Use of flax processing products in the food industry

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Annotation. The article analyzes the results of research in the field of nutrition physiology. The expediency of adding flax processing products to bakery products and determining the optimal ratio of wheat and flax flour in the production technology of bread enriched with omega-3 fatty acids has been scientifically substantiated. The recipe for wheat bread with the addition of flax seeds was developed, the physicochemical parameters (moisture, acidity, porosity) of the dough and the finished product were comprehensively investigated at the entire technological stage of production. Organoleptic properties of wheat-flax bread and indicators of biological value of flax and wheat flour were determined. Vitamins E and C, which exhibit antioxidant properties in the body, were also present in much larger quantities in flax flour compared to wheat flour. This indicates that flax seeds are an excellent source of enrichment of the body in antioxidant vitamins.

Keywords: flax, bread, omega-3 fatty acids, vitamins, technological process of bread production.

Використання продуктів переробки льону у харчовій промисловості

Анотація. В останні роки, завдяки еволюції наукових досліджень, лляне насіння стає важливим функціональним харчовим інгредієнтом. Насіння льону добре відоме своїм вмістом хімічних сполук зі специфічною біологічною активністю та функціональними властивостями: поліненасичені жирні кислоти (ПНЖК) сімейства омега-3, розчинні харчові волокна, лігнани, білки та вуглеводи. Продукти його переробки можна віднести до продуктів, які збагатять і покращать жирнокислотний склад продуктів виготовлених на основі пшеничного борошна.

У статті проаналізовано результати досліджень в галузі фізіології харчування. Науково обґрунтовано доцільність додавання продуктів переробки льону у хлібопекарську продукцію та визначення оптимального співвідношення пшеничного і лляного борошна у технології виробництва хліба збагаченого омега-3 жирними кислотами.

Експериментальними дослідженнями було визначено і порівняно біологічну цінність лляного та пшеничного борошна. Розроблено рецептуру пшеничного хліба із додаванням насіння льону, комплексно досліджено фізико-хімічні параметри

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(вологість, кислотність, пористість) тіста і готового продукту на всьому технологічному відрізку виробництва. Визначено органолептичні властивості пшенично-лляного хліба та показники біологічної цінності лляного і пшеничного борошна. Вітаміни, які проявляють антиоксидантні властивості в організмі – Е і С, також були у значно більших кількостях у лляному борошні, порівнюючи з пшеничним. Це вказує на те, що насіння льону є чудовим джерелом збагачення організму у антиоксидантних вітамінах. Отримані дані щодо вмісту вітамінів у лляному і пшеничному борошні дають однозначну відповідь про значну перевагу лляного борошна, як джерела вітамінів, особливо токоферолу та більшості вітамінів групи В та мінеральними речовинами, як Кальцій, Магній, Фосфор, Мідь, Цинк, які регулюють ряд функцій в організмі, а також є пластичним матеріалом.

Таким чином часткове додавання лляного борошна до пшеничного буде сприяти покращенню жирнокислотної фракції пшеничного хліба, підвищить його амінокислотний скор. Це дає обґрунтовано вважати на доцільність і перспективність збагачення пшеничного борошна лляним у хлібопекарському виробництві.

Ключові слова: льон, хліб, омега-3 жирні кислоти, вітаміни, технологічний процес виробництва хліба.

Introduction

Changes in the diet are taking place in many industrialized countries, because the way of life and nutrition, which involves the consumption of a large number of products with a high degree of "purification", has led to an increase in the so-called diseases of civilization (obesity, atherosclerosis, diabetes, and others). [7, 8, 9]. Interest in products containing substances that have a beneficial effect on the human body due to their dietary properties and ability to prevent some diseases is growing significantly [2, 3, 5]. The problem of wider use of various grain crops in the food industry for human consumption has been the subject of intensive research for many years in various scientific and industrial institutions.

