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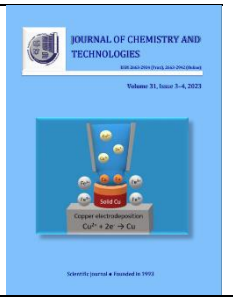

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ANALYSIS OF STRUCTURAL AND MECHANICAL PROPERTIES OF SPRING VETCH FLOUR AND ITS INFLUENCE ON THE QUALITY OF GLUTEN IN WHEAT FLOUR AND PASTA PRODUCTS

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Abstract

Relevance. Pasta products, which are products of mass and everyday use, are in wide demand today. However, the retail network mainly presents pasta products, which are made from wheat flour of the highest grade and water, and therefore belong to the so-called refined food products, depleted of vitamins, minerals and biologically active substances. Therefore, the development of new types of pasta enriched with scarce nutrients is very important. Aim. The purpose is to develop and substantiate an improved technology of pasta products using flour from the seeds of spring vetch. Results. A review of the scientific literature proved the suitability for practical use of various products from spring vetch seeds (including vetch seed flour) in the technologies of products not only for general use, but also for dietary purposes. Studies of the effect of adding BNV in the amount of 15.0...20.0 % of the total mass of flour have established the fact of strengthening the gluten of wheat flour, reducing its yield and affecting the physical and structural-mechanical properties of wheat dough, improving the water absorption capacity of dough with vetch seed flour, lengthening the duration of its formation, reducing stability and increasing the degree of rarefaction under the influence of mechanical processing. The technology and technological scheme for the production of noodles from vetch seed flour were developed, the organoleptic quality indicators and taste properties of the new products were investigated. Studies of the nutritional and energy values of noodles with vetch seed flour were conducted, the amino acid composion of new products was analyzed. Conclusions. Studies of the influence of adding flour from vetch seeds in an amount of 15.0...20.0 % of the total mass of flour have established the fact of strengthening the gluten of wheat flour, reducing its yield and affecting the physical and structural-mechanical properties of wheat dough. Noodles contain an increased (up to 12 %) concentration of proteins with a balanced amino acid composition, an increased (up to 3.5 %) concentration of high-quality unsaturated fatty acids, an increased content of vitamins and trace elements, which determines their high nutritional value.

Keywords: structural and mechanical properties; quality; gluten; pasta; noodles; flour; seeds; vetch.

АНАЛІЗ СТРУКТУРНО-МЕХАНІЧНИХ ВЛАСТИВОСТЕЙ БОРОШНА З НАСІННЯ ВИКИ ЯРОВОЇ ТА ЙОГО ВПЛИВ НА ЯКІСТЬ КЛЕЙКОВИНИ БОРОШНА ПШЕНИЧНОГО І МАКАРОННИХ ВИРОБІВ

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Анотація

Актуальність. Широким попитом на сьогодні користуються макаронні вироби, що є продуктами масового та повсякденного вжитку. Проте у торговельній мережі представлені переважно макаронні вироби, які виробляються з борошна пшеничного вищого ґатунку та води, а отже, належать до так званих рафінованих продуктів харчування, збіднених на вітаміни, мінеральні та біологічно активні речовини. Тому розроблення нових видів макаронних виробів, збагачених на дефіцитні нутрієнти, є дуже актуальним. Мета. Метою є розробка та обґрунтування удосконаленої технології макаронних виробів з використанням борошна з насіння вики ярової (БНВ).

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Результати. Оглядом наукової літератури доведено придатність до практичного використання різних продуктів із насіння вики ярової (в т.ч. і борошна з насіння вики) у технологіях продуктів не тільки загального вжитку, а й дієтичного призначення. Дослідженнями впливу внесення БНВ у кількості 15.0… 20.0 % від загальної маси борошна, встановлено факт зміцнення клейковини пшеничного борошна, зниження її виходу та вплив на фізичні й структурно-механічні властивості пшеничного тіста, відмічено покращення водопоглинальної здатності тіста з БНВ, подовження тривалості його утворення, зниження стійкості та підвищення ступеню розрідження під дією механічної обробки. Розроблені технологія та технологічна схема виробництва локшини з БНВ, досліджені органолептичні показники якості та смакові властивості нових виробів. Проведені дослідження харчової та енергетичної цінностей локшини з БНВ, проаналізований амінокислотний склад нових виробів. Висновки. Дослідженнями впливу внесення БНВ у кількості 15.0…20.0 % від загальної маси борошна, встановлено факт зміцнення клейковини пшеничного борошна, зниження її виходу та вплив на фізичні й структурно-механічні властивості пшеничного тіста. Було відмічено покращення водопоглинальної здатності тіста з БНВ, подовження тривалості його утворення, зниження стійкості та підвищення ступеню розрідження під дією механічної обробки. Локшина містить підвищену (до 12 %) концентрацію білків, які мають збалансований амінокислотний склад, підвищену (до 3.5 %) концентрацію високоякісних ненасичених жирних кислот, підвищений вміст вітамінів і мікроелементів, що й зумовлює їх високу харчову цінність.
Ключові слова: структурно-механічні властивості; якість; клейковина; макаронні вироби; локшина; борошно; насіння; вика ярова.

