The Annals of the University *Dunarea de Jos* of Galati
Fascicle VI – Food Technology, 34(2)

ORIGINAL ARTICLE

EVALUATION OF RHEOLOGICAL PROPERTIES OF FLOUR AND POTATO PULP BLENDS USING BRABENDER FARINOGRAPH AND E6 HAUBELT FLOURGRAPH

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Received 9 March 2010
Revised 26 April 2010

The aim of this work is to establish correlations between the values of the Brabender Farinograph and the E6 Haubert Flourgraph. We analyzed two types of flours, white flour with additives (WF add) and brown flour with additives (BF add). The following parameters were varied: water absorption capacity, development time, the stability, the degree of softening and the quality number of wheat and potato flour mixture. A statistical analysis was made from linear regression equations. The obtained values for the E6 Flourgraph are comparable with Farinograph values and units. Hydration capacity values, calculated for a standard consistency of 500 HE, UF, obtained on these two devices are in a close correlation, R^2_{WFadd} = 0.8441; R^2_{BFadd} = 0.9995. This demonstrates that flour dough can be characterized in a similar manner by the two devices. Moreover, the behaviour of the dough obtained from WF add and BF add blended with 5%, 10%, 20%, 30% minced hydrothermally treated potato (Laura variety), was studied. Mixtures with different rheological properties were obtained. When increasing the percentage of minced hydrothermally treated potato the formation time and stability decreased the degree of softening increased and the quality number was lower. The hydration capacity of the mixture dropped by 18,9% for white flour with additives and 18.71% for brown flour with additives. Predictive results were obtained for each parameter, R^2 ranging from 0.81 to 0.9965. The obtained results indicated that while increasing the potato starch content in dough, the mixing tolerance decreases, and from this point of view it is advisable to choose potato varieties which have a low dry matter content.

Keywords: water absorbtion, Flourgraph E6 Haubelt, Farinograph Brabender, additivated white flour, additivated brown flour, potato Laura variety

1. Introduction

Rheological measurements are relevant tools in the food industry for the physical characterization of raw material prior to and during processing, and of final food products (Tabilo-Munizaga and Barbosa Canovas, 2005).

However, food products are complex materials from the structural and rheological point of view and, in many cases, they consist of mixtures of solid as well as fluid structural components (Finney, 1972).

To determine the rheological properties of the dough made from flour which was replaced by modified corn starch (10% -15%), pectin, carboxymethylcellulose, agarose, xanthan, β-glucan (Lazaridou, A., et al, 2007) we used the Brabender Farinograph (Hung.VP, at al.,2004). The rheological characteristics of the dough and the hydration capacity of the mixture depended on the hydrocolloid type.

To characterize the rheological properties of the dough other devices such as the mixolab (Haros et al., 2006, Collar et al, 2007, Rosell et al 2007; Kahraman et al, 2008; Banu et al., 2009) can be used.

The replacement of gluten represents a major technological challenge, as it is an essential structure-building protein, contributing to the appearance and crumb structure of many baked products. Thus, the gluten matrix is a major determinant of the important rheological characteristics of dough, such as elasticity, mixing tolerance and gas holding ability. Several rheological techniques were used in many studies for probing fundamental mechanical properties of gluten (Janssen,van Vliet et al, 1996 b), as well as for establishing relations between those properties and quality attributes of the end-product (Autio,F.,at al, 2001; Dobraszezyk,et al., 2003)

Dough rheology allows better understanding of the way in which various elements act upon the technological process of bakery. When using the Farinograph Brabender and Flourgraph E6 mixer devices the flour is first mixed with water to form the dough and afterwards is kept under mechanical stress until its structure is destroyed.The maximum viscosity decreases with increasing protein content. This behaviour is given by the other major component of the dough, the starch (Bordei, 2004). The potato, which is the major component of the dough, contains mainly water and starch (Burton, 1989, McComber, et al 1994, van Marle et al., 1997, Micklander, E., et al., 2008, Qiang, L., et al., 2009).

The aim of this study was to establish the correlations between the rheological parameters gathered through Brabender Farinograph and the Flourgraph E6 Haubelt. We analyzed two types of flours, additive-improved white flour (WF add) and additive-improved brown flour (BF add). Parameters as the following have been varied: water absorption capacity, development time, stability, degree of softening and quality number of wheat and potato flour mixture. Another objective was to test flours behaviour when adding potato pulp. We replaced 5%, 10%, 20%, 30% of WF add and BF add with minced hydrothermally treated potato, Laura variety. Mixtures with different rheological properties were obtained. A statistical analysis was made using multilinear regression equation.

