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Prediction of Wheat Baking Quality Using Reomixer Analysis of Whole-grain Meal

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A 10-gram computerised mixograph-based Reomixer instrument was used to analyse eight bread wheat cultivars. The influence of flour or whole-grain meal and different hydration methods for whole-grain meal on the prediction of baking quality was studied. Using flour/whole-grain meal materials and different hydration methods, several Reomixer parameters were found to correlate with bread-making performance. Regression equations were constructed using statistically significant Reomixer parameters. Whole-grain meal Reomixer analysis under constant hydration of 75% proved to be as comparable a method for bread-making performance evaluation as flour analysis.

Keywords: wheat, bread-making quality, mixograph, Reomixer, whole-grain meal

Introduction

Wheat (*Triticum aestivum* L.), a widely grown and major crop important for the human diet, is of great economic importance. For bread-baking, high-quality wheat grain is required. Among the quality characteristics, protein content has been found to be the most important factor (Dowel et al. 2008). Nevertheless, protein content does not explain variations in bread-making quality as the quality of the protein is an important factor (Peterson et al. 1986). At the start of wheat grain-processing chains, such as grain elevators and grain receipt at mills, often only protein content, moisture, specific weight and falling number are measured. This can lead to the incorrect determination of wheat quality and economic losses. Therefore, relatively time-efficient and simple methods to evaluate wheat quality are required. Such methods are valuable for breeders as well (Dobraszczyk and Salmanovicz 2008). The mixograph is a fast tool used to measure the mixing characteristics of flour; therefore, it has the potential to fulfil these requirements (Miles et al. 2013). It has been used since Swanston et al. (1933) introduced the basic mixograph system, and its applications are very broad (Walker et al. 1998). Mixograph methodology is well-documented in AACC 54-40.02 (1999). According to this method, water addition is based on protein content. Another possibility for water addition is constant base (Dobraszczyk and Salmanovicz 2008) or addition according to farinograph absorption

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(Tronsmo et al. 2003). Unfortunately, standard mixograph evaluation requires laborious and time-consuming flour milling with a special laboratory mill. An alternative approach could be analysis using whole-grain meal (Anderson 2003). Whole-grain meal can easily be prepared using a hammer mill, which is among the standard equipment used for determining falling number (AACC method 56-81.03, 1999). This study aims to evaluate the ability of whole-grain meal rheology to predict wheat bread-making quality in comparison with flour rheology.

Materials and Methods

Grain samples of Akteur, Baletka, Caroll, Elly, Jindra, Matylda, Seladon and Sultan winter wheat varieties were obtained from trials at the Stupice testing location, Czech Republic, harvest year 2012. The trials were grown using standard farming technology for wheat. The official classification of bread-making quality of the examined wheat varieties is stated in Table 1. Basic grain (protein, moisture, gluten, Zeleny sedimentation value, hardness and specific weight), flour (protein, moisture, farinograph water absorption) and whole-grain meal (protein, moisture, farinograph water absorption) parameters were measured on an NIT Infratec1241 analyser (FOSS, Hillerød, Denmark). Whole-grain meal was milled on an LM 3100 hammer mill (Perten, Hägersten, Sweden). Flour was milled on a WWGM cylinder mill (Yucebas Makine, Izmir, Turkey). A MiniRMT test (Sedláček and Horčička 2011) was used for experimental bread-baking. A computer-driven 10-g Reomixer instrument (Reologen i Lund AB, Lund, Sweden; Fig. 1) based on the AACC Mixograph standard was used for rheological analysis. The Reomixer software allows for the determination of 14 mixing parameters describing specific characters of the mixing curve, plus three integrating parameters (Bohlin 2007). From these parameters, 10 are main and other auxiliary (Fig. 2). Water was added to flour according to the AACC 54-40.02 method. Water was added to whole-grain meal according to AACC 54-40.02, farinograph absorption and constant base 75% methods. Two replications of all experiments were performed. Statistical analysis was conducted using the Statgraphics Centurion software (Statpoint Technologies Inc., Warrenton, USA).

