Studii şi Cercetări Ştiinţifice
Chimie şi Inginerie Chimică, Biotehnologii, Industrie Alimentară

2014, **15** (2), pp. 113 – 122

Scientific Study & Research
Chemistry & Chemical Engineering, Biotechnology, Food Industry

ISSN 1582-540X

ORIGINAL RESEARCH PAPER

PREDICTION OF WHITE FLOUR QUALITY OBTAINED BY INDUSTRIAL MILLING OF WHEAT

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Received: June, 02, 2014
Accepted: July, 18, 2014

Abstract: In order to establish the relations between quality of the wheat and white flour obtained through industrial milling, several parameters related to functional properties of the proteins and starch were analyzed. The parameters defining the proteins functionality are wet gluten, Gluten index, deformation energy of dough and minimum torque C2 and allowed establishing significant correlations between wheat and flour. Concerning the starch baking performance, the parameters that allowed establishing significant correlations between wheat and flour are falling number value, amylase activity, starch gelatinization and cooking stability range. Analyzing the trend of variation of the quality parameters given by Mixolab and Alveograph tests for wheat and flour, one can see that it is possible to predict the flour quality based on wheat quality.

Keywords: *flour, industrial milling, proteins, quality, starch, wheat*

INTRODUCTION

Wheat milling is a mechanical gradual reduction process when the endosperm is separated from the bran and germ. The wheat milling process includes three systems: break, purification and reduction. The purification system may be replaced in many mills by the sizing system [1]. The break and reduction systems include grinding and sieving stages and different flour mill streams are produced at each stage. The quality and quantity of flour mill streams from break and reduction stages are different. Combining the different flour mill streams results in various types of flour for diverse end-use products [2].

Flour quality depends on the wheat quality, cleaning process, storage and conditioning regimes, the flow sheet followed in the mill and setting of the processing equipments [3]. The factors influencing the wheat quality include wheat variety, climate factors (such as temperature, rainfall, and solar radiation) and growing conditions [1]. On the other hand, the cleaning process, storage and conditioning regimes are very important in order to ensure a good performance of the milling process.

The properties of the flour mill streams can be controlled through the adjustments of roller mills and by choosing various size meshes for the sieving equipment. Furthermore, blending flour streams, carefully selected based on the specific characteristics, is the ultimate strategy to control the quality of the flour intended for certain end products [2]. The flours types differ in their extraction rate, which is defined as the proportion of extracted flour with respect to the initial weight [4]. Moreover, the extraction rate has a major impact on the quality of the flour produced. Usually the white flour is obtained for extraction rates lower than 75%. Increasing the extraction rate up to 80% the flour will retain fine bran particles, and when the extraction approaches 100%, whole meal flour is produced [1, 5].

In order to predict the flour quality, the milling industry requires wheat with standardized parameters. Several studies reported the relations between quality of wheat and corresponding flour [6 – 9].

In this work, we analyzed the relations between the quality of the wheat and flour obtained by its grinding in an industrial mill. The aim was to identify any trend in the variation of the wheat-flour quality parameters.

MATERIALS AND METHODS

Romanian wheat (25 samples), Glossa variety (harvest 2012), was milled with an industrial roller mill (Buhler, Uzwil, Switzerland, capacity 3300 kg·hr^{-1}), to an extraction rate of 76.5%. The industrial roller mill consisted on four break rolls, nine reduction rolls, one coarse middlings divider, three bran finishers, and one turbostar sifter [2]. The characteristics of the roller mill and the milling diagram ensure an efficient particle size separation that compensates the absence of the purifier machines. The obtained wheat mill streams consisted of 4 break mill streams, 13 reduction flour fractions, 1 coarse middlings divider, and a bran finisher fraction. The white flour type (ash content of 0.52% ± 0.02) was obtained by blending the fractions collected at the break, coarse middlings divider and reduction passages. The flour was sampled according to the standard SR EN ISO 13690:2007 [10].

In order to assess physical-chemical and rheological characteristics of the wheat, the samples were grinded by means of a disc laboratory mill (WZ-2, Sadkiewicz, Poland).

