STUDYING THE EFFECT OF MILK PROCESSING PRODUCTS ON THE STRUCTURAL-MECHANICAL PROPERTIES OF WHEAT FLOUR DOUGH

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Abstract

Dry whey enriched with magnesium and manganese (DW) that contains protein in the amount of 13 %, and a whey protein concentrate (WPC) with a protein content of 65 %, have been chosen as functional bases in the production of complex baking improvers with a targeted effect. When developing a composition of the complex improver, the rational dosage of DW is 2 % by weight of flour, and that of WPC – 3 % by weight of flour.

Adding DW and WPC during the kneading of wheat flour dough predetermines a decrease in its gluten content, by 4 % and 6.1 %, respectively, after 20 minutes of the dough rest, and by 7.5 and 10.7 % after two hours of the dough fermentation. This is due to the introduction of lactic acid with milk processing products, which peptizes proteins resulting in that the gluten proteins are partially converted into water-soluble ones.

If DW and WPC are included in the dough formulation, there is an increase in the total amount of proteins in it, as well as a change in their fractional composition: the mass fraction of water-soluble and intermediate fractions of proteins increases while the amount of gluten proteins decreases. That confirms a decrease in the amount of gluten washed out from the dough with the addition of DW and WPC. Increasing the mass fraction of water-soluble proteins contributes to the intensification of the fermentation process through the additional nutrition of microflora with nitrogenous substances and an increase in the content of free water in the dough, which predetermines its thinning.

It was established that despite the high water absorption capacity of DW and WPC, the water-absorbing ability of the dough that contains them decreases compared to control by 8.4 and 10.7 %, respectively. Studying the dough at the farinograph has shown that in the case of using DW, its stability is somewhat prolonged while in the case of WPC introduction the dough stability is extended by almost 10 minutes, which leads to prolonging the dough kneading. Along with this, in the case of using WPC, there is a rapid descent of the farinogram curve, which could lead to a strong weakening of the dough during fermentation and rest, even though that the thinning after 12 minutes is lower than that of control.

Keywords: dry whey, dough, whey protein concentrate, farinogram, thinning, proteins, lactic acid.

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1. Introduction

The basic indicator of the consumer properties of bakery products is their freshness. Freshly baked bakery products have pronounced aroma and taste, elastic crumb, crispy crust. During storage, the quality of bakery products is reduced, which is associated with the processes of staleness and drying. These processes depend on the formulation components, dough preparation technique, the quality of flour, storage conditions, etc. [1].

To improve the consumer properties of bakery products, manufacturers in most cases use complex bakery improvers, which are designed to adjust the baking properties of flour, to intensify the production process, improve the organoleptic and physicochemical quality indicators, as well as prolong the duration of freshness [2, 3].

A relevant field of scientific research in the technology of bakery products is the development of new complex bakery improvers of targeted action, which, along with improving the consumer properties of bakery products, would improve their nutritional value [4]. Complex bakery improvers consist of a functional base (in most cases, it is dry wheat gluten, flour, starch) and the active part (additives with oxidative and reducing effect, enzymes, emulsifiers, moisture-holding agents) [5], which are selected in an optimal ratio, which allows them to simultaneously interact with flour biopolymers, thereby intensifying the process of dough preparation and improving the quality of bakery products [6].

When developing a complex baking improver, much attention is paid to the choice of a functional base that plays the role of filler in the improver itself and a technological role in the production of bakery products.

The production of bakery involves products based on milk, as well as products of its processing, aimed to prolong freshness and improve nutritional value. Milk processing products include skimmed milk powder, lactose, milk, cheese, whey, or protein whey concentrates that are rich in protein, vitamins, minerals such as potassium, calcium, magnesium, iron, etc.

Based on trial laboratory baking at the National University of Food Technologies (Ukraine), scientists established the effectiveness of using dry whey (DW) powder enriched with magnesium and manganese [7] and a whey protein concentrate (WPC) [8].

It was found that in the development of a complex bakery improver, the rational dosage of DW is 2 % by weight of flour [9], and WPC – 3 % by weight of flour [4]. In further studies, it is advisable to reveal the effect of DW and WPC on the structural and mechanical properties of the dough for the logical choice of food additives in the active part of the improver.

The object of this research is wheat flour dough of the highest grade, dough with DW in the amount of 2 % by weight of flour, and dough with WPC in the amount of 3 % by weight of flour.

