Estimation of the Baking Quality of Wheat Flours Based on Rheological Parameters of the Mixolab Curve

Iuliana BANU[1], Georgeta STOENESCU[2], Violeta IONESCU[2] and Iuliana APRODU[1]

[1]"Dunărea de Jos" University, Faculty of Food Science and Engineering, Galați, Romania;
[2]Research Laboratory Arcada, Arcada Mill, Lunca Siretului, Romania

Abstract

Banu I., Stoenescu G., Ionescu V., Aprodu I. (2011): **Estimation of the baking quality of wheat flours based on rheological parameters of the Mixolab curve**. Czech J. Food Sci., **29**: 35–44.

The Mixolab device in view of the characterisation of the thermo-mechanical behaviour of ten different flours, and establishing the correlations between the rheological parameters of wheat flour supplemented with different additives such as fungal α-amylase, fungal hemicellulase, and fungal xylanase weres exploted. The rheological measurements were performed using the Mixolab, Alveograph, and Rheofermentometer. Our results indicated significant positive and negative correlations between the parameters investigated. The changes of the Mixolab curve trend depended on the amylase doses. Significant correlations were established also between the Mixolab parameters and the results of the baking tests; the β slope, C2, C3, and C4 were positively correlated with the specific volume of the bread. Taking into account the results obtained, we may conclude that Mixolab is a complex device that renders the evolution of the bread during the entire technological process, from the dough making to the starch retrogradation.

Keywords: Mixolab; Alveograph; Rheofermentometer; dough; baking quality

The nonlinear viscoelastic behaviour of wheat flour dough is mainly due to the continuous gluten matrix and starch granules embedded in it (Edwards *et al.* 2002; Tronsmo *et al.* 2003; Agyare *et al.* 2004; Collar *et al.* 2007). It has typical properties of both solid and liquid bodies, and an intermediary rheological behaviour between the ideal solid and fluid bodies. Therefore, an accurate characterisation of the dough requires estimating rheological parameters such as elasticity, viscosity, relaxation, and creep.

Different empirical methods based on classical Extensograph, Alveograph, Farinograph, and Mixograph instruments are currently employed to obtain accurate data on the baking properties of the respective flour, by simulating the bread making steps (Autio *et al.* 2001; Chung *et al.* 2001; Chiotelli *et al.* 2004; Collar *et al.* 2007).

The kneading properties are usually studied with the Farinograph and Mixograph, which provide information on the rheological properties of the standard firm dough. The stretching properties of the dough give indications about the relationship between the force and deformation, and are studied with the use of the Extensograph and Alveograph.

In the case of the Extensograph method, the dough is submitted to uniaxial deformation, while in the case of the Alveograph method, the dough is submitted to biaxial deformation (Uthayakumaran *et al.* 2002; Dobraszczyk *et al.* 2003; Sliwinski *et al.* 2004). Moreover, the viscous

Supported 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), Project No. 52-132/01.10.2008.

properties of the flour gel can be evaluated on the basis of the gas phase evolution during fermentation by means of amylographic and viscographic methods.

The descriptive empirical methods allow establishing good correlations between the rheological properties of the dough and the contents and quality of the gluten proteins (Konopka *et al*. 2004). The high quality flour is characterised by a high resistance to stretching and moderate extensibility of the dough. The high resistance is typical of the unsticky dough, while the moderate extensibility allows obtaining bread with a large volume (Dobraszczyk *et al*. 2003).

This study was focused on a new generation instrument, Mixolab, which measures the torque (Nm) produced by mixing the dough between two kneading arms, where the dough is subjected to dual mixing and temperature constrains (Rosell *et al*. 2007; Kahraman *et al*. 2008; Ozturk *et al*. 2008). The Mixolab technique allows a complete characterisation of flour in terms of (*i*) proteins quality by determining their water absorption, stability, elasticity, and weakening properties; (*ii*) starch behaviour during gelatinisation and retrogradation; (*iii*) consistency modification when adding additives, and (*iv*) enzymatic activity of proteases, amylases, etc. (Collar *et al*. 2007; Kahraman *et al*. 2008).

The present study was aimed at (*i*) establishing the correlation between thermo-mechanical behaviour and gluten quality of ten different flours, (*ii*) investigating the trend of the Mixolab plot for one flour supplemented with different commonly used additives (fungal α-amylase, fungal hemicellulase, and fungal xylanase), and establishing the correlations between the rheological parameters recorded using the Mixolab, Alveograph, and Rheofermentometer instruments for the supplemented flour.

MATERIALS AND METHODS

White flours were obtained by milling (Buhler equipment) wheat (2007 crop) using the direct extraction (76%) method. The capacity of the mill was 80 t/24 hours. The flours were sampled according to the standard SR EN ISO 13690:2007 (Uthayakumaran *et al*. 2008).