2. Materials and methods

The white flour (Mill Cibin Sibiu, Romania) supplemented with ascorbic acid 1.5 g/100 kg flour; L-cysteine 3 g/100 kg flour; α-amylase, xylanase, hemicellulase 8-9 g/100 kg flour had the following characteristics moisture u=13.9%; wet gluten Gl_u=32%; gluten deformation ID=4 mm; gluten index I_{GL}=55.68; Falling Number FN=290-300s; titratable acidity TTA= 2.2 degree, ash 0.649 %; water absorption value of flour WA = 56.9 %.

The brown flour (Mill Cibin Sibiu, Romania) supplemented with ascorbic acid 4g/100 kg flour; L-cysteine; α-amylase, hemicellulase 8-9 g/100 kg flour had the following characteristics u=12.9%; Gl_u=30%; ID=8 mm; I_{GL}=44.4; FN=280 s; TTA=3.3 degree, ash 0.1250%, WA= 61.5 %.

The red potato LAURA variety (Potato Research and Development Station Targu Secuiesc, Covasna, Romania) was characterized by starch content of 13 %, pasta moisture of 73.5 %, and pasta TTA of 2.24 degree.

The physico-chemical properties of the flour were evaluated as follows: the wet-gluten content using the 106 /2 ICC STANDARD method; gluten deformation index using STAS 89-90-6238; the ash content using 104/1 ICC method; the acid content using STAS 90-88 method; the "falling number", according to 107/1, ICC Hagberg-Perten STANDARD; the hydration potential through No115/1 ICC STANDARD flour.

The acidity of the potato paste was determined according to STAS 90-88 and the moisture using the gravimetric method with thermobalance.

The Farinograph Brabender with large bowl (300g flour) measures and records the resistence of dough to mixing. It is used to evaluate absorption of flours and to determine stability and other characteristics of doughs during mixing. Different basica methods are commonly used: Constant Flour Weight Procedure and Constant Dough Weight Procedure. Sience the two procedures may not yield identical results, the method employed must be specified when absorbtion and other farinogram values are reported.

For the farinograph-E both the methodology and result are identical to those of the mechanical farinograph, 63 ± 2 rpm .

The E6 FLOURGRAPH that rely on the same principle makes programmable electronic measurements using Windows XP, and the titration curves are easy to follow on a touch-screen monitor located directly near the mixer device that has a capacity of 100 g of flour. Kneading arms rotation is of 63 r.min^{-1}.

Preparing the potatoes for analysis: the potato paste (PP) was obtained by hydro thermal processing of the unpeeled raw potato for 30 minutes at water boiling temperature, then cooling it, peeling, and mashing it by passing it through the 2 mm mesh sieve.

3. Result and Discussions

Hydration capacity (CH) is the amount of water absorbed to achieve standard consistency of 500 BU (Lazaridou, A., et al., 2007). The studied equipment expresses the consistency as HE (Haubelt Einheit)- in case of flourgraph and UF (Unit farinograph)- in case of farinograph.

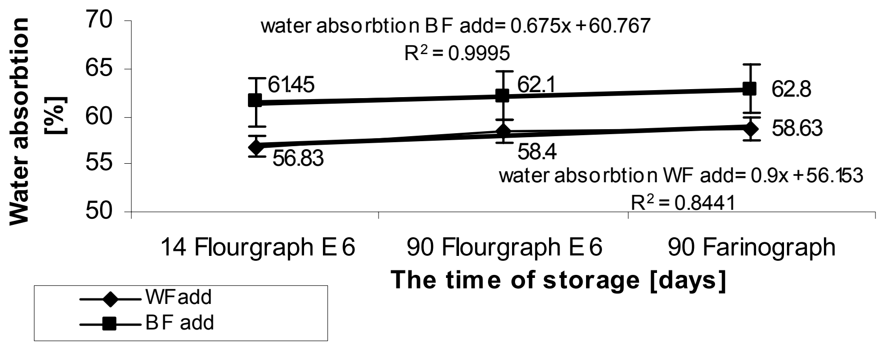

Figure 1. Variation of water absorption measured on the FL-Flourgraph E6 Haubelt and FR-Farinograph Brabender as function of storage time for the two tested flour types (WF add and BF add). The significance threshold was $\alpha = 0.05$ and the standard deviation represented on the graph was calculated based on 6 flourgrams and 3 farinograms.

