Near infrared spectroscopy estimation of pearl millet grain composition and feed quality

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Introduction

Pearl millet is an important cereal crop of South Asia and sub-Saharan Africa where dry land crop-livestock production systems are practiced. In large breeding programmes, compared to conventional laboratory analysis, NIRS is potentially attractive for assessing grain composition and digestibility-related traits of large numbers of samples, because of the short time requirement, lower labour requirement, reduced consumables costs, and reduction in hazardous chemicals required for conventional laboratory analysis. However, grinding of grain samples before NIR scanning can be laborious, costly and slow. Studies on other cereals have demonstrated that NIR models have been developed with sufficient accuracy to predict chemical composition of ground grain samples. However, reports regarding the potential for non-destructive assessment of grain composition and digestibility are few and far between, therefore, we focused this study on non-destructive assessment of pearl millet grain quality by NIR spectroscopy.

Material and methods

Chemical analysis was performed for all (195) samples for composition factors, (dry matter content, protein content, starch content, and fat content), by using standard methods.[1] Feed quality traits [*in vitro* organic matter digestibility (IVOMD), gas production during 24 h of *in vitro* digestion (Gas 24) and metabolisable energy (*ME*)] were analysed[2,3] for 54 samples only, which were selected on the basis of flour spectrum Mahalanobis distances. Mahalanobis distance is most commonly used as a multivariate statistic. On the basis of 54 samples the remaining 141 samples were predicted. A monochromator (FOSS Tecator, NIRSystems, Laurel, MD, USA) was used to scan the whole grain samples in a small circular cup of 36 mm inner diameter. Each sample was scanned 32 times in the NIRS instrument in small ring cells. Wet lab results from previously

Table 1. Calibration and cross-validation statistics of NIR equations for pearl millet grain composition and feed quality traits based on ground grain samples.

Grain traits	Calibration				Cross validation	
	N	*SD*	*SEC*	r^2	*SECV*	1-VR
Dry matter content	94	0.277	0.016	0.996	0.036	0.983
Ash content	91	0.179	0.025	0.981	0.031	0.969
Protein content	94	1.424	0.126	0.992	0.237	0.972
Starch content	91	4.064	0.588	0.979	0.949	0.946
Fat content	97	0.415	0.023	0.996	0.051	0.985
Gas24	25	1.726	0.089	0.997	0.275	0.975
ME content	24	0.164	0.025	0.976	0.0577	0.882
IVOMD	22	0.856	0.061	0.994	0.359	0.831

analysed ground samples from the same single-plot grain lots were used as reference data for NIRS calibration. The scanned whole grain samples were then ground through a 1 mm screen using a Cyclone Sample Mill 3383-N92 and dried overnight at 105°C. The dried ground grain samples were then scanned again, and NIR calibrations determined for the ground samples.

Results and discussion

The calibration and cross-validation statistics for NIRS equations for the ground and intact pearl millet grain samples are presented in Tables 1 & 2 respectively.

Table 2. Calibration and cross-validation statistics of NIR equations pearl millet grain composition and feed quality traits based on intact grain samples.

Grain traits	Calibration				Cross Validation	
	N	*SD*	*SEC*	r^2	*SECV*	1-VR
Dry matter content	89	0.249	0.160	0.585	0.171	0.534
Ash content	98	0.174	0.072	0.836	0.087	0.766
Protein content	95	1.432	0.466	0.894	0.092	0.837
Starch content	98	4.123	2.417	0.656	2.601	0.604
Fat content	97	0.430	0.160	0.860	0.219	0.743
Gas24	22	1.538	0.551	0.871	1.043	0.562
ME content	20	0.182	0.021	0.986	0.097	0.729
IVOMD	21	1.103	0.295	0.928	0.623	0.697

N = number of samples used for calibration; *SD* = standard deviation; *SEC* = standard error of calibration; r^2 = coefficient of determination; *SECV* = standard error of cross validation; 1-VR = coefficient of determination in cross validation.

Table 3. Comparisons of NIR external validation statistics for pearl millet grain composition and feed quality traits that were obtained from scans of ground and intact grain samples.

Grain trait	Ground grain sample			Intact grain sample		
	RSQ	*SEP*	Slope	*RSQ*	*SEP*	Slope
Dry matter content	0.943	0.065	0.984	0.438	0.213	0.939
Ash content	0.942	0.048	1.045	0.765	0.096	1.059
Protein content	0.912	0.066	0.909	0.841	0.085	0.969
Starch content	0.884	1.207	0.920	0.534	2.369	0.878
Fat content	0.890	0.152	0.912	0.749	0.223	0.980
Gas24	0.913	0.595	0.944	0.641	1.168	0.849
ME content	0.892	0.075	0.978	0.462	0.182	0.667
IVOMD	0.823	0.604	0.935	0.261	1.324	0.532

SEP = standard error of prediction; *RSQ* = squared simple correlation coefficient.

NIR spectroscopy gave good estimates of the composition traits (dry matter, ash, protein, starch and fat) of ground pearl millet grain samples, and also indicated that NIR spectroscopy can predict differences in the digestibility, *ME* and Gas 24 of ground pearl millet grain samples.

Predicted values of *SECV* were lower, and r^2 values higher from NIR equations, based on scans of ground grain samples, than those from equations based on scans of intact grain samples (Table 3).

This was not surprising, because of the diversity of surface area and size of materials in the intact grain samples, and/or due to vacant space in the NIRS scanning cups. Intact grains are not as compact as flour samples, which affects the absorption spectra.

Among the whole (intact) grain samples the best *RSQ* was observed for crude protein content (*RSQ* = 0.841), compared to data reported previously for grain sorghum,[4] oilseeds[5–7] and other cereals.[8] NIR predictions were also good for ash and fat contents[9] but Hicks *et al.*[4] reported very low coefficients of determination for predictions of fat content from both intact and ground sorghum grain samples. Intermediate predictions were found for starch content and Gas 24. These results are summarized in table 3. Similar results were reported previously for starch in barle.[10]

Validation statistics for NIRS predictions based on intact grain samples of pearl millet were poor for dry matter and *ME* contents, and those for IVOMD were poorer still. Digestibility is influenced by the relative amounts of feed constituents, such as NDF, ADF and lignin,[11] which affects the feed digestibility NIRS prediction with somewhat lower precision than chemical composition.[12]

Conclusion

NIR spectroscopy predicted protein content of whole grain sample with encouraging results Non-destructive preliminary NIR screening of intact pearl millet grain samples, to predict their crude protein, ash, and fat contents (and perhaps Gas24 and starch contents), could permit rapid and economical culling of less desirable genotypes, prior to more elaborate evaluations of these and other traits on a selected subset of the more promising genotypes. However, More research is required to standardize non-destructive NIR estimation of dry matter content, *ME* and IVOMD of intact pearl millet grain samples.

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