The supplemented flour was obtained by thorough homogenisation of small quantities (1 kg) of white flour with appropriate additives doses, as recommended by the provider (Enzymes & Derivates, Neamt, Romania) to obtain: 0.01, 0.02, 0.03, and 0.04 g fungal α-amylase/kg flour, 0.04, 0.05, 0.06, and 0.10 g fungal hemicellulase/kg flour, and 0.01, 0.02, and 0.03 g fungal xylanase/kg flour, respectively.

The enzymes, α-amylase (Clarase Gplus, from *Aspergillus oryzae*), fungal hemicellulase (Belpan Hemi C, from *Aspergillus oryzae*), and fungal xylanase (Belpan Xila L) were purchased from Enzymes & Derivates (Neamt, Romania).

Evaluation of physical-chemical properties. The physical-chemical characteristics of the wheat and flour were evaluated as follows:

– the moisture content by means of the AACC 44-51 method (Uthayakumaran *et al*. 2000);
– the ash content by means of the SR ISO 2171:2002 method (ASRO 2008);
– the gluten index by means of the SR ISO 21415-1:2007 method (Sistem Glutomatic 2200, Perten Instruments AB) (Uthayakumaran *et al*. 2008);
– the wet gluten content using the SR ISO 21415-2:2007 method (Sistem Glutomatic 2200, Perten Instruments AB) (Uthayakumaran *et al*. 2008);
– the Zeleny test using the ISO 5529 method (Sadkiewicz Instruments Polonia, model SWD) (Uthayakumaran *et al*. 2008);
– the falling number by means of the AACC 56-81B method (Falling Number, model 1400PT, Perten Instruments AB) (Uthayakumaran *et al*. 2000).

Evaluation of rheological properties. The rheological characteristics were tested by means of:

– the NG Chopin Alveograph using the AACC 54-30 method (Uthayakumaran *et al*. 2000);
– 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 Chopin Mixolab using the standard "Chopin+" protocol; the running parameters of the device are depicted in Table 1. A typical curve recorded by the Mixolab is shown in Figure 1. The parameters enlightened in the curve are:

C1 (Nm – maximum torque during mixing;
C2 (Nm) – measures the protein weakening based on the mechanical work and temperature;
C3 (Nm) – expresses the starch gelatinisation;
C4 (Nm) – indicates the stability of the starch gel formed;
C5 (Nm) – measures the starch retrogradation during the cooling stage;

Table 1. Settings of the Mixolab

Parameter	Value
Mixing rate (rpm)	80
Dough weight (g)	75
Tank temperature (°C)	30
Temperature of the first plateau (°C)	30
Duration of the first plateau (min)	8
Temperature of the second plateau (°C)	90
First temperature gradient (°C/min)	4
Duration of the second plateau (min)	7
Second temperature gradient (°C/min)	4
Temperature of the third plateau (°C)	50
Duration of the third plateau (min)	5
Total analysis time (min)	45

α – represents the slope of the curve between the end of the period of 30°C and C2; gives indication about the rate of the proteins thermal weakening;

β – represents the slope of the curve between C2 and C3; gives indications about the gelatinisation rate;

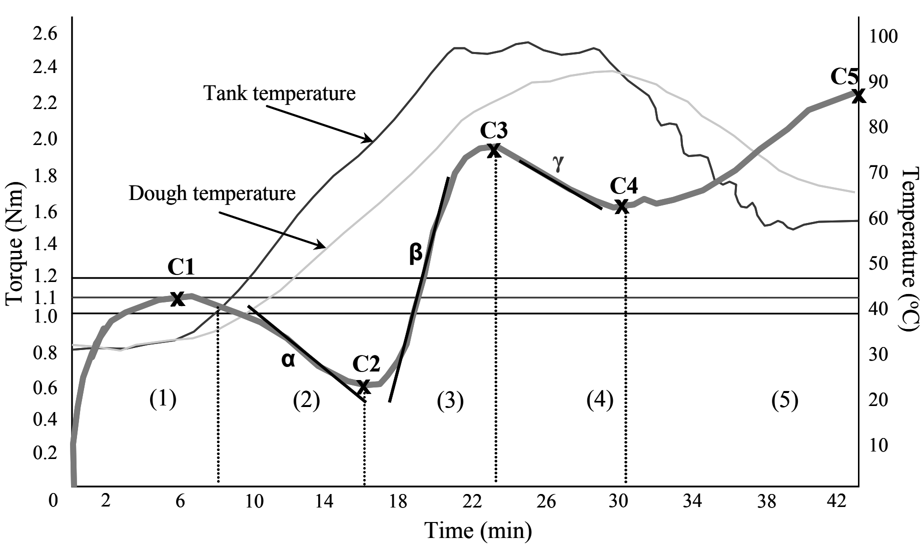
γ – represents the slope of the curve between C3 and C4; gives indications about the rate of enzymatic hydrolysis.

