UDC 66.075.8
DOI: 10.15587/1729-4061.2023.276429

DEVELOPMENT OF TECHNOLOGY OF CRACKERS WUTH INCREASED FOOD VALUE TO IMPROVE THE FOOD SUPPLY TO MILITARY SERVANTS DURING A SPECIAL PERIOD

Iryna Tsykhanovska
Corresponding author
Doctor of Technical Sciences, Professor*
E-mail: cikhanovskaja@gmail.com
Lidiia Tovma
PhD, Associate Professor
Department of Technical and Rear Support
National Academy of National Guard of Ukraine
Zakhysnykiv Ukrainy sq., 3, Kharkiv, Ukraine, 61001
Victoria Yevlash
Doctor of Technical Sciences, Professor
Deparment of Chemistry, Biochemistry, Microbiology and Food Hygiene
State Biotechnological University
Alchevskykh str., 44, Kharkiv, Ukraine, 61002
Tetiana Lazarieva
Doctor of Pedagogical Sciences, Professor*
Olga Blahyi
PhD, Associate Professor*
Alexandr Alexandrov
PhD, Associate Professor*
Mykola Riabchykov
Doctor of Technical Sciences, Professor
Department of Light Industry Technologies
Lutsk National Technical University
Lvivska str., 75, Lutsk, Ukraine, 43018
Karyna Svidlo
Doctor of Technical Sciences, Professor
Department of Tourism and Hospitality Management
O. M. Beketov National University of Urban Economy in Kharkiv
Marshala Bazhanova str., 17, Kharkiv, Ukraine, 61002
Natalia Korolyova
Senior Lecturer
Department of Physical Education
Educational Institute of Pedagogy, Psychology, Management of adults**
Tatyana Gontar
PhD, Associate Professor
Department of Restaurant, Hotel and Tourism Business**
*Department of Food Technology, Light Industry and Design**
**Ukrainian Engineering Pedagogics Academy
Universitetska str., 16, Kharkiv, Ukraine, 61003

Flour confectionery products have an unstable polyphase structure that needs stabilization. The nutrient composition of these products is characterized by a high content of sugar and saturated fatty acids. The content of protein, dietary fiber, vitamins, and minerals is low. This predetermines the feasibility of using the latest raw materials. This paper has proven the possibility of using flour from extruded sunflower seed kernels (FESSK). FESSK is a unique protein-mineral raw material ingredient that contains essential amino and polyunsaturated fatty acids, as well as biologically active substances.

In FESSK, compared to high grade wheat flour (HGWF), the content of protein increases by 3.1–3.3 times; minerals – 13.80–13.82 times; fiber – 98.91–98.93 times; fat – 2.54–2.56 times; the total amount of essential amino acids – by 3.15–3.19 times. One should note the balance of amino acid composition and the usefulness of FESSK proteins (amino acid number (AAN) of essential amino acids approaches 100 %). Compared to HGWF, FESSK has increased biological value index and utilization rate of amino acid composition, by 48.74 % and 39.29 %, respectively. Of the 13 vitamins necessary for the human body, 12 vitamins (92.3 % of the total amount of vitamins) were identified as part of the FESSK composition. In FESSK, compared to HGWF, fat-absorbing capacity increases by 1.50–1.52 times and water retention capacity by 3.62–3.64 times.

It was found that the addition of 10.0 % FESSK increases wettability by 6.58–11.19 %; expansion rate by (1,0±0,1) %; ash content – 5.71–13.33 times; fat content by 2,19–6,17 %; protein content by 8.29–21.37 %. The integrated quality indicator increases by 5.1–6.8 %. Alkalinity decreases by 1.04–2.06 %. The expediency of the production of crackers with improved nutritional properties to improve the food supply of servicemen in a special period has been proven

Keywords: flour from extruded sunflower seed kernels, crackers, nutritional properties, food supply for military personnel

Received date 12.01.2023
Accepted date 13.03.2023
Published date 28.04.2023

***How to Cite**: Tsykhanovska, I., Tovma, L., Yevlash, V., Lazarieva, T., Blahyi, O., Alexandrov, A., Riabchykov, M., Svidlo, K., Korolyova, N., Gontar, T. (2023). Development of technology of crackers wuth increased food value to improve the food supply to military servants during a special period. Eastern-European Journal of Enterprise Technologies, 2 (11 (122)), 24–37. doi: https://doi.org/10.15587/1729-4061.2023.276429*

1. Introduction

An important issue of food supply for troops is the adjustment of the diets of military personnel through the use of protein-vitamin-mineral food components. They are functional ingredients in the composition of food products, and, above all, those made from flour: bakery and flour confectionery products (cookies, crackers, gingerbread, etc.). The top priority is to increase the nutritional and biological value of the daily rations of military personnel and their balance in terms of nutrient composition. This is possible by creating innovative food products with improved nutritional properties containing functional ingredients: proteins, fats, carbohydrates in an optimal ratio for the body. The latest food products should be rich in vitamins, antioxidants, macro- and microelements. The food products to be developed should have a convenient packaging form and an extended period of freshness. This is important because under extreme conditions of hostilities there is not always the possibility of timely supply of food and, especially, perishable products.

Hence, the relevant direction of improving the quality of food supply for personnel is:

– introduction of innovative technologies in the process of food production, in particular flour [1];

– study of the experience of the armies of the countries belonging to the NATO bloc (their rations include flour products: cookies, muffins, biscuits, crackers, etc., which have an extended shelf life and high nutritional and biological value) [2];

– the use of the latest raw materials of integrated action, which are characterized by a wide range of functional and technological properties that contribute to the solution of this problem in areas of conflict [3];

– extending the range of high-quality and socially significant food products for the military of Ukraine for consumption under extreme conditions [2, 3].

Innovative resource-saving technologies imply using the maximum benefit from food components, including useful secondary products of the agro-industrial sector. In particular, the use of bioactive compounds, mineral-vitamin complex, dietary fiber, etc. by-products [4]. It is possible to recirculate secondary products of sunflower seed processing as raw materials in the process of production of functional food products with added value. The result is the introduction of the concept of "waste-food" into production [5].

Secondary resources of the oil and fat industry are widely used in solving food problems, being an additional source of substances of natural origin. A significant amount of secondary food raw materials (sunflower cake/meal/flour) is formed in the process of processing sunflower seeds – the main oilseed in Ukraine. The most valuable properties of secondary products of sunflower seed processing are the high content of protein and mineral-vitamin complex, the presence of polyunsaturated fatty acids, low cost, and the absence of toxic and anti-nutrients in them (protease inhibitors – trypsin and chymotrypsin, hemagglutinins, saponins, glycosides, allergens, alkaloids). Therefore, it can be concluded that sunflower cake/meal/flour are good sources of nutrients and can be used in food technology [6, 7].

A relevant direction in the production of crackers is the use of new types of raw materials. In particular, secondary products of sunflower seed processing – FESSK. FESSK is obtained with the help of innovative integrated technology – extrusion of the collapsed kernel of sunflower seeds at elevated temperatures, followed by fractional grinding [8, 9]. The most valuable properties of FESSK are the high protein content (~39.0 %) as well as essential amino and polyunsaturated fatty acids. A significant amount of antioxidants: vitamin E – 15.4 mg % and chlorogenic acid – 0.321 % [7, 10].

At the same time, a low content of phenolic compounds in FESSK [7] provides its light color [8], which indicates the possibility of introducing FESSK into flour confectionery products without deteriorating the coloration of the finished product. All this makes FESSK a promising secondary product with a integrated effect that can be used in food production [7, 8, 11].

In this regard, it is relevant to prove the expediency of using FESSK in the technologies of flour confectionery products on the example of crackers with improved nutritional properties.

2. Literature review and problem statement

In the production of flour confectionery products in the context of the circular bioeconomy, there is a growing interest in the use of inexpensive secondary products of processing plant materials for partial replacement of flour, fat, or sugar. Works [6, 11] report the results of research into the use of such raw materials in the production of environmentally friendly products with high nutritional properties, extended periods of freshness and added value. But the issues related to the study of the functional and technological properties of these raw materials remained unresolved. And above all, such promising by-products of processing sunflower seeds as cake/meal/flour because they are valuable food ingredients with a rich nutrient composition [12, 13]. However, water- and fat-absorbing, water- and fat-binding, water- and fat-retaining capacities have not been sufficiently investigated because of objective difficulties associated with the cost part in terms of equipment and research tools. In [14], the rich chemical composition of sunflower seeds – the main raw material for cake/meal/flour – has been established. But issues related to functional and technological properties remained unresolved. The reason for this may be objective difficulties associated with the complexity of the technology of production of secondary products of processing sunflower seeds with the necessary functional and technological characteristics. This will help improve the nutritional properties of food products, in particular flour confectionery. In works [15, 16] it is noted that secondary products of processing sunflower seeds (in addition to enrichment of food products with protein, vitamin-mineral complex, fiber, etc.) are also an alternative to reduce the environmental problem caused by the production of sunflower oil. However, issues related to hydro- and lipophilic properties require additional research. In [8, 9], it has been shown that the use of sunflower meal/cake/flour benefits by its small particle size and high protein content compared to fruit processing by-products. The disadvantage is the lack of integrated effect. Works [9, 17] emphasize a higher rate of antioxidant activity of sunflower flour compared to wheat flour. However, the issues of fat-emulsifying, stabilizing and structure-forming capacity have not been resolved. In [18], it was found that the addition of 10.0 % sunflower meal improves the organoleptic characteristics of shortbread cookies; as well as increases digestible protein content, water-absorbing and foaming capacity of sunflower-wheat mixture. The disadvantage of this raw material ingredient is the greenish-brown color of the finished products. Paper [19] notes a positive effect of partial replacement (15.0 %; 25.0 %; 35.0 %) of wheat flour with sunflower flour in the recipe of cracker cookies. The nutritional value and organoleptic performance of crackers are improved. The disadvantage of this food component is the lack of integrated effect and the dark color of the finished products. In works [9, 20], it is shown that the addition of 18.0 % and 36.0 % of low-fat sunflower flour contributes to the improvement of the technological properties of butter dough and the biological value of the product. However, a gray-brown color of finished products is formed. Works [8, 21] prove that the addition of 10.0 % and 20.0 % sunflower meal to traditional recipes of chapati, cookies, and pakodi contributes to an increase in the nutritional value and quality indicators of finished flour products. The disadvantage is the short period of preservation of freshness. In works [22, 23] it was found that the addition of 15.0 % and 30.0 % of low-fat sunflower flour increases the biological value, technological properties of the dough and sensory indicators of muffins made from it. The disadvantage of this secondary product of sunflower seed processing is green pigmentation during baking the flour product. Studies [24, 25] show that the addition of sunflower meal/isolate/flour/cake to the recipe of flour products helps improve the consistency, plasticity, and elasticity of the dough. But the disadvantage is that the undesirable gray-green color of the finished products is masked by the use of cocoa powder or whole grain flour.

