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Prospects of the "Green" Technologies of the Complex Processing Of Sunflower Seeds.

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ABSTRACT

The paper is dedicated to the scientific and practical substantiation of new approaches to the processing of sunflower seeds, based on the use of "green technologies". It provides a brief analysis of existing and prospective methods of the processing of sunflower seeds, on the basis of which are source-saving technology of complex processing is proposed, which makes it possible to obtain innovativeprotein and lipid products.It was shown that the proposed technology has a reduced impact on the lipid part of a sunflower kernel and makes it possibleto preserve a maximum amount of lipid-solublephysiologically valuable nutrients in the resulting oil. The obtained phospholipid complex consists primarily of phosphatidylcholines, while other groups of phospholipids are mainly represented in a native hydratable form. The paper presents the data, which characterize the amino acid composition ofthe obtainedprotein products, the analysis of which showed that the developed technology does not result in a significant change in the native amino acid composition of the protein part of sunflower kernels. On the basis of the analysis of quality and safety performance of test samples of oil, extruded kernel, food protein meal andfractionated lecithin, produced at pilot plants, the authors draw the conclusion of the compliance of theobtainedproductswith the requirements of the standards, as well as the possibility of their use in food technologies as functional ingredients.

Keywords: husk-free sunflower kernel, extrusion, extraction, bio-solvent, vegetable protein, vegetable oil, phospholipids.

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INTRODUCTION

Currently “green” technologies form the basis of the implementationof the priority strategy of ecologically-oriented growth in developed countries. In terms of the level of the development of "green" technologies in many fields Russia lags far behind most developed countries, which is evidenced by the proportion of patents, amounting to less than 1% of the total number of patents for the developments in this area in the world[1-2].

General criteria for qualifying a technology as a "green" technology include the implementation of the following principles: the use of renewable energy resources; maximum utilization of the resources of raw materials; innovation contributing to the achievement of a set of goals within the same managed process; minimization of the harmful effects on human beings and the environment [3]. Thus, the benefits of "green" technologies are reducing pollution, improving the health of the population, saving resources, improving the efficiency of production, and hence the competitiveness of manufactured products [2].

The main industrial methods of processing sunflower seeds are pressing and extraction [4-5].

Significant disadvantagesof pressing include intense thermal effect on sunflower seeds, which results in a significant change in the composition and properties of both lipid and protein parts of seeds, as well as the impossibility of complete separation of proteins and lipids. Besides, the design features of the existing presses allow using only appropriately prepared seeds as feedstock. Such preparation should ensure the opening of lipid-containing cellular structures and giving to the material (oil seed meal) structural and rheological properties, characterized by specified plasticity and elasticity. In the development of these propertiesan important role is played by the use of hard modes of wet-heat treatment, having a denaturating effect on protein structures, as well as by the presence of residual huskness [6-7].

It should be emphasized that the processing of husk-free sunflower kernel, especially ofhigh-oleic varieties, is not effective in case of using conventional pressing equipment.

The analysis of scientific literature and patent information showed that an effective direction of the processing of husk-free sunflower kernel with the purpose of obtaining not only oil, but also food protein and lecithin, is the extraction of specially prepared kernel based on the principles of "green technologies" [3, 7-10]. A promising method of the opening ofcellular structures and the transformation of the material into a capillary-porous body is extrusion [11-13].

In contrast with the conventional technology of obtaining oil using the method of pressing with the preliminary wet-heat treatment of oil seed meal, where the raw material is subjected to intense multiple heating, in case of using the extrusion technology the processed material is subjected to the influence of high temperatures duringa short period of time (5-6 seconds). The extrusion technology impliesthesimultaneous combined impact of moisture, heat and mechanical stresses of various kind on the processed material. Rapid pressure drop at the moment of thedischarge of the material from the extruder, which reaches 40 Bar, contributes to the destruction of lipid-containing structures [14]. This ensures obtaining the material with preset structural and rheological and physicochemical properties. Given the complex nature of the impact on the raw material, an extruder is regarded by many researchers as a universal reactor [15-16].

It should be noted that for sunflower seeds, which are a high-oleic material, direct extraction of extruded material will not be effective due to obtaining a considerable amount of miscella, which has to be distilled. On the other hand, preliminary removal ofoil in the extruder also proves to be problematic due to the high viscosity of the material, which will result in developing high temperatures due to friction and lead to the deep denaturation of protein.

