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INFLUENCE OF HEMP SEED PROCESSING PRODUCTS ON STRUCTURAL AND MECHANICAL PROPERTIES OF DOUGH

Abstract

The assortment of bread and bakery products on the market of Ukraine mostly has a low nutritional and biological value. Promising raw materials for enriching bread and bakery products are hemp seed processing products, namely hemp flour, hemp protein and kernels. The quality of hemp seed processing products and their influence on the structural and mechanical properties of the dough using these products were investigated. As a result of determining the granulometric composition of hemp protein, it was established that the largest content of 39.55% of particles with a size of 100.0...200.0 microns, at the same time, the diameter of the particles of hemp flour is greater than that of hemp protein and reaches a maximum of 2500 microns. It was established that compared to the control sample, the introduction of hemp processing products reduces the amount of raw gluten from 4.64 to 6.7%, its hydration capacity by 21% to 40%, stretchability, increases its elasticity from 18.4 to 26.5% . The gluten quality of all test samples, depending on the color, elasticity and stretchability, corresponds to the II quality group. As a result of deciphering farinograms, it was established that the stability of dough with hemp flour and protein decreases by 1.5 and 6 minutes, respectively. Alveograms showed that samples with hemp products have a lower extensibility index than the control sample and, accordingly, a higher P/L ratio. The strength of the flour, respectively, is the highest in the control sample, which is 239 a.u., in the samples with the replacement of 10% wheat flour for hemp and 15% wheat flour for hemp protein by 70 and 104 a.u. less than the control. In the course of the study, it was established that the specific volume of the dough and the blurring of the dough ball with the addition of hemp processing products decreases. Based on the results of determining the viscosity of the experimental dough samples, it was found that the control sample has the lowest shear stress, and therefore the lowest viscosity, compared to the samples dough with the introduction of hemp products.

Key words: bread, hemp, flour, protein, core, dough.

Introduction

Bread and bakery products are among the main products consumed by the Ukrainian population. The consumption of bread by Ukrainians significantly exceeds the norm set out in the ‘consumer basket’ of 101 kg per person per year, or 277 g per day [1].

However, despite their popularity, most bakery products on the Ukrainian market have low nutritional and biological value. Consumption of such products does not provide the body with important macro- and microelements, vitamins, minerals, essential amino acids, etc. Traditional bread formulations contain insufficient amounts of these important elements, which reduces their health benefits [2].

The solution to the problem of low nutritional and biological value of bread and bakery products is to expand the range by using non-traditional types of plant materials and enriching traditional recipes with them [3].

Literary review

Scientists from around the world are conducting research on enriching bread recipes with non-traditional raw materials: seaweed [4], dietary fibre from rice bran [5], fruits and vegetables [6], etc.

One of the most promising types of raw materials for improving the nutritional and biological value of bread and bakery products may be hemp seed processing products [7].

Scientists have investigated the possibility of using hemp seed processing products in food products [8].

The use of hemp flour in the production of biscuits has been investigated [9].

Hemp seeds, which are ready for consumption and use in food preparation, are kernels that have been peeled from their shells. They have a nutty and vegetable flavour and have a positive effect on the human body, especially the gastrointestinal tract.

Hemp kernels are a source of omega-6 and omega-3 polyunsaturated fatty acids (30% of total calories) and proteins (25%). The combination of these substances contributes to a long-term feeling of satiety and reduces the risk of overeating and cravings for unhealthy fats and carbohydrates. Whole hemp seeds are a source of soluble (20%) and insoluble fibre (80%). Soluble fibre promotes the digestion of beneficial digestive bacteria, reduces blood sugar and regulates cholesterol levels. Insoluble fibre helps food and waste pass through the intestines.

Classic hemp oil is made from hemp seeds by cold pressing. It does not contain any psychoactive substances. In Ukraine, working with hemp inflorescences is prohibited by law, so CBD oil is not produced.

Hemp oil contains (%) 5.8-9.9 palmitic, 1.7-5.6 stearic, 6-16 oleic, 36-50 linoleic, 15-28 linolenic acids [10].

Hemp oil contains linoleic acid, which helps to reduce the level of unwanted cholesterol. This reduces the risk of high blood pressure, stroke, and other heart diseases. Gamma-linoleic acid (GLA) contained in hemp oil fights inflammation in the body.

