NOTE

Prediction of Wheat Kernel Texture in Whole Grains by Near-Infrared Transmittance[1]

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Wheat kernel texture (degree of hardness and softness) is an important factor affecting wheat flour functionality. It exerts a significant influence on the yield of flour and on flour-damaged starch incurred during milling, which in turn governs parameters such as water absorption and gas production (Williams 1967). Methods for measuring wheat kernel texture are legion and date back to 1896, when Cobb first assigned a numerical value to the hardness of Australian wheats. All the methods currently in use are destructive in that they involve some form of measurement of either the resistance of the kernel to breakage or the granularity of the meal resulting from grinding. The most important methods were summarized by Obuchowski and Bushuk (1980), Yamazaki and Donelson (1983), and, more recently, by Pomeranz and Williams (1990).

The Tecator Company (Hoganas, Sweden) recently introduced a new type of near-infrared transmittance (NIT) instrument for determining protein and moisture in cereal grains. The instrument (Infratec) operates in the near-visible range of 850–1,050 nm, using a monochromator. It uses partial least-squares regression to compute calibration and composition parameters. Several workers (e.g., Saurer 1978, Miller et al 1982) have shown that wheat kernel texture can be predicted effectively by near-infrared reflectance (NIR) of ground material. This communication describes the results of application of the Infratec to the nondestructive prediction of wheat kernel texture using NIT.

MATERIALS AND METHODS

The work was done with two Infratec model 1225 instruments with "flow-through" sample access. Four series of wheats were assembled, representing a calibration and prediction series for each instrument. The samples included wheats from Canada, the United States, Australia, the West Asia-North Africa region, Europe, and Latin America. Earlier work by Meppelink (1974) showed that the grinding-sieving (particle size index, or PSI) method was the most highly correlated of all hardness testing methods to flour functionality. Williams and co-workers (1987) showed that a PSI test based on wheat ground in a Udy Cyclone grinder gave results more closely correlated with flour starch damage, water absorption, and gassing power than PSI data originating from samples ground in a burr mill. Accordingly, the PSI test, using a Cyclone grinder, was used as the reference method for this work.

The Udy Cyclone grinder was fitted with a feed-rate regulator. Sample size was 22 g. After careful mixing, duplicate 10-g samples of whole meal were sieved for 10 min over stainless steel, round, 200-mesh (75 μm) sieves on a Ro-Tap sieve-shaker. Six 3/4-in. plastic cubes were placed on each sieve during sieving to prevent clogging of the sieves. The PSI is equal to the weight of throughs multiplied by 10.

The moisture level of all wheats ranged from 11.5 to 13.0% before grinding, using Approved Method 44-18 of the American Association of Cereal Chemists (1983). The Infratec performs tests on whole grain, so the moisture level will have less impact on the results than is the case with test methods that involve grinding. However, we used a narrow moisture range to minimize errors in the reference PSI testing. Sample size was about 500 g, but the sample did not need to be weighed into the instrument.

The Infratec was programmed to use 10 subsamples per reading, using a 25-mm path length. Earlier work using a check sample of hard red spring wheat showed that five subsamples were insufficient and resulted in poor reproducibility. The samples were subdivided into independent calibration and prediction sets for two Infratecs on the basis of the PSI results. Table I summarizes the makeup of the respective sample sets. Samples from all sources were used in the four sample sets.

Calibrations were set up using the instruments' internal microprocessor and autocalibration software programs. First, both machines were calibrated over a period of about three months. Next, the calibration developed for the first machine was transferred to the second machine by transferring the floppy disk that carried the calibration. Four sets of data are reported. Kernel texture was predicted in samples of both prediction sets by calibrations developed for each of the two instruments. Then, both prediction sets were analyzed on the second instrument, using the calibration developed for the first, to illustrate calibration transferability.

In both series of calibration and prediction sets, samples were distributed uniformly across the range of PSI values to eliminate the possibility of "dumb-bell" distribution of prediction results. All results were single determinations, which is the system used in "real-world" application by grain elevator operators. Each sample of the prediction sample sets was analyzed individually on the respective machines using the respective calibrations. The results for each set were then analyzed statistically (the samples were not preread as a block and analyzed subsequently).

The Tecator model 1225 can accommodate a smaller sample using a sample transport mechanism. The sample cell holds about 50 g, which again does not require weighing. A calibration was set up on instrument 2, with the same calibration and prediction sample sets as those used for calibration 2 with large samples. The small-cell calibration used 11 factors.

Precision of the instruments was determined by periodic readings of two check samples (hard red and soft white spring wheats) over the test period.

RESULTS AND DISCUSSION

Table II illustrates the precision of the two instruments using individual calibrations.

Reproducibility of the NIT method of predicting wheat kernel texture was equal or superior to that of the reference (PSI) method, and superior to the near-infrared reflectance (NIR) method for PSI prediction. Two reasons for this are apparent. First, the sample size for NIT testing was about 500 g, which is 20 times larger than that of the reference and NIR methods, so the sampling error was reduced. Second, the reference method included grinding error, which is eliminated by NIT testing.

