Near-Infrared Reflectance Spectroscopy for the Determination of Fiber in Oats

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INTRODUCTION

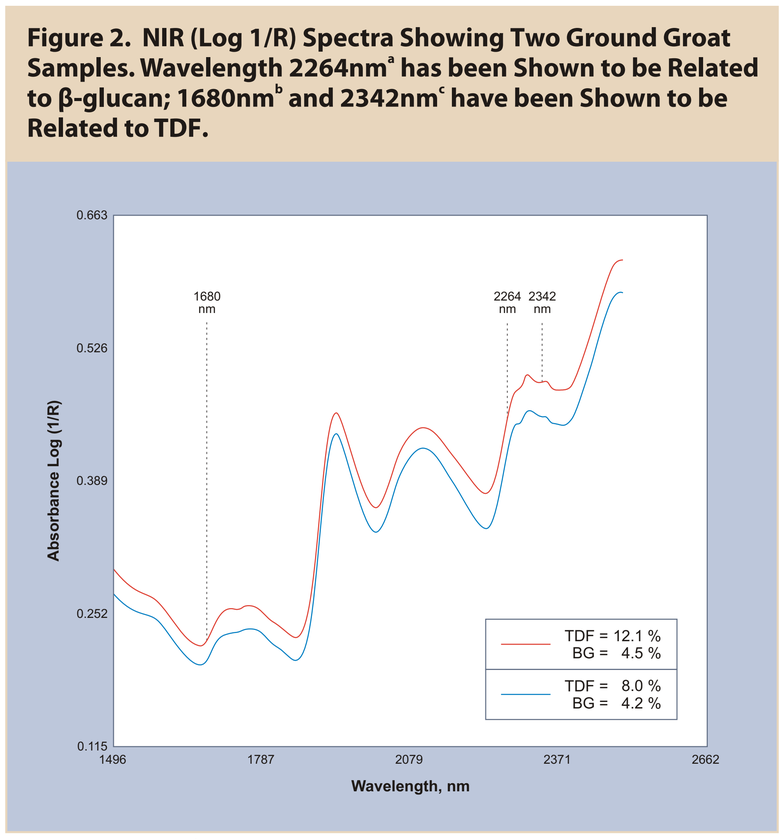
Availability of oat cultivars with high levels of soluble fiber (β-glucan) is essential for food processors to meet health claim specifications and improve consumer nutrition. The current procedures recommended for measuring total, soluble and insoluble dietary fiber are enzymatic/gravimetric methods that are extremely time-consuming and labor intensive, and thus unsuited for early-generation screening for thousands of plants with low quantities of seed available. Development of rapid screening methodology for quantification of β-glucan in Canadian oat genotypes will speed the breeding process and registration of cultivars with higher levels of β-glucan. Near-infrared reflectance spectroscopy (NIRS) provides fast, inexpensive analysis. However, NIRS is a comparative technique that relies on accurate reference analysis and multivariate calibration of sample spectra so selection of representative samples and analytical precision are critical in determining potential applications of this technique. This study investigated the use of NIRS for measurement of β-glucan content of whole oats and ground groats compared to a traditional enzymatic determination. Ground groats were also analyzed for total dietary fiber (TDF) using standard methods prior to development of calibration equations.

MATERIAL & METHODS

Oat samples grown between crop years 2001-2004 were collected and subjected to simultaneous NIR scanning (Foss NIRSystems 6500) and quantification of β-glucan (AACC Approved Method 32-23) and TDF (AACC Approved Method 32-07). The samples were scanned first as whole oats, then hulls were removed with a Codema dehulling machine and the resulting groats were ground with a Retsch centrifugal mill (0.5 mm screen) to produce a wholemeal product hereafter referred to as ground groats. Both types of material were scanned using a spinning sample cup (#NR-7072, Foss, Eden Prairie, MN) and spectra were recorded using ISIScan Ver.1.25 software (Foss, Eden Prairie, MN). Samples were scanned from 400 to 2494nm although only 1104 to 2494 are considered relevant to the components of interest in this study (Blakeney, A., and Flinn, P. 2005, Mol. Nutr. Food Res.). Laboratory reference data were used on a dry weight basis and additional calculations were performed to account for hull content prior to whole oat equation development.

Figure 1. The Samples were Scanned as Whole Oats, then the Hulls were Removed and the Resulting Groats were Ground.

Figure 2. NIR (Log 1/R) Spectra Showing Two Ground Groat Samples. Wavelength 2264nm[a] has been Shown to be Related to β-glucan; 1680nm[b] and 2342nm[c] have been Shown to be Related to TDF.



[a]Szczodrac et al, Cereal Chem.1992; [b]Kim et al, J. Agric. Food Chem. 2006; [c]Czuchoajowska et al, Cereal Chem.1992

WinISI Ver.1.50e software (Foss, Eden Prairie, MN) was used to compute optimum prediction equations.

RESULTS

For β-glucan: a total of 762 ground groat and 264 whole oat samples were chemically analyzed, representing a range from 3.47 to 8.37 and 1.47 to 6.09 % β-glucan respectively. For TDF a total of 157 ground groat samples were chemically analysed representing a range from 8.42 to 19.19 % TDF. Every fifth sample across the range was removed from the calibration to create a validation set. Spectra obtained from this sample set along with relevant wavelengths are shown in Figure 2. The optimum calibration equations were calculated using standard MSC procedures for both types of material, with the whole oat equation requiring a second derivative math treatment. Figures 3 and 4 show the total β-glucan and TDF content of samples as reference and NIR predicted values.