After the oil is pressed, the seed residue contains up to 10% fat, and the protein concentration is 44-60%. That is why hemp protein is made from it.

Hemp flour contains 20 amino acids, vitamins E, C, D and K, B vitamins (B_1, B_2, B_3, B_4 (choline), B_5, B_6, B_8 (inositol), B_7 (biotin), B_9 and B_{12}), as well as carotenoids (precursors of vitamin A), macro- and microelements (iron, magnesium, potassium, phosphorus, calcium, manganese, zinc, sulphur, chlorine, etc.) and does not contain gluten. Hemp flour contains omega-6 and omega-3 polyunsaturated fatty acids in an ideal ratio of 3:1 [11].

Formulation of the problem

The aim and objectives of the study are to determine the quality indicators of hemp seed processing products and to investigate their influence on the properties of wheat flour dough.

Materials and methods

The falling number for the raw materials (first-grade wheat flour, hemp flour, hemp protein) was determined using the PCP-3 device, which is designed to characterise the total autolytic activity, the main role of which is played by ɑ-amylase.

Two weights of equal weight were taken from the product (for first-grade wheat flour - 6.8 g; hemp flour - 6.6 g; hemp protein - 6.6 g). Fill the water bath of the device with distilled water. The condenser is connected to a tap with cold water, which should circulate until the device is switched off. Within about 30 minutes after switching on the heater, the water in the bath boils. Transfer the flour to two viscometric tubes, pour 25 cm³ of distilled water at 20±5 ºC into each tube with a pipette. Shake the tubes vigorously 20-25 times, remove the stopper, and use the disc of a stirrer to add the flour particles adhering to the tube walls to the total mass of the suspension. Place the test tubes with the stirrer discs installed in them into the holes in the lid of the water bath and press the 'Start 'button immediately. The device automatically calculates the arithmetic mean of the falling number and, if the difference between the parallel determinations does not exceed 10%, the result is displayed after pressing the 'Result 'button [12].

The acidity of the raw materials (first-grade wheat flour, hemp flour, hemp protein, hemp seed kernels), as well as the acidity of the dough during the ripening process, was determined by titrating the extract [12].

The amount and quality of gluten was determined in experimental samples with the replacement of wheat flour with hemp products and comparison with the control sample [12].

Determination of flour strength on the automated penetrometer AP-4/1 by the K60 index [12].

Determination of the autolytic activity of flour by the autolytic test method [12].

Determination of dough ball spreading. The dough was prepared according to the recipes in Table 1. Two balls weighing 100 g each, were formed from the kneaded dough. Place the ball in the middle of the glass plate of the device and cover it with a lid and place it in a thermostat with a temperature of +30 ºC. The average diameter of the dough ball is recorded immediately after forming, and then after 60, 120 and 180 min of fermentation in the thermostat [12].

The diameter of the dough ball is less than 83 mm - strong, 83-97 mm - medium strength, 97 mm and more - weak.

To determine the specific volume of the dough, weigh 50 g of dough to the nearest 0.01 g, place it in a 250 cm³ measuring cylinder, pre-oiled with vegetable oil, and place it in a thermostat at +30 ºC. The initial volume of the dough and its changes during the fermentation of the dough are recorded every 30 minutes for 3 hours [12].

Determination of the viscosity of semi-finished products using a Reotest-2 viscometer. To measure the rheological characteristics, 20-25 g of semi-finished product is taken after kneading and after 60, 120, 180 minutes of fermentation. The device readings are taken at 12 shear rates. The shear stress and dynamic viscosity are calculated and a graph of the strain rate versus shear stress is plotted [12].

Results of the study and their discussion

Since during the organoleptic evaluation of the quality of raw materials, namely hemp flour and protein, a corresponding crunch was felt, which is explained by the presence of shell parts, it was advisable to determine their particle size distribution. The results are shown in Fig. 1.