Thus, the experience of scientists and specialists has shown the expediency of using useful secondary products of processing sunflower seeds of cake/meal/flour in flour confectionery products. They correct the functional and technological properties of flour systems, contribute to the creation of high-quality flour products with dietary and therapeutic properties. It should be noted that flour confectionery products made from refined wheat flour are much poorer in nutritional value and do not properly meet the needs of the body in many macro- and microelements [9, 26].

In addition, wheat protein lacks a balance of essential amino acids – lysine, threonine, and valine. Nutritionists consider it important to include in the daily diet complex plant foods, in particular, seeds, nuts, whole grains, secondary products of the oil and fat industry [27, 28].

However, this requires additional research, in particular, the determination of the functional and technological capabilities of sunflower-wheat mixtures [29] and the consumer characteristics of flour products [24, 30].

Therefore, work on the creation of new functional and technological properties of flour systems with the help of secondary products of sunflower seed processing, in particular FESSK, is relevant. FESSK is a fine homogeneous powder with a particle size of (90–110) microns, grayish-white in color, with a soft and delicate taste, and a distinct smell of sunflower seeds [11].

The study of the influence of FESSK on the quality indicators of flour confectionery products will be appropriate to find economic ways to improve the nutritional quality of flour products and increase the profitability of sunflower meal/cake residues.

Scientific substantiation of the use of FESSK for flour products with high quality and nutritional value as well as the extended period of freshness has great practical prospects in the food industry.

3. The aim and objectives of the study

The aim of our study is to develop a technology of crackers of high nutritional value using FESSK. This will make it possible to improve the nutritional properties and extend the shelf life of flour confectionery products.

To accomplish the aim, the following tasks have been set:

– to determine the chemical composition and functional and technological characteristics of FESSK;

– to investigate the influence of FESSK on the physicochemical parameters of prototypes of crackers;

– to investigate the effect of FESSK on organoleptic parameters and nutritional value of prototype crackers.

4. The study materials and methods

The object of this study is the technology of cracker cookies.

The hypothesis of the study assumes that adding to the recipe of flour confectionery products, in particular crackers, a secondary product of sunflower seed processing (FESSK) will provide an opportunity to improve the nutritional properties and extend the shelf life of flour confectionery products.

The chemical composition and functional and technological characteristics of FESSK were investigated. The influence of FESSK on the physicochemical, organoleptic parameters, and nutritional value of crackers in order to improve their quality and nutritional value.

The following materials were used:

– flour from extruded sunflower seed kernels (FESSK), obtained with the help of innovative integrated technology for processing sunflower seeds; produced by TOV "NAUTECH PLUS", Ukraine;

– high grade wheat flour (HGWF) GSTU 46.004–99 with quality indicators: humidity – no more than 15.0 %; ash content in terms of dry matter – not more than 0,55 %; whiteness, conventional units of the device RP-BPL – 54 or more; amount of raw gluten – not less than 24.0 %; the number of fall – not less than 160 s. Manufactured by TOV "Vasilkovsky Bakery Plant", Ukraine;

– flour mixes "HGWF:FESSK" (%) – 95:5; 90:10; 85:15; 80:20;

– sample 1, control, cracker "Gentle", DSTU 4052:2017 with quality indicators: mass fraction of moisture – no more than 8.0 %; alkalinity using the indicator of phenolphthalein not more than – 2.0°; ash mass fraction, not less than 0,1 %; wettability – not less than 150,0 %;

– sample 2 – cracker with partial replacement of HGWF with FESSK in the amount of 5.0 % by weight of HGWF;

– sample 3 – cracker with partial replacement of HGWF with FESSK in the amount of 10.0 % by weight of HGWF;

– sample 4 – cracker with partial replacement of high grade wheat flour HGWF with FESSK in the amount of 15.0 % by weight of HGWF.

To implement the tasks set, generally accepted [31–35] and standard research methods were used in accordance with DSTU 5023:2008, DSTU 4052:2017, and DSTU 46.004–99, as well as modern instrumental methods of biochemical and physico-chemical analysis. The content of raw fat and moisture was determined using the YMR-relaxometer minispec mq-20 (Bruker, Germany) according to DSTU 7491:2013. The mass fraction of protein (crude protein) was determined using the quantitative identification system N_2/protein DKL8 (VELP SCIENTIFICA, Italy) in accordance with DSTU 7491:2013. The biological value of the protein complex was studied by experimental determination of the amino acid composition using the capillary electrophoresis system “KRAPEL-105M”, manufactured by Lumex. The relative biological value (RBV) of protein products was determined by an express method using *Tetrahymena pyriformis* ciliates, a strain of WH14 in accordance with the recommendations in line with the recommendations from [31, 32]. The mass fraction of fiber was determined at the fiber analysis plant FIBRETHERM FT12 (Gerhardt, Germany) in accordance with DSTU 7491:2013. The mass fraction of fat in the protein complex was determined at the automatic installation for solid-liquid extraction SOXTHERM SOX414a (Gerhardt, Germany) according to the user manual and DSTU 7491:2013. The fatty acid composition of lipids was determined on a gas chromatograph with a flame-ionization detector and the integrator “Crystal 5000”. The content of calcium and magnesium was established by the complexometric method. The content of other minerals was determined using the Agilent 7500 S (USA) mass spectrometer. Vitamin content analysis was performed using a highly efficient four-channel liquid chromatograph Agilent 1100 (Agilent Technologies, USA) in combination with a diode-matrix detector (DAD) and mass spectrometry (MS). Statistical processing of the results of the experiment was carried out according to the Student’s method. The organoleptic and physico-chemical properties of crackers were determined by standard procedures [31, 32]. The total phenol content (TPC) and antioxidant capacity (DPPH and CUPRAC) of flour/flour mixtures were determined by the spectrophotometric method [8, 33, 34]. The diameter and thickness of the crackers were measured with a digital caliper; the distribution coefficient was calculated by dividing the width by thickness; hardness was measured using a texture analyzer TA-XT 2i (Stable Micro Systems, UK), equipped with a three-point bending device (HDP/3PB [8]. The water-holding and fat-absorbing capacity of flour was determined by the gravimetric method [8, 35]. The color of flour and crackers was measured using the CR-400 colorimeter (Konica Minolta Sensing, Inc., Japan), calibrated using a white standard plate. The measured values: L^* (white 100/black 0), a^* (red positive/green negative) and b^* (yellow positive/blue negative). The total color difference (ΔE) was calculated using the equation $\Delta E=\left[\left(a^*-a_0^*\right)^2+\left(b^*-b_0^*\right)^2+\left(L^*-L_0^*\right)^2\right]^{1/2}$ from [8].

5. Results of investigating the effect of flour from extruded sunflower seed kernels on the quality indicators of crackers

5. 1. Determination of the chemical composition and functional and technological characteristics of flour from extruded sunflower seed kernels

FESSK is a promising raw material for the enrichment of flour confectionery products. The traditional production technology of wheat flour crackers is shown in Fig. 1.

Some chemical indicators of high grade wheat flour (HGWF), FESSK, and flour mixtures “HGWF:FESSK” (in %): 95:5; 90:10; 85:15 are given in Table 1.

From Table 1, it follows that when FESSK is added, the content of protein, ash, fat, macronutrients Ca and Mg, as well as fiber, increases in proportion to the mass fraction of FESSK. This agrees with the literary data [26, 36].

Fig. 2 shows the mineral composition of FESSK.

Fig. 2 demonstrates that FESSK is a source of macro- and microelements. Similar results were obtained in the works of other authors [7, 36, 37].

Table 2 gives the fatty acid composition of FESSK.

As part of FESSK, a whole fatty acid complex (Table 2) of 16 fatty acids was determined. And the presence of fat-soluble antioxidants: vitamin E and chlorogenic acid. Which is consistent with literary sources [38, 39].

Table 3 gives the amino acid composition of FESSK.

The total content of amino acids in FESSK (Table 3) is 257.09 mg/g, essential – 112.26 mg/g (43.67 %); non-essential– 144.83 mg/g (56.33 %). This is consistent with the data of other authors [7, 40, 41].

