Wheat Flour Dough Alveograph Characteristics Predicted by NIRSystems 6500

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Abstract

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Rheological quality of wheat dough prepared from 130 variety, stream, and commercial wheat flour samples (wheat harvest 1999, 2000 and 2001) was assessed with alveograph. Spectra of all samples were measured on spectrograph NIRSystems 6500. Calibration equations with cross and independent validation for all rheological characteristics were computed by NIR Software ISI Present WINISI II using MPLS and PLS methods. The quality of the prediction was evaluated by the coefficient of correlation between the measured and the predicted values from cross and independent validation. A statistically significant dependence between the predicted and the measured values (with probability $P < 0.01$) was determined in P (elasticity) and W (energy) characteristics in the case of cross validation only in the commercial flour sets. P (with $P < 0.01$) and W (with $P < 0.05$) were successfully predicted by independent validation in the set of all samples.

Keywords: wheat flour dough; alveograph; NIRSystems 6500; prediction of rheological characteristics

Wheat flour is able to form a cohesive dough having viscoelastic properties and possessing the ability to retain gas which is essential for the production of bakery products with a light texture. The factor responsible for the dough formation is gluten protein and its development during mixing, fermentation and handling actions has an influence on the rheological properties of dough.

Rheological characteristics such as elasticity, viscosity and extensibility are important for the milling and bakery industries in view of the prediction of the processing parameters of dough and the quality of the final products. These rheological characteristics change during the breadmaking process and are difficult to measure in definitive terms.

To predict the quality of flour and the dough of it, a number of physical, chemical, and rheological characteristics must be known. Such tests as farinograph (Shuey 1972) and extensigraph (Rasper & Preston 1991) are frequently used. The alveographic technique, originally developed in France as an empirical physical test to assess the breadmaking quality of soft wheat flours, finds currently an increasing use in many countries. Khattak *et al*. (1974) used the alveograph to evaluate HRS wheat and reported low and insignificant correlations with the loaf volume. Preston *et al*. (1987) suggested that part of the problem in assessing the quality of HRS wheat with the alveograph under the standard conditions (50% dough absorption) was related to high levels of the starch damage in flours. Weipert (1981) found considerable differences in the correlation between alveograph indices and the baking quality in German flours. Bettge *et al*. (1988) used the alveograph to evaluate the breadmaking quality of soft and hard wheat flours from the Pacific Northwest. In both types, L (dough extensibility) produced the highest correlation with the specific bread volume. At Czech mills, the alveograph belongs to the most used rheological apparatuses for the flour quality testing.

Because rheological measurements require a lot of time and equipment, a fast and reliable test is necessary. This problem can be solved by the NIR spectroscopy which is almost well established for the control of analytical properties of flour in many industrial mills. NIR was also applied for many predictions of flour rheological characteristics such as farinograph dough behaviour (Williams *et al*. 1988; Hrušková *et al*. 2001), mixograph dough parameters (Delwiche & Weaver 1994), extensigraph dough characteristics (Delwiche *et al*. 1998), and alveograph dough properties (Rubenthaler & Pomeranz 1987; Williams *et al*. 1988).

The prediction of the dough properties by NIR spectra analyses was influenced by many factors, especially errors of rheological methods and the dependence on the protein content of the flour tested. The reliability of the computed characteristics of dough varies according to the calibration sample set, the extent and quality range of flour parameters.

The main objective of this work was to predict the rheological properties of wheat flour dough as measured on alveograph by NIR spectroscopy.

MATERIAL AND METHODS

Samples. Variety flours (forty and thirty samples) were milled on an experimental Búhler mill (type MLU-202) from wheat varieties (harvest 1999 and 2001). Stream flours (thirty samples) were obtained from industrial mills (harvest 2000). Commercial flours (thirty and ten samples) also came from industrial mills (harvest 2001).

References analysis. Rheological properties of wheat flour were determined by a Chopin MA 82 alveograph (according ICC Standard 55 30-3). Each alveograph chart was analysed for four factors: P – the maximum over pressure needed to blow the dough bubble-expresses dough elasticity, L – the average abscissa at bubble rupture-expresses dough elasticity, P/L – alveograph ratio and W – the deformation energy. The variables represent the average of five curves from five dough patties (Faradi & Rasper 1987). The results of analysis were expressed by average, minimum and maximum values and by the standard deviation in each samples set.