The baking test. The one-stage method was used to prepare dough using a laboratory Philips HR mixer. The dough was prepared at 29–30°C by mixing flour (100%), water (according to the water absorption capacity indicated by the Mixolab), salt (1.5%), and yeast (3%). The dough was fermented at 30°C for 150 min in a laboratory leavener. Two re-kneading of 30 s each were then performed after 60 min and 120 minutes. The dough was then divided into two pieces which were moulded and placed in trays. After the final leavening of 30 min, the trays were put into the oven (Micro 4T, Mondial Forni, Italy). The samples were baked at 230°C for 30 min (when placing them into the oven, the steam tap was turned on for 10–15 s). After 2 h cooling, each sample was weighed and analysed in terms of specific volume (cm^3/100 g bread) and porosity of the crumb (Uthayakumaran *et al*. 2008).

The bread volume was determined through the rapeseed displacement method using a bread volumeter (Fornet, Chopin, France). The bread porosity (%) was estimated by cutting a piece of crumb from a 60 mm slice obtained from the middle of a loaf with a cylindrical sharpened brass perforator (internal diameter 45 mm). The cylindrically cut crumb was afterwards weighed and the total volume of the pores in the bread crumb was determined on the basis of its known density (1.310 g/cm^3) and weight.

All tests were carried out at least in triplicates, and the average values were used.

Statistical analysis. The multiple regression analysis was performed using the package Statistica for Windows 4.3 to calculate the level of significance for the correlation coefficients.



Zone (1) – dough development (constant temperature. 30°C);
Zone (2) – thermal weakening of the proteins
Zone (3) – starch gelatinization
Zone (4) – enzymatic activity constant heating rate
Zone (5) – starch retrogradation

Figure 1. Typical curve recorded by the Mixolab Zone

RESULTS AND DISCUSSION

Thermo-mechanical behaviour of flour vs. gluten quality

White flour was obtained from eleven samples of Romanian common wheat from 2007 crop. The flours obtained were characterised in terms of the most important specific parameters such as ash content, wet gluten content, and Zeleny test (Table 2), and their thermo-mechanical behaviour was evaluated by means of Mixolab device (Table 3).

The quantity and quality of the wet gluten of flour are the essential parameters determining the baking quality. Different experimental studies established the correlations between the gluten quality and Alveograph parameters (Konopka *et al*. 2004) as well as between the gluten quality and Rheofermetomer parameters (Švec & Hrušková 2004). Concerning the correlations between the Mixolab characteristics and wet gluten content and Zeleny test (Table 4) as estimated in the present work for the ten flours analysed, significant correlations were observed between the Zeleny test and C3 and C4. Moreover, the Mixolab stability correlated with the Zeleny test and wet gluten content. Our results agree with the observations of Kahraman *et al*. (2008) who indicated a significant correlation between the Zeleny test and C1, C3, C4, and C5.

Table 2. Wet gluten content and Zeleny test of the flour sample*

Sample	Ash content (%)	Wet gluten content (%)	Zeleny test (ml)
1	0.52	26.44	24
2	0.53	25.68	21
3	0.48	26.40	19
4	0.53	25.52	22
5	0.52	27.68	36
6	0.49	27.68	35
7	0.51	26.00	33
8	0.49	30.64	31
9	0.49	28.52	29
10	0.52	31.92	36
11	0.51	23.50	32

*The results are given at 14% moisture basis

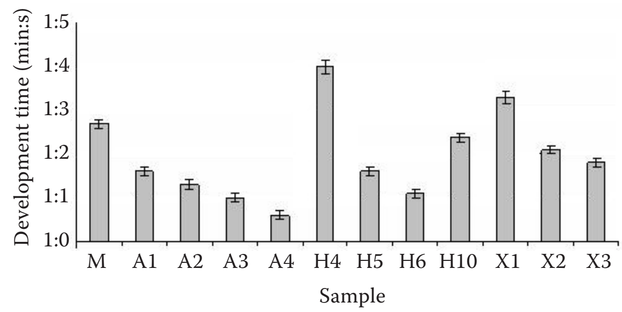
Table 3. Mixolab characteristics of the flours

Sample	C1	C2	C3	C4	C5	α slope	β slope	γ slope	Amplitude (Nm)	Stability (min:s)
	(Nm)									
1	1.11	0.50	2.40	2.01	3.35	–0.016	0.658	–0.012	0.10	9:50
2	1.20	0.51	2.40	2.02	3.42	0.000	0.668	0.004	0.06	8:57
3	1.14	0.46	2.35	1.94	3.23	–0.044	0.574	–0.048	0.09	6:21
4	1.14	0.45	2.30	1.89	3.11	–0.014	0.548	–0.170	0.07	6:22
5	1.11	0.51	2.13	1.78	3.14	–0.010	0.502	–0.002	0.08	9:59
6	1.13	0.48	2.17	1.83	3.04	–0.060	0.532	–0.020	0.09	8:46
7	1.11	0.48	2.07	1.66	2.81	–0.052	0.500	–0.068	0.08	9:28
8	1.10	0.46	2.26	1.98	3.46	–0.034	0.064	–0.218	0.06	9:44
9	1.09	0.43	2.29	1.97	3.40	–0.022	0.118	–0.440	0.06	8:54
10	1.12	0.47	1.81	1.49	2.45	0.000	0.400	–0.028	0.08	9:37
11	1.04	0.41	2.09	1.68	2.93	–0.020	0.536	–0.292	0.07	8:36
Mean ± SD	1.11 ± 0.04	0.47 ± 0.03	2.21 ± 0.18	1.84 ± 0.17	3.12 ± 0.31	–0.02 ± 0.02	0.463 ± 0.198	–0.117 ± 0.145	0.08 ± 0.013	8:46 ± 1:16