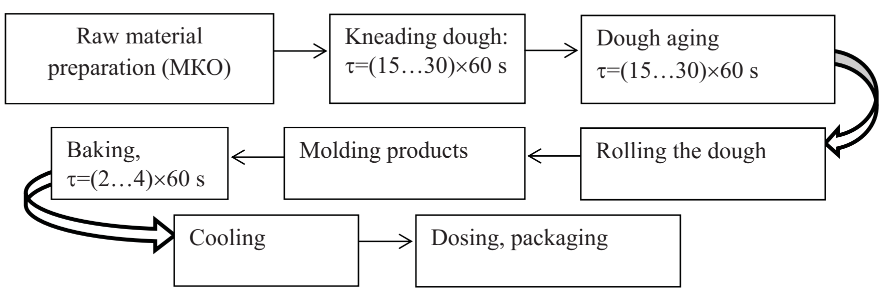

Fig. 1. Schematic diagram of the production of crackers from wheat flour

Table 1

Comparative chemical composition of FESSK, HGWF, and flour mixtures “HGWF: FESSK”

Product	Protein, g	Fats, g	Starch, g	Cellulose, g	Ash, g	Ca, mg	Mg, mg	Moisture content, %
FESSK	38.73	4.87	12.53	11.87	8.01	367.0	317.0	4.72
HGWF	12.02	1.91	70.7	0.12	0.58	21.0	19.0	13. 85
«HGWF:FESSK», %: 95:5	30. 61	3.18	59. 12	7.62	5. 21	256.0	284.0	11. 40
«HGWF:FESSK», %: 90:10	32. 82	3.58	61. 24	7.84	5.52	258.2	286.2	11. 20
«HGWF:FESSK», %: 85:15	34. 94	3. 98	63. 36	8.12	5. 84	260.1	288.4	11. 00

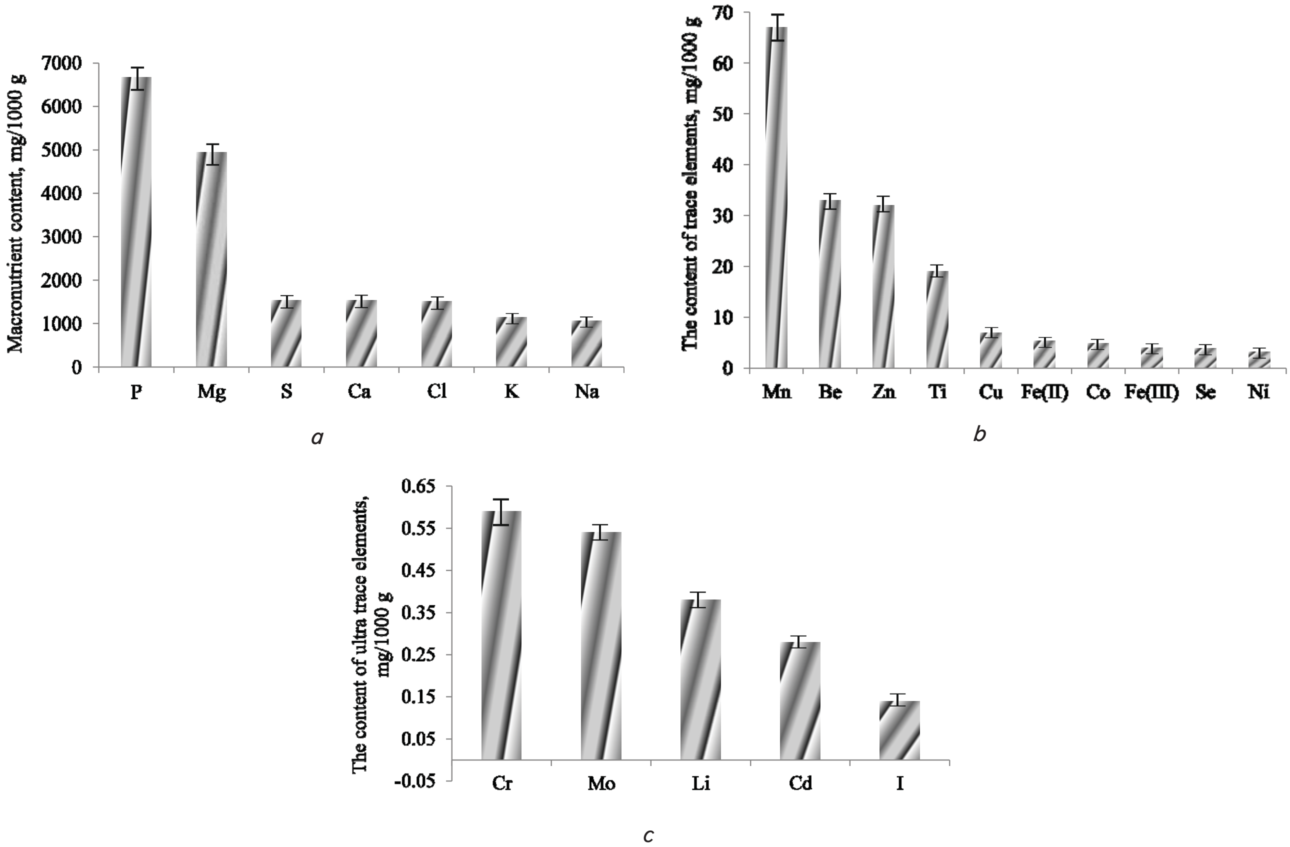

Fig. 2. Mineral composition of flour from extruded sunflower seed kernels:
a – macronutrients; *b* – trace elements;
c – ultramicroelements

Table 2

Fatty acid composition of flour from extruded sunflower seed kernels and the content of fat-soluble antioxidants

Name of the indicator	Amount of fatty acid in terms of fat FESSK	
	mg/ml	% by weight
Lauric acid – C12:0	0.006±0.0	0.01±0.0
Myristic acid – C14:0	0.045±0.002	0.08±0.003
Palmitic acid – C16:0	0.443±0.022	7.82±0.389
Palmitoleic acid – C16:1	0.113±0.005	0.20±0.010
Stearic acid – C18:0	0.344±0.017	6.06±0.289
Oleic acid – C18:1(ω–9)	10.954±0.545	19.32±0.913
Linoleic acid – C18:2 (ω–6)	36.883±1.844	65.05±3.002
Linolenic acid – C18:3 (ω–3)	0.096±0.004	0.17±0.006
Arachidic acid – C20:0	0.136±0.006	0.24±0.011
Eicosenoic acid – C20:1 (ω–9)	0.022±0.001	0.04±0.002
Arachidonic acid – C20:4 (ω–6)	0.011±0.0	0.02±0.0
Eicosapentaenoic acid – C20:5	0.153±0.007	0.27±0.012
Geneicosanoic acid – C21:0	0.022±0.001	0.04±0.002
Behenic acid – C22:0	0.414±0.020	0.73±0.036
Trisanoic acid – C23:0	0.028±0.001	0.05±0.002
Lignoceric acid – C24:0	0.108±0.003	0.19±0.007
Vitamin E (α–tocopherol), mg/kg	15.40±0.5	0.322±0.02
Chlorogenic acid, mg/kg	15.38±0.5	0.321±0.02

Table 3

Amino acid composition of flour from extruded sunflower seed kernels and the total content of amino acids in high grade wheat flour

Name of the indicator	Amino acid index	
	*Amount of AA, mg/g	ACC, %
Essential amino acids (EAA)		
Hydrophilic:		
Threonine	36.61±0.86	94.08±0.97
Arginine	94.59±1.12	105.82±1.08
Histidine	24.88±0.52	92.01±0.78
Lysine	36.92±0.59	83.25±0.71
Total content of hydrophilic essential amino acids, mg/g	193. 10±0.58	19.31±0.94
Hydrophobic:		
Valin	51.82 ±0.65	96.72±0.97
Leucine	65.68±0.81	94.14±0.89
Isoleucine	44.82±0.43	92.65±0.78
Methionine	20.88±0.22	86.73±0.72
Phenylalanine	46.51±0.48	93.68±0.84
Tryptophan	13.89±0.18	95.72±0.99
Total vist of hydrophobic essential amino acids, mg/g	243.60±0.97	24.36±1.19
Non-essential amino acids (NEAA)		
Hydrophilic:		
Serin	42.32±0.51	–
Asparagine	30.38±0.39	–
Aspartic acid	96.33±1.18	–
Glutamic acid	219.77±1.72	–
Tyrosine	26.30±0.28	–
Total content of hydrophilic non-essential amino acids, mg/g	415.10±1.37	–
Alanine	44.03±0.45	–
Glycine	44.57±0.46	–
Proline	33.52±0.56	–
Cystine	26.08±0.27	–
Total vist of hydrophobic non-essential amino acids, mg/g	148.20±1.27	–
Total content of amino acids, mg/g dry protein	1000.00±4.12	–
Total amino acid content in FESSK, mg/100 g flour	7416±12.14	–
Total amino acid content in HGWF, mg/100 g flour	3471±6.12	–

Note: Amount of amino acid (mg) in terms of dry protein (g)