The purpose of this work was to determine the influence of DW and WPC on the formation of structural and mechanical properties of dough and their changes in the process of dough maturation.

To accomplish the aim, the following tasks have been set:

– to establish regularities of DW and WPC influence on the viscoelastic properties of dough;

– to establish regularities of influence of DW and WPC on viscoplastic properties of dough.

2. Materials and Methods

In the current study, we used dry whey enriched with magnesium and manganese particles, prepared by applying Kochubey-Litvinenko technology at the National University of Food Technologies (Ukraine). According to the technology, the content of Mg and Mn in whey is replenished with valuable biogenic metal by the underwater electro-spark dispersion of magnesium and manganese granules in its environment. The electro-sparking treatment of whey increases the content of magnesium and manganese by 2.5...3.0 times depending on the processing time [7]. Another valuable ingredient as a functional base is the dry whey protein concentrate KSB-UV-65 (WPC) made by TOV Techmolprom (Ukraine). WPC is whey protein that is a byproduct of the production of both curd cheese and fermented milk cheese, which is made by using the membrane methods for separating whey and subsequent drying. It belongs to the "complete" proteins, contains all the necessary amino acids, is very easily and quickly absorbed by the body [10, 11].

To determine the influence of DW and WPC on the processes of wheat flour dough formation and maturation, we performed model experiments involving wheat flour of the highest grade (control) and a mixture of wheat flour of the highest grade and DW in the amount of 2 % of the mass of flour; a mixture of flour and WPC in the amount of 3 % by weight of flour. The dough was made from these mixtures with the addition of 3 % pressed bakery yeast and 1.5 % table salt.

The viscoelastic characteristics of the dough were studied at the farinograph made by "Brabender" (Germany) [12].

The quantity and quality of gluten in the control and examined samples were evaluated according to standard procedures [12].

The gas-holding capacity of the dough was determined by a change in the specific volume of 100 g of dough in the cylinder during the fermentation of the dough [13].

The fractional composition of dough proteins was evaluated according to the method proposed by Chizhova [13].

The spread of the dough ball was determined by a change in the diameter of the dough ball during the fermentation of the dough [13].

The results of our experimental studies were statistically treated using the standard Microsoft Office software.

3. Results

Structural and mechanical properties of the dough, namely springiness, elasticity, viscosity, plasticity play an important role in the shape stability of dough blanks during resting and baking, as well as predetermine the volume of finished products, porosity, and stale process.

We determined the patterns of influence of DW and WPC in the selected rational dosages, namely DW in the amount of 2 % % by weight of flour, and WPC in the amount of 3 % by weight of flour, on the gluten quality of dough kneaded from these mixtures. The gluten from the dough was washed out after 20 minutes of its rest and in 180 minutes.

Table 1 gives the quality indicators of the dough gluten: quantity, the elasticity of gluten at the device IDK-2, as well as its extensibility, hydration ability.

Less gluten is washed off the dough when using DW and WPC (**Table 1**). This is observed both after 20 minutes of rest and after two hours of fermentation. Compared to the control, the dough containing DW releases, after 20 min of rest, 4 % less of gluten; the dough with DW – 6.1 % less; after two hours of fermentation, 7.5 % less and 10.7 % less, respectively. There is also a decrease in gluten hydration ability when using DW and WPC. This is due to the introduction of lactic acid along with milk processing products, which peptizes proteins; the peptization of proteins is intensified by the fermentation of the dough. Therefore, the amount of gluten washed out of the dough is less, that is, those fractions of the protein remain that undergo less peptization. The analysis of our study results has revealed that the use of DW and WPC predetermines changes in the physical properties of dough gluten, namely its strengthening; thus, the extensibility in the dough with DW after 20 minutes of rest is reduced by 2 cm, compared to control, with WPC – by 3.5 cm; the same pattern is observed after two hours of fermentation. These data are consistent with the elasticity indicator but that does not confirm that milk processing products strengthen gluten, this is due to a change in the protein composition of gluten.

Therefore, our further study determined the influence of DW and WPC on the fractional composition of dough proteins according to the procedure proposed by Chizhova [13]. Because yeast consumes nitrogenous substances in the process of its life activities, the study was carried out using the yeast-free dough immediately after kneading, and after 90 minutes of autolysis. Protein fractions were split into a gluten fraction of protein, as well as water-soluble and intermediate fractions – proteins that are not washed out in the form of gluten but are not transferred to a solution. The study results are given in **Table 2**.