The physico-chemical characteristics of the wheat and flour were evaluated as follows: the ash content using the SR ISO 2171:2002 method [10]; the gluten index and wet gluten content using the SR ISO 21415-2:2007 method [10] (System Glutomatic 2200, Perten Instruments AB); the falling number value using the AACC 56-81B method [11] (Falling Number, model 1400PT, Perten Instruments AB).

The rheological characteristics were tested by means of the NG Chopin Alveograph using the AACC 54-30 method [11] and the Chopin Mixolab using the ICC 173 method [12]. The running parameters of the Mixolab device during the tests are: mixing rate 80 rpm, dough weight 75 g, tank temperature 30 ºC, temperature of the first plateau 30 ºC, duration of the first plateau 8 min, temperature of the second plateau 90 ºC, first temperature gradient 4 $^{\circ}C\cdot min^{-1}$, duration of the second plateau 7 min, second temperature gradient 4 $^{\circ}C\cdot min^{-1}$, temperature of the third plateau 50 ºC and duration of the third plateau 5 min.

Three independent experiments were performed, and all analyses were carried out in triplicate; the average, median values, standard deviation, coefficient of variation, confidence level (95.0%) and significant ($p < 0.05$) correlation coefficients were calculated using the Microsoft Excel software.

RESULTS AND DISCUSSION

Quality and performance of the end-use products are influenced, to certain extents, by functional properties of starch and proteins [13], which are the main constituents of wheat and wheat milling products. In order to establish the relations between quality of the wheat and white flour obtained by industrial milling of wheat, several parameters covering aspects of functional properties of the proteins and starch were estimated.

Proteins functionality

In case of wheat, the functional properties of proteins are mainly due to the glutenin and gliadin fractions because of their ability to form the cohesive glutenic network of the dough when subjecting it to hydration and mixing [14]. The gluten network provides to the dough the ability to trap gases during fermentation, proofing and baking, ensuring the transition from flour to bread,

The wet gluten content is a major determinant of baking quality. The average wet gluten (WG) content of the investigated wheat and flour samples were 28.5% and 29.1%, respectively, and coefficients of variation were 13% and 11.9%, respectively (Table 1). The correlation coefficient between wet gluten content of wheat and flour (0.92) obtained in the present study was higher compared to that reported by Hruskova *et al.* [6] (0.44).

The Gluten index (GI) provides information on the quality of gluten, in particular about gluten strength; a high gluten index indicates strong gluten. The Gluten index of the investigated wheat samples ranged from 67 to 99%, while in case of the flour samples ranged from 88 to 99%. The variation coefficients were lower for flour compared to wheat (Table 1).

Table 1. *Descriptive statistics on parameters related to the proteins functionality for wheat and flour samples*

Parameters	Average	Median	Max	Min	Standard deviation	Coefficient of variation
Wheat						
Wet gluten [%]	28.5	30.3	32.6	22.3	3.7	13.0
Gluten index [%]	72.7	67.0	99.0	46.0	18.4	25.3
Extensibility [mm]	28.0	28.0	33.0	23.0	1.8	6.6
Elasticity [mm]	125.2	125.0	137.0	110.0	6.7	5.4
P/L	4.5	4.5	5.1	3.8	0.3	7.2
Energy x10^{-4} [J]	132.6	135.0	150.0	110.0	10.4	7.8
Water absorption [%]	62.64	62.90	63.70	61.50	0.67	1.06
Dough development time [min]	5.99	5.63	8.87	4.80	1.21	20.28
Dough stability [min]	8.25	7.98	10.30	6.68	1.19	14.38
Minimum torque [Nm]	0.44	0.43	0.49	0.41	0.03	5.83
Mechanical weakening [Nm]	0.66	0.67	0.73	0.59	0.04	5.67
Flour						
Wet gluten [%]	29.1	30.0	33.2	22.1	3.5	11.9
Gluten index [%]	85.0	88.0	99.0	55.0	12.2	14.4
Extensibility [mm]	101.0	100.0	122.0	88.0	8.8	7.9
Elasticity [mm]	69.2	69.0	79.0	62.0	4.8	7.0
P/L	0.7	0.7	0.9	0.5	0.1	13.4
Energy x 10^{-4} [J]	219.2	222.0	248.0	187.0	17.4	7.9
Water absorption [%]	53.27	57.20	58.40	56.20	0.53	0.93
Dough development time [min]	3.18	3.72	4.78	1.27	1.17	36.88
Dough stability [min]	7.68	7.68	8.55	6.63	0.57	7.46
Minimum torque [Nm]	0.35	0.35	0.38	0.31	0.02	6.24
Mechanical weakening [Nm]	0.75	0.75	0.79	0.71	0.02	2.74

