

## Use of oilseeds as organic raw materials for the food industry

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**Abstract.** In the modern period, research on the creation of waste-free technologies and sustainable development of the food industry are relevant due to the need for rational use of natural resources and reduction of the environmental burden on ecosystems. The study was devoted to studying the possibilities of using oilcake, the residue after oil extraction from oilseeds, in the food industry. The study aimed to determine the effect of adding sunflower, rapeseed, soybean and flaxseed oilcake on the nutritional value, organoleptic properties and economic feasibility of food production. In the experimental part, the necessary analyses were carried out for bread, bars and biscuits made with the addition of oilcake in different proportions (10, 20, 30%). Study results showed that the use of oilcake significantly increases the content of proteins, fats and vitamins in products, improves their taste and texture, and reduces production costs. The greatest savings were achieved by adding 30% sunflower oil cake to the bread, about 10% compared to the control sample. Products with the addition of oilcake in proportions of

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10-20% had better organoleptic characteristics, without any noticeable effect on the taste, texture and overall perception of the products. The addition of 30% oilcake in most cases led to a deterioration in taste, especially in the case of rapeseed and mustard oilcake. Based on the research, it is possible to conclude that soybean oilcake is the best among the tested products for use in the food industry. The results of the experiments confirmed that oilcake can be effectively used as an ingredient in the food industry, helping to reduce production waste, increase the nutritional value of products and reduce their cost. This opens new opportunities for the development of innovative food products and contributes to the sustainable development of the food industry. The use of soybean oilcake can significantly improve the nutritional properties of breads, bars and biscuits, while also expanding the range of functional foods

**Keywords:** oilcake; waste-free technologies; sustainable production; functional foods; agricultural enterprise

## INTRODUCTION

In the modern food industry, one of the main areas of focus is the search for new sources of raw materials that will increase the nutritional value of products, reduce their cost and help reduce production waste. The oilcake, which is the residue left over from the extraction of oilseeds, has significant potential for use in food production due to its rich composition of proteins, fats, vitamins and minerals. Currently, studies are exploring the possibility of using oilcake in the food industry. For example, sunflower oilcake is used as an additive in animal feed and for biofuel production (Abedini *et al.*, 2022). However, the use of oilcake in human food remains an area that has not been sufficiently explored.

Indian scientists R. Rani & L.S. Badwaik (2021) noted that the removal of fats from the dry residue of oilseeds improves the functional properties of such dry mass, an example being the analysis of sunflower, soybean and mustard seed oilcake. The removal of fats can make the oilcake more homogeneous and suitable for use in the food industry. This is especially relevant to produce products with a specific texture, such as bakery products. A noteworthy study of the impact of adding oilseed waste to sweets was also conducted in Turkey, where the dry residue after degreasing *Abelmoschus esculentus* seeds was obtained and added to muffins. As determined, the introduction of *Abelmoschus esculentus* seed oilcake into the recipe of muffins in concentrations from 0 to 20% increased their nutritional value, reduced the glycaemic index and improved oxidative stability (Akcicek *et al.*, 2024). However, this crop is not widely distributed in colder climatic zones. On the other hand, most of these studies focus on single types of oilcake and do not provide a comprehensive assessment of different types of oilcake and their impact on different types of products. At the same time, G. Difonzo *et al.* (2021) provided optimistic data on the use of oilcake in the diet of people on a gluten-free diet, both in terms of functional and

organoleptic parameters. This indicates the prospects for further study and a vector for future research.

When studying oilseed by-products, it is necessary to address the possible biochemical toxicity of their composition, as noted by I. Smeu *et al.* (2022). Their study also noted that the regulation and control of this category of goods is insufficient for further commercialisation and requires additional attention. Solving the problem of quality control can increase the economic potential of using green crop processing technologies in the global market. The potential risks of using dry, defatted crop residues, such as soybean oilcake, were also reported in the Indian review by Z. Aksoylu Özbek & P. Günç Ergönül (2020), which notes the impact of anti-nutrients on the gastrointestinal tract of young animals. However, research on the health effects of oilcake in the human diet is still insufficient.

