Direct prediction of energy digestibility from poultry faeces using near infrared spectroscopy

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Introduction

In animal production, digestibility is an essential factor in the evaluation of diets. The main factor contributing to variability of digestibility is the characteristics of the feed itself. In recent experiments [1, 2] we have shown that there are also differences between individual animals and birds in their ability to digest diets. This means that there is a possibility of genetic selection based on the efficiency of digestion. Such genetic experiments require several hundreds of digestibility trials. These assays require the recording of the exact quantity of feed and faeces, and the determination of the chemical composition of numerous faecal samples. We now routinely use near infrared (NIR) spectroscopy for the prediction of the chemical composition of poultry faeces in terms of dry matter, gross energy, protein, starch and fat content [3]. The accuracy of the calibrations used is high, with values of the measured standard deviation divided by the standard error of cross-validation ranging from 6 to 12 across different nutrients.

A further step in the use of NIR spectroscopy would be the prediction of digestibility directly from scanning a faecal sample. This would avoid the need to precisely measure feed intake and faecal output thereby considerably simplifying the experimental work.

Materials and methods

Spectra acquisition and data analysis

In the framework of our experiments on genetic selection in poultry, digestibility trials have been performed on nearly 2,000 broilers that differ in their digestive capacity while fed the same feed. This has required recording the feed intake and faecal output of every bird.

A total of 2,000 faecal samples were collected, freeze-dried and ground. Diffuse reflectance NIR spectra were collected in duplicate on a Foss 6500 equipped with a spinning cell (Foss NIRSystems, Silver Spring, MD, USA) and averaged. Approximately 200 samples, deemed representative of spectral variability, were selected and the gross energy content measured (GE_m) by adiabatic bomb calorimetry as a reference value. From the data on feed intake, faecal output and the gross energy content of the faeces, 190 reference values for gross energy digestibility (dGE_m) were calculated.

Calibration equations for gross energy content and gross energy digestibility were built after mathematical pre-processing of spectral data using standard normal variate and detrend with 2nd derivative of spectra. Visible wavelengths were discarded because they introduced instability in models with lower values for the standard error of calibration but higher values for the standard error of cross-validation. Partial least squares regression was found to be the most efficient method for developing a calibration model. Data were processed with the "modified PLS" procedure of WinISI software (Win-ISI, Infrasoft International, Port Matilda, PA, USA).

Digestibility calculations and calibration strategies

Two prediction strategies were compared to the reference energy digestibility (dGE_m), an indirect and a direct prediction. The indirect prediction (dGE_i) was performed using NIR spectroscopy prediction of gross energy (GEp) and reference feed intake measurement. This is our standard procedure. The direct prediction (dGE_d) was performed by calibrating against dGE_m directly. The principle of calculation and calibration strategies is shown in Figure 1.

