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ORIGINAL RESEARCH PAPER

EFFECT OF THE INDUSTRIAL MILLING PROCESS ON THE RHEOLOGICAL BEHAVIOR OF DIFFERENT TYPES OF WHEAT FLOUR

Iuliana Aprodu[1*], Iuliana Banu[1], Georgeta Stoenescu[2], Violeta Ionescu[2]

[1] "Dunarea de Jos" University of Galati, Faculty of Food Science and Engineering, 111, Domneasca St., 800201, Romania
[2]Research laboratory Arcada, Arcada Mill, Lunca Siretului, Zonă Banda Barbosi /1 bis, 800416, Romania

*Corresponding author: iuliana.aprodu@ugal.ro

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Abstract: In the milling process a large number of milling streams are obtained. These fractions are usually combined into a single composite product, but it is possible to select for blending certain fractions to obtaining different types of flours. In this work the rheological behavior, of the industrial flours obtained in different extraction levels was analyzed using Mixolab and Alveograph devices. Our results showed that the flour extraction rate is an important factor influencing rheological behavior. When by the milling process were obtained two types of flour, the flour with high ash content presented higher values of C3, C4 and C5 torques compared to flour with lower ash content. Therefore, the quality of the white flour obtained from wheat milling at different extraction levels highly depends on the flour fractions that are selected for blending.

Keywords: *wheat, milling process, flour, quality prediction, Mixolab, Alveograph*

INTRODUCTION

The objective of milling is to separated the endosperm from the kernel, and gradually grind the endosperm into a high number of milling streams flour [1 – 5]. These fractions are usually combined into a single composite product based on the balance between yield and quality, to get flours with specific characteristics. The quality of the resulting flour is given by the composition of the different mill streams that are selected for blending and the functionality of the different components. Pure white four can be obtained by accepting a low extraction, but as endosperm extraction rates approach the theoretical maximum of 81 – 84%, the flour becomes increasingly contaminated with bran [1]. White flour is generated when the extraction rate is 75% or less. If the extraction rate exceeds 80%, the flour will contain bran particles, and if the flour extraction approaches 100%, whole meal flour is obtained [6].
The aim of the present study was to investigate the influence of the industrial milling process on the rheological behavior of the flour obtained by milling the wheat at different extraction levels. In order to investigate the rheological behavior of the dough the Mixolab and Alveograph devices were used.
Using the Mixolab it is possible to make a complete characterization of the flours in terms of: (i) proteins' quality by determining their water absorption, stability, elasticity, and weakening properties; (ii) starch behavior during gelatinization and retrogradation; (iii) consistency modification when adding additives and (iv) enzymatic activity of the proteases, amylases etc [7 – 8].

MATERIALS AND METHODS

Five Romanian wheat varieties (harvest 2007) were used for milling. Wheat samples were milled in an industrial mill (Arcada Mill, Galati, Romania) in order to obtain the mill streams. Every wheat sample was milled twice on two different days (2 × 2). The capacity of the mill was 80 t/24 h. Previously the wheat grains were conditioned to 16% moisture and set for 12 h to homogenize the grain humidity. Four break streams (B1/B2, B3, B4 and B5f), thirteen reduction streams (C1I, C1II, C1III, C2/C3I, C2/C3II, C2/C3III, C4I, C5I, C6I, C7I, C8I, C9I, C9II), one break reduced fraction (DIV), and a bran finisher flour (BF) were obtained. These mill streams were combined to obtain flours with different characteristics: (i) white flours of 77% extraction with 0.55% ash content; (ii) white flours of 20% extraction with 0.45% ash content, and white flours of 60% extraction with 0.55% ash content; (iii) white flours of 45% extraction with 0.55% ash content, and 37% extraction brown flours with 1.1% ash content (Table 1). The flours were sampled according to the standard SR EN ISO 13690:2007. The whole wheat flour was obtained by grounding the wheat in a laboratory mill (Perten Mill 3100).