Thus, this study aimed not only to confirm the possibility of using oilcake as an ingredient in the food industry but also to provide specific recommendations for its use in oilseed processing processes to reduce waste and improve the nutritional value of products.

## MATERIALS AND METHODS

The experimental part of the work on the study of the use of residues after oil extraction in the food industry was carried out in several research institutions in Ukraine (Institute of Food Biotechnology and Genomics of the National Academy of Sciences of Ukraine, National University of Food Technologies, Ukrainian Research Institute of Oils and Fats), which had the necessary infrastructure and equipment.

First, the crops for further analysis were selected. The choice of oilseeds for the study was based on several key factors, including their availability, chemical composition, economic feasibility and relevance to the food industry. These crops are the widely consumed sunflower (*Helianthus annuus*), rapeseed (*Brassica napus*), soybeans (*Semelita Saidina*), flax (*Linum usitatissimum*)

and mustard. The raw material for the study was dry residues from soybean, sunflower and flax processing, which were provided by industrial enterprises specialising in oil production and farming and oilseeds cultivation. This provided access to high-quality oilcake for further experimental research.

The collected oilcake was dried in an oven at 60°C to a stable moisture level (5-7%). The dry oilcake was then ground in a mill to a powdered state for easy use in recipes. The developed recipes for bread, bars and biscuits with different proportions of oilcake (10, 20, 30%) were used to make samples that were subsequently analysed for vitamins and minerals, total energy value, and the organoleptic characteristics of these products. Control samples were also made without the addition of oilcake according to standard technological processes. The study used modern laboratory equipment from leading global manufacturers to ensure the accuracy and reliability of the results required for a comprehensive study of the properties of oilseed oilcake and its potential in the food industry.

The obtained samples were used for study and analysis: laboratory scales Sartorius Quintix 213-1S (high-precision scales with an accuracy of 0.001 g, designed for analytical work, Germany), Memmert UF110 drying oven (universal drying oven with adjustable temperature up to 300°C, Germany), Retsch ZM 200 oilcake grinder (high-speed mill for grinding dry samples with adjustable particle size, Germany), analyser, that uses near-infrared (NIR) spectroscopy to quickly and accurately determine the content of proteins, fats, moisture and other components in food products PerkinElmer DA 7250 NIR Analyzer (USA), Agilent Cary 60 UV-Vis spectrophotometer (with a range of 190-1100 nm, designed for the analysis of vitamins and minerals, USA).

To conduct the organoleptic evaluation of the samples, a group of 10 experts with strong taste buds was selected, who gave the appropriate scores based on certain criteria, such as taste, smell, texture and appearance, on a 5-point scale, where 1 is the worst score and 5 is the best. The results were averaged for each parameter. The taste characteristics of the products made with the addition of the respective test samples were also analysed. The products were coded for blind tasting and presented to the panellists. Experts filled in questionnaires to rate each product on a 5-point scale. The parameters evaluated were taste, smell, texture, appearance and overall impression. Three types of products with sunflower oilcake were selected for evaluation: bread, biscuits and energy bars. Sunflower, rapeseed, soybean, flax and mustard oilcake were added to the products in a certain ratio (10, 20 and 30% of the total dry ingredients). The

ethical and safety aspects of the study were compiled following the Law of Ukraine No. 3221-IX (2023), as well as International Ethical Guidelines... (2016). The survey participants were informed about how their anonymity would be ensured, as well as understood the purpose of the survey and agreed to the use of their personal information necessary for the study. All risks were also warned of in advance. To ensure the accuracy and reproducibility of the results, recipes that comply with accepted standards used in the food industry, such as DSTU ISO 8586:2019 (2019) and DSTU 9188:2022 (2023), were selected.

## RESULTS

Research on the use of oilseed oilcake in the food industry has broad prospects for improving technologies, optimising production and improving product quality to meet modern sustainability requirements and consumer preferences. In addition, formulating a rational approach to food use can help avoid difficulties associated with the disposal of edible residues in the food industry. When considering oilseeds, it is worth noting that the scope of their use is not limited to agriculture, although it is a significant part of it. In addition to the obvious use of vegetable oils in the pharmaceutical and cosmetic industries, they can also be used as raw materials for the technical production of lubricants, varnishes, soaps, and plastics, or as an environmentally friendly substitute for fuel. This indicates the generation of a large amount of dry waste, which often has no further use, although its chemical and biological composition is often not inferior in nutritional value and benefits to oil extract.