Table 1

Effect of dry whey enriched with magnesium and manganese, and of whey protein concentrate, on gluten content in the dough and its quality (*n*=3, *p*≤0.95, δ 3…5 %)

Sample	Control (no additives)	DW	WPC
Gluten color	light-creme		
Elasticity	Proper (stated according to the quality group if you write good – this means that the quality of gluten is one group lower)		
Raw gluten mass, %			
after 20 min of dough rest	29.7	28.5	27.9
after 180 min of dough fermentation	31.8	29.4	28.4
Dry gluten mass, %			
after 20 min of dough rest	11.2	10.8	10.1
after 180 min of dough fermentation	10.6	9.2	8.9
Hydration ability, %			
after 20 min of dough rest	166.5	166.0	161.0
after 180 min of dough fermentation	198.0	189.0	182.0
Springiness at the IDK device, device unit			
after 20 min of dough rest	48.9	51.7	50.4
after 180 min of dough fermentation	78.4	68.5	64.3
Extensibility, cm			
after 20 min of dough rest	16.0	14.0	12.5
after 180 min of dough fermentation	19.0	15.5	14.5

Table 2

Effect of dry whey, enriched with magnesium and manganese, and whey protein concentrate, on the fractional composition of proteins in the non-yeast dough (*n*=3, *p*≤0.95, δ 3…5 %)

Sample	Content of nitrogen, % to dough DS							
	total		gluten		water-soluble		intermediate fraction	
	starting	final	starting	final	starting	final	starting	final
1	2	3	4	5	6	7	8	9
Control (no additives)	2.540	2.540	1.710	1.501	0.402	0.508	0.428	0.531
With DW, 2 % by weight of flour	2.760	2.760	1.614	1.438	0.568	0.694	0.578	0.628
With WPC, 3 % by weight of flour	4.060	4.060	1.580	1.368	1.644	1.706	0.836	0.986

The above results (**Table 2**) confirm changes in the fractional composition of dough protein substances when introducing DW and WPC. Along with an increase in the total amount of nitrogen, the mass fraction of water-soluble nitrogen and intermediate fraction increases. Thus, when using DW, the amount of water-soluble nitrogen in the dough after kneading increases by 41.3 %, the intermediate fraction – by 35.0 % compared to control. After autolysis, the mass fraction of water-soluble nitrogen increases by 42.5 %, the intermediate fraction – 18.2 %, compared to control. The reason for such changes in the redistribution of the amount of fractions is the additional introduction of water-soluble proteins and additional peptization of protein fractions by lactic acid in the process of autolysis. The same patterns are observed when using WPC but, in this case, the total protein content increases significantly, due to the fact that WPC contains 65...66 % protein. Thus, when using

DW, the total protein content increases by 59.8 %, the amount of water-soluble nitrogen in the dough after kneading increases by 308.9 %, the intermediate fraction – by 195.3 %; along with this, there is a decrease in gluten proteins by 7.6 % compared to control. After autolysis, the mass fraction of water-soluble nitrogen increases by 235.8 %, the intermediate fraction – 85.6 %, compared to control.

Thus, when using DW and WPC, the total amount of proteins increases in the dough, the mass fraction of water-soluble and intermediate fractions of proteins, and the amount of gluten proteins decreases, which confirms a decrease in the amount of gluten washed out from the dough. Increasing the mass fraction of water-soluble proteins contributes to the intensification of the fermentation process by additional nutrition of microflora with nitrogenous substances and an increase in the amount of free water in the dough, which predetermines its thinning.

To confirm the results obtained, our further study investigated the influence of DW and WPC on the structural and mechanical properties of the dough, namely the water-absorbing ability of the dough, the duration of its formation, stability, and elasticity in the kneading process. The research was carried out at the Farinograph-AT (made by Brabender® Germany). The mixture that was examined had been prepared from 1,000 g of flour, and 20 g of DW, or 30 g of WPC. The study results are given in **Table 3** and shown in **Fig. 1**.

