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## THE POTENTIAL OF FLOUR FROM SOLVENT-EXTRACTION HEMP OILCAKE AS AN INGREDIENT OF LOW-MOISTURE BAKERY PRODUCTS

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### Correspondence:

N.Sokolova  
E-mail: [techinstoffood@gmail.com](mailto:techinstoffood@gmail.com)

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**K. Iorgachova**, Doctor of Technical Sciences, Professor  
**N. Sokolova**, PhD, Associate Professor  
Department of bakery, confectionary,  
pasta and food concentrates technologies  
Odessa National Academy of Food Technologies  
112, Kanatna Str., Odessa, Ukraine, 65039

**Abstract.** The paper focuses on how to improve the nutritional value of traditional low moisture bakery products from wheat flour by using flour from hemp oilcakes obtained by solvent extraction of oil. It has been considered how to provide enough raw materials in the case of wide use of hemp and products of its processing in the food industry. The main tendencies in cultivating and applying industrial hemp in Ukraine and worldwide have been outlined; the chemical composition of hemp seeds (the plant's part mainly used in food products) has been analysed and characterised; and it has been suggested how hemp by-products can be used in the bakery technology. It has been studied whether flour from hemp extraction cake can be used in the technology of low-moisture bakery products such as breadsticks. It has been found that 10, 15, and 20% of hemp flour added to wheat flour increase the water absorption capacity of the resulting flour blend by 3, 6, and 13% respectively, in comparison with the control. If hemp flour is included in the formulation of breadstick dough, the slackness of a dough ball increases by 6.1, 7.4, and 11%, and this increase is bigger, the higher the hemp flour content in the formulation is. However, it has been found that if the flour component of the recipe is partly replaced with hemp flour, this changes the growth medium of yeast cells and lactic acid bacteria and thus leads to a 23, 16, and 30% decrease in the amount of carbon dioxide formed during the 180 min fermentation period of the dough. The 6, 16, and 40% increase of titratable acidity in the samples analysed is due to the content of biogenic and oligobiogenic elements in the flour mixture, which satisfy the needs of lactic acid bacteria rather than those of baker's yeast. The quality assessment of the finished products by their sensory and physicochemical characteristics has shown how promising it is to use hemp flour in the breadstick technology, provided that the recipe and the production parameters are modified to improve the products' rheological properties and quality.

**Key words:** hemp flour, technological properties, breadsticks, quality.

### Introduction. Formulation of the problem

In the human diet, wheat bread is an important source of energy, vegetable protein, digested carbohydrates, vitamins (B1, B6, PP, E), minerals (P, Mg, S, Fe), and dietary fibre [1,2]. However, it is a well-known and widely discussed fact that bakery products, especially those based on all-purpose wheat flour, are highly calorific and of low nutritional value. On the other hand, a wide range of vitamins can serve as biological catalysts for chemical reactions in the body. Within an amino acid complex, vitamins, macro- and microelements are involved in the body's metabolic processes at the molecular level. So, with years, the problem of how to enrich bread recipes is only becoming more vital.

Bakery products are consumed every day around the world, so improving their quality and enriching them with essential components is a task of extreme importance. In the bakery industry, along with traditional production methods, it makes sense to involve new sources of by-products or flours not typically used in breadmaking. A promising tendency in creation of enriched foods is using non-traditional raw materials in the food industry, which are a natural source of biologically active substances and are well adapted to the human digestive system.

The assortment of flour-based products is changing, too. In today's diet, there are fewer traditional bakery products, but more healthy foods due to the growing demand for them. Besides, the share of low-moisture bakery products, such as crispbread, breadsticks, rusks, etc., manufactured and consumed in Ukraine is increasing

from year to year, as they belong to the category of healthy food. In the practice of breadbaking, to make products healthier and more functional, various dietary supplements of vegetable and animal origin are used. They are obtained by pre-treating raw materials, by microbiological synthesis, or by processing natural materials chemically. To manufacture baked goods, local, non-traditional raw materials and by-products are widely used. These can be pseudocereals, legumes, oil crops, and various non-traditional flours from seeds, roots, and other parts of plants [3-5].