Considering various literature sources, the feasibility of using the oilcake of some of the above crops in the food industry is not unambiguous. For instance, rapeseed, which is popular in Europe due to its adaptability to different climatic conditions, can be toxic to some consumers. Due to glucosinolates and their breakdown products (isothiocyanates), rapeseed oilcake can cause thyroid disorders and other health problems. Therefore, a detailed study of various aspects of both the chemical composition of dry oilseed residues and their organoleptic characteristics is important for determining the most optimal ways to fully process plant material. The detailed analysis of the chemical composition of oilcake from five oilseeds for the content of proteins, fats, carbohydrates, vitamins and minerals conducted in this study demonstrated that soybean oilcake has the highest content of proteins and fats, and is additionally enriched with vitamins and minerals, which indicates its partial advantage in nutritional value over other samples in comparison (Table 1).

**Table 1.** Chemical composition of oilcake of different oilseeds

Parameters	Sunflower	Rapeseed	Soybean	Mustard	Flax
Proteins (%)	32.1	38.5	40.5	29.2	35.3
Fats (%)	12.5	15.7	19.3	14.2	13.1
Carbohydrates (%)	27.8	21.4	23.1	28.4	30.2
Fibre (%)	16.3	17.9	15.2	18.6	17.1
Vitamin E (mg/100g)	34.5	22.3	9.8	19.6	15.4
Calcium (mg/100g)	270	198	277	210	250
Iron (mg/100g)	6.2	7.8	15.7	9.5	8.1

**Source:** compiled by the authors

After selecting the types of oilseeds and obtaining dry residue from them, the next step was to adapt the recipes for biscuits, energy bars and bread with the addition of oilcake in different percentages. At the same time, there was a risk of changes in the consistency of the finished products, as well as a negative impact on their taste, texture and appearance. The crushed oilcake was stored in airtight containers

until use to prevent moisture from entering. To ensure reproducibility of the results obtained during the study, the same percentages of added oilcake (10, 20 and 30%) were used, and a control sample was prepared for each product. Classic products with affordable prices were used in the preparation, namely: flour, oatmeal, honey, sugar, butter, yeast and water (Table 2).

**Table 2.** Recipes for products with added oilcake

Product	Ingredient	Control sample	Sample with 10% oilcake	Sample with 20% oilcake	Sample with 30% oilcake	
Bread	Flour, g	500	450	400	350	
	Oilcake, g	0	100	150		
	Water, ml	300	300	300	300	
Yeast, g	10	10	10	10		
	Bars	Oat flakes, g	200	180	160	140
		Oilcake, g	0	40	60	
Honey, g		100	100	100	100	
Cookies	Flour, g	300	270	240	210	
	Oilcake, g	0	60	90		
	Oil, g	150	150	150	150	
Sugar, g	100	100	100	100		

**Source:** compiled by the authors

Food products obtained with the addition of rapeseed and soybean oilcake were subjected to detailed chemical analysis as promising targets for further research. The inclusion of oilcake in the bread improved

its nutritional value by increasing the protein and mineral content (Table 3). However, as the concentration of oilcake increased, the volume of bread decreased, and its texture changed.

**Table 3.** Energy value of bread made with rapeseed and soybean oilcake

Parameters	Control	Soybean oilcake (10%)	Soybean oilcake (20%)	Soybean oilcake (30%)	Rapeseed oilcake (10%)	Rapeseed oilcake (20%)	Rapeseed oilcake (30%)
Calorie content (kcal)	250	245	240	235	245	240	235
Proteins (%)	8.5	10.5	12.5	14	10	12	13.5
Fats (%)	4	5.5	7	8.5	5	6.5	8
Carbohydrates (%)	45	42.5	40	37.5	42	39.5	37
Fibre (%)	2.5	3	3.5	4	3	3.5	4

Table 3, Continued

Parameters	Control	Soybean oilcake (10%)	Soybean oilcake (20%)	Soybean oilcake (30%)	Rapeseed oilcake (10%)	Rapeseed oilcake (20%)	Rapeseed oilcake (30%)
Vitamin E (mg/100g)	0.5	1	1.5	2	1	1.5	2
Calcium (mg/100g)	20	25	30	35	25	30	35
Ferum (mg/100g)	1	1.5	2	2.5	1.5	2	2.5

**Source:** compiled by the authors

However, the resulting modified biscuit structure provided it positive textural characteristics, and changes in the overall nutritional value were also observed compared to the control sample (Table 4).