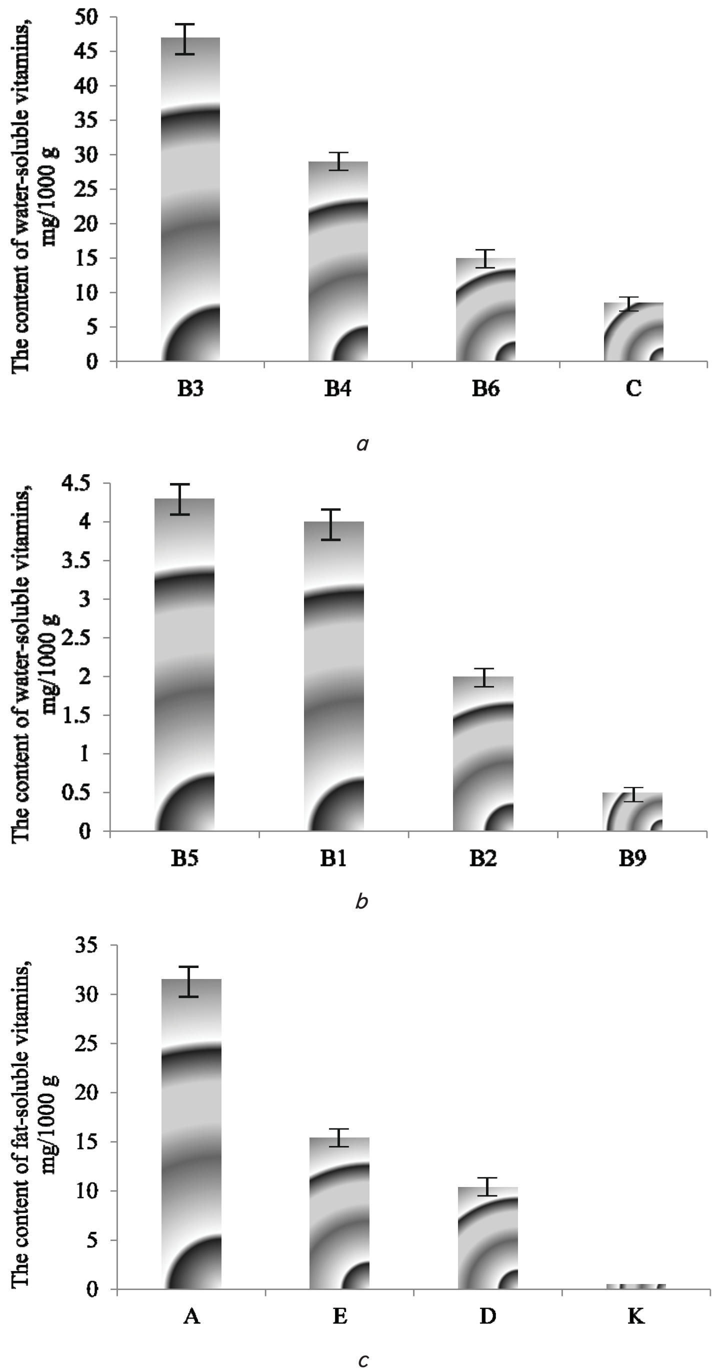

Fig. 3. Vitamin composition of flour from extruded sunflower seed kernels: *a* — water-soluble vitamins: B_3, B_4, B_6, C; *b* — water-soluble vitamins: B_5, B_1, B_2, B_9; *c* — fat-soluble vitamins: A, E, D, K

Fig. 3 shows the analysis of the vitamin composition of FESSK.

The presence of a complex of biologically active substances (Fig. 3): 8 water-soluble and 4 fat-soluble vitamins was determined in the composition of FESSK. This is consistent with literary sources on sunflower meal/meal [42, 43].

The preliminary determination of the rational ratio of FESSK and HGWF was carried out using aminograms (Fig. 4).

More accurately, the rational ratio of FESSK and HGWF is determined using the indicator of biological value (BV) and amino acid SCOR (SCOR – author's abbreviation of Mitchell and Block) (Tables 4, 5, and Fig. 5).

Table 4

SCOR of essential amino acids of flour from extruded kernel of sunflower seeds and high grade wheat flour

Limiting essential amino acids	SCOR, %	
	HGWF	FESSK
Tryptophan	91.13±0.91	95.72±0.95
Lysine	45.50±0.81	83.25±0.83
Methionine	44.20±0.79	86.73±0.86
Valin	92.4±0.95	96.72±0.86
Phenylalanine+tyrosine	66.2±0.62	93.68±0.93

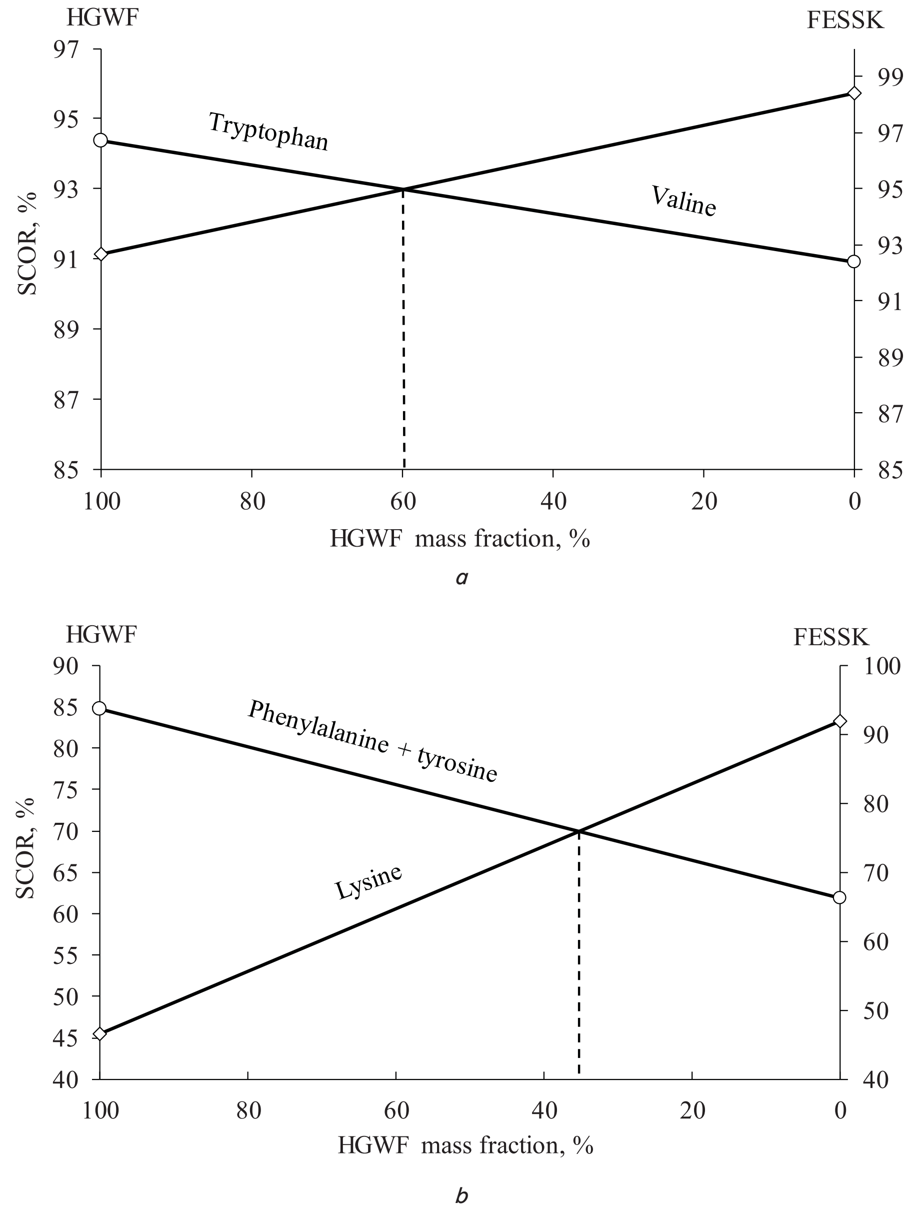

Fig. 4. Aminograms for flour from extruded sunflower seed kernels and high grade wheat flour by limiting amino acids: *a* – Tryptophan and Valine; *b* – Phenylalanine+Tyrosine and Lysine

As can be seen from Table 4, the SCOR of essential amino acids of FESSK protein is 1.05–1.96 times higher compared to the HGWF protein. In addition, the established SCOR values of limiting amino acids for FESSK correspond to the SCOR values of these amino acids for sunflower meal/meal in the works of other researchers [41, 44].

Table 5 gives the biological value of proteins in FESSK, HGWF, and flour mixtures "FESSK+HGWF".

The higher the value of *U*, the more balanced the essential amino acids in the protein and the more rationally they can be used by the body.

Table 6 gives a comparative analysis of the functional and technological properties of FESSK and HGWF.

The improvement of functional and technological properties (Table 6) of FESSK compared to HGWF is consistent with the works of other authors [11, 45, 46].

Table 5

Indicators of biological value of proteins in FESSK, HGWF, and flour mixtures "FESSK+HGWF"

Indicator	HGWF	FESSK	Flour mixture «FESSK+HGWF», %			
			5+95	10+90	15+85	20+80
The biological value of proteins (BV), %	53.01±0.53	78.85±0.81	68.25±0.67	71.35±0.72	73.35±0.73	75.25±0.75
Amino acid scor difference coefficient (ASDC), %	46.99±0.45	+	31.75±0.32	28.65±0.29	26.65±0.27	24.75±0.25
Utilization rate of amino acid composition (U)	0.56±0.03	0.78±0.03	0.61±0.03	0.63±0.03	0.65±0.03	0.67±0.03

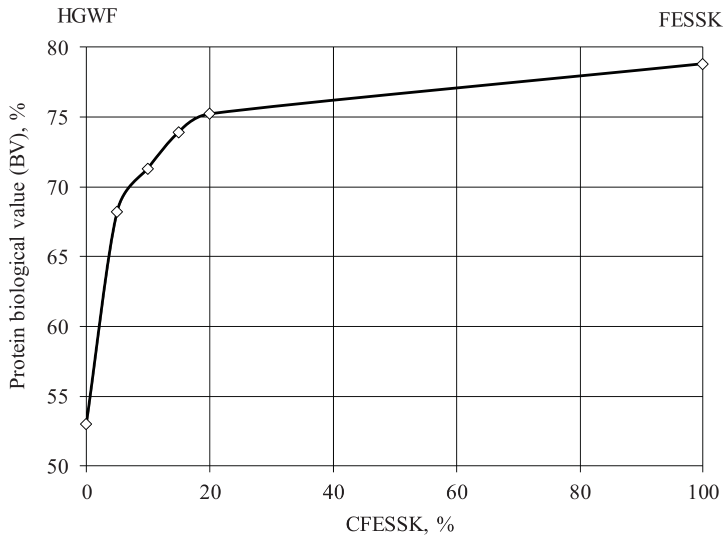

Fig. 5. The biological value of protein depending on the mass fraction of flour from extruded sunflower seed kernels mixed with high grade wheat flour

Table 6

Comparative analysis of the functional and technological properties of flour from the extruded core of sunflower seeds and high grade wheat flour

Indicator	HGWF	FESSK
Fat-absorbing capacity (FAC), g of dry matter/g	0.96±0.04	1.45±0.08
Water holding capacity (WHC), g of water/g dry matter	0.79±0.14	2.87±0.38
Color *L**	94.85±0.36	78.84±0.26
*a**	–0.87±0.02	1.42±0.02
*b**	10.95±0.15	14.25±0.15
Total phenols (TPC), mg GAE/g	5.59±0.84	12.54±0.95
Ability to absorb radicals 2,2-diphe-nyl-1-pycrylhydrazil (DPPH), mg TE/g	0.42±0.25	4.16±0.75
Antioxidant capacity to reduce copper (CUPRAC), mg TE/g	2.22±0.65	16.75±1.05

5. 2. Investigation of the effect of flour from extruded sunflower seed kernels on the physicochemical parameters of cracker samples

The physical properties of prototypes of crackers are given in Table 7.