The two devices used to characterize the flours, E6 Haubelt Flour Graf and Brabender Farinograph indicate very close quality values for the analyzed samples. The hydration capacity in the storage period, determined by E6 Flourgraph increased by 2.68% for white flour with additives and 1.046% for brown flour with additives. The flour absorption rate as determined by the farinograph, compared with the one tested by the flourgraph is higher by 0.39% for WF add and 1.11% for BF add. Hydration capacity values obtained on these two devices are in a close correlation: $R^2_{FAadd} = 0.8441$; $R^2_{FNadd} = 0.9995$. This demonstrates that flour can very well be characterized using the two devices. The values of the independent variable coefficient (x), 0.675 for BF add and 0.9 for WF add, show the influence of the factors depending on the device specificity; in the studied case, it also depends on the storage time. The influence is greater for the white flour (Figure 1, Table 1).

Analyzing the results in Table1, one can observe that, for a constant value of the amount of water added while kneading, the mixture consistency has variations. This is a consequence of the values oscillating around a fixed one for the other parameters (Table 1).

The influence of potato addition on rheological characteristics of dough

Dough viscosity gives evidence on its capacity to retain gas, viscosity and elasticity of bread volume. In practice, the variation of water absorption is given by the protein content, pentosans from wheat flour, mechanically destroyed starch granules (Bordei, D., et al 2007).

Dough consistency is the maximum resistance of the dough during kneading. It was taken into account at the loss of 500 HE consistency, in the presence of additives, the flour substitution degree as well as the flour type (Figure 2).

According to these statements the potato pulp addition should change the mixture structure. The humidity of the mixture subjected to determination is the key starting point in this study and it is calculated according to balance equations in the dry matter (Iancu, et al, 2010).

Table 1. The characteristics of flours depending on the viscosity of the formed dough at a constant quantity of water added for the kneading process

Flour type	Nume of Apparatus	Time of storage[days]	The indicators on diagram						
			Consistency [BU] [HE]	Develop ment time [min]	Stability [min]	Degree of softening 12 min after max. [FU];[HE]	Degree of softening 10 min after beginning [FU];[HE]	Degree of softening 20 min after beginning [FU];[HE]	Quality number
White flour with additives	Flourgraph E6	14	499 ±4.8	2.52 ±0.97	5.62 ±0.61	73.36 ±6.5	44.75 ±6.6	109.25 ±9.54	69.66 ±10.18
		90	499.75 ±7.0	2.02 ±0.19	5.6 ± 2.3	68 ±6.68	41.5 ±7.2	7.41 ±9.05	30.33 ±10.4
	Farinograph	90	501 ±5.55	2.13 ±0.17	7.5 ±0.00	68.6 ±2.44	46 ±1.58		65 ±24.2
Brown flour with additives	Flourgraph E 6	14	506.75 ±6.8	4.85 ±0.19	5.2 ±0.19	97 ± 5.35	46.5 ±2.447	115.25 ±5.3	73.25 ±4.6
		90	508 ±0.97	5.77 ±0.39	9.0 ±0.58	62.75 ±3.2	18.5 ±2.91	72.75 ±3.91	100.5 ±12.85
	Farinograph Brabender	90	499.6 ±9.26	6.06 ±0.094	9.7 ±3.34	63 ±3.2	20 ±5.55		118.33 ±6.46

The significance threshold was α = 0.05 and the standard deviation was calculated based on 6 flourgrams and 3 farinograms.

Figure 2 presents the average values of the hydration capacity of the mixture that gives a standard consistency of 500 HE for a constant amount of water added to the kneading process.

The hydration capacity of the blends with additivated white flour is correlated with the proportion of potato according to equation (1) while the hydration capacity of the blends with additive-improved black flour is correlated with the proportion of potato according to equation (2).

$$WA_{WF\ add} = -2.584x+60.642 \qquad R^2= 0.8991 \qquad (1)$$

$$WA_{BF\ add}= -2.772x+ 63.127 \qquad R^2= 0.9617 \qquad (2)$$

According to Equations (1) and (2) and Figure 2, one can notice that by increasing the percentage of hydrothermally treated and minced potato pulp which replaces flour, the hydrating ability of the blends decreases by 18.90% for the white flour with additives and by 18.71% for the brown flour with additives. The independent variable coefficients have negative values in equations (1) and (2), meaning that, if flour is replaced, the hydration capacity decreases. This proves that the more flour is replaced by potato pulp, the lower the moisture content of the mixture. The correlation ratio of the moisture content of the white additivated flour and potato mixture with the potato proportion is lower (0.8991) than that of the samples with brown additivated flour (0.9617). The values are very close to 1, which suggests a strong connection between the moisture content of the mixture and the proportion of flour replaced by potato pulp.