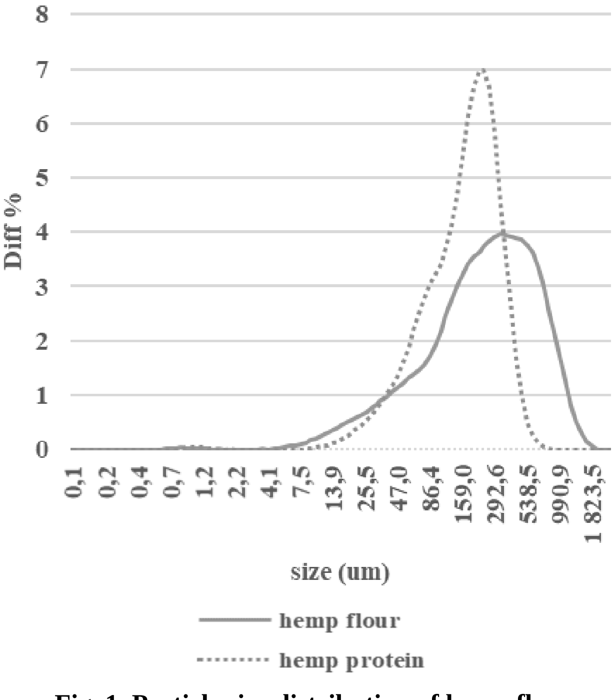

Fig. 1. Particle size distribution of hemp flour and protein

As a result of determining the particle size distribution of hemp protein, it was found that the highest content of 39.55% of particles was 100.0...200.0 µm in size, and the largest particle size was up to 700.0 µm. At the same time, the particle size distribution of hemp flour showed that the particle diameter is larger than in hemp protein and reaches a maximum of 2500 µm, the highest content of 59.49% falls on the particle size from 0.0 to 400.0 µm.

Table 1 - Quality indicators of first-grade wheat flour and hemp seed processing products
arithmetic mean values, n=3; p≥0.95; δ=3-5%

Indicator name*	First grade wheat flour	Hemp flour	Hemp protein	Hemp kernels
Color	White	Grey-green with brownish-green dark spots	Not a bright green color	Light greenish kernels, dark green shells
Taste	Inherent in wheat	Bitter	Sweetly herbaceous	Sour and nutty
Smell	Raw flour, without impurities	Smell of raw flour with a slightly sour tinge	Sour	Nutty
Acidity, degrees	2,8	6,0	5,0	7,2
Falling number, sec	240	180	185	-

For a complete characterisation of the quality of raw materials, we determined the organoleptic characteristics, acidity of raw materials, the falling number of first-grade wheat flour and hemp seed products (Table 1) [12].

The acidity of hemp seed processing products is higher by 3.2, 2.2 and 4.4 degrees, respectively, in hemp flour, protein and hemp kernels compared to the acidity of first-grade wheat flour. This is probably due to the increased amino acid and fatty acid composition.

The falling point was determined for first-grade wheat flour, flour and hemp protein. The data obtained comply with the requirements of regulatory documents, however, the falling point of hemp flour and protein is lower by 25 and 22.9 %, respectively, compared to first-grade wheat flour, which may indicate a higher activity of the α-amylase enzyme.

The color, smell and taste of hemp seed products have a significant difference compared to first-grade wheat flour, in particular, the color of hemp products mostly has inherent green shades, the taste and aroma are more pronouncedly sour with nutty and grassy notes.

Since hemp seed products do not contain gluten, it is necessary to determine the effect of these products on the quality and quantity of gluten in wheat dough. For this study, we used test dough samples with 10% wheat flour substitution for hemp flour, 15% wheat flour substitution for hemp protein, and a sample with 15% wheat flour substitution for hemp flour and protein and an additional 7% hemp kernels.

Thus, compared to the control sample, the addition of hemp processing products reduces the amount of raw gluten, its hydration capacity, extensibility, and increases its elasticity. This is due to the high content of hulls in hemp seed products, as well as the absence of gluten.

In particular, the amount of crude gluten decreased from 4.64 to 6.7% in the samples after replacing wheat flour with hemp products, and the hydration capacity decreased by 21% to 40%. The elasticity of gluten according to the IDK-3 device in the experimental samples with the replacement of first-grade wheat flour is lower by 18.4 to 26.5% compared to the control sample, however, all indicators of the experimental samples correspond to the second group of gluten quality, which characterises gluten as satisfactorily strong.

The quality of gluten of all the test samples, depending on color, elasticity and extensibility, corresponds to the second quality group.

Table 2 - Gluten quantity and quality indicators of the experimental samples
arithmetic mean values, n=3; p≥0.95; δ=3-5%.