Table 7

Physical properties of prototypes of crackers

Parameter	Prototypes of crackers			
	Control – HGWF	Flour mixture «HGWF:FESSK», %		
		95:5	90:10	85:15
Diameter, mm	40.25±1.06	39.85±1.03	39.55±0.99	39.25±0.97
Thickness, mm	1.99±0.01	1.97±0.01	1.95±0.01	1.93±0.01
Spreading coefficient	20.23±0.12	20.23±0.12	20.28±0.13	20.33±0.14
Color *L**	58.31±0.58	57.40±0.58	57.20±0.56	57.05±0.55
*a**	8.8±0.28	7.96±0.26	7.82±0.24	7.70±0.23
*b**	7.76±0.60	6.79±0.39	6.67±0.37	6.56±0.35
Overall color difference (ΔE)	–	3.3	3.6	3.9
Hardness (N)	39.98±4.26	40.18±4.28	40.26±4.30	40.36±4.32

Changes in the physical parameters of prototypes of crackers (Table 7) correspond to the results of research by other authors [13, 47, 48].

Table 8 gives the physicochemical properties of prototypes of crackers.

Table 8

Physico-chemical properties of prototypes of crackers

Indicator	Prototypes of crackers			
	Control – HGWF	Flour mixture «HGWF:FESSK», %		
		95:5	90:10	85:15
Mass fraction of moisture, %	5.48±0.08	5.55±0.08	5.67±0.08	5.78±0.08
Alkalinity, °	1.89±0.01	1.87±0.01	1.85±0.01	1.84±0.01
Mass fraction of total ash, in terms of dry matter, %	0.52±0.01	2.97±0.03	4.68±0.07	6.93±0.09
Wettability, %	152.0±2.2	162.0±2.3	166.0±2.2	169.0±2.2
Mass fraction of crude fat in terms of dry matter, %	11.34±0.16	11.66±0.16	11.87±0.17	12.04±0.17
Mass fraction of crude protein in terms of dry matter, %	14.46±0.18	15.66±0.19	16.54±0.19	17.55±0.19

As can be seen from Table 8, the introduction of FESSK in the amount of 5.0 %; 10,0 %; 15.0 % of the mass of HGWF reduces alkalinity and contributes to an increase in humidity, ash content, fat content, wettability, and protein content in the sample crackers in proportion to the amount of FESSK. This is consistent with the works of other authors [9, 11].

In the work, we experimentally established the optimal mass fraction of FESSK – 10.0 % of the amount of HGWF. The mass fraction was set taking into account the nutritional properties of crackers and based on the calculation of the cost of finished products.

Thus, FESSK is a valuable raw material ingredient for the flour confectionery industry, the decisive task of which is to create flour products with increased biological and nutritional value; as well as improved nutritional properties.

5. 3. Investigating the effect of flour from extruded sunflower seed kernels on the organoleptic parameters of cracker samples

Table 9 gives the organoleptic indicators of prototypes of crackers.

Sensory analysis of prototype crackers revealed an increase in the overall quality indicator by (0.07±0.01); (0,18±0,01); (0.10±0.01) points, respectively. With a partial replacement of HGWF with FESSK in the amount of 5.0 %; 10.0 %; 15.0 % of the amount of HGWF (Table 9). The optimal amount of FESSK was determined, which is 10.0 % of the amount of HGWF. The technology of production of crackers "Guards" with the introduction of FESSK has been developed. A distinctive feature is the partial replacement of HGWF with 10.0 % FESSK and the addition of FESSK at the stage of kneading the dough. The technological scheme of production of crackers "Guards" with high nutritional value is shown in Fig. 6.

Table 9

Evaluation of organoleptic indicators of prototypes of crackers

Prototypes of crackers	Organoleptic indicators of crackers					
	Taste and smell	Color	Shape	Appearance and surface	Fractured view	General indicator
Sample 1 – control	5.00±0.02	5.00±0.02	4.90±0.01	4.92±0.01	5.00±0.02	24.82±0.01
Sample 2 – with 5.0 % FESSK	5.00±0.02	5.00±0.02	4.92±0.01	4.97±0.02	5.00±0.02	24.89±0.01
Sample 3 – with 10.0 % FESSK	5.00±0.02	5.00±0.02	5.00±0.01	5.00±0.01	5.00±0.02	25.00±0.01
Sample 4 – with 15,0 % FESSK	5.00±0.02	5.00±0.02	4.97±0.01	4.98±0.01	4.97±0.02	24.92±0.01

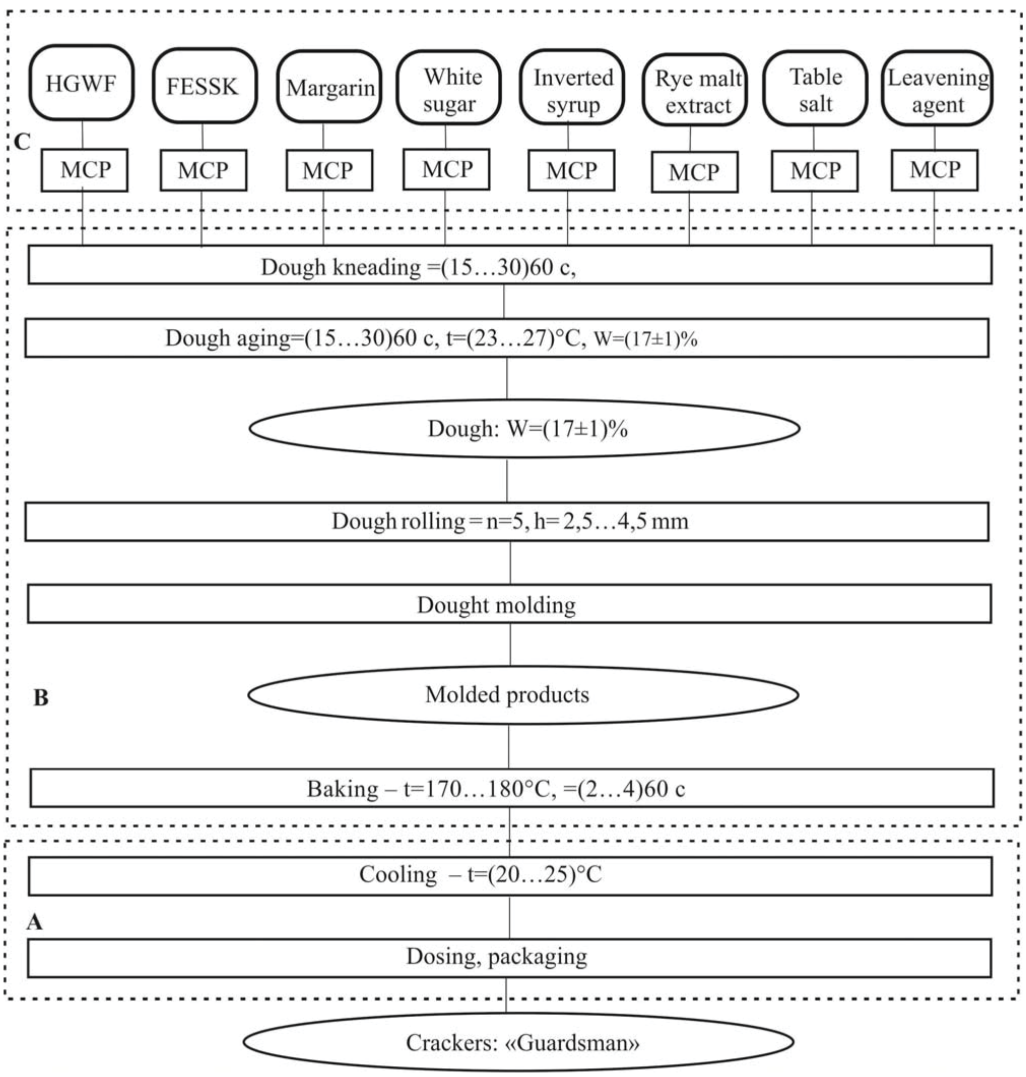

Fig. 6. Technological scheme of production of crackers "Gvardiisky" with high nutritional value: A, B, C – subsystems for the production of crackers

However, to determine the functional and technological capabilities of flour mixtures "HGWF+FESSK" in the production of a wide range of flour confectionery products, additional research is needed. It is known that the production of crackers requires soft wheat flour with high gluten strength but low water binding capacity. Or the moisture-absorbing capacity of flour and flour mixtures affects the parameters of kneading biscuit dough and baking biscuits. And, accordingly, such sensory parameters as color, consistency, and texture of the finished flour product [28].

