ASSESSMENT OF THE RHEOLOGICAL PROPERTIES OF FLOUR USING THE MIXOLAB

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Abstract

The rheological properties of dough are important basis for the process of production of quality products (Létang et al., 1999; Moreira et al., 2010). The main techniques used for measuring flour dough's properties are empirical or fundamental. Empirical measurements can be conducted by means of farinograph, Falling Number apparatus, rapid visco analyser, etc., and multifunctional new apparatus like Mixolab (Jansen et al., 1996; Moreira et al., 2010). The aim of research was to evaluate the rheological properties of dough made from different cereal flours and flour blends using Mixolab.

Whole grain flour of triticale, rye, hull-less barley, rice, maize and flour blends were used in this research. Flour blends were made from triticale in a combination with other flour in various proportions. Wheat flour was used as a control. Rheological properties of mixed flour dough were studied using Mixolab (*Chopin Technologies*), which was capable of evaluating rheological properties and enzymatic activity of flour and flour blends.

In the Mixolab test triticale flour demonstrated equivalent dough properties to wheat flour: formation time, protein weakening and starch gelatinization peak value. But values of amylase activity and starch retogradation in triticale flour were lower than in wheat flour. Evaluation of the Mixolab test results demonstrated that decrease of triticale flour proportion in flour blend resulted in increase of the dough stability, but did not change substantially dough properties.

Key words: triticale, wheat, hull-less barley, flour blend, Mixolab.

Introduction

The cereals or grain crops are the most important sources of food for people. The type of cereal mainly used in food depends on specificity of the region, in the Far East it is rice, in America – maize, in Central Asia, North America and Northern and Eastern Europe – rye and wheat. There are various grindings of rye and wheat flour mainly used in preparation of bread and pastry production in Latvia.

In order to extend the product assortment and improve their nutritional value, there can be used triticale, hull-less barley, buckwheat, hull-less oat, and other grain flour that are used elsewhere in the world and various scientific studies demonstrate their value (Taketa et al., 2004). Triticale (*Triticosecale Wittmack*) is a hybrid crop developed by crossing wheat (*Triticum*) and rye (*Secale*). The nutritional value of triticale is close to that of wheat and rye (Salmon et al., 2002). In Baltic countries in 1997 Estonians adapted Western triticale cultivars to Northern growing conditions and they have done serious investigations on triticale for bread making (Tohver et al., 2005).

For expanding the range of bakery and pastry production in the world there are being developed various recipes for product enriching with fibre, especially β-glucan, proteins, vitamins and other nutrients for a healthier diet. It can be done making a flour blend from whole grain triticale, rye, hull-less barley, rice and maize flour (Straumite et al., 2010). The Mixolab allows the characterization of the physicochemical behavior of dough when submitted to dual mixing and temperature constraints. Therefore, it is possible to record the mechanical changes due to mixing and heating simulate the mechanical work as well as the heat conditions that might be expected during the baking process (Rosell et al., 2007).

The rheological properties of dough are important basis for the process of production of quality products (Collar and Armero, 1996; Létang et al., 1999; Rosell et al., 2007; Moreira et al., 2010). During the baking process, flour compounds are subjected to mechanical work and heat treatment that promote changes in their rheological properties (Bollain and Collar, 2004). Many investigations into the cross-linking of wheat protein have demonstrated that the enzyme catalysis reaction not only affects the biochemical characteristics of the dough, but also the rheological properties (Köksel et al., 2001; Autio et al., 2005). The main techniques used for measuring flour dough's properties are empirical or fundamental. Empirical measurements can be conducted by means of farinograph, Falling Number apparatus, rapid visco analyser, etc., and multifunctional new apparatus like Mixolab (Jansen et al., 1996; Moreira et al., 2010). The aim of research was to evaluate the rheological properties of dough made from different cereal flours and flour blends using Mixolab.

