Use of near infrared spectroscopy for evaluation of nutrient digestibility for genetic experiments in poultry

D. Bastianelli,[a] N. Muley,[b] B. Carré,[b] L. Bonnal[a] and F. Davrieux[a]

[a]*CIRAD Centre de Coopération Internationale en Recherche Agronomique pour le Développement, TA30/A, 34398 Montpellier cedex 5, France. denis.bastianelli@cirad.fr*

[b]*INRA Institut National de la Recherche Agronomique. Station de Recherches Avicoles. 37380 Nouzilly, France. carre@tours.inra.fr*

Introduction

Experiments of genetic selection on animals require the registration of individual performance parameters on a large number of animals. In an experiment aiming at determining the genetic component of digestibility of broilers, the measurement of individual digestibility in a large number of birds was needed. The digestibility of a compound is calculated by difference between the amounts consumed and excreted. Thus the chemical composition of hundreds of excreta had to be determined. The quantity of work required for such analyses make them really difficult to be carried out (time, cost). Therefore a rapid and cheap evaluation of chemical composition would be really of great value.

It was decided to evaluate the potential of near infrared (NIR) spectroscopy for this experiment by doing a calibration on the basis of a limited number of samples of excreta. For such genetic studies, even a prediction with a moderate precision would be acceptable since the principal objective is to rank the samples and identify the extreme values. But the precision of the evaluation of genetic heritability of digestibility is linked to the precision of information, and it was also anticipated that more precise calibrations could be used in other contexts (digestibility studies other than in genetic experiments) that require very precise information.

Materials and methods

Animals

A total of 432 broilers of known genetic origin and pedigree were fed with a low digestibility diet. Growth performance and feed intake were recorded throughout the experiment. Digestibility trials were performed between 19 and 22 days of age on every chicken, resulting in 432 excreta samples.

Analyses

Excreta samples were freeze-dried and ground. Spectra were collected in reflectance mode on a Foss NIRSystem 6500 spin cell equipment. The spectra were measured in duplicate (with two different cup fillings) and averaged. A selection of 100 samples was made on the basis of the Mahalanobis distance between the spectra, with the aim of keeping the most spectral variability of the database. These samples were analysed in the laboratory for reference values for gross energy (GE), starch (enzymatic method) and crude fat (CFat) content. Total nitrogen (Kjeldahl method) and True proteins (TP, Terpstra[1] method) were chemically determined on 61 samples only.

Data treatment

Various data processing were applied, with several mathematical treatments (derivatives, SNV, Detrend, etc.) in the WINISI package (Infrasoft Intl.). Reliability of prediction models was assessed by cross validation (with four subgroups) resulting in the calculation of a standard error of cross validation (*SECV*).

Equations for GE, starch and CFat were computed from the 100 reference values, whereas equations for total N and TP were derived from existing databases[2] extended with the 61 reference values from this experiment. The few outlier samples which appeared during the calibration process were analysed again in the laboratory and the new reference value was kept when appropriate.

Calculations

Digestibilities of energy and nutrients were calculated from the chemical composition of all 432 excreta. In order to avoid the introduction of a bias, predicted values were used for all samples including the samples analysed for reference values in the calibration phase.

Results and discussion

Calibrations

The best calibrations were obtained with PLS method, on the first derivative of spectra, pretreated with SNV and detrend corrections. The visible wavelengths were discarded because they introduced instability in equations, for example, *SECV* values much greater than standard error of calibration (*SEC*) values.

The precision obtained in the calibration of gross energy, starch and crude fat was very high: The ratio of standard deviation (*RPD*) (estimated as *SECV* / *SD*) values were around 10 and *SECV* recorded in this experiment were only slightly higher than the reference value for this kind of materials. Even if these parameters are known to be quite easy to calibrate in most kind of materials, the precision reached in this study is unusual in such type of samples. One of the only publications describing calibration on GE in poultry excreta[3] reports a *RPD* of 1.88, with a *SECV* of 0.27. This difference could be due to the higher variability of their sample set compared to the very homogenous one used here (excreta all derived from the same diet), and probably to the extreme precision of the analyses performed in the current studies, with re-analysis of outlier samples.