Evaluation of physical-chemical properties

The physical-chemical properties of the flour were determined as follows:
- the moisture content through the AACC 44-51 method [9];

- the ash content through the SR ISO 2171:2002 method [10];
- the gluten index through the SR ISO 21415-2:2007 method (Sistem Glutomatic 2200, Perten Instruments AB) [10];
- the wet gluten content through the SR ISO 21415-2:2007 method (Sistem Glutomatic 2200, Perten Instruments AB) [10];
- the falling number through the AACC 56-81B method (Falling Number, model 1400PT, Perten Instruments AB) [9].

Table 1. *The composition of the flour varieties in the analyzed technological variants*

Flour		Component fractions
(i)	Flour I: ash content 0.55%, extraction 77%.	C2/C3I, C2/C3III, C4I, C5I, C7I, B1/B2, FD, C1I, C1II, C1III, C2/C3II, C6I, C9I, C9II, B3, B4, B5f, DIV
(ii)	Flour I: ash content 0.45%, extraction 20%.	C4I, DIV, B1/B2, C1I
	Flour II: ash content 0.55%, extraction 60%	C2/C3I, C2/C3III, C5I, C7I, FD, C1II, C1III, C2/C3II, C6I, C9I, C9II, B3, B4, B5f
(iii)	Flour I: ash content 0.55%, extraction 45%.	C2/C3I, C2/C3III, C4I, C5I, C7I, B1/B2, FD
	Flour II: ash content 1.1%, extraction 37%.	C1I, C1II, C1III, C2/C3II, C6I, C9I, C9II, B3, B4, B5f

Evaluation of rheological properties

The rheological characteristics were tested by means of:
- the NG Chopin Alveograph using the AACC 54-30 method [9];
- the Chopin Mixolab [7]; the running parameters of the device during the tests are depicted in Table 2.

The typical curve recorded by the Mixolab is shown in Fig. 1. The parameters enlighten in the curve are:
C1 [Nm] – indicates the peak torque of the dough, used to determine the water absorption;
C2 [Nm] – measures the protein weakening based on the mechanical work and temperature;
C3 [Nm] – expresses the starch gelatinization;
C4 [Nm] – indicates the stability of the starch gel formed;
C5 [Nm] – measures the starch retrogradation during the cooling stage;
α – represents the slope of the curve between the end of the period of 30 °C and C2; gives indications about the rate of the proteins' thermal weakening;
β – represents the slope of the curve between C2 and C3; gives indications about the gelatinization rate;
γ – represents the slope of the curve between C3 and C4; gives indications about the rate of enzymatic hydrolysis.

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. The same package was used for descriptive statistics (mean, standard deviations, range and coefficients of variation).

Table 2. *Settings of the Mixolab*

Parameters	Values
Mixing rate [rpm]	80
Dough weight [g]	75
Tank temperature [ºC]	30
Temperature of the first plateau [ºC]	30
Duration of the first plateau [min]	8
Temperature of the second plateau [ºC]	90
First temperature gradient [ºC·min^{-1}]	4
Duration of the second plateau [min]	7
Second temperature gradient [ºC·min^{-1}]	4
Temperature of the third plateau [ºC]	50
Duration of the third plateau [min]	5
Total analysis time [min]	45