The results of many studies in the field of nutrition physiology have made it possible to link the occurrence of civilization diseases with the consumption of products low in biologically active substances, indigestible ingredients and a deficiency of dietary fiber, etc. [12, 13]. In the light of modern knowledge, flax seeds and its processing products (oil and flour) as ingredients of the daily diet can be an important factor in enriching the body with polyunsaturated fatty acids (omega-3 family), amino acids, vitamins and minerals. Recent studies recommend consuming 30–70 g of flax seed products to lower serum cholesterol levels in individuals suffering from lipid metabolism disorders [16, 17].

Many studies, both by Ukrainian and foreign scientists, were aimed at studying the enrichment of bakery products with seeds or flax seed oil to improve their fatty acid composition and increase their biological value. Some sources of dietary fiber were investigated [29] as enrichment substances for wheat bread: oatmeal, flax, and apple. It was found that the addition of oat and flax fibers to bread significantly changed the fatty acid profiles. Other researchers [30] conducted a comparative study of the physical and sensory properties of gluten-free bread with the addition of whole and ground flax seeds. Researchers [31] considered the problem of using flax in the production of functional bread and flour confectionery products.

According to the literature sources, both domestic and foreign researchers have worked on the problem of improving the biological value of wheat bread, in particular, its fatty acid composition and antioxidant activity by introducing seeds or flour from golden or brown flax into its recipe. However, these studies were more focused on the production of bread, which would have excellent technological properties during dough fermentation, and the quality of the finished product. However, the fatty acid composition of the product was less taken into account in terms of providing consumers with essential fatty acids. Therefore, in our opinion, the development of a new type of bread with the introduction of flax flour into its composition and evaluation of the fatty acid composition indicator is quite relevant and will have a practical effect on its introduction into production.

The research consists in scientific substantiation of the feasibility of adding flax processing products to bakery products and determining the optimal ratio of wheat and flax flour in the production technology of bread enriched with omega-3 fatty acids. At the same time, during the introduction of a certain concentration of flax seeds into the recipe of wheat bread, it is necessary to comprehensively investigate the physicochemical parameters of the dough and the finished product at the entire technological stage of production in order to choose the optimal ratio between flours.

Researching results

In recent decades, consumer interest in nutrition has changed, to a greater extent, consumers have begun to choose "healthy" potentially useful products and ingredients for health [1]. In fact, food should be designed not only to satisfy hunger and provide basic nutritional needs, but also to prevent the development of metabolic diseases that are related to nutrition, improve the physical and mental well-being of consumers.

Such consumer demand for products with a greater beneficial effect poses a challenge for the food industry to increase the production of functional food products, which now constitute a significant proportion of new food products. In the relationship between diet, health and well-being, functional products play a priority role. There are many definitions for functional foods worldwide, but there is no official or universally accepted definition.

The European Commission's Concerted Action on Functional Food Science in Europe (FuFoSE) has defined that a food product or food ingredient can be considered functional only if, together with the basic nutritional effect, it has a beneficial effect on one or more functions of the human body in such a way or by improving general and physical condition or reduces the risk of developing diseases.

In recent years, thanks to the evolution of scientific research, flaxseed has become an important functional food ingredient. Flaxseed has been widely used in Europe since the Middle Ages as a food additive and is considered an important functional ingredient, which is a source of alpha-linoleic acid, high-quality proteins, phenolic compounds, fiber and minerals [40]. Flax seeds are well known for their content of chemical compounds with specific biological activity and functional properties: polyunsaturated fatty acids (PUFAs) of the omega-3 family, soluble dietary fibers, lignans, proteins and carbohydrates. However, flaxseed contains several harmful compounds such as cadmium, protease inhibitors, and cyanogenic compounds [1].

Of all the lipids in flaxseed (about 30%), 53% are α-linolenic acid (ALA), 17% linoleic acid (LA), 19% oleic acid, 3% stearic acid, and 5% palmitic acid, which provides an excellent n-6 to n-3 fatty acid ratio of approximately 0.3:1 [4, 5]. Therefore, seeds can be an alternative to provide the population with this fatty acid in regions of the world where there is not much access to marine products, which are the best source of n-3 fatty acids [6]. Chemical analysis of brown Canadian flaxseed on average showed the presence of 41% fat, 20% protein, 28% total fiber, 7.7% moisture, and 3.4% ash, which is rich in minerals [5]. However, the chemical composition of flax can vary depending on genetics, growing conditions, seed treatment and analysis method.