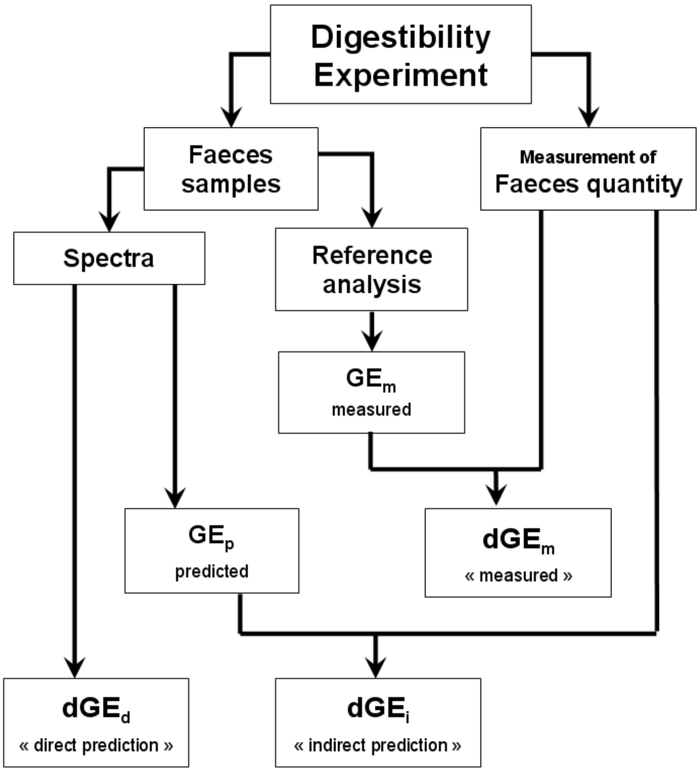

Figure 1. Procedures used for data production.

Results and discussion

The characteristics of calibration equations are presented in Table 1. Prediction of gross energy in faeces was very accurate, with a standard error of cross-validation (SECV) of 0.14 $MJ.kg^{-1}$ which is close to the reference measurement and leads to a high RPD (ratio of performance to deviation, standard deviation divided by SECV) value. This precision was close to our previous work where our estimates of the SECV were 0.12 $MJ.kg^{-1}$ [3], and allowed the use of GE_p in digestibility calculations.

Table 1. Calibration models for gross energy and gross energy digestibility.

Constituent	Population			Calibration statistics			
	n	Mean	SD	SEC	R^2	SECV	RPD
Gross energy ($MJ.kg^{-1}$)	200	16.45	1.25	0.11	0.99	0.14	9.2
Gross energy digestibility (%)	190	68.2	11.2	1.5	0.98	2.1	5.3

n: number of samples
SD: standard deviation
SEC: standard error of calibration
R^2: coefficient of determination of calibration
SECV: standard error of cross-validation
RPD: ratio of performance to deviation ($SD.SECV^{-1}$)

Figure 2 shows the relationship between dGE_m and the estimates derived by the indirect and direct prediction strategies. The values predicted for dGE_i are very close to the dGE_m values ($R^2 = 0.999$ with no outliers). This is due to the fact that the indirect prediction was based on faecal quantity, which was measured directly and an accurate prediction of gross energy, as shown above. The direct prediction of gross energy digestibility had a SECV of 2.1% and a RPD of 5.3, which can be considered as really good for such a parameter. This prediction did not use the information on feed intake or quantity of excreta. There were some outlier values when dGE_d was compared to dGE_m. These outliers were mainly found in the more extreme digestibility values.

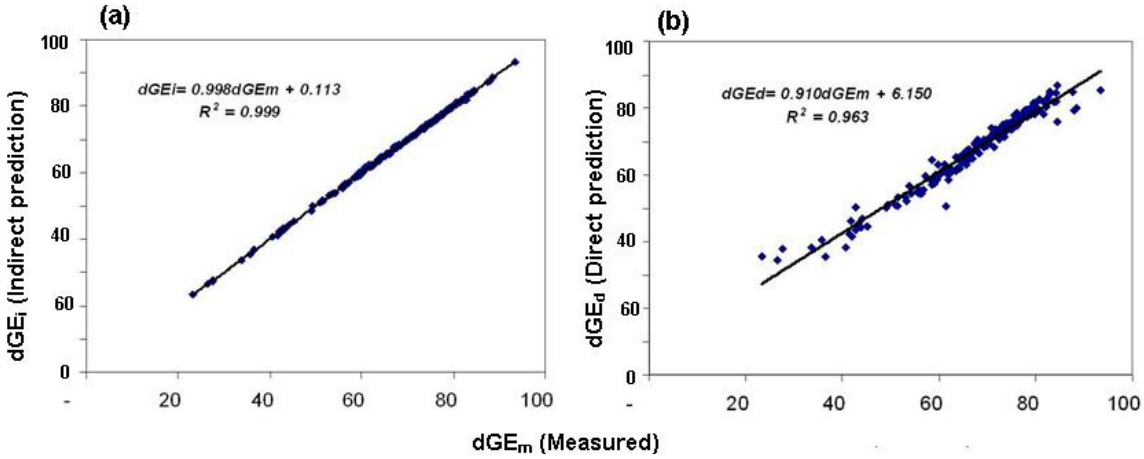

Figure 2. Performance of (a) indirect and (b) direct predictions.