Apparatus. Spectra were obtained by the wavelength scanning instrument NIRS 6500 (NIRSystems, Inc.) using a small ring cup. A scanning range from 400 to 2500 nm and wavelength increments of 2 nm were used. Diffuse reflectance was recorded as log 1/R. Each sample was scanned twice and the average spectra were used for calibration.

Statistics. NIR Software ISI Present WINSI II (Infrasoft Int.) was used to evaluated the data and to develop chemometric models. Scatter correction was performed by Standard Normal Variate Transformation (SNV) and then transformed with the first derivative which was calculated by treatment 1,4,4,1 and 1,8,8,1. Calibration was carried out by Modified Partial Least Square (MPLS), and Partial Least Square (PLS) regression and correlation coefficient (*r*) were determined. No samples were left out because of their higher deviations. The calibration of dough rheological properties was verified by cross validation (the number of selected segments was equal to the number of samples in each set) and independent validation (the calibration for samples – harvest 1999, 2000 and 2001 was verified by an independent ten – sample set-harvest 2001). The selection of the optimum number of PLS terms for the calibration was based on the standard error of prediction (SEP) which should be minimised. Two statistical parameters (SEP and *r*) were used to determine the calibration equation.

RESULTS AND DISCUSSION

Analytical characteristics. The quality of wheat flours from harvest 1999, 2000, and 2001 (except stream flours) corresponded to the Czech standard for mill products of fine type. The analytical ranges were from 11.5 to 12.8% for protein, from 31 to 40 ml for Zeleny sedimentation value and from 305 to 464 s for Falling Number.

Rheological characteristics. The results obtained from alveographic measurement of dough are summarised in Table 1. According to these characteristics, flours from harvest 2001 were evaluated as stronger – with higher P and W parameters. Doughs prepared from these flours did not have optimal viscoelastic behaviour as described by the higher ratio P/L.

Prediction according cross validation. Prediction of rheological properties of flours from harvest 1999 (set of forty samples), from harvest 2000 (set of thirty samples) and from harvest 2001(three sets of seventy samples) are shown in Table 2. For the calibration of alveograph characteristics, the following parameters only were found significant on 99% statistical level – in variety sets it was alveograph elasticity, and in commercial sets alveograph extensibility. No satisfactory calibration was calculated for the set of stream flours. Alveograph parameters P and P/L were computed by cross validation with sufficient accuracy only in commercial flours sets.

Table 1. Flour alveograph properties

Parameter	Range				
	average	min.	max.	S.D.	v.c. (%)
Variety flours 1999					
P (mm)	105.9	52.3	153.8	24.1	22.7
L (mm)	63.9	42.2	95.3	13.5	21.2
P/L	1.79	0.70	3.56	0.70	40.3
W (10^{-4} J)	163.1	78.6	230.2	36.8	22.6
Stream flours 2000					
P (mm)	85.2	47.8	117.1	19.5	22.9
L (mm)	55.7	23.2	104.6	15.7	28.1
P/L	1.80	0.62	6.94	1.2	65.0
W (10^{-4} J)	141.4	94.4	206.0	26.4	18.7
Commercial flours 2001					
P (mm)	102.7	51.7	136.8	22.9	22.3
L (mm)	58.4	37.5	96.9	14.3	24.4
P/L	1.98	0.94	3.62	0.80	38.5
W (10^{-4} J)	165.7	100.0	247.7	35.5	21.4
Variety flours 2001					
P (mm)	125.9	67.9	192.0	31.0	24.6
L (mm)	52.5	30.5	82.3	12.4	23.6
P/L	2.59	0.88	5.72	1.1	44.2
W (10^{-4} J)	181.1	89.8	286.5	43.0	23.8
Commercial flours 2001					
P (mm)	104.9	91.7	120.6	9.4	8.9
L (mm)	68.8	59.4	75.2	6.0	8.7
P/L	1.55	1.25	2.03	0.3	16.6
W (10^{-4} J)	181.6	166.9	202.4	11.7	6.5

P – dough elasticity, L – dough extensibility, W – deformation energy

For the calibration of alveograph characteristics, all measured parameters were found significant on 99% statistical level in the set of all samples (Table 3) but P and W were predicted successfully by cross validation.