Table 1 shows the NIR calibration statistics for β-glucan and TDF as measured in the various oat samples. NIR reflectance spectroscopy resulted in squared correlation coefficients (RSQval) and standard errors of prediction (SEP) for β-glucan in ground groat and whole oat samples. For ground groats RSQval = 0.88 and SEP = 0.34 compared to RSQval = 0.75 and SEP = 0.42 for whole

Figure 3. Correlation of Actual Ground Groat β-glucan vs. NIR Predicted β-glucan.

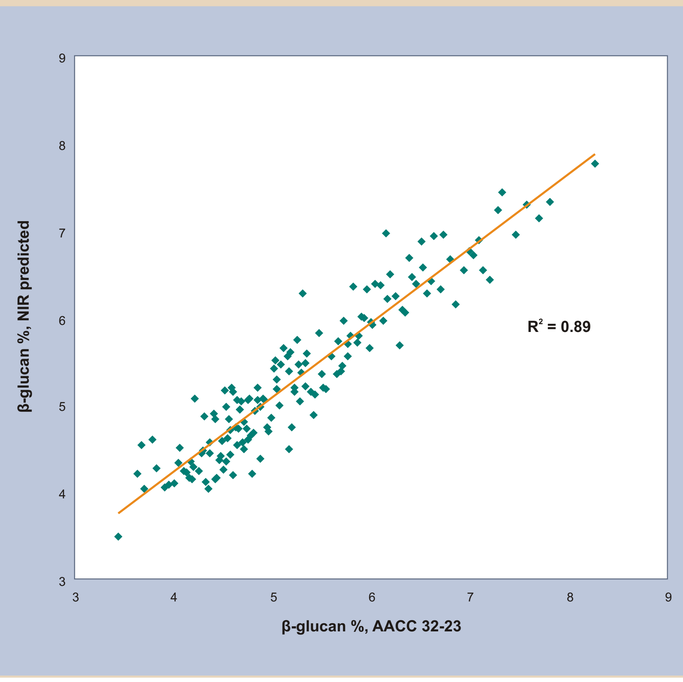


Figure 4. Correlation of Actual Ground Groat TDF vs. NIR Predicted TDF.

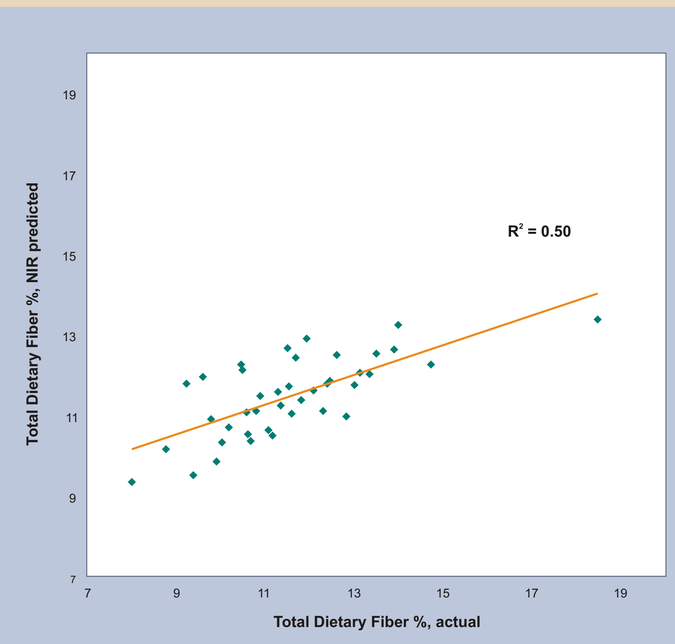


Table 1. NIR Statistics for β-glucan and TDF in Oat.

	NIR statistics from ISI calibration software for β-glucan and TDF						
Sample type	***N***	**Mean (%)**	**Range (%)**	**SD**	**RSQval**	**SEPc**	**RPD**
Ground Groat β-glucan	609	5.30	3.44 - 8.27	1.00	0.88	0.34	2.9
Whole Oat β-glucan	213	3.83	1.28 - 6.00	0.83	0.75	0.42	2.0
Ground Groat TDF	157	11.58	8.01 - 18.46	1.87	0.50	1.37	1.4

N = number of samples in calibration
SD = standard deviation of reference data
RSQval = squared correlation coefficient (r^2) for validation data
SEPc = standard error of prediction
RPD = ratio of standard deviation of reference data and standard error of prediction

oat. The precision in prediction of TDF was significantly lower with RSQval = 0.50 and SEP = 1.37. For a RSQval of 0.88, 88 % of the variance in the NIR can be accounted for by the sample reference analytical result. The ratio of prediction to standard deviation (RPD) was used to evaluate the calibrations. Equations with a RPD > 3 are considered suitable for screening samples (Williams, P, 2004. Near Infrared Technology Manual) therefore in the present study, the NIRS calibration for β-glucan in ground groats is suitable for screening breeding samples for this soluble fiber.

CONCLUSIONS

Although the calibration developed for β-glucan may not be as accurate as predicting other parameters such as protein, oil and moisture (as determined in our lab and literature), an RPD value close to 3 indicates NIRS can be used in plant breeding, nutritional and product studies to obtain simple and rapid estimates of oat β-glucan using ground groat samples. The greater RSQval and RPD from ground groats vs. whole oat justifies the additional resources required to remove hulls and grind into wholemeal to obtain the more accurate ground groat predictions.

The apparently poor result for the TDF model may be due to low precision and accuracy associated with the analysis of reference material for TDF, suggesting further development is necessary before this technique could be used in selection of high TDF cultivars.

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