Preliminary Observations on the Determination of Wheat Strength by Near-Infrared Reflectance[1]

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Cereal Chem. 65(2):109–114

ABSTRACT

Samples of hard (mainly red spring), medium strength-medium hard, and soft wheats were assembled to give three series, each with a minimum range in protein content and hardness but maximum range in strength, as measured by simple screening tests, physical dough testing, and baking where applicable. Calibrations were developed using a Pacific Scientific Research Composition Analyzer model 6250 to predict the various strength parameters. Results for prediction of farinograph absorption and stability and for remix loaf volume were excellent in hard wheats. Farinograph stability was highly predictable in medium strength-medium hard wheats, in which the Pelshenke wheat meal fermentation time and sodium dodecyl sulfate sediment volumes were also predictable, with sufficient accuracy for use in breeding programs. In soft wheats, alveograph *W* was predictable and had higher accuracy than farinograph stability. Both protein and oil bands were prominent in the development of calibrations for most of the strength parameters. The interrelationship between protein and oil in their respective contributions to strength parameters in wheat is discussed.

The most important factors necessary to categorize wheats for end-product potential are kernel hardness, kernel size and color, protein content, and protein strength. Of these, protein and/or flour strength remains the most enigmatic, and despite nearly a century of extensive and elegant research, the tests of most value to a breeding program are the wheat meal fermentation time (WMFT) test (Pelshenke 1930) and the sodium dodecyl sulfate (SDS) sedimentation test (Axford et al 1978), which is based on the Zeleny sedimentation test (Zeleny 1947).

Wheat, flour, or gluten strength has traditionally been associated with hardness. In general, harder wheats tend to be stronger, although this generalization is by no means inviolate. "Strength," in terms of bread quality, is a function of gas production and retention. Gas production is affected by damaged starch, which is produced during milling of flour, and the activities of amylases and yeast enzyme activity. Because of the additional work involved in grinding hard wheat, more starch damage is produced during milling hard than soft wheat. The retention of gas is a function of the gluten matrix developed during mixing and fermentation and is affected mainly by the hydration and oxidation status of the flour. Strength is also strongly influenced by protein content, but wheat genotypes differ widely as to the inherent properties of their gluten proteins. It is best evaluated by a baking test, although there is a significant interaction between individual flours and the baking method used. In terms of raised breads, loaf volume is the most important parameter, but appearance and crumb texture also contribute to the assessment of strength. Other methods of strength measurement include physical dough-testing instruments such as the Brabender Farinograph and Chopin Alveograph. Farinograph development time, stability, and mixing tolerance, alveograph "*W*," peak height, and length are all recognized strength parameters. The Brabender Extensograph, the National Manufacturing Corporation mixograph, and the Simon extensimeter are also used to measure wheat (flour, gluten) strength. Baking and physical dough testing require relatively large amounts of flour, and for this reason in breeding programs these tests are of necessity applicable mainly to later generation (F_6 and upwards) material. Also, some segregation involving many of the factors contributing toward strength continues during early generations, although tests such as the SDS sedimentation test may provide valuable guidelines to the breeders as to the potential strength of a genotype. Near-infrared reflectance (NIR) technology has been in routine use in North America for about 12 years for the determination of protein and moisture contents in wheat. The technique has also been applied to the determination of wheat hardness (Saurer 1978, Bruinsma and Rubenthaler 1978, Williams 1979, Williams and Sobering 1986). This communication describes the application of NIR to testing directly for strength in wheat, in an attempt to achieve a simple, early-generation screening for use in breeding programs.

