Recent developments in improving the prediction of digestibility of feed grains

P.C. Flinn[1,2], P.G. Heazlewood[1] and S.L. Dalton[1]

[1]Department of Primary Industries, Private Bag 105, Hamilton, Victoria 3300
[2]*Current address*: Kelspec Services Pty Ltd, PO Box 31, Dunkeld, Victoria 3294

Abstract

"Feed grain" has always been regarded as an inferior product in Australia because it is unsuitable for milling. However the recent sharp increase in the feeding of grains to livestock has resulted in a large collaborative research project being established to improve the quality and marketing opportunities for feed grain. This study addresses one of the project's objectives which is to develop rapid tests for nutritional value, specifically dry matter digestibility (DMD) and hence metabolisable energy. *In vivo* DMD was measured on 40 grains in sheep using a standard protocol, with values ranging from 61.9 to 92.3% (standard deviation 6.64). NIR could predict *in vivo* DMD satisfactorily for whole grain (R^2 0.92, *SECV* 1.94) and ground grain (R^2 0.93, *SECV* 1.74). However a more even distribution of values is required for a robust relationship, with further samples having DMD values between 60 and 80%. Additional *in vivo* trials are in progress with 20 diverse grains using sheep, and 8 of these using cattle. These grain "standards" will form the basis of a uniform procedure for rapid prediction of DMD between Australian laboratories.

Introduction

The grain industry in Australia has traditionally regarded "feed grain" as an inferior product because its milling quality makes it unsuitable for food production. Whilst the quantity of grains fed to livestock in Australia has doubled in the last five years, little has been done to define or improve quality and marketing opportunities for feed grains. This is now being addressed with the funding of a large collaborative research project entitled "Premium Grains for Livestock". One of the objectives of this project is to develop rapid tests for the nutritional value of grains. These tests would be available at the site of grain receival, and would enable the grains to be priced according to their suitability as an animal feed.

Obviously NIR is the prime candidate to meet this demand. It is routinely used to measure moisture, protein, fat and fibre in grain, but has also proved valuable for the estimation of functional properties[1,2]. Energy content of grain is such a property, and has been identified as one of the most important indicators of nutritional value. NIR has been used for many years to predict digestibility (and hence metabolisable energy) of forages, grains and mixed feeds for ruminants, based on an enzymatic technique which in turn is correlated to *in vivo* digestibility[3]. However the *in vivo* "standards" used to calibrate this technique (and hence NIR) were few in number and had not been produced using a standard protocol. This is a particular problem with grains, the digestibility of which can vary with animal type, method of grain processing and quality and quantity of forage fed with the grain.

In the case of forages fed to ruminants, NIR has been used to directly predict *in vivo* digestibility, avoiding any intermediate laboratory method[4,5,6]. Digestible energy of grains for pigs has also been calibrated against NIR in this way[7]. The limitation of this approach is the difficulty and expense in obtaining enough samples with *in vivo* data for a robust calibration.

The objective of this study was to measure *in vivo* digestibility in ruminants of a wide range of grains (in terms of both species and quality) using a standard protocol, and to compare NIR calibrations based on both *in vivo* and enzymatic procedures.

Materials and methods

A unique feature of the Australian research project is the production, collection and distribution of a common set of grains from a central source for both laboratory analysis and feeding studies with ruminants, pigs and poultry.

In this study, 40 grains were fed to sheep, comprising barley (15), wheat (6), triticale (3), oats (4), sorghum (2), maize (1), lupins (4), field peas (2), chickpeas (2) and faba beans (1). Each grain was fed in rolled form to 8 sheep, together with chaffed lucerne hay in a 70:30 grain:hay mixture. Separate sheep were fed a diet of hay only. All diets were fed at a maintenance level of intake for 30 days (10 days each for introduction, adaptation and measurement). *In vivo* digestibility of the mixed diets and the hay was measured as the percentage difference between feed eaten and faeces excreted, and expressed as dry matter digestibility (DMD) or organic matter digestibility (OMD). DMD and OMD of the grains themselves were calculated by difference.

Samples of all 40 grains and the lucerne hay were analysed for pepsin-cellulase dry matter disappearance (PCDMD), and DMD was predicted on the grains using a linear regression relating PCDMD to *in vivo* DMD for an existing set of grain "standards"[3]. An additional heating step[8] was included in the pepsin-cellulase procedure to digest the starch.

NIR spectra were collected on all grains in reflectance mode (log $1/R$). Whole samples were scanned twice in a natural product cell using the sample transport module in a model 6500 scanning monochromator (Foss NIRSystems, Silver Spring, MD, USA), and the mean spectra obtained. Ground samples were scanned once in small ring cups using the spinning sample module in a Foss NIRSystems model 5000 spectrophotometer, which had previously been spectrally matched to the 6500 instrument.

ISI NIRS-3 software, version 4.0 (Infrasoft International, Port Matilda, PA, USA) was used to transform spectral data using "standard normal variate" and "detrend" options. Calibrations for both *in vivo* DMD and DMD predicted from PCDMD were derived using modified partial least squares regression and a first derivative math treatment (1,4,4,1). Calibration success was judged using standard error of cross-validation (*SECV*), coefficient of determination (R^2) and the ratio of *SECV* to standard deviation of the reference data (*SD*).

Results and discussion

The mean, range and standard deviation for *in vivo* and predicted DMD of the 40 grains are shown in Table 1. Table 2 shows the NIR calibration statistics for both measurements, and for both whole and ground samples.