6. Discussion of results of investigating the effect of extruded sunflower kernel flour on the quality of crackers

When assessing the possibility of introducing FESSK into the technology of crackers (Fig. 1), we studied the chemical composition of FESSK and compared it with the chemical composition of the main raw material of crackers – wheat flour. As can be seen from the data in Table 1, in FESSK and in flour mixtures "HGWF:FESSK" compared to HGWF there is a much higher biological potential compared to HGWF. The protein content compared to HGWF is higher: 3.2 times in FESSK and 1.12–1.27 times in the mixture of "HGWF:FESSK". The content of mineral substances in comparison with HGWF increases: 13.81 times in FESSK and 1.37–1.54 times in the mixture of "HGWF:FESSK". Including calcium – by 17.48 times in FESSK and 1.41–1.43 times in the mixture of "HGWF:FESSK". Magnesium – by 16.68 times in FESSK and 1.10–1.12 times in the mixture of "HGWF:FESSK". Analysis of the mineral composition (Fig. 2) shows that FESSK is a rich source of minerals (7 macro-, 10 micro- and 5 ultramicronutrients were found). The carbohydrate component is represented by fiber and starch. The fiber content increases compared to HGWF in FESSK by 98.92 times and 1.46–1.55 times in the mixture of "HGWF:FESSK" (Table 1). The data obtained are consistent with the works of other authors [37, 44].

Regarding the fat content of FESSK and flour mixtures "HGWF:FESSK", an increase of 2.55 times compared to HGWF was found in FESSK and an average increase of 22.4 % for every 5.0 % with FESSK added to the mixture with HGWF (Table 1).

The total content of higher fatty acids (HFAs) in FESSK was 49.778 mg/ml (84.78±4.18) % (Table 2). At the same time, FESSK is rich in polyunsaturated fatty acids (PUSFAs) – (65.22±3.12 %) and monounsaturated fatty acids (MUSFAs) – (19.56±0.96 %). Saturated fatty acid content (SFAs) is also quite sufficient – (15.22±0.75 %). The predominant fatty acids in FESSK are oleic, C18:1 (ω–9) (19.32 %) and linoleic, C18:2 (ω–6) (65.05 %). They make up (84.37±4.22) % of the total fatty acid profile of FESSK. The content of linolenic acid is 0.17 %. These polyunsaturated fatty acids are the main components of flour fat and play an important role in maintaining health, triglyceride and cholesterol levels, normalizing blood pressure. This makes FESSK an important dietary source of essential fatty acids. The presence of fat-soluble antioxidants: vitamin E (α-tocopherol) in the amount of 15.40 mg/kg and chlorogenic acid 0.321 % helps reduce various diseases caused by oxidative stress (cancer, cardiovascular and coronary heart disease). Analysis of the amino acid profile of FESSK (Table 3) shows that the total amount of essential amino acids in FESSK is 3.15–3.19 times greater than in wheat flour. In FESSK, the first limiting amino acid is lysine (AAN=83.25 %). The amino acid number (AAN) of the two second most deficient essential amino acids is greater: tryptophan (AAN=95.72 %) – 1.15 times; methionine (ANN=86.73 %) – 1.04 times. Compared to lysine, the AAN of other essential amino acids also increases by (1.08–1.27) times. One should note the balance of amino acid composition and the usefulness of proteins FESSK (AAN of essential amino acids approaches 100 %). The obtained data are consistent with literary sources [7, 40, 41] and emphasize the higher biological value of FESSK compared with HGWF.

Of the 13 vitamins necessary for the human body, 12 vitamins (92.3 % of the total amount of vitamins) are present in the composition of FESSK, the daily needs of which range from 0.01 to 100 mg (Fig. 3). Water-soluble vitamins: vitamin C and vitamins of group B. Fat-soluble vitamins: A, D, E, K. Of which, the following vitamins predominate: $C<D<B_6<E<B_4<A<B_3$. Similar results were reported in [42, 43].

With the help of aminograms (Fig. 4), a preliminary determination of the rational ratio of FESSK and HGWF was carried out. The maximum increase in the biological value of the protein of the flour mixture "HGWF+FESSK" can be achieved in the ratio range of HGWF and FESSK (%): 41:59...64:36. The balance of the amino acid composition of the FESSK protein is confirmed by the approximation of the SCOR of limiting essential amino acids to 100 % (Table 4). Also, the SCOR of essential amino acids of the FESSK protein increases compared to the HGWF protein: for tryptophan, by 1.04–1.06 times; for lysine, 1.82–1.84 times; for methionine, 1.95–1.97 times; for valine, 1.04–1.06 times; for phenylalanine+tyrosine, 1.41–1.43 times. Data analysis of Table 5 and Fig. 5 shows that compared to HGWF protein, the BV indicator and the utilization rate of the amino acid composition (U) increase. Namely, in FESSK, by 48.74 % and 39.29 %, respectively; in "FESSK+HGWF" flour mixtures – by 28.75–41.95 % and 8.93–19.60 %, respectively. Which emphasizes the balance of the amino acid composition of FESSK protein and the improvement of the biological and nutritional values of FESSK and flour mixtures "FESSK+HGWF" compared to HGWF. The rational amount of FESSK was determined – 10.0 % of the amount of HGWF.

Analysis of Table 6 indicates an improvement in the hydration and lipophilic properties of FESSK compared to HGWF: fat-absorbing capacity increases by 1.50–1.52 times and water retention capacity by 3.62–3.64 times. This is due to the higher dispersion, chemical composition, and high soluble dietary fiber content in FESSK. As for color, FESSK compared to HGWF has a slightly darker color with higher values of redness and blueness. A sufficiently high content of compounds with an antioxidant effect in FESSK helps improve the antioxidant properties of sunflower flour compared to HGWF. Namely, the total content of phenols (TPC) increases by 2.22–2.26 times; DPPH 9.8–10.0 times; CUPRAC 7.51–7.56 times. Previous studies have shown that FESSK is a good source of phenolic compounds, including chlorogenic, coffee, n-hydroxybenzoic, n-coumar, cinamic, μ-hydroxybenzoic, vanillic, siridic, transcortic, isoferulic, and synapic acids. These compounds have high antioxidant properties [8, 11, 45]. On the other hand, it is reported that wheat flour has a very low content of polyphenols [8, 46], which explains its lower antioxidant ability compared to FESSK [11, 46]. The obtained results (Table 6) contribute to the improvement of consumer properties and extend the period of preservation of freshness of crackers.

As can be seen from Table 7, the diameter and thickness of crackers with the addition of FESSK in the amount of 5.0 %; 10,0 %; 15.0 % of the mass of HGWF decreased by an average of 0.8–1.0 % compared to the control. Due to the dilution of gluten and an increase in fiber content [46, 47]. At the same time they grew: the coefficient of distribution by (1.0±0.1) % (due to an increase in the fat content in FESSK compared to HGWF [48–50]). The hardness of crackers is 5.1–9.5 % (due to the higher protein content in FESSK compared to HGWF [51, 52]). A decrease in the lightness of coloring of finished cracker products with an increase in the mass fraction of FESSK compared to the control was established. This can be explained by the more saturated color of FESSK compared to HGWF (Table 6) [53, 54].

From the analysis of physicochemical properties of prototypes of crackers (Table 8), it follows that the introduction of FESSK in the amount of 5.0–15.0 % by weight of HGWF contributes to an increase in comparison with the control: humidity, by 1.28–5.47 %; wet capacity, by 6.58–11.19 % (due to the stabilizing and water-holding capacity of FESSK). Ash content increases by 5.71–13.33 times; fat content by 2.19–6.17 %; protein content by 8.29–21.37 %, and alkalinity of finished products decreases by 1.04–2.06 % (due to the chemical composition of FESSK). Which contributes to the improvement of biological and nutritional value; consumer properties of cracker products.

Sensory analysis (Table 9) found that organoleptic indicators of the quality of crackers with a partial replacement of HGWF by 5.0 % of FESSK compared to the control almost did not change. When replacing HGWF with 15.0 % FESSK, the texture of the products becomes granular, dry, and fragile; the structure is rough. At the same time, the finished product becomes harder, less aerated, and more compact (Table 9). With the introduction of FESSK in the amount of 10.0 %, the texture is preserved; products acquire a pleasant nutty flavor. Improved: appearance – correct, with a convex surface shape. Surface – with the presence of bubbles; consistency – finely supported. The view in the fault is thin-walled layering with uneven pores. The best organoleptic indicators have products when replacing HGWF with 10.0 % FESSK, that is, with a ratio (%) of HGWF:FESSK=90:10. Similar results were obtained in [8, 48, 54].

So, experimental studies have shown the feasibility of using FESSK for the partial replacement of wheat flour in the production of "Guards" crackers with high nutritional value. A rational amount of FESSK, which is 10.0 % of the amount of HGWF, has been determined. The technology of production of "Guards" crackers with a partial replacement of HGWF by 10.0 % FESSK from the mass of HGWF has been developed (Fig. 6). A distinctive feature is the addition of FESSK when kneading the dough.

It should be noted that the rational amount of FESSK is 10.0 % of the volume of HGWF. Reducing and increasing the mass fraction of FESSK does not contribute to the achievement of the necessary functional and technological characteristics of flour products.

Thus, the results of our studies make it possible to substantiate the expediency of using FESSK in the technologies of flour confectionery products – crackers, cookies, gingerbread, muffins, etc. with improved quality indicators. But to determine the functional and technological capabilities of flour mixtures "HGWF+FESSK", additional research is needed – mathematical, methodological, experimental. In addition, it is necessary to assess the impact of the innovative raw material ingredient (FESSK) on the functional and technological properties and nutritional characteristics of certain types of flour products.