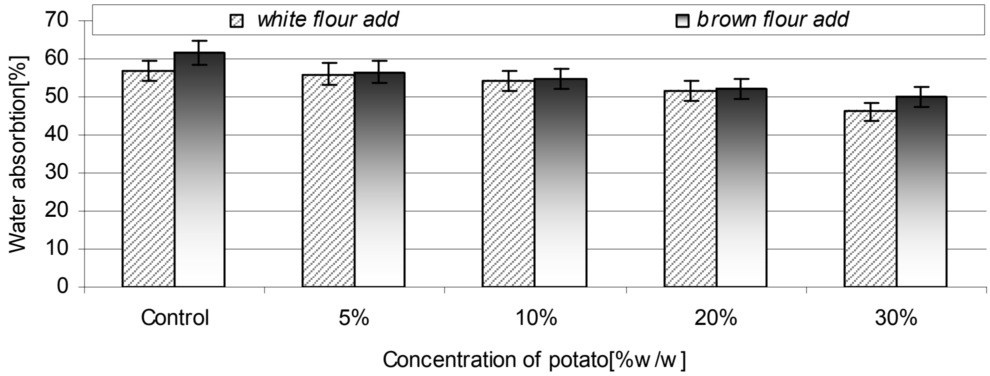

Figure 2. Variation of water absorption of the blend containing WF add or BF add, and 5%, 10%, 20%, 30% potato pulp, Laura variety. The significance threshold was α = 0.05 and ± the deviation was calculated for 4 lines at the making of flourgrams.

If the amount of water added to the mixture while the dough is being kneaded in the mixer drum of the flourgraph is not adapted to the proportion of the potato paste, and the same amount of water is added as in the control sample, the consistency of the dough will diminish from 501 to 414 for the 30% additivated white flour content, and from 499 to 317 for the 30% additivated brown flour content. For the intermediate stages, as seen in Figure 3 for the same percentage of replacement and the same potato variety the destabilization of the mixture structure was influenced by the type of flour. The mixture of white flour with additives was more stable compared to the brown flour with additives mixture.

The development time is the necessary time needed for the mixture to reach the maximum consistency (Bordei, 2007). It is dependent on the formation time of gluten structure in the dough. By increasing the potato pulp percentage, the formation time decreased. For the white flour with additives the decrease was of 61,9% and for the brown flour with additives it was of 69.48% (Figure 4 a). This decrease is due to gluten protein in the mixture dilution.

The stability is the time interval between the moment when the top edge of the curve crosses the line corresponding to the maximum consistency of the dough and the moment when it exceeds it (Bordei, 2007). The dough stability evolution trend was to decrease with the increase of the potato pulp percentage that substitutes flour. The decrease was of 75% for WF add and 73% for BF add (Figure 4b).

The degree of softening is given by the difference in consistency between the center of the curve measured at the end of the leavening process and the center of the curve measured 12 minutes (according to AACC, 54-21), 10 minutes, 20 minutes (according to ICC 115/1) after this point. The tolerance index [HE] is the difference between the maximum dough consistency and consistency value after 5 minutes of kneading or after 10, 20 minutes from the beginning of tracing the curve. It shows how fast the dough falls when it is over kneaded (Bordei, 2007).

Softening at 12 minutes from the maximum tends to increase with increasing the percentages of flour replaced by 69% WF add and 73% for BF add (Figure 4c).

Softening at 10 minutes from the beginning of determination has an increasing trend. As for the mixture of white flour with additives, the softening increases by 64.87% and for brown flour with additives by 58.9% (Figure 4d).

The degree of softening at 20 minutes from the start of record is even higher if the potato pulp percentage increases. Thus, for the white flour mixture it increases by 83% and for the one with brown flour it increases by 79% (Figure 4e). We notice that the tolerance to over kneading is not high and black flour with additives is more resistant.