MATERIALS AND METHODS

Because strength is affected by both protein content and kernel hardness, it is important that both of these variables are minimized in any study of strength. Three series of wheats were assembled. These included hard, medium hard, and soft wheats. The samples in each individual series were selected for the maximum range in strength parameters and the minimum range in both protein content and hardness. The hard wheats were all western Canadian hard red spring (HRS) commercial wheats submitted from country and terminal elevators, and breeders' advanced genotypes. The soft wheat series contained Canadian eastern soft white winter (SWW),

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western soft white spring (SWS), and Canada prairie spring (CPS) wheats. The medium hardness, medium strength series consisted of material from the bread wheat breeding program at the International Center for Agricultural Research in the Dry Areas (ICARDA). The ICARDA Cereal Quality Nursery is located in 10 sites throughout the Middle East and North Africa every season. It is used to establish the stability of quality parameters in advanced wheat lines and annually generates material with a wide range of protein content and other characteristics. For the present study, only the medium hard wheats were used from this material. The protein range of all three series was limited to about 3% for wavelength selection and calibration, and the individual series had very low ranges in hardness. On the other hand, individual samples within each series were selected for maximum range in strength in terms of farinograph stability and other factors. The quality characteristics of the wheats used are given in Tables I–III. Each series of wheats was divided into two subseries, one for calibration, the other for prediction of strength parameters.

Test Procedures

Tests common to all three series. For all three series, farinograph analyses were performed according to method 54-21 of the AACC (1983), using a 50-g bowl and constant flour weight. Farinograph stability is the time in minutes between the arrival of the curve at and the departure of the curve from the 500 Brabender unit (BU) line. Farinograph mixing tolerance was taken as the difference between the center of the curve and the 500 BU line, measured 15 min after commencement of the test. Hardness was determined by a standardized grinding/sieving test (Williams and Sobering 1986). A KT-3303 burr mill set at its finest setting was used to grind the samples. Moisture content of samples for all three series was in the 10–12% range. For the NIR strength studies, a Pacific Scientific Research Composition Analyzer (RCA) model 6250 was used. Wavelengths were searched using log $1/R$, and first derivative and second derivative of log $1/R$. The sizes of the derivatives were optimized and further studied using the quotient algorithm (Norris and Williams 1985).

Hard red spring wheats. Extensigraph analyses were performed according to AACC method 54-10 (1983). Alveographs were carried out in HRS and SWS wheats according to ICC method 121 (ICC 1980), using the Chopin model MA82 instrument. Alveograph W value, expressed in ergs, was calculated from the area under the curve. Protein was determined in HRS and SWS wheats by a Dickey-john Instalab 800 NIR instrument, using the Grain Research Laboratory (GRL) universal constants. Bread was baked from HRS wheats by the GRL remix method (Irvine and McMullan 1960).

Soft white spring wheats. Alkaline water retention capacity (AWRC) was determined on laboratory-milled flours by the procedure described by Yamazaki (1953). Cookies were baked according to the AACC standard procedure (method 10-50D).

Medium hard wheats. All laboratory standard tests on these wheats were carried out at the cereal quality laboratories of ICARDA, Tel Hadya, Syria. Flours were milled using a Buhler model MLU 202 laboratory flour mill. Protein content was determined by means of a Pacific Scientific Feed Quality Analyzer, model FQA 51A. Wheat meal fermentation time tests were performed according to AACC method 56-50 (1983). The SDS sedimentation tests were performed as described by Axford et al (1982) on the "flour" obtained by sieving Udy cyclone-ground wheat (1.0-mm screen) through a 100-mesh (149-μm) sieve for 2 min.

For the reconstitution work, a sample of commercially milled Canadian HRS straight run bakers' flour was used. Oil was extracted using hexane, anhydrous ether, 50:50 ethanol/ether, and dry or water-saturated n-butanol from 100-g amounts of a

TABLE I
Quality Parameters of Hard Red Spring Wheat "Strength" Samples

Parameter	Series[a]	Mean	CV%[b]	High	Low
Farinograph absorption, %	Calibration	63.4	1.8	65.9	61.3
	Prediction	63.0	2.9	65.1	56.4
Farinograph stability, min	Calibration	10.7	54.5	30.0	3.8
	Prediction	10.9	59.4	28.5	4.5
Baking absorption, %	Calibration	63.9	2.4	68.0	61.0
	Prediction	63.4	3.8	67.0	56.0
Remix loaf volume cm^3	Calibration	917	11.4	1,100	570
	Prediction	900	11.7	1,070	735
Protein, %	Calibration	14.8	7.1	15.5	13.0
	Prediction	14.8	9.7	15.7	12.1

[a]Calibration series included 66 samples, prediction series 26 samples.
[b]Coefficient of variation.

