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MULTIPARAMETER METHOD OF CONTROLLING THE RHEOLOGICAL CHARACTERISTICS OF THE DOUGH AFTER KNEADING

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ABSTRACT

Bread is a product of daily necessity and in any economic conditions – is the cheapest food. Bread-baking industry is most susceptible to market changes and is completely dependent on fluctuations in supply and demand in the market. The main task of the bread-baking industry is to provide the population with qualitative bread and bakery products in the assortment and quantity, corresponding to everyday needs of the people. In this regard, the problem of the quality of bread and bakery products is becoming increasingly important.

The quality of bread, like any food product, is a complex concept, including a whole range of its attributes. At bread production plants, the evaluation of the quality of bakery products is carried out in accordance with the requirements of GOSTs, by organoleptic and physicochemical parameters. However, among the physicochemical parameters, there are no rheological indicators, upon which the rheological characteristics of the wheat dough after kneading can be objectively evaluated and the quality of the bread can be predicted.

The paper presents the method for controlling the rheological characteristics of a dough after kneading, the use of which will allow to influence the formation of the finished product quality at the stage of its production.

Key words: Strukturometr, wheaten flour, farinograf, rheology, wheat bread.

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INTRODUCTION

In the production of bakery products, wheat flour is the most unstable raw material, therefore, the preparation of finished products with specified texture parameters can be achieved only by controlling the rheological characteristics of semi-finished products, taking into account the baking properties of raw materials and baking formula.

In the technological cycle of the bakery products production, the first and one of the main operations is a kneading of dough (Kihlberg et al., 2004; Machihin et al., 2004). In the process of kneading, the rheological properties of semi-finished product are formed and than they influence the structure of finished products.

Assessing the rheological behavior, for example, of a wheat dough when kneading according to the parameters of farinogram, first of all, the consistency of the dough and the moment of its readiness are established. The consistency of the dough allows to set the required amount of water (Oke et al., 2013), but there is no information about the viscosity of the dough after kneading, i.e. the information on the cohesiveness of coagulative structure for the rye dough, and the coagulative-crystallization structure for the wheat dough. All subsequent operations, such as fermentation, forming, final proofing (rasstoyka) and baking, will depend on the rheological properties of the dough, formed during the kneading process. The degree of machining, i.e., the intensity of mechanical energizing during the kneading process, affects the construction of the gluten dough network, which subsequently provides the porosity structure of the finished bread crumb (Boltenko et al., 2015).

The ratio of dough formulation components and the measure of impact on the dough by kneading machine causes a certain ratio of rheological characteristics, such as total, elastic and plastic deformations, adhesive stress, shear stress, relaxation rate, etc., forming an integral structure and subsequently influencing the technological process of bakery products production.

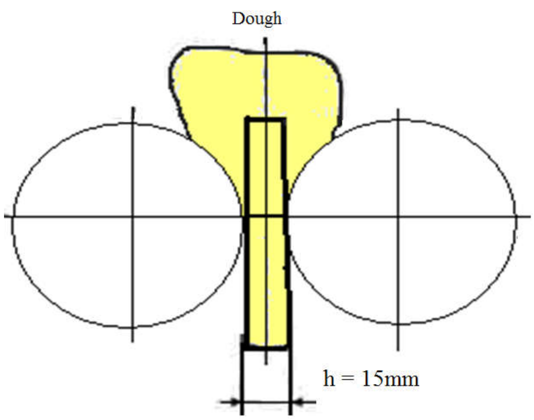
Each of the dough rheological components, as a food mass, is subsequently responsible for the behavior of this mass in the course of technological operations, following the kneading. For example, the porosity of finished bread is due to the ability of the *dough* to increase in volume by means of plastic deformation, retaining carbon dioxide, released in the process of fermentation. The shape stability of baked bread in the process of final proofing and at the beginning of baking, directly depends on the amount of elastic deformation of the dough. The value of dough adhesive stress allow to assess the degree of dough adhesiveness to the working parts of the dough shapers and thereby to assess the technological losses.

Entirely, these separate rheological characteristics form an integral rheological characteristic of the dough n the process of its kneading – torque value on the drive of kneading machine. For this characteristic of the dough, the term "consistency" is used. The consistency of the dough is used to determine the water-absorbing capacity of wheat flour (according to the Brabender method), according to which its "strength" is evaluated, while the dough is kneaded with a consistency of 500 EP.