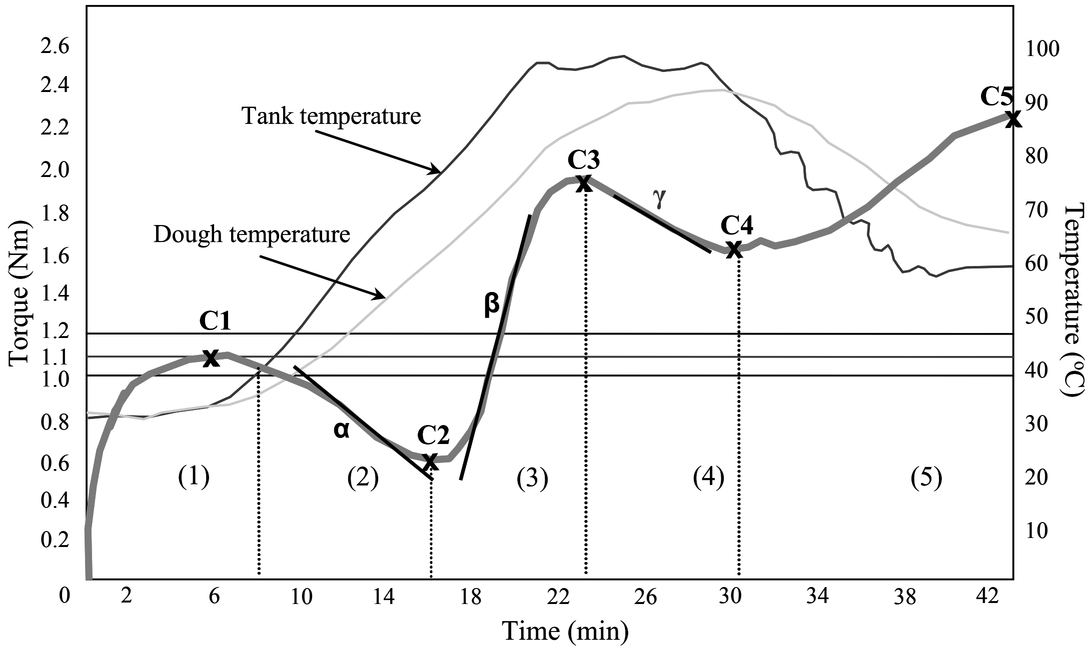

Figure 1. *Typical curve recorded by the Mixolab:*
Zone (1) - dough development (constant temperature. 30 °C); Zone (2) – thermal weakening of the proteins; Zone (3) - starch gelatinization; Zone (4) - enzymatic activity, constant heating rate; Zone (5) - starch retrogradation

RESULTS AND DISCUSSION

Physical-chemical and rheological characteristics of the wheat samples are indicated in the Table 3.
The experimental data obtained by analysing the different types of flours resulting from milling the wheat samples using the Mixolab and Alveograph devices are shown in Fig. 2 and Fig. 3.

Table 3. *Physical-chemical and rheological characteristics of the wheat samples**

Parameters	Mean	Range	SD
Physical-chemical characteristics			
Wet gluten content [%]	26	25.5 – 26.5	0.50
Gluten index [%]	95	94 – 96	1.00
Falling number value [s]	420	415 – 425	5.00
Rheological characteristics			
Water absorbtion capacity [%]	62.1	61.6 – 62.7	0.57
C2 [Nm]	0.43	0.42 – 0.44	0.01
C3 [Nm]	2.02	1.98 – 2.06	0.03
C4 [Nm]	1.63	1.61 – 1.64	0.02
C5 [Nm]	2.53	2.47 – 2.59	0.06
S [$min \cdot s^{-1}$]	6.27	6.00 – 6.51	0.26
P (dough elasticity) [mm]	95.3	92 – 100	4.10
L (dough extensibility) [mm]	20.7	19 – 23	2.10
G (dough blowing index)	10.1	9.7 – 10.7	0.50
W (dough strength) [10^{-4} J]	84	78 – 90	6.00

* - The moisture of the samples was 14%

The alveograph parameters give information about the elasticity, extensibility and dough strength.
The dough strength, that is used to estimate the dough behavior during the baking process, presented significant differences for different types of flours obtained by the milling process. The mean value of the dough strength obtained for the studied wheat varieties was very lower, 84 (Table 3); in order to get a good quality bread W must range from 250 to 300. When the wheat was milled to different extraction levels the dough strength was: 180 in case of white flour of 77% extraction (i); 144 in case of white flour of 45% extraction, and 65 in case of brown flour of 37% extraction (iii); 150 in case of superior flour of 20% extraction, and 116 in case of white flour of 60% extraction (ii) (Fig. 2a).
Concerning the dough elasticity specific to the studied wheat varieties, the mean value was 95.3 mm (Table 3). The P values of standard wheat range from 92 to 100 mm that signify a very good quality of wheat. The extensibility for wheat varieties was very lower, ranging from 19 to 23 mm; the extensibility of 100 mm is considered as being optimum. A high elasticity and a low extensibility characterize a strong protein quality.
When from the milling process was obtained only white flour of 77% extraction (i), dough elasticity and extensibility were 81 mm and 60 mm respectively (Fig. 2b). In case

of superior flour obtained in the experiment (ii), the dough elasticity was very good (91 mm), but the extensibility was low (41 mm).