Bread baked from flour containing flax additives showed more than 2 times higher content of polyphenols and more than 10 times higher antioxidant activity in relation to bread of the control sample. At the same time, ground flax added to bread increased the value of polyphenols and antioxidant activity almost twice as much as bread with whole flax seeds added. This means that the active compounds of flax (including unsaturated esters of fatty acids) have passed into the bread mass and during heat treatment did not undergo chemical changes along with other ingredients of bread. It was also found that the highest content of polyphenols and antioxidant activity was inherent in bread baked from flour containing 30% ground (low-linolenic) flax. Most of the tasters positively evaluated the bread with flax flour, while according to the organoleptic indicators (color, smell, taste and texture) the obtained product had the highest number of points with 30% flax flour. The authors recommend bread made from 30% flax flour containing 96.9% low linolenic acid for both industrial and household production.

Other studies [19] have shown that consumers in 65% of cases would prefer bread that has increased biological value due to enrichment with flax flour. At the same time, the authors made samples of wheat bread according to different recipes and established that wheat bread with the addition of a certain amount of flax flour is quite suitable for consumption and in terms of organoleptic properties it was practically not inferior to the control sample of bread. Researchers assure that in order to expand and enrich the market of bakery products, it is advisable to include flax flour in the technology of bread, this will reduce its cost price, while enriching it with polyunsaturated acids.

Reports indicate that the prospect of including flax seeds in the production of gluten-free bread has several useful aspects, which are related to the biological value of bread and its influence on structural and technological indicators during the fermentation of dough and finished products. After all, the production of high-quality gluten-free bread is difficult due to the lack of viscoelastic starch-gluten. Several defects in the quality of gluten-free bread can be distinguished, for example, its smaller volume, lack of proper cell structure, dryness, crumbly and granular texture, cracked crust, bad taste sensations [20]. Gluten-free dough shows incomplete expansion and gas retention during fermentation. In addition, the excessive amount of starch in the recipe makes the product more prone to staleness than bread fermented on the basis of wheat flour, thus reducing the shelf life [21].

Studies have shown that whole flax seeds can be used as a partial substitute for flour in the technology of baking bread and buns (containing 11.6% of flax seeds) and cookies (20%) [5]. Along with a protein content of about 20 g/100 g, the soluble fiber found in flaxseed (10 g/100 g) [22] accounts for its binding and gelling properties, making it a promising additive in gluten-free bakery products [23].

Studies report that the inclusion of 10% ground flaxseed in the bread recipe increased the specific volume of the loaf and slowed down the staleness [24]. Similarly, Khattab et al. (2012) [25] confirmed that the texture of bread was improved after the addition of linseed in amounts from 5 to 20 %. The addition of linseed gum led to an increase in the water-absorbing capacity of bread with an improvement in the volume of the loaf and an improvement in the physico-technological characteristics of the properties of bread, thus making it a food thickener for bakery products [26]. Mucus from linen exhibits showed better emulsifying properties compared to gum arabic, tragacanth gum, and Tween 80 [27].

It was shown [28] that linseed gum increases the viscosity of bread dough. At the same time, the study consisted in evaluating the effect of 1% (total basis) addition of linseed powders (Linum usitatissimum) and four varieties of acacia (Acacia dealbata, A. decurrens, A. terminalis and A. verniciflua) on the bonding properties, textures and volume of gluten-free bread. The inclusion of all flax and acacia seed powders reduced the bread crumb hardness by 30–65% and increased the specific volume of the loaf by 50%. The water absorption and emulsifying capacity is explained by the texture improvement data and attributed to water-soluble carbohydrates and insoluble fibers, while foaming was not detected. A darker pulp was observed when flax powder was added. The most significant increase in the volume of bread and the greatest decrease in crumbling was observed for bread with the addition of a large fraction of flax, crushed by ball milling. In comparison with the control sample of gluten-free bread; a significant improvement in bread volume, texture and sensory evaluation was observed after using whole and ground flaxseed. In addition, the crumb index has been associated with organoleptic evaluation and can be used to evaluate bread quality as a complement to instrumental texture measurements.