Prediction according independent validation. The correlation coefficient *r* and standard error of independent prediction SEP for alveograph parameters are shown in Table 4. The alveograph elasticity P and energy W were independently predicted as it was found by Williams *et al*. (1988). These authors give SEP for P 31 mm, $r = 0.77$ and for W 17×10^{-4} J, $r = 0.87$. Our results were computed more accurately in the case of P (SEP 6.3 mm) and comparable for W (SEP 11.6×10^{-4}). The accuracy of NIR method predictions depends on the range of flour quality parameters used as confirmed by many works (Rubenthaler & Pomeranz 1987).

CONCLUSIONS

NIR spectroscopy was used for the screening of analytical properties of wheat and flour in mills and bakeries. In rheological properties of wheat

Table 2. Prediction of flour alveograph characteristics

Parameter	*n*	Calibration			Cross validation		
		term	SEC	*r*	segment	SEP	*r*
Variety flours 1999							
P (mm)	40	1	19.7	0.300	40	84.8	0.197
L (mm)	40	4	8.90	**0.563**	40	11.5	0.295
P/L	40	1	0.60	0.264	40	0.70	0.183
W (10^{-4} J)	40	4	27.0	**0.456**	40	34.0	0.167
				$r_{(P<0.01)}$ = **0.403**		$r_{(P<0.05)}$ = *0.312*	
Stream flours 2000							
P (mm)	30	2	15.51	*0.367*	30	16.94	0.270
L (mm)	30	2	13.81	*0.222*	30	15.57	0.044
P/L	30	1	1.17	0.005	30	1.30	0.000
W (10^{-4} J)	30	1	26.70	0.000	30	27.25	0.000
				$r_{(P<0.01)}$ = **0.464**		$r_{(P<0.05)}$ = *0.362*	
Commercial flours 2001							
P (mm)	30	4	11.74	**0.746**	30	15.78	**0.557**
L (mm)	30	3	10.12	0.514	30	13.02	0.222
P/L	30	4	0.38	**0.753**	30	0.53	**0.545**
W (10^{-4} J)	30	4	20.82	**0.668**	30	28.81	**0.574**
				$r_{(P<0.01)}$ = **0.464**		$r_{(P<0.05)}$ = *0.362*	
Variety flours 2001							
P (mm)	30	2	24.51	*0.395*	30	28.14	0.230
L (mm)	30	4	7.47	**0.648**	30	11.66	0.171
P/L	30	2	1.00	0.260	30	1.17	0.015
W (10^{-4} J)	30	3	33.21	*0.424*	30	37.40	0.294
				$r_{(P<0.01)}$ = **0.464**		$r_{(P<0.05)}$ = *0.362*	
Commercial flours 2001							
P (mm)	10	4	3.4	**0.881**	10	4.94	**0.775**
L (mm)	10	4	0.57	**0.992**	10	1.21	**0.967**
P/L	10	4	0.04	**0.973**	10	0.08	**0.916**
W (10^{-4} J)	10	1	11.94	0.069	10	12.84	0.032
				$r_{(P<0.01)}$ = **0.765**		$r_{(P<0.05)}$ = *0.632*	

P – dough elasticity, L – dough extensibility, W – deformation energy

dough, greater differences were found between measured and computed data. Farinograph water absorption, dough time development and dough stability could be predicted with comparative accuracy as reference methods. Alveograph elasticity and energy of wheat flours were successfully predicted according to the results obtained in this experiment. The NIR methods predicted alveograph energy better than farinograph stability (Hrušková *et al.* 2001; Williams *et al.* 1988). The alveograph was originally developed for the evaluation of soft wheats and it seems to be suitable for rheological testing of the majority of Czech commercial flours.

