Acta Alimentaria, Vol. 33 (1), pp. 19–29 (2004)

RHEOLOGICAL PROPERTIES OF SOME CROATIAN AND GERMAN WHEAT VARIETIES AND THEIR RELATION TO PROTEIN COMPOSITION*

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(Received: 6 August 2002; accepted: 3 October 2003)

Rheological properties and protein macro fraction of ten Croatian and five German wheat varieties were studied. Differences in dough rheological properties of German and Croatian wheat varieties were analysed by ANOVA. Multiple regression was used to determine the influences of protein macro fractions of Croatian and German wheat varieties on rheological properties of their doughs. The investigation had shown that Croatian and German wheat varieties had similar dough properties. Protein content and protein composition influenced many of investigated rheological parameters. However, most of the influences were found in the mixing properties of doughs in both German and Croatian wheat varieties. Dough development time, stability and the degree of softening from the Farinograph and dough strength from the Alveograph showed the highest correlation coefficients with the protein composition. Influences of protein macro fraction of Croatian wheat varieties and influences of protein macro fraction of German wheat varieties on rheological parameters showed some differences.

Keywords: Croatian wheat variety, German wheat variety, protein composition, rheological properties

Rheological properties are significant in determining the behaviour of wheat flour doughs during mechanical handling in addition to their influence on the quality of the finished product. There are two principal dough testing methods of flour: (1) to monitor and control the prediction of a flour within specified parameters, and (2) to predict the dough behaviour in a commercial bakery (OLIVER & ALLEN, 1992). Austrian and many European cereal chemists have been using the Brabender Farinograph and Extensograph as a means of monitoring production with considerable success. The Alveograph test is used to measure dough quality in France, Spain and Italy. In the industry, dough performance is usually measured by these empirical instruments. It is generally accepted that the viscoelastic properties of wheat flour dough depend primarily on the dough's protein constituents MACRITCHIE (1992), which are primarily under genetic control, and to a lesser degree on the affect by environmental and agronomic

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* Publication number 7416 of Federal Center for Cereal, Potato and Lipid Research in Detmold and Münster.
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contributions. Cereal proteins are usually divided into four groups according to the solubility fractionation scheme of Osborne (EWART, 1979), in which albumins are those proteins soluble in distilled water; globulins are soluble in dilute salt solutions; gliadins in aqueous ethanol; and glutenins in dilute acids and alkalis (FARIDI & FAUBION, 1990). The fractionation and quantification of components to determine statistical relationships with quality is one of several approaches which have been used to determine quality differences (WEEGELS et al., 1996). Recently, research has increased our knowledge of the complex mixture of wheat proteins. However, the view that two main groups of proteins glutenins and gliadins control dough properties has not changed (SOUTHAN & MACRITCHIE, 1999). During processing of flour to the final product, many physico-chemical changes take place in the protein matrix. The functional properties of wheat flour proteins in dough at various stages of the bread making process depend on the composition of the protein constituent, the molecular properties of the proteins, and their interactions with themselves and other flour constituents (BLOKSMA & BUSHUK, 1988, HOU et al., 1996). Reconstitution studies have shown that the physical properties of doughs are determined primarily by the balance between gliadins and glutenins (MACRITCHIE, 1987, UTHAYAKUMARAN et al., 1999). SLIWINSKI and co-workers (1996) showed several factors which can be related to a strong tendency for the aggregation of gluten protein, and as such to a long mixing time: these are the amount of gluten protein, the amount of polymeric gluten protein, the polymerisation-degree of the polymeric gluten protein.

The aim of this paper was to determine rheological properties of the chosen Croatian and German wheat varieties and to analyse influences of protein macro fractions on dough rheology.

1. Material and methods

1.1. Samples

All investigations were performed with ten Croatian and five German winter wheat varieties different in quality. The quality of used samples was described by UNBEHEND and co-workers (2003a). Selected quality parameters are shown in Table 1.

1.2. Extraction of protein fractions

Protein macro/fractions were extracted as described by UNBEHEND co-workers (2003b).

1.3. Rheological testing

Farinograph, Extensograph and Alveograph data were determined by the ICC standard methods (ICC, 1995).