Introduction

Pasta products, which are products of mass and everyday use, are in wide demand today. However, the retail network mainly presents pasta products made from wheat flour of the highest grade and water, and therefore belonging to the so-called refined food products, depleted of vitamins, minerals and biologically active substances. Therefore, the development of new types of pasta enriched with deficient nutrients is very important.

The purpose of the research is the development and substantiation of the improved technology of pasta products using spring vetch seed flour.

Based on this goal, a number of the following tasks were formed:

- to study the current trends in the production of the researched products;
- to establish the prospects for the use of plant raw materials, in particular vetch seeds;
- to determine objects, materials and research methods;
- to investigate the quality indicators of traditional pasta dough and the effect of spring vetch seeds on its technological properties;
- to develop a recipe and production technology of pasta semi-finished products with the addition of vetch seeds.

The object of the research is the technology of pasta products made from pasta dough with the addition of vetch seed flour.

The subject of the research is pasta made from pasta dough with the addition of vetch seed flour.

According to SSTU 7347:2013 “Pasta products. Terms and definitions” pasta products are products that obtained by drying (up to 13% moisture content and less) of formed products from pasta flour dough with or without additives [1]. It is one of the most common foods around the world. According to the World Association of Pasta Manufacturers, in 2021 the global demand for such products reached 118 billion servings [2]. Asia and Oceania account for almost 83 % of the total demand for instant noodles. About 37 % of production is consumed in China [3]. The leaders in per capita consumption are South Korea and Nepal. Outside of Asia, the countries with the highest per capita consumption are New Zealand and Australia, which have large populations of Asian descent. In addition to the countries of Asia and Oceania, the most portions are consumed in the USA, Brazil, and Nigeria [4].

The volume of pasta consumption is influenced by the yield of potatoes, vegetables and fruits. In years with a high yield of these products, consumption of pasta products decreases, while in low-harvest years it increases. It is also noted that the consumption of pasta products is uneven throughout the year, decreasing in summer and autumn and increasing in winter and spring. [5].

The study of modern trends in the production of the studied products should begin with the study of global trends in the production of pasta products. Polish scientists added spirulina to pasta, enriching it with protein and minerals, improving nutritional value and taste [6]. Kabylda et al have created a high-vitamin gluten-free pasta, adding 25 % starch for better structure [7]. Ukrainian scientist O. Horach developed high-quality gluten-free products for healthy nutrition [8]. Employees of the Sumy National Agrarian University developed pasta with β-carotene of improved appearance, and scientists from the Tavriia State University named after D. Motornyi developed mushroom noodles with an improved taste and aroma [9; 10].

The well-known study reduced the production time and improved the quality of long pasta due to

a new technological approach [11]. In addition, there are certain pasta products with vegetable and berry powders, in particular, flavored and enriched with additives [12]. There is also a famed recipe for pasta with lupine flour and gelatin for the food industry [13], pasta with lecithin that improves the structure and helps to preserve β-carotene [14], a dietary pasta product that includes flour, quail eggs and flavor additives [15].

The preliminary results of the literature research indicate the active use of processed products of vegetable raw materials (wheat, spinach, beets, corn, etc.) to obtain pasta products with high nutritional properties and a more natural composition. This enables the creation of alternatives to traditional pasta products that meet modern consumption trends, such as the demand for low-gluten products, vegan or organic products. Plant raw materials can also provide functional or technological properties.

In general, the use of vegetable raw materials in the production of pasta products supports trends towards a healthier and more sustainable way of eating, which meets the requirements of modern consumers and contributes to the preservation of the environment. To date, there is an imbalance in the diet in Ukraine: high-calorie foods saturated with carbohydrates and fats predominate. However, the protein content of food should not decrease. After all, it is known that protein substances have important structural, hormonal, enzymatic and other functions. Proteins are a source of energy for humans. Under the conditions of a threatening manufactured environment, proteins perform a protective function in the human body; therefore, it is necessary to consume products of increased nutritional and biological value.