Table 4. Correlation coefficients between Mixolab characteristics and wet gluten content and Zeleny test

Correlation		Correlation coefficient
Zeleny test:	C3	–0.79*
	C4	–0.68*
	stability	0.68*
Wet gluten:	C3	–0.63*
	stability	–0.69*

*$P < 0.05$



M – blanc sample; A1 – 1 g α-amylase/100 kg flour; A2 – 2 g α-amylase/100 kg flour; A3 – 3 g α-amylase/100 kg flour; A4 – 4 g α-amylase/100 kg flour; H4 – 4 g hemicellulase/100 kg flour; H5 – 5 g hemicellulase/100 kg flour; H6 – 6 g hemicellulase/100 kg flour; H10 – 10 g hemicellulase/100 kg flour; X1 – 1 g xylanase/100 kg flour; X2 – 2 g xylanase/100 kg flour; X3 – 3 g xylanase/100 kg flour. Error bar represents standard deviation

Figure 2. Dough development time as a function of enzymes dose

Rheological behaviour of the supplemented flour

Dough development. Because of their low baking properties, the flours with low gluten values and high FN values are commonly supplemented with different enzymes (Shah *et al*. 2006; Caballero *et al*. 2007). In order to study the influence of fungal α-amylase, fungal hemicellulase, and fungal xylanase on the rheological behaviour of the dough, the flour sample with the lowest baking quality (wheat gluten content of 23.5%) was chosen out of the eleven wheat samples. The main quality indices of the blanc sample (flour without additives) are the moisture content of 13.5% and FN of 502 s which recommend the addition of α-amylase to improve its baking properties.

The wheat flour used was supplied with different concentrations of fungal α-amylase, fungal hemicellulase, and fungal xylanase, and each sample was characterised in terms of rheological parameters by means of Mixolab (Figures 2, 4, and 5), Alveo-

Table 5. Parameters of the alveogramme, rheofermentogram and baking quality of the flour supplement with different enzymes doses (For label notations see Figure 2.)

Sample	M	A1	A2	A3	A4	H4	H5	H6	H10	X1	X2	X3
Alveogramme parameters												
P (mm)	77	69	75	67	64	78	79	78	78	80	78	80
L (mm)	72	82	59	70	97	70	59	73	44	59	68	63
P/L	1.07	0.84	1.27	0.96	0.66	1.11	1.34	1.07	1.77	1.36	1.15	1.27
G	18.9	20.2	17.1	18.6	21.9	18.6	17.1	19	14.8	17.1	18.4	17.7
$W \times 10^{-4}$ J	201	200	177	175	212	196	179	203	136	177	191	185
Ie (%)	55.4	57.8	58.4	58.3	58.6	57.7	54.2	55.4	45.3	52.4	54.1	53.6
Rheofermentogram parameters												
*T*1 (min)	180	63	174	180	34	79	156	180	69	180	180	180
H'm (mm)	58.5	66.0	64.7	66.8	65.4	67.1	64.3	59.4	66.2	62.5	64.2	64.5
Tx (min)	67	108	106	118	114	94	102	106	103	100	111	96
Vt (ml)	1309	1624	1472	1590	1571	1468	1418	1343	1486	1420	1435	1413
Vr (ml)	1157	1558	1392	1543	1531	1424	1369	1299	1440	1379	1402	1367
Baking quality												
Vsp (cm^3per 100 g) bread	338.0	376.0	374.6	357.7	350.1	307.0	330.4	289.4	333.3	321.7	327.0	334.3
P (%)	78.0	82.0	82.7	83.5	82.6	76.9	79.0	74.9	80.6	77.7	78.0	76.3

Table 6. Correlations between parameters of the dough development zone of the Mixolab curve and parameters of the alveogramme and rheofermentogram

Correlation		Correlation coefficient
Development time	P	0.76**
	L	0.88**
	P/L	0.60*
	G	0.84*
	H'm	0.80*
Dough stability	P	0.84*
	W	–0.95**
	P/L	0.76*
	Ie	–0.60*
	Tx	–0.55*
	Vt	–0.71**
	Vr	–0.62*
	bread specific volume	–0.66**
	porosity	–0.82***

*$P < 0.05$, **$P < 0.01$, ****$P < 0.001$

Table 7. Correlations between parameters of the proteins' weakening zone of the Mixolab curve and parameters of the alveogramme and rheofermentogram

Correlation		Correlation coefficient
α	P	0.84***
	P/L	0.51*
	Ie	–0.69**
	Vt	–0.79***
	Vr	–0.75**
	H'm	–0.87**
	*T*1	–0.51**
C2	P	0.87***
	P/L	0.55*
	Vt	–0.70**
	Vr	–0.57*
	porosity	–0.78***
C1–C2	*Cr*	–0.67**
	bread specific volume	–0.73**

*$P < 0.05$, **$P < 0.01$, ****$P < 0.001$

graph, and Rheofermentometer, and in terms of the baking quality (Table 5).