One of the methods, making is possible to reduce the viscosity of the material and to ensure the extraction of oil from oilseeds, is the impregnation of oil-bearing material with organic solvents or gases in above-critical state [17-20].

For example, in [21] it is shown that adding 20-25% ofhydrocarbon solvent to corn germs before pressing, followed by heating to 60-70 °C for 35-40 minutes, made it possible to considerably increase oil

output. However, the use of hydrocarbon solvent or other similar solvents, characterized by neurotoxicity, doesn't comply with the principles of "green technologies", and also causes the need in a complete distillation of the resulting oil and oil meal, which is accompanied by the profound changes of the natural properties of oilseeds [22]. Proceeding from the technological feasibility, impregnation and subsequent extraction should be carried out using one and the same solvent.

Currently there is a renewed interest in using polar solvents, such as water and low molecular weight alcohols, as extractants of lipids from oil-containing raw material [8-10, 23-31].

Another well-known bio-solvent, complying with the principles of "green" technologies and produced on an industrial scale, is ethyl alcohol or ethanol [24].

Ethanol is obtained by the bioconversion of renewable agricultural raw materials, most commonly sugar beet and cereals [8]. Despite the fact that ethanol is a fire hazardous and potentially explosive substance, it is widely used in food technologies. This is due to its availability, chemical purity, relative safety and low cost. Besides, complete removal of the extractant, which is compulsory in case of usingpetrochemical solvents, is not necessary in case of using ethanol, as it doesn't affect the quality and safety of the end product.
It should be noted that ethanol, along with water and carbon dioxide in above-critical state, is classified among the materials, the use of which in food technology, according to the EU directive, does not get in the way ofobtainingend products classified as "natural" or "organic food" [9].

The use of ethanol as an extractant of oilseeds has been practiced for a long time [32-35].

In Russia the works on the extraction of oilseeds, mainly soybeans, using ethanol, were actively carried out at the All-Union Scientific Research Institute of Fats in 1960s and 1970s [34-35].

Currently, both in the CIS countries and countries outside the former Soviet Union there is a renewed interestin the use of ethanol as a selective extractant of oilseeds. This is evidenced by the publications of scientific research, most of which has been carried out during the last 5 years [7-8, 10, 24-25, 36-44]. The analysis of these studies suggests that the interests of foreign scientists in the field of oilseed extraction using ethanol are focused on studying the balance in oil-ethanol-watersystems at different temperatures, as well as on the selective extraction of associated lipids and minor components of raw materials. Meanwhile, the authors of the published works, devoted to the study of selective extraction of associated lipids, focus on the extraction of free fatty acids and virtually don't address the issues of redistribution and extraction of phospholipids, as well as their impact on the process of extracting.

In the CIS countries, the most active research in the field of the use of ethanol as an extractant of oilseeds is carried out by Ukrainian researchers of the Ukrainian Scientific Research Institute of Oils and Fats and the National Technical University "Kharkiv Polytechnic Institute"[41-44].

When using ethanol, the main problem is high residual oil content in the oil meal due to the low solubility of neutral lipids in ethanol and its insufficient penetrating capacity. Accordingly, the main tasks to be solved are the following: optimal preparation of husk-free sunflower seeds for the extraction by ethanol using extrusion; organisation of the process of ethanol extraction in relation to the obtained extrudate; efficient separation of the system "ethanol-water-oil-phospholipids."

MATERIALS AND METHODS

As objects of study the authors used a mixture of sunflower seed samples of domestic breeding, including varieties and hybrids (varieties Rodnik R-453, Master, Buzuluk; hybrids Mercury, Melint, Altair), taken in equal shares. The seeds were purchased from the FSBSI "All-Russian Research Institute of Oil Crops named after V.S. Pustovoit".

In terms of safety performance the studied samples of sunflower seeds complied with the requirements of TR TS 015/2011 "On the safety of grain."

