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THE INFLUENCE OF WATER CONTENT ON WHEAT DOUGH IN CHANGING THE RHEOLOGICAL CHARACTERISTICS AND QUALITY OF THE FINISHED PRODUCT

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Abstract

The most important task facing the baking enterprise under market conditions is the production of bakery products with the best qualities that can be achieved from a particular batch of processed flour.

In assessing the quality of bakery products the consumer pays special attention to indicators of texture. In producing bakery products, wheat flour is the most volatile commodity. Then in order to obtain finished products with desired texture parameters the rheological properties of the semi-finished baking properties created from the raw materials and formulation products must be controlled.

Key words: Farinograf E, Strukturometr, Rheotest, wheaten flour, acidity, wheat bread.

Introduction: Technology at the Department of Bakery and Pasta Industries (MGUPP) was used in order to establish the optimum consistency wheat dough after mixing, as defined by using the device «Farinograf E» (Ivanoski *et al.*, 2002) (640-650 EP). Thus, the best quality bread can be produced, and will provide the user with the ability to set the water absorption for flour based recipes during the kneading of dough (Kihlberg *et al.*, 2004; Machihin *et al.*, 2004; Puchkova, 2004). In this case, we found that for the same consistency of the dough at the time it was ready for mixing, the products were of different quality when different variables was changes. Thus, the assumption was made that the value of this parameter was a function of the torque of drive mixers used, and this determined the ability of the flour to absorb water and the optimal quantity of water added to the dough. This information was also used to predict the quality of bakery products in conjunction with complex rheological measurements, such as: viscosity, elastic modulus, stress relaxation time, the relative deformation, and others (Bucsella *et al.*, 2016; Van Vliet *et al.*,1992).

Therefore, the purpose of this study was to test the influence changing the rheological variables on the properties wheat dough after each batch, subject to the same consistency as indicated by the 640-650 EP.

Data and Methods: Research was carried out using the following three instruments for measuring the qualities of the wheat dough:

- The «Before Corder DCE-330» (Fig. 1a), which determines the changes in the consistency of dough during kneading, setting the time it is ready for baking, and adjusting the amount of mechanical energy expended during tests (Maximov, 2004; Oke *et al.*, 2013; Puchkova, 2004);

- The «Strukturometr ST-2M» (see Fig. 1b), which determines the complex rheology of the wheat dough after mixing;

- The discometer «Rheotest 2.1» (see Fig. 1c), which determines the effective viscosity of wheat dough after mixing (Maximov, 2004).

a b c

Figure 1. A picture of the DCE-330(a), CT-2 (b), Rheotest 2.1 (c)

Results: Studies were performed using three samples of wheat flour and their baking properties which are listed in Table 1. The dough is prepared by using the compounding method except for the sourdough sliced loaf (Puchkova, 2004). The consistency of the changed (Oke *et al.*, 2013) by 50 EP as the dough was kneaded due to the addition of water, so that the moment the bread dough was ready over the range from 540 to 740 EP. The optimal consistency was in the middle of this range.

Figure 2 shows a family of curves for wheat dough consistency during mixing with varying water content (Oke *et al.*, 2013) at the rotation speed of 63ob/min for the mixers.

On the basis of these studies, we found that the increase in water content from 40.5% to 42.8% led to a decrease in the amount of mechanical energy expended producing the dough until ready to 74.0 to 36.5 kJ/kg. The length of time for the dough to be ready decreased from 200 to 120 sec.

