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Research Article

Possibilities of usage of oilcakes from non-traditional oil plants for development of health-friendly functional food products

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Abstract

The research studies have shown that the nutrition of Lithuanian population is not healthy. The objective of this study was to investigate the possibilities of usage of oilcakes from non-conventional oil plants for the development of new food products in the bakery industry and estimation of their quality and nutritional properties. For this purpose the standard methods were used to determine and compare the nutritional value of non-traditional oilseed cakes and the possibilities of their use for development of new confectionery products were analyzed. During experimental tests, the bread samples were developed and made enriched with 2.5%, 5% chia (*Salvia hispanica L.)* oilcake flour and also the donuts were enriched with 2 to 8% citrus fibers Citri – Fi and with 8% chia oilcake flour. The physico-chemical quality, organoleptic properties of oilcakes and new products were determined by standard methods. Nutritional value of new breads was calculated using Excel program. It was found that oilcakes from non-traditional oilseeds contain up to 50% protein and up to 35% fiber. Chia oilcake is rich in omega-3 fatty acids. Laboratory tests showed that the bread with 2.5% chia oilcake addition was distinguished by the best technological and organoleptic characteristics. The use of chia oilcake in the production of yeast donuts reduced the loss of fritting fat and the amount of fat in the donuts was lower by about 40% than the amount of fat in the control sample. Chia oilcakes have the same technological properties as citrus fibers Citri-Fi. Practical applications: By including chia (*Salvia hispanica L.)* oilcake flour in breads or donuts as determined by the experimental design, it was possible to increase the levels of polyunsaturated fat, mainly u-3 fatty acid, in addition to increasing the level of fiber, yielding products with the features of functional foods. Laboratory tests showed that the bread with 2.5% chia oilcake addition was distinguished by the best technological and organoleptic characteristics. The use of chia oilcake in the production of yeast donuts reduced the fat absorption and the loss of fritting fat.

Keywords: oilcake, functional food product, fiber, chia

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Introduction

According to the World Health Organization, our health depends to a large extent on lifestyle and nutrition. Research has shown that nutrition of the Lithuanian population is favorable for the emergence of chronic diseases and needs to be changed. The lack of fiber and vegetable protein, excessive saturated fats in the diet of the Lithuanian population is a particularly acute problem. In order to improve the health of the population of Lithuania, it is relevant to develop, promote and sell functional food rich in biologically active substances. By assessing the stable trend towards reducing the consumption of animal origin protein, the protein products derived from the processing of raw materials of vegetables become the promising ingredients for the production of functional foods. One of such raw materials could be oil-based by-products - oilcakes of non-traditional oilseeds. Non-traditional raw materials, such as hemp, sesame, amaranth, chia, etc., are rarely considered as a potential for plant proteins and fibers in the food industry. Seeds and nutrition of most non-traditional oil-bearing crops are most often used as valuable raw materials for the production of feed products or isolates and protein concentrates, and the main source of vegetable origin protein is soybean and its products. Oilcakes of non-traditional oil cultures are unlikely to be used extensively due to the lack of research on their potential use in the food industry. One of the areas for the use of oilcakes is the bread and confectionery industry. In order to meet the needs of consumers for healthy flour foods, the recipes of these products are supplemented with fiber, various seeds and flour of them. *Salvia hispanica L.*, commonly known as chia, is an ancient food that provides a balanced amount of nutrients composed of insoluble fiber, high 3/-ω -6 fatty acids, proteins with an excellent quality of amino acids, high content of antioxidants, and minerals. Nutritionists, researchers, and industry have paid attention to chia for its outstanding benefits. According to Orona-Tamayo et al. (2017) chia is now recognized as a "seed for the first 21st century" that confers invaluable nutraceutical benefits such as antihypertensive and antioxidant functions. The seed compounds may be improved and modified by genome edition technologies to obtain better nutraceutical attributes for health and food industry. Chia can be crowned as the new golden and super seed with excellent benefits for human health. Therapeutic effects of chia in the control of diabetes, dyslipidaemia, hypertension, as anti-inflammatory, antioxidant, anti-blood clotting, laxative, antidepressant, antianxiety, analgesic, vision and immune improver is scientifically established (Ullah et al. 2015). Chia seed meal is a rich source of bioactive phenolics. Chia phenolics inhibited lipase and α-glucosidase activity in vitro. Chia phenolics prevented human LDL-cholesterol oxidation and DNA damage in vitro (Rahman et al. 2017). Main phenolic compounds present in chia are important dietary sources of natural antioxidants for prevention of diseases caused by oxidative stress. The total phenolic content from chia seeds and fiber flour extracts were similar (Oliveira-Alves et al. 2017). Chia is considered to be a food with functional properties that can be added into bakery products. It was possible to develop breads containing chia and reduced hydrogenated vegetable fat. The technological quality was affected by the addition of chia to the formulations (Coelho et al. 2015). According to EFSA (2005), EFSA (2009) and EC (2013), the use of chia seeds and ground whole chia seeds in bread products at a maximum of 5%, and in baked products at a maximum of 10% chia seeds would have an adverse effect on public health. Chia and teff are as improvers of wheat-barley dough and cookies (Švec et al. Wheat flours with three different degrees of substitution (5%, 10% and 15%) were tested. Bread presented reduced water activity, and contained the same amount of moisture compared with the control. The mucilage provided by chia has properties that can explain these observed effects given the influence on water-holding capacity and its interactions with gluten proteins throughout the gluten matrix-forming process (Verdu et al. 2015). Pre-hydration of chia flour increased bread volume and reduced hardness. Chia flour breads had higher specific volume than chia seed breads. Pre-hydration of chia flour increased bread overall acceptability (Steffolani et al. 2017). Chia seeds contain 30-35% of the oil. Chia oil is mainly composed of triglycerides, in which polyunsaturated fatty acids are found in high amounts. Although it seems evident that such fatty acid composition is favorable from a nutritional point of view, a higher content of linoleic and linolenic acids results in poorer oxidative stability and shorter shelf life of the oil (Bodoira et al. 2017). Lipid oxidation, particularly polymerization compounds, was accelerated in chia-enriched biscuits, which decreased the shelf-life of the product by promoting a rapid rancidity under accelerated storage conditions. Therefore, although nutritional properties are improved by the incorporation of chia into the biscuits, the increase in the content of process contaminants and the extent of the lipid oxidation should be carefully considered in a context of risk/benefit (Mesías et al. 2016). The *Salvia hispanica L.* fat oxidation is likely to be reduced in the bread and confectionery industry using chia oilcake powder - low fat chia mehl. The objective of this study was to investigate the possibilities of usage of