Bakery products have been for centuries, and still are, the core of most people's diet. That is why it is believed that enriching them with a variety of nutritional, protective, and functional compounds is an effective strategy for updating them. Today, consumers want bakery products with a low glycemic index, low in fat, sugar-free, with a balanced protein content, and high in dietary fibre, vitamins, minerals and biologically active vegetable components. Hemp, a plant traditional for Ukrainian culture, can become an effective means of solving most of these problems.

#### Analysis of recent research and publications

Industrial hemp is a non-psychoactive strain of the plant species *Cannabis sativa* grown specifically for the industrial use of its derived products [6]. Now industrial hemp is grown in at least 47 countries (Fig.1). China processes 70% of the world's total yield of industrial hemp and is itself the leading hemp producer worldwide (Table 1). Today, Europe is estimated to produce about 1/4 of the world's hemp, but historically, this geographical area used to be the global leader [7,8]. At the present stage of development, processes of adapting the cultivation of hemp to market conditions are taking place in Ukraine. The industry is in its formative period, which is due to the appearance of more farming land to cultivate industrial hemp [9]. Mostly, industrial hemp is grown to obtain fibre and seeds. For the past six years, the number of hemp-related businesses in Ukraine has increased tenfold. This tendency makes it very likely that there will be enough raw materials if industrial hemp and products derived from it are used in the food industry.



Fig. 1. Countries cultivating or utilising natural hemp (highlighted in green)

Table 1 – Industrial hemp harvest in different countries [7,8]

Country	Total, ha
Canada	34,262
China	10,500
France	8,306
Chile	6,700
Romania	3,040
<b>Ukraine</b>	<b>4,100</b>
Hungary	1,700

The Canadian researchers [10] analysed the composition of ten industrial hemp cultivars grown in Southern Québec. They found that a seed contained, on average, 292 g/kg of oil and 256 g/kg of crude protein, its average phenolic content was 2224 mg/100g GAE, the total phenolic concentration per cultivar ranged 1368 to 5160 mg/100g, depending on the cultivar, the average ratio of linoleic and  $\alpha$ -linolenic acids was 3.5:1. Thus, these hemp seeds are, potentially, a highly nutritive food source. As for hemp cultivars of Ukrainian breeding, we can see some differences in their chemical composition due to different growing conditions. Ukrainian hemp seeds contain 30–35% of lipids. This fraction consists of large amounts of linoleic acid (omega-3) and  $\alpha$ -linolenic acid (omega-6), often in the optimum ratio 3:1, 17–25% of protein, 14–27% of fibre, 2.5–7.0% of crude ash, and 14–27% of nitrogen-free extractives [9]. Nevertheless, all hemp varieties are among the best sources of highly digestible plant protein, essential fatty acids, vitamins A, D, E, and B group vitamins, calcium, sodium, iron, and dietary fibre [11-13]. Not once, too, has it been shown that hemp as a functional ingredient has a nutraceutical potential [10-12].

There is information that hemp flour has been used to develop recipes of gluten-free products [14-16]. Different types of bread based on hemp raw materials and wheat flour have been developed abroad [17-20]. There are various ways to enrich the formulations of bakery products with hemp seeds and flour. Besides being added directly to the dough as powdered ingredients, they can be used to prepare pre-ferments, including those causing spontaneous fermentation based on hemp flour, on hulled or unhulled hemp seeds [21,22].

Several studies show some Ukrainian technological developments that allow using hemp in flour-based products such as wheat and rye bread [23-25]. The widespread use of hemp products in the food industry is somewhat hampered by the presence of certain antinutrients in this crop: phytic acid, condensed tannins, trypsin inhibitors, saponins [22]. This factor should be taken into account when developing new foods.

At each stage of bakery production, the ingredients making up the complex system of dough go through a number of complicated processes: physicochemical, colloidal, biochemical, and

microbiological. The studies [23,24] established that during fermentation, under the action of lactic acid bacteria, the activity of  $\alpha$ -galactosides, tannins, phytic acid, and trypsin inhibitors was partially or completely eliminated. So, in the baking technology, using hemp flour could be especially helpful: it allows expecting higher bioavailability of the nutrients of hemp seeds and flour and a smaller effect of anti-nutritional factors. Almost all hemp seeds exhibit high antioxidant activity due to tocopherol and polyphenolic substances. They allow hemp oil to stay fresh for a long time and prevents its rancidity. These properties reveal the potential of using hemp flour in the technologies of high-fat foods and of products supposed to retain their consumer properties for a long time, such as low-moisture bakery products [26].