The content of crude fat and moisture in seeds was determined using the NMR-relaxometer Minispec MQ-20 (Bruker, Germany) according to GOST 8.597. The mass fraction of protein was determined using the systems of quantitative identification of N_2 protein DKL8(VELP SCIENTIFICA, Italy) according to GOST 13496.4. The biological value of the protein complex was studied by the experimental determination of amino acid composition using capillary electrophoresis system "KAPEL'-105 M", manufactured by Lyumeks (Russia) [45].The relative biological value (RBV) of protein products was determined by the express-method using infusoria Tetrahymenapyriformis in accordance with the recommendations of A.D. Ignatyev and his co-authors [46].The mass fraction of fibre was determined using the fibre analysis plant FIBRETHERM FT12 (Gerhardt, Germany) according to GOST 31675. The mass fraction offat in the protein complex was determined using the automaticsolid-liquid extraction plant SOXTHERM SOX414a (Gerhardt, Germany) according to the user manual and GOST 10857.

Free and bound lipids were isolated from sunflower seed kernels crushed in the laboratory mill using the method of exhaustive extraction with chloroform-methanol mixture at a ratio of 9:1 at a temperature of 20°C. The phospholipid complex was isolated from the total amount of lipids using the method of dialysis against hexane [47].

The composition of fatty acids of the lipid complex was determined according to GOST R 51486 using the gas chromatograph Crystal-5000 (CJSC SCB "Khromatek", Russia), column SOLGEL-WAX30 m × 0.32 mm ID SOLGEL-WAX × 0.5 µm. The mass fraction of phospholipids was determined by thecolorimetric method according to GOST 31753.

The composition of associatedlipids was studied by the method ofthin layer chromatography, followed by densitometry [48] and HELC using the liquid chromatograph Agilent 1260 Infinity (Agilent Technology, USA),column LiChrospher 100250 x 4 mm, Diol (5 µm) according to the procedures of [49-50].The quantitative composition of carotenoids and chlorophylls was determined using the tintometer Lovibond (The Tintometer Ltd., United Kingdom) according to the recommended practices (user guide PFX 995/950).The content of tocopherols was determined according to GOST EN 12822.

The content of chlorogenic acid was determined by the method of LC using the liquid chromatograph Agilent 1260 Infinity (Agilent Technology, USA), column EcLipse Plus C185 µm (4.6 x 250) according to the method of [51]. The preparation of samples was carried out in accordance with the recommendations of [52].

The structural analysis of sunflower seeds was carried out by scanning electron microscopyusing the SEM microscope JEOL 6360LA. The characteristics of capillary-porous structure of sunflowerkernels were determined by the method of porometry using the specific surface area analyser Sorbometr-M.

The oxidation stability of the obtained oilswas determined according to the standard procedure (GOST 31758), carried out using the device Ransimat Professional 892 (Metrohm, Switzerland).

All the experiments were carried out at least in triplicate. The assessment of the obtained results was carried out using the modern methods of the calculation of the static reliability using the software Statistica 6.0, Microsoft Office Excel 2007, and Mathcad. The confidence coefficient is 0.95.

The studies were carried out using the equipment of the Common Use Center "Research Centre of Food and Chemical Technology" of the FSBEI HPE"Kuban State Technological University".

RESULTS

For research, the seed mixture, chosen as the object of study, was hulled and separated by the previously developed technology [53-56].

For hulling seeds the combined bench plant was used. The separation of hulled seeds and kernel was carried out using the photoelectronic Separator ACE 3 (South Korea, DAEWON GSI CO. LTD).

The characteristics of the efficiency of the process of obtainingkernels from sunflower seeds of modernbreeding by the specifiedtechnology are presented in Table 1.

ISSN: 0975-8585

Table 1 – Characteristics of the efficiency of the process of obtaining kernels from sunflower seeds

Parameter	Value of the parameter
Characteristics of hulled seeds	
Content in hulled seeds, %:	
unhulledand incompletely hulled seeds	27.8
broken seeds	4.3
oil dust	4.2
Coefficient of hulling (C_{hull}), %	72.2
Kernel quality characteristics after separation:	
Mass fraction of husk, %	5.2
Husk quality characteristics after separation:	
Mass fraction of kernel, %	0.58
Kernel quality characteristics after control:	
Mass fraction of husk, %	0.1
Moisture content, %	3.7
The output of the whole kernel, %	51.0

It was shown that the applied technology makes it possible to obtain a kernel fraction, containing more than 50% ofwhole kernel andalmost no husk.

The characteristics of the obtained sunflower kernel, used for further studies, are presented in Table 2.