The impact of flax processing products on the quality of dough and bread made it possible to identify the optimal dosages of recipe components with repeated use of wheat flour, linseed flour and linseed oil, these ratios are 90:10:3, respectively; with repeated use of wheat flour, flour for cakes and linseed oil - 93:7:2.

The experimental part of the work was divided into four independent stages.

At the first stage of research, the biological value of flax and wheat flour was determined and compared. At the second stage, experimental samples of dough with different ratios of wheat and flax flour were developed (one control and five experimental samples were developed) and they were examined for their physicochemical properties (third stage). In particular, the degree of acidity, its specific volume and the diameter of the ball's melting were determined in the dough. After baking experimental samples of bread, they were evaluated according to the following physicochemical properties: moisture, acidity, porosity, and an organoleptic evaluation was carried out with the participation of the tasting commission (fourth stage of the experimental part).

According to researchers, flaxseed bread has more protein, "healthy" fats and dietary fiber, as well as ingredients such as minerals and vitamins. The beneficial effect of flaxseed on lipid metabolism in consumers due to its effect on lowering the level of cholesterol in the blood serum was noted.

It is believed that the beneficial properties of flax are important due to the high content of unsaturated fatty acids, especially such as alpha-linolenic acid (C18:3, n-3), which accounts for almost half of the total amount of fatty acids contained in flax seeds [38]. There are also valuable lignans and dietary fibers (pectins, hemicellulose), which have a beneficial effect on the processes of digestion and passage of food through the gastrointestinal tract.

Therefore, due to the presence of a significant amount of useful substances in flax seeds, which improve the physiological processes in the body of consumers, we decided to include flax seeds flour in the composition of ordinary wheat bread and to determine its organoleptic and physico-chemical properties at the entire stage of the technological process. At the same time, we used a comprehensive approach to conducting research.

At the first stage of the experiments, the biological value of wheat flour and flaxseed flour was compared. In particular, we compared the fatty acid composition of two types of oils: linseed and wheat, and also determined the amount of amino acids and the vitamin-mineral composition in this raw material. Flax seeds from the Debut variety were used in the experiment, from which oil was produced by cold pressing.

The value of linseed oil lies in the content of monounsaturated and polyunsaturated fatty acids. At the same time, the amount of polyunsaturated a-linolenic acid, which belongs to the omega-3 family, in flaxseed oil was 7.9 times ($p < 0.05$) higher than its content in wheat flour oil. That is, in linseed oil, the amount of this essential acid was 54.629 ±0.007% of the mass of all fatty acids. It is thanks to this fatty acid that flax seeds have a significant effective effect in the prevention of cardiovascular diseases, which are associated with the deposition of cholesterol in blood vessels. In addition, linseed oil is significantly richer in oleic acid content than wheat oil, its amount in linseed oil was 19.708 ± 0.006% of the total mass of acids, which is 1.3 times higher ($p < 0.05$). The obtained results coincide and are consistent with the data of researchers [2, 6], who report a high content of α-linolenic and linoleic acids in flax seeds, which makes it an important food ingredient.

The amino acid composition of a food product is one of its most important characteristics. After all, essential amino acids (threonine, valine, methionine, cysteine, leucine, isoleucine, lysine, phenylalanine, tyrosine) must constantly supplied the human body, since they are not synthesized, and the biological value of the created food product is determined by the content of these acids. After all, it is known that wheat bread does not have a balanced composition in terms of amino acid content [10, 11].