Although the results obtained are considerable, the potential of using hemp as a raw material with bioactive compounds to manufacture long-storage bakery products has, so far, been shown but insufficiently. The long shelf life of this group of products allows viewing them as import-oriented and promoting Ukrainian products to the European and global food markets. There are not enough data on how Ukrainian hemp flour effects on the sensory properties and quality of dough for breadsticks – low-moisture pencil-sized stick-like crispy baked articles.

**The purpose** of the study is to assess whether hemp flour can be used in the recipe of low-moisture bakery products. To achieve this purpose, the research objectives were:

- to determine the water absorption of mixtures of wheat flour and hemp flour;
- to analyse the effect of different dosages of hemp flour on the rheological properties of wheat dough for breadsticks;
- to study how hemp flour, as an ingredient of wheat dough for breadsticks, effected on the processes of fermentation and CO<sub>2</sub> formation;
- to study the influence of hemp flour in the recipe of wheat dough on the sensory characteristics and physical properties of breadsticks.

#### Research materials and methods

Hemp flour is made from oilcake obtained after extracting oil from hemp seeds. It is a greenish powder, with particles smaller than 0.02mm. The technology of obtaining hemp flour involves grinding hemp oilcake with a microgrinder and then sifting it through a sieve.

The hemp flour used in the research was manufactured by the company Richoil and certificated as meeting the organic production and processing standard, which is equivalent to European Council Regulations, with the moisture content 16%.

The water absorption in the flour blend made from all-purpose wheat flour and hemp flour, was determined by the method of the American Association of Cereal Chemists with a Brabender farinograph, model RSM65NG (Brabender OHG, Duisberg, Germany), according to ISO 5530-1:2013. Absorption is the amount of water required to centre the farinograph curve for standard preparation of dough with the consistency 500 units (according to ISO 5530-1:2013).

To study the rheological properties, the diameter of the dough ball was measured by the traditional method. From the kneaded dough, two pieces of 100 g each were taken, shaped into balls, and placed in the centre of a glass plate with millimetre calibrations. The plates with the dough were placed in a thermostat (humidified as much as 75–80%) at 30°C. The diameter of the diffuent dough balls was measured after 60, 120, and 180 min [25].

The intensity of gas formation in the dough was measured with AG-1M. This measurement involves the volumetric method to determine the amount of carbon dioxide formed during dough fermentation [25]. To measure the total titratable acidity, the sample was grated, mixed with water as warm as 40°C, and filtered. The filtrate is titrated against 0.1M NaOH, with phenolphthalein as the indicator (according to DSTU 7045:2009), and expressed in ml NaOH.

The breadstick samples were made following the recipe in Table 2. The dough was kneaded in batch-type dough mixers from a mixture of wheat flour, hemp flour (10, 15, 20%), sunflower oil, yeast, and salt during 10 min. The temperature after kneading was 26–28°C, the moisture content 32±1%. The dough fermentation after kneading lasted 60 min at 32±1°C. The formation of a breadstick before testing included the following operations: rolling the dough out into 12 mm wide strips; sprinkling the strips with salt; cutting the strips lengthwise with the simultaneous formation of 200 mm long dough strips; cutting into thin strips. The parameters of resting were: temperature 40°C, relative humidity 85%, duration 30 minutes. The breadsticks were baked on the sheets in the oven at 220°C for 13 minutes.

**Table 2 – Recipe of breadsticks**

Ingredients	Control sample	10% of hemp flour	15% of hemp flour	20% of hemp flour
Wheat flour, g	100.0	90.0	85.0	80.0
Hemp flour, g	–	10.0	15.0	20.0
Baking yeast, g	5.0	5.0	5.0	5.0
Margarine, g	2.0	2.0	2.0	2.0
Vegetable oil, g	2.5	2.5	2.5	2.5
Salt, g	2.0	2.0	2.0	2.0
Water, g	according to the water absorption of the flour blends			

