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ASSESSMENT OF ENERGY EXPENDITURE ON THE KNEADING WHEAT DOUGH PROCESS

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Abstract: *A quantitative assessment of the quality of the process of kneading the dough in the dough machines, of both periodic and continuous this is the total and specific energy expenditure. Determination of energy expenditure is necessary for the calculation of the dough machine as well as the energy analysis of specific stages of the process. Studies were conducted on a laboratory kneading machine of periodic action. To measure the energy expenditure used wattmeter. An analysis of the experimental data showed how energy expenditure varied throughout the experiment and confirmed three stages of the kneading wheat dough process. Comparing the calculated theoretical values with the obtained experimental values, they were found to be different. Studies of the process of kneading wheat dough prove the need for changes in the method of calculating energy expenditure for kneading, eliminating the formal approach to this process and taking into account the energy expenditure of structural transformations.*

Keywords: *dough, mixing machine, energy expenditure, kneading, qualities.*

INTRODUCTION

The dough kneading is the most important technological operation, on which the further course of the technological process and the quality of the bread depend. Traditionally, dough is made by combining flour and water and mixing by an input of mechanical energy. This energy input contributes not only to a uniform distribution of all ingredients but also to the hydration of the flour particles leading to the formation of a continuous gluten structure surrounding the starch granules. [1] Mixing requirement (known by mixing time or development time) is related to dough strength and is important as it determines the cost of an end-product through the energy requirement of mixing. [2] A quantitative assessment of the quality of the process of kneading the dough in dough machines, of both periodic and continuous, is the total and specific energy expenditure.

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The dough kneading is performed for 1-20 minutes in the working chamber of the dough mixing machine, where three functions are performed: (a) creating a homogeneous mass of ingredients that have different characteristics, (b) developing (kneading) the dough sufficiently to prepare it for further processing and (c) absorption (occlusion) of air into the dough mass to form cell structures necessary for the quality of the finished products. During kneading the mixing components and their machining and the formation of resiliently-elastic gluten framework.

To facilitate the analysis of the laws of the process of mixing A.T. Lisovenko [3] has been proposed a three-stage model of the process of wheat dough kneading (Fig. 1):

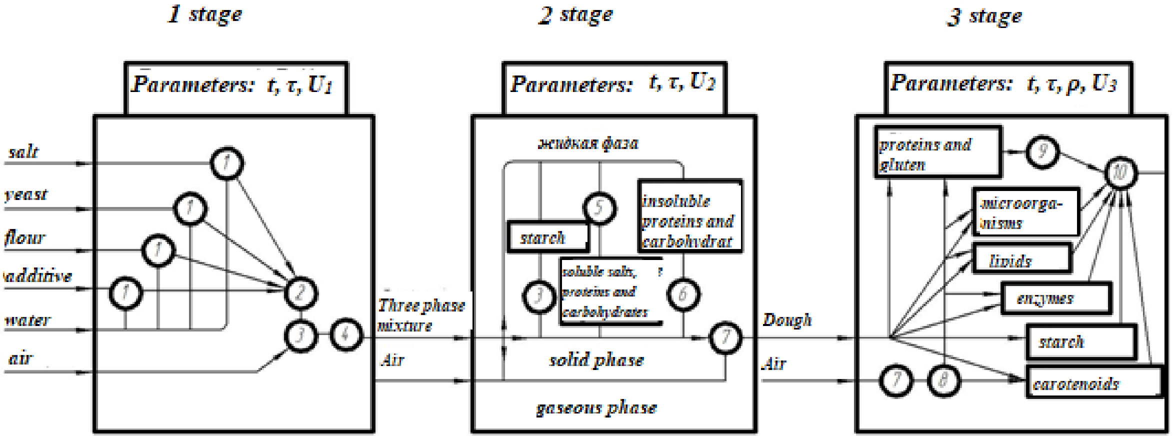

Fig. 1. Three-stage model of the process of kneading wheat dough
Processes during dough kneading:
1.Damping; 2. Aggregation; 3. Sorption; 4. Dispersion 5. Dissolution; 6. Swelling; 7. Occlusion; 8. Oxidation; 9. Intermolar compound 10. Structural formation

The first stage – the mechanical mixing and aeration of the components. As a result of this stage, a uniform distribution of the components of the mixture is achieved. Accompanied by moistening of dry ingredients, their dispersion, aggregation, and moisture sorption. This stage should be carried out as soon as possible with minimal energy consumption. With an increase in the duration of the first stage, the process is complicated by the swelling of flour particles and their cohesion, which complicates further mixing and uniform distribution of components.