It was found that the lipid complex of the studiedsunflower kernel contains an average of 0.62% phospholipids; 0.11% of glycolipids; 0.83% of unsaponifiable lipids, including 0.32 mg% β-carotene; 0.37 mg% chlorophylls and 660 mg% tocopherols. The predominant fatty acid is linoleic acid(55%). The phospholipid complex is represented by phosphatidylcholines (23%), phosphatidylethanolamines (22%), phosphatidylinositols (16%), phosphatidylserines (3%); phosphatidylglycerols (11%), phosphatidic and polyphosphatidic acids (25%).

Table 2 – Composition and physicochemical parameters of sunflowerkernels

Parameter	Value of the parameter
Humidity, %	4.2
Mass fraction in the kernel, % on an absolute dry matter basis:	
crude fat	52.5
crude protein	11.0
crude fibre	11.7
Acid value of oil extracted from the kernel, mg KOH/g	1.7
Peroxide value of oil extracted from the kernel, mmol active oxygen/kg	1.8

The protein part of seeds contains 52% of crude protein; 17% of crude fibre; 3.1% of chlorogenic acid. The predominant amino acids are glutamic acid and aspartic acid.

The obtained datamake it possible to conclude that sunflower seeds of modern breeding are apromising raw material for obtaining a complex of food products with high nutritional value, such as vegetable oil, lecithin, food protein and a complex of natural antioxidants, including chlorogenic acid.

It is known that the main technological properties of oilseeds, such as diffusional permeability, hydrodynamic resistance, filtration capacity, developed internalsurface and sorption properties largely depend on the characteristics of the capillary-porous structure of the kernel [5, 12].

ISSN: 0975-8585

The main characteristics of the capillary-porous structure of sunflower seed kernels of the studied varieties and hybrids are presented in Table 3.

The obtained data, characterizing the capillary-porous structure of thesunflower seed kernel, were taken into account when developing the effective methods of its processing.

Table 3 – Characteristics of the capillary-porous structure of sunflower seed kernel

Parameter	Value of the parameter
Bulk density, g/cm^3	1.037
Pore volume, mm^3/g	78.16
Pore surface area, m^2/g	8.92

The process of obtaining oil from oilseeds involves the need todestruct cellular structures – spherosomes, which is usually carried out by grinding with subsequent pressing and (or) extraction.

It should be noted that according to some authors [11-13], the extrusion treatment should result in the formation ofthe optimal internal and external structure of the material. The internal structure should be characterized by the maximum destruction of cells and lipid spherosomes, high porosity, ensuring the necessary permeability for the extractant and the diffusion transfer of the extracted target substances. The characteristics of external structure should ensure equal accessibility of all material particles for the extractant and the minimum diffusion path.

Theexperiments, carried out by the authors using a conventional model of extruder (without preliminary removal of oil) showed that its use for the preparation of the material for direct extraction can be effective, if the initial oil content in raw materials does not exceed 35%, while the humidity of raw materials should range from 4.5to 10.0%. Besides, the use ofa conventional extruder requires preliminary grinding of the material,which ensures than no less than 60% of material pass through a sieve with the mesh size of 1 mm [13, 57].

Given that the object of study is the husk-free kernel of high-oleic sunflower, the experiments were carried out using a retrofit extruder, the scheme of which is presented in Figure 1.