Table 1. Selected characteristics of used wheat flour samples

Sample	Moisture content (%)	Ash content (%)	Protein content (%)	Loaf volume (ml/100 g flour)
Zitarka	15.0	0.60	15.7	696
Sana	15.4	0.58	11.6	680
Astra	14.8	0.55	13.2	680
Kruna	14.6	0.56	13.9	722
Lara	15.2	0.59	14.2	710
Lenta	14.5	0.52	13.7	687
Perla	13.9	0.60	10.6	534
AG-15	14.0	0.56	11.6	571
AG-261	13.8	0.58	13.3	605
AG-45	15.1	0.55	12.3	621
Batis (A)[a]	14.7	0.60	12.1	612
Ritmo (B)[a]	14.6	0.60	12.0	568
Bussard (E)[a]	14.7	0.52	14.5	733
Contra (C)[a]	14.9	0.58	11.0	533
Zentos (E)[a]	14.6	0.59	15.7	750

[a] Group classification according to German standard protocol.

1.4. Statistical analyses

Analysis of variance was concluded based on the mean of two replicates, considering each wheat variety and treating the country as a fixed effect to determine differences between rheological properties of Croatian and German wheats. Data were subjected to multiple regression analysis to show the influences of protein macro/fractions on rheological properties.

2. Results and discussion

2.1. Rheological properties

Comparison of the quality of some Croatian and German wheat varieties according to German standard protocol was investigated by UNBEHEND and co-workers (2003a). The investigation showed that Croatian wheat varieties were comparable in many parameters, however, some differences were also found. The standard protocol represents results of different chosen analyses, which should show the suitability characteristics of the varieties for baking purposes, but more specific information about the behaviour of wheat varieties in different stages of productions can be obtained using other analyses. It has been recognised for long that flour doughs are viscoelastic (SCHOFIELD & SCOTT BLAIR, 1932). The knowledge of both the viscous and elastic properties is necessary for quality control, determining the behaviour of dough during mechanical handling (dividing, rounding, moulding), which affects the quality of the finished bread.

Figures 1a–1d represent the results of extensogram parameters. The highest energy for Croatian wheat varieties were determined for Ag-15, Lenta and Lara. Somewhat lower values were found for Sana, Kruna, Perla, Ag-45 and Zitarka. Astra and Ag-261 showed the lowest energy values. German Zentos had higher energy value than all of Croatian and other German wheat varieties. Batis and Bussard showed lower energy than Zentos and higher than Ritmo and Contra. Croatian wheat varieties Kruna and Lenta and German wheat varieties Bussard and Zentos had the highest extensibility. Extensibility of Zitarka, Sana, Lara, Batis and Ritmo was between 160 and 180 mm. Ag-15 and Ag-45 showed extensibility between 140 and 160 mm. Astra, Perla, Ag-261 and Contra had the lowest values of extensibility. Wheat varieties Ag-15, Perla, Lara, Zentos and Batis had resistance higher than 200 BU. Resistance between 100 and 200 BU were measured for Lenta, Ag-45, Kruna, Sana, Zitarka, Contra, Bussard and Ritmo. The lowest resistance was found for Astra and Ag-261. Similar distribution of results can be seen in the graph for maximum resistance.

When doughs were measured in biaxial extension using Alveograph, Croatian wheat varieties Lara, Ag-261, Perla, Zitarka, Ag-15, and German wheat varieties Batis, Zentos and Ritmo showed tenacity values higher than 80 mm H_2O. Ag-45, Lenta, Kruna and Bussard had tenacity values in range from 60 to 80 mm H_2O (Figs 1a'–1d'). Only Sana, Astra and Contra had low values from 40 to 50 mm H_2O. Similar distribution of extensibility results was obtained using Alveograph and Extensograph. Tenacity/Extensibility ratio was only in three wheat varieties (Perla, Ag-15 and Batis) between 1.5 and 2.5. Ag-261, Lara, Ag-45, and Ritmo showed values for this ratio in the range from 1 to 1.5. The other wheat varieties had values from 0.3 to 1. Only the German wheat variety Contra had strength value lower than 100 E-4 J. Strength values in the range from 100 to 200 E-4 J were found for Ag-15, Ag-45, Sana, Perla, Astra and Ritmo. Wheat varieties Lara, Lenta, Zitarka, Kruna, Ag-261, Bussardand Batis had strength values from 200 to 350 E-4 J. Zentos showed the highest value.

