The Annals of the University *Dunarea de Jos* of Galati
Fascicle VI – Food Technology *35(1) 54-62*

ORIGINAL RESEARCH PAPER

RHEOLOGICAL PROPERTIES OF THE WHEAT FLOUR SUPPLEMENTED WITH DIFFERENT ADDITIVES

GEORGETA STOENESCU, VIOLETA SORINA IONESCU
Research laboratory Arcada, Arcada Mill, Lunca Siretului, Zonă Banda Barbosi /1 bis, 800416, Romania, geta_stoenescu@yahoo.com, violetasorinaionescu@yahoo.com

IULIANA BANU
Dunarea de Jos University, Faculty of Food Science and Engineering, Galati, 111 Domneasca St., 800201 Galati, Romania, iuliana.banu@ugal.ro

Received 20 February 2011
Revised 30 March 2011

One characteristic of the Romanian wheat flour in the recent years consists of high values of the falling number. The aim of the present study was to explore the Mixolab device to characterize the thermo-mechanical behaviour of flour supplemented with different additives that contain α-amylase. Mixolab parameters C4 and C5 were found to be lower in samples with high doses of additives containing α-amylases. The increase of the α-amylase dose reduces the dough stability. The samples that contain higher doses of additives presented low values of the β slope, which gives indications about starch gelatinization. The samples with reduced α-amylases activity showed high values of the γ slope.

Keywords: wheat flour, rheological behaviour, Mixolab, Alveograph, Rheofermentometer, α-amylase

Introduction

The different empirical methods based on classical extensograph, alveograph, farinograph and mixograph instruments are currently used to obtain data on rheological properties and baking properties of flour (Uthayakumaran *et al*., 2002; Dobraszczyk *et al*., 2003; Tronsmo *et al.*, 2003; Collar *et al.*, 2003; Chiotelli *et al*., 2004).

Recently, the rheological behaviour of flour was studied using Mixolab, a new system which measures the torque produced by mixing the dough between two kneading arms, when dough is subjected to dual mixing and temperature constrains (Mixolab Applications Handbook, 2006; Rosell *et al*., 2007; Ozturk *et al*., 2008; Kahraman *et al.*, 2008; Banu *et al*., 2010a, 2010b, 2011).

The Mixolab technique allows the complete characterization of the flours in terms of proteins' quality by determining their water absorption, stability, elasticity, and weakening properties; starch behaviour during gelatinization and retrogradation; consistency modification when adding additives and enzymatic activity of the proteases, amylases, etc. (Collar *et al.*, 2007; Kahraman *et al*., 2008).

The Mixolab device was used by Rosell *et al.* (2007) to investigate the effects of several hydrocolloids widely used in breadmaking, as additives on wheat dough behaviour.

Collar *et al.* (2007) analyzed the potential of the Mixolab device to determine the rheological behaviour of bread dough from white flour and whole meal. Banu et al. (2011) explored the Mixolab device to characterise the thermo-mechanical behaviour of wheat flours and to establish the correlations within rheological parameters of the wheat flour supplemented with different additives such as fungal α-amylase, fungal hemicellulase and fungal xylanase.

Studies on the use of Mixolab to predict the baking quality of different wheat flours were carried out by Kahraman *et al.* (2008) and Ozturk *et al.* (2008). Marco and Rosell (2008) investigated the rheological characteristics of soybean and rice dough to obtain gluten-free breads.

Other experiments were performed by Bonet *et al.* (2006), Rosell *et al.* (2009) and Banu *et al.* (2010b) on wheat dough enriched with different protein sources and highly nutritious Andean crops quinoa, kaniwa, kiwicha and tarwi.

The aim of the present study was to investigate the thermo-mechanical behaviour of flour supplemented with different additive mixtures containing α-amylase, by means of Mixolab device.

Materials and Methods

The white flours (P0) were obtained by milling through Buhler equipment the wheat (2010 crop) using the direct extraction (76%) method. The capacity of the mill (Arcada Mill, Galati, Romania) was 80 t/24 h. The flours were sampled according to the standard SR EN ISO 13690:2007 (ASRO, 2008). The flour was supplemented with the following premixes (additives mixtures, provided by EDR Ingredients România): Belpan ecodor that contains fungic amylase, xylanase, hemicelulase, phospholipase and glucoxidase; Belpan malt that contains malt flour; Belpan alfa G that contains fungic amylase and EKA that contains xylanase, phospholipase, fungic amylase and ascorbic acid. The supplemented flour was obtained by well homogenizing small quantities (1 kg) of white flour with appropriate doses of additives mixtures, as recommended by the provider to obtain: 0.25, 0.50, 1.00, 2.00 and 3.00 g Belpan ecodor/kg flour (P1, P2, P3, P4, P5); 0.20, 1.00 and 2.00 g Belpan malt/kg flour (P6, P7, P8); 2.00, 3.50 and 5.00 g Eka 2000/kg flour (P9, P10, P11) and 0.01, 0.025 and 0.05 g Belpan alfa G/kg flour (P12, P13, P14).