TABLE II
Quality Parameters of Medium Hardness Wheat "Strength" Samples

Parameter	Series[a]	Mean	CV%[b]	High	Low
Farinograph stability, min	Calibration	8.2	56.7	26.7	1.6
	Prediction	9.6	51.2	20.0	3.5
Farinograph mixing tolerance, BU[c]	Calibration	55	52.2	135	5
	Prediction	57	59.6	145	30
Wheat meal fermentation time, min	Calibration	126	53.8	254	56
	Prediction	106	61.5	212	59
Sodium dodecyl sulfate sedimentation, cm^3	Calibration	64	21.4	78	47
	Prediction	57	16.9	71	35
Protein, %	Calibration	13.6	9.1	14.8	13.0
	Prediction	13.6	8.3	15.1	12.0

[a]Calibration series included 36 samples, prediction series 11 samples.
[b]Coefficient of variation.
[c]Brabender units.

TABLE III
Quality Parameters of Soft White Spring Wheat "Strength" Samples

Parameter	Series[a]	Mean	CV%[b]	High	Low
Farinograph stability, min	Calibration	2.4	42	7.5	0.8
	Prediction	3.0	58	6.1	0.9
Alveograph W, ergs	Calibration	107	53	252	44
	Prediction	132	61	292	47
Alveograph P, mm	Calibration	29	38	59	19
	Prediction	31	40	56	20
Alveograph L, mm	Calibration	176	24	268	101
	Prediction	194	22	258	132
AWRC,[c] %	Calibration	79	10	99	63
	Prediction	78	7	86	66
Protein, %	Calibration	13.0	5	13.9	11.8
	Prediction	12.4	10	15.1	10.6
Cookie spread, mm	Calibration	77.8	4	84.5	72.3
	Prediction	77.8	3	80.4	73.0

[a]Calibration series included 35 samples, prediction series 15 samples.
[b]Coefficient of variation.
[c]AWRC = alkaline water retention capacity.

TABLE IV
Accuracy of Prediction of Strength in Hard Red Spring Wheat by Near-Infrared Reflectance

Parameter	SEP[a]	$\bar{d}$[b]	r[c]
Farinograph stability	3.3	0.2	0.86
Extensigraph area	29	0.3	0.81
Alveograph W	17	0.1	0.83
Remix loaf volume	30.0	0.4	0.94
Protein	0.2	−0.07	0.99
Farinograph absorption	0.65	0.14	0.73
Baking absorption (remix)	0.88	−0.03	0.87

[a]SEP = standard error of performance = standard deviation of differences.
[b]$\bar{d}$ = Mean difference.
[c]r = Coefficient of correlation between near-infrared reflectance and reference analyses.

TABLE V
Primary Wavelength Points (nm) Used in Near-Infrared Reflectance Prediction of Strength in Hard Red Spring Wheat and Associated Constituents[a]

Parameter	λ_1	λ_2	λ_3	λ_4
Farinograph stability	2,038 (protein***)[b,c]	1,714 (oil***)	1,610	1,990 (protein)
Extensigraph area	1,732 (oil***)	2,428 (protein*)		
Alveograph *W*	1,552 (protein*)	1,900	1,348 (protein)	
Remix loaf volume	1,782 (oil**)	2,324 (oil***)	2,034 (protein***)	
Protein	2,144 (protein***)	2,416 (protein*, oil*)		
Farinograph absorption	2,044 (protein***)			
Baking absorption (remix)	1,938 (water****)	2,048 (protein***)		

[a] Algorithm used was first derivative of log $1/R$, segment 10 nm, derivative 30 nm.
[b] **** Extra strong, *** very strong, ** strong, * fair, no asterisk = weak intensity of absorbances.
[c] "2,038 (protein***)" indicates that the primary wavelength point selected was 2,038 nm. This band occurs in the same region as a very strong absorber for protein. Similarly, the 1,714 nm point is associated with a very strong absorber for oil, the 1,610 nm point is not associated with absorbers for any of the more common constituents of wheat or flour, and the 1,990 band is associated with a weak protein band.