A significant positive correlation (0.63) was found between Gluten index of flour and wheat. Hruskova *et al*. [6] reported a slightly lower correlation of 0.44 between Gluten index of wheat and flour provided from industrial mill. These differences can be attributed to influences exerted by environmental factors and cultivar on wheat protein quality as measured through the Gluten index [15]. The correlation between Gluten index of wheat and flour can be influenced the milling conditions. Bonfil and Posner [15] reported that, in case of the flour obtained through the Perten Lab Mill 3100, the Gluten index test does not accurately represent the protein quality.

Rheological parameters of dough are currently used to predict the breadmaking quality of wheat and flour. The Alveograph involves the biaxial extension of dough that under air pressure becomes a bubble; gluten extensibility and hence dough quality are given by the bubble inflation and persistence [16]. As a measure of dough elasticity, the maximum over pressure (P), varied for wheat and flour from 23 to 138 mm and from 62 to 79 mm, respectively. The dough extensibility (L) ranged from 23 to 33 mm and from 88 to 122 for wheat and flour, respectively. In the experiments performed by Bordes *et al*. [7], the P values for standard wheat ranged from 60 to 80 mm, and L was above 100 mm. The values of the curve configuration ratio (dough elasticity over extensibility) varied from 3.8 to 5.1 in case of wheat and from 0.5 to 0.9 in case of flour. In order to get high quality final products the baking industry requires for flour a P/L of 0.5-0.8 [17]. The deformation energy of dough (W) summarizes all the parameters of the alveograph curves and is therefore the most widely used characteristic for assessing flour quality [7]. According to Bordei *et al*. [17], the W of good baking quality flours should be above 250 x10^{-4} J. Our results indicated an average deformation energy (W) of 132.6 x 10^{-4} J in case of wheat, and 219.2 x 10^{-4} J, in case of flour.

We can see from Table 1 that the average and median values of the alveograph characteristics are similar for the wheat and flour samples, suggesting a symmetrical statistic distribution of these parameters. Moreover, the coefficients of variation of P, L and W were below 8%. The highest positive correlation (0.92) between wheat and flour was obtained for W values.

In addition to the alveograph tests, the Mixolab was further used to determine the rheological properties of the wheat and flour samples. Mixolab is a state of the art device that allows measuring in real time the torque of the dough while kneading and subjecting it to thermal treatment. Therefore Mixolab can be used to study mixing and pasting behavior of the flours [18]. The functional role of the proteins is given by the following Mixolab parameters: percentage of water required for the dough to develop a torque of 1.1 ± 0.07 Nm (water absorption, WA), the time to reach the maximum torque at 30 °C (dough development time), the elapsed time at which the torque is maintained at about 1.1 Nm (stability, S), or the minimum torque (C2) of dough while being subjected to mechanical and thermal constraints, and the torque difference between the maximum torque at 30 °C and the torque at the end of the holding time at 30 °C (mechanical weakening, C2-C1) [19].

For both wheat and flour samples, low values of the coefficients of variation were obtained for the Mixolab parameters WA, C2 and (C1-C2), and higher for the development time. Concerning dough stability, the coefficient of variation had high values only in case of wheat (Table 1). The values of the average and median of C2 and (C1-C2) for wheat and flour samples were very close, suggesting a symmetrical statistic distribution of these parameters. According to Dubat and Boinot [20], the wheat having the best breadmaking quality is characterized by dough development time ranging from 3 to 8 min, stability between 8 and 10 min, and C2 below 0.5 Nm. The C2 of flour was positively correlated with the C2 of wheat (0.55).