Materials and Methods

Triticale, rye and hull-less barley crops of 2010 cultivated at the Priekuli Plant Breeding Institute (Latvia) were used in the current study. For this research 4 samples of flour blends were made too (Table 1). Triticale, rye and hull-less barley used for study were ground in a laboratory mill Hawos (Hawos Kornmühlen GmbH, Germany) obtaining whole grain fine flour. Rice and maize flour was purchased from Joint Stock Company *Ustuniu Malunas* (Lithuania).

Table 1

Sample composition per 100 g of flour blend

Flour type	Flour blend			
	A	B	C	D
Whole grain triticale, g	90.00	80.0	70.00	60.00
Whole grain rye, g	3.75	7.50	11.25	15.00
Whole grain hull-less barley, g	3.75	7.50	11.25	15.00
Rice, g	1.25	2.50	3.75	5.00
Maize, g	1.25	2.50	3.75	5.00

Moisture content in raw materials and flour blends was determined using an express oven-dry method, where 2.00±0.06 g of sample was placed for drying in a moisture scale Precisa XM120 (Precisa Instruments AG, Switzerland) till a constant weight (when 4 subsequent measurements did not change more than 0.01 g) at temperature +110±1 °C.

Mixing and pasting behaviour of dough made from whole grain flour of triticale, rye, hull-less barley, rice, maize and flour blends (Table 2) was studied using the Mixolab analyser (Chopin, Tripette et Renaud, Paris, France). All measurements were performed using the Mixolab standard Chopin+ protocol (ICC No. 173). Mixolab is a sensor that allows measurement of the rheological behaviour of dough that is subjected to both kneading and heating. It measures, in real time, the torque (Nm) produced by the dough between two kneading arms. The test is based on preparing a constant hydrated dough mass so as to obtain a target consistency during the first test phase.

Table 2

Instrumental settings defined in the Mixolab for running the samples

No.	Parameters	Wheat, rye, hull-less barley, and flour blends	Rice, maize
1	Dough mass	75 g	90 g
2	Kneading speed	80 rpm	
3	Target torque (C1)	1.10 Nm	
4	Tank temperature	30 °C	
5	Temperature, 1st level	30 °C	
6	Duration, 1st level	8 min	
7	Temperature, 2nd level	90 °C	
8	1st temperature gradient	4 °C min^{-1}	

Continue of Table 2

No.	Parameters	Wheat, rye, hull-less barley, and flour blends	Rice, maize
9	Duration, 2nd level	7 min	
10	2nd temperature gradient	-4 °C min^{-1}	
11	Temperature, 3rd level	50 °C	
12	Duration, 3rd level	5 min	
13	Total analysis time	45 min	

The dough weight for rice and maize testing was changed from 75 g to 90 g due to the specific nature of the system (Table 2). The whole test can be divided into five different stages (Figure 1): dough development (1), protein denaturation (2), starch gelatinization (3), amylase activity (4) and starch retrogradation (5).

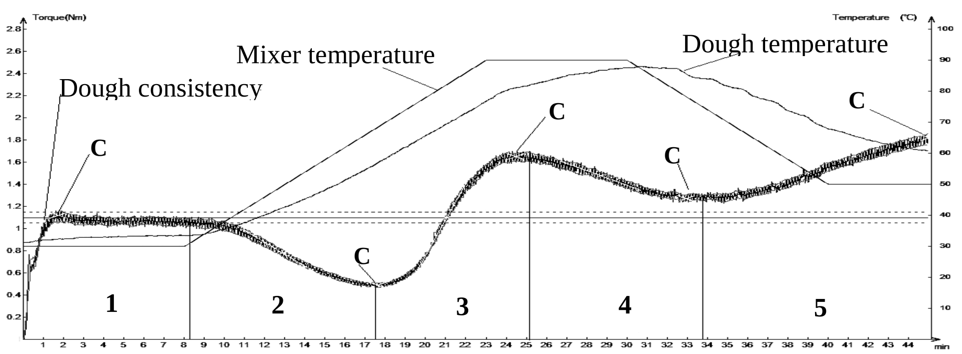

Figure 1. Typical curve from Mixolab analysis of wheat dough

The first stage C1 at constant temperature 30 °C determines the water absorption capacity of the flour and measures the characteristics of dough during mixing (stability, elasticity, and absorbed power), shows the maximum torque at 30 °C. The parameters that were obtained from the recorded curve were water absorption (%) or the percentage of water required for the dough to produce a torque of 1.1±0.03 Nm.
Means and standard deviations of the means were calculated using Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, WA).