The results of the rheological tests indicate significant positive correlations between the development time of the dough, registered with Mixolab at 30°C until reaching the maximum consistency during mixing, and the parameters of the alveogramme and rheofermentogram (Table 6). Therefore, between the development time of the dough and the P/L ratio a correlation of 0.60 ($P < 0.05$) was obtained, while the correlation between the development time and the H'm was 0.80 ($P < 0.05$).

In analysing the results presented in Figure 2, it can be seen that the increase of the enzymatic activity of the dough involves the decrease of the development time. In the case of the sample with α-amylase the development time was shorter than that characterising the blanc sample, while small doses of hemicellulase and xylanases increased the development time of the dough (Figure 2). The longest time was obtained when adding 4 g hemicellulase/100 kg flour, and the development time of the dough increased after reaching a minimum value at 6 g hemicellulase/100 kg flour.

After achieving the maximum torque at a constant temperature of 30°C, the dough was stable at deformations. The period of time when the torque and the temperature are constant corresponds to stable dough. We could note significant positive and negative correlations between the dough stability and parameters of the alveogramme and of the rheofermentogram (Table 6). The quality indices of the bread, such as specific volume and porosity, were significantly negatively correlated with the stability of the dough, the correlation coefficients registered being –0.66 ($P < 0.001$) and –0.82 ($P < 0.001$), respectively.

The increase of the α-amylase dose reduced the dough stability (zone (1) in Figure 3), while different doses of hemicellulases and xylanases did not induce significant changes of the dough stability (Figure 4).

Proteins weakening. The zone (2) in Figure 1 gives indications about the dough weakening due to protein unfolding, which is coupled with torque decrease. The dough weakening (C1–C2) characterising zone (2) is smaller compared to the thermal weakening (C3–C4) after 90°C (zone (4) in Figure 1). Actually, the temperature increase destabilises and unfolds the proteins, which become hydrophobic (Haros *et al.* 2006; Rosell *et al.* 2007). The rise of the dough temperature in the Mixolab implies protein denaturation involving the release of a large quantity of water. There is a significant negative correlation between the dough weakening (C1–C2) registered in the Mixolab curve and the gas retention coefficient (*Cr*) in

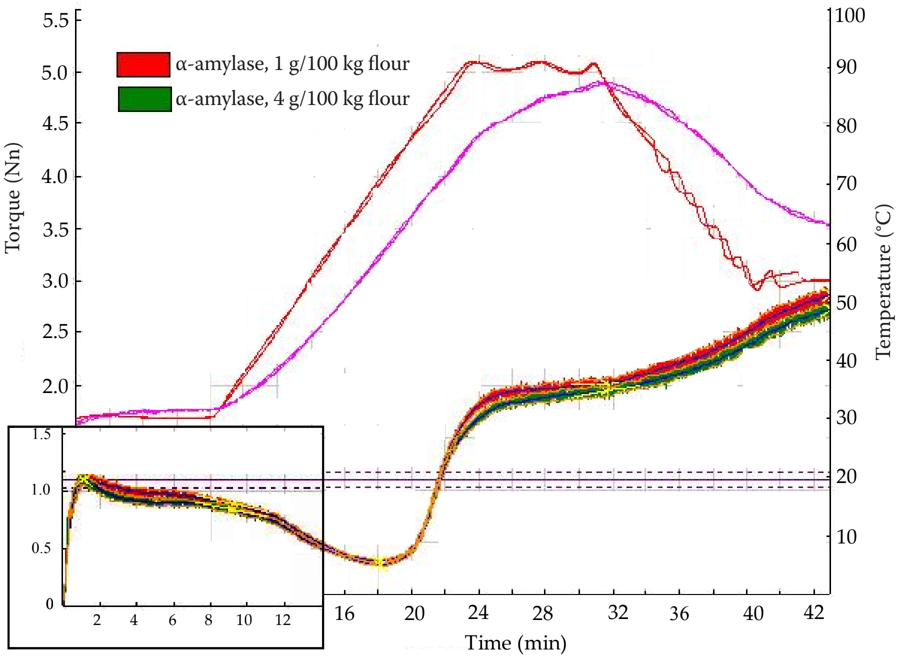


Figure 3. Influence of the α-amylase dose on the dough stability

the rheofermentogram (–0.67, $P < 0.01$), as well as between–0.73, $P < 0.01$).