The breadsticks were evaluated according to the standards of DSTU (State Standard of Ukraine) 4584:2006 "Bakery products. Breadsticks" and by some additional characteristics, such as the product's density and degree of wetting. Porosity is an important characteristic of bakery products, however, it cannot be determined in low moisture products, so the density of finished products was measured as it depends on porosity. Using laboratory scales, one breadstick is weighed to the nearest 0.01g. Then it is dipped into molten paraffin with a temperature close to its solidification point and quickly taken out. When the paraffin on the surface of the sample becomes hard, it is reweighed and placed in a suspension. The paraffinised sample was weighed twice with the suspension: in the air and fully immersed in water at a temperature of about 20°C. If the suspension with the sample was too light to sink in the water, a weight of 10 g was attached to its lower hook. The density was calculated in kg/m<sup>3</sup> by the formula

$$\rho = \frac{m}{V_3 - (V_1 + V_2)} \cdot 1000, (1)$$

where  $\rho$  – density, kg/m<sup>3</sup>;

$m$  – mass of the biscuit in the air, g;

$V_1$  – volume of the suspension, cm<sup>3</sup>;

$V_2$  – volume of paraffin, cm<sup>3</sup>;

$V_3$  – volume of the paraffinised biscuit with the suspension, cm<sup>3</sup>;

1000 – coefficient of conversion of density into kg/m<sup>3</sup>.

The wetting of the products was evaluated similarly to the wetting of the biscuits by measuring the increase in the product's weight when it was immersed in water at 20°C for 2 minutes. This parameter is determined by the ratio of the weight of the wetted product to that of the dry one, and is expressed as a percentage.

The hardness of the products was determined on a device designed in Odessa Academy of Food Technologies. The parameter measured is the force  $P$ , and its value is determined by the indicator of the sample's breakdown. The hardness (determined in N/m<sup>2</sup>) was calculated by the formula

$$H = \frac{P}{S}, (2)$$

where  $H$  – hardness, N/m<sup>2</sup>;

$P$  – force acting on area, N;

$S$  – contact area, m<sup>2</sup>.

The sensory characteristics were evaluated by 20 people (both men and women) who had experience of sensory evaluation. There were 6 parameters all panellists were to rate on a 1 to 10 scale. The swelling ability of the breadsticks was determined by measuring the water absorption of a sample submerged in water at 60°C for a given period of time. The moisture content in the bakery products was determined according to

ISO 712:2009 "Cereals and cereal products - Determination of moisture content."

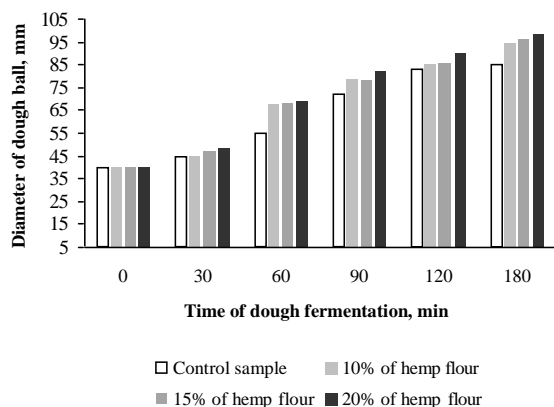
The experimental data were mathematically processed with the programme MATSTAT. The dependencies established when processing the findings were graphically interpreted using the STATISTICA 6.0 software

### Results of the research and their discussion

The initial stage of research provided a rationale in the range 10–15% of flour weight in the formula based on the quality parameters of wheat bread according to the research [26], and calculation of the nutritional value of breadsticks. Dough preparation is an important technological operation in bakery production. The properties of the prepared dough determine its state during mechanical treatment (when it is divided into parts, moulded, rested, and baked) and the quality of finished products. When the dough is being kneaded, the flour particles begin to absorb water, which results in their swelling, and the swollen particles form a continuous mass. The amount of water the flour can absorb to form dough of normal consistency depends on the content and condition of swellable biopolymers: proteins, starch, pentosans, fibre. Protein substances play a major role in the formation of dough texture. When determining the effect of hemp flour on water adsorption, a system of wheat flour – hemp flour – water was used to exclude the effect of other ingredients on this characteristic. When non-typical flour raw material is added, there are always significant changes in dough's water absorption capacity. In view of the above, the water absorption of the flour mixture was determined. It has been found that the water absorption capacity of a flour blend with increased proportions of hemp flour was higher by 3, 6, and 13% than it was in the control. For the control sample, this parameter was 60%, and for the blends, it was 62, 64, and 68%.