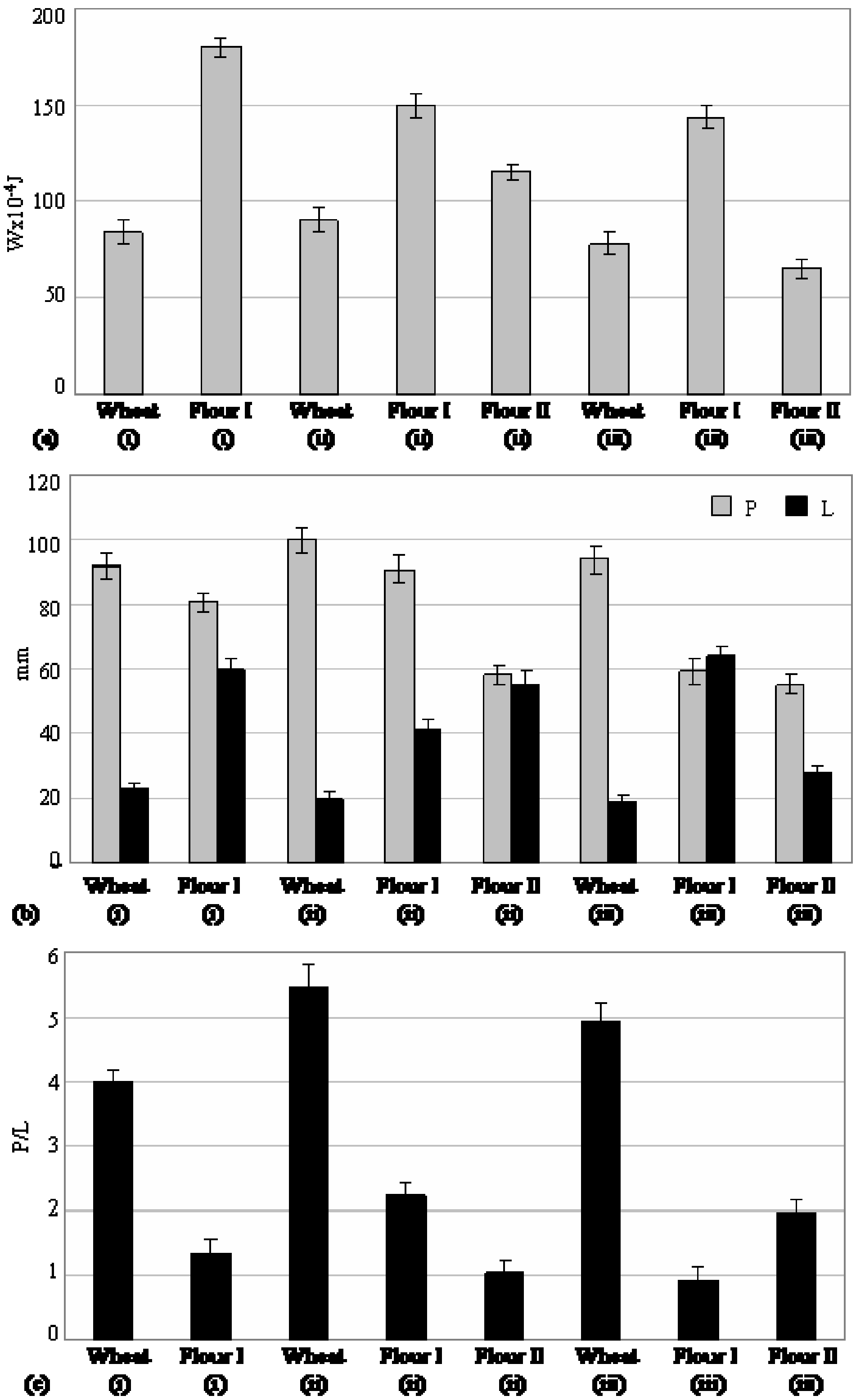

__Figure 2.__ Alveograph parameters of the wheat and different types of flours

The P/L ratios obtained were high, ranging from 4 to 5.5 in case of wheat, while the optimum values for P/L are 0.5 – 0.8. The white flour of 77% extraction had the P/L value of 1.45 (i). The values of P/L were 0.92 in case of the white flour of 45% extraction, and 1.96 in case of the brown flour of 37% extraction (iii).

Mixolab gives indications about the rheological behavior of dough during mixing and heating. In the Mixolab system the water absorption capacity represent the percentage of water required for the dough to produce a torque of 1.1 Nm.

In zone (1) in Fig. 1 an increase in the torque it is observed until a maximum, and after achieving the value of 1.1 Nm at a constant temperature of 30 °C, the dough is stable at deformations. The period of time when the torque and the temperature are constant corresponds to stable dough.

The dough stability of the wheat was higher compared to the white flours obtained in (i) and (iii) experiments, indicating better protein behavior. Analyzing the results in Fig. 3, one can see that in case of the dough stability was higher than wheat, but in case of superior flour, Flour I (ii) in Fig. 3, the dough stability was lower.

In the first heating stage (zone (2)) (Fig. 1) the torque C2 is decreased because the proteolytic enzymes have an optimal activity.

The zone (2) gives indications about the dough weakening due to protein unfolding. The high value of C2 is a characteristic of the good protein quality [8]. The difference between maximum torque at 30 °C (C1) and torque C2 defines the protein weakening [11 – 12]. The C2 was lower in case of flours compared to the wheat, except for Flour (II) (ii) (Fig. 3). Our results are in agreement with Collar *et al.