As depicted in Figure 5, when using hemicellulases and xylanase, the processibility was improved by limiting the dough weakening. In these cases, the dough weakening is reduced due to the ability of these enzymes to hydrolyse non-starch polysaccharides, releasing fractions capable of absorbing the water released by the proteins. Within the temperature range of zone (2), the proteolytic enzymes have an optimal activity, represented in the Mixolab curve by the α slope. According to our results, the α slope correlated both with the parameters of the alveogramme (P, P/L, *Ie*) and with those of the rheofermentogram (*Vt*, *Vr*, H'm, *T*1) (Table 7). The minimum values of the torque (C2) significantly correlate with the arameters of the alveogramme (P, P/L, *Ie*) and rheofermentogram (*Vt*, *Vr*), but also with the results of the baking test – the specific volume and porosity (Table 7).

As concerns the minimum torque (C2), we noticed a decrease when using α-amylase, while in the case of hemicellulases and xylanases additions,there were no significant differences with respect to the blanc sample (insert in Figure 6).

Starch gelatinisation

At the minimum torque (C2), the dough reaches the specific temperature for the beginning of starch gelatinisation. In the case of the blanc sample, the minimum torque (C2) was reached faster (17.00 min:s) at a temperature of 55.4°C, compared to the samples with α-amylase, where the value of the minimum torque was achieved after 18:22 min:s and was

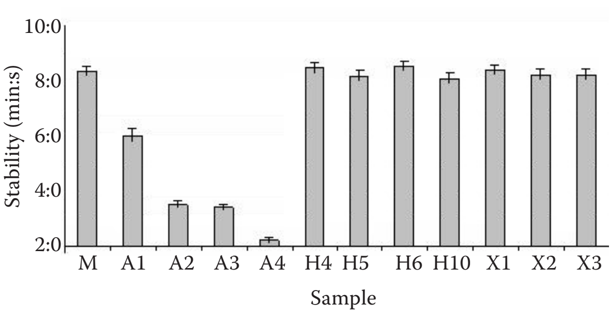


Figure 4. Dough stability as a function of additives dose (For label notations, see Figure 2.). Error bar represents standard deviation

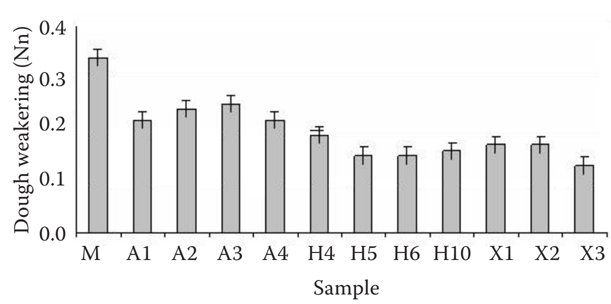


Figure 5. Dough weakening as a function of additives dose (For label notations, see Figure 2.) Error bar represents standard deviation

specific to a higher temperature (57.6–58.2°C). The starch gelatinisation rate recorded in the second heating stage (zone (3)) for temperatures above 55°C is defined by the β slope. The positive correlation between the β slope and falling number (0.85, P < 0.001) gives indications about the hydrolytic activity of α-amylase during the heating period. The dough heating coupled with the water released by the thermally denaturated proteins causes the starch gelatinisation. The starch granules swelling and hydration induce the dough consistency increase. This process is stopped when the mechanic shear forces and temperature lead to the physical division of the granules (Rosell *et al*. 2007).

According to our results, α-amylase changed significantly the value of the β slope which ranged between 0.006 and 0.030 Nm/min. In the case of the samples with added hemicellulase and xylanase, the β slope ranged between 0.404 and 0.586 Nm/min, comparable with the blanc sample (0.536 Nm/min).

We could note significant correlations between the maximum torque (C3) and parameters of the alveogramme (P, *Ie*) and of the rheofermentogram (*Tx*, *Vt*, *Vr*, *Cr*), as well as between C3 and the falling number and parameters of the baking test (specific volume and porosity) (Table 8).

Enzymatic activity

When reaching the plateau of 90°C (zone (4)), the rate of the dough consistency decrease is given by the γ slope. Significant correlations were found between the γ slope and *Ie* (0.79, P < 0.05) and between the γ slope and *Cr* (–0.84, P < 0.001). Moreover, C4 significantly correlated with Ie, but also with the parameters of the rheofermentogram (*Tx*, *Vt*, and *Vr*), the falling number, the specific volume of the bread and its porosity (Table 8).

The volume of the gas formed during the fermentation increased with the addition of enzymes (1413–1486 cm^3) as compared with the blanc sample (1309 cm^3). This phenomenon is due to the increase of the fermentable carbohydrates quantity which consequently increases the quantity of CO_2 formed during fermentation (Shah *et al*. 2006). Moreover, the capacity of the dough to retain gas increases from 88.4% (blanc sample) to 96.5–97.7% when enzymes are added.

Starch retrogradation

During the period of cooling the starch gel (zone (5) in Figure 1), the dough consistency increases up to C5.

C5 significantly correlates with P and Ie, as well as with the parameters of the rheofermentogram (*Tx*, *Vt*, and *Vr*), falling number, bread specific volume, and porosity (Table 8).