Compared to wheat flour, hemp flour contains 30 times as much dietary fibre and twice as much protein. They are mainly albumins and globulins [19], which are extremely high in arginine and glutamic acid [27]. However, they are not gluten proteins, so they cannot make dough viscoelastic and adhesive, which properties help it rise and hold its shape. Hemp flour contains quite a lot of fats. They, too, can regulate the degree of swelling of flour colloids, but their mechanism of action is different: they adsorb on the surface of colloidal particles, weaken their interconnection, and prevent the penetration of moisture, increasing the content of the liquid phase of the dough. Thus, it can be assumed that the increase in the water absorption capacity is due not to the swelling of hemp flour protein substances, but rather to the presence of dietary fibre. According to data from publications, flour from Ukrainian hemp contains 31% of dietary fibre, and 80% of it is insoluble [28]. Further

studies dealt with the recipes for breadsticks, which are given in Table 2.



**Fig. 2. Influence of the hemp flour percentage on dough diffuence**

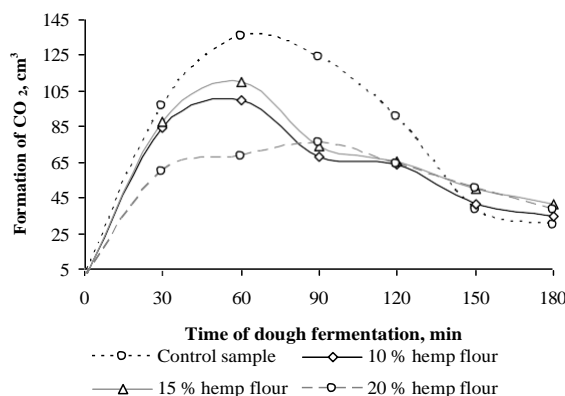
The analysis of the dough's viscoplastic properties was based on its ability to hold its shape, which was studied by watching the diffuence of a dough ball in the course of fermentation (Fig. 2). During proofing, dough pieces expand enormously. That is why it is essential that dough is well-developed or there is a gluten structure in order to withstand dough's internal pressure created by expanding carbon dioxide. The control sample was losing its shape in a uniform process throughout the fermentation period: in the first 60 minutes, it increased its diameter by 40%, and in the second 60 minutes, by 44%. Addition of hemp flour slightly destabilises this tendency: in the first 60 minutes, all the three samples lose their shape rapidly by an average of 67–68%, and in another 60 minutes, in the samples containing 10, 15, and 20% of hemp flour, the dough ball slackening is 28, 28, and 32%, respectively. Analysis of the data obtained by the end of fermentation shows that with the increase in the proportion of hemp flour, the dough diffuence parameter increased by 6.1, 7.4, and 11%, compared to the control.

The recipe for breadsticks includes fats of both vegetable and animal origin. Their total amount is 4.5% by weight of flour, and besides, hemp flour contains, by various estimates, 7.9–10.2% of fat [12,18,19]. The fatty components of dough can have a number of simultaneous actions. On the one hand, fat introduced in a liquid state (like vegetable oil) dilutes the consistency of the dough by increasing the free moisture. On the other hand, fats with high concentrations of polyunsaturated fatty acids can improve the rheological properties of the dough due to their oxidation by lipoxygenases of flour. This process is accompanied by formation of peroxide compounds that enhance oxidation of sulphhydryl groups of the flour's protein-proteinase complex in the dough [29].

Fat products significantly change the rheological properties of dough. When it contains different types of fat components, it is difficult to isolate and characterise

the effect of each. To some extent, the “lubricating” properties of fat facilitate the relative sliding of the structural components of dough, its protein network, and the starch grains it incorporates. This, perhaps, is responsible for the increased extensibility of gluten films, which can result in a higher gas-retaining capacity of dough, but not in its higher shape stability.

For the vital activity of yeast cells and normal alcoholic fermentation, dough should contain fermented sugars, nitrogenous substances, mineral salts, and vitamins, and have certain moisture content, pH, and temperature. The rate of carbon dioxide formation and its amount correlate with the activity of yeast cells. The fermentation activity of dough mixed according to a particular recipe characterises its ability to produce a certain amount of carbon dioxide. Since fermentation is the process when yeast acts on sugars and converts them into carbon dioxide and alcohol, the gas-forming ability is a great technological value in manufacture of bakery products, especially those that are sugar-free.