Table III summarizes the accuracy of the NIT method, and Table IV summarizes the results of measuring wheat kernel texture with the Tecator Infratec model 1225 using the small sample cell. Precision data are also included.

An earlier collaborative exercise, which involved 21 laboratories in North America and Australia, showed that all laboratories

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TABLE I
Calibration and Prediction Sample Sets Used in Determination of Wheat Kernel Texture by Near-Infrared Transmittance

	Calibration I			Calibration II			Prediction I			Prediction II		
Wheat Type	n	High	Low	n	High	Low	n	High	Low	n	High	Low
Durum	6	42	36	5	46	37	2	43	38	2	42	36
Hard spring	12	57	50	13	56	49	6	57	52	6	56	52
Hard winter	13	65	56	13	62	55	5	64	56	6	63	57
Soft spring	12	70	65	11	71	64	6	70	65	6	69	65
Soft winter	12	76	65	13	75	66	6	76	65	7	74	66
White club	2	73	71	2	70	68	1	72	72	1	70	70
Total	57	76	36	57	75	37	26	76	38	28	74	36
Mean		60.7			60.1			60.3			59.6	
SD		11.3			11.8			11.1			12.5	
Factors[a]		10			10							

[a] Number of factors used in development of calibration.

TABLE II
Precision of Near-Infrared Transmittance (NIT) Instruments for Predicton of Wheat Kernel Texture[a]

Wheat Type	Method	Standard Deviation per Test	Coefficient of Variation (%)
Hard red spring	NIT	0.76	1.4
	PSI[b]	1.31	2.7
	NIR[c]	1.70	3.3
Soft white spring	NIT	1.62	2.3
	PSI	1.44	2.1
	NIR	2.11	3.0

[a] n = 27 determinations.
[b] Particle size index (grinding-sieving), used for reference.
[c] Near infrared reflectance (filter instrument) PSI included for comparison.

TABLE III
Prediction of Wheat Kernel Texture by Near-Infrared Transmittance (NIT)

	Calibration 1[a] Instrument 1	Calibration 2[a] Instrument 2	Calibration 1[b] Instrument 2	
Parameter	Prediction 1	Prediction 2	Prediction 1	Prediction 2
r[c]	0.96	0.96	0.95	0.96
b	1.009	0.915	1.043	1.012
a	0.88	0.91	1.53	0.94
SEP	3.37	3.38	3.47	3.39
Mean PSI	57.10	56.10	57.10	56.10
Mean NIT	57.80	57.30	57.30	57.20

[a] The analysis was made on the same instrument for which the calibration was developed. Prediction samples were analyzed individually on that calibration.
[b] The analysis was made on instrument 2, using a calibration developed for instrument 1 and transferred to instrument 2. Both prediction sample sets were analyzed.
[c] r = coefficient of correlation, b = slope, a = bias, SEP = standard deviation of differences between reference particle size index (PSI) and NIT results.

could arrive at a similar classification of wheats on the basis of kernel texture by using NIR discrete filter instruments (Williams and Sobering 1986). In that study, the average coefficient of correlation among collaborators was 0.977, and the average standard error of prediction (SEP) was 2.67. The standard deviation of reference data (sieved Cyclone-ground PSI) was 10.78. The RPD, which is the standard deviation of reference data divided by the SEP (Williams 1987) is an indication of the efficiency of a calibration. In the 1987 NIR study, the average RPD was 4.02. In the present NIT study, the average RPD was 3.43 for calibrations involving large samples and 3.80 for the small sample cell.

Another method of evaluating calibrations, proposed by Starr et al (1981), is dividing the range in reference (RER) data by the SEP. Using this criterion, the 1986 NIR study (Williams and Sobering 1986) had an overall RER of 13.6, whereas the present NIT large-sample calibrations had an average RER of 11.7. The

TABLE IV
Measurement of Wheat Kernel Texture by Near-Infrared Transmittance Using Small Sample Cell

	Reproducibility		
Parameter[a]	HRS[b]	SWW[b]	Accuracy
SE per test	0.76	1.44	...
CV	1.73	2.15	...
n	15	15	...
r	...	...	0.960
b	...	...	1.150
a	...	...	1.050
SEP	...	...	3.290

[a] SE = standard error, CV = coefficient of variation, SEP = standard error of prediction.
[b] HRS = hard red spring wheat, SWW = soft white winter wheat.

small sample cell had an RER of 11.6. Both the 1986 NIR and the present NIT studies used Cyclone-ground PSI as the reference method for measuring wheat kernel texture, and some of the samples were common to both experiments.

The present investigation has shown that an NIT instrument is capable of predicting wheat kernel texture with precision equal to that of the reference (PSI) method and that it is slightly superior to the NIR method. The method differentiated successfully between wheats of different hardness, and it would be very valuable in breeding programs because it is nondestructive. The small cell holds about 50 g of wheat and would be more appropriate for use in wheat breeding than the standard Infratec model 1225 because of the small sample size.

As with most methods of measuring wheat hardness, overlap occurs between hard spring and winter wheat types and between soft spring and winter wheat types. Nevertheless, the NIT method distinguishes clearly between hard and soft common wheats with no overlap. It would also be useful when commercial wheat shipments are received to identify wheats of different texture.

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