Outliers in low gross energy digestibility values could be due to feed spoilage by the birds. During digestibility trials, spilt feed falls and mixes with faeces. This can cause an over-estimation of excreta quantity and an under-estimation of dGE_m. In that case the reference dGE_m value itself is wrong. At the same time the spectrum of faeces contains feed and the prediction can also be under-estimated by an increase of gross energy content.

Outliers in high gross energy digestibility values could in some cases be explained by incomplete experimental recovery of excreta, which would cause an over-estimation of the reference dGE_m value.

In short, dGE_d is less accurate than dGE_i but would be less sensitive to experimental problems like errors in feed or faeces quantities.

The use of NIR spectroscopy information on faecal samples for the prediction of nutritional value of feeds is now common in ruminants [4, 5]. In poultry, use of NIR spectroscopy has been attempted for the prediction of feed digestibility from feed samples [6]. Experiments on poultry faeces are mainly concerned with characterization of chemical composition in relation to environmental studies [7], with some calibrations relating to gross energy values [8]. The absence of references for the prediction of digestibility from faeces does not allow the comparison of the present results to existing literature. However dGE_d values can be compared to the errors associated with measuring gross energy digestibility directly in a digestibility trial, where the residual standard deviation has been estimated as 1.88% [9].

Conclusion

These results confirm that gross energy digestibility can be predicted with a reasonable accuracy directly from poultry faeces. This point is extremely promising since it avoids the measurement of exact feed intake and faecal output, which are very demanding and time consuming when running digestibility experiments. Digestibility of nutrients other than gross energy, such as protein or starch, could be achieved with the same principle. It must be underlined that the experimental design reported here aimed to study only the within bird part of digestibility where the same feed was fed to all birds. Prediction of digestibility of different feeds is not possible from this particular equation. The procedure would need to be recalibrated when comparing variable diets.

The perspectives of using NIR spectroscopy in this way for digestibility studies are new and could lead to simplified experimental procedures in future poultry digestibility trials.

References

1. S. Mignon-Grasteau, N. Muley, D. Bastianelli, J. Gomez, A. Péron, N. Sellier, N. Millet, J. Besnard, J.M Hallouis and B.Carré. *Poult. Sci*. **83,** 860 (2004).
2. S. Mignon-Grasteau, N. Muley, D. Bastianelli, J. Gomez, J.M. Hallouis, J. Besnard, N. Millet and B. Carré, in *5èmes Journées de la Recherche Avicole*, Tours, France, p. 359 (2003).
3. D. Bastianelli, N. Muley, B. Carré, L. Bonnal and F. Davrieux, in. *Near infrared spectroscopy: Proceedings of the 11th International Conference*. Ed by A.M.C. Davies and A. Garrido-Varo, NIR Publications, Chichester, UK. p. 735 (2003).
4. E.R. Leite and J.W. Stuth. *Small Rumin. Res*. **15**, 223 (1995).
5. R.K. Lyons and J.W. Stuth. *J. Range Manag*. **45**, 238 (1992).
6. T. van Kempen and Bodin J.C., *Anim. Feed Sci. Technol*. **76**, 139 (1998).
7. E.K. Kemsley, H.S. Tapp, A.J. Scarlett, S.J. Miles, R. Hammond and R.H.Wilson. *J. Agric. Food Chem*. **49**, 603 (2001).
8. T.N. Smith, G.M. Pesti, R.I. Bakalli, J. Kilburn and H.M. Edwards Jr. *Poult. Sci*. **80**, 314 (2001).
9. A. Bourdillon, B. Carré, L. Conan, M. Francesch, M. Fuentes, G. Huyghebaert, W.M.M.A. Janssen, B. Leclerc, M. Lessire, J. Mc Nab, M. Rigoni and J. Wiseman. Br. *Poult. Sci*. **31**, 567 (1990).