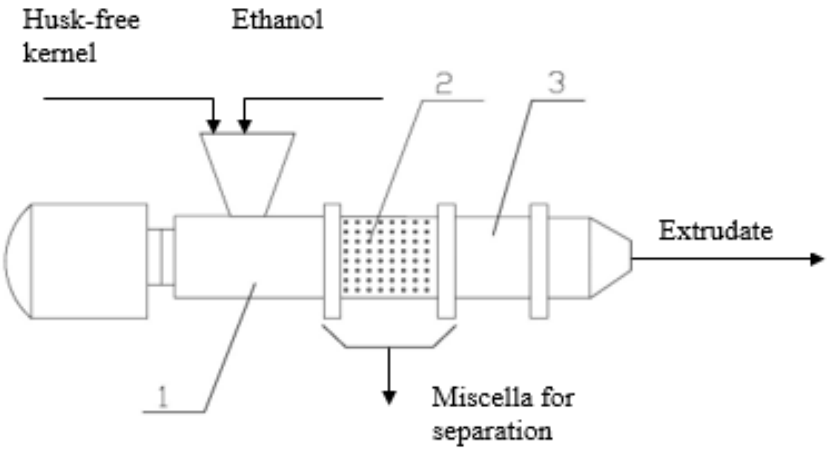

Figure 1 – Scheme of the retrofit extruder

With the purpose of combining the processes of grinding kernels and partial removal of oil,feeding of sunflower seed kernel flow, located inthe extruder screw, is implemented through a system of throttles, representing a narrow annular gap between the screw and the throttle elements (area 2). Severalthrottle elements are installed inside the "blind" part of the extruder, which ensures the development ofshear load and the repetitive grinding and mixing of the material. Thus, in the process of the movement of the kernel through the screw it is ground and partially degreased, while the material discharged from the matrix as the form of porous granules.

One of the main methods of the preparation of oilseeds for oil expression is wet-heat treatment, which should improve the efficiency of oil extraction in the process of the subsequent pressing or extrusion treatment.

It is conventionally believed that the selective wetting of hydrophilic components of groundkernel results in theloosening of the link of lipid and protein components, as well as the "expression" of the oil out ofcapillaries and pores, where it enters duringgrinding, under the action of swelling forces [5, 57]. However, in [11-12] it is shown that the wet-heat treatment of ungroundkernel also has a significant effect on the degree of separation of oil during subsequent pressing or extruding, which is related to the change of the porous structure of the material.

Thestudies on the impact of the modes of wet-heat treatment ofunground kernel on the efficiency of the preliminary removal of oil and the characteristics of extrudate, conducted by the authors, showed that the positive effect can be achieved only at a sufficiently high temperature and humidity, which is levelled off by the intensification of the processes of lipid peroxidation.

Taking this into account, in order to eliminate the preliminary stage of wet-heat treatment, to reduce the viscosity of the processed feedstock and improve the efficiency of extrusion, itwas proposed to feedethanol into the loading chamber of theextruder.

The best results were obtained when feeding kernel and ethanol into the loading chamber in the mass ratio of 1.0:0.3 to 1.0:0.5.

The oil output in this case averaged 87%, and the obtained extrudate was characterized the bulk density of 0.90 to 0.92 g/cm^3 and developed pore surface area (more than 11 m^2/g).

In the course of further studies the authors varied main technological modesinfluencing the composition of extracted lipids: the temperature and the residence time of the material in the extruder. As the main parameters of the composition of extracted lipids, the content of phospholipids, free fatty acids and unsaponifiable lipids composed of tocopherols and carotenoids were evaluated.

The step-by-step variation of studied factors was carried out. When changing the temperature in the range from 40 to 100 °C, the residence time of the material in the extruder was constant and amounted to 60 seconds.

The results of the study of the influence of temperature on the lipid composition of miscella are presented in Figure 2.

The presented data shows that with the increase of temperature the content of free fatty acids considerably increases. The content of unsaponifiable lipids also increases, although to a lesser extent. The change of the content of phospholipids has an extreme nature. The increase of the content of phospholipids with the increase of temperatureto 60 °C can be attributed to the collapse of lipoprotein complexes. The further increase of temperature, apparently, results in the increased intensity of the interaction between the individual groups of phospholipids with carbohydrates and other associated substances with the formation of compounds characterized by low solubility in ethanol and triacylglycerols.

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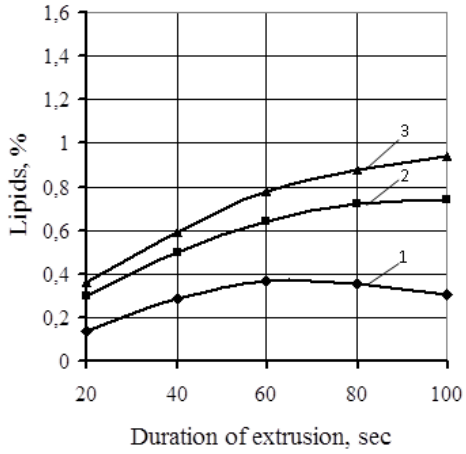