One of the effective measures to increase the biological value of pasta is the addition of protein products. Protein fortifiers differ in their amino acid composition. Egg products have a higher content of essential amino acids compared to dairy products. In addition, egg fortifiers contain significant amounts of phenylalanine and valine, as well as lysine, which is a limited amino acid for wheat flour. In particular, the content of lysine in dry egg white is 20 times higher than in flour.

There is a well-known study, the object of which is pea (*Pisum sativum var. arvense*) and its protein isolate as an alternative to soy protein isolate in the food industry [16]. Also, food products enriched with irreplaceable components, including dietary fibers, have been developed. A group of scientists substantiated the use of an oat bran vegetable supplement containing dietary fibers in improving the quality of food products [17]. In turn, V. Kalyna & O. Rodyhin developed dietary gluten-free pasta with amaranth, which positively affects human health [18]. In addition, there is a known method for producing pasta with amaranth and other crops to obtain a balanced flour [19].

Ukrainian scientists have developed a method for obtaining protein isolate from vetch while preserving the chemical composition. The ratio of essential amino acids to essential amino acids in vetch seeds (0.65). This is more than the amount recommended by the World Health Organization. In order to confirm the functional properties of vetch seed protein isolate, indicators of water retention and fat binding ability were studied. The seeds of vetch and its protein isolate showed high functional properties and a high-quality chemical composition of proteins and minerals for use in the technology of sausage and confectionery products, as well as an ingredient for dietary and vegetarian food [20]. Chinese scientists have studied vetch starch and its properties for food technology. These and other results demonstrate the wide application of common vetch starches in food technology [21]. The toxicity of isolated vetch protein and dietary selenium-protein supplement was investigated; as a result, their practical non-toxicity was established [22].

Therefore, the review of scientific literature proved the suitability for practical use of various products from spring vetch seeds (including flour from vetch seeds (FVS)) in the technologies of products not only for general use, but also for dietary purposes. This is confirmed by recent studies of domestic and foreign scientists regarding the nutritional and biological value of products from vetch seeds, their functional and technological properties, as well as the qualities acquired by food products derived from vetch seeds.

Materials and methods

Experimental data were obtained during research in the laboratories of the Department of Food Technologies, Faculty of Chemistry, Oles Honchar Dnipro National University.

The materials and raw materials used as a source for the production of experimental samples comply with the current regulatory documentation:

– wheat flour of the highest grade according to SSTU 46.004-99 “Wheat flour. Specifications”;

– spring vetch seeds according to SSTU 4828:2007 “Vetch. Specifications”;

– table salt according to SSTU 3583:2015

"Table salt. General technical conditions";

– drinking water according to SSTU 7525:2014 "Drinking water. Requirements and methods of quality control";

– dry egg yolk according to SSTU 8719:2017 "Egg products. Specifications".

Food products are complex multi-component systems in which the forms of moisture binding play a significant role, affecting shelf life. The objects of study were:

- Sample 1 – control, semi-finished "Pasta dough" without additives;
- Sample 2 – semi-finished product "Macaron Dough" with 5 % FVS of the total mass of flour in the dough;
- Sample 3 – semi-finished product "Pasta dough" with 10 % BNV;
- Sample 4 – semi-finished product "Pasta dough" with 15 % BNV;
- Sample 5 – semi-finished product "Pasta dough" with 20 % BNV;
- Sample 6 – noodles without additives (control);
- Sample 7 – noodles with 20 % FVS from the total mass of flour in the pasta dough.

The objects of research were medium-strength wheat flour of the highest grade and mixtures of flour and additives, in which the content of FVS was 5, 10, 15 and 20 %. The influence of FVS on the technological properties of flour was assessed by changes in the quantity and quality of gluten, as well as by the physical and structural-mechanical properties of the dough. The content of raw and dry gluten was determined by the weight method. The quality of gluten was determined according to the indicators of extensibility, elasticity on the IDK-1 device, spreading of the gluten ball within 180 minutes, and hydration capacity according to standard methods [23; 24].

Results and discussion

To improve the chemical composition of pasta products, we propose to use flour obtained after grinding a non-traditional raw material for food science – spring vetch seeds. To substantiate the possibility of using vetch seed flour in the technology of pasta products, it was considered appropriate to study its effect on the technological properties of wheat flour.