Starch behaviour

Starch influences baking performance of flour mainly due to the contribution as carbohydrate substrate for the yeast growth, due the susceptibility to the action of amylolytic enzymes and due the gelatinisation and retrogradation behaviour [21]. The parameters that define the starch behaviour are summarized in Table 2. When considering the Mixolab test, the role and behaviour of the starch are described by the following parameters: starch gelatinization (C3), thermal weakening (C3-C2), amylase activity (C4), cooking stability range (C3-C4), starch gelling (C5) and cooling setback (C5-C4).

The falling number (FN) values for both wheat and flour were high (Table 2); average values over 400 s indicate minimal amylase activity. The FN and C4 of flour were positively correlated with the FN (0.87) and C4 (0.84) of wheat. Coefficients of variation for starch gelatinization were low, below 2.5% for wheat and below 9% for flour (Table 2).

Table 2. *Descriptive statistics on parameters related to the starch behaviour of wheat and flour samples*

Parameters	Average	Median	Max	Min	Standard deviation	Coefficient of variation
Wheat						
Falling number [s]	437.5	462.0	545.0	269.0	77.9	17.8
Starch gelatinization [Nm]	1.97	1.96	2.08	1.89	0.05	2.49
Thermal weakening (pasting) [Nm]	1.53	1.52	1.62	1.45	0.04	2.46
Amylase activity (peak torque) [Nm]	1.66	1.74	1.93	1.15	0.21	12.54
Cooking stability range [Nm]	0.31	0.24	0.79	0.09	0.21	65.28
Starch gelling [Nm]	2.59	2.65	3.04	1.85	0.29	11.13
Cooling setback (gelling) [Nm]	0.94	0.96	1.12	0.70	0.10	10.56
Flour						
Falling number [s]	427.7	433.0	509.0	304.0	59.0	13.8
Starch gelatinization [Nm]	1.50	1.46	1.75	1.33	0.13	8.55
Thermal weakening (pasting) [Nm]	1.16	1.08	1.43	1.00	0.14	12.29
Amylase activity (peak torque) [Nm]	1.70	1.78	1.85	1.36	0.14	8.41
Cooking stability range [Nm]	0.19	0.31	0.32	0.40	0.24	125.49
Starch gelling [Nm]	2.55	2.65	2.82	2.01	0.26	10.09
Cooling setback (gelling) [Nm]	0.85	0.89	1.01	0.65	0.12	14.54

The significant correlations between wheat and flour were obtained for cooking stability range (0.89) and starch gelling (0.81). These correlations are very important taking into account that the viscosimetric profile of starch is related to shelf life of bread. According Collar *et al.* (2007) [18], low cooking stabilities indicate an extended shelf life of bread.

Trend of variation of the quality parameters of wheat and flour

In order to highlight the trend of variation of the quality parameters of wheat and flour the control chart with limits defined as average ± 1.711 standard deviation were used. For a better visualization of the results, the differences in terms of protein functionality and starch behavior, identified in the flour samples obtained through industrial milling, are presented in Figure 1 (a, b) and Figure 2 as percentages with respect to the wheat samples.

The quality parameters of all investigated wheat and flour samples were considered. The wet gluten, gluten index and water absorption presented trends within the limits adopted. Analyzing the results presented in Figure 1b one can see that the samples (7 and 8) with P < 110 mm and W < 110 x 10^{-4} J were at superior limit in case of P, or outside of this limit in case of W. Samples having C2 values higher than 0.49 Nm do not comply with the identified trend, being outside the superior limit.

The falling number value and starch gelatinization presented trends complying with adopted limits (Figure 2). In case of C4 and C5, the samples (17 and 18) with values well below the average were outside of the superior limits.