Evaluation of physico-chemical properties

The physico-chemical characteristics of the wheat and flour were evaluated as follows:

- the moisture content through the AACC 44-51 method (AACC, 2000);
- the ash content through the SR ISO 2171:2002 method (ASRO, 2008);

- the gluten index through the SR ISO 21415-2:2007 method (System Glutomatic 2200, Perten Instruments AB) (ASRO, 2008);
- the wet gluten content through the SR ISO 21415-2:2007 method (System Glutomatic 2200, Perten Instruments AB) (ASRO, 2008);
- the falling number (FN) through the AACC 56-81B method (Falling Number, model 1400PT, Perten Instruments AB) (AACC, 2000).

Evaluation of rheological properties

The dough elasticity (P), dough extensibility (L) and work (W) were determined by means of the NG Chopin Alveograph using the AACC 54-30 method (AACC, 2000);

The total volume of CO_2 (Vt), retention coefficient (Cr), maximum dough fermentation height (H'm), the time at which dough attains the maximum height (T1) and the time when gas starts to escape from the dough (Tx) were determined by means of the F3 Chopin Rheofermentometer using the Chopin protocol. The dough to be analysed was prepared in the mixer of the Alveograph using 250 g flour, 7 g pressed baker's yeast, 5 g salt and water.

The maximum torque during mixing (C1), the protein weakening based on the mechanical work and temperature (C2), the starch gelatinization (C3), the stability of the starch gel formed (C4), the starch retrogradation during the cooling stage (C5), the slope α of the curve between the end of the period of 30ºC and C2, the slope β of the curve between C2 and C3 and the slope (γ) of the curve between C3 and C4 were determined by means of the Chopin Mixolab using the standard ''Chopin+'' protocol. The running parameters of the Mixolab device during the tests are: mixing rate 80 rpm, dough weight 75 g, tank temperature 30ºC, temperature of the first plateau 30ºC, duration of the first plateau 8 min, temperature of the second plateau 90ºC, first temperature gradient 4ºC/min, duration of the second plateau 7 min, second temperature gradient 4ºC/min, temperature of the third plateau 50ºC and duration of the third plateau 5 min.

Results and discussion

Flour characterisation

The quality indices of the wheat flour before supplementation with additives are depicted in Table 1.

Table 1. Quality indices of the wheat flour without additives

Quality indices	Values
Moisture content, %	14.6
Ash content, %	0.43
Falling number, s	478
Wet gluten content, %	26.2
Gluten index, %	97

The main quality indices of the flour without additives are wet gluten content of 26.2% and FN of 478 s. The high value of the FN recommends the addition of α-amylase to improve its baking properties. The decrease of the FN value to 220, 240, 380 and 402 s was obtained when supplementing the flour with the highest doses of Belpan ecodor, Belpan malt, Eka 2000 and Belpan alfa G, respectively (Figure 1). The samples P3, P4, P5, P10 and P11 have FN lower than 300 s, indicating an appropriate flour supplementation; the flour with good baking proprieties must have FN ranging from 250 to 300 s.

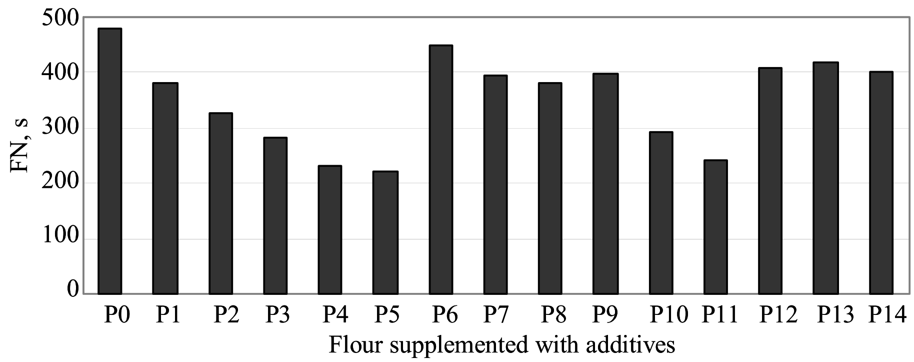

Figure 1. FN of the flour without additives (P0) and of the flour supplemented with additives (P1, …, P14)

Dough characterisation

The dough prepared from flour without additives had dough elasticity of 92 mm and extensibility of 42 mm. The addition of Belpan ecodor allowed obtaining dough with elasticity ranging from 76 to 29 mm and extensibility ranging from 42 to 82 mm (Figure 2). The lowest decrease of the dough elasticity (81-85 mm) was obtained in case of the flour supplemented with Belpan malt.