Figures 1a"–1d" represents the results of farinogram parameters. Two wheat varieties Ag-15 and Contra had water absorption lower than 55%. Kruna, Ag-45, Astra, Perla, Sana, Zentos and Ritmo showed water absorption values between 55 and 60%. Ag-261, Zitarka, Lara, Bussard and Batis had higher values than 60%. Short dough development times were found for Ag-15, Perla, Batis and Contra, but Sana and Ritmo had somewhat higher values. Zitarka, Lara, Kruna, Astra, Ag-261 and Bussard had from 3 to 5 min of dough development time. Only Lenta, Ag-45 and Zentos showed the values higher than 5 min. The lowest mixing stability was observed for Perla and Contra (1–3 min). Stability higher than 7 min was found for Lara, Lenta, Bussard and Zentos. The other wheat varieties had mixing stability in the range from 3 to 7 min. Lower degree of softening than 80 BU was displayed by Lara, Lenta, Zitarka, Bussard and Zentos. Wheat varieties Ag-45, Astra, Kruna, Ag-15, Ritmo and Batis showed degree of softening in the range from 80 to 100 BU. Sana, Ag-261 and Perla had values between 100 and 120 BU. The highest values were found in Contra.

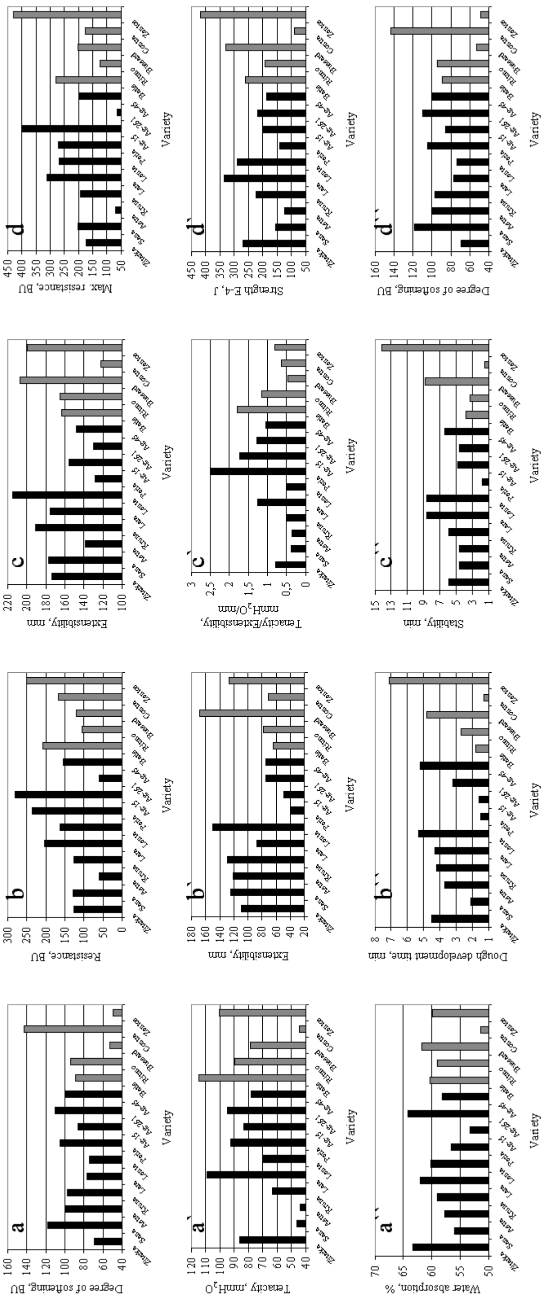

Fig. 1. Rheological properties of doughs prepared from Croatian and German wheat varieties. ■: Croatian wheat varieties; □: German wheat varieties; a–d: results of Extensograph analyses; a'–b': results of Alveograph analyses; a''–b'': results of Farinograph analyses

Investigations in this paper showed that Croatian wheat varieties and German wheat varieties, regarded as two groups, had the same rheological properties supposing the same behaviour during mechanical handling and quality of finished bread (no differences were found between rheological properties of Croatian and German wheat varieties when country was treated as a fixed effect using statistical analysis (ANOVA)). This is in accordance with the results of previous investigations (dough handling properties determined subjectively by trained baker and volume yield) (UNBEHEND et al., 2003a).