TABLE VI
Accuracy of Prediction of Strength in Medium Hardness Wheat by Near-Infrared Reflectance

Parameter	SEP[a]	$\bar{d}$[b]	r[c]
Farinograph stability	2.6	−0.03	0.86
Farinograph mixing tolerance	23.0	0.40	0.78
WMFT[d] (Pelshenke)	31	0.1	0.70
SDS[e] sedimentation volume	5.6	0.1	0.75
Protein	0.23	−0.1	0.99

[a] SEP = standard error of performance = standard deviation of differences.
[b] $\bar{d}$ = Mean difference.
[c] r = Coefficient of correlation between near-infrared reflectance and reference analyses.
[d] Wheat meal fermentation time.
[e] Sodium dodecyl sulfate.

commercially milled HRS flour by trituration and decantation until the extracts were completely clear. The amount of oil extracted was determined gravimetrically after evaporation of the solvents. Flours were placed on open trays in a fume chamber for removal of the solvents. In the case of the dry and water-saturated *n*-butanol extracts, the solvents were removed from both oil and flour in a rotary evaporator. For reconstitution, the individual oils were all dissolved in an excess of anhydrous ether. All oils dissolved completely. Using a large excess of ether as a solvent and dispersant, the extracted flours were saturated with the solutions of the oils that had been extracted by the respective solvents. The slurries of flour in ether were mixed very thoroughly, and the ether removed by evaporation in a fume chamber. They were again thoroughly mixed after removal of the ether in an attempt to ensure complete dispersion of the oil in the flour. "Treated" flours were simply saturated with the respective solvents, mixed thoroughly, and the solvent removed as described above. Saturation of treated flours was assessed by the appearance of small droplets of the solvent at the surface of the treated flours after the flour-solvent "doughs" were allowed to stand for a few minutes.

Gluten was prepared from the solvent-extracted flours as follows: 100 g of flour was mixed in the GRL mixer to a soft dough using 0.5% sodium chloride solution at a "water" absorption of 70%. The dough was then flooded with a further volume of salt solution and mixed until aggregations of gluten appeared. The gluten mass was separated on a 100-mesh stainless steel sieve, and residual starch was removed by washing with tap water. The gluten was dispersed in 0.05*M* acetic acid, and centrifuged at about 5,000 *g*. The gluten was precipitated from the supernatant with saturated calcium hydroxide solution, removed on the stainless steel sieve, redispersed in 0.05*M* acetic acid solution, and recentrifuged. The gluten was finally precipitated with saturated $Ca(OH)_2$ solution, washed free of $Ca(OH)_2$ using tap water, and the silvery-white, sticky gluten dried by "puffing" in a freeze-drier, without preliminary freezing. The procedure yielded glutens with up to 97% protein (N × 5.7%, dry basis). Gluten was also prepared from control unextracted flour in the same manner. It was not possible to prepare a true gluten from the water-saturated-butanol-extracted flour, because the cohesive properties of the gluten appeared to have been completely destroyed. A "gluten" powder was obtained by washing the starch and solubles from 50 g of flour enclosed in a bag made of 12XX flour silk. Washing by tap water was continued until washings were clear. The greyish-white paste remaining was freeze-dried and contained 94% protein (N × 5.7%, dry basis).

RESULTS

Hard Red Spring Wheat

The efficiency of prediction of "strength" in HRS wheat is summarized in Table IV. SEP (standard error of performance, or standard deviation of differences between NIR and standard laboratory analyses) values are quoted after slope-bias correction. All parameters were predictable with an accuracy sufficient for use in breeding programs, and excellent data were obtained for the prediction of loaf volume. The wavelengths selected for these predictions are given in Table V. Most of the wavelengths could be assigned to either protein or oil bands, with about one-third being attributable to oil bands. The influence of the oil component was particularly apparent in the prediction of loaf volume. Baking absorption was predictable with a coefficient of correlation of 0.87, using water and protein bands. Farinograph absorption was not so well predicted ($r = 0.73$), but the same bands were evident.