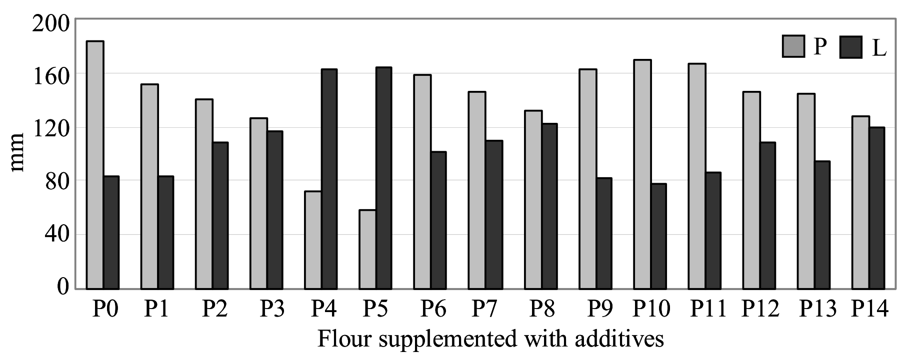

Figure 2. Elasticity and extensibility of the dough prepared from flour without additives (P0) and flour supplemented with additives (P1, …, P14)

The optimum values of the dough elasticity for bread flour are 60-70 mm. From this point of view, the best qualities of the flour supplemented with additives were obtained in case of samples P3, P8 and P14 (Figure 2). The improvement of the dough elasticity can be attributed to ascorbic acid found in the additives mixtures. The dough extensibility increased by adding the additives. The optimum values of the dough extensibility are 80-100 mm, and the samples P4 and P5 had appropriate values for this parameter (Figure 2). Concerning the work (Figure 3), all samples were characterised by a lower value than the optimum one recommended for a good baking quality.

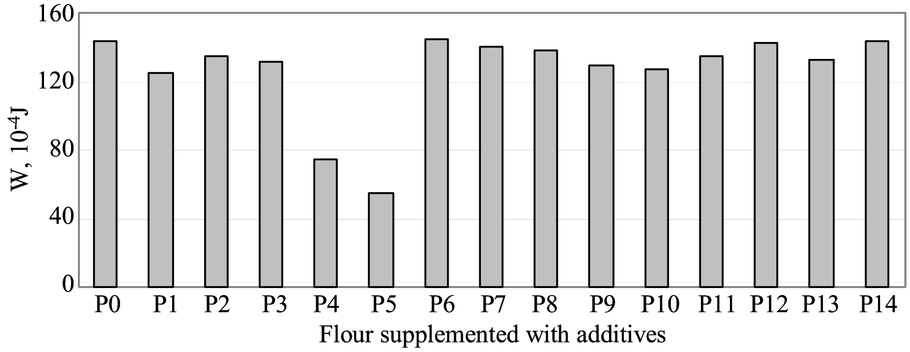

Figure 3. Dough work of the flour without additives (P0) and of the flour supplemented with additives (P1, …, P14)

The flour supplemented with additives allowed obtaining dough with higher forming gas capacity, compared to the flour without additives (1528 cm^3). The samples P5, P8 and P14 had the highest forming gas capacity, over 1700 cm^3 (Figure 4).

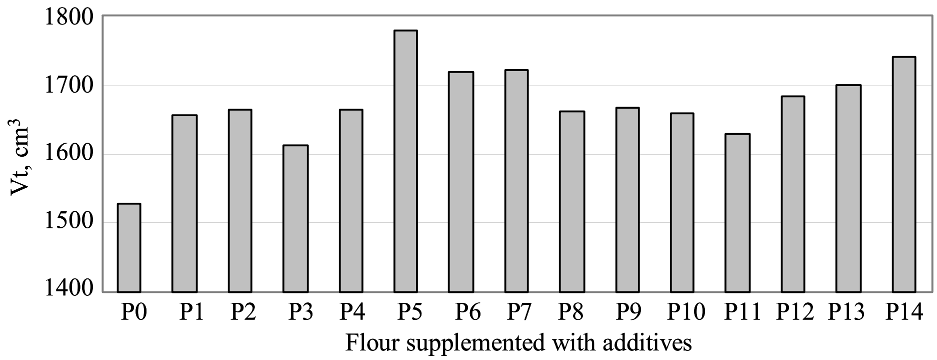

Figure 4. Total volume of gas production (Vt) of the dough obtained from flour without additives (P0) and from flour supplemented with additives (P1, …, P14)