**Fig. 3. Influence of the hemp flour percentage on CO<sub>2</sub> formation**

The rate and direction of biochemical reactions caused by yeast cells are adaptive parameters. It has been found that partial replacement of the flour ingredient with hemp flour as a constituent of the yeast growth medium reduces the concentration of soluble substances that can maintain the structure, function, and activity of enzymes. There was more carbon dioxide in the control sample than in the samples with hemp flour. Over the entire fermentation period, the reduction in the total amount of carbon dioxide was 23, 16, and 30%, compared to the control. Most probably, hemp flour, due to its chemical composition, has a smaller amount of simple carbohydrates than wheat flour. Besides, we cannot exclude the negative effect the fat component has on the yeast activity, since by adding hemp flour, we add more fat to the recipe already containing 4.5% of it by weight of the flour component. More than 5% of fat added to dough reduces gas formation in it, because adsorbed films of fat wrap the surface of yeast cells, which inhibits or prevents nutrient

permeability into a cell. We can see in Fig. 3 that in the first 30 minutes, carbon dioxide generation in all the samples was almost the same, except for the sample with 20% of hemp flour added. The graph shows that in this sample, the carbon dioxide level tended to go down till the time point of 90 minutes, after which the fermentation rate was equal to that of other samples containing hemp flour. Besides, there were changes in the physicochemical characteristics of the liquid phase due to the increased viscosity of the dough, which complicated the transport of nutrients and of yeast metabolism products.

The data obtained make it clear that the growth of microorganisms is influenced by the composition of nutrients in the medium, which directly depends on the properties and chemical composition of the water and flour mixture. Their behaviour is determined by the flour type, the amount and the state of carbohydrates, the activity of amylolytic enzymes, the additives and the degree of physical and biochemical transformations of their components during dough fermentation. Differences in the rate and sequence of enzyme induction by a yeast cell leads to non-uniform fermentation of sugars in a semi-finished product, and to a disproportionate increase in the intensity of gas formation.

Besides alcoholic, there are other types of fermentation in wheat dough, which are caused by microflora of raw materials. A type as important is lactic acid fermentation, which increases the acidity of dough. There is information [22] that 25 strains of lactic acid bacteria were isolated from hemp flour and then used in the spontaneous fermentation starter technology. So, it can be assumed that adding hemp flour will contribute to an increase in the number of lactic acid bacteria in a dough system.

Lactic acid bacteria are more demanding of nutrients than baker's yeast is: to grow, they require almost all amino acids, purines, pyrimidines, vitamins. They can use mono- and disaccharides, organic acids [14]. At the end of fermentation, in the samples with hemp flour, the acidity increased, compared to the control, by 6, 16, and 40%. This is probably due to the presence of biogenic and oligobiogenic elements in the flour, which satisfy the needs of lactic acid bacteria better than baker's yeast does, and because hemp flour has a significant content of amino acids that are necessary for their activity. The highest in the flour is

the content of glutamic acid, arginine, aspartic acid, leucine, alanine, lysine [30]. In the study [26], it was found what effect hemp flour, seeds, and oil additives had on the quality of bread. The results of this research showed that the acidity of the samples with hemp products was higher than that of the control, varying between 1.54 for bread with 8% of hemp oils added and 2.25 for bread with 25% of hemp flour added. Fermented dough should contain the minimum required amount of proteolysis products, sugars to provide the proper colour of the crust, alcoholic and lactic acid fermentation products determining the taste and aroma. However, the acidity is the parameter by which it is determined how ready dough is for the next stage of the process. The research data indicate that dough maturation is more intensified, the more hemp flour is added to the recipe.