Medium Hardness-Medium Strength Wheat

These wheats were identified from the bread wheat breeding program of ICARDA, where baking quality is evaluated by the baking of Arabic two-layered flat bread. The Brabender farinograph is used to assess physico-chemical characteristics. Earlier studies (Williams et al 1985) established that farinograph stability and mixing tolerance are the parameters most closely related to dough strength, as judged by handling properties at dividing and sheeting. The same study established that the Pelshenke WMFT test gives a better indication of dough strength than the SDS sedimentation test, due to the wide ranges in protein content and particle size index (kernel hardness) of the genetic material. The relationships of the WMFT test to farinograph stability and mixing tolerance were expressed in terms of coefficients of correlation of about 0.82 and 0.76, respectively. In the present study, the NIR instrument was able to predict farinograph stability and mixing tolerance with higher coefficients of correlation than the WMFT test and was able to predict both WMFT and SDS sedimentation well enough for use in early generation testing. These data are summarized in Table VI. Again, the oil bands were prominent in the prediction of physico-chemical parameters, WMFT, and SDS sediment volume (Table VII). The supporting wavelength for WMFT prediction was a starch band, and neither of the two wavelengths used in WMFT prediction were attributable to protein.

Soft Wheat

Soft wheats are not used for baking breads, and when they are used in baking products traditionally associated with soft wheats

TABLE VII
Primary Wavelength Points (nm) Used in Near-Infrared Reflectance Prediction of Strength in Medium Hardness Wheat and Associated Constituents[a]

Parameter	λ_1	λ_2	λ_3
Farinograph stability	2,050 (protein***)[b,c]	2,290 (oil****)	2,378 (oil*)
Farinograph mixing tolerance	1,204 (oil**)/ 2,364 (oil*** or protein**)		
WMFT[d] (Pelshenke)	1,718 (oil***)	2,442 (starch*)	
SDS[c] sedimentation volume	1,206 (oil*)	2,220 (protein***)	
Protein	2,126 (protein**)	1,550 (protein*)	1,668 (protein***)

[a] Algorithm used was first derivative of log $1/R$, segment 10 nm, derivative 30 nm.
[b] **** Extra strong, *** very strong, ** strong, * fair, no asterisk = weak intensity of absorbances.
[c] As for Table V.
[d] Wheat meal fermentation time.

TABLE VIII
Accuracy of Prediction of Strength in Soft Wheat by Near-Infrared Reflectance

Parameter	SEP[a]	$\bar{d}$[b]	r[c]
Farinograph stability	1.1	0.1	0.79
Alveograph *W*	21	0.7	0.89
Alveograph *P*	4.4	−0.2	0.77
Alveograph *L*	12	0.1	0.77
AWRC[d]	0.4	0.1	0.84
Protein	0.15	0.1	0.98
Cookie spread	2.1	0.1	0.43

[a] SEP = standard error of performance = standard deviation of differences.
[b] $\bar{d}$ = Mean difference.
[c] r = Coefficient of correlation between near-infrared reflectance and reference analyses.
[d] Alkaline water retention capacity.

TABLE IX
Primary Wavelength Points Used in Near-Infrared Reflectance Prediction of Strength in Soft Wheats and Associated Constituents[a]

Parameter	λ_1	λ_2
Farinograph stability	2,178 (protein***)[b,c]	1,690 (protein***)
Alveograph *W*	2,432 (oil*, protein*)	1,184 (protein***)
Alveograph *P*	2,244 (protein**, oil*)	1,188 (protein***)
Alveograph *L*	1,762 (oil**)/ 1,588 (protein*)	
AWRC[d]	1,668 (protein***)/ 2,282 (starch***)	
Protein	1,666 (protein***)	2,228 (protein***)
Cookie spread	2,264 (protein**)	2,342 (oil***)

[a] Algorithm used was first derivative of log $1/R$, segment 10 nm, derivative 30 nm.
[b] **** Extra strong, *** very strong, ** strong, * fair, no asterisk = weak intensity of absorbances.
[c] As for Table V.
[d] Alkaline water retention capacity.