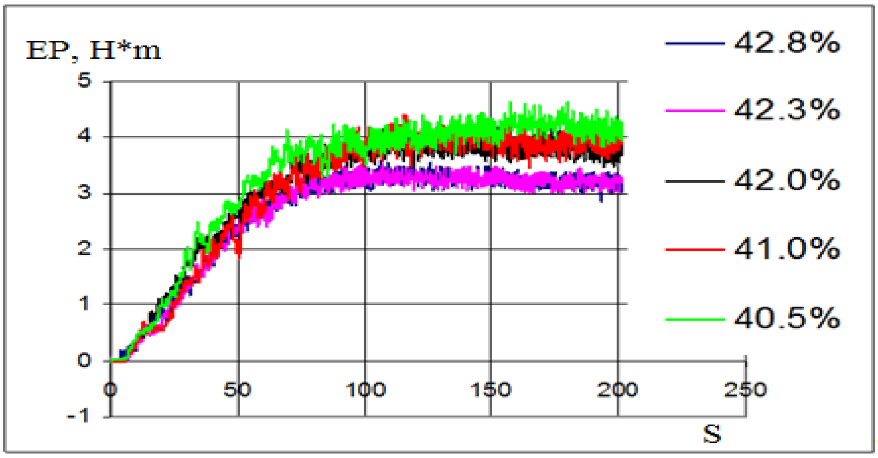

Figure 2. Family of curves of the test of wheat during mixing with change of content of water at a rotation speed 63ob/min.

Table 1: Indicators of quality of wheat flour.

The name of indicators	The value of indicators		
	Sample number 1	Sample number 2	Sample number 3
Moisture, %	13.6	13.0	12.0
Acidity, degrees	2.5	2.6	2.1
Content of wet gluten, %	30	28	27
The total deformation of gluten, units of the device, IDK	63	53	59
White flour, units of the device «Blik-R3»	55	55	54
Falling number, c	240	340	370

The determination of the rheological characteristics for wheat dough after [3] kneading was carried out was modeled mathematically as an exponential curve for the relaxation of mechanical stress (Fig. 3) using a cylindrical indenter. The cylindrical indenter was introduced to the dough under the following loading conditions (Alekseev *et al.*, 2012; Kosoy, 2005):

• effort touch (Ft = 5 g);

• strain rate (Vr = 1 mm / s);

• depth of indentation in the sample test (hi = 5 mm);

• duration of stabilization of the depth of penetration (tst = 120 s) (Maximov, 2004).

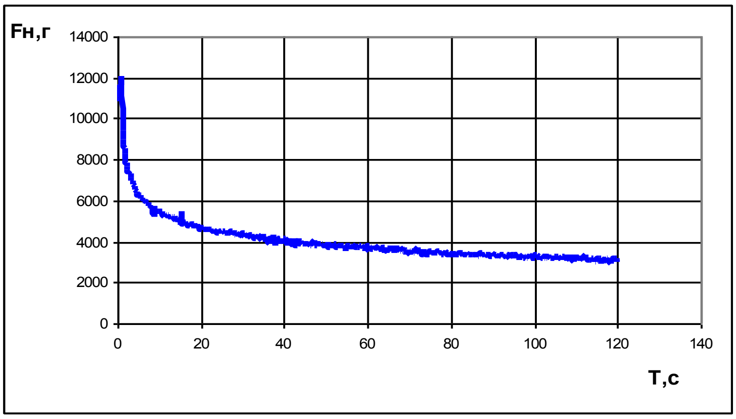

Figure 3. Changing the effort of loading on the indenter during the relaxation of stresses in wheat dough.

The rheological properties of the wheat (Bucsella *et al.*, 2016; Dobraszczyk *et al.*, 2003) dough were calculated using the following model below (Létang *et al.*, 1999; Maximov, 2004):

$$\frac{\sigma}{\sigma_{\max}} = K_1 \times \exp(-\lambda_1 \tau_1) + K_2 \times \exp(\lambda_2 \tau_2) + K_3 \qquad (1)$$

$$K_1 + K_2 + K_3 = 1 \qquad (1a)$$

where the percentage of the relaxation time was represented by;

K_1 – the rapid relaxation of the stress;

K_2 – the long-term stress relaxation;

K_3 – the residual stress;

and λ_1, λ_2 – are the rate of instantaneous and long-term relaxation of mechanical stresses (s^{-1}), repectively, and;

τ – the current time (Kuznetsov *et al.*, 2005).