As is well known today, vegetable protein is an alternative to animal protein in the food industry. So far, seeds of vetch (*Vicia sativa L.*) have not been widely used in the food industry due to the lack of industrial processing technologies. Studies of the chemical and biological composition have established that vetch seeds are one of the most promising and healing crops. However, with traditional grinding technology, it is difficult to obtain flour from vetch seeds only, because they contain a large amount of oil and protein, and have high strength and hardness, which leads to clogging of the disc surfaces and complicates the grinding process.

To overcome these problems, other plants that contain less oil (wheat, rye, barley or corn), but instead contain oil adsorbents such as fiber or starch, are added to vetch seeds. Therefore, flour obtained from vetch seeds contains less than 95% of these seeds for technological reasons. This is an important feature of such flour.

The use of vetch seed flour is considered expensive compared to wheat flour, so it is advisable to use it as an additional component to other flour mixtures to give products a pleasant taste and aroma. The presence of vetch seeds in the general composition of flour provides the taste and aroma of hazelnuts and almonds, and the higher the concentration of vetch seeds in the general composition of flour is, the brighter their properties are revealed.

A study of the chemical and biological composition of vetch seeds showed that they contain a large amount of vegetable protein and high-quality oil. This is achieved thanks to a balanced combination of essential amino acids in protein and polyunsaturated and monounsaturated fatty acids in the fat fraction, as well as an increased content of vitamins and trace elements. The studies describe the composition of vetch seed flour in grams per 100 g (fig. 1).

The amount of valuable protein in vetch seeds of some varieties reaches 28.0 or more percent, while in wheat it is only about 10 %.

Vegetable oil in vetch seed flour contains an average of 2%, and in wheat – only 1 %, that is, 2 times less. Vitamins and microelements are significantly less in wheat flour compared to flour from vetch seeds.

In order to find out the difference between the composition of vetch and wheat flour, as well as to understand the average daily need of the human body for amino acids, protein, vitamins and minerals, the corresponding components are listed below (fig. 2). The ratio of amino acids in vetch seed flour is exactly what the human body is most comfortable with, which indicates a balanced amino acid composition in vetch seed flour. The described vetch seed flour contains 25.0...31.0 % protein. As can be seen from fig. 3, the described flour contains all essential amino acids and in the required ratios.

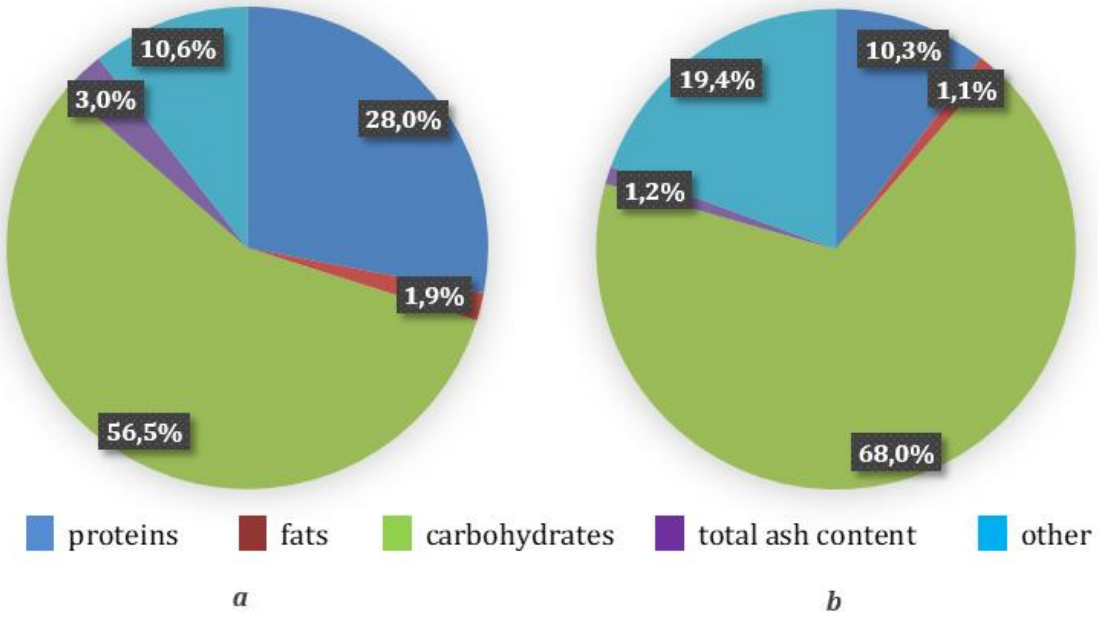

Fig. 1. Chemical composition of flour: *a* – from the seeds of spring vetch; *b* – wheat flour [21; 22]

Peculiarities of the chemical composition of FVS, in particular, the presence in them of a significant amount of polyunsaturated fatty acids, dietary fibers, carbohydrates, including starches, and high α-amylase activity determine a certain interaction of additives with flour if they are used in pasta technology.