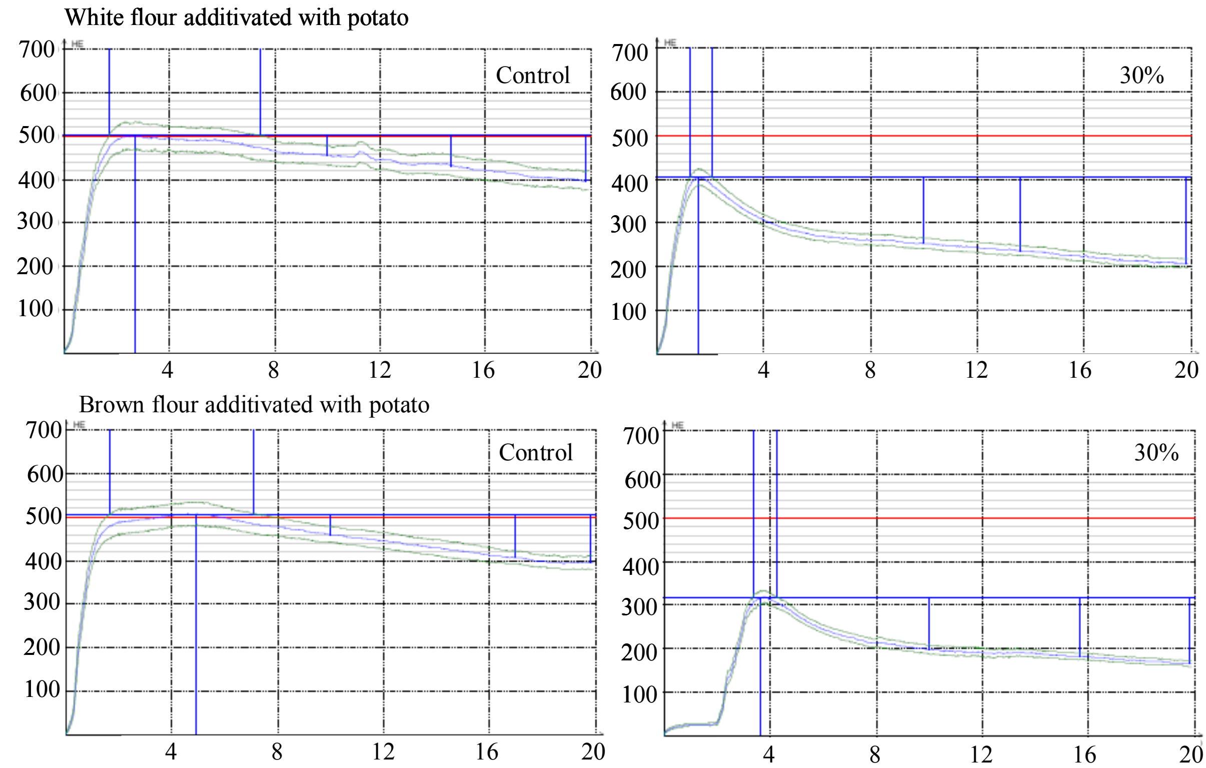

Figure 3. The loss of consistency in the mixture composed of WF add, Laura potato variety and 56.9% water constant value and BF add., Laura potato variety, and 61.5% water constant value. The potato replaced the flour at a rate of 5%, 10%, 20%, 30%. Determinations were made by E6 Flourograph Haubelt.

The quality number is the length in mm along the time axis between the point of water adding and the point where the height of the curve centre has decreased by 30 HE compared with the height of the curve centre during development (Bordei, 2007).

The studied additions have led to a decrease of this value by 87% for white flour with additives mixture and by 80% for black flour with additives. The lower the note was, the lower the dough tolerance in kneading was. This destabilization of the structure increased with the percentage of potato that replaces flour.

Except for the stability dependence of brown flour added on the concentration of potato (Figure 4b), the correlation coefficients (R^2) which were obtained from statistically processing data ranged between 0.81 and 0.9965. This demonstrates that the link between all studied characteristics and the percentage of minced hydrothermal treated potato is very close.

Computerized assessment of diagrams obtained by Flour Graf was set for a constant quantity of water. The errors were corrected by the program used to calculate the amount of water needed for a consistency of 500 [HE]. The deviations calculated for each quality index resulted from obtaining mixtures with different consistencies, but very close, that were within the range of tolerance of the method, 500 ± 20 HE (Figure 4; Table 2).

4. Conclusions

The main findings of the study consist in establishing the correlation between the mixture structure and the water quantity added.