According to the rheological model presented in Eq. (1) (Kosoy, 2005), the rapid loading mechanical stress tests are divided into three parts. Two parts (K_1 and K_2) are the shorter term relaxation. One of them (K_1) decays almost instantly (the period of relaxation is in the range 3 sec.) and the second term (K_2) for a longer time or on the order of tens of seconds. The third part (K_3) remains unchanged. The relaxation of the third part (K_3) characterizes the pliability of the material deformation, its plasticity. Thus, residual stress characterizes the strength of the material.

If we take the initial load of a unit, then the test results can be represented as a triangular diagram containing three samples; a – wheat dough, b – crumb loaf and c – Pasta (Fig. 4).

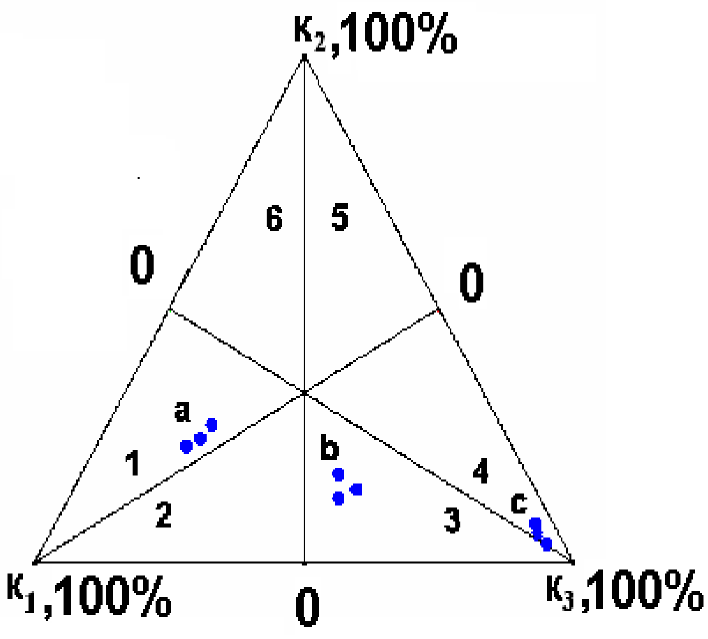

Figure 4. Determination of the structural-mechanical type of the material.

In the diagram above, K_1 represents rapidly relaxing tension, K_2 share slowly relaxing, and K_3 – the proportion of residual stresses. Digits denote the area of the diagram defining the structural and mechanical type of material. Point position on a chart allows us to assign the material under study to a particular structural mechanical type. Thus, regions 1 and 2 show high viscosity and plasticity of the materials, 3 and 4 are the elastic-plastic properties of 5 and 6 of the relatively high strength and hardness of the material.

The effective viscosity of wheat dough after mixing was determined using the instrument «REOTEST 2.1» in accord with the procedure described in laboratory practicum (Maximov, 2004; Machihin *et al.*, 2004).

Changing the rheological characteristics of wheat dough, depending on its consistency, was simulated by adding different amounts of water. The results are presented in Table 2.

Table 2: Changing the rheological character of wheat dough after mixing in water depending on its consistency.

Indicators	Values of indicators at different humidity test				
	40.5%	40.8%	41.3%	41.8%	42.1%
The consistency of the test units. Ave Farinograf, EP	740	690	640	590	540
Effective viscosity of the dough, Pa * s	1916	1429	1197	856	1024
The share of fast stress relaxation, K_1	0.54	0.49	0.57	0.60	0.59
Proportion of slow relaxation of tension, K_2	0.27	0.28	0.25	0.23	0.24
Fraction of residual stresses K_3	0.19	0.23	0.18	0.17	0.59
Instantaneous velocity of stress relaxation λ_1, s^{-1}	0.479	0.525	0.571	0.663	0.636
The rate of long-term stress relaxation λ_2, s^{-1}	0.033	0.034	0.036	0.040	0.038
Compressive , Ауд, kJ/kg	74.0	46.7	52.8	31.8	36.5

After the laboratory baking test, we confirmed that the best indicator of bread quality was at a texture 640 EP (Table 3).