2017). According to Verdu et al. (2017), chia improved bread-making process of dough without affecting bread sensory attributes.

oilcakes from non- conventional oil plants for the development of new food products in the bakery industry and estimation of their quality and nutritional properties.

Materials and Methods

Materials

Raw materials and ingredients. The experiments were based on the use of flour of *Salvia hispanica L.* grown in Paraguay. The chia oilcake specification is given in Table 1. The raw material, wheat flour 550 D (13.5% moisture, 1.3% fat, 74.2% total carbohydrates, 3.1% fiber, 10.7% protein), rye flour (13.5% moisture, 1.3% fat, 75.70% total carbohydrates, 8.4% fiber, 7.1% protein) used for the preparation of bread and donuts were bought from Malsena JSC (Lithuania). Some of the ingredients that were used for the production of the breads and donuts, such as caraway, honey, butter, eggs, sunflower oil, sodium chloride, sugar and yeast, were purchased in local shops. CITRI-FI®100 FG (producer Fiberstar Inc., USA) are the all natural citrus fiber products, made from orange pulp by physical processing. The composition of citrus fiber is 6.38% moisture, 7.53% protein, 1.08% fat, 82.55% total carbohydrates, 75.3% total dietary fiber (35.7% of that is insoluble fiber), 2.46% ash. Citrus fiber is neutral in terms of flavor, aroma and color, is nonallergenic.

Chemicals and reagents. Sulphuric acid, sodium hydroxide, sodium sulfate, Kjeltabs, petroleum ether and other reagents and chemicals were supplied by Merck KGaA (Darmstadt, Germany). All chemicals, solvents and reagents were of analytical grade.

Analysis

Determination of moisture. Oilcake and bakery products moisture content, expressed as percentage by mass, was determined using 5 g of oilcakes by adapting the AOAC method 934.06 (AOAC 2013).