2.2. Influences of protein composition on rheological properties

Another equally important theme is the relationship between dough structure and dough rheology. The identification of key ingredients influencing dough properties remains important for the improvement of end-product quality (HUSSAIN & LUKOW, 1997). Because of the proven importance of protein influences of protein macro fractions of both Croatian and German wheat varieties on dough properties were investigated in this study.

Energy showed a significant relationship only to the protein content in German wheat varieties (Table 2). The amount of investigated protein groups of German and Croatian wheat varieties did not show a relationship with dough resistance. The total amount of gluten, glutenin and insoluble glutenin of Croatian wheat varieties was highly correlated with the extensibility, and protein content of German wheat varieties showed positive influence on extensibility. The importance of the extensibility of dough in bread production is connected to retention of gas bubbles, which produce pores during fermentation.

Tenacity and tenacity/extensibility ratio did not show any relationship with the protein content, protein composition or protein balance (Table 3). By contrast, strength showed very close correlation to the protein content and protein composition. The relative size distribution of glutenin proteins is most likely responsible for all the individual and combined effects of different glutenin subunits on the dough strength (GUPTA & MACRITCHIE, 1994). In this paper strength showed the strongest relationship with protein content, percent gluten, glutenin and insoluble glutenin in flour in both Croatian and German wheat varieties. Protein balance of German wheat varieties had also significant correlation coefficients to strength.

In Table 4 farinogram parameters are represented as a function of protein content, protein composition and protein balance. Water absorption of Croatian wheat varieties was found to be significantly correlated with the protein content. Also the balance of gluten and non-gluten proteins and the balance of gluten proteins significantly influenced water absorption in Croatian wheat varieties. Water absorption of German wheat varieties did not have any significant relationship with protein composition. The dough development time and dough stability of both Croatian and German wheat varieties strongly correlated with the protein content, gluten content in flour and the percentage of glutenin in flour, percentage of insoluble glutenin in flour.

Table 2. Correlation coefficients for the protein content, protein composition and protein balance with extensogram parameters[a]

	Parameter							
	Energy[b]	Energy[c]	Resistance[b]	Resistance[c]	Extensibility[b]	Extensibility[c]	Max. resistance[b]	Max. resistance[c]
Protein	0.078	0.875*	0.460	0.446	0.471	0.873*	0.312	0.756
Gluten in flour	0.262	0.845	0.145	0.438	0.682*	0.794	0.019	0.732
Glutenin in flour	0.294	0.840	0.110	0.429	0.695*	0.812	0.045	0.727
Insoluble glutenin in flour	0.340	0.845	0.061	0.429	0.716*	0.827	0.091	0.729
Soluble glutenin in flour	–0.071	–0.472	–0.311	–0.212	–0.268	–0.683	–0.021	–0.406
Gliadin in flour	–0.344	–0.654	–0.058	–0.298	–0.561	–0.755	–0.139	–0.558
Gliadin, soluble glutenin and insoluble glutenin in flour	0.459	0.898	0.390	0.483	0.721	0.925	0.329	0.783
Gluten proteins and no gluten proteins	0.806	0.878	0.800	0.446	0.772	0.938	0.808	0.758

[a] Based on linear regression. $P = 0.05$ for *
[b] Croatian wheat varieties n = 10.
[c] German wheat varieties n = 5.

Table 3. Correlation coefficients for the protein content, protein composition and protein balance with alveogram parameters[a]

	Parameter							
	Tenacity (P)[b]	Tenacity (P)[c]	Extensibility (L)[b]	Extensibility (L)[c]	P/L[b]	P/L[c]	Strength[b]	Strength[c]
Protein	0.152	0.393	0.554	0.774	0.520	0.341	0.720*	0.947**
Gluten in flour	0.146	0.254	0.586	0.758	0.466	0.458	0.797**	0.875*
Glutenin in flour	0.129	0.239	0.599	0.801	0.433	0.476	0.773**	0.883*
Insoluble glutenin in flour	0.144	0.256	0.576	0.812	0.401	0.462	0.776**	0.895*
Soluble glutenin in flour	–0.007	–0.460	–0.446	–0.609	–0.396	–0.052	–0.406	–0.666
Gliadin in flour	–0.027	–0.112	–0.496	–0.883	–0.187	–0.487	–0.475	–0.76
Gliadin, soluble glutenin and insoluble glutenin in flour	0.211	0.995	0.610	0.896	0.521	0.947	0.808	0.999**
Gluten proteins and no gluten proteins	0.154	0.822	0.589	0.774	0.520	0.752	0.797	0.995*

[a] Based on linear regression. $P = 0.05$ and 0.01 for * and **

[b] Croatian wheat varieties n = 10.

