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Using faecal near-infrared spectroscopy (FNIRS) to estimate nutrient digestibility and chemical composition of diets and faeces of growing pigs

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ABSTRACT

Near-infrared spectroscopy has been successfully used in predicting nutrient digestibility and other parameters, e.g. diet composition from the spectra of faeces samples in herbivores (FNIRS). The objective of the present study was to investigate if the chemical composition of diets and faeces, as well as the apparent digestibility of organic matter (OM), crude protein (CP), neutral-detergent and acid-detergent fibre (aNDFom, ADFom) and crude fibre (CF) can be predicted with sufficient accuracy from spectra of pigs' faeces. Faecal samples ($n = 202$), together with detailed information about the chemical composition of these samples and the diets supplied, were provided from five very different digestibility trials with growing pigs. Faecal spectra were obtained by NIRS and calibrations were developed using the complete dataset. Accuracy of calibration equations was assessed by means of standard error of cross-validation (SECV) and the RPD value (standard deviation of lab results/SECV). The prediction of the chemical composition of the diet was considered successful, as all calibration equations had RPD values well above 2, the value that indicates sufficient accuracy. The chemical composition of faeces was predicted with good to sufficient accuracy. Calibrations developed to estimate the apparent nutrient digestibility from faecal spectra worked well for OM and CP, with a SECV of 0.024 for both and RPD values of 2.1 and 2.4. This very promising result merits further investigation. The prediction of the apparent digestibility of fibre fractions was less successful. We conclude that the FNIRS approach is feasible for use in pig nutrition research for predicting the chemical composition of diet and faeces, as well as to determine the apparent digestibility of OM and CP in situations where controlled digestibility trials are not possible.

Abbreviations: NIRS, near-infrared spectroscopy; FNIRS, faecal NIRS; R/F/DOM, R/F/DCP, R/F/DNDF, R/F/DADF, R/F/DCF, concentration of OM, CP, aNDFom, ADFom, CF in ration (R), faeces (F) and apparent digestibility (D); SNV-D, standard normal variance and detrend; MPLS, modified partial least-square routine; SEC, standard error of calibration; SECV, standard error of cross-calibration; R^2_c, coefficient of calibration; R^2_{cv}, coefficient of cross-calibration; r, correlation coefficient; b, regression coefficient; RPD, ratio of standard deviation of laboratory results to the SECV.

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1. Introduction

Faeces consist mainly of the indigestible residues of feed that were resistant to the digestion process, and therefore they can provide valuable information regarding the nutritional value of a diet. Hence, estimating the nutritional value of a diet from the characteristics of faeces is a promising approach. In herbivores, near-infrared spectroscopy (NIRS) has been used successfully to monitor the nutritional status and quality of feed ingested, based on the spectral information of faeces (Dixon and Coates, 2009). Faecal NIRS (FNIRS) has been used to predict the apparent digestibility of organic matter (DOM) of temperate forages (Decruyenaere et al., 2012), tropical grasses and legumes (Boval et al., 2004; Dixon and Coates, 2008), mixed rations (Nyholm et al., 2009) and pelleted diets (Núñez-Sánchez et al., 2012). Calibrations have been established to predict the chemical composition of diets ingested by grazing livestock (Garnsworthy and Unal, 2004; Boval et al., 2010), the quantitative feed intake (Decruyenaere et al., 2009; Huntington et al., 2011) and also its botanical composition (Walker et al., 2002; Glasser et al., 2008). Such parameters were predicted for several livestock species, including cattle (Lyons and Stuth, 1992; Dixon and Coates, 2010), small ruminants (Leite and Stuth, 1995; Landau et al., 2008; Kumara Mahipala et al., 2010), donkeys (Kidane et al., 2008), rabbits (Núñez-Sánchez et al., 2012) and poultry (Bastianelli et al., 2007). Recently, this technique was also used successfully to predict nutrient and energy digestibility of a cereal-based diet high in dietary fibre from faeces samples obtained from growing pigs of different genetic background (Bastianelli et al., 2014).

The major advantage of the FNIRS technique is that after establishing robust calibration equations only small-sized faecal samples are needed to assess such important diet characteristics, meaning that total faeces collection is not necessary. It is therefore particularly appropriate for investigations with grazing and free-ranging animals, when feed intake and diet selection cannot be determined directly. Nevertheless, NIRS calibrations can only be established from feed-faeces pairs obtained in controlled digestibility trials. This may present limitations for the accuracy of FNIRS predictions, since diet selection of free-ranging animals cannot be mimicked exactly in such trials. Free-ranging systems for pigs are of considerable importance today, not only as specialised high-value systems like the traditional “dehesa” system of southern Europe (Joffre et al., 1999), but also as part of modern common pig production systems (Sørensen et al., 2006). In Great Britain for example, 27% of breeding sows were kept outdoors (Sheppard, 2004). Outdoor pig production has significance in the context of animal welfare issues (Lassen et al., 2006) and in the increasing demand for organic pork. In many developing countries large numbers of pigs are raised under free-range conditions (Ocampo et al., 2005; Riedel et al., 2012). In order to determine nutrient balances and nutrient-use efficiencies of such outdoor pig production systems, as well as the physiological aspects of pig nutrition, methods are needed that are able to determine the nutritional value of ingested feed and quantify nutrient intake and faecal output of free-ranging animals. The use of FNIRS has potential to meet these requirements and therefore needs to be investigated. We hypothesise that FNIRS can be used not only to estimate the chemical composition of the diet of pigs and their faeces, but also to predict the nutritional value of the diet, i.e. the apparent digestibility, with sufficient accuracy.

The objective of the present study was therefore to test if the chemical composition of diets and faeces, as well as the apparent digestibility of organic matter, crude protein and fibre fractions of pigs’ diets can be predicted from faecal spectra obtained in five different digestibility experiments involving 36 very different diets.

2. Materials and methods

2.1. Sample origin and trial description

Faecal samples from growing pigs were obtained from digestibility trials in which there was total faecal collection. The trials were conducted at five different locations (Christian-Albrechts-Universität Kiel, Martin-Luther-Universität Halle-Wittenberg and Friedrich-Loeffler-Institute Braunschweig, Germany; University of Agriculture Abeokuta, Nigeria, and the Nabanhe National Nature Reserve Research Station, Xishuangbanna, China). Trial details are presented in Table 1. All trials were carried out in accordance with the EU Directive 2010/63/EU concerning animal experiments.

2.2. Chemical analyses

Chemical analyses of feed and faecal samples for all five trials were conducted in Germany, either at the institution where the digestibility trials were carried out, or at the University of Kassel in the case of trials conducted in Abeokuta and Xishuangbanna.

Faecal samples from the trials in Abeokuta, Xishuangbanna and Halle were dried at 60 °C until constant dry weight was reached. The faecal samples from Kiel and Braunschweig were freeze-dried. Samples were then ground with a hammer mill (ZM 100, Retsch, Germany) using a 1 mm screen, except the samples from Halle, which were ground to 1 mm particle size in a CYCLOTEC 1093 sample mill (Foss, Denmark).

Dry matter and organic matter concentrations in faeces (FDM, FOM) and feed samples (ration: RDM, ROM) were analysed by drying two 1.5 g subsamples at 105 °C overnight and consecutively incinerating the same subsamples after weighing at 550 °C for 3 h according Naumann and Bassler (1976).

The crude protein concentration in feed (RCP) and faeces samples (FCP) was calculated from the N concentration (CP = $N \times 6.25$), which was analysed by means of the DUMAS combustion technique using a C/N–TCD analyser