Results and Discussion

Moisture content of flour used in the research was from 10.3% (rice flour) to 11.9% (whole grain rye flour), but in flour blend samples – from 8.3% to 9.5%. Moisture content in the flour blend samples increased, with increasing proportions of other flours used in combination with triticale flour (Table 3).

Table 3

Moisture content in flours and flour blend samples

No.	Sample	Moisture, %
1.	Wheat flour (control)	11.6
2.	Whole grain triticale flour	10.5
3.	Whole grain rye flour	11.9
4.	Whole grain hull-less barley flour	10.8
5.	Rice flour	10.3
6.	Maize flour	11.6
7.	Flour blend A	8.3
8.	Flour blend B	8.6
9.	Flour blend C	9.2
10.	Flour blend D	9.5

It has been already established that rheological tests on dough can predict its behaviour in a bakery, although only if the rates and the extent of the deformation are in the same range as those during dough processing (Bloksma, 1990; Dobraszczyk and Roberts, 1992). The data of peak viscosity, pasting temperature and setback, can be useful predictors of bread firming behaviour during storage (Collar, 2003). As it is well known wheat flour possesses the unique bread making properties due to the ability of wheat storage protein to form viscoelastic dough when wetted and kneaded (Cauvain and Young, 2007). Therefore, Mixolab curve obtained for the wheat flour system was used as a standard curve.

The early stages (C1 and C2) mainly represent the properties of the protein in wheat, whole grain triticale, whole grain rye, whole grain hull-less barley, rice, maize flour and flour blend samples, but the latter stages (C3, C4 and C5) show the properties of the flour starch.

The Mixolab test data showed optimal water absorption 76.30±1.00% (14% basis) for whole grain hull-less barley flour with moisture content 10.8%. Whole grain hull-less barley flour did not reach optimum torque of 1.1 Nm at the mentioned water absorption. At lower water absorption for hull-less barley flour, it was not possible to analyse the properties of starch in Mixolab analyser, because the dough stuck around the kneading arms.

Table 4

Mixolab parameters of flours and flour blends samples

Sample	Water absorption (%)	Dough stability (min)	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)
Flour:							
Wheat (control)	57.03	10.21	1.10	0.48	1.65	1.27	1.82
Whole grain triticale	62.40	**3.66**	1.12	0.45	1.62	0.39	0.60
Whole grain rye	65.00	9.34	1.08	0.68	1.98	0.51	0.93
Whole grain hull-less barley	76.30	8.81	0.66	0.28	1.21	0.30	0.52
Rice	90.00	-	-	-	1.31	1.26	1.61
Maize	90.00	0.29	0.21	0.04	1.22	0.87	1.20
Flour blends:							
A	59.67	**6.03**	1.04	0.46	1.53	0.32	0.50
B	59.30	**6.23**	1.06	0.47	1.51	0.31	0.48
C	60.00	**6.87**	1.08	0.50	1.51	0.31	0.48
D	59.87	**7.19**	1.08	0.50	1.48	0.33	0.51

Values represent the means; n = 3.

Water absorption of whole grain triticale flour was 62.40±0.35%, but rye flour 65.00±0.07% (Table 4), while rice and maize flour had the highest water absorption 90% (by standard method modification). For rice flour the optimal value of water absorption to characterize starch gelatinization, amylase activity and starch retrogradation was 90%, but reducing the water absorption Mixolab analyser showed only data on dough development and protein denaturation. Water absorption for all samples of flour blends was from 59.30±0.10% to 60.00±0.10%.