Table 1. Comparison of oilcake and flour quality parameters

Oilcake/ flour name	Test parameter (g / 100 g product)					
	Moisture content	Protein	Fat	Carbohydrate	Crude fiber	Ash
Wheat flour 550D	13.50±0.80	10.70±0.75	1.30±0.10	74.20±0.80	3.10±0.20	0.50±0.05
Rye flour	13.50±0.70	7.10±0.20	1.30±0.10	75.70±0.85	8.40±0.24	0.80±0.1
Hazelnut oilcake	8.10±0.35	35.70±0.80	23.40±0.40	27.50±0.70	Not tested	5.30±0.20
Almond oilcake	5.80±0.20	51.30±0.90	19.0±0.50	18.80±0.60	Not tested	5.30±0.20
Walnut oilcake	8.20±0.40	50.40±0.85	15.90±0.40	20.60±0.65	Not tested	4.90±0.15
Safflower oilcake	6.80±0.20	23.25±0.50	9.14±0.20	55.71±0.70	34.41±0.40	5.10±0.20
Hemp oilcake	8.11±0.35	31.51±0.60	8.54±0.20	48.54±0.80	31.41±0.50	3.30±0.15
Chia oilcake	6.8±0.25	28.20±0.65	9.52±0.30	50.9±0.65	30.46±0.45	4.58±0.10
Thistle oilcake	7.49±0.30	21.31±0.40	7.66±0.24	58.94±0.60	30.11±0.50	4.60±0.20
Pumpkin shelled oilcake	6.77±0.40	54.6±0.90	14.77±0.35	19.73±0.40	3.89±0.10	4.20±0.20
Black sesame oilcake	5.59±0.20	47.15±0.55	27.04±0.60	18.82±0.45	4.62±0.20	1.40±0.10
Peanut oilcake	4.57±0.25	46.68±0.60	22.59±0.60	24.66±0.50	4.33±0.15	1.5±0.10

A Jouan Quality Systems oven regulated at 105^0C was used. The difference between the results of two last determinations was 0.1 g of moisture per 100 g of sample.

Determination of nutrition composition.

Nutritional composition of the chia oilcake was determined using the recommended methods of the association of official analytical chemists AOAC (2005). Ash content was determined by incinerating 5 g of oilcake at 550°C in a muffle furnace. Crude protein content was calculated from the nitrogen content measured by the Kjeldahl procedure AOAC (2002). Total fat content was determined by Soxhlet extraction (Soxtec System HT6, Tecator AB, Sweden), according to the AOAC (2005) method using petroleum ether. The results were expressed as g lipid 100 g^{-1} sample. Crude fiber was determined according to the gravimetric procedure on defatted samples. The difference between dry weight and ash content of the residue was taken as an estimation of the crude fiber content (AOAC 2005). All analyses were performed in triplicate.

Total carbohydrate content was obtained by difference between 1000 and the sum of total ash, crude fat and total protein.

Physical chemical investigation of bread.

pH was measured by pH-meter ORION 3STAR. Bread and donuts crumb moisture content was determined by drying of a crushed sample at 130±2°C (LST 1492:2013 Bakery goods – Methods for determination of moisture content). Total titratable acidity expressed as the amount of NaOH (ml) consumed for the neutralization of free acids per 100g of bread sample (LST 1553:1998 Bakery goods and confectionery. Methods for determination of acidity and alkalinity). Loaf volume was measured by rapeseed displacement method, cm^3, of the standard ICC 131:1995. Specific volume was calculated as loaf volume to weight ratio, cm^3 g^{-1}, of the standard ICC 131:1995. The bread porosity index was determined by using the Zuravliov equipment according to the standard LST 1442:1996.

Sensory evaluation. The sensory analysis was conducted in a Sensory laboratory at Klaipeda State University of Applied Sciences, Lithuania. A quantitative descriptive analysis was performed for assessing the sensory characteristics of bread and donuts. The sensory analysis was preceded by four training sessions at which a panel of 6 assessors was trained to identify and evaluate sensory characteristics of the products. They were also trained in the use of 5-point scale. Breads and donuts were evaluated for color of the crust, taste, aroma, appearance of crust, texture and overall acceptability, with the score 1-5, where 1 represented extremely disliked and 5 extremely liked. Each assessor was provided with one bun on a paper plate which was coded with a 3 digit random number for the evaluation. Sample evaluations were performed for 24 h after baking at room temperature under normal lightening conditions. All samples were assessed in random order in two replicates. The data collection was done by using a computer system and analyzed statistically.

Nutrition and energy value calculation method – nutritional and energy values of bread and donuts were calculated using a specific Excel spreadsheet.

Statistical analysis. The bread and donuts baking experiments were repeated twice. Mathematical statistical data analysis was performed using SPSS 17.0. P-values less than 0.05 were interpreted as statistically significant.