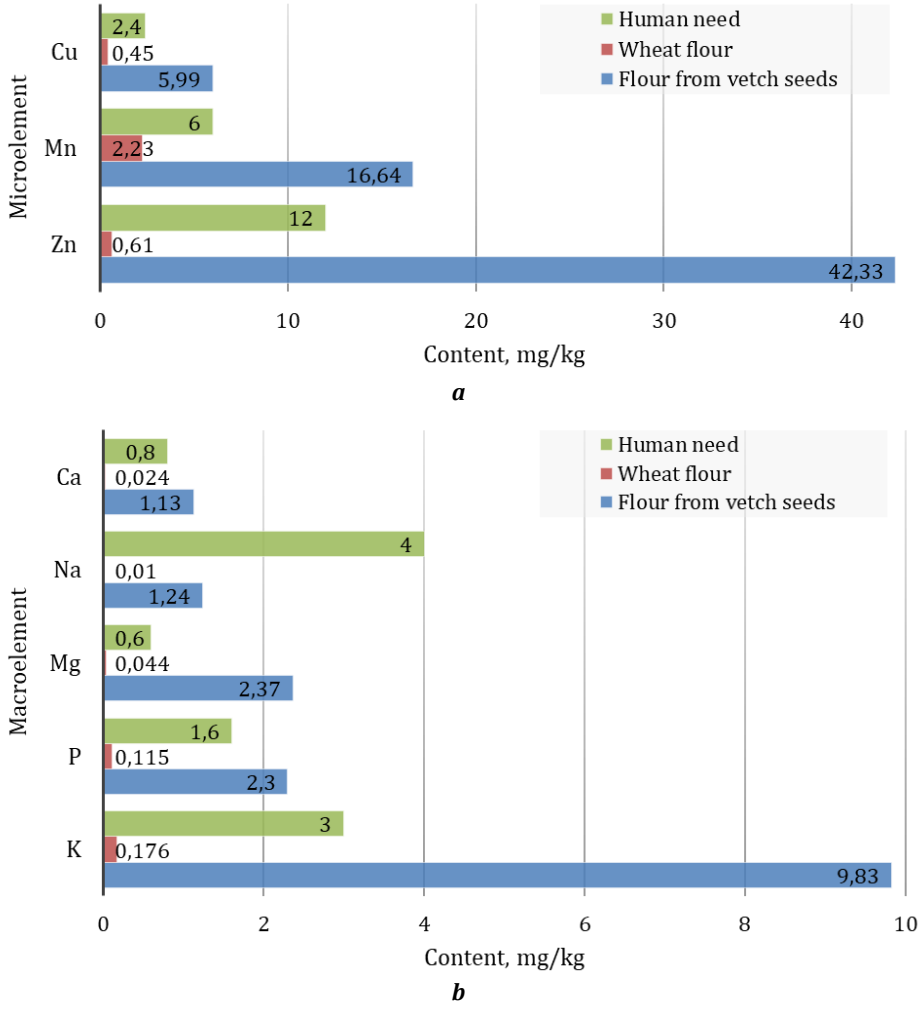

Fig. 2. Mineral composition of flour from vetch seeds and wheat flour [17; 20]