For the hydration capacity established based on the calculations for a constant value of the newly formed dough consistency, of 500 BU or HE, for a constant amount of water that is added to the dough formation we obtained:

-the absorption of flour determined by the farinograph compared with the one tested using the flourgraph is higher by 0.39% for WF add and 1.11% for BF add,

-hydration capacity values obtained on these two devices are in a close correlation, R^2_{FA}=0.8441 ; R^2_{FN} = 0.9995. This demonstrates that the flour can be characterized as well by the two devices.

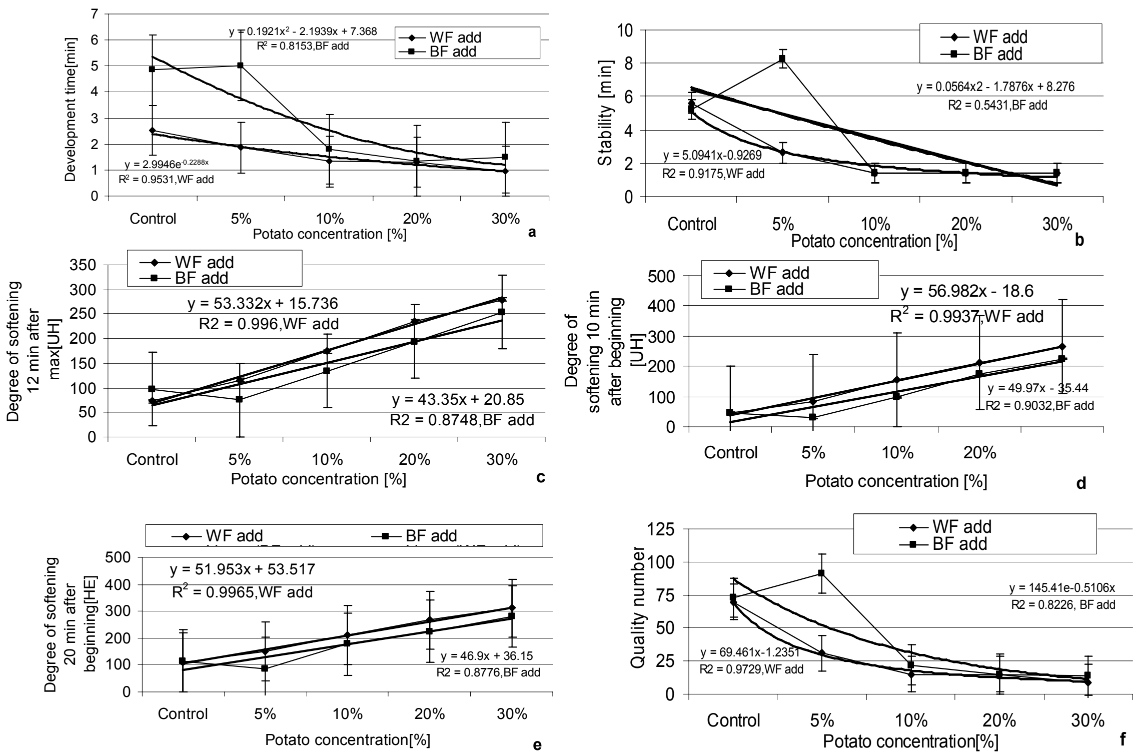

Figure 4. Variation of development time (a), stability (b), degree of softening 12 after max (c), degree of softening 10 min after the beginning (d), degree of softening 20 min after the beginning (e), and flour quality number (f), conveyed by the Flourgraph, for mixture of white and brown flour and 5% , 10% , 20 % , 30% potato pasta variety Laura.

The hydration capacity of additivated white flour and additivated brown flour mixed with potato pulp is influenced by the amount of potato pulp used in the mixture. The higher the amount of potato pulp, the lower the hydration capacity of the mixture. The chart parameters change with the altering of the mixture composition and the hydration capacity. Thus, the leavening time decreases due to a dilution of the gluten protein content of the mixture, the dough stability decreases, the softening degree 12 minutes after reaching the peak increases, the softening degree increases 10 minutes after the experiment has begun, while the softening degree increases, 20 minutes after the experiment has begun, according to the percentage of potato pulp in the mixture, which also determines a decrease in the quality score. We noticed that the tolerance to over kneading is not high and that brown flour with additives is more resistant. The determined qualitative indices recommend the white flour as being more tolerant because it has a higher gluten content that is stronger than in the case of brown flour. This behavior contrary to the theory is given by the starch content. Therefore, as the starch content increases in potato dough mixture, the tolerance to mixing decreases and in this regard it is better to choose varieties of potatoes with low dry matter content.

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