Sample preparations. Semi-wheat bread and yeast donuts samples were prepared in Laboratory for Food Technologies at Klaipeda State University of Applied Sciences in accordance with the leavened bread and donuts production technology. The bread samples were prepared according to the recipe given in Table 2.

Table 2. Recipes of bread samples

Sample	C	CH2.5	CH5.0
	g	g	g
Rye flour	225.0	219.0	214.0
Wheat flour 550D	225.0	218.7	213.5
Chia oilcake	-	11.3	22.5
Honey	100.0	100.0	100.0
Salt	10.0	10.0	10.0
Caraway	10	10	10
Water	*	*	*

When activating yeast, obtained mass of bread samples was mixed in a mixer "Kitchen Aid" (Germany) for 20 min, the dough was leavened in a thermostat at 32-34°C temperature for 120 minutes. Then the dough was divided (mass of dough – 900 g), put up in forms, then leavened once more for 30 minutes at 32-34°C and baked in an oven "Metos Chef" at 240°C for 40 min. Baked goods were stored for 60 min, then placed in plastic bags and stored for 24 h at room temperature (18-20°C). Yeast donuts samples were prepared using citrus fibers and chia oilcakes instead of the flour Citri - Fi 100. The donuts recipe is given in Table 3.

Table 3. Recipes of yeast donuts

Sample	C	CF2	CF4	CF6	CF8	CH8
	g	g	g	g	g	g
Wheat flour 550D	222	217.6	213	208.8	204.4	204.4
Citrus fiber	-	4.4	9	13.2	17.6	-
Chia oilcake	-	-	-	-	-	17.6
Water	100	135	150	160	180	150
Yeast	2	2	2	2	2	2
Butter	22	22	22	22	22	22
Eggs	40	40	40	40	40	40
Sugar	30	30	30	30	30	30
Salt	0.02	0.02	0.02	0.02	0.02	0.02

All ingredients of yeast donuts were mixed in a mixer "Kitchen Aid" (Germany) for 5 min, the dough was leavened in a thermostat at 32-34°C temperature for 120 min. Then the donuts were baked in sunflower oil. The yeast donuts were baked at 160-180°C submerged in sunflower oil. When testing each functional supplement, sunflower oil was weighed before baking and after baking. Baked donuts were placed on paper towels to absorb excess fat.

Results and Discussion

Studies on the nutritiousness of non-traditional oilseeds. In order to evaluate the possibilities of using non-traditional oil cultures in the confectionery industry, the chemical composition of oilcakes was compared with the highest quality wheat and rye flour indicators (Table1). Non-traditional oilcake meal has a distinct smell and taste, is technologically adaptable, because its fineness and particle size are equivalent to wheat flour. The analysis of the results of laboratory tests presented in Table 1 showed that non-traditional oil cultures have a high nutritional value. The protein content of various oilseed cakes ranges from 21.31% to 54.6%, depending on the type of processed raw materials. The minimum value of this indicator of the following types of oilcakes - safflower oilcake, chia oilcake, thistle oilcake - is less than 30%. The amount of fat in the tested oilcakes varies from 7.7% to 27.04%. The residual fat content of the oilcakes is determined by seed moisture content and the specifics of the oil pressure technology (Martínez et al 2012). The highest amount of fat in the investigated oilcakes is found in sesame oilcake. The amount of fat in the oilcakes directly determines their technological properties (dryness, degree of rancidity). Oilcake with amount of fat greater than 25% starts to turn into pasty mass when crushing, and does not mix well with other components. When compared with flour, investigated oilcakes have more protein and oil, this is not detected in wheat and rye flour. Functional properties of one of the main proteins are the properties of water absorption, fat retention, fat emulsion and foaming. Water absorption is the protein's ability to absorb and retain water due to hydroxyl groups. The water absorption characterizes the properties of the protein product to firmly bind free moisture during the technological process of the food product. This feature allows to predict the amount of protein products in the recipe, ensuring the necessary water retention and rheological properties of the product, its consistency, increase of output and loss reduction, reduction of defects during technological treatment. Fat retaining properties describe protein's ability to absorb and retain fat. The surface of the protein molecule contains hydrophilic and hydrophobic groups. The protein molecule is characterized by its ability to retain fat molecules due to the formation of hydrophobic bonds. Protein molecules that have a porous structure bind and retain fat. Fibers are one of the major macro components of the tested oilcakes. For some types of oilseeds, the husk or shell is removed before pressure and therefore they have a relatively low amount of fiber. Other oilseeds are put in a press, without breaking the shell. In this case, the oilcake comes in a darker color and has a higher fiber content. Recently, fibers are considered as one of the most important ingredients in functional foods, and therefore non-traditional oil cultures with high fiber content can be used as a source of insoluble dietary fiber for the development of novel foods. Nutrient fibers in many cases have water binding ability, are soluble, heat-resistant, frost – resistant, acid-resistant, and as a functional supplement, nutritional fibers are suitable for production of both liquid and solid foods. We have chosen the chia oilcake for studies. The choice of chia oilcake is determined by several factors: the oilcake contains a lot of protein, fiber and oil, which is a source of ω-3 polyunsaturated fatty acids. The main constituent in the chia oil is ω-3 α-linolenic fatty acid, and ranged from 64.8% to 56.9% (Ayerza et al 2011; EC 2014). It is likely that the use of chia oilcake will lead to changes in the nutritional status of newly developed confectionery products.

