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RATIONALE FOR DOSING AND MIXING GERMINATED FLAX SEEDS WITH WHEAT FLOUR

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Summary. *The reasons of low quality and changes of the diet are analyzed, the nutritional value of bakery products and the use of non-traditional sources in new developments of high value technologies are considered. The general scheme of bakery products production technology is given, where the parameters of the kneading process and the connection between the factors influencing the complex system of dough formation and the characteristics of the finished product are revealed.Ways of using germinated flax seeds in recipes based on wheat and rye-wheat bread with preservation of high organoleptic characteristics are proposed and selected. The analysis and the ways of regulation of structural and mechanical properties of dough on the basis of factors of influence are given: – usage of thick rye leaven and first-class flour 30:70 and supreme quality wheat flour with addition of germinated flaxseed (15% of the mass of wheat flour); – usage of thick rye leaven and first-class flour 50:50 with addition of germinated flaxseed (10% of the mass of wheat flour); – the usage of thick rye leaven and first-class flour 50:50 with addition of 20% of germinated flaxseed and also adding supreme quality wheat flour (15% of the mass of wheat flour). The even distribution of GFS in flour due to efficient mixing in determining the nature of the process is considered. Influential parameters were chosen: duration of mixing and non-variable factor – frequency of revolutions of the working body of the mixer. The quality of mixing of the mixture based on the key component – GFS – was evaluated. The quality of mixing was determined by the coefficient of variation of the key component of the mixture, i.e. GFS. Mixing curves are constructed – dependence of the coefficient of variation on the duration of mixing and the optimal mixing time is determined, which corresponds to the first minimum value of the coefficient of variation of the mixing curve. Three stages of kneading are distinguished: I (0…60 s) – zone of intensive mixing; II (60…120 s) – zone of slow mixing and III (120…180 c) – zone of segregation. The recommendations to be followed for effective mixing of flour with GFS in production conditions are given.*

Key words: *for dosing, mixing, germinated flax seeds, bread, wheat dough.*

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Introduction. In recent years, the diet has become largely characterized by refined and high-calorie foods. Due to the low content of vegetable proteins, polyunsaturated fatty acids, dietary fiber and minerals, food became low-nutritious and respectively changed quality. This in turn has disrupted the supply of nutrients to the human body [1]. Undoubtedly, the value of bakery products takes a special place in nutrition [1]. Therefore, an integral part of new developments in the technology of highly nutritious bakery production, is of high popularity today. Many of recent researches suggest using non-traditional sources of nutrients to improve the nutritional value of bakery products, especially the variety of oilseeds: flax, hemp, pumpkin, etc. It is believed that flaxseeds are non-traditional source of nutrients.

Therefore, bakery are products with high nutritional value and they depend on the recipe and moisture content of the product. Nutritionists describe them as harmful and unhealthy and do not refer them as useful ones. Bakery products are considered to be harmful for the reason they are manufactured from high-quality flour with rich carbohydrate content and high glycemic index. In addition, the caloricity of bakery products is related with a significant content of carbohydrates and fat. It is often pointed out that bakery products are unhealthy to consume due to their low biological

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value which is explained by the low content of essential amino acids, minerals, vitamins, dietary fiber, antioxidants and more.

Considering the history of improvement of bakery technology for several decades, it was noticed that the recipes were mainly changed in order to make the appearance and taste of produce better. In the last period of the new century, we see that more attention is paid to their benefits for human health.

For this reason, the development of recipes of bread with the addition of germinated flax is an important aspect of our research. Taking into account the studies about the benefits of flaxseed meal on the quality of products, the problem was to determine the amount of germinated flaxseeds not to lower the organoleptic and structural-mechanical properties of bakery products.

Analysis of available investigations. It is known that the dough is prepared from a mixture of components in order to make it with the best quality indicators. It is necessary to ensure the efficiency of the technological process and achieve the desired productivity. The parameters of the kneading process are the relationship between the factors influencing the complex system of dough formation and the characteristics of the finished product. In other words, the system variables of the process and the qualities of the dough can be influenced by quantity and quality of the ingredients, specification of machinery configuration, the modes of three stages of kneading, such as temperature and duration. The problem of correct composing of determining equations and formulation of the main assumptions is essential for considering the kneading process, as by its rheological features the dough is one of the least studied and most complicated systems that significantly influence the vital activity of human organism and the health condition.

By changing these factors, it is possible to determine the rational conditions of kneading in order to make various types of dough. The recipes of dough, when reasonably adding physiologically functional ingredients and with proper process modes, helps increase the product quality and save the resources. For this reason, the scientists pay that particular attention to this problem when developing new technologies.