When dough temperature increased, dough viscosity decreased and the intensity of this decrease depended on protein quality. Flour protein content is not only an indicator of nutritional value, but it has also an important effect on dough rheological properties. Maize flour showed the lowest peak value 0.04 Nm what characterise protein weakening due to mechanical and thermal constraints. It can be assumed that rice and maize flour has lower protein quality. Rye flour showed the highest peak value 0.68±0.01 Nm, what means better flour protein quality or the highest gluten strength, comparing with other studied flour samples. But, value of C2 was equivalent for wheat, triticale flour, and flour blend samples (Table 4 and Figure 2). It means they have the same gluten strength.

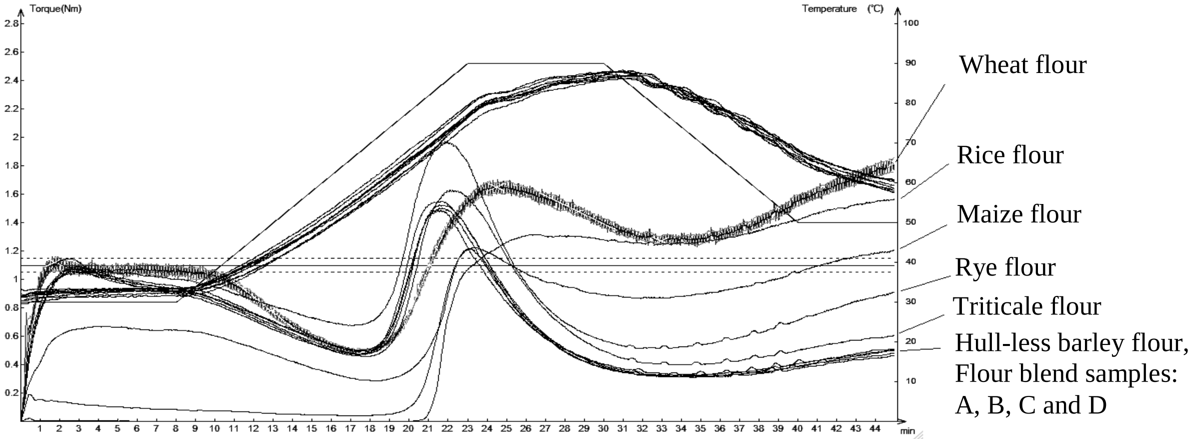

Figure 2. Mixolab profiles of flours and flour blend samples

Also, the second part of the curve (C3, C4, C5) involves heat treatment and therefore its parameters are related to starch behaviour (Köksel et al., 2009), it can be observed that wheat flour has the highest curve comparing with other flour curves. As it can be seen in Table 4 and Figure 2, triticale and flour blends, according to Mixolab parameters, did not reach the optimal properties during the heating and cooling period contrary to wheat flour. The C3 value of whole grain rye flour is the highest among the studied flours, what means high dough viscosity during heating. It depends on amylase activity and starch quality.

Comparing (Table 2) wheat flour with triticale flour and flour blend samples peak values of C4 and C5 decreased. It showed that the triticale flour and flour blends had low amylase activity when heating and low starch retogradation during the cooling period. The low starch retogradation value corresponds to a long shelf life of the end product.

Comparing dough stability of triticale (3.66 min) with dough stability of flour blend samples (sample A–6.03 min; sample B–6.23 min; sample C–6.87 min and sample D–7.19 min) it was found that the stability of triticale dough increased in mixing time at temperature 30 °C when proportion of other flour increased in a flour blend. Dough stability shows dough resistance to kneading: the longer time it takes the “stronger” dough gets. Sample D shows the highest dough stability in mixing comparing to other flour blend samples. In the research the highest dough stability showed wheat flour – 10.21 min.

Conclusions

1. Moisture content in the studied flour was from 10.3% (rice flour) to 11.9% (whole grain rye flour), but in flour blend samples from 8.3% to 9.5%.
2. Rice and maize flour had the highest water absorption (90%) necessary for measurement of dough rheological properties; change of the dough weight from 75 to 90 g is required in the standard method.
3. Triticale dough stability increased in mixing time at temperature 30 °C when proportion of other flours was increased in a flour blend.
4. Triticale flour and flour blends had low amylase activity when heating and low starch retogradation during the cooling period.
5. Maize and rice flour showed high starch retrogradation peak value, comparing to whole grain triticale, rye and hull-less barley flour, what means shorter shelf life of the end product.