The torque (C5) corresponding to the end of the starch retrogradation period reached the lowest values in the samples with α-amylases (2.78 ± 0.062 Nm); C5 was 2.93 Nm for the blanc sample,

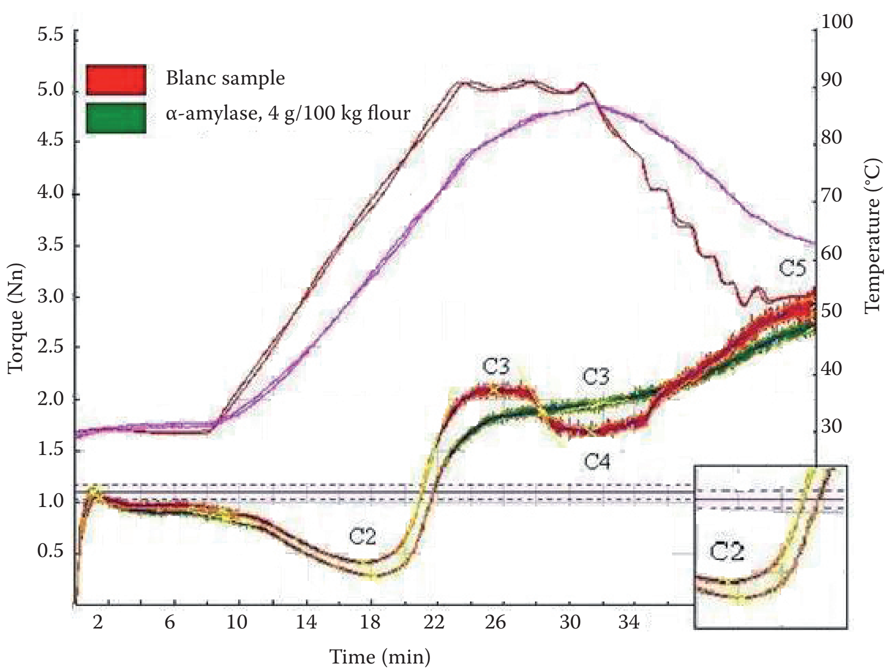


Figure 6. Mixolab curve for the blanc sample and the sample supplied with 4 g α-amylase/100 kg flour

Table 8. Correlations between torque values (C3, C4, C5) of the Mixolab curves and parameters of the alveogramme. and rheofermentogram. falling number and results of the baking test

Correlation		Correlation coefficient
C3	P	–0.82***
	Ie	0.66**
	Tx	0.54*
	Vt	0.82***
	Vr	–0.82*
	Cr	–0.89**
	FN	–0.84***
	bread specific volume	0.80***
	porosity	0.85***
C4	*Ie*	–0.67**
	Tx	–0.54*
	Vt	–0.80***
	Vr	–0.68**
	FN	0.85***
	bread specific volume	–0.78***
	porosity	–0.85***
C5	P	0.85***
	Ie	–0.67**
	Tx	–0.54*
	Vt	–0.81***
	Vr	–0.88**
	FN	0.85***
	bread specific volume	–0.79***
	porosity	–0.85***

*$P < 0.05$, **$P < 0.01$, ****$P < 0.001$

2.94 ± 0.009 Nm for the sample with hemicellulase, and 2.96 ± 0.061 Nm for the samples with xylanases, respectively. As concerns the sample with α-amylase, our results agree with the observations of Rojas *et al.* (1999).

The rheological behaviour of the dough in zones (4) and (5) of the Mixolab curve describing the starch retrogradation and gelatinisation process was strongly influenced when adding α-amylase (Figure 6). In the case of the blanc sample, C4 is placed in the curve area, while as to the samples with α-amylase, C4 and C5 cannot be identified and C3 is recorded on an ascending slope at the end of the time established by the protocol.

In the case of the blanc sample, one can note a plateau of minimum values of the torque where C4 is placed (typical behaviour), while in the case of the samples with α-amylase, C3, C4, and C5 are placed on an ascending straight line (Figure 6). Moreover, for the sample with α-amylase the β values are very small, while γ completely disappears.

CONCLUSIONS

The Mixolab is a new apparatus which measures the dough torque associated with mixing and temperature constraints. Recent experiments (Collar *et al.* 2007; Kahraman *et al.* 2008) showed that the Mixolab is capable of determining dough the rheological properties of bread dough. Kahraman *et.al* (2008) investigated the possibility of using Mixolab to predict the quality of from cakes different wheat flours. Mixolab characteristics C2, C3, C4, and C5 were found to be significantly correlated with the volume index while C5 was correlated with the hardness of the cakes (Kahraman *et al.* 2008).

Moreover, Collar *et al.* (2007) compared the Mixolab test with other methodologies available (pasting method performed by the Rapid Visco Analyser, the gluten index, and uni- and bi-axial extensional measurements) in order to explore its use as a suitable technique for determining the bread dough rheological properties.

Here, we performed a comparative study of the rheological behaviour of the dough using the Mixolab, Alveograph, and Rheofermentometer instruments. Our results indicated significant positive and negative correlations between the parameters investigated. The changes of the Mixolab curve trend depended on the value of the falling number and were correlated with the results of the baking tests. In agreement with the observations by Kahraman *et al.* (2008) and Collar *et al.* (2007) we may conclude that Mixolab is a promising tool for the rheological assessment of the bread dough.