Theoretic research of any process, as well as the one of making dough, are rather complicated, as it is difficult to take into account all the real rules of behaviour of dough and the equipment operation conditions. Observing the features of the dough which has been studied is possible by statistic method. It is based on theoretical analysis of behavior of the single piece of dough which shows its main characteristics.

The working hypothesis is formed on the way of possible increasing the structure-forming properties of the mixture of flour and flaxseed-processing products. Therefore, we considered it expedient to apply a systematic approach for solving the scientific problem. For the main statements, a specific scientific problem has been formulated as a system-wide. The essence of the presented systematic scientific approach is to select the flaxseed processing product for improving the structural, mechanical and chemical properties of the dough, increase the quality of bakery products and scientifically substantiate its positive impact on the main components of the produce.

Such particular scientific problematic approach is used due to the absence of the research concerning the germinated flaxseed which has better indexes than flaxseeds or flaxseed meal. It is evident that the necessary approach is caused by enrichment of the bakery products with complete proteins and dietary nutrient fibers, i.e. physiologically functional ingredients.

The general scientific problem during adding flaxseed flour, meal when making bakery products, is that their components have negative impact on structural and mechanical properties of the dough and quality of the produce: their size and porosity decrease, the crumb gets significantly worse when more flaxseed meal is added to the dough [1, 2, 3].

We analysed and determined the means of regulation structural and mechanical properties of dough in order to create dough and bread with improved structure. The first way

of influence is the usage of thick rye leaven and first-class flour 30:70 and supreme quality wheat flour with addition of germinated flaxseed (15% of the mass of wheat flour). The second way of the influence factor is the usage of thick rye leaven and first-class flour 50:50 with addition of germinated flaxseed (10% of the mass of wheat flour). The third way of the influence factor is the usage of thick rye leaven and first-class flour 50:50 with addition of 20% of germinated flaxseed and also adding supreme quality wheat flour (15% of the mass of wheat flour). It will let significantly raise the nutritious and biological value and structure of bread, extend the variety of bakery produce.

In fact, a wide range of flaxseed processing products can be used with a flour mixture to create a recipe for bakery products. Therefore, for creating the recipes for bakery products, according to the developed method of flax germination, in our opinion, these ways are selected to use germinated flax in the recipe preserving high organoleptic characteristics.

Nowadays, as is mentioned above, there are restriction of adding the flaxseed processing products in the recipes based on rye and wheat rye bread. However, the opinions of reputable scientists and doctors support the fact that germinated flaxseeds are effective in obtaining new scientific data in the search for the structure of bakery products.

Summarizing the technology of bakery products using germinated flaxseeds, the following aspects have been considered:

- use of one- and two-phase method of dough making by modern enterprise;
- modes of preparation and dosing of ingredients;
- intensity of individual stages of the process;
- machinery design of manufacturing process;
- possible ways to put in additives;
- the effectiveness of the additive when introduced into the recipe of additional components.

The applied system analysis, as a scientifically generalized research method, allows to scientifically substantiate the technology of bakery products on the basis of the considered method. Determining the main indicators of quality and safety, patterns of changes in the technological process, makes it possible to explore products with germinated flaxseeds more scientifically.

According to modern scientific ideas about the absence of hydrated gluten network, one important factor in optimizing and stabilizing the process of gas accumulation in the dough is the required amount of water to hydrate the biopolymers of the dough. Sufficient amount of water usually forms the spatial structure of wheat dough and the dough acquires the desired viscosity. In our proposed ways of factors influencing the increase in hydration capacity are germinated flaxseeds with noticeable gem-forming properties. In addition [4, 5], the diversity of amino acid composition and fatty acids in the dough will certainly contribute to efficient enzymatic processing.

Thus, our justification of ways and means to improve the structural and chemical properties of bakery products with the addition of germinated flaxseeds, is considered relevant and needs research and optimization of technological modes.

Statement of the problem. To increase the biological value of bakery products, germinated flaxseeds were chosen as an additive. The aim of the work is to substantiate the dosage and even mixing of germinated flaxseeds (SFS) with wheat flour in the laboratory.

For control, preparation of the dough according to the recipe with 1st quality wheat flour was chosen. The studies evaluated the possibility of influence of percentage of flour replacement by SFS on the technological process of dough preparation. Due to the fact that data on the chemical composition of germinated flaxseeds indicate their better composition than of usual ones [6, 7], when making the pre-ferment and dough, it is recommended to add it on the day of sprouting. In this series of experiments, they were used exactly on the 3rd day of germination with 1–2 mm

shoots. According to previous studies, the dosage of GFS should not exceed 25% of the weight of flour. Preparation of experimental samples of GFS dough was made in the amount equivalent to 10, 20 and 25% instead of the mass of flour in the recipe.