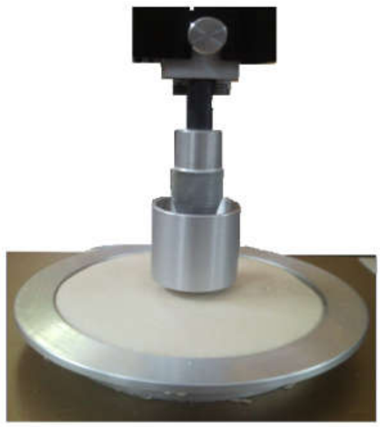
Special method was developed to determine the degree of contribution of individual rheological characteristics of the wheat dough after kneading in the formation of its consistency. The purpose of this work is to develop a multi-parameter method for controlling the rheological characteristics of the dough after kneading.

DATA AND METHODS

For determining the rheological characteristics of the wheat dough after kneading, it was rolled between rollers in the form of 15 mm thick layer (Figure 1a) and a sample was cut out by the cylindrical probe with diameter of 110 mm (Figure 1b). The sample after sweating during 60 seconds was placed on the platen and a rheological profile of the dough was taken by cylindrical indentor Ø36 mm, i.e., the diagram of the change in loading stress of a wheat dough, depending on its deformation (Figure 2).



a)



b)

Fig.1. Sample preparation of the dough after kneading:

a) rolling the dough between the rollers;

b) preparing the dough using a cylindrical probe.

After mathematical processing of rheological profile, the criterion point "A" was established, reflecting the transition of the wheat dough from the plastic-elastic state to the viscousflowing one, and determining the loading stress of the wheat dough in the process of determining of its deformation and relaxation characteristics (Bucsella et al., 2016; Van Vliet et al., 1992).

Then, the next dough sample was taken and the deformation characteristics of dough were defined, with the set value of the loading stress, taken from the point "A" (Figure 3).

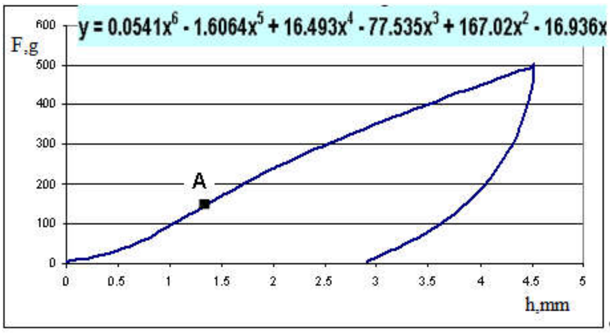


Fig.2. Change of the loading stress of wheat dough depending on the penetration depth of the indenter.

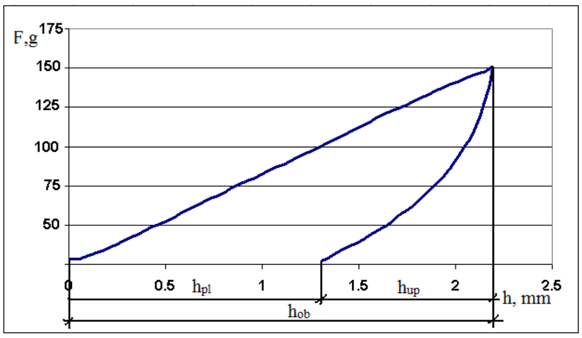


Fig.3. Diagram of loading wheat dough with a stress, defined from the inflection point "A" in Figure 2.

Total, plastic and elastic deformation was determined from the deformation characteristics for a given loading stress. The ratio of plastic deformation ($h_{пл}$) to the total deformation ($h_{общ}$) was taken as one of the rheological criteria, according to which the rheological behavior of the wheat dough can be evaluated (equation 1):

$$\Delta h = \frac{h_{пл}}{h_{общ}} \tag{1}$$

Then the rheological characteristics were determined from the analysis of exponential curve of mechanical stresses relaxation, by means of its mathematical processing. Mechanical stresses relaxation arises on a cylindrical indenter, when it is placed into the dough. The exponential curve of mechanical stresses relaxation (Figure 4) was controlled under the following loading conditions:

- Touch force (Ft = 5 g);
- Velocity rate of deformation (Vr = 0,5 mm/s);

- Loading stress (Fn = 150 g);
- Duration of stabilization of indenter position after its placement into the dough to a depth of 5 mm (τst = 120 s) (Maximov, 2004).