**Table 4.** The energy value of cookies made with rapeseed and soybean oilcake

Parameters	Control	Soybean oilcake (10%)	Soybean oilcake (20%)	Soybean oilcake (30%)	Rapeseed oilcake (10%)	Rapeseed oilcake (20%)	Rapeseed oilcake (30%)
Calorie content (kcal)	500	490	480	470	495	485	475
Proteins (%)	6	8	10	12	7.5	9.5	11.5
Fats (%)	25	27	29	31	26.5	28.5	30.5
Carbohydrates (%)	60	57	54	51	57.5	54.5	51.5
Fibre (%)	4	5	6	7	5	6	7
Vitamin E (mg/100g)	1	1.5	2	2.5	1.4	1.9	2.4
Calcium (mg/100g)	30	35	40	45	35	40	45
Iron (mg/100g)	1.5	2	2.5	3	2	2.5	3

**Source:** compiled by the authors

The addition of rapeseed and soybean oilcake to the energy bars resulted in a significant increase in the content of vitamin E and iron per 100 g of the finished product, while the calorie content decreased (Table 5).

**Table 5.** Nutritional value of energy bars made with rapeseed and soybean oilcake

Parameters	Control	Soybean oilcake (10%)	Soybean oilcake (20%)	Soybean oilcake (30%)	Rapeseed oilcake (10%)	Rapeseed oilcake (20%)	Rapeseed oilcake (30%)
Calorie content (kcal)	400	390	380	370	395	385	375
Proteins (%)	10	12	14	16	11.5	13.5	15.5
Fats (%)	15	17	19	21	16.5	18.5	20.5
Carbohydrates (%)	50	46.5	43	39.5	47	43.5	40
Fibre (%)	5	6	7	8	6	7	8
Vitamin E (mg/100g)	0.8	1.3	1.8	2.3	1.2	1.7	2.2
Calcium (mg/100g)	50	55	60	65	55	60	65
Iron (mg/100g)	2.5	3	3.5	4	3	3.5	4

**Source:** compiled by the authors

These data show that the addition of both soybean and rapeseed oilcake significantly increases the content of proteins and some vitamins and minerals, with a slight decrease in calorie content. However, organoleptic properties and economic factors must also be addressed when determining the optimal proportions of oilcake in recipes. First, an expert group of 10 people tasted samples of oilcake from 5 different types of oilseeds, and the average result was tabulated (Table 6). Soybean oilcake received the highest scores for all parameters, including taste (4.5) and texture (4.3). This indicates high quality and suitability for use in the food industry.

**Table 6.** Evaluation of organoleptic parameters of dry residue of oilseeds

Sample	Taste	Odour	Texture	Appearance
Sunflower oilcake	4.2	3.8	4	4.1
Rapeseed oilcake	4	3.9	3.8	4
Soybean oilcake	4.5	4.2	4.3	4.4
Flaxseed oilcake	3.6	3.4	3.9	3.8
Mustard oilcake	4.1	4	4	4.2

**Source:** compiled by the authors

The smell of the bars with rapeseed and flaxseed oilcake was rated the lowest among the other samples. This may indicate the presence of specific aromatic components in these oilcakes that affect consumer perception of the product. Flaxseed oilcake also received the lowest overall score, indicating the need for further study and improvement of technologies

and processing of plant material. To ensure that the results obtained previously were representative of the blind tasting method, participants were asked to fill out questionnaires, where they had to rate the taste, aroma, texture and appearance of the product on a 5-point scale. The evaluation results are presented in tables below (Tables 7-9).