The second stage – the kneading itself. It is characterized by equalization of moisture of various components, the transition to a solution of soluble parts of flour. In this case, the shear stress increases and, as a result, the energy expenditure for the drive of the dough mixer increase.

The third stage – plasticization. Accompanied by structural changes in the starch particles and creating a gluten grating which covers a starch granule. The third stage requires enhanced mechanical impact, and not just mixing, since the creation of gluten films (grinding) takes place along with the destruction of gluten molecules, the latter is significantly affected by the activity of some enzymes, as well as humidity and temperature of the dough.

Bakers and specialists also distinguish three consecutive stages of kneading the dough – phase: hydration, dough formation and mixing the mixture [4].

EXPOSITION

The amount of energy expenditure by kneading can be determined experimentally and calculated according to the proposed procedure by Prof. A.T. Lisovenko. [3]

In most modern kneading machines, the kneading process is carried out as a result of the rotational movement of one or more kneading blades. The energy balance is determined per cycle of the kneading blade (1).

$$A_i = A_1 + A_2 + A_3 + A_4 \tag{1}$$

where: A_1 – the work spent on mixing the mass (2)**:**

$$A_1 = a \cdot b \cdot \pi \cdot \rho_m \cdot n^2 \cdot cos(90 - \alpha) \cdot (r_1^2 - r_2^2) \cdot ((1 - k) \cdot \pi^2 \cdot (r_1^2 + r_2^2) + \frac{k \cdot S^2}{2}) \tag{2}$$

A_2 - work spent on moving the blades (3) **:**

$$A_2 = \frac{2}{3} \cdot a \cdot b \cdot \delta \cdot \rho_m \cdot \pi^2 \cdot n^2 \cdot (r_1^2 - r_2^2) \tag{3}$$

A_3-work spent on heating the dough and tangential to it the metal parts of the machine (4)**:**

$$A_3 = (\frac{(t_1 - t_2)}{n \cdot \tau_k}) \cdot (m_d \cdot c_d + m_m \cdot c_m) \tag{4}$$

A_4 - work spent on changing of the structure of the dough: (5)**:**

$$A_4 = (0.05 \ldots 0.1) \cdot A_1 \tag{5}$$

To compare the energy expenditure of various types of kneading machines, they should be recalculated for 1 g of dough and calculate specific work according to equation (6)**:**

$$A_{i\ sp.} = \left(\frac{\tau_k \cdot n}{m_d}\right) \cdot A_i \tag{6}$$

The intensity of the process is calculated based on the specific work (7)**:**

$$U = \frac{A_{i\ sp.}}{\tau} \tag{7}$$

The aim of our research was to determine the correspondence of the calculated values of energy expenditures for a batch of dough with experimentally obtained data. The studies were carried out on a batch-mixing laboratory dough mixing machine (Fig. 1), which consists of a drive with the ability to adjust the number of revolutions of the boiler stands on the bed, a bowl for mixing with a lid. The working body is kneading burst anchor type. The dough was kneaded according to the recipe for 20 minutes. As a controlled parameter, the rotation speed of the working body of the kneading machine is considered. To measure energy consumption, a Lemanso LM669 power meter was used.