Abbreviations

FN – falling number
P – dough elasticity
L – dough extensibility
G – dough blowing index
W – work (10^{-4} J)
Ie – flexibility index

Vt – total volume of CO_2
Vr – volume of the gas retained in the dough at the end of the procedure
Cr – retention coefficient
H'm – maximum dough fermentation height
*T*1 – the time at which dough attains the maximum height
Tx – the time when gas starts to escape from the dough

References

Agyare K.K., Xiong Y.L., Addo K., Akoh C.C. (2004): Dynamic rheological and thermal properties of soft wheat flour dough containing structured lipid. Food Engineering and Physical Properties, **69**: 297–302.

Autio K., Flander L., Kinnunen A., Heinonen R. (2001): Bread quality relationship with rheological measurements of wheat flour dough. Cereal Chemistry, **78**: 654–657.

Caballero P.A., Gomez M., Rosell C.M. (2007): Improvement of dough rheology, bread quality and bread shelf-lifeby enzymes combination. Journal of Food Engineering, **81**: 42–53.

Chiotelli E., Rolée A., Le Meste M. (2004): Rheological properties of soft wheat flour doughs: effect of salt and triglicerides. Cereal Chemistry, **81**: 459–468.

Chung O.K., Ohm J.B., Caley S.M., Seabourn B.W. (2001): Prediction of baking characteristics of hard winter wheat flours using computer – Analyzed Mixograph parameters. Cereal Chemistry, **78**: 493–497.

Collar C., Bollain C., Rosell C.M. (2007): Rheological behaviour of formulated bread doughs during mixing and heating. Food Science and Technology International, **13**: 99–107.

Dobraszczyk B.J., Morgenstern M.P. (2003): Rheology and the breadmaking process. Journal of Cereal Science, **38**: 229–245.

Edwards N.M., Dexter J.E., Scanlon M.G. (2002): Starch participation in durum dough linear viscoelastic properties. Cereal Chemistry, **79**: 850–856.

Haros M., Ferrer A., Rosell C.M. (2006). Rheological behaviour of whole wheat flour, In: IUFoST – World Congress 13th World Congress of Food Science & Technology. DOI 10. 1051/UFoST:20060681

Kahraman K, Sakýyan O., Ozturk S., Koksel H., Sumnu G, Dubat A. (2008): Utilization of Mixolab1 to predict the suitability of flours in terms of cake quality. European Food Research Technology, **227**: 565–570,

Konopka I., Fornal L., Abramczyk D., Rothkaehl J., Rotkiewicz D. (2004): Statistical evaluation of different technological and rheological tests of Polish wheat varieties for bread volume prediction. International Journal of Food Science and Technology, **39**: 11–20.

Ozturk S., Kahraman K., Tiftik B., Koksel H. (2008): Predicting the cookie quality of flours by using Mixolab. European Food Research Technology, **227**: 1549–1554.

Rojas J.A., Rosell C.M, Benedito C. (1999): Pasting properties of different wheat flourhydrocolloid systems. Food Hydrocolloids, **13**: 27–33.

Rosell C.M., Collar C., Haros M. (2007): Assessment of hydrocolloid on the thermomechanical properties of wheat using the mixolab. Food Hydrocolloids, **21**: 452–462.

Shah A.R., Shah R.K., Madamwar D. (2006): Improvement of the quality of whole wheat bread by supplementation of xylanase from *Aspergillus foetidus*. Bioresource Technology, **97**: 2047–2053.

Sliwinski E.L., Kolster P., van Vliet T. (2004): On the relationship between large-deformation properties of wheat flour dough and baking quality. Journal of Cereal Science, **39**: 231–245.

Švec I., Hrušková M. (2004): Wheat flour fermentation study. Czech Journal of Food Sciences, **22**: 17–22.

Tronsmo K.M., Magnus E.M., Baardseth P., Schofield J.D., Aamondt A., Faergestad E.M. (2003): Comparison of small and large deformation rheological properties of wheat dough and gluten. Cereal Chemistry, **80**: 587–595.

Uthayakumaran S., Newberry M., Phan-Tien N., Tanner R. (2000): AACC Approved Methods. American Association of Cereal Chemists, St. Paul.

Uthayakumaran S., Newberry M., Phan-Tien N., Tanner R. (2002): Small and large strain rheology of wheat gluten. Rheologica Acta, **41**: 162–172.

Uthayakumaran S., Newberry M., Phan-Tien N., Tanner R. (2008): ASRO Romanian Standards Cataloque, Bucharest, Romania.

Received for publication February 20, 2009
Accepted after corrections August 25, 2010

Corresponding author

Prof. Iuliana Banu, Dunarea de Jos Galati University, Faculty of Food Science and Engineering, 111, Domneasca St., 800201 Galați, Romania
tel.: + 40 236 460 165, e-mail: juliana.banu@ugal.ro