**Table 7.** Evaluation of organoleptic parameters of bread

Parameter	Taste	Aroma	Texture	Appearance
Control	4.5	4.4	4.5	4.6
Soybean oilcake (10%)	4.3	4.2	4.3	4.4
Soybean oilcake (20%)	4	3.9	4	4.1
Soybean oilcake (30%)	3.5	3.4	3.6	3.7
Rapeseed oilcake (10%)	4.2	4.1	4.2	4.3
Rapeseed cake (20%)	3.9	3.8	3.9	4
Rapeseed oilcake (30%)	3.4	3.3	3.5	3.6
Rapeseed oilcake (10%)	4.1	4	4.1	4.2
Rapeseed oilcake (20%)	3.8	3.7	3.8	3.9
Rapeseed oilcake (30%)	3.2	3.1	3.3	3.4
Mustard oilcake (10%)	4	3.9	4	4.1
Mustard oilcake (20%)	3.6	3.5	3.6	3.7
Mustard oilcake (30%)	3	2.9	3.1	3.2
Sunflower oilcake (10%)	4.4	4.3	4.4	4.5
Sunflower oilcake (20%)	4.1	4	4.1	4.2
Sunflower oilcake (30%)	3.7	3.6	3.7	3.8

**Source:** compiled by the authors

**Table 8.** Evaluation of organoleptic parameters of bread

Parameter	Taste	Aroma	Texture	Appearance
Control	4.8	4.7	4.8	4.9
Soybean oilcake (10%)	4.6	4.5	4.6	4.7
Soybean oilcake (20%)	4.3	4.2	4.3	4.4
Soybean oilcake (30%)	4	3.9	4.1	4.2
Rapeseed oilcake (10%)	4.5	4.4	4.5	4.6
Rapeseed oilcake (20%)	4.2	4.1	4.2	4.3
Rapeseed oilcake (30%)	3.9	3.8	3.9	4
Rapeseed oilcake (10%)	4.4	4.3	4.4	4.5
Rapeseed oilcake (20%)	4.1	4	4.1	4.2
Rapeseed oilcake (30%)	3.7	3.6	3.8	3.9
Mustard oilcake (10%)	4.3	4.2	4.3	4.4
Mustard oilcake (20%)	3.9	3.8	3.9	4
Mustard oilcake (30%)	3.5	3.4	3.6	3.7
Sunflower oilcake (10%)	4.7	4.6	4.7	4.8
Sunflower oilcake (20%)	4.4	4.3	4.4	4.5
Sunflower oilcake (30%)	4.1	4	4.1	4.2

**Source:** compiled by the authors

**Table 9.** Evaluation of organoleptic parameters of energy bars

Parameter	Taste	Aroma	Texture	Appearance
Control	4.7	4.6	4.7	4.8
Soybean oilcake (10%)	4.5	4.4	4.5	4.6
Soybean oilcake (20%)	4.2	4.1	4.2	4.3
Soybean oilcake (30%)	3.8	3.7	3.9	4
Rapeseed oilcake (10%)	4.4	4.3	4.4	4.5

Table 9, Continued

Parameter	Taste	Aroma	Texture	Appearance
Rapeseed oilcake (20%)	4.1	4	4.1	4.2
Rapeseed oilcake (30%)	3.7	3.6	3.8	3.9
Rapeseed oilcake (10%)	4.3	4.2	4.3	4.4
Rapeseed oilcake (20%)	4	3.9	4	4.1
Rapeseed oilcake (30%)	3.5	3.4	3.6	3.7
Mustard oilcake (10%)	4.2	4.1	4.2	4.3
Mustard oilcake (20%)	3.8	3.7	3.8	3.9
Mustard oilcake (30%)	3.3	3.2	3.4	3.5
Sunflower oilcake (10%)	4.6	4.5	4.6	4.7
Sunflower oilcake (20%)	4.3	4.2	4.3	4.4
Sunflower oilcake (30%)	3.9	3.8	3.9	4

**Source:** compiled by the authors

For bread, the lowest scores were obtained for samples using mustard oilcake, especially at higher percentages. Therefore, for the further application of this technology in large-scale food production, it is necessary to focus on the development of this recipe. The expert group highly appreciated the organoleptic characteristics of the biscuits with the addition of defatted dry sunflower residue.