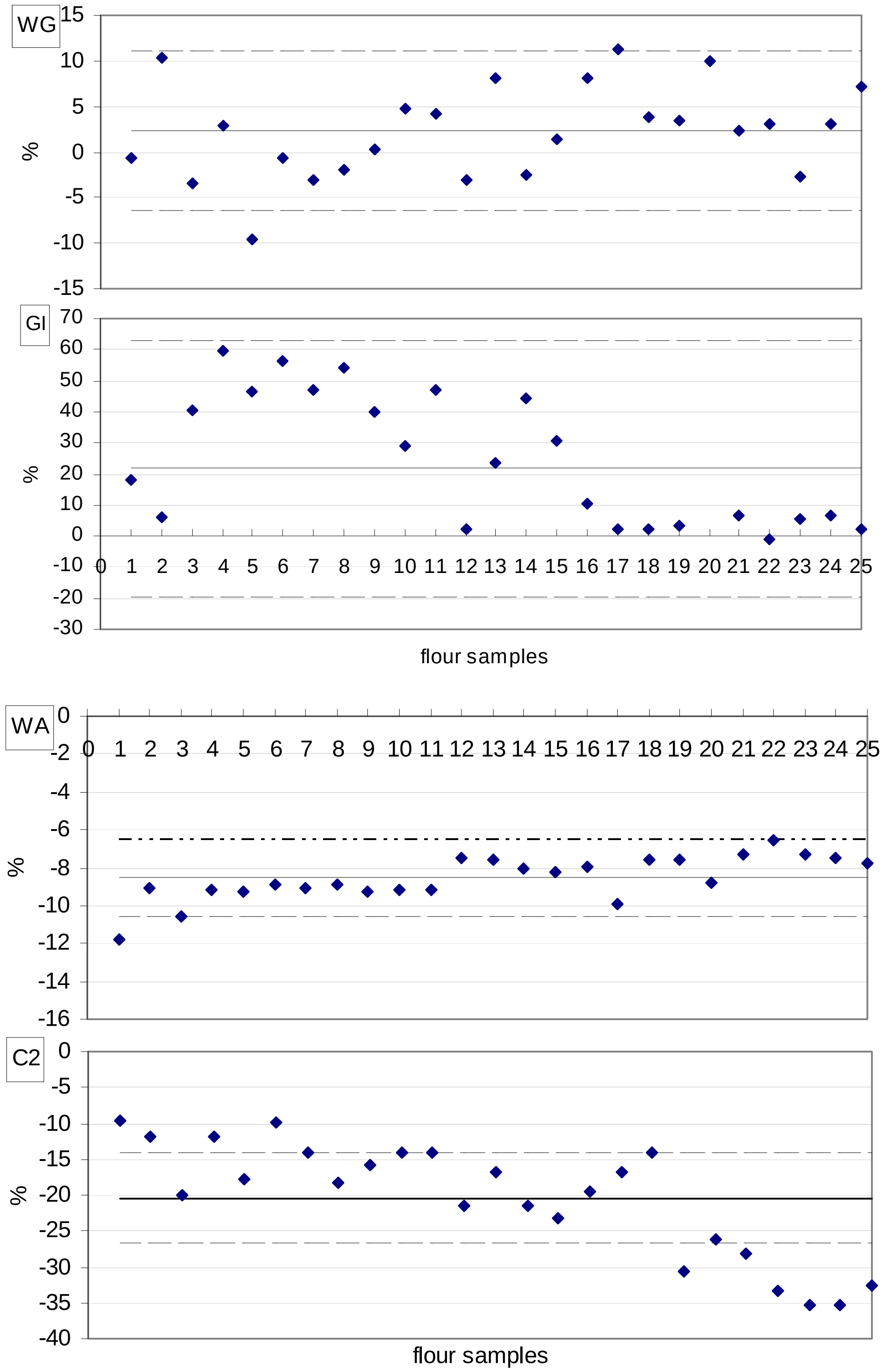

Figure 1a. *Trend of variation of the quality parameters defining the functionality of the proteins from wheat and flour samples*