Indicators*	Control	10% of hemp flour by weight of flour	15% of hemp seed protein by weight of flour + 7% of kernels additionally	15% of hemp seed protein by weight of flour
Amount of crude gluten, %.	23,72	18,44	17,02	19,08
Hydration capacity, %.	184	163	144	156
IDC, unit of device	49	38	36	40
Extensibility, cm	17 (average)	15 (average)	13 (average)	16 (average)
Elasticity	good	good	satisfactory	good
Color	light	Light grey	Grey with a green tint	Grey-green

Table 3 - Characteristics of wheat flour and its mixtures with hemp products
arithmetic mean values, n=3; p≥0.95; δ=3-5%.

Indicators*	First grade wheat flour	Mix of wheat flour and 10% replacement with hemp flour	Mix of wheat flour and 15% replacement with hemp protein
Flour strength on the automated penetrometer, unit of the device	145	100	68
Autolytic activity, % on dry matter of flour	20	26	25

Since the chemical composition of hemp seed processing products has a significant difference from first-grade wheat flour, it is necessary to determine and compare the control sample with first-grade wheat flour and samples of mixtures of wheat flour with 10% replacement with hemp flour and wheat flour with 15% replacement with hemp protein in terms of flour strength on an automated penetrometer and autolytic activity. The flour strength and autolytic activity were determined in Table 3.

The strength of the mixtures of wheat flour and hemp seed products was determined by the consistency of the dough. The strength of first-grade wheat flour corresponds to the strong flour quality group, while the samples of mixtures with hemp flour and protein correspond to the very strong quality group.

The approximate norm of autolytic activity with low gluten content and poor gluten quality is no more than 20% dry matter. According to studies of the autolytic activity of first-grade wheat flour within the normal range, for mixtures with flour and hemp protein, it can be argued that the activity of ɑ-amylase is excessive.

Dough is a complex system, the structural and mechanical properties of which, to a certain extent, depend on the recipe components. The structural and mechanical properties of dough combine rheological, visco-plastic, elastic and elastic properties; these include viscosity, elasticity, elasticity of dough, mouldability, etc.

The structural and mechanical properties of the dough determine the subsequent quality of the finished product, its porosity, crumb condition, and organoleptic characteristics.

Flour is one of the main recipe components that provides certain dough properties. Hemp seed processing products, namely flour and hemp protein, are proposed to be used to replace a certain percentage of first-grade wheat flour in wheat bread recipes. Therefore, model experiments were conducted to determine the effect of using hemp seed processing products on the structural and mechanical properties of the dough using a pharynograph [13] and an alveograph.

The results of decoding the pharynograms in Table 4 showed that dough samples with hemp flour and protein have a slightly lower water absorption capacity and a shorter kneading time. Based on the duration of kneading, we can talk about a reduction in the plasticisation process of the dough with the added components. The stability of the dough with hemp flour and protein decreases by 1.5 and 6 minutes, respectively. It should be noted that the sample with the replacement of 10 % of wheat flour with hemp flour had the lowest dilution. The dough thinning with the addition of 15 % hemp protein to replace wheat flour was 15 % higher than in the control sample.

Probably, during the kneading of the dough, particles of hemp products wedge into the glutenous backbone of wheat flour, forming complexes with proteins. This results in gluten liquefaction due to the breakdown of disulfide bonds [14].

According to the results of decoding the alveograms in Table 5, it was determined that the sample with the replacement of 10% of wheat flour with hemp flour has the highest elasticity. Along with this, the samples with hemp seed processing products have a lower extensibility index than the control sample and, accordingly, a higher P/L ratio. This is probably due to the size and heterogeneity of particles in the hemp seed processing products, which forms a less elastic dough mass.

The extensibility index, which characterises the volume of air used to inflate the dough ball, is highest in the control sample, while in the samples with the addition of hemp seed products it is the same.

The strength of the flour is, respectively, the highest in the control sample, which is 239 units, in the

Table 4 - Test results by pharynograph

Indicators*	Control	10% hemp flour by weight of flour	15% hemp seed protein by weight of flour
Water absorption capacity of flour, %.	54,8	52,7	53,3
Time of dough formation, %	2,5	2,0	2,0
Stability, min	13,0	11,5	7,0
Dough thinning, units	85	60	100

* arithmetic mean values, n=3; p≥0.95; δ=3-5%

samples with the replacement of 10% wheat flour with hemp flour and 15% wheat flour with hemp protein, which is 70 and 104 units less than the control.