The samples with dough elasticity higher than the optimal values indicated by the alveogram, presented a reduced gas retention capacity (Figures 5). The values of the maximum dough fermentation height (H'm), are higher in case of flour supplemented with the maximum doses of additives (Figure 6). The trend of the gas formation and retention curves allow to two distinct individual situations

(Figure 7) for the optimal time of dough processing, based on the relationship between the times at which dough attains the maximum height (T'1) and the moment when the gas starts to escape from the dough (Tx):

- Tx<T'1, the gas retention coefficient is reduced, when the optimal time for the dough processing is Tx - this situation characterises the flour supplemented with low doses of additives;
- T'1<Tx, when the optimal time of dough processing is T'1 - this situation characterises the flour supplemented with high doses additives.

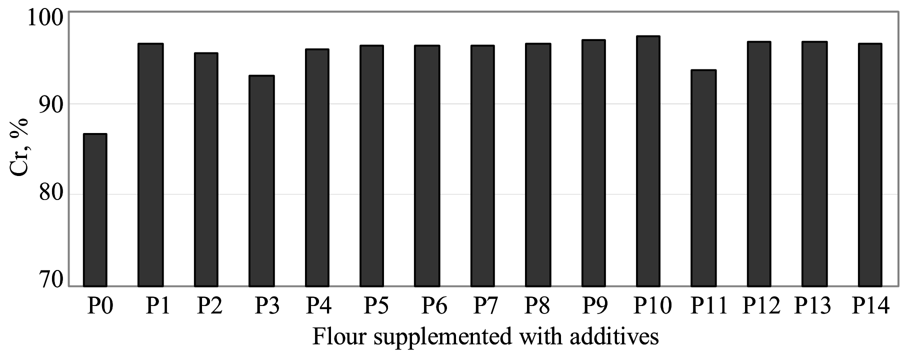

Figure 5. Gas retention capacity (Cr) of the dough obtained from flour without additives (P0) and from flour supplemented with additives (P1, …, P14)

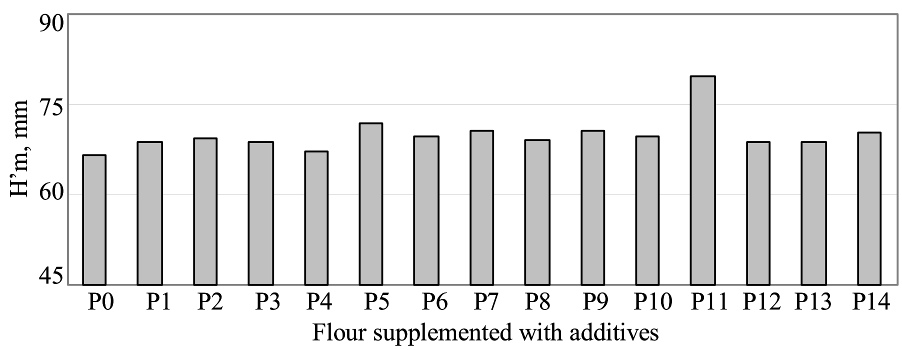

Figure 6. Maximum dough fermentation height (H'm) of the dough obtained from flour without additives (P0) and from flour supplemented with additives (P1, …, P14)

After achieving the maximum torque (1.1 Nm) at a constant temperature of 30ºC, the dough is stable at deformations. The period of time when the torque and the temperature are constant corresponds to stable dough. Through the increase of the additives doses, the dough stability and the protein weakening based on the mechanical work and temperature were reduced (Table 2).

When comparing the samples P4, P8 and P9, with the same doses of additives (2.00 g/kg flour), the lowest dough stability (4.05 min) was obtained in case of P8 prepared with Belpan malt, while the highest dough stability (7.48 min) was obtained in case of P9 prepared with Eka 2000. The Eka 2000 contains α-amylase and xylanases. According to Banu et al. (2011), the increase of the α-amylase dose reduces the dough stability, while different doses of hemicellulases and the xylanases do not induce significant changes of the dough stability.