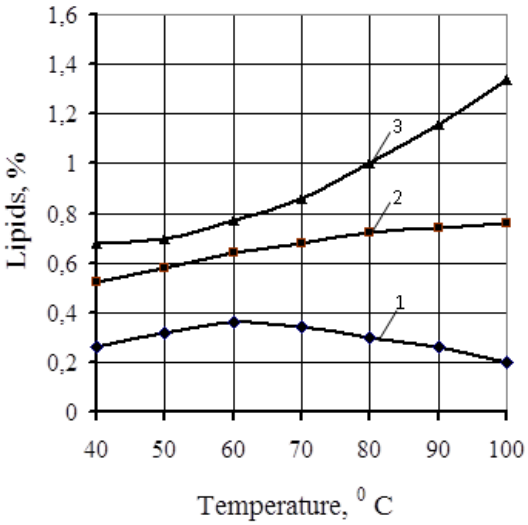
1 – phospholipids;
2 – unsaponifiable lipids;
3 – free fatty acids

Figure 2 – Impactof thetemperature in the extruder on the composition of extracted lipids

The analysis of the presented curves makes it possible to conclude that the temperature in the first section of the extruder shall be 60°C, which will ensure the balance between the target components (unsaponifiable lipids and phospholipids) and the unwanted component – free fatty acids.

At the next stage the residence time of the material in the extruder was variedin the range from 20 to 100 sec (Figure 3).

It was shown that the increase in theextrusion time results in the increase in the content of unsaponifiable lipids and free fatty acids in miscella and to a certain reduction of the content of phospholipids. On the basis of the above considerations, the length of extrusion shall be 60 sec.



1 – phospholipids;
2 – unsaponifiable lipids;
3 – free fatty acids

Figure 3 – Impact of the residence time of the material in the extruder on the lipid composition

On the basis of the conducted research, a technology for processing husk-free sunflower kernels was developed, which is presented in the form of a block diagram in Figure 4.

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The implementation of the developed technology using the available pilot plants of the Common Use Center "Research Centre of Food and Chemical Technology" of the FSBEI HPE "Kuban State Technological University" made it possible to develop test samples of products: sunflower oil, extruded kernel, fractioned lecithin and food protein meal.

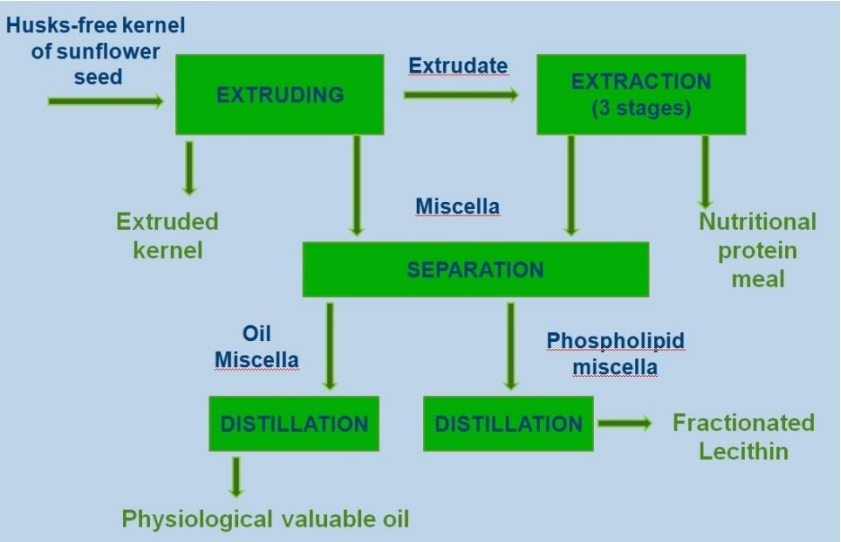

Figure 4 – Block diagram of the processing of husk-free sunflower kernels

Averagedresults of the studies of the composition and physicochemical parameters of oil samples are presented in Table 4. For comparison, the table shows the data for oil obtained from similar raw materials by the conventional technology of single pressing using a laboratory extruder.

The analysis of the data presented in Table 4 shows that the developed technology makes it possible to get oil with the best organoleptic and physicochemical characteristics.

It is particularly noteworthy that the studied oil has a low prooxidant potential, which is evidenced by the lower values of acid value, as well as a higherindex of oxidation stability.

The developed technology ensures preserving physiologically valuable nutrients in oil, such as β-carotene and tocopherols, with the minimal content of phospholipids.

It is known that phospholipids, while having a high physiological value, are surface-active substances, which complicates the further ruse of oil in food technology and requires their removal.