The lower accuracy of prediction for total nitrogen and true proteins is mainly due to the origin of the database, which was very wide (nearly 400 samples) and not specific of this experiment. This database is described elsewhere.[2] They were however reliable enough for our studies and *RPD* values were higher with the ones found in literature,[3,4] which ranged from 2 to 3 for total nitrogen. Use of local calibrations might improve the precision of models but our studies did not require such small improvements that could have been obtained by this way.

Table 1. Performance of calibration models

Component of excreta	*n*	Population		Calibrations statistics			
		Mean	*SD*	*SEC*	R^2	*SECV*	*RPD**
Gross energy (MJ kg^{-1})	96	16.54	1.11	0.096	0.99	0.115	9.7
Starch (%DM)	94	7.66	6.04	0.51	0.99	0.59	10.2
Crude fat (%DM)	93	8.90	3.67	0.33	0.99	0.36	10.2
Total N. (%DM)	375	5.38	1.13	0.19	0.97	0.26	4.3
True protein (%DM)	379	12.37	2.77	0.53	0.96	0.61	4.4

**RPD = SD / SECV*

It is noticeable that *SECV* values are not much higher than *SEC* values (15% difference in mean), indicating that the population is homogeneous enough for good calibrations. The only case in which this is not fully verified is the total N equation for which the ratio *SECV*/*SEC* is 1.37.

Genetic studies

The digestibility measurement obtained on animals of known pedigree allowed a first evaluation of the heritability (h^2) of digestibility parameters and apparent metabolisable energy (AMEn) in broilers.[5] Data for AMEn are shown in Table 2.

The heritability of these parameters appears to be quite high (h^2 = 0.50 for AMEn) compared with performance traits such as average daily gain (ADG, h^2 = 0.22–0.31) or feed conversion ratio (FCR, h^2=0.34–0.48) which are classically used in genetic selection.

Moreover it was determined that there is a low genetic correlation between AMEn and body weight (or ADG), which means that it would be possible to select animals for a high digestion efficiency without affecting growth parameters.

Table 2. Results of the genetic studies allowed by NIR predictions.[5]

Character	Age of animals	Heritability		Genetic correlation with AMEn
		h^2	*SD*	
Body weight	22 d.	0.37	0.10	+ 0.01
Average daily gain	19–22 d.	0.31	0.05	+ 0.32
Feed conversion ratio	19–22 d.	0.48	0.08	– 0.90
Digestibility of dry matter	19–22 d.	0.52	0.09	+ 0.99
Metabolisable energy (AMEn)	19–22 d.	0.50	0.06	—

Conclusion

Animal selection

This experiment showed very promising results for genetic selection: the high heritability of digestion parameters can lead to selection of animals that can make a higher profit on diets with low nutritional value (i.e. less expensive). After this study, divergent genetic lines for high (D+) or low (D–) digestion capacity have been selected. These lines will be useful models to understand some aspects of digestion efficiency.

Use of NIR

This experiment illustrates the possible use of NIR in genetic / feeding research experiments. Very often the high number of analyses required for a complete experimental design is difficult to performed because of the cost and time required. In the case of genetic selection, the most important feature is to identify extreme values and therefore the use of reference methods is not an absolute necessity. However, in the present case, the predictions were nearly as reliable as reference methods. In principle the calibrations developed here cannot be extrapolated directly to all poultry excreta because of the very standardised experimental conditions. However, it will be applied in the further steps for the selection process of D+ and D– lines. It could also be usefully extended to other types of situations by adding appropriate samples in the database.

References

1. K. Terpstra and N. de Hart, *Z. Tierphysiol., Tierernährg. U. Futtermittelkde.* **32,** 306 (1974).

2. D. Bastianelli, F. Davrieux, D. Friot, L. Bonnal and M. Lessire, *Proc. 11th International Conference on Near Infrared Spectroscopy*, in press (2003).
3. T.N. Smith, G.M. Pesti, R.I. Bakalli, J. Kilburn and H.M. Edwards, Jr, *Poultry Sci*. **80,** 314 (2001).
4. J.B. Reeves, *J. Agric. Food Chem.* **49(5),** 2193 (2001).
5. S. Mignon Grasteau, N. Muley, D. Bastianelli, J. Gomez, J.M. Hallouis, J. Besnard, N. Millet and B. Carré, *Proc. 5èmes journées de la recherché Avicole*, in press (2003).