7. Conclusions

1. We have studied the chemical composition and functional-technological properties of FESSK, which has a higher biological potential compared to wheat flour. In the nutrient composition of FESSK there is a rich mineral-vitamin complex (22 elements, 8 water-soluble, and 4 fat-soluble vitamins were found). Compared to HGWF, the following increases: protein content – by 3.2 times; mineral content – 13.81 times (including calcium – 17.48 times, magnesium – 16.68 times); fiber content – 98.92 times. The presence of fat-soluble antioxidants: vitamin E (α-tocopherol) in the amount of 15.40 mg/kg and chlorogenic acid 0.321 % helps reduce various diseases caused by oxidative stress (cancer, cardiovascular and coronary heart disease).

The content of essential amino acids in the protein complex of FESSK is more than ~38.73 %. In FESSK, the predominant amino acid is lysine, in addition, a higher content of the amino acids leucine and threonine, deficient for all varieties of wheat flour, was noted. The total amount of essential amino acids in FESSK is 3.15–3.19 times greater than in HGWF. The SCOR of essential amino acids of the FESSK protein increases compared to the HGWF protein. Namely, for tryptophan, by 1.04–1.06 times; for lysine, 1.82–1.84 times. For methionine, by 1.95–1.97 times; for valine, 1.04–1.06 times; for phenylalanine+tyrosine – 1.41–1.43 times. Compared to HGWF protein, BV and utilization rate of amino acid composition (U) increase: in FESSK, by 48.74 % and 39.29 %, respectively. That is, the biological value of FESSK is higher than that of HGWF.

In FESSK, fat-soluble physiologically valuable nutrients in native form, as well as replaceable and essential fatty acids, are preserved as much as possible. The predominant fatty acids in FESSK are oleic, C18:1 (ω–9) (19.32 %) and linoleic, C18:2 (ω–6) (65.05 %).

FESSK has better hydration, lipophilic, and antioxidant properties than HGWF. In FESSK, there is an increase in fat absorption capacity – by 1.51 times; water holding capacity – 3.63 times; total content of phenols (TPC) – 2.22–2.26 times; DPPH, 9.8–10.0 times; CUPRAC, 7.51–7.56 times.

2. The influence of FESSK on the physicochemical parameters of prototypes of crackers has been studied. The use of FESSK contributes to an increase in the coefficient of distribution of crackers by (1.0±0.1) %; hardness of crackers by 5.1–9.5 %; humidity by 1.28–5.47 %; wettability by 6.58–11.19 %; ash content 5.71–13.33 times; fat content by 2,19–6,17 %; protein content by 8.29–21.37 %. Alkalinity decreases by 1.04–2.06 % as well as the ease of coloring of finished cracker products.

3. The data of organoleptic analysis confirm the improvement in the quality of crackers using FESSK by an average of

5.1–6.8 % compared to control. A rational volume of FESSK has been established – 10.0 % of the volume of HGWF. The technology of production of crackers "Gvardiisky" with partial replacement of HGWF by 10.0 % of FESSK has been developed. Its distinctive feature is the addition of FESSK when kneading the dough.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

Funding

The study was conducted without financial support.

Data availability

All data are available in the main text of the manuscript.

References

1. Tovma, L. F., Kaplun, S. O., Kasyanov, I. V. (2018). Military feeding ration optimization method during special period. Chest i zakon, 1 (64), 128–137. Available at: http://nbuv.gov.ua/UJRN/Chiz_2018_1_20
2. Tovma, L. F., Morozov, I. Ye., Zozulia, A. V. (2018). Yakisne kharchuvannia osib, shcho znakhodiatsia v nespryiatlyvykh umovakh zovnishnoho seredovyshcha. Science Review, 5 (3 (10)), 30–32. Available at: https://www.academia.edu/36440045/ЯКІСНЕ_ХАРЧУВАННЯ_ОСІБ_ЩО_ЗНАХОДЯТЬСЯ_В_НЕСПРИЯТЛИВИХ_УМОВАХ_ЗОВНІШНЬОГО_СЕРЕДОВИЩА
3. Nutrition Science and Food Standards for Military Operations (Nutrition et normes d'alimentation pour les opérations militaires) (2010). Final Report of RTO Task Group RTG-154. Available at: https://apps.dtic.mil/sti/pdfs/ADA526318.pdf
4. Kowalczewski, P. Ł., Olejnik, A., Białas, W., Kubiak, P., Siger, A., Nowicki, M., Lewandowicz, G. (2019). Effect of Thermal Processing on Antioxidant Activity and Cytotoxicity of Waste Potato Juice. Open Life Sciences, 14 (1), 150–157. doi: https://doi.org/10.1515/biol-2019-0017
5. Kumar, S., Kushwaha, R., Verma, M. L. (2020). Recovery and utilization of bioactives from food processing waste. Biotechnological Production of Bioactive Compounds, 37–68. doi: https://doi.org/10.1016/b978-0-444-64323-0.00002-3
6. Alexandrino, T. D., Ferrari, R. A., de Oliveira, L. M., de Cássia S.C. Ormenese, R., Pacheco, M. T. B. (2017). Fractioning of the sunflower flour components: Physical, chemical and nutritional evaluation of the fractions. LWT, 84, 426–432. doi: https://doi.org/10.1016/j.lwt.2017.05.062
7. Petraru, A., Ursachi, F., Amariei, S. (2021). Nutritional Characteristics Assessment of Sunflower Seeds, Oil and Cake. Perspective of Using Sunflower Oilcakes as a Functional Ingredient. Plants, 10 (11), 2487. doi: https://doi.org/10.3390/plants10112487
8. Grasso, S., Omoarukhe, E., Wen, X., Papoutsis, K., Methven, L. (2019). The Use of Upcycled Defatted Sunflower Seed Flour as a Functional Ingredient in Biscuits. Foods, 8 (8), 305. doi: https://doi.org/10.3390/foods8080305
9. Man, S., Păucean, A., Muste, S., Pop, A., Sturza, A., Mureșan, V., Salanță, L. C. (2017). Effect Of Incorporation Of Sunflower Seed Flour On The Chemical And Sensory Characteristics Of Cracker Biscuits. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Food Science and Technology, 74 (2), 95. doi: https://doi.org/10.15835/buasvmcn-fst:0018
10. Akkaya, M. R. (2018). Fatty acid compositions of sunflowers (Helianthus annuus L.) grown in east Mediterranea region. Rivista Italiana Delle Sostanze Grasse, XCV (4), 239–247. Available at: https://www.researchgate.net/publication/328143287_Fatty_acid_compositions_of_sunflowers_Helianthus_annuus_L_grown_in_east_Mediterranea_region
11. Evlash, V., Tovma, L., Tsykhanovska, I., Gaprindashvili, N. (2019). Innovative Technology of the Scoured Core of the Sunflower Seeds After Oil Expression for the Bread Quality Increasing. Modern Development Paths of Agricultural Production, 665–679. doi: https://doi.org/10.1007/978-3-030-14918-5_65
12. de Oliveira Filho, J. G., Egea, M. B. (2021). Sunflower seed byproduct and its fractions for food application: An attempt to improve the sustainability of the oil process. Journal of Food Science, 86 (5), 1497–1510. doi: https://doi.org/10.1111/1750-3841.15719
13. Kuchtová, V., Karovičová, J., Kohajdová, Z., Minarovičová, L., Kimličková, V. (2016). Effects of white grape preparation on sensory quality of cookies. Acta Chimica Slovaca, 9 (2), 84–88. doi: https://doi.org/10.1515/acs-2016-0014
14. Adeleke, B. S., Babalola, O. O. (2020). Oilseed crop sunflower (Helianthus annuus) as a source of food: Nutritional and health benefits. Food Science & Nutrition, 8 (9), 4666–4684. doi: https://doi.org/10.1002/fsn3.1783
15. Caldeira, C., De Laurentiis, V., Corrado, S., van Holsteijn, F., Sala, S. (2019). Quantification of food waste per product group along the food supply chain in the European Union: a mass flow analysis. Resources, Conservation and Recycling, 149, 479–488. doi: https://doi.org/10.1016/j.resconrec.2019.06.011
16. Comunian, T. A., Silva, M. P., Souza, C. J. F. (2021). The use of food by-products as a novel for functional foods: Their use as ingredients and for the encapsulation process. Trends in Food Science & Technology, 108, 269–280. doi: https://doi.org/10.1016/j.tifs.2021.01.003
17. Manchuliantsau, A., Tkacheva, A. (2019). Pat. No. US20190223475A1. Upcycling solid food wastes and by-products into human consumption products. Available at: https://patents.google.com/patent/US20190223475A1/en
18. Bhise, S., Kaur, A., Ahluwali, P., Thind, S. S. (2014). Texturization of deoiled cake of sunflower, soybean and flaxseed into food grade meal and its utilization in preparation of cookies. Nutrition & Food Science, 44 (6), 576–585. doi: https://doi.org/10.1108/nfs-01-2014-0002