On the one hand, it results in the need of additional technological impact on oil, causing quantitative and qualitative losses, and on the other hand, leads to the considerable complication of the manufacturing procedure when obtaining phospholipids in the form of an independent competitive product.

Fatty acid composition of the studied sample and control sample are substantially similar. The exception is linolenic acid, the content of which is slightly higher in the studied sample as compared to the control sample. This may be due to the sparing technological modes, which do not lead to oxidative transformations of the most unstable polyunsaturated fatty acids. This is confirmed by the data on higher oxidation stability of the studied sample.

It was established that the obtained oil complies with the requirements of TR TC 024/2011 "Technical regulation for oil and fat products" in terms of safety performance.

The phospholipid complex, isolated in the process of the division of the alcohol miscella, is a translucent viscous-flow yellow product with flat taste and smell; the results of its study are presented in Table 5.

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Table 4 – Composition and physicochemical parameters of oils derived from husk-free sunflower kernels

Parameter	Characteristic and value of the parameter for oil obtained by	
	developed technology	conventional technology (control)
Taste and smell	Flat, soft, with a flavor, characteristic for the original sunflower kernel	Pronounced, characteristic for the worm-press sunflower oil
Color	Light yellow	Yellow
Mass fraction, %:		
unsaponifiable lipids	0.48	0.42
phospholipids	0.08	0.64
glycolipids	0.02	0.11
Mass fraction, mg/kg:		
tocopherols	802	753
β-carotene	0.20	0.14
chlorophyll	0.016	0.017
Fatty acid composition, % of the total volume:		
$C_{14:0}$Myristic acid	0.07	0.07
$C_{16:0}$Palmitic acid	6.36	6.28
$C_{16:1}$Palmitoleic acid	0.08	0.10
$C_{18:0}$ Stearic acid	4.36	4.36
$C_{18:1}$ Oleic acid	36.03	35.85
$C_{18:2}$ Linoleic acid	51.03	51.46
$C_{18:3}$Linolenic acid	0.37	0.05
$C_{20:0}$Arachidic acid	0.32	0.33
$C_{20:1}$Gondoinic acid	0.16	0.18
$C_{22:0}$Behenic acid	0.83	0.89
$C_{22:1}$Erucic acid	0.11	0.14
$C_{24:0}$Lignoceric acid	0.27	0.33
Color value, units I_2	8	7
AOCS tintometer color value	0.9R 3.2Y	0.6R 1.9Y
Acid value, mg KOH/g	1.9	2.6
Peroxide value, mmol active oxygen/kg	2.1	1.9
Index of oxidation stability, hours	3.6	2.3

Table 5 – Composition and physicochemical parameters of phospholipid complex

Parameter	Value of the parameter
Mass fraction, %:	
acetone-insolublesubstances	61.0
toluene-insoluble substances	0.01
protein	4.4
Acid value, mg KOH/g	20.7
Peroxide value, mmol active oxygen/kg	0.57
Composition of phospholipid groups, % of the total amount	
Phosphatidylinositols (PI)	8.0
Phosphatidylcholines (PC)	60.0
Phosphatidylserines(PS) and lyso-phosphatidylethanolamines (LPEA)	not detected
Phosphatidylethanolamines (PEA)	25.0
Phosphatidic acids (PA)	1.0
Diphosphatidylglycerols (DPG)	4.0
Polyphosphatidic acids (PPA)	2.0

As can be seen from the presented data, the isolated phospholipid complex is characterized by a high content of acetone-insoluble lipids.

The group composition of phospholipids is characterized by the predominance of phosphatidylcholines (60%) – a group having pronounced physiologically active properties such as membrane protection activity, hypolipidemic activity, hypocholesterolemic activity, etc. Besides, groups with low physiological activity, such as phosphatidic and polyphosphatidic acids, are presented in the group composition in small amount. This makes it possible to classify the obtained phospholipid complex as fractioned lecithin.

The presence of protein in the phospholipid complex may indicate that a part of phospholipids has a form of lipoprotein complexes. Lipoprotein complexes formed by phospholipids are among the best natural emulsifiers-stabilizers andhave a high physiological value. Taking this into account, the resulting product is promising forthe use as a functional food ingredient in stabilizingemulsion products for dietary and therapeutic nutrition, as well as a valuable raw material for obtaining pharmaceutical substances, microemulsions and liposomal systems.