This article discusses the preparation of wheat dough with the addition of 25% of GFS.

Results and discussion. The initial stages of research have shown that the dough with GFS additives first partially absorbs and then gives most of water. Therefore, the moisture of the control samples of the dough was first determined during the study: from first-quality wheat flour; rye-wheat; samples with 15 and 20% of the GFS additive (Fig. 1). It was found that with increasing GFS dosage there is a decrease in dough moisture by 0.4–1.6%. Based on the data, it is recommended to increase the moisture of the dough by 1.0–1.5%, relative to the addition of GFS.

From the point of view of water-retaining properties of GFS, synergism of action of mucous substances of seeds and albumin proteins is of fundamental importance. One of their components is a complex formation with better surfactant properties than a single protein. However, clarifying the physical nature of the process, it should also be noted about the change in structure with the addition of GFS. For example, it has more air bubbles.

This approach reduces the load and facilitates the process of mixing the components. As a result, the dough improves the structural and mechanical properties are improved as well as the number of finished bakery products grows, i.e. the economic performance of its production increases.

Given the possibility of biotransformation of the distribution of flaxseed mucus polysaccharides, it was assumed that three high molecular weight polysaccharides are added to the dough: 75.0% (of the total mucus content) of the most viscous neutral polysaccharide with a molar mass of $1.2–10^6$ g/mol; 3.75% of acid polysaccharide AF1 with a molar mass of $6.5 \cdot 10^5$ g/mol; 21.55% of acid polysaccharide AF2 with a molar mass of $1.7 \cdot 10^4$ g/mol. Besides, extra amounts vitamins and minerals are added with GFS. All this has a positive effect on the fermentation of the dough. The results of the assumptions are determined by the gas-forming ability of the dough and calculations of the dynamics of this process, which are reflected below.

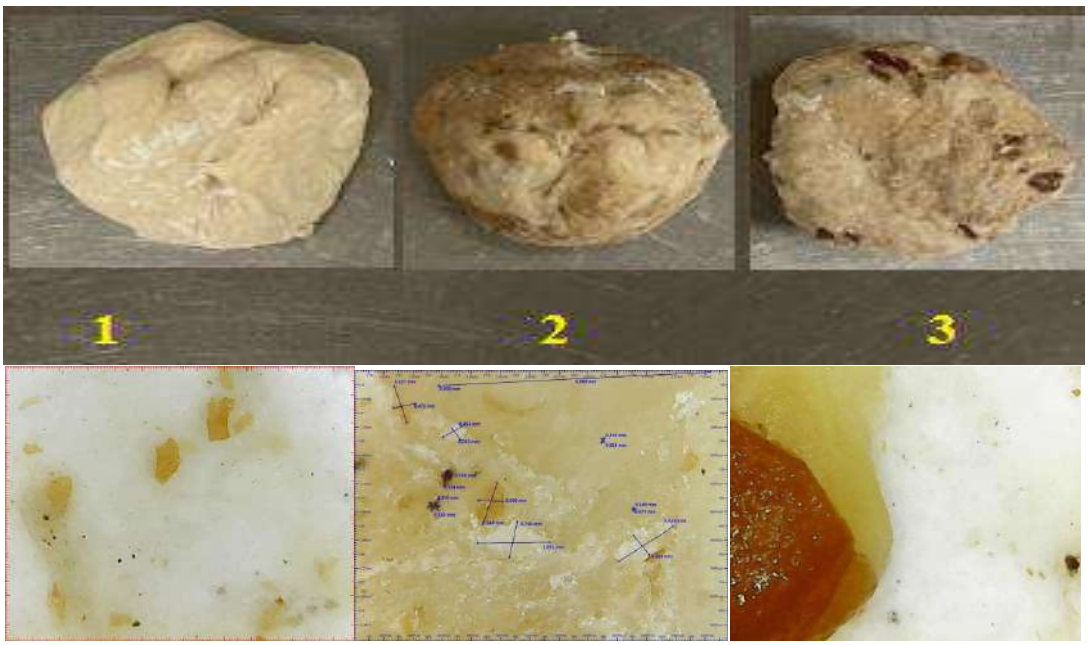

Figure 1. Photographs of the studied samples of dough and their dispersed composition: 1 – wheat dough from first-quality flour; 2 – rye-wheat; 3 – wheat with the addition of GFS in the amount of 20%

From Fig. 2 (1, 2) it can be noted that the structure of the test specimens has an even distribution of components. Solid particles of flour, which are still present after kneading, did not react. Their measuring showed: length 1.202 mm and width 0.318; length 0.917 and width 0.417, i.e. there is variance. In addition, small air bubbles are visible, especially on sample 2. Putting in GFS to wheat flour dough (sample 3) showed a partial transition of flaxseed mucus to dough. A sample of rye-wheat dough with GFS showed the same results. When testing the dispersed composition of the samples after the 40 minutes' fermentation, a different structure has been established (Fig. 2).