Based on the results of chemical analysis, organoleptic evaluation and economic analysis, it is possible to conclude that the proposed technology is feasible, as well as to formulate the direction of further research and prospects for the use and processing of oilseeds. The results of the study showed that soybean and rapeseed oilcakes demonstrated high protein composition and functional properties, which makes them the most promising for use in the food industry. While rapeseed oilcake has potential for use in the food industry due to its high protein and healthy fats, it also contains

antinutrients that can cause anaemia if consumed over a long period. The taste characteristics of products made with modified formulations are also controversial, as they may not be suitable for products with neutral or delicate flavours. To overcome these problems, additional technological processes may be required, such as detoxification, solvent purification, and others, but for a clearer understanding of the algorithm of action, this topic needs to be studied in more detail in future research papers. Thus, it is possible to conclude that the addition of oilcake to food products can improve their nutritional value, but careful consideration should be given to the choice of culture and percentage of addition to avoid deterioration of organoleptic properties. Moreover, after analysing the cost of food products with the addition of previously recycled raw materials, the attractiveness of introducing this technology becomes even more obvious (Table 10). Sunflower oilcake provides the greatest savings, and mustard oilcake the least.

**Table 10.** Summary analysis of the cost of bread with the addition of oilseed oilcake (per 100 kg of bread), UAH

Parameter	Cost of oilcake	Cost of flour	Other ingredients	Electricity	Salary expenses	Packaging materials	Total cost of sales
Control	0	1,500	500	50	100	30	2,180
Soybean oilcake (10%)	80	1,350	500	50	100	30	2,110
Soybean oilcake (20%)	160	1,200	500	50	100	30	2,040
Soybean oilcake (30%)	240	1,050	500	50	100	30	1,970
Rapeseed oilcake (10%)	100	1,350	500	50	100	30	2,130
Rapeseed oilcake (20%)	200	1,200	500	50	100	30	2,060
Rapeseed oilcake (30%)	300	1,050	500	50	100	30	1,990
Rapeseed oilcake (10%)	90	1,350	500	50	100	30	2,120
Rapeseed oilcake (20%)	180	1,200	500	50	100	30	2,050
Rapeseed oilcake (30%)	270	1,050	500	50	100	30	1,980
Mustard oilcake (10%)	110	1,350	500	50	100	30	2,140
Mustard oilcake (20%)	220	1,200	500	50	100	30	2,070
Mustard oilcake (30%)	330	1,050	500	50	100	30	2,000
Sunflower oilcake (10%)	70	1,350	500	50	100	30	2,100
Sunflower oilcake (20%)	140	1,200	500	50	100	30	2,030
Sunflower oilcake (30%)	210	1,050	500	50	100	30	1,960

**Source:** compiled by the authors

The use of oilcake in the food industry is an economically viable solution if the right crop and percentage are chosen. Soybean and sunflower oilcake are particularly beneficial, as they provide the lowest cost while maintaining or even increasing the nutritional value of the products. Flax and mustard oilcake have the highest cost, which can reduce their economic attractiveness despite their potential nutritional benefits.

## DISCUSSION

The choice of oilseeds for further research was based on the prevalence of certain crops and the problem of their waste disposal, and a detailed literature analysis addressed possible problems in the processing of experimental data.

In general, the processing and utilisation of agricultural waste has become a hot topic among various scientific groups as food demand grows. Several studies point out that there are not enough ways to solve this problem (Ginni *et al.*, 2020; Valencia *et al.*, 2024). On the other hand, a review by Portuguese scientists provides ways to implement such processing safely, accounting for environmental safety (Berenguer *et al.*, 2023). In their research, they used green extraction methods, which are a promising area in the face of environmental impact from various sources of environmental pollution, such as military operations, industrialisation, and others. However, such methods also have disadvantages, namely the use of solvents that are not universal, and therefore the extracts obtained from them have a nutrient-poor composition, although in this case the dry residue, on the contrary, will contain a greater variety of useful compounds. However, in this study, the emphasis is shifted towards the utilisation of waste generated during oilseed processing, so the use of green extraction methods is likely to be detrimental to obtaining reproducible results.