(cakes and cookies) the flour constitutes only about 30% of the final formula mix. The NIR method predicted alveograph *W* better than farinograph stability, and the coefficient of correlation between NIR data and farinograph stability was similar to those for alveograph *P* and *L* values (Table VIII). The alveograph was originally developed for evaluation of soft wheats. The variance in the alveograph *W* was considerably higher than the farinograph stability for the soft wheats, and partly as a result of this, the statistics favored the prediction of alveograph *W*. Oil bands were also associated with wavelengths used in prediction of alveograph parameters (Table IX). AWRC values of western Canadian SWS wheats tend to be much higher than those reported in the literature for soft winter wheats. This is attributable mainly to higher starch damage. The NIR method predicted AWRC well enough for use in a breeding program. Cookie spread was not predictable by NIR in the series of wheats and flours studied.

DISCUSSION

"Strength" in wheat is more accurately described as "functionality," or end-product utilization potential. In HRS, medium hard-medium strength, and soft wheats, the NIR technique appeared to be capable of predicting most of the important parameters used to assess functionality with an accuracy satisfactory for use in a grading-pricing system or in breeding programs. The selection of oil bands in addition to protein bands for calibration, together with the fact that the samples within a class contained a minimum range in protein, supported the observation that the NIR technique was predicting functionality parameters independent of protein content. Grosskreutz (1962) postulated the existence of a lipoprotein model for gluten, whereas other studies summarized by Mecham (1978) demonstrated that the presence of lipids is essential for optimum baking performance. An earlier study in this laboratory showed that removal of lipids with solvents differing in polarity caused a progressive reduction in remix loaf volume that could be partially recovered by reincorporation of the lipids. The exception was extraction by water-saturated *n*-butanol, where loaf volume was reduced almost to the volume of the ingredients themselves and could not be improved by reconstitution. Crumb texture was also affected by extraction with all solvents. The results are summarized in Table X. The data indicate that the significant reductions in loaf volume were not caused by reductions in gassing power or water absorption. Although both were reduced when the solvent used was water-saturated butanol, both the gassing power and water absorption were adequate for the production of a loaf with a volume of at least 600–700 cm^3.

The reduction in loaf volume and texture due to removal of the lipids verifies the importance of naturally occurring lipids to baking performance. We suggest the possibility of a continuous matrix present in dough, involving protein, lipid, and water molecules. Figure 1 illustrates the NIR spectrum of gluten prepared from control and extracted HRS flours. The lipid band at 2,306 nm, prominent in the gluten prepared from unextracted flour, is reduced in the gluten prepared from flour that was extracted with ether and not noticeable at all in the gluten prepared from flour extracted with water-saturated *n*-butanol. This is illustrated more clearly in Figure 2, which is a close-up of the spectra in the region of 2,306 nm.

Removal of oil by less polar solvents such as hexane and anhydrous ether may disrupt the protein-lipid-water hydrogen-bonded structure throughout the dough, which could be partially but not completely reestablished by reconstitution with extracted lipids. This would account for the reduction in loaf volume of reconstituted flours relative to the control. Removal of lipids by water-saturated *n*-butanol may dislodge the lipid molecules from within the actual gluten molecules, thereby causing extensive disruption of the native gluten molecules that cannot be reestablished by reconstitution. As a result, the functionality of the gluten is seriously impaired, which in turn would account for the dramatic reduction in loaf volume.