The study found that the specific volume of the dough in Fig. 2 decreases with the addition of hemp processing products. Thus, the specific volume of the dough of the control sample after three hours of fermentation is 2.6 m3/kg, while the specific volume of the dough of the samples with the replacement of 10% wheat flour with hemp and the sample with the replacement of 15% wheat flour with hemp protein is 0.2 m3/kg less than the control sample. The specific volume of the dough sample with the replacement of 15 % wheat flour with hemp protein and the additional addition of 7 % hemp kernels is 0.3 m3/ in comparison with the control sample. This result is explained by the replacement of part of the first-grade wheat flour with hemp processing products that do not contain gluten proteins, and therefore the gluten backbone is not sufficiently formed compared to the control sample.

Table 5 - Test results by alveograph

Indicators*.	Control	10% hemp flour by weight of flour	10% hemp flour by weight of flour
Dough elasticity P, mm	73	117	100
P/L	0,7	3,4	2,9
Flour strength, W, o.a.	239	169	135
Elasticity index Ie, %.	54,9	0,0	0,0
Dough extensibility L, mm	105	34	34
Extensibility index G, mm	22,8	13,0	13,0

* arithmetic mean values, n=3; p≥0.95; δ=3-5%.

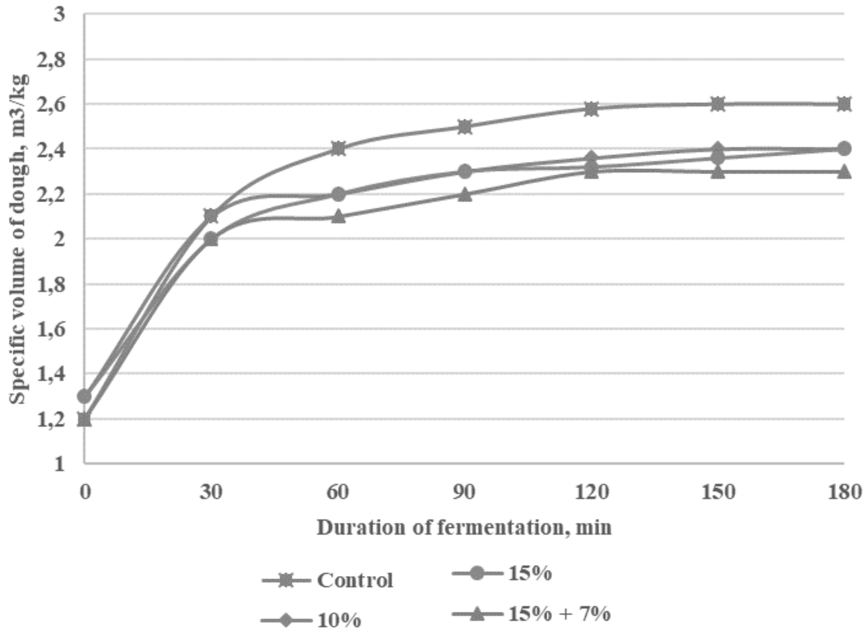

Fig. 2. Specific volume of the dough of the prototypes

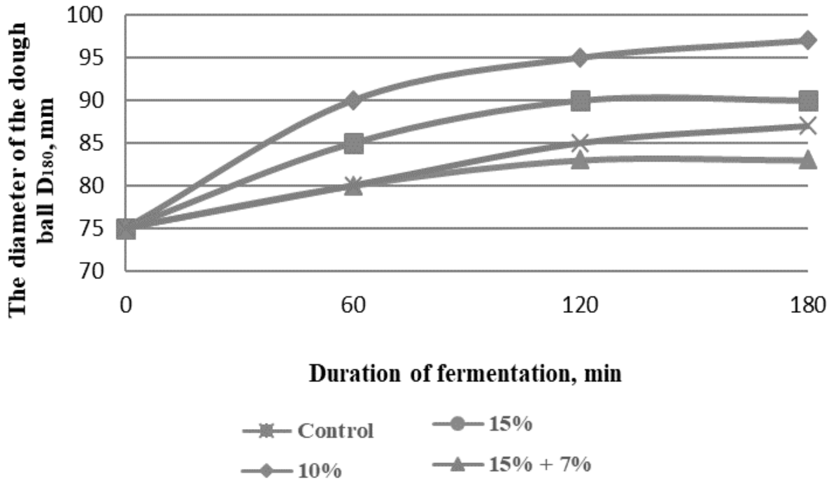

Fig. 3. Dough ball spreading of the prototypes

The effect of hemp seed processing products on the visco-plastic properties of the dough was determined.