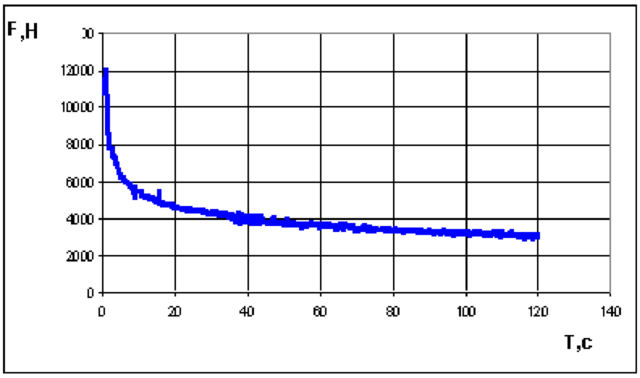


Fig.4. Changing the loading stress on the indenter, in the process of mechanical stresses relaxation in wheat dough

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

$$\frac{\sigma}{\sigma_{\max}} = K_1 \exp(-\lambda_1 \tau_1) + K_2 \exp(-\lambda_2 \tau_2) + K_3 \qquad (2)$$

Where $K_1+K_2+K_3=1$ (3)

K1 - is the rapid relaxation of stress;
K2 - is the long-term stress relaxation;
K3 – is the residual stress;
λ_1, λ_2 - are the rate of instantaneous and long-term relaxation of mechanical stresses c^{-1};
T – is the current time, s (Kuznetsov et al., 2005).

RESULTS

When loading a sample of wheat dough, arising mechanical stresses are divided into three parts: two parts (K_1 and K_2) are relaxing, one of which dissolves almost instantly (the relaxation period is in the range of 1-3 s), and the second dissolves during a long time - tens of seconds (Kosoy, 2005). The third part K_3 remains unchanged. The relaxing part of the stress characterizes its plasticity, and the residual - the strength of the material.

In the process of organization of multiparameter control of the rheological properties of wheat dough, if it is not in the form of a layer, it is impossible to determine its relative deformation, therefore, in the rheological model, its coefficients K_1, K_2 and K_3 are not represented in the form of elastic moduli, but in the form of parts of relaxing and residual mechanical stresses.

The relaxation rate of mechanical stress $\lambda = E/\eta$, reflecting the ratio of the modulus of elasticity to viscosity, was chosen as the main criterion for the rheological behavior of the wheat dough. The results of the researches are presented in Table 1.

Table 1. Rheological characteristics of wheat dough after kneading

Item №	Rheological characteristics	Value of rheological characteristics
1	Rapid relaxation of stress, K_1	0.52
2	Long-term stress relaxation, K_2	0.29
3	Residual stress, K_3	0.19
4	Total deformation h_{ob}, mm	2.34
5	Elastic deformation h_{up}, mm	0.69
6	Plastic deformation h_{pl},mm	1.65
7	Instantaneous velocity of stress relaxation λ_1, s^{-1}	0.59
8	The rate of long-term stress relaxation λ_2, s^{-1}	0.06
9	Average long-term stress relaxation λ, c^{-1}	0.32
10	The ratio of plastic deformation to the total deformation Δh	0.70

DEDUCTIONS

The influence of the mechanical specific energy, spent for the formation of the wheat dough, and the optimal values of the total, elastic and plastic deformation of the wheat dough after kneading were determined.

The operating mode of the Strukturometr ST-2M was developed and the rheological criteria were defined. The rheological criteria are the following: Δh - is the ratio of deformation characteristics (the ratio of plastic deformation to total deformation) and λ – is the relaxation rate of mechanical stresses (the ratio of the modulus of elasticity to the coefficient of dynamic viscosity), which should be 0, 70/0.32.

CONCLUSION

Based on the conducted research, a method for evaluating the rheological behavior of a wheat dough was developed, using an information and measuring system, including device Strukturometr ST-2M, a cylindrical indenter with a diameter of 36 mm, a ring with a diameter of 120 mm, which limits the volume of the dough, where the control of rheological characteristics of the semi-finished product was carried out.

The evaluation of the rheological behavior of the wheat dough should be carried out after it's kneading with the same consistency, equal to 640-650 EP and a temperature of 28 ± 1°C, when determining the amount of specific mechanical energy, spent on forming of the dough structure until readiness with the specified consistency.

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