Table 3: The effect of dough consistency on the sliced loaf quality (sample of wheat flour VS № 1).

The consistency of dough, EP.	Specific volume; sm^3/g	Porosity; %	Kroshkovatost; %
540	3.2	79	10.5
590	3.6	81	10.8
640	3.75	82	5.0
690	4.1	81	9.6
740	4.2	80	9.0

Further studies of the effect had baking properties of wheat flour (dough of the same consistency) on the change of rheological characteristics of individual test (see Table 4) and the quality of the loaf sliced (see Table 5).

Table 4: Effect of baking properties of wheat flour (sample number) on the rheological characteristics of wheat dough with the same consistency it – 640 EP.

№	Designation	1 test flour	2 test flour	3 test flour
1	Elastic modulus E_1, Pa	4587	3279	3325
2	Elastic modulus E_2, Pa	2274	7444	2015
3	Elastic modulus E_3, Pa	6154	2496	6477
4	The dynamic viscosity η_1, Pa *s	8166	1082	6347
5	The dynamic viscosity η_2, Pa *s	5781	3997	6784
6	Instantaneous velocity of stress relaxation λ_1, s^{-1}	0.5618	0.7355	0.5242
7	The rate of long-term stress relaxation λ_2, s^{-1}	0.0383	0.1862	0.0301
8	Total strain $h_{ob,}$ mm	7.84	4.7	10.3
9	Elastic deformation h_{up}, mm	3.4	2.1	4.6
10	Plastic deformation h_{pl}, mm	4.4	2.6	5.7
11	Force loading F g	482	310	274
12	Kroshkovatost, %	5.0	15.8	9.2
13	Sponginess, %	82.0	85.0	84.0
14	Specific volume, sm^3/g	3.75	4.89	3.9

Based on these data, we found that the wheat dough viscosity due to the gluten content and meaning «falling number», i.e. autolytic activity of flour.

Table 5: Effect of baking properties of wheat flour (sample number) to change the rheological and physico-chemical characteristics of crumb batten rifled at him the same consistency of the dough – 640 EP.

№	Designation	1 sample mealp.	2 sample meal	3 sample meal
1	Elastic modulus E_1, Pa	4587	3279	3325
2	Elastic modulus E_2, Pa	2274	7444	2015
3	Elastic modulus E_3, Pa	6154	2496	6477
4	The dynamic viscosity η_1, Pa *s	8166	1082	6347

5	The dynamic viscosity η_2, Pa *s	5781	3997	6784
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11	Force loading F g	482	310	274
12	Kroshkovatost, %	5.0	15.8	9.2
13	Porosity, %	82.0	85.0	84.0
14	Specific volume, sm^3/g	3.75	4.89	3.9

From the data shown above (Table 5), we concluded that the best physico-chemical and rheological characteristics has a crumb batten rifled a consistency test 640 EP prepared from wheat flour sample number 1, as the crumb of the loaves had the lowest bulk stock.

Thus, on the basis of these studies, we confirmed that the optimum consistency of the texture for wheat dough is 640-650 EP. This allowed us to determine the ability water absorption by the flour through the baking properties of the wheat dough in recipes, as well as accurately set the quantity of water required for the dough. As a result of the water tests we were able to; calculate the duration of kneading until tender, determine the amount of mechanical energy expended in forming the dough during mixing, and change the rheological characteristics of wheat dough.

The best quality of the finished products were obtained using the integral values of the rheological characteristics as follows; the torque on the drive mixers for the time necessary to knead the dough (640-650 EP), which corresponds to the effective viscosity of the dough (1197 Pa * s), the values of the immediate and long-term stress relaxation (K_1 – 0.57, K_2 – 0.25) and the proportion of residual stress (K_3 – 0.18), and finally, the rate of instantaneous and long-term relaxation of mechanical stresses (λ_1- 0.571 s-1 ; λ_1- 0.036 s-1).

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