* [13]; they considered that a good protein provide a significant higher stability during heating, later beginning of protein weakening, higher protein reduction and slower protein breakdown. In case of the experiment (iii) the C2 of the brown flour was lower compared to the white flour, which is normal because of the lower quality of the proteins in the brown flour.

The dough heating coupled with the water released by the thermally denaturated proteins causes the starch gelatinization (zone (3)). The starch granules swollen and hydration induce the dough consistency increase. This process is stopped when the mechanic shear forces and the temperature lead to the physical division of the granules [14].

When reaching the plateau of 90 °C (zone (4)), the rate of dough consistency decrease is given by the γ slope.

During the period of cooling the starch gel (zone (5) in Fig. 1), the dough consistency increases up to C5. The torque (C5) corresponds to the end of the starch retrogradation period.

In case of Flour II (ii) and Flour II (iii), the C3 were higher compared to C3 of the wheat (Fig. 3). C4 torqueses of flours were higher than C4 of the wheat. When through the milling process were obtained two types of flour, the second flour (Flour II (ii) and Flour II (iii)) presented higher values of the C3, C4 and C5 torques than the same torques of the first flour (Flour I (ii) and Flour I (iii)). This behavior gives indications about better starch performances, consisting in higher starch gelatinization, amylase activity, starch gelling, and cooling setback. Rosell *et al.* [14] explained there differences by the competition for water established between the starch and the bran present in the whole meal flour.