[c] German wheat varieties n = 5.

Table 4. Correlation coefficients for the protein content, protein composition and protein balance with farinogram parameters[a]

	Parameter							
	Water absorption[b]	Water absorption[c]	Dough development time[b]	Dough development time[c]	Stability[b]	Stability[c]	Degree of softening[b]	Degree of softening[c]
Protein	0.804**	0.600	0.722*	0.985**	0.646*	0.997***	–0.720*	–0.947**
Gluten in flour	0.570	0.460	0.662*	0.992***	0.703	0.987**	–0.830**	–0.809
Glutenin in flour	0.604	0.476	0.681*	0.983**	0.728	0.986**	–0.819**	–0.822
Insoluble glutenin in flour	0.548	0.499	0.663*	0.978**	0.698	0.986**	–0.864**	–0.836
Soluble glutenin in flour	–0.426	–0.703	–0.353	–0.382	–0.414	–0.479	0.275	0.680
Gliadin in flour	–0.287	–0.472	–0.411	–0.738	–0.424	–0.789	0.657*	0.730
Gliadin, soluble Glutenin and insoluble glutenin in flour	0.632	0.926	0.688	0.996	0.735	0.998*	0.878*	0.964
Gluten proteins and no gluten proteins	0.847*	0.927	0.725	0.994*	0.728	0.998*	0.846*	0.969*

[a] Based on linear regression. $P = 0.05$; 0.01 and 0.001 for *; ** and ***, respectively.
[b] Croatian wheat varieties n = 10.
[c] German wheat varieties n = 5.

The balance between gliadin, soluble glutenin and insoluble glutenin in flour had influenced the dough development time of German wheat varieties. The degree of softening of German and Croatian wheat varieties was negatively influenced by the total amount of protein. The degree of softening correlated negatively with the percent of gluten in flour, percent of glutenin in flour and the percent of insoluble glutenin in Croatian wheat varieties. The degree of softening showed a relationship with the percent of gliadin in flour (Croatian wheat varieties). Degree of softening was also influenced by protein balance in Croatian wheat varieties. From the results obtained in this study it is noticeable that protein composition plays a very important role in dough mixing properties, even more than in extension. This indicates that the desired stability in dough making processes can be achieved by using genetic manipulation of proteins.

In a previous study differences in protein composition (fraction of soluble glutenin and fraction of gliadin) between Croatian and German wheat varieties were found (UNBEHEND et al., 2003b) influencing differences between Croatin and German wheat varieties in relation of protein composition to rheological properties. This type of investigation proves that protein composition and protein balance play a very important role in bread making quality. However, from the results of this investigation it can be seen that it was not possible to explain physical properties perfectly by protein composition only. Although Croatian and German wheat varieties had different protein composition, the rheological properties of Croatian and German wheat varieties did not show any differences. This is the result of the complexity of dough forming and structure. Therefore the investigations should also include other constituents such as starch for example and try to find an optimal balance between them. Thus, it would be possible to understand the main differences in wheat quality and the background of the dough forming and dough properties.

3. Conclusions

Rheological properties of Croatian and German wheat varieties were the same. In uniaxial extension measurements (Extensograph), extensibility was the parameter which was influenced the most by protein content and protein composition (more in Croatian wheats). Biaxial extension (Alveograph) of doughs from Croatian and German wheat varieties showed that strength was significantly correlated with the protein content, gluten amount, glutenin amount and the amount of insoluble glutenin in flour. Extensibility also correlated with them, but only in German wheat varieties. Dough development time and stability determined by Farinograph of both Croatian and German wheat varieties, and the degree of softening of Croatian wheat varieties, also determined by Farinograph, had a strong relationship with the total amount of proteins.

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