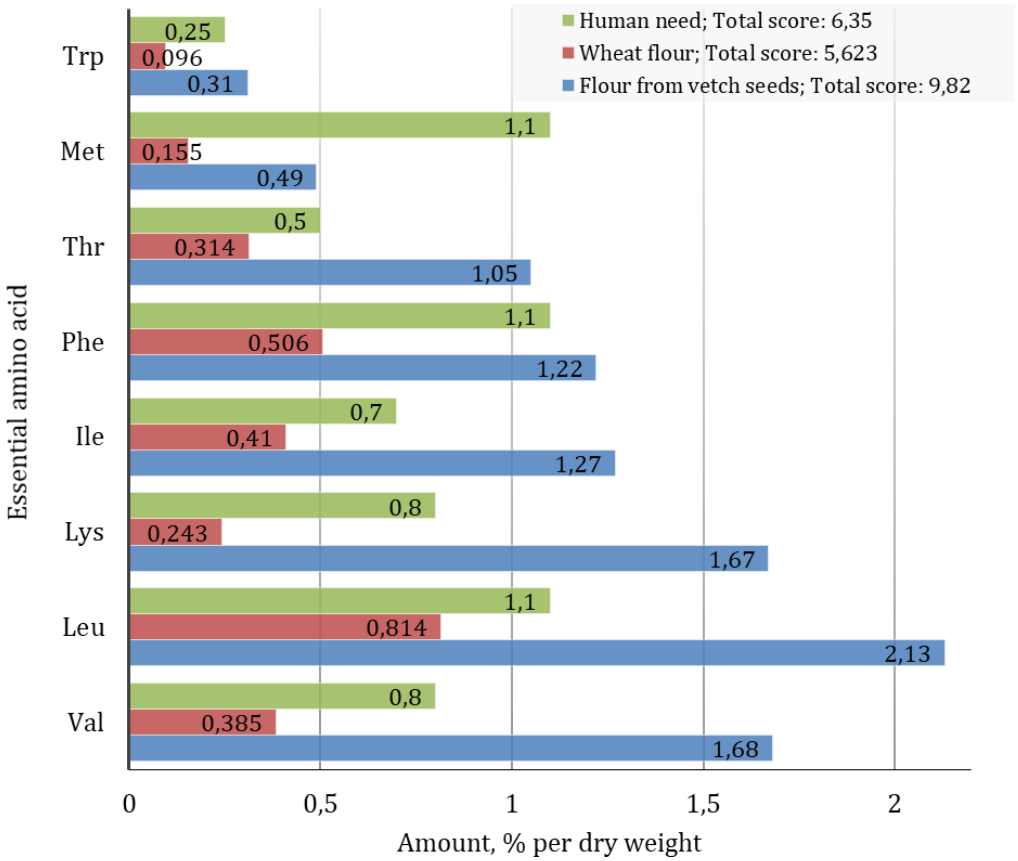

Fig. 3. Composion of essential amino acid of flour from vetch seeds and wheat flour [20; 21]

The results of the study of the influence of FVS on the gluten content and properties of wheat flour are presented in the table. 1

Table 1

The effect of FVS on the content and properties of wheat flour gluten (n=3; p≤0,95)

Sample	Additive dosage, %	Index				
		Crude gluten content, %	Dry gluten content, %	Hydration capacity, %	Elasticity, IDK device units	Extensibility, cm
without additive (control)	0	27.6±1.4	9.1±0.5	183.7±9.2	77.7±3.9	12.1±0.6
with FVS	5.0	26.8±1.3	9.0±0.5	180.7±9.0	72.7±3.6	9.6±0.5
	10.0	25.9±1.3	8.9±0.4	174.7±8.7	67.7±3.4	8.6±0.4
	15.0	23.6±1.2	8.2±0.4	168.7±8.4	62.7±3.1	7.6±0.4
	20.0	19.7±1.0	6.9±0.3	165.7±8.3	57.7±2.9	6.6±0.3

It was established that the introduction of FVS in the amount of 5.0 and 10.0 % has almost no effect on the content of raw and dry gluten – the changes in the values of these indicators are within the experimental error. In the case of increasing the dosage of FVS to 15 and 20 %, the amount of raw and dry gluten decreases relative to the control sample by 4 and 7.9 %.

In our opinion, the decrease in the amount of gluten can be explained by several factors. Firstly, the studied FVS contains fats (twice as much as wheat flour), which, being distributed on the surface of protein molecules, shield their hydrophilic compounds and limit the swelling and structuring of protein micelles. As a result, non-swollen proteins are washed away together with starch and other components. Secondly, the composition of FVS includes a significant amount of non-starch polysaccharides, which have a high water absorption capacity, because of which they compete with flour biopolymers in moisture absorption. They are also able to form protein-polysaccharide complexes with protein substances of flour, which will not form gluten.

The above also explains the decrease in the hydration capacity of gluten. In particular, under the conditions of the maximum investigated dosage of FVS, the hydration capacity of gluten

proteins decreases by 18 % relative to the control sample.

The tensile strength of the samples decreases by 20.7...45.6 % as the dosage of FVS increases, which is associated with a violation of the integrity of the gluten frame due to the distribution of FVS particles between flour particles

A study of elasticity indicators (table. 1) and spreading of the gluten ball (fig. 4) indicates its strengthening.