The viscosity of the dough is determined by its ability to spread, which determines the behaviour of dough pieces during proofing and baking.

The effect of hemp processing products on dough viscosity was studied by determining the spreading of a dough ball during 3 hours of fermentation. The results are presented in Fig.3.

It was found that the introduction of hemp seed processing products into the dough, the spreading of the dough ball decreases compared to the control sample by 7.2 %, 14.4 % and 10.3 % in samples with the replacement of 10 % of wheat flour with hemp flour; replacement of 15 % of wheat flour with hemp protein; replacement of 15 % of wheat flour with hemp protein and, accordingly, increases the viscosity.

Taking into account the results of the study, it is necessary to investigate the rheological properties of the dough, namely the shear stress, which indicates changes in the viscosity of the dough with the addition of hemp products compared to the control sample.

According to the results of determining the viscosity of the test dough samples using the Reotest-2

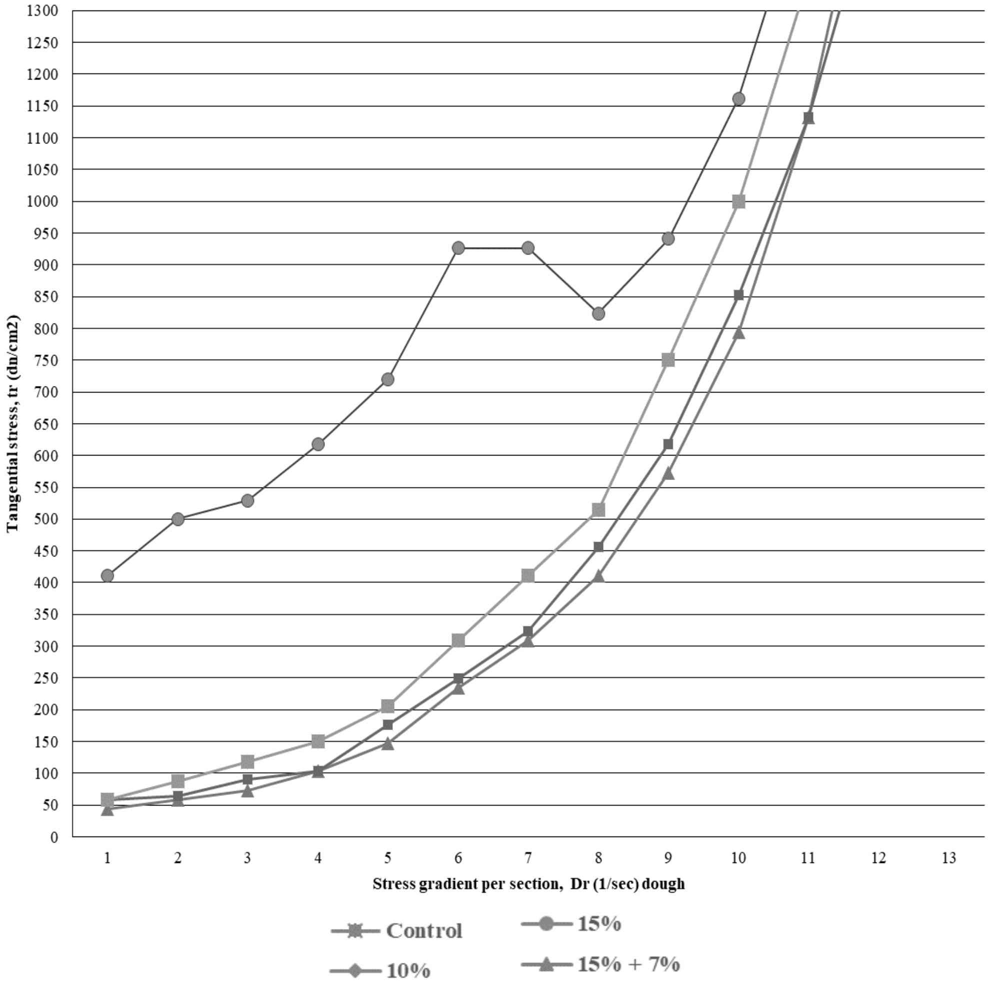

Fig. 4. Graphs of measuring the shear stress of the test dough samples

device, it was found that the control sample had the lowest shear stress and, consequently, the lowest viscosity compared to the dough samples with the addition of hemp seed processing products. It should also be noted that the sample with the replacement of 15% of wheat flour with hemp protein and the additional addition of 7% of hemp kernels has the highest viscosity, since hemp kernels have a hard structure, which is evident in the graphs of Fig. 4.