It is essential to consider flour and dough as an entity rather than as an association of individual components. Dough, and particularly fermenting dough, is a living, dynamic system; a gas retention matrix formed by an association involving protein, lipid, and water would explain the changes in functionality of doughs as

TABLE X
Baking Performance, Gassing Power (GP), and Water Absorption of Oil-Extracted and Reconstituted Flours

Solvent	% Oil Extracted	Loaf Volume[a] (cm^3)		GP (mm Hg, 6 hr)		Baking Absorption (remix) %	
		Extracted	Reconstituted	Extracted	Reconstituted	Extracted	Reconstituted
Hexane	0.88	790	820	450	439	60	62
Ether	1.02	770	820	465	444	62	61
Alcohol/ether	1.23	720	830	442	424	60	62
Dry *n*-butanol	1.20	720	840	419	401	61	61
Water-saturated *n*-butanol	2.15	260	240	437	378	56	56
Control	...	920[b]	920[b]	478[b]	...	61[b]	...

[a]GRL remix method.
[b]Lipids not extracted.

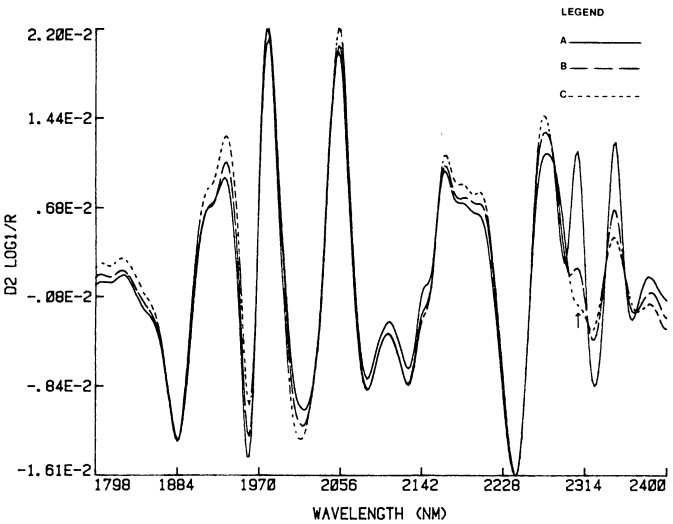

Fig. 1. Second derivative of log $1/R$ freeze-dried wheat glutens. Segment = 10, derivative (gap) = 10 nm. Legend: gluten prepared from —— unextracted, ----- water-saturated *n*-butanol extracted, and — — ether-extracted hard red spring flour.

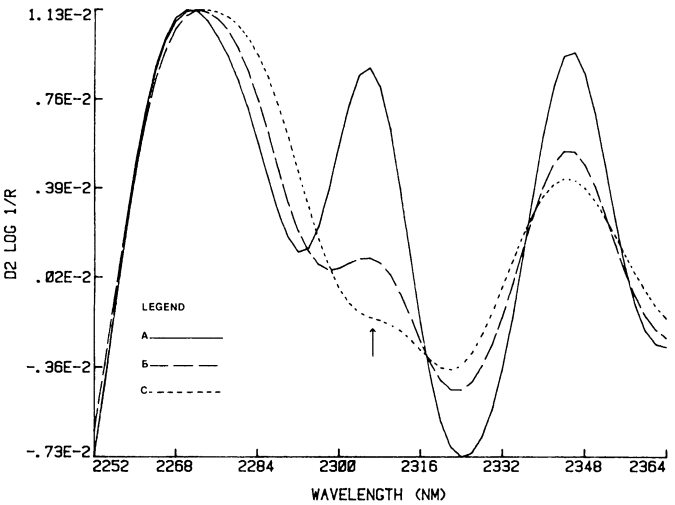

Fig. 2. Expanded spectra of second derivative of log $1/R$ freeze-dried wheat glutens in the 2,250–2,360 nm region.

a result of oxidation by oxygen and oxidizing agents and also explain the influences of agents that affect hydration and water activity, such as sodium chloride.