Results

Basic qualitative parameters

All cultivars used in this study are released commercial cultivars with a qualitative range from C (non-bread-making) to E (Elite bread-making quality). Basic grain qualitative parameters are summarised in Table 1. With the exception of specific weight, not one of the basic qualitative parameters was found to correlate with bread volume (data not shown) in a statistically significant way.

Table 1. Qualitative characteristics for grain, whole-grain meal and flour

Sample	HMW glutenin alleles			Grain						Whole-grain meal			Flour				
(classification of grain quality)	Glu A	Glu B	Glu D	Protein (%)	Moisture (%)	Gluten (%)	Zeleny sedimentation (ml)	Hardness	Specific weight ($kg.m^{-3}$)	Protein (%)	Moisture (%)	Water-absorption (%)	Yield (%)	Protein (%)	Moisture (%)	Water absorption %	Bread volume ($cm^3 .100g^{-1}$)
Akteur (E)	1	7+9	5+10	13.4	14.3	34.9	49	35	808	13.4	13.2	62.4	71.9	13.9	14.2	59.1	405
Baletka (B)	0	7+9	5+10	12.8	14.6	31.7	42	39	780	12.7	13.4	59.4	72.7	12.5	14.2	57.2	364
Caroll (C)	0	17+18	2+12	12.8	14.4	32.4	41	10	691	12.8	13.2	58.6	69.8	11.8	15	58.0	341
Elly (A)	0	6+8	5+10	13.9	14.5	36.3	53	38	785	14.0	13.2	60.9	61.9	14.1	13.6	63.6	437
Jindra (A)	1	7+9	2+12	13.3	13.6	33.9	49	39	799	13.3	12.4	60.9	61.6	13.6	13.3	60.8	413
Matylda (A)	0	6+8	5+10	13.9	14.5	36.4	53	39	781	14.0	13.5	61.1	63.4	14.0	15	63.4	375
Seladon (B)	0	7+9	2+12	12.6	14.7	30.1	34	40	757	12.6	13.8	60.7	70.1	11.9	12.6	63.1	373
Sultan (A)	0	7+8	5+10	13.3	14.3	33.8	50	33	781	13.3	13.2	60.9	66.8	13.3	13.9	59.9	392
Average	–	–	–	13.3	14.4	33.7	47	34	772.6	13.3	13.2	60.6	67.3	13.1	14	60.6	387.5
Standard deviation	–	–	–	0.49	0.34	2.17	6.46	9.98	35.10	0.54	0.42	1.14	4.49	0.94	0.81	2.51	29.49
Coeff. of variation (%)	–	–	–	3.73	2.35	6.45	13.89	29.30	4.54	4.11	3.20	1.88	6.67	7.17	5.81	4.14	7.61

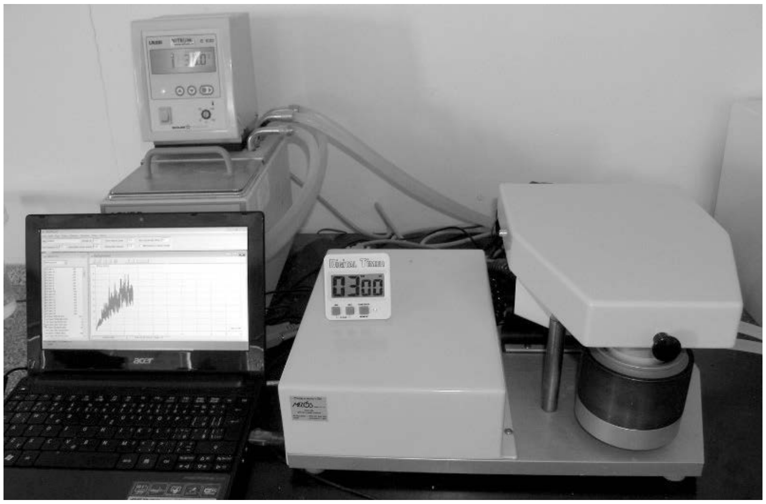

Figure 1. Typical Reomixer set at work (Reomixer, circulating water bath, computer)