Therefore, similar studies were conducted to compare the amino acid composition of two wheat and flax flours and their percentage content, compared to the reference "ideal" protein. In flaxseed flour, we observe a significantly lower excess content of essential amino acids, compared to wheat flour. In particular, the excess is noted only for the amino acid isoleucine, the rate is 105.5%, which is almost 1.6 times less than the excess in wheat flour. Other essential amino acids in whole grain flax meal were limiting. It should also be noted that whole wheat flour was used in the study, which is characterized by a higher content of amino acids in terms of amino acid composition, compared to flour of the highest and first grades.

Important components of food products, such as minerals, take part in metabolic processes in the body and perform catalytic, plastic and regulatory functions [11, 18, 19]. Therefore, the biological value of a food product is also determined by the content of minerals important for vital activities and the full functioning of a person. Regarding the mineral composition of wheat and flax flour, it follows that the content of minerals in flax flour is much higher than in wheat flour. A significantly higher amount ($p < 0.05$) of such minerals was found in flax flour compared to wheat flour, in particular, Calcium by 4.8 times, Potassium by 2.6 times, Magnesium by 4.2 times, Phosphorus and Zinc by 2.0 times and Copper by 1.8 times. Only in terms of iron content, wheat and flax flour do not reliably differ from each other. At the same time, it should be noted that 100 g of flax seeds provide 50-70% of the daily need for certain minerals [5]. Taking into account the obtained data, we support the opinion of scientists [10] that flax seeds belong to a biologically valuable product that can improve traditional food systems by the content of macro and microelements.

In addition to the mineral composition, we analyzed wheat and flax flour for the content of the main vitamins. Studies [14, 15] report that flax seeds and their processing products are particularly rich in vitamin E (tocopherols α-, β-, and γ-) and group B. In addition to antioxidant properties, tocopherols participate in blocking nitrosamines in the gastrointestinal tract that are formed from nitrates and nitrites of food products. The second important group of vitamins is the B group of biologically active substances that have a systemic effect on many functions of the body. Vitamins E and C, which exhibit antioxidant properties in the body, were also present in much larger quantities in flax flour compared to wheat flour. Thus, the amount of vitamin E in flax flour was 5.37 ± 0.12 mg/100 g, which was 1.9 times ($p < 0.05$) higher than in wheat flour, and the amount of vitamin C was 1.7 times ($p < 0.05$) higher, respectively, in flax flour. This indicates that flax seeds are an excellent source of enrichment of the body in antioxidant vitamins. Vitamin K (phylloquinone) was also found in significantly greater amounts in flax flour compared to wheat flour. In particular, in the first one, its amount was 4.21 ± 0.2 μg/100 g, which is almost 2.2 times ($p < 0.05$) higher than in wheat flour.

Conclusions

So, based on the results of this study, it can be stated that flaxseed and its processing products can be classified as products that will enrich and improve the fatty acid composition of products made on the basis of wheat flour. From the analysis of research on the amino acid composition of wheat and flax flour, the following should be noted. Despite the fact that a significant number of essential amino acids in flax flour are limiting, compared to wheat flour, which has only two limiting amino acids, it is advisable to enrich the recipe composition of wheat bread with flax flour, as it additionally increases the amount of the two limiting acids of wheat, threonine and lysine, which are almost 10-14% more abundant in flax. Thus, the partial addition of flax flour to wheat flour will contribute to the following: firstly, to improve the fatty acid fraction of wheat bread, and secondly, to increase its amino acid score.

The obtained data indicate that the partial replacement of wheat flour with flax during the production of bread will have a positive effect on its enrichment with such important minerals as Calcium, Magnesium, Phosphorus, Copper, Zinc, which regulate a number of functions in the body, and are also a plastic material.

Thus, the obtained data on the content of vitamins in flax and wheat flour give an unequivocal answer about the significant advantage of flax flour as a source of vitamins, especially tocopherol and most vitamins of the B group. This gives a reasonable basis for considering the feasibility and prospects of enriching wheat flour with flax in bakery production.

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