Although tests such as the WMFT and SDS sedimentation tests, and physico-chemical methods such as the farinograph provide valuable information about the end-product potential of a flour, they do not test all parameters of a dough and especially not of a fermenting dough. Only a baking test specific to the desired end product can realize the true value of the flour. In view of the high correlations between NIR optical signals and characteristics such as loaf volume, farinograph and alveograph characteristics, and also of its capabilities in the determination of protein and kernel hardness, it appears that an NIR evaluation may serve as a more valuable early generation prediction of the overall end-product potential of a wheat than either the WMFT or SDS sedimentation tests, as well as offering the potential for development of new concepts in wheat grading and pricing. The NIR technique using a computerized spectrophotometer also offers interesting possibilities in qualitative basic research. In studies such as the one described, association of computer-selected wavelengths with oil, cellulose, protein, water, and other components may serve as valuable indicators of the structure and behavior of complex materials, of which a fermenting dough is a classical example.

ACKNOWLEDGMENTS

The authors acknowledge the competent technical assistance of L. Minty and I. Phillips in the physical dough testing of the hard and soft wheat series, and E. Mydlo in the baking of the hard wheat flours. Cookie baking and AWRC tests of soft wheat flours were carried out by H. M. Cordeiro. Finally, the painstaking work of Fred Kuzina in preparation of the dried glutens is deeply appreciated.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. Method 10-50D, revised October 1984; Methods 54-10, 54-21, and 56-50, approved April 1961. The Association: St. Paul, MN.

AXFORD, D. W. E., McDERMOTT, E. E., and REDMAN, D. G. 1978. Small-scale tests of bread-making quality. Mill. Feeds Fert. 66(5):18.

AXFORD, D. W. E., McDERMOTT, E. E., and REDMAN, D. G. 1982. Note on the sodium dodecyl sulfate test of breadmaking quality: Comparison with Pelshenke and Zeleny tests. Cereal Chem. 56:582.

BRUINSMA, B. L., and RUBENTHALER, G. L. 1978. Estimation of lysine and texture in cereals by NIR. Crop Sci. 18:1039.

GROSSKREUTZ, J. C. 1961. A lipoprotein model of wheat gluten structure. Cereal Chem. 38:336.

INTERNATIONAL ASSOCIATION FOR CEREAL CHEMISTRY (ICC). 1980. Method 121. The Association: Schwechat, Austria.

IRVINE, G. N., and McMULLAN, M. 1960. The "Remix" baking test. Cereal Chem. 37:603.

MECHAM, D. 1978. Lipids. Pages 430–434 in: Wheat Chemistry and Technology. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

NORRIS, K. H., and WILLIAMS, P. C. 1985. Optimization of mathematical treatments of raw near-infrared signal in the measurement of protein in hard red spring wheat. I. Influence of particle size. Cereal Chem. 61:158.

PELSHENKE, P. F. 1930. Beitrage zur Bestimmung der Bäckfahigkeit von Weizen und Weizenmehlen. Arch. Pflanzenbau 5:108.

SAURER, W. 1978. Verwendung von Infrarot-Reflexionsmessung für die Bestimmung von Protein und Wassergehalt sowie der Kornhärte in Weizen. Getreide Mehl Brot 32:272.

WILLIAMS, P. C. 1979. Screening wheat for protein and hardness by near-infrared reflectance spectroscopy. Cereal Chem. 56:169.

WILLIAMS, P. C., and SOBERING, D. C. 1986. Attempts at standardization of hardness testing in wheat. I. The grinding/sieving (Particle Size Index) method. Cereal Foods World 31:359.

WILLIAMS, P. C., SRIVASTAVA, J. P., and JABY EL-HARAMEIN, M. F. 1985. The ICARDA Cereal Quality Nursery. Tech. Rep. Int.

Center Agric. Res. Dry Areas, Aleppo, Syria, 1984.
YAMAZAKI, W. T. 1953. An alkaline water retention capacity test for the evaluation of cookie baking potentialities of soft winter wheat flours. Cereal Chem. 30:242.
ZELENY, L. 1947. A simple sedimentation test for estimating the bread-baking and gluten qualities of wheat flour. Cereal Chem. 24:465.

[Received February 19, 1987. Accepted September 17, 1987.]