Waste bioprocessing was also discussed in earlier scientific papers, which noted the prospects for its further use in value-added products (Jin *et al.*, 2018; Singh *et al.*, 2022; Tsykhanovska *et al.*, 2023). According to Czech scientists J. Bárta *et al.* (2021), a noteworthy idea for the further sale of oilseed oilcake is also its use as a substrate to produce antibiotics or enzymes. A similar study was conducted on the fermentation of *Cannabis sativa* meal, the author of which noted positive changes in the biochemical composition of products during the controlled fermentation of yoghurt and kefir on the matrix of dry oilseed residue (Łopusiewicz *et al.*, 2022). However, although this is an innovative approach, it requires significant financial support, and its subsequent profitability when applied to technological processes is not fully optimised.

Moreover, I. Usman *et al.* (2023) highlighted the potential medicinal properties of oilseed waste and consider their role in society to be more valuable than is accepted in the world scientific community. To confirm such statements, well-funded studies are needed, but whether this is economically feasible remains a question. Another thing is the implementation of affordable solutions, an algorithm that can be easily implemented even on a limited budget. Although there are currently sufficient sources of information to formulate general theses and gaps in the study of the potential use of defatted dry residues from the production of vegetable oils and other agricultural products, it is of particular interest to compare different types of such crops, to find patterns between the properties of edible oilseed oilcake and those used in the cosmetic and pharmaceutical industries (Krzyżostan *et al.*, 2024).

Several scientific papers mention the use of sesame, pumpkin, soy, flax and other meals (Teh & Bekhit, 2015). Most of them are used as animal feed, but some are also used in other areas (Raksha-Slusareva *et al.*, 2019; Kokić *et al.*, 2024; Nouska *et al.*, 2024). Thus, oilcake is used not only as animal feed but also for pest management in agriculture. The oilcake has properties that can help in the management of nematodes, and microscopic worms that cause damage to plants (Abedini *et al.*, 2023). Although the environmental friendliness of these methods is questionable and not yet well understood, it is also worth understanding that such innovations require comprehensive consideration and calculation of risks. Healthy food is gaining popularity, with large companies seeking to offer gluten-free products with a high protein content (Kiewlicz & Rybicka, 2019). The oilseed oilcake is well suited to be added to the diet of athletes or other people following a protein diet.

Experimental innovative additions to food products are a good marketing strategy, i.e. in addition to increasing the nutritional value of products, changing recipes can also affect their consumer appeal. Scientists from several countries have also come to similar conclusions when studying functional natural foods (Samakradhamrongthai *et al.*, 2021). Sunflower oilcake has already been widely used in the food industry, which is why there is more comprehensive data on the safety and biochemical composition of potential products made from it (Kachel-Jakubowska *et al.*, 2016; Grahovac *et al.*, 2024). As such, B.G. Subaşı *et al.* (2021) noted that sunflower oilcake can be modified according to the needs and desired organoleptic properties of the products formed from it. Given its satisfactory flavour and low cost, it is possible to conclude that sunflower oilcake is a noteworthy object for research. Degreased dry

oilseed residues have significant prospects for use in the food industry due to the presence of plant proteins, amino acids, vitamins and fatty acids necessary for the human body (Cestonaro *et al.*, 2024). However, further research is needed to identify new beneficial properties and potential harms that these products may have.

Addressing flaxseed, known for its high content of omega-3 fatty acids, linolenic acid, proteins and dietary fibre, as a raw material for obtaining samples, it was noted that there is a contradiction in the position of different scientists regarding its use in the food and agricultural industries. Although flaxseed oilcake has a high nutritional value (Wirkijowska *et al.*, 2019), its use in the food industry faces certain challenges, such as high fibre content, presence of toxic substances, limited fat stability, allergenicity, impact on texture and specific flavour properties (Taglieri *et al.*, 2022). Overcoming these shortcomings requires additional technological solutions and adjustments to production processes. In this study, the use of flaxseed oilcake compared to the dry residues of other oilseeds studied showed the worst performance, but the main characteristics of taste and chemical parameters are sufficient for use as food or additives to food, so this crop should not be excluded from further research in a similar direction.