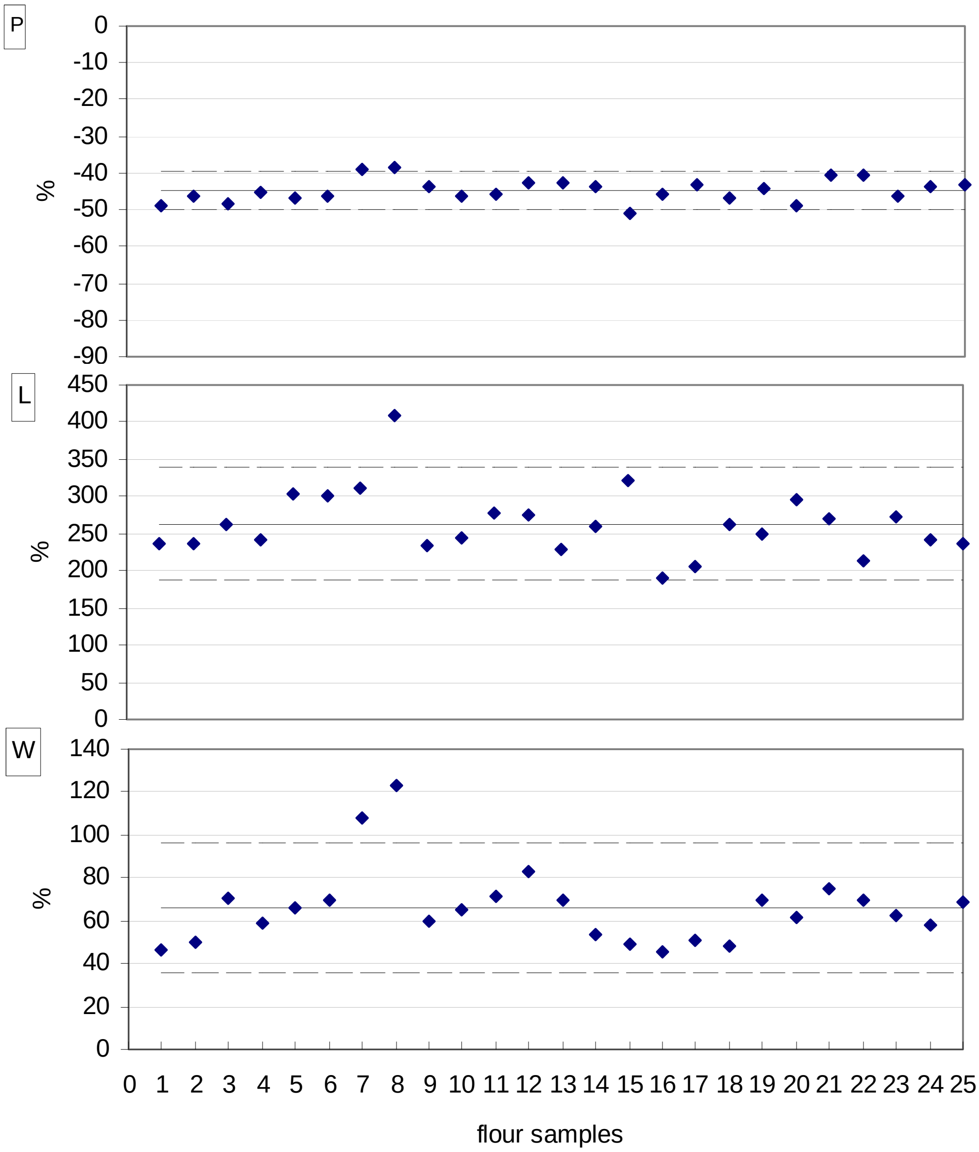

***Figure 1b**. Trend of variation of the quality parameters defining the functionality of the proteins from wheat and flour samples*