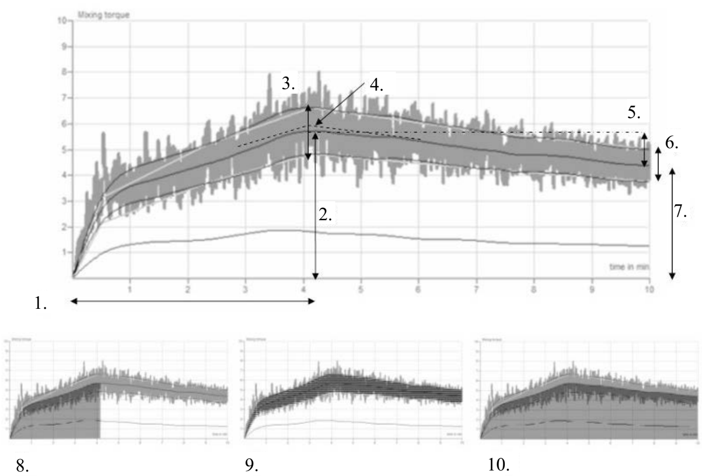

Figure 2. Reading of the main Reomixer parameters from the graph: 1. peaktime, 2. peakheight, 3. peakwidth, 4. peakangle, 5. breakdown, 6. endwidth, 7. endheight, 8. IHTP, 9. areawithin, 10. areabelow

Rheological analysis

Flour

Correlation coefficients for statistically significant Reomixer parameters "peakheight", "areabelow", "endheight", with bread volume as the main bread-making quality parameter, are shown in Table 2. Several regression models, summarised in Table 3, were constructed using these parameters as inputs.

Whole-grain meal – AACC 54.40.02 hydration

The correlation coefficient for the statistically significant Reomixer parameter "peakwidth", with bread volume as the main bread-making quality parameter, is shown in Table 2. The regression model, shown in Table 3, was constructed using this parameter as an input.

Table 2. Statistically significant correlations between bread volume and Reomixer parameters for flour and whole-grain meal under different hydration methods

Reomixer parameter	White flour AACC 54-40.02	Whole-grain meal constant 75%	Whole-grain meal farinograph absorption	Whole-grain meal AACC 54-40.02
Peakwidth				0.64**
Peakheight	0.69**	0.85**	0.66**	
Peakangle		0.69**	0.78**	
Breakdown			0.55*	
Areabelow	0.57*	0.78**		
Endwidth		0.56*		
Endheight	0.56*	0.66**	0.68**	

* $P < 0.01$, ** $P < 0.001$

Whole-grain meal – farinograph hydration

Correlation coefficients for statistically significant Reomixer parameters "peakheight", "peakangle", "breakdown", "endheight", with bread volume as the main bread-making quality parameter, are shown in Table 2. Several regression models, summarised in Table 3, were constructed using these parameters as an input.

Whole-grain meal – constant hydration

Correlation coefficients for statistically significant Reomixer parameters "peakheight", "peakangle", "areabelow", "endwidth", "endheight", with bread volume as the main bread-making quality parameter, are shown in Table 2. Several regression models, summarised in Table 3, were constructed using these parameters as inputs.

Discussion

Among the basic qualitative parameters, only specific weight was found to be significantly correlated with bread volume. But when Caroll is excluded as a non-bread-making variety, specific weight correlation with bread volume was not significant either. This finding indicates that basic qualitative parameters are sufficient for grading wheat as bread-making, but insufficient for more detailed quality determination. Using the flour mixograph analysis, several works (Chung et al. 2001; Dobraszczyk et al. 2005; Bordes et al. 2008; Miles et al. 2013, and others) have found a better discrimination of wheat bread-making quality.

Table 3. Regression models for predicting bread volume using Reomixer parameters of flour and whole-grain meal under different hydration methods