1 2 3 4

Figure 2. Photographs of the dispersed composition of the studied dough samples: 1 – wheat dough from first-quality flour; 2 – wheat with the addition of GFS in the amount of 20%; 3 – rye-wheat; 4 – rye-wheat with the addition of GFS in the amount of 20%

The results of the dispersed composition showed the fermentation process. Thus, wheat dough (Fig. 2, 1 and 2) has become almost homogeneous, where partially there are small particles with a length of 0.085 mm and a width of 0.066 mm. There was also more absorption of GFS mucus during fermentation of the dough. The mucus, losing its darker color, gradually turns brighter. This proves that GFS takes part in the dough fermentation, giving away its vitamins and minerals. The same happens with rye-wheat dough Fig. 2, (3 and 4). The figures show the formation of air bubbles, a more uniform dispersed structure of the dough samples. This us to prove the previously proposed assumptions and optimization of yeast activation.

Germinated flaxseeds provide full effect with its even distribution in the flour due to effective mixing. When determining the nature of the process, the influential parameter is chosen – duration of mixing – which makes it possible to change this factor of influence [7]. A constant factor is the speed of the working body of the mixer which is equal to $1.67 s^{-1}$. In studies, the load factor of the working chamber of the mixer was 75%. The resulting mixture should be evenly distributed over the volume of the working chamber [8, 9, 11].

Assessment of the quality of mixing a mixture of one random variable, is conditionally considered as bi-component. To do this, one component was selected from the mixture, which is conditionally the main (key). The key component in this study is GFS, the other is flour. The quality of mixing was determined by the coefficient of variation of the key component of the mixture, i.e. GFS. Pre-weighed GFS was added to the flour with a vibrating dispenser and mixed in a discrete-pulse mixer under certain modes. 10 samples were taken from the mixture, each of which was of 20 g.

The criterion for the quality of mixing, used for evaluation of the process efficiency, is the coefficient of variation of the key component, which was calculated by the formula [10]:

$$V = \frac{100}{X_c}\sqrt{\frac{\sum_{i=1}^{n}(X_i - X_c)}{n-1}}, \%$$

where X c is the average content of the key component, %;
Xi is the content of the key component in the i-th sample, %;
n number of samples for analysis.

According to the results of experimental studies, curves of mixing were constructed – the dependence of the coefficient of variation on the duration of mixing (Fig. 3). The optimal mixing time is the moment of establishing dynamic equilibrium, which corresponds to the first minimum value of the coefficient of variation of the mixing curve.

Analysis of the obtained curves shows that with increasing mixing time, the homogeneity of the mixture gradually increases regardless of the concentration of the key component. On the curves, three stages of kneading are clearly distinguished: I (0…60 s) is a zone of intensive mixing; II (60…120 s) is a zone of slow mixing and III (120…180 c) is a zone of segregation.

According to the research results, it is found that the flour sample with a higher concentration of the key component (20%) reaches the minimum value of the coefficient of variation after 90 s, i.e. increasing the concentration of the key component improves the efficiency of the mixing process.

Increasing the speed of the working body of the mixer from 1.0 to 1.67 s^{-1}, i.e. from 60 to 100 rpm, also helps to improve the mixing process and reduce the coefficient of variation [9, 10, 11].