Table 1. Dry matter digestibility % (DMD) values for the 40 grain samples.

Measurement	Mean	Min.	Max.	*SD*
In vivo DMD	85.2	61.9	92.3	6.64
Predicted DMD*	85.0	63.1	91.5	6.73

Min. = minimum.   Max. = maximum.   *SD* = standard deviation of values across population

*Predicted from a linear regression relating pepsin-cellulase dry matter disappearance to *in vivo* DMD for an existing small set of grains.

Table 2. NIR calibration statistics for dry matter digestibility % (DMD) measurements for the 40 grain samples.

Measurement	*SECV*		R^2		*SECV/SD*	
	Whole	Ground	Whole	Ground	Whole	Ground
In vivo DMD	1.94	1.74	0.92	0.93	0.29	0.27
Predicted DMD*	1.49	1.38	0.95	0.96	0.22	0.21

SECV = standard error of cross-validation.
R^2 = coefficient of determination.
SECV/SD = ratio of *SECV* to the standard deviation of the reference data.
*Predicted from a linear regression relating pepsin-cellulase dry matter disappearance to *in vivo* DMD for an existing small set of grains.

In vivo DMD ranged from 61.9% (oats) to 92.3% (lupins), but apart from the oats there was little variation apparent within grain types. For example, DMD values for the 15 barleys ranged only from 82.9% to 85.9%.

Direct NIR calibrations for *in vivo* DMD appeared accurate (low *SECV*, high R^2, *SECV/SD* ratio below 0.3), even on a relatively small number of samples. The results compare favourably with a previous study[3] involving 80 grains, where the samples and *in vivo* reference values originated from a wide variety of trials, locations and methods. The accuracy for whole grain samples was only slightly lower than for ground samples. Similar results were obtained for NIR calibrations based on DMD values predicted in turn from PCDMD, with calibration accuracy slightly higher than for direct calibration against *in vivo* DMD. This is not surprising, given the expected higher error associated with *in vivo* measurements compared with laboratory measurements. However, the predicted DMD values (from PCDMD) used as reference values for NIR were based on a few grains selected from the above larger diverse set.

Figures 1 and 2 show the relationship between reference and NIR-predicted *in vivo* DMD values for whole and ground grains respectively.
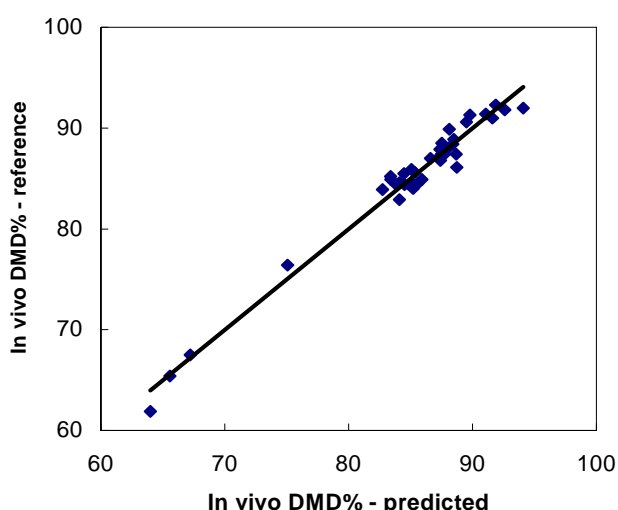

Figure 1. Scatterplot showing the relationship between reference and NIR-predicted *in vivo* dry matter digestibility for whole grain samples.
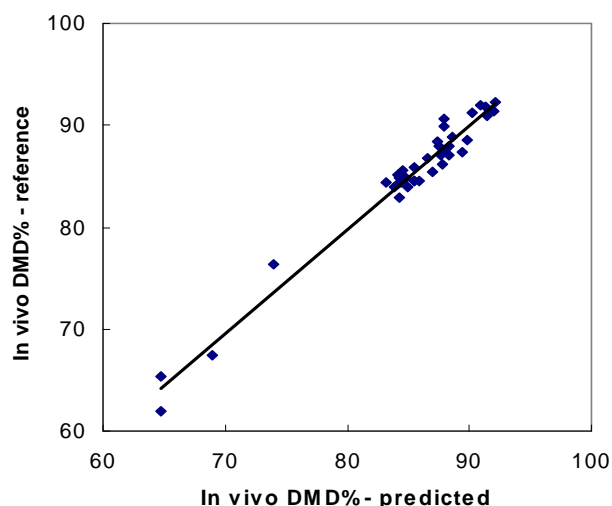
Figure 2. Scatterplot showing the relationship between reference and NIR-predicted *in vivo* dry matter digestibility for ground grain samples.

It was noticeable from these figures that, despite the apparently accurate calibration statistics, all samples except the four oats were clustered between 83% and 92% DMD. Additional samples and a more even distribution of points are required for a robust relationship. This is likely to be achieved in further work currently in progress. An additional 20 grains have been identified through NIR tests to have a wider and more even range in DMD, partly due to weather damage caused by frost, rain and drought in various parts of Australia. These grains are currently being fed to sheep in additional *in vivo* trials using the same protocol described in this paper. Eight of these 20 grains are also being fed to beef cattle, in order to quantify differences in DMD between sheep and cattle.

The ultimate objective of this project is to retain quantities of 60 or more grains with *in vivo* DMD values for distribution to appropriate testing laboratories. This will enable the estimation of DMD and metabolisable energy to be standardised throughout Australia, thus increasing confidence in grain testing by NIR for the livestock industries.

Acknowledgement

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