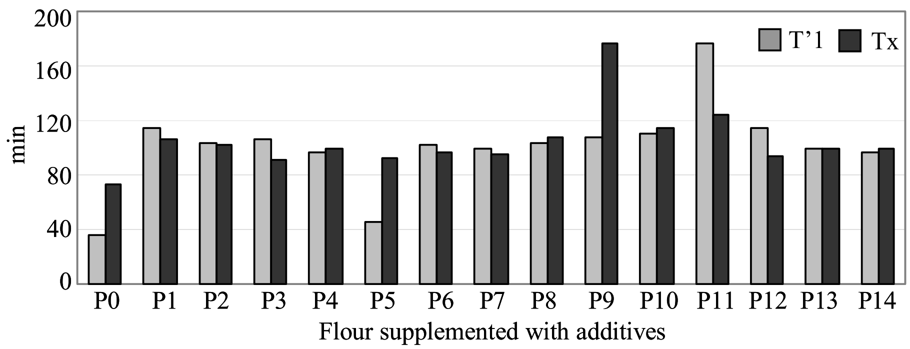

Figure 7. The time at which dough attains the maximum height (T1) and the time when gas starts to escape from the dough (Tx) of the flour without additives (P0) and of the flour supplemented with additives (P1, …, P14)

Table 2. Parameters of the Mixolab curve

Samples	Stability, min	C2, Nm	C3, Nm	C4, Nm	C5, Nm	α, Nm/min	β, Nm/min	γ, Nm/min
P0	9.03	0.49	1.90	2.01	2.91	-0.042	0.400	-0.006
P1	7.15	0.36	1.73	1.59	2.07	-0.048	0.400	-0.038
P2	5.62	0.31	1.63	1.34	1.76	-0.070	0.358	-0.048
P3	5.42	0.29	1.52	1.09	1.48	-0.078	0.354	-0.062
P4	4.05	0.26	1.39	0.84	1.15	-0.084	0.270	-0.063
P5	3.68	0.26	1.29	0.71	0.91	-0.090	0.260	-0.064
P6	6.93	0.35	1.60	1.83	2.56	-0.018	0.362	0.000
P7	5.88	0.33	1.57	1.79	2.48	-0.038	0.324	-0.008
P8	3.75	0.32	1.52	1.73	2.40	-0.034	0.290	-0.022
P9	7.48	0.35	1.61	1.80	2.43	-0.110	0.328	-0.016
P10	6.57	0.33	1.62	1.83	2.53	-0.076	0.312	-0.022
P11	6.40	0.30	1.56	1.78	2.51	-0.080	0.304	-0.032
P12	9.10	0.49	1.98	1.84	2.47	-0.092	0.454	-0.010
P13	9.10	0.42	1.74	1.31	1.78	-0.082	0.444	-0.072
P14	8.62	0.38	1.61	1.03	1.41	-0.050	0.440	-0.084

The samples that contain higher doses of additives presented low values of the β slope (Table 2), which gives indications about starch gelatinization. According to Haros et al. (2006), Collar *et al.* (2007), Rosell *et al*. (2007) and Banu *et al.* (2010a), the flour with high enzymatic activity has low absolute value of the β slope.

Samples P2, P6, P9, P10 and P14 had close values for the couple C3 (1.60-1.63 Nm), but the β slope varied significantly. The β slopes with high values indicate a fast gelatinization processes (Banu *et al.*, 2010a); the highest value of the

β slope was obtained in case of the sample P14 and was of 0.440 Nm/min. The samples with reduced α-amylases activity showed high values of the γ slope (Table 2).
C4 indicating the stability of the starch gel formed is lower for samples with high α-amylases activity (Table 2). According to Banu *et al.* (2011) C4 significantly correlates with the parameters of the rheofermentogram (Tx, Vt, and Vr), the falling number, the specific volume of the bread and its porosity.
The couple C5 gives indications about starch retrogradation (Haros *et al.,*2006; Collar *et al.*, 2007; Rosell *et al.*, 2007; Kahraman *et al*., 2008) and had smaller values for samples with higher additives doses (Table 2).

Conclusions

The Mixolab is an apparatus capable to enlighten dough rheological properties of flour supplemented with additives. The changes of the Mixolab parameters depended on the value of the falling number. Mixolab characteristics C4, C5, β, γ were found to be lower in samples with high doses of additives containing α-amylases.

Acknowledgements

This research was supported by Project 52-132/01.10.2008 financed by the Romanian National Centre for Programme Management (R&D Programme "Partnerships in Priority S&T Areas / 2nd National Plan for Research, Development & Innovation 2007-2013).

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