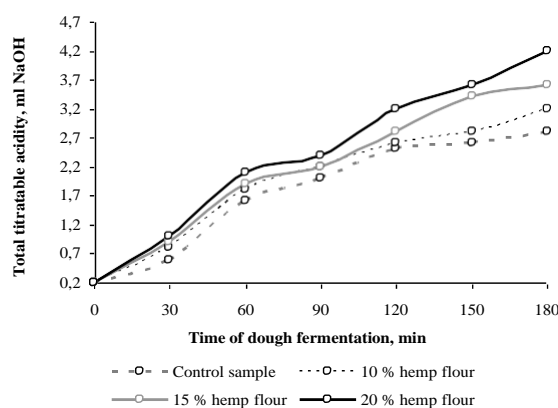


Fig. 4. Influence of the hemp flour percentage on the titratable acidity of dough

The moisture content of all the samples was within the normal range of 8–10% (Table 4), but with an increase in the dosage of hemp flour, the swelling index increased, too. Naturally, the acidity of the products correlated with the obtained data on the intensity of acid accumulation in the dough, and did not exceed the normal value of not more than 6 degrees, according to DSTU 4584:2006 “Bakery products. Breadsticks.”

Reduction of gluten in the dough by the replacement of hemp flour led to formation of fewer gluten matrices, which contributed to a slight (4%) decrease in the hardness of finished products.

Table 4 – Physicochemical characteristics of breadsticks (n=3, P<0.05)

Parameter	Control sample	10% of hemp flour	15% of hemp flour	20% of hemp flour
Moisture content, %	9.1	8.6	8.8	8.4
Titratable acidity, ml NaOH	3.0	3.3	3.3	4.0
Density, kg/m <sup>3</sup>	560	620	640	645
Swelling, %	150	152	160	173
Hardness, N/m <sup>2</sup>	9.0	8.7	8.7	8.6

There was also a slight (by 10, 14, and 16%, compared to the control) decrease in the density, which indirectly characterises the porosity of products. This, too, naturally results from a decrease in gluten proteins in the dough. However, no significant effect of the hemp flour dosage on the physicochemical quality characteristics of breadsticks has been established. According to the report [17] about how the bread quality depends on 15% of extruded and non-extruded hemp/rice flour, with different hemp/rice ratios, added to wheat flour, it has been found that adding hemp increases the specific volume of bread and decreases its hardness during storage.

When evaluating the sensory characteristics of products, attention is paid to the organoleptic parameters and to how typical they are of a given species or variety. The profile chart drawn on the basis of a 10-point rating scale is presented in Fig. 5. It indicates that the tastes of the control and the test samples differed.

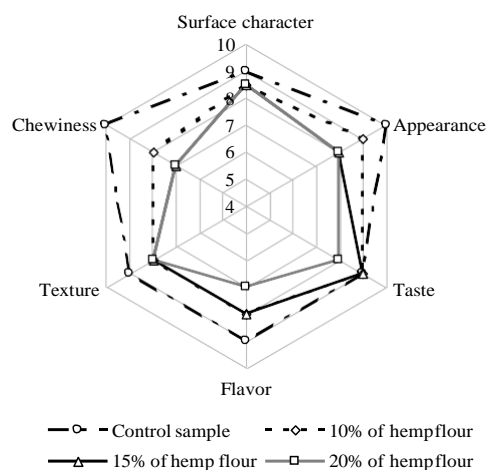


Fig. 5. Sensory evaluation of the breadsticks

Adding hemp flour instead of wheat flour leads to changes in the flavour: the product starts tasting grassy. This off-flavour was faintly noticeable in the sample with 15% of hemp flour, and slightly more pronounced in the sample with 20% of hemp flour. In general, all samples were rated high by experts. The taste of the sample with 20% of hemp flour was rated the lowest (7 points), but even this result is satisfactory. It has been found that increasing the dosage of hemp flour slightly reduces the sensory characteristics of breadsticks. Nevertheless, A. Mikulec *et al.* [19] found that addition

of hemp flour to a bread formula changed the textural features of the bread, and the proportion of hemp flour for industrial bread production should not exceed 30%.

### Conclusion

It has been studied what effect hemp flour, in the amount of 10, 15, 20% of the total flour weight in the breadstick formula, has on the technological properties of wheat dough. In this aspect, the microbiological processes in the dough, its ability to retain its shape, and the quality of finished products have been assessed.

It has been found that the water absorption of the mixture with an increasing level of hemp flour is higher by 3, 6, and 13%, compared to the control. This dependency can have a positive effect on dough. The proper degree of binding of the absorbed moisture can increase the storability of breadsticks, so this technological effect requires further study.

