one takes into account their manufacturing process. Implementation of the NIRS technology is a good development strategy for, the animal feed factories, considering the complexity of their production process. NIRS method, as a rapid analytical method, allows timely obtaining of the required results, improvement of the quality control and efficiency, leading to higher profitability and competitiveness.

Advantages of the NIRS technique implementation:

- Fast control of the content of the important components in raw materials and finished products (a large number of measurements in a short period of time)
- Improvement of the product quality
- Costs decrease
- The possibility of installing NIRS device within the production process -continuous process-control
- No chemicals – no chemical waste

Although the implementation of the NIRS technology requires sigbificant start up costs, and relays on chemomtrics, in the long term, and if it is developed properly, it becomes very cost effective.

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