19. Škrbić, B., Filipčev, B. (2008). Nutritional and sensory evaluation of wheat breads supplemented with oleic-rich sunflower seed. Food Chemistry, 108 (1), 119–129. doi: https://doi.org/10.1016/j.foodchem.2007.10.052
20. Srilatha, K., Krishnakumari, K. (2003). Proximate composition and protein quality evaluation of recipes containing sunflower cake. Plant Foods for Human Nutrition, 58 (3), 1–11. doi: https://doi.org/10.1023/b:qual.0000041139.37434.5c
21. Grasso, S., Liu, S., Methven, L. (2020). Quality of muffins enriched with upcycled defatted sunflower seed flour. LWT, 119, 108893. doi: https://doi.org/10.1016/j.lwt.2019.108893
22. Liang, S., Were, L. M. (2018). Chlorogenic acid induced colored reactions and their effect on carbonyls, phenolic content, and antioxidant capacity in sunflower butter cookies. LWT, 87, 16–22. doi: https://doi.org/10.1016/j.lwt.2017.08.069
23. Wildermuth, S. R., Young, E. E., Were, L. M. (2016). Chlorogenic Acid Oxidation and Its Reaction with Sunflower Proteins to Form Green-Colored Complexes. Comprehensive Reviews in Food Science and Food Safety, 15 (5), 829–843. doi: https://doi.org/10.1111/1541-4337.12213
24. Subaşı, B. G., Casanova, F., Capanoglu, E., Ajalloueian, F., Sloth, J. J., Mohammadifar, M. A. (2020). Protein extracts from de-oiled sunflower cake: Structural, physico-chemical and functional properties after removal of phenolics. Food Bioscience, 38, 100749. doi: https://doi.org/10.1016/j.fbio.2020.100749
25. Gómez, M., Martinez, M. M. (2017). Fruit and vegetable by-products as novel ingredients to improve the nutritional quality of baked goods. Critical Reviews in Food Science and Nutrition, 58 (13), 2119–2135. doi: https://doi.org/10.1080/10408398.2017.1305946
26. Nadeem, M., Anjum, F. M., Arshad, M. U., Hussain, S. (2010). Chemical characteristics and antioxidant activity of different sunflower hybrids and their utilization in bread. Food Science, 4 (10), 618–626.
27. Sabitha, N. Puraikalan, Y. (2014). Development and Sensory Evaluation of Sunflower Seed Fortified Cookies. International Journal of Scientific Research, 3 (2), 214–215. doi: https://doi.org/10.15373/22778179/feb2014/70
28. Kweon, M., Slade, L., Levine, H. (2011). Solvent Retention Capacity (SRC) Testing of Wheat Flour: Principles and Value in Predicting Flour Functionality in Different Wheat-Based Food Processes and in Wheat Breeding – A Review. Cereal Chemistry Journal, 88 (6), 537–552. doi: https://doi.org/10.1094/cchem-07-11-0092
29. Mohammed, K., Mohammed, O., Omedi, J. O., Letsididi, K. S., Koko, M., Zaaboul, F. et al. (2018). Effect of sunflower meal protein isolate (SMPI) addition on wheat bread quality. Journal of Academia and Industrial Research, 6 (9), 159–164. Available at: https://www.researchgate.net/publication/324079011_Effect_of_Sunflower_Meal_Protein_Isolate_SMPI_Addition_on_Wheat_Bread_Quality
30. Shchekoldina, T., Aider, M. (2012). Production of low chlorogenic and caffeic acid containing sunflower meal protein isolate and its use in functional wheat bread making. Journal of Food Science and Technology, 51 (10), 2331–2343. doi: https://doi.org/10.1007/s13197-012-0780-2
31. Koriachkina, S. Ya., Berezina, N. A., Khmeleva, Ye. V. (2010). Metody doslidzhennia yakosti khlibobulochnykh vyrobiv. Kyiv: Nauka, 166.
32. Kasymova, Ch. K. (2012). Laboratornyi praktykum z kursu "Tekhnolohiya khliba, kondyterskykh ta makaronnykh vyrobiv". Bishkek: Kyrhyzkyi derzhavnyi tekhnichnyi universytet im. I. Razakova, 48.
33. Singleton, V. L., Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Am. J. Enol. Vitic., 16 (3), 144–158. Available at: http://www.ajevonline.org/content/16/3/144.full.pdf+html
34. Vamanu, E., Nita, S. (2013). Antioxidant Capacity and the Correlation with Major Phenolic Compounds, Anthocyanin, and Tocopherol Content in Various Extracts from the Wild EdibleBoletus edulisMushroom. BioMed Research International, 2013, 1–11. doi: https://doi.org/10.1155/2013/313905
35. Sudha, M. L., Baskaran, V., Leelavathi, K. (2007). Apple pomace as a source of dietary fiber and polyphenols and its effect on the rheological characteristics and cake making. Food Chemistry, 104 (2), 686–692. doi: https://doi.org/10.1016/j.foodchem.2006.12.016
36. Goiri, I., Zubiria, I., Benhissi, H., Atxaerandio, R., Ruiz, R., Mandaluniz, N., Garcia-Rodriguez, A. (2019). Use of Cold-Pressed Sunflower Cake in the Concentrate as a Low-Input Local Strategy to Modify the Milk Fatty Acid Profile of Dairy Cows. Animals, 9 (10), 803. doi: https://doi.org/10.3390/ani9100803
37. Kollathova, R., Varga, B., Ivanisova, E., Biro, D., Rolinec, M., Juracek, M. et al. (2019). Mineral Profile Analysis of Oilseeds and Their By-Products As Feeding Sources for Animal Nutrition. Slovak J. Anim. Sci, 52 (1), 9–15.
38. Adams, A. K., Best, T. M. (2002). The Role of Antioxidants in Exercise and Disease Prevention. The Physician and Sportsmedicine, 30 (5), 37–44. doi: https://doi.org/10.3810/psm.2002.05.281
39. Mirpoor, S. F., Giosafatto, C. V. L., Porta, R. (2021). Biorefining of seed oil cakes as industrial co-streams for production of innovative bioplastics. A review. Trends in Food Science & Technology, 109, 259–270. doi: https://doi.org/10.1016/j.tifs.2021.01.014
40. Rosa, P. M., Antoniassi, R., Freitas, S. C., Bizzo, H. R., Zanotto, D. L., Oliveira, M. F., Castiglion, V. B. R. (2009). Chemical composition of Brazilian sunflower varieties. Helia, 32 (50), 145–155. doi: https://doi.org/10.2298/hel0950145r
41. Oseyko, M., Romanovska, T., Shevchyk, V. (2020). Justification of the amino acid composition of sunflower proteins for dietary and functional products. Ukrainian Food Journal, 9 (2), 394–403. doi: https://doi.org/10.24263/2304-974x-2020-9-2-11
42. Garg, M., Sharma, A., Vats, S., Tiwari, V., Kumari, A., Mishra, V., Krishania, M. (2021). Vitamins in Cereals: A Critical Review of Content, Health Effects, Processing Losses, Bioaccessibility, Fortification, and Biofortification Strategies for Their Improvement. Frontiers in Nutrition, 8. doi: https://doi.org/10.3389/fnut.2021.586815

43. Guo, S., Ge, Y., Na Jom, K. (2017). A review of phytochemistry, metabolite changes, and medicinal uses of the common sunflower seed and sprouts (Helianthus annuus L.). Chemistry Central Journal, 11 (1). doi: https://doi.org/10.1186/s13065-017-0328-7
44. Vasudha, C., Sarla, L. (2021). Nutritional quality analysis of sunflower seed cake (SSC). The Pharma Innovation Journal, 10 (4), 720–728. Available at: https://www.thepharmajournal.com/archives/2021/vol10issue4/PartK/10-3-59-923.pdf
45. Lomascolo, A., Uzan-Boukhris, E., Sigoillot, J.-C., Fine, F. (2012). Rapeseed and sunflower meal: a review on biotechnology status and challenges. Applied Microbiology and Biotechnology, 95 (5), 1105–1114. doi: https://doi.org/10.1007/s00253-012-4250-6
46. Vaher, M., Matso, K., Levandi, T., Helmja, K., Kaljurand, M. (2010). Phenolic compounds and the antioxidant activity of the bran, flour and whole grain of different wheat varieties. Procedia Chemistry, 2 (1), 76–82. doi: https://doi.org/10.1016/j.proche.2009.12.013
47. Kohajdová, Z., Karovičová, J., Magala, M., Kuchtová, V. (2014). Effect of apple pomace powder addition on farinographic properties of wheat dough and biscuits quality. Chemical Papers, 68 (8). doi: https://doi.org/10.2478/s11696-014-0567-1
48. Alongi, M., Melchior, S., Anese, M. (2019). Reducing the glycemic index of short dough biscuits by using apple pomace as a functional ingredient. LWT, 100, 300–305. doi: https://doi.org/10.1016/j.lwt.2018.10.068
49. Srivastava, S. (2012). Preparation and Quality Evaluation of Flour and Biscuit from Sweet Potato. Journal of Food Processing & Technology, 03 (12). doi: https://doi.org/10.4172/2157-7110.1000192
50. Chauhan, A., Saxena, D. C., Singh, S. (2016). Physical, textural, and sensory characteristics of wheat and amaranth flour blend cookies. Cogent Food & Agriculture, 2 (1). doi: https://doi.org/10.1080/23311932.2015.1125773
51. Gandhi, A., Kotwaliwale, N., Kawalkar, J., Srivastav, D., Parihar, V., Nadh, P.R. (2021). Effect of incorporation of defatted soyflour on the quality of sweet biscuits. Journal of Food Science and Technology, 38 (5), 502–503.
52. Gallagher, E., Kenny, S., Arendt, E. K. (2005). Impact of dairy protein powders on biscuit quality. European Food Research and Technology, 221 (3-4), 237–243. doi: https://doi.org/10.1007/s00217-005-1140-5
53. Ahmad Bhat, M., Ahsan, H. (2016). Physico-Chemical Characteristics of Cookies Prepared with Tomato Pomace Powder. Journal of Food Processing & Technology, 07 (01). doi: https://doi.org/10.4172/2157-7110.1000543
54. de Toledo, N. M. V., Nunes, L. P., da Silva, P. P. M., Spoto, M. H. F., Canniatti-Brazaca, S. G. (2017). Influence of pineapple, apple and melon by-products on cookies: physicochemical and sensory aspects. International Journal of Food Science & Technology, 52 (5), 1185–1192. doi: https://doi.org/10.1111/ijfs.13383