Material	Hydration method	Regression equation	*P*-value	R^2	Standard error of estimation
Flour	AACC 54–40.02	1. Bread volume = –17.15 + 168.7*peakheight – 15.79*areabelow – 6.926*endheight	0.001	72.14	17.4
		2. Bread volume = –16.09 + 157.5*peakheight – 14.95*areabelow	<0.001	71.58	16.9
		3. Bread volume = 131.3 + 36.31*peakheight	0.003	47	22.25
Whole-grain meal	constant base 75%	4. Bread volume = 79.57 + 62.27*peakheight – 3.932*areabelow + 0.9523*peakangle + 16.25*endheight – 51.29*endwidth	0.005	77.91	16.99
		5. Bread volume = 35.65 + 56.34*peakheight – 2.3*areabelow + 0.9062*peakangle + 4.346*endheight	0.002	75.95	16.91
		6. Bread volume = 14.69 + 51.82*peakheight – 0.4695*areabelow + 0.7548*peakangle	<0.001	74.76	16.58
		7. Bread volume = –13.79 + 67.92*peakheight – 1.297*areabelow	<0.001	73.32	16.38
		8. Bread volume = 15.26 + 55.11*peakheight	<0.001	72.81	15.93
Whole-grain meal	farinograph absorption	9. Bread volume = 364.4 + 1.881*peakangle + 46.49*endheight – 48.88*peakheight + 10.55*breakdown	0.004	72.63	18.04
		10. Bread volume = 330.8 + 1.877*peakangle + 45.51*endheight – 42.08*peakheight	0.001	72.1	17.43
		11. Bread volume = 206.8 + 1.16*peakangle + 22.25*endheight	<0.001	66.08	18.47
		12. Bread volume = 320.9 + 1.523*peakangle	<0.001	61.36	18.99
Whole-grain meal	AACC 54–40.02	13. Bread volume = –186.0 + 272.2*peakwidth	0.007	41.15	23.44

Values of Reomixer parameters obtained using flour/whole-grain meal and different methods for water addition differed. When comparing whole-grain meal methods vs. flour, AACC 54-40.02, hydration is the most divergent. This method had only one Reomixer parameter that significantly correlated with bread volume – "peakwidth". This parameter was not found to be significant in flour and other whole-grain methods. Whole-grain meal analysis using farinograph absorption was closer to flour. This method had Reomixer parameters "peakheight" and "endheight" that significantly correlated with bread volume. The same Reomixer parameters were observed for flour, with similar correlation coefficient values. Using this method, further Reomixer parameters "peakangle" and "breakdown" were found to correlate with bread volume, but they were not found to be significant in flour. The best whole-grain meal water addition method was constant hydration at 75%. This method had the highest number of Reomixer parameters that significantly correlated with bread volume. According to Wikström and Bohlin (1996), higher number of factors in regression model enable better discrimination ability. All Reomixer parameters significant for flour ("peakheight", "areabelow", "endheight") were also observed to be significant in this method. We observed the further Reomixer parameters, "peakangle" and "endwidth", as being important for bread volume. Neacșu et al. (2009) studied Reomixer parameters from the perspective of reproducibility, complementarity, etc. They selected "initslope", "peaktime", "peakheight", "endwidth" and "breakdown" as being well-descriptive of all basic rheological aspects of mixing. For discriminating baking quality, "peaktime" was reported to be a poor parameter (Khatkar et. al. 1996; Martinant et al. 1998). From this point of view, "peakheight", "peakangle" (correlated with "breakdown") and "endwidth" have good potential for constructing a regression model with good prediction power.

When regression models developed for flour are compared, model no. 2 (Table 3) – using "peakheight" and "areabelow" Reomixer parameters – has the lowest standard error of estimation. Similar Reomixer parameters and ability to predict wheat bread-making performance were found by Dobraszczyk and Salmanowicz (2008). For whole-grain meal regression models, the group of models using the constant hydration method had the lowest standard error of estimation on average. For practical wheat bread-making quality determination, whole-grain meal regression model no. 7 (Table 3) seems to be promising – it uses identical Reomixer parameters as in flour model no. 2 with similar R^2 and standard error of estimation. Furthermore, it is simple to measure whole-grain meal moisture and perform Reomixer analysis. Anderson (2003) presented the correlation between sieved whole-grain meal and flour analysis for Reomixer parameters, which is in agreement with our results. Sieving used by Anderson (2003) is laborious and could be a source of potential problems, so the use of Perten LM3100 whole-grain meal, as described in this work, could be a better alternative.

In conclusion, whole-grain meal Reomixer analysis under constant hydration seems to be as comparable a method for bread-making performance evaluation as flour analysis.

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