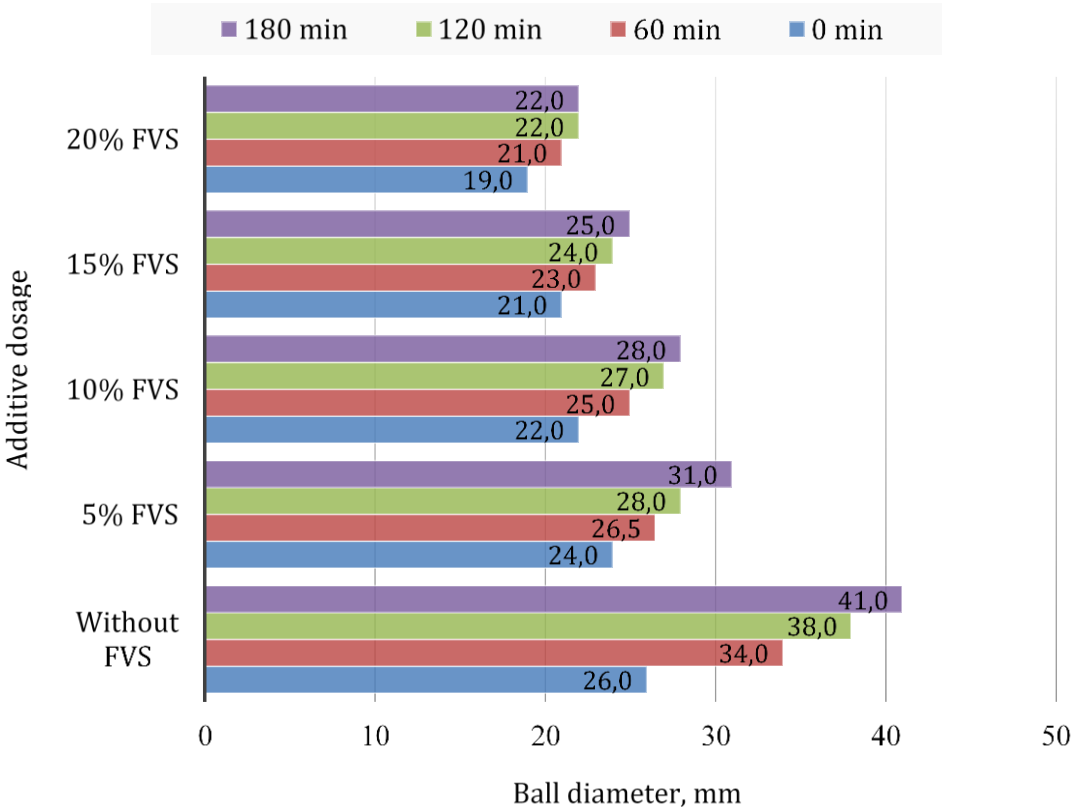

Fig. 4. Kinetics of the effect of FVS on spreading of gluten balls

In particular, in the case of adding FVS to the flour mixture in the amount of 5.0...20.0 %, a decrease in the value of the gluten elasticity index by 6.4...25.7 % is observed relative to the control sample. It was established that the index of spreading of the gluten ball after 180 min in samples with FVS decreases compared to the control by 1.1...1.4 and 1.3 and 1.9 times, respectively.

Phenolic compounds present in the studied FVS, which are able to form complexes with proteins, can have a strengthening effect on gluten. Also, FVS fats are mainly represented by polyunsaturated fatty acids, which during oxidation form peroxide compounds. Peroxides and hydroperoxides contribute to the oxidation of sulfhydryl groups of protein molecules with the formation of disulfide bonds, which strengthen the structure of gluten and contribute to its compaction [25].

Thus, the introduction of FVS in the amount of 15.0...20.0 % of the total mass of flour helps to strengthen the gluten of wheat flour, reduce its yield, and has a certain effect on the physical and structural-mechanical properties of wheat dough. This must be taken into account when developing recipes and substantiating the parameters of pasta production technologies using FVS.

An improvement in the water-absorbing capacity of the dough with FVS, an extension of the duration of its formation, a decrease in stability and an increase in the degree of liquefaction under the influence of mechanical processing are noted. This is due to competition in moisture absorption between food fibers of additives and biopolymers of flour, dehydrating ability of sugars of additives and higher activity of their α-amylases compared to flour.

Based on the results of marketing research, the development of an improved recipe for ribbon-like noodle-type pasta will be relevant. Such products are in the greatest demand among Ukrainians.