Table 3
Influence of DW and WPC on the formation of viscoelastic properties of dough (based on data acquired from farinograph) (n=3, p≤0.95, δ 3…5 %)

Indicator	Indicator designation	Measuring unit	Control (no additives)	With DW, 2 % by weight	With WPC, 3 % by weight of flour
Duration of measurement	T	mm:ss	20:00	20:00	20:00
Dosing temperature	DT	°C	28.0	28.2	28.1
Duration of dough formation	DDT	mm:ss	01:33	01:20	07:20
Consistency	C	FE	527	493	513
Water added	WZ	%	59.0	54.0	53.0
Water absorption capacity adjusted for consistency	WAC	%	59.7	53.8	53.3
Water absorption capacity adjusted for the mass fraction of moisture in flour	WAM	%	57.2	50.8	50.6
Stability	S	mm:ss	02:13	03:04	12:36
Dough thinning (10 min after start)	DS	FE	80	45	11
Dough thinning (12 min after start)	DS(ICC)	FE	87	52	66
Farinograph quality factor	FQN	mm	29	32	129

The initial stage of assessing the structural and mechanical properties at a farinograph is to determine the water absorption ability needed to obtain the dough of the required consistency (500 FE). The above results (**Table 3**) indicate that despite the high water absorption capacity of DW and WPC, the water absorption capacity in the dough decreases compared, to control, by 8.4 and 10.7 %, respectively. This is because the introduction of DW and WPC into the dough system reduces the amount of gluten by peptizing proteins with lactic acid.

The farinograms provide a graphical representation of the process of dough formation, which can be divided into five phases: rapid hydration, dough formation, thinning of the dough structure, and the achievement of asymptotic equilibrium [14, 15]. An important indicator of the farinogram is the width of the curve: at the stage of rapid hydration, there is a sharp increase in the width of the curve, then it reaches the maximum value, after which it stabilizes at a certain level, which characterizes the beginning of the asymptomatic equilibrium. In the rapid hydration phase, water is distributed in flour, the local gluten particles form. The phase of dough formation is determined by the reduced slope of the farinogram curve. The rate of increase in the width of the curve at this stage increases, which indicates the transition of the dough from the elastic to viscoelastic state, as well as the final formation of a uniform gluten structure [15, 16]. The introduction of DW into the dough did not affect the duration of dough formation but, at the same time, there is a sharp decrease in the peak indicating the rapid formation of gluten, and further stabilization of the decrease in the curve indicates an improvement in the swelling of the dough. When using WPC, a sharp decrease is observed first, and then the consistency begins to increase (the second peak), and, at this value, it exceeds the height of the first peak, which is why the device counts the duration of dough formation based on the second peak, this is technically incorrect, so we believe that the duration of dough formation does not differ from that of control [16]. However, the formation of the second peak is not characteristic of regular flour without additives, so its formation indicates that there are proteins in the dough system that absorb water and then eventually begin to swell. The process of transition from the dough formation phase to the stabilization phase is almost not noticeable on the curves, this is because this is influenced by many factors, namely the maximum force of the dough resistance to kneading. The stabilization phase of the dough structure is determined by the duration of the period over which the farinogram curve stays above the value of 500 FE. When using DW, the stability is somewhat prolonged; when using WPC, the stability increases by almost 10 minutes, which leads to the lengthening of kneading the dough. The transition from the phase of weakening the dough structure to the equilibrium phase during the use of DW proceeds, first, abruptly, then gradually. When using WPC, there is also a rapid descend, which could lead to a strong weakening of the dough during fermentation and resting, even though the thinning after 12 minutes is lower than that of control. The results of our analysis confirm the high correlation between the quality factor of the farinogram and stability, namely the smallest coefficient was observed for flour, and its stability is the smallest; when using DW, these indicators increase and grow by an order of magnitude when using WPC.

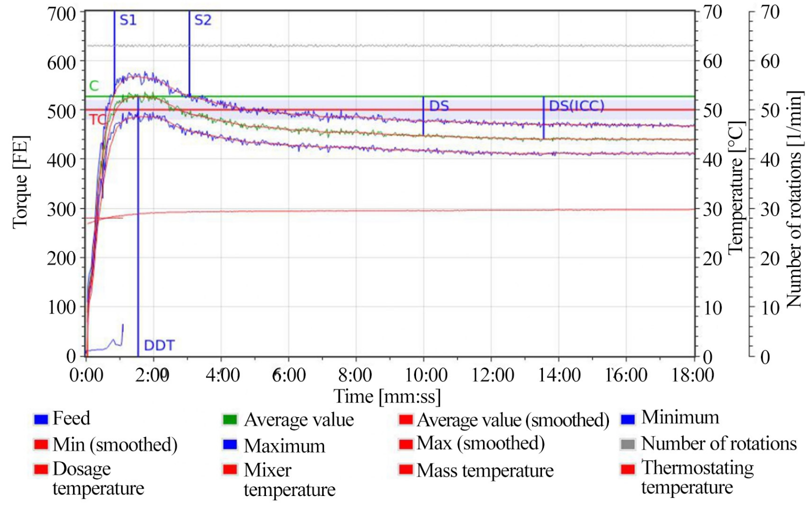
Consequently, the use of DW and WPC in the preparation of dough for bread from wheat flour of the highest grade could lead to thinning of the dough during fermentation and resting. To verify this statement, we investigated the effect of DW and WPC on the dough fluidity, that is, the spreading of a dough ball weighing 50 g, which is predetermined by the displacement of its layers due to a decrease in the “internal friction” within the system (viscosity). The study results are shown in **Fig. 2**.