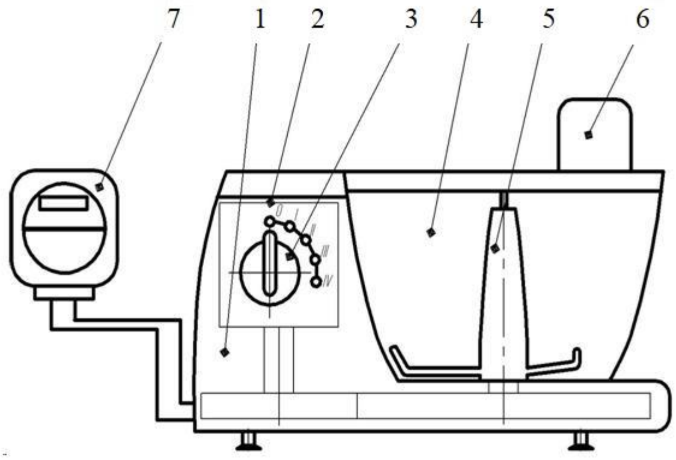

Fig. 2. Scheme of the laboratory kneading machine:
1-bedplate; 2-drive with the possibility of adjusting the number of revolutions; 3 - gear shift lever; 4-kneading container; 5 - working body; 6- cover; 7- Lemanso LM669 – device for measuring electric power.

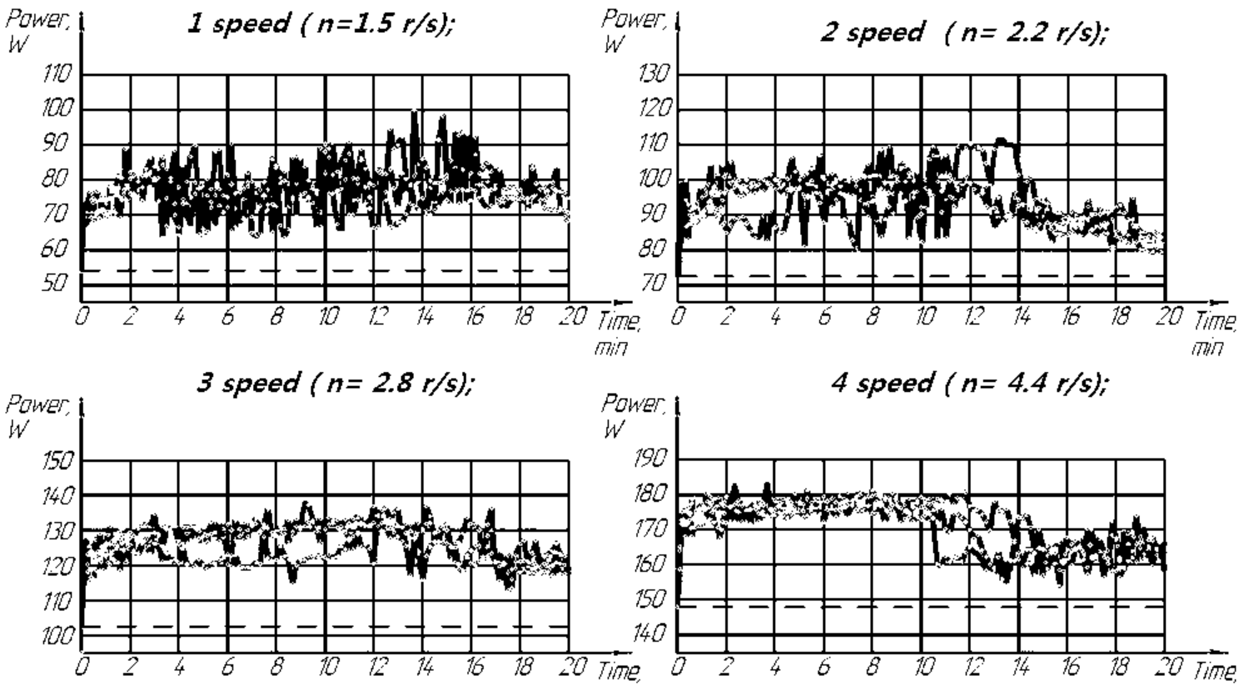

Fig. 3. Experimental energy expenditure

The experimental values of the energy expenditure during the kneading (Fig. 3).