Based on a set of conducted experimental studies, the optimal component composition of the ingredients of the pasta dough was selected, which was the basis for developing the appropriate recipe. The technology for making noodle-type pasta involves the preparation of the semi-finished product “Macaroni dough with FVS”.

When choosing the technological parameters of the dough recipe with FVS, we were guided by the main features of the formation of this food subsystem.

We chose a soft type of dough kneading, which provides dough moisture at the level of 31.1...32.5 % with a cold kneading method at a water temperature of 40...45 °C. So, the preparation of the dough consists of the following stages. Water heated to 40...45 °C is poured into a vessel, salt and sifted egg powder are dissolved and quickly mixed with a sifted mixture of wheat flour and FVS for 15...20 % until a homogenious stiff dough is obtained within 15...20 minutes.

After an hour, the dough is rolled into a thin layer 1.5 mm thick. The noodles are cut into strips of the size: width – 2 mm, length – 50–70 mm, after which the noodles are dried to the specified moisture content. The semi-finished product "Noodles with FVS" is poured with boiling salted water and, stirring, cooked until tender.

In addition, the nutritional and energy value of noodle samples without additives and with the addition of FVS were calculated. The results are presented in the table. 2.

Table 2

Nutritional and energy value of noodles without additives and with FVS

Pasta products	Chemical composition, g/100 g					Energy value, kcal/100 g
	water	proteins	fats	carbohydrates	other compounds	
Control without additives (from pasta grits)	13	10.4	1.1	69.8	5.6	337
Sample with FVS	13	11.5	3.0	43.3	4.6	249

As can be seen from the table. 2, the proteins of noodles with FVS do not differ significantly from the control sample made according to the traditional recipe. However, the difference in fat and carbohydrate content is more drastic. Thus, the amount of fat increased almost three times compared to the control value (3.0 and 1.1 g, respectively; deviation +1.9 g or +170.4 %). This is explained by the chemical composition of FVS (the mass fraction of fat is twice as large as the share in wheat flour) and the presence of dry egg yolk in the recipe of noodles with FVS, the composition of which is represented in almost equal parts by protein and fat fractions. In addition, the carbohydrate fraction decreased (69.8 and 43.3 g, respectively; deviation -26.5 g or –37.9 %) compared to the control noodle sample. In turn, this can be similarly explained by the chemical composition of FVS, in which only half of the total number of nutrients is carbohydrates, in contrast to wheat flour, in which 2/3 of the total number of nutrients are carbohydrates of various nature.

In addition, the score of essential amino acids in noodles with FVS was calculated. It was found to increase by 0.6 g compared to the control (3.6 and 4.2, respectively). The increase in the total number of essential amino acids in the pasta product by 14.5 % can be explained by the chemical composition of FVS, which significantly exceeds wheat flour (9.82 and 5.62 %, respectively).

Thus, the developed noodles with FVS are characterized by a pleasant taste and smell of roasted nuts. Noodles contain an increased (up to 12 %) concentration of proteins with a balanced amino acid composition, an increased (up to 3.5 %) concentration of high-quality unsaturated fatty acids, and an increased content of vitamins and trace elements, which determine their high nutritional value.

Conclusions

The review of the scientific literature proved the suitability for practical use of various products from spring vetch seeds (including vetch seed flour) in the technologies of products not only for general use, but also for dietary purposes. This is confirmed by recent studies of domestic and foreign scientists on the nutritional and biological value of products from vetch seeds, their functional and technological properties, as well as the qualities acquired by new food products.

Studies of the effect of adding FVS in an amount of 15.0...20.0 % of the total mass of flour have established the fact of strengthening the gluten of wheat flour, reducing its yield and affecting the physical and structural-mechanical properties of wheat dough. This must be taken into account during the development of recipes and justification parameters of pasta production technologies using FVS. There was an improvement in the water absorption capacity of the dough with FVS, an extension of the duration of its formation, a decrease in stability and an increase in the degree of liquefaction under the influence of mechanical processing.

The noodles contain an increased (up to 12 %) concentration of proteins with a balanced amino acid composition, an increased (up to 3.5 %) concentration of high-quality unsaturated fatty acids, an increased content of vitamins and trace elements, which determines their high nutritional value.

These pasta products with FVS belong to dietary products that can provide people's diets with complete proteins, balanced in terms of amino acid composition, polyunsaturated fatty acids, a sufficient amount of vitamins and trace elements. The formation of such dietary properties in pasta products is achieved due to the introduction of vetch seed flour into the dough, which is confirmed by the above studies.

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