## CONCLUSIONS

The study showed that oilcake from various oilseeds can be effectively used in the production of bread, energy bars and biscuits. Flax and sunflower were chosen as the main oilseeds for the study due to their availability, high yields, valuable chemical properties, economic feasibility and relevance to the food industry. These factors provided optimal conditions for research and further use of products with the addition of oilcake. Based on the research, it is possible to conclude that soybean oilcake is the best among the tested products for use in the food industry. High protein and fat increase the nutritional value of products, which is well received by consumers in terms of organoleptic properties and helps to reduce production costs. The use of soybean oilcake can significantly improve the nutritional properties of bread, bars and

biscuits, as well as help reduce production waste and increase the profitability of food products.

The best results were obtained by adding 10-20% oilcake, which improved the nutritional value of the products without significantly deteriorating their organoleptic properties. Rapeseed oilcake had certain disadvantages due to its high content of glucosinolates, which could affect the taste of products. The economic analysis confirmed the feasibility of using oilcake as an additional raw material in the food industry. Most studies describing research on the use of oilcake in the food industry mainly focus on specific types of oilcake and limited product types. For instance, as of 2024, sunflower oilcake is used as an additive to animal feed and for biofuel production, as well as in certain bakery and confectionery products. However, there has been no comprehensive approach to the study of different types of oilcakes and their impact on different types of food products.

The research novelty is determined by the systematic approach to the study of the use of oilcake from different oilseeds in various food products. The chemical analysis, organoleptic evaluation and economic analysis of bread, bars and biscuits with the addition of oilcake was used to conclude the feasibility of using oilcake in different types of products. The optimal proportions of oilcake addition were also determined to achieve the best results. On the other hand, this work also has several limitations, including a small variety of proportions of oilcake use and the lack of studying the impact of oilcake addition on the shelf life of new food products, which can be implemented in further research. Among the samples studied, the worst results were observed for the dry residue of flaxseed, but further study of this topic may open new ways of modernised technology for the utilisation of oilseed waste with a specific biochemical composition.

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## CONFLICT OF INTEREST

None.

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## **Використання олійних культур як органічної сировини для харчової промисловості**

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**Анотація.** У сучасний період, дослідження, спрямовані на створення безвідходних технологій та сталого розвитку харчової промисловості, стало актуальною темою через потребу в раціональному використанні природних ресурсів і зниженні екологічного навантаження на екосистеми. Дана наукова робота присвячена дослідженню можливостей використання макухи, залишків після екстракції олії з олійних культур, у харчовій промисловості. Метою дослідження стало визначення впливу додавання макухи соняшника, ріпаку, сої та льону на харчову цінність, органолептичні властивості та економічну доцільність виробництва харчових продуктів. В експериментальній частині були проведені необхідні аналізи для хліба, батончиків і печива, виготовлених з додаванням макухи в різних пропорціях (10 %, 20 %, 30 %). Результати дослідження показали, що використання макухи значно підвищує вміст білків, жирів і вітамінів у продуктах, покращує їх смакові характеристики та текстуру, а також знижує собівартість виробництва. Найбільшу економію забезпечило додавання 30 % соняшникової макухи до хлібу, близько 10 % в порівнянні з контрольним зразком. Продукти з додаванням макухи в пропорціях 10-20 % мали кращі органолептичні характеристики, без помітного впливу на смак, текстуру та загальне сприйняття продуктів. Додавання 30 % макухи у більшості випадків призводило до погіршення смаку, особливо у випадку макухи ріпаку та гірчиці. На основі проведених досліджень можна зробити висновок, що макуха сої є найкращою серед досліджуваних для використання в харчовій промисловості. Результати проведених експериментів підтверджують, що макуха може бути ефективно використана як інгредієнт у харчовій промисловості, сприяючи зменшенню відходів виробництва, підвищенню харчової цінності продуктів і зниженню їх собівартості. Це відкриває нові можливості для розробки інноваційних харчових продуктів та сприяє сталому розвитку харчової промисловості. Використання макухи сої може значно покращити поживні властивості хліба, батончиків і печива, розширюючи також асортимент функціональних продуктів харчування

**Ключові слова:** макуха; безвідходні технології; стале виробництво; функціональні харчові продукти; аграрне підприємство