It has been established that addition of hemp flour to the recipes of low-moisture wheat bakery products intensifies accumulation of acids in the dough and thus has a positive effect on dough maturation. At the same time, the intensity of alcoholic fermentation is slightly reduced, as evidenced by the 23%, 16%, and 30% decrease in the carbon dioxide production during the period of bulk dough fermentation. Besides, the study has shown that adding hemp flour leads to lower shape stability of dough: with higher doses of hemp flour, the dough ball slackening increased by 6.1, 7.4, and 11%. However, in general, all these findings did not affect the results of evaluating the finished products' sensory characteristics, (such as *Texture* and *Appearance*), which directly determined them. Thus, by all parameters, the quality breadsticks made with the addition of hemp flour met the national requirements. So, it has been shown that hemp flour, in the amount of up to 15% by weight of the total flour, can be used in the formulation without significant changes in the rheological characteristics of dough. Adding 20% of hemp flour to the recipe of breadsticks is possible, too, but only with certain additional technological measures aimed at improving the rheological properties of the dough. Besides, the patterns established in the biochemical processes in dough make it clear that further studies should consider using sourdough and rye flour, and reducing the amount of fat in the recipe.

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## **ПОТЕНЦІАЛ БОРОШНА З КОНОПЛЯНОГО ШРОТУ ЯК РЕЦЕПТУРНОГО ІНГРЕДІЄНТА ХЛІБОБУЛОЧНИХ ВИРОБІВ ЗНИЖЕНОЇ ВОЛОГОСТІ**

**К.Г. Іоргачова**, доктор технічних наук, професор, *E-mail: iorgachova@gmail.com*  
**Н.Ю. Соколова**, кандидат технічних наук, доцент, *E-mail: techinstoffood@gmail.com*

Кафедра технології хліба, кондитерських, макаронних виробів і харчоконцентратів  
Одеська національна академія харчових технологій, вул. Канатна, 112, м. Одеса, Україна, 65039

**Анотація.** Стаття присвячена вирішенню питання підвищення харчової цінності традиційних пшеничних хлібобулочних виробів зниженої вологості з пшеничного борошна шляхом використання борошна зі шроту технічних конопель. Розглянуто питання забезпечення сировинної бази у разі широкого запровадження застосування цієї сировини та продуктів її переробки у харчовій промисловості. Наведено інформацію щодо основних тенденцій вирощування та використання конопель як в Україні так і світі, проаналізовано та охарактеризовано хімічний склад їхнього насіння, як основної частини рослини, яка використовується у продуктах харчування, розкрито питання застосування продуктів їхньої переробки у технології хлібобулочних виробів. Досліджено можливість застосування

борошна з конопляного шроту у технології хлібобулочних виробів зниженої вологості, таких як, хлібні палички. Встановлено, що додавання конопляного борошна у кількості 10, 15 та 20% до пшеничного борошна збільшує водопоглинальну здатність такої борошняної суміші у порівнянні з контролем на 3%, 6% та 13% відповідно. Додавання ж конопляного борошна у рецептуру тіста для хлібних паличок приводить до збільшення показника розливання кульки тіста на 6.1%, 7.4%, 11%. Разом з цим встановлено, що зміна частини борошняного компоненту на конопляне борошно, як складової рецептури, а значить живильного середовища для дріжджових клітин і молочнокислих бактерій призводить до зменшення кількості утворення вуглекислого газу за період бродіння тіста протягом 180 хв на 23%, 16%, 30%. При цьому помічено збільшення титрованої кислотності у дослідних зразках на 6%, 16% та 40%, що пояснюється вмістом у борошні біогенних елементів, які краще забезпечують протікання метаболічних процесів молочнокислих бактерій ніж хлібопекарських дріжджів. Оцінка якості готових виробів як за органолептичними, так і фізико-хімічними показниками показала перспективність використання конопляного борошна у технології хлібних паличок в кількості 15% до маси борошняних інгредієнтів в рецептурі, вона може бути збільшена лише за умови зміни параметрів технологічного процесу, що дозволять покращити реологічні характеристики та показники якості готових виробів.

**Ключові слова:** конопляне борошно, технологічні властивості, хлібні палички, якість.

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