As a result of processing and analysis of experimental data (Fig. 4), the averaging curves were obtained for the changes in energy consumption at different speeds of rotation of the working body: 1 - first speed (n = 1.5 r / s); 2 - second speed (n = 2.2 r / s); 3 - third speed (n = 2.8 rpm); 4 - fourth speed (n = 4.4 r / s) obtaining the dependences show how energy expenditure changes over the course of the experiment and confirm the three-stage process of mixing wheat dough: I - stage of components mixing; II - stage of kneading itself; III - stage of plasticization;

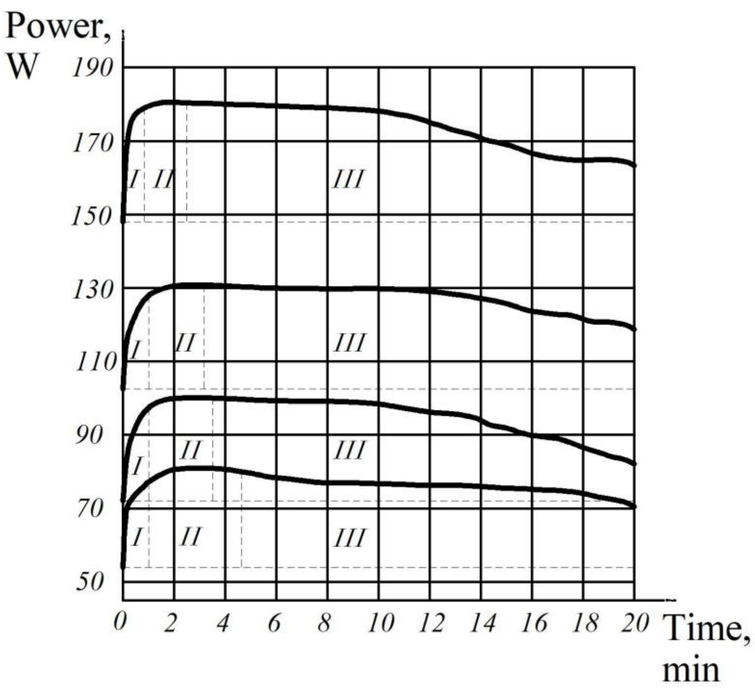

Fig. 4. Dependence of the energy expenditure in time

We calculated the energy according to formulas (1), (2), (3), (4), (5) and (6) and the intensity of the kneading process (7) and, accordingly, the energy expenditure of the experiments. Data entered into the table for comparison (table 1)

Table 1. Comparative analysis of experimental and theoretical energy consumption.

		Specific work in stages, J/g							
		First speed, n=1.5 r/s		Second speed, n= 2.2 r/s		Third speed, n= 2.8 r/s		Fourth speed, n= 4.4 r/s	
		exp.	theor.	exp.	theor.	exp.	theor.	exp.	theor.
Work spent on mixing	1 stage	1,722	0,161	2,346	0,165	2,423	0,169	2,767	0,187
	2 stage	10,288		7,775		6,770		6,361	
Work spent on moving the blades		—	0,020	—	0,025	—	0,030	—	0,052
Work spent on heating		—	4,976	—	5,233	—	6,610	—	11,035
Work spent on changing of the structure (3 stage)		46,796	0,016	49,134	0,016	50,701	0,017	51,791	0,019
Specific work		58,806	5,172	59,255	5,438	59,894	6,826	60,919	11,293
Intensity of the process (W/g)		0,0490	0,0043	0,0494	0,0045	0,0499	0,0057	0,0508	0,0094

So according to the calculation results, the specific energy consumption per batch is from 5 according to the first speed to 11 j / g according to the fourth speed, while the experimental values are from 58.8 to 60.9 j / g.

In the first and second stages, the difference is not so insignificant. We see the largest deviations in the of specific work spent on changing the structure of the doudg.

The theoretical calculation does not fully take into account the energy consumption for viscous friction of the dough mass during mixing and the change in the structurally mechanical properties of the dough mass, the transition during kneading from individual powder and liquid masses to a complex structure that is characterized by non-new properties.

CONCLUSION

Obtaining experimental and theoretical values of energy expenditure differ: in the first and second stages, the difference is insignificant. The largest deviations are observed in the costs of specific work at the plasticization stage.

It is necessary to make changes to the methodology for calculating the energy expenditure for the kneading process, excluding the formal approach to this process and accounting for energy expenditure for structural transformations, which are decisive in terms of both energy expenditure and the quality of the dough semi-finished product. We propose to change the formula for calculating the work spent on changing the structure of the dough (stage 3), according to the existing methodology, the work spent on changing the structure of the dough is calculated as 5-10% of the work on mixing the mass of the dough itself. We propose to increase this percentage and calculate the work on the structural change of the dough as 10 multiply the value of the work on heating the dough and metal parts (A3).

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