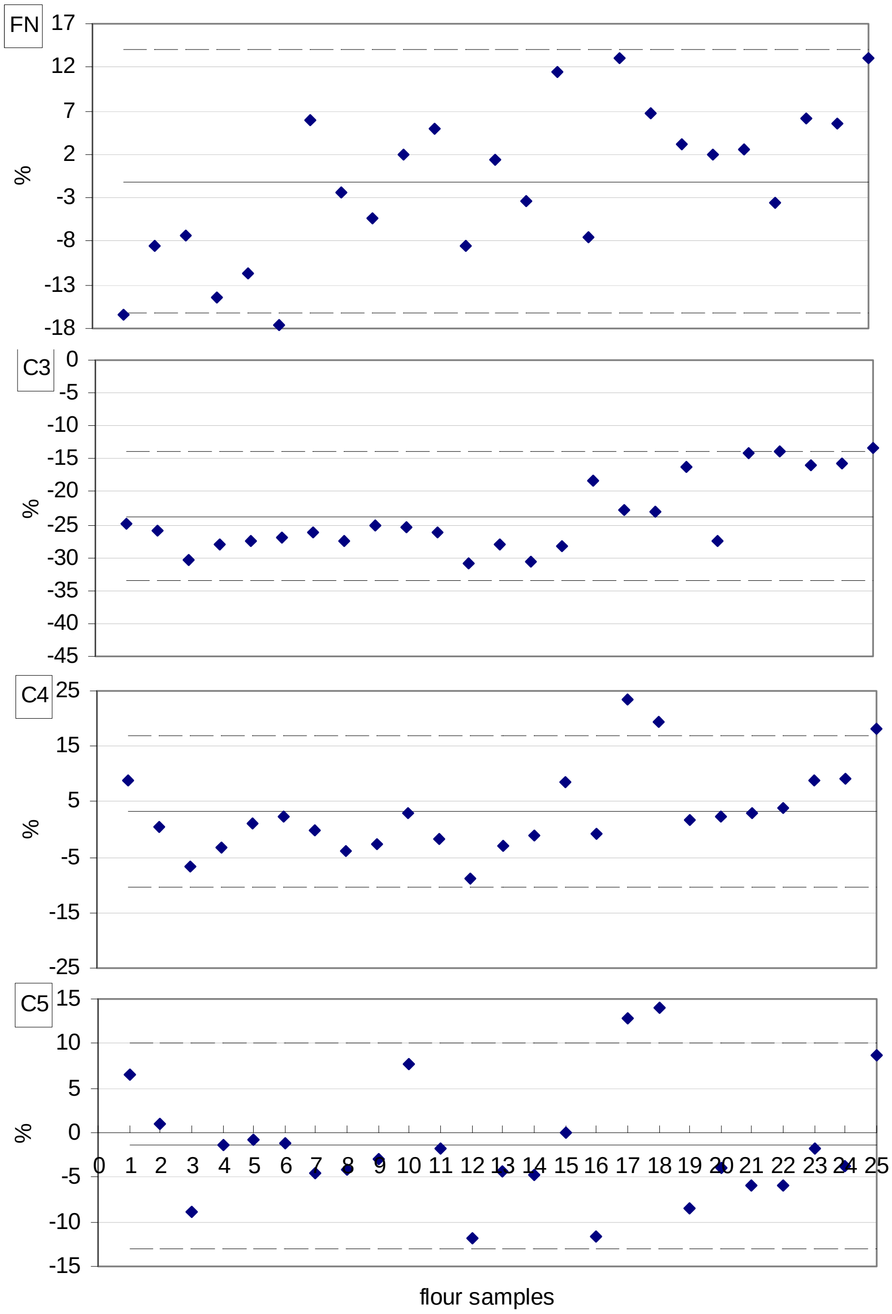

Figure 2. *Trend of variation of the quality parameters defining the behavior of the starch from wheat and flour samples*

CONCLUSIONS

The quality of the flour resulting from industrial milling of wheat can be estimated based on the quality parameters of wheat. Significant correlations were established between parameters defining the proteins functionality (such as wet gluten, Gluten index, deformation energy of dough and minimum torque C2) and starch baking performance (such as falling number value, amylase activity, starch gelatinization and cooking stability range) of the flour and wheat, respectively. In summary, based on the trend of variation of the quality parameters from the Mixolab and Alveograph plots, it is possible to predict the flour quality based wheat quality.

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