The above data demonstrate that in the case of using DW and WPC, there is an increase in the spread of a dough ball by 3.1 and 12.5 %, respectively, compared to control, which indicates the largening of the structure of the dough, that is, increasing water-soluble proteins creates a large amount of free water, as well as proteins hydrated with lactic acid, which evenly distributes in the dough mass and does not form gluten. In this regard, it was wise to investigate the effect of DW and WPC on the viscoplastic properties of the dough, namely the gas-retaining capacity of the dough.

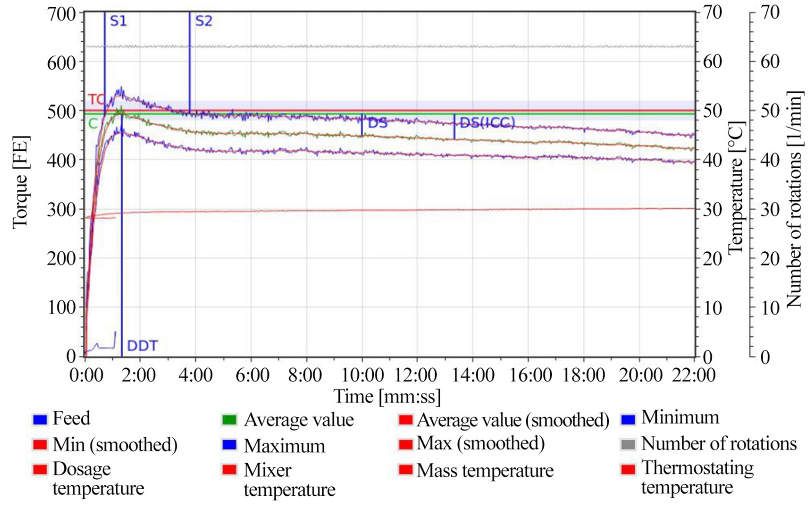
The gas-retaining capacity was determined by a change in the dough volume in a measuring cylinder, 250 cm^3, in the thermostat at a temperature of 30 °C, during 90 minutes of maturation; the specific volume of the dough was calculated (**Fig. 3**).

The above data demonstrate that in the case of using DW, the volume of the dough increased by 5.0 %, compared to control; in the case of using WPC – by 7.0 %. This is due to the redistribution in the structure of protein between gluten fractions and water-soluble ones and the emulsifying action of whey proteins that plasticize the dough.

Consequently, the use of DW and WPC in the preparation of dough for bread from wheat flour of the highest grade could lead to thinning of the dough during fermentation and resting. Therefore, it is necessary, during the production of a complex bakery improver, to use nutritional additives of oxidative action, as well as additives to increase water absorption capacity [17–19].



a



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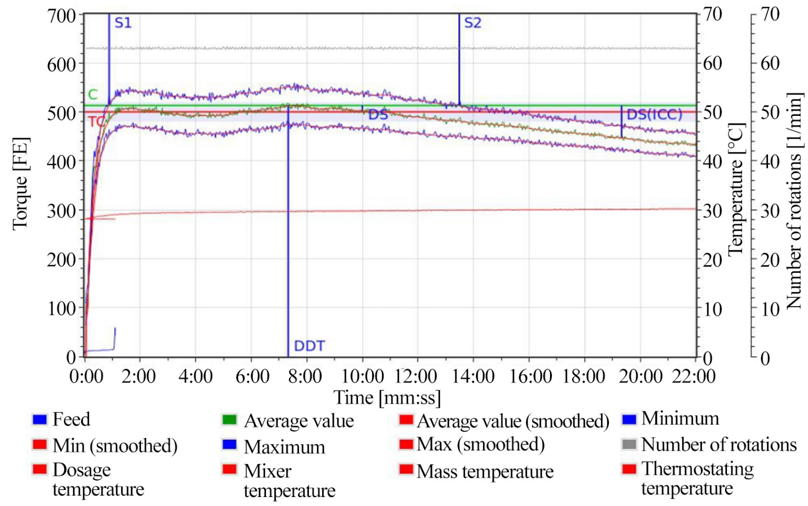

c

Fig. 1. Farinograms of the dough made from wheat flour of the highest grade: *a* – control (without additives); *b* – with DW, 2 % by weight of flour; *c* – with WPC, 3 % by weight of flour