Table 3. Prediction of flour alveograph characteristics – all samples (flours 1999, 2000, 2001)

Parameter		Calibration			Cross validation		
	n	term	SEC	*r*	segment	SEP	*r*
P (mm)	130	4	20.23	**0.488**	130	21.72	**0.415**
L (mm)	130	4	12.06	**0.314**	130	12.92	*0.219*
P/L	130	3	0.86	**0.261**	130	0.91	0.178
W (10^{-4} J)	130	3	31.61	**0.324**	130	33.1	**0.263**
				$r_{(P < 0.01)}$ = **0.257**		$r_{(P < 0.05)}$ = *0.197*	

Table 4. Independent validation of calibration equations (flours 1999, 2000, 2001)

Parameter	*n*	Calibration			Independent validation		
		term	SEC	*r*	segment	SEP	*r*
P (mm)	130	4	20.23	**0.488**	10	6.33	**0.593**
L (mm)	130	4	12.06	**0.314**	10	6.69	0.027
P/L	130	3	0.86	**0.261**	10	0.27	0.091
W (10^{-4} J)	130	3	31.61	**0.324**	10	11.6	*0.205*
				$r_{(P < 0.01)}$ = **0.257**		$r_{(P < 0.05)}$ = *0.197*	

References

Bettge A., Rubenthaler G.I., Pomeranz Y. (1988): Alveograph algorithms to predict functional properties of wheat in bread and cookie baking. Cereal Chem., **66**: 81–86.

Delwiche S.R., Weaver G. (1994): Bread quality of wheat flour by NIR spectroscopy: Feasibility of modeling. J. Food Sci., **59**: 410–415.

Delwiche S.R., Graybosh R.A., Peterson C.J. (1998): Predicting protein and biological properties of HRW wheat by NIR. Cereal. Chem., **75**: 412–416.

Faradi H., Rasper V.F. (1987): The Alveograph Handbook. AACC, Inc., St. Paul, Minnesota, US: 17–22.

Hrušková M., Bednářová M., Novotný F. (2001): Wheat flour dough rheological characteristics predicted by NIRSystem 6500. Czech J. Food Sci., **19**: 213–218.

Khattak S., D'Appolonia R.H., Banasik O.J. (1974): Use of the alveograph for quality evaluation of HRS wheat. Cereal Chem., **51**: 355–351.

Preston K.R., Kilborn R.H., Dexter J.E. (1987): Effects of starch damage and water adsorption on the alveograph properties of Canadien HRS wheats. Can. Inst. Food Sci. Technol. J.**,** **20**: 75–76.

Rasper V.F., Preston K.R. (1991): The Extensigraph Handbook. AACC, Inc., St. Paul, Minnesota, US: 13–18.

Rubenthaler G.L., Pomeranz Y. (1987): NIR spectra of HRW wheat varying widely in protein content and breadmaking potential. Cereal. Chem., **64**: 407–411.

Shuey W.C. (1972): The Farinograph Handbook. AACC, Inc., St. Paul, Minnesota, US: 20–33.

Weipert P. (1981): Teigrheologische Untersuchungsmethoden und ihre Einsatzmöglichkeiten in Mühlenlaboratorium. Getreide, Mehl u. Brot, **35**: 5–9.

Williams P.C., El-Haramen F.J., Ortis-Ferira G., Srivasta J.P. (1988): Preliminary observations of the determination of wheat strength by NIR. Cereal Chem., **65**: 109–114.

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Souhrn

Hrušková M., Šmejda P. (2003): **Predikce alveografických charakteristik pšeničného těsta pomocí NIRSystems 6500.** Czech J. Food Sci., **21**: 28–33.

Reologické vlastnosti pšeničného těsta, vyrobeného ze 130 vzorků pšeničných mouk z odrůd potravinářské pšenice ze sklizně 1999 a 2001, pasážních mouk z pšenice sklizně 2000 a komerčních mouk z pšenice sklizně 2001 byly hodnoceny pomocí alveografu. Na spektrofotometru NIRSystems 6500 byla u všech vzorků naměřena NIR spektra. Pro alveografické charakteristiky byla programem NIR Software ISI Present WINISI II metodami MPLS a PLS provedena kalibrace, křížová a nezávislá validace. Kvalita předpovědi byla posuzována podle hodnot korelačního koeficientu z výsledků křížové a nezávislé validace. Statisticky významná závislost mezi předpověděnými a naměřenými hodnotami s pravděpodobností vyšší než 99 % byla zjištěna u všech sledovaných ukazatelů při kalibraci a pro parametry P a W při křížové validaci ve spojeném souboru všech vzorků. Při nezávislé validaci bylo zjištěno, že v daném souboru lze úspěšně predikovat alveografickou pružnost P (na 99% hladině významnosti) a alveografickou energii W (na 95% hladině významnosti).

Klíčová slova: pšeničné těsto; alveograf; NIRSystems 6500; predikce alveografických ukazatelů

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