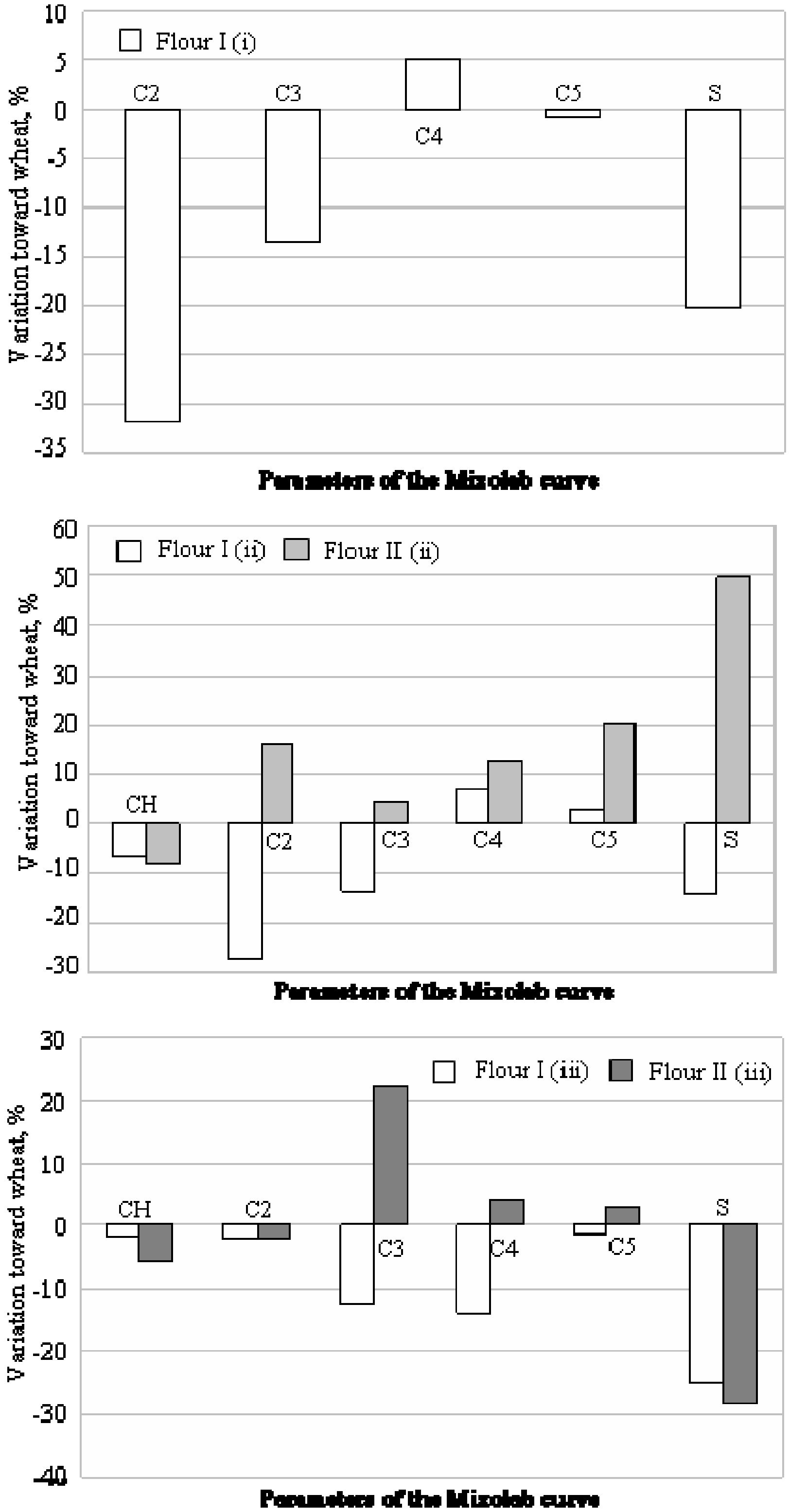

Figure 3. *Parameters of the Mixolab curves for wheat and different types of flours*

CONCLUSIONS

The flour extraction rate is an important factor influencing the rheological behavior. The elasticity, extensibility and dough strength measured by means of the alveograph, and the dough stability at 30 °C, stability during heating, starch gelatinization, amylase activity, starch gelling, and cooling setback measured by means of the Mixolab device depend by the properties of the flour fractions that are selected for blending to get a certain flour.

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