Thus, the introduction of hemp processing products, namely hemp flour, protein and hemp kernels, affects the viscosity, increasing it.

Conclusion

1. The quality of hemp seed processing products and their influence on the formation of dough properties of the experimental samples were studied, which confirmed the possibility of using the above raw materials in the baking industry.

2. The quantity and quality of gluten of the experimental samples with the addition of hemp seed processing products decreases and deteriorates compared to the control sample of wheat dough.

3. The strength of the first-grade wheat flour corresponds to the quality group of strong flour, while the samples of mixtures with hemp flour and protein are very strong in quality. According to the results of studies of the autolytic activity of first-grade wheat flour and mixtures with hemp flour and protein, it can be argued that the activity of α-amylase is excessive.

4. The structural and mechanical properties of the dough according to the pharynograph and alveograph, as well as the specific volume of the dough of the experimental samples with the addition of hemp seed processing products have slightly lower results compared to the control sample.

5. The influence of the use of hemp seed processing products on the visco-plastic properties of the dough was determined, in particular, the spreading of the dough ball decreases compared to the control sample. At the same time, the sample with the replacement of 15% of first-grade wheat flour with hemp protein and the additional addition of 7% of kernels has the highest viscosity.

6. Samples with the addition of hemp seed processing products have deviations in quality indicators from the control sample. However, they are insignificant, and by adjusting the parameters of the technological process, it is possible to ensure good quality of the finished products.

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ВПЛИВ ПРОДУКТІВ ПЕРЕРОБКИ НАСІННЯ КОНОПЕЛЬ НА СТРУКТУРНО-МЕХАНІЧНІ ВЛАСТИВОСТІ ТІСТА

Анотація

Асортимент хліба та хлібобулочних виробів на ринку України здебільшого має низьку харчову та біологічну цінність. Перспективною сировиною для збагачення хліба та хлібобулочних виробів є продукти переробки насіння конопель, а саме конопляне борошно, конопляний протеїн та ядра. Досліджено якість продуктів переробки насіння конопель та їх вплив на структурно-механічні властивості тіста з використанням цих продуктів. В результаті визначення гранулометричного складу конопляного протеїну встановлено, що найбільший вміст 39,55% частинок розміром 100,0…200,0 мкм, водночас, діаметр частинок борошна конопляного більший ніж в конопляному протеїні і максимально доходить до 2500 мкм. Встановлено, що порівняно із контрольним зразком, внесення продуктів переробки конопель знижує кількість сирої клейковини від 4,64 до 6,7 %, її гідратаційну здатність на 21% до 40%, розтяжність, підвищує її пружність від 18,4 до 26,5 %. Якість клейковини усіх дослідних зразків, залежно від кольору, еластичності та розтяжності, відповідає ІІ групі якості. В результаті розшифрування фаринограм, встановлено, що стабільність тіста із конопляним борошном і протеїном зменшується на 1,5 та 6 хв відповідно. Альвеограми показали, що зразки з конопляними продуктами мають менший показник розтяжності ніж в контрольному зразку і відповідно більше відношення P/L. Сила борошна відповідно найбільша в контрольному зразку, що становить 239 о.а., в зразках за заміною 10% борошна пшеничного на конопляне та 15% борошна пшеничного на конопляний протеїн на 70 та 104 о.а. менше від контрольного. В ході дослідження встановлено, що питомий об'єм тіста та розпливання кульки тіста із доданням продуктів переробки конопель зменшується За результатами визначення в'язкості дослідних зразків тіста встановлено, що найменше напруження зсуву, а отже і найменшу в'язкість має контрольний зразок порівняно зі зразками тіста з внесення конопляних продуктів.

Ключові слова: хліб, коноплі, борошно, протеїн, ядра, тісто.

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