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References

1. Autio, K., Kruus, K., Knaapila, A., Gerber, N., Flander, L., Buchert, J. (2005) Kinetics of transglutaminase-induced cross-linking of wheat proteins in dough. *Journal of Agricultural and Food Chemistry*, 53, pp. 1039–1045.
2. Bloksma, A.H. (1990) Rheology of the breadmaking process. *Cereal Foods World*, 35, pp. 228–236.
3. Cauvain S.P., Young L.S. (2007) Technology of breadmaking (2nd edition). NY: Springer. 398 pp.
4. Collar, C. (2003) Significance of viscosity profile of pasted and gelled formulated wheat doughs on bread staling. *European Food Research and Technology*, 216, pp. 505–513.
5. Collar, C., Armero, E. (1996) Physico-chemical mechanisms of bread staling during storage: Formulated doughs as a technological issue for improvement of bread functionality and keeping quality. *Recent Research Developments in Nutrition*, 1, pp. 115–143.
6. Dobraszczyk, B.J., Roberts, C.A. (1994) Strain hardening and dough gas cell wall failure in biaxial extension. *Journal of Cereal Science*, 20, pp. 265–274.
7. ICC STANDARD No. 173. (2006). Whole meal and flour from T. aestivum – determination of rheological behavior as a function of mixing and temperature increase.
8. Jansen, A.M., Vliet, T., Vereijken, J.M. (1996) Fundamental and empirical rheological behavior of wheat flour doughs and comparison with breadmaking performance. *Journal of Cereal Science*, 23, pp. 43–45.
9. Kökse, H., Sivri, D., Ng, P.K.W., Steffe, J.F. (2001) Effects of transglutaminase enzyme on fundamental rheological properties of sound and bug-damaged wheat flour doughs. *Cereal Chemistry*, 78, pp. 26–30.
10. Köksel, H., Kahraman, K., Sanal, T., Ozay, D.S., Dubat, A. (2009) Potential utilization of Mixolab for quality evaluation of bread wheat genotypes. *Cereal Chemistry*, 86, pp. 522–526.
11. Létang, C., Piau, M., Verdier, C. (1999) Characterization of wheat flour-water doughs. *Part I, Rheometry and microstructure, Journal of Food Engineering*, 41, pp. 121–132.
12. Moreira, R., Chenlo, F., Torres, M.D., Prieto, D.M. (2010) Influence of the particle size on the rheological behavior of chestnut flour dough. *Journal of Food Engineering*, 100, pp. 270–277.
13. Rosell, M.C., Collar, C., Haros, M. (2007) Assessment of hydrocolloid effects on the thermo-mechanical properties of wheat using the Mixolab. *Food Hydrocolloids*, 21, pp. 452–462.
14. Salmon, D., Temelli, F., Spence, S. (2002) Chemical composition of Western Canadian triticale varieties. *Proceedings of the 5th international Triticale symposium*, Volume II, pp. 445–450.
15. Straumite, E., Sabovics, M., Gramatina, I., Galoburda, R., Kronberga, A. (2010) Flour blend from non-traditional cereals in Latvia. Abstract book, *Enchancing health benefits of cereal foods, Results, perspectives and challenges*, pp. 103.
16. Taketa, S., Kikuchi, S., Awayama, T., Yamamoto, S., Ichii, M., Kawasaki, S. (2004) Monophyletic origin of naked barley inferred from molecular analyses of a marker closely linked to the naked caryopsis gene (nud). *Theoretical and Applied Genetics*, 108, pp. 1236–1242.
17. Tohver, M., Kann, A., Täht, R., Mihhalevski, A., Hakman, J. (2005) Quality of triticale cultivars suitable for growing and bread-making in northern conditions. *Food Chemistry*, 89, pp. 125–132.