The use of chia oilcake in the production of bread with increased biological value. The quality of baked bread depends on the level of moisture content, volume, crumb grain quality, and the texture of the bread. It was found that upon increasing the chia oilcake content the moisture content of the product decreased slightly (Table 4). The lower content of moisture in bread is likely to be due to higher fiber content and protein content in oilcake. These materials bind water, which reduces the amount of free water in the product. After analysis of the data in Table 4, we observed that the maximum acidity was in the control bread (5.6°N) and the lowest - in bread containing 5% of *Salvia hispanica L.* oilcake (5.1°N). Chia oilcakes increased the porosity and specific volume of bread (Table 4).

Table 4. Characteristics of bread samples

Sample	Moisture content	Total titratable acidity	Crumb porosity	Specific volume
	%	° N	%	$cm^3\ g^{-1}$
C	40.28±0.80	5.6±0.16	48±0.39	1.75±0.11
CH 2.5	38.21±0.90	5.4±0.14	50±0.54	1.82±0.06
CH 5.0	34.46±0.68	5.1±0.10	51±0.51	1.96±0.08

The mean score values of color, taste, texture and overall acceptability for control and chia oilcake fortified breads are presented in Fig. 1. When comparing the bread sample profiles, the differences in taste and aroma were distinguished compared with the control sample. The tasters best appreciated the bread containing 2.5% of chia oilcake. The sensory analysis confirmed the results of physicochemical indices. Bread with 2.5% of chia oilcake is characterized by a regular, symmetrical shape; an evenly brown color of the crust, uniform porosity, elastic flesh, a pleasant taste and a scent characteristic of this flourproduct.

The enrichment of bread with chia oilcake flour from 2.5 to 5% of the flour weight affected its physical chemical characteristics. The best quality indicators were determined in bread with 2.5% of chia oilcake. In order to assess bread nutritional value and protein and fat content increase, nutritional and energy values were calculated using the recipe and product composition database. As the results showed, the 2.5% chia oilcake supplement increased content of fiber by 6%, fat - by 6.5% and protein content by 3.5% in functional bread samples. The caloric content (192 kcal.100 g^{-1}) of the bread was almost unchanged.