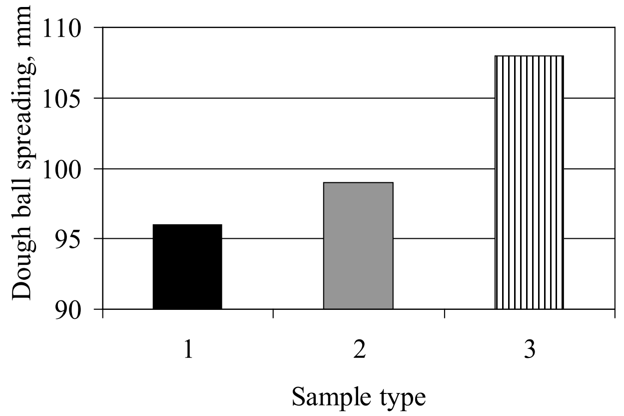

Fig. 2. Influence of DW and WPC on spreading a dough ball: 1 – control without additives, 2 – with DW; 3 – with WPC

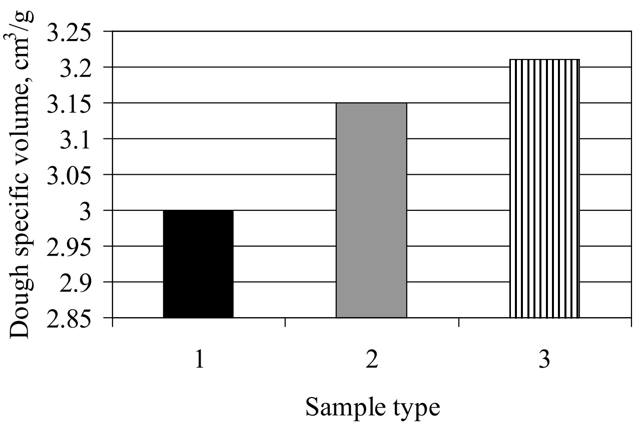

Fig. 3. Influence of DW and WPC on the gas-retaining capacity of dough: 1 – control without additives; 2 – with DW; 3 – with WPC

4. Conclusions

It was established during the research that the use of DW and WPC, along with the introduction of additional proteins into the dough system, exerts a negative impact on the viscoelastic properties of the dough when the dosage of DW is in the amount of 2 % by weight of flour, and that of WPC is in the amount of 3 % by weight of flour. It was found that for the dough containing DW, the amount of gluten, washed out after 20 minutes of rest, is less by 4 %; for the dough with WPC, by 6.1 %; after two hours of fermentation, by 7.5 % and 10.7 %, respectively. It was established that when using DW and WPC in the dough, the total amount of proteins in the dough increases, as well as the mass fraction of the water-soluble and intermediate fractions of proteins, while the amount of gluten proteins decreases, which confirms a decrease in the amount of gluten washed out of the dough. Increasing the mass fraction of water-soluble proteins contributes to the intensification of the fermentation process by additional nutrition of microflora with nitrogenous substances and an increase in the amount of free water in the dough, which predetermines its thinning.

We have found that despite the high water absorption capacity of DW and WPC, the water absorption capacity in the dough decreases, compared to control, by 8.4 and 10.7 %, respectively. Studying the dough at the farinograph has shown that in the case of using DW, its stability is somewhat increased, and, in the case of WPC, the dough stability is extended by almost 10 minutes, which leads to prolonging the dough kneading. Along with that, when using WPC, there is a rapid descend of the farinogram curve, which would lead to a strong weakening of the dough during fermentation and rest even though the thinning after 12 minutes is lower than that of control.

The reported results confirm that DW and WPC could be used as a functional base in the production of complex bakery improvers. DW and WPC play a technological function in dough preparation along with the filler function in improvers. Our analysis of the study results demonstrated that when using DW and WPC as functional bases of complex bakery improvers, it is necessary to introduce an emulsifier, the nutritional supplements of oxidative action, into the active part.

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