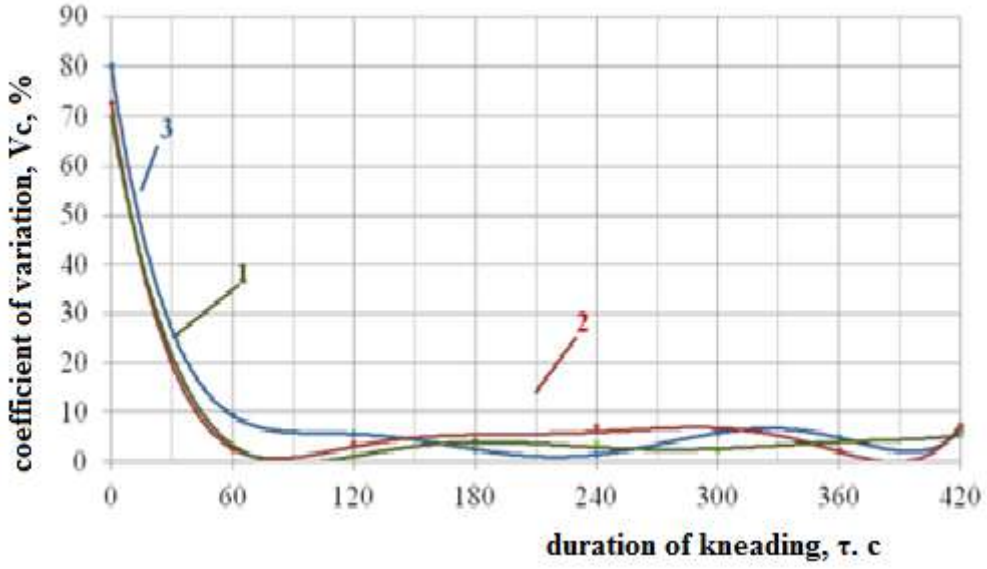

Figure 3. Curve of mixing the wheat flour with concentration of the key component of 20 %:1 – 1,67^{c-1} (100 rpm); 2–1,33c^{-1} (80 rpm); 3–1,0c^{-1} (60 rpm)

On the basis of the carried out experimental researches the optimum modes of mixing of first-quality wheat flour with GFS with concentration of 10-20% in the vertical disk mixer of discrete action are established:

frequency of rotation of the working body of the mixer 1,33–1,67 s^{-1}; mixing duration – 90…180 s (1.5…3 min.) [10, 12].

Conclusion. For effective mixing of flour with PNL in production conditions it is necessary to follow these recommendations:

- for the addition of flaxseeds according to the recipe, before use, it must be pre-germinated in production conditions and stored at a temperature of 2–6^{0}C;
- to prepare the dough with germinated flaxseeds, the design of the mixer of periodic action with intense impact on the components can be used;
- the flour dispensers the and vibratory dispenser components for GFS must interact discretely over the dosing time from the beginning to the end of the process.

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ОБҐРУНТУВАННЯ ДОЗУВАННЯ І ЗМІШУВАННЯ ПРОРОЩЕНОГО НАСІННЯ ЛЬОНУ З ПШЕНИЧНИМ БОРОШНОМ

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Резюме. *Аналізовано причини характеру бідності й зміни якості раціону харчування, розглянуто харчову цінність хлібобулочних виробів та використання нетрадиційних джерел у нових розробках технологій підвищеної цінності. Подано загальну блок-схему технології виробництва хлібобулочних виробів, де*

розкрито параметри процесу замішування та зв'язком між факторами, що впливають на комплексну систему тістоутворення і характеристиками готової продукції. Запропоновано і вибрано шляхи використання пророщеного насіння льону в рецептурах на базі пшеничного й житньо-пшеничного хліба зі збереженням високих органолептичних показників. Наведено аналіз і визначено шляхи щодо регулювання структурно-механічних властивостей тіста на основі факторів впливу – застосування житньої густої закваски і борошна першого сорту 30:70 і пшеничного борошна вищого сорту з додаванням 10% пророщеного зерна льону від маси пшеничного борошна; застосування житньої густої закваски і борошна першого сорту 50:50 з додаванням 15% пророщеного зерна льону від маси пшеничного борошна; застосування житньої густої закваски і борошна першого сорту 50:50 з додаванням 20% пророщеного зерна льону і пшеничного борошна вищого сорту з додаванням також 15% від маси пшеничного борошна. Розглянуто рівномірне розподілення ПНЛ у борошні за рахунок ефективного змішування при встановленні характеру проходження процесу. Вибрано впливові параметри: тривалість змішування й незмінний фактор – частота обертів робочого органу змішувача. Проведено оцінювання якості змішування суміші на основі ключового компоненту – ПНЛ. Якість змішування визначали за коефіцієнтом варіації ключового компоненту суміші, тобто ПНЛ. Побудовано криві змішування – залежність коефіцієнта варіації від тривалості змішування й встановлено оптимальний час змішування, що відповідає першому мінімальному значенню коефіцієнта варіації кривої змішування. Виділено три етапи змішування: I (0…60 с) – зону інтенсивного змішування; II (60…120 с) – зону уповільненого змішування та III (120…180с) – зону сегрегації. Дано умови рекомендації, які необхідно виконувати для ефективного змішування борошна з ПНЛ у виробничих умовах.

Ключові слова: *дозування, замішування, пророщене насіння льону, хліб, пшеничне тісто.*

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