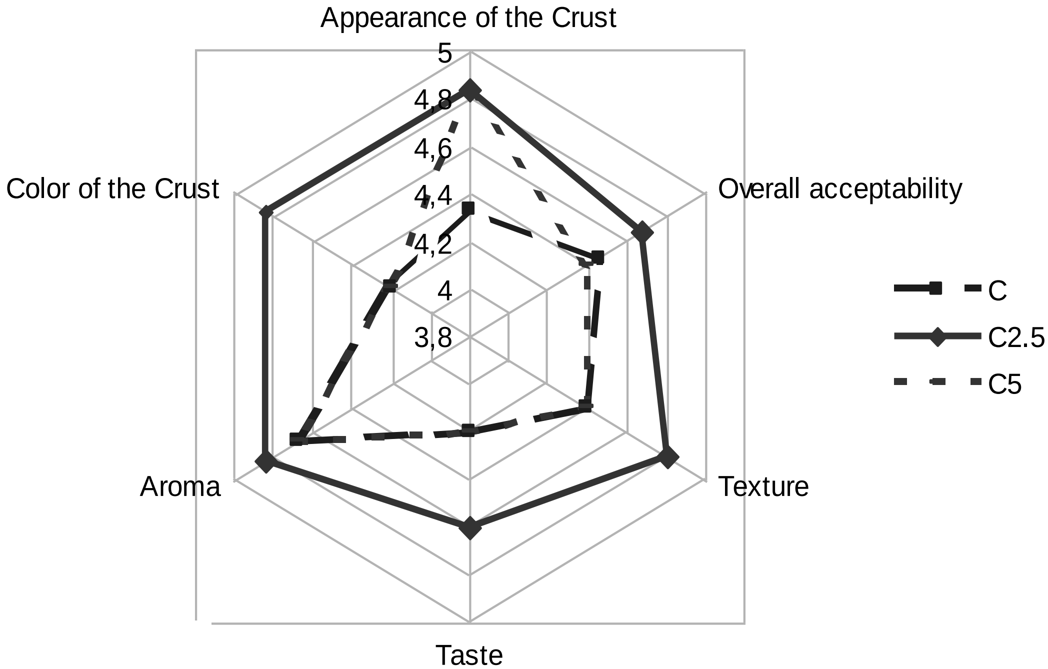

Figure 1. Sensory evaluation of the bread samples
C – control, CH 2.5 – 2.5 % chia oilcake, CH5 – 5 % chia oilcake

The use of chia oilcake to reduce fat absorption.

Chia oilcake contains over 30% fiber and up to 20% protein, also about 10% fat (Table 1). These substances are likely to affect water absorption and fat intake in confectionery products. To assess the effect of chia oilcake on moisture and fat content in confectionery products during frying, technological experiments with donuts containing chia oilcakes and citrus fibers were conducted. The citrus fibers Citri-Fi 100, which contain almost no fat and protein, were selected for comparison. The fiber content is relatively high - 75.2%. Analyzing the data in Table 5, it can be stated that free water is mainly found in yeast donuts containing *Salvia hispanica L.* oilcake (40%) and in control samples (37.77%). Probably because of the higher fiber content in samples with Citri-Fi, coagulation of water is higher, and the moisture content in the donuts is lower. Using Citri-Fi fibers, in each test the fat loss varied depending on the amount of fiber in the dough, and the moisture content of the products decreased. The loss of baking oil is the smallest when baking donuts with 8% of Citri Fi 100 fiber and donuts with 8% of *Salvia hispanica L.* oilcake. In order to compare the ability of citrus fiber and chia oilcake to absorb fat, we have conducted laboratory analyzes of fat content in the control sample and in samples with Citri Fi 100 fibers and 8% of *Salvia hispanica L.* oilcake. It is determined a significant ($p<0.05$)

increase in the loss of baking oil and an increase in fat content in donuts. Studies have shown (Table 5) that the fat content in control donuts is higher than in donuts fortified with Citri-Fi fibers and *Salvia hispanica L.* oilcake.

Table 5. Characteristics of yeast donuts samples

Sample	Moisture content	Fat loss	Fat content
	%	g/500 g. dough	%
C	37.77±0.85	62±1.20	15.6±0.60
CH8	40.50±0.75	45±0.90	9.50±0.85
CF2	25.90±0.60	58±0.95	14.20±0.50
CF4	32.80±0.80	51±0.80	11.50±0.65
CF6	29.70±0.80	49 ± 0.85	9.40±0.45
CF8	15.20±0.75	46±0.90	8.60±0.80

According to the results of the study, the fat content in yeast donuts (in the control sample) amounts to 15.6%, while in the sample with *Salvia hispanica L.* oilcake the amount of fat is 9.5%, and in the sample fortified with Citri-Fi 100 fibers - 8.6%. Citrus fibers did not affect the sensory properties of donuts, but increased their porosity. Organoleptic characteristics of *Salvia hispanica L.* oilcake have slightly changed compared to citrus fibers, only the color, that made the product darker, has changed.

Conclusions

The oilcakes from non-traditional oilseeds contain up to 50% protein and up to 35% fiber. The amount of fat in the oilcake depends on the selected oil pressure technology. Chia oilcake is rich in omega-3 fatty acids. It was found that upon increasing the chia oilcake content the moisture content of the product decreased slightly. Chia oilcakes increased the porosity and specific volume of bread. Laboratory tests showed that the bread with 2.5% chia oilcake addition was distinguished by the best technological and organoleptic characteristics. The use of chia oilcake in the production of yeast donuts reduced the loss of fritting fat and the amount of fat in the donuts was lower by about 40% than the amount of fat in the control sample. Chia oilcakes have the same technological properties as citrus fibers Citri-Fi.

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