The implementation of the developed technology makes it possible to obtain two kinds of protein products – extruded kernel and food protein meal.

The averagedresults of the study of organoleptic and physicochemical parameters of the quality of the samples of extruded kernel and food protein meal are presented in Tables 6 and 7.

Table 6 – Organoleptic parameters of protein products

Parameter	Characteristics of the parameter	
	Extruded kernel	Food protein meal
Color	Uniform beige	Uniform white with cream tint
Smell	Flat, with a slight grassy tint, characteristic for sunflower seeds	Flat, with a slight grassy tint, characteristic for sunflower seeds
Taste	Flat, with a slight grassy tint, characteristic for sunflower seeds, without specific oily flavor	Flat, with a slight grassy tint, characteristic for sunflower seeds, without specific oily flavor

Table 7 – Physicochemical parameters of protein products

Parameter	Value of the parameter	
	Extruded kernel	Food protein meal
Mass fraction of moisture and volatile substances, %	6.8	6.5
Mass fraction of lipids on an absolute dry matter basis, %	7.7	0.5
Mass fraction of ash, insoluble in hydrochloric acid, on an absolute dry matter basis, %	0.60	0.57
Mass fraction of chlorogenic acid, %	1.0	0.94
Mass fraction of crude protein on an absolute dry matter basis, %	51.0	60.7
Mass fraction ofsoluble protein in sunflower meal as a percentage of the total protein content, %	85.9	80.4
including:		
albumins	29.3	26.1
globulins	35.8	33.3
glutelins	20.8	21.0
Mass fraction of crude fibre on an absolute dry matter basis, %	13.3	10.6

It was shown that the protein products, derived from husk-free sunflower kernel, are characterized by relatively high quality performance. In terms of the content of crude protein, the food protein meal obtained by the developed technology can be classified as a protein concentrate.
The amino acid composition of protein products is presented in Table 8.

Table 8 – Amino acid composition of protein products

Amino acid	Content of amino acid, g/100 g protein:		Amino-acid score	
	Food protein product	Extruded kernel	Food protein product	Extruded kernel
1	2	3	4	5
Essential:				
lysine	4.39	3.77	79.8	68.7
phenylalanine + tyrosine	8.86	6.46	147.7	107.7
Leucine + isoleucine	13.85	10.92	125.9	99.3
methionine + cystine	4.70	4.60	134.3	131.4
valine	6.38	4.86	127.6	97.2
threonine	4.77	3.65	119.3	91.3
tryptophan	1.82	1.96	182.0	196.0
Σ of essential amino acids	44.77	36.22	-	-
Nonessential:				
alanine	7.00	5.69		
arginine	4.78	13.11		
histidine	2.58	2.17		
glycine	8.39	6.72		
serine	5.68	4.56		
glutamic acid	14.59	18.72		
aspartic acid	6.82	8.36		
proline	5.39	4.45		

The data presented in Table 8 indicate that the developed technology does not lead to a significant change in the native amino acid composition of the protein part ofsunflower kernels. The content of essential amino acids in the protein complex is more than 36% for extruded kernel and more than 44% for food protein meal. The first limiting amino acid is lysine.

It was established thatthe obtained protein products comply with the requirements of TR TS 024/2011 to food protein concentrates in terms of safety performance and can be ranged as food products intended for using in the technologies for the production of foodstuff as a functional ingredient.

CONCLUSION

On the basis of the analysis of existing and prospective methods of the processing of sunflower seeds and the results of experimental studies,aresource-saving technology of complex processing of sunflower seeds was proposed, which makes it possible to obtain innovativeprotein and lipid products.

It was found that adding ethanol to the kernel beforethe loading chamber of the extruder in the amount of 30-50% significantly improves the efficiency of extrusion, which is indicated by the increase of porosity and extrudate and increasing oil output.

A method of extruding husk-free sunflower kernel with the purpose of preparing it for the extraction by bioethanol was developed.

The evaluation of the parameters, determining the physiological value of oils, showed that the developed technology has a reduced impact on the lipid part of a sunflower kernel and makes it possible to preserve a maximum amount of lipid-solublephysiologically valuable nutrients in the resulting oil. Thecomposition of the phospholipid complex is characterized by the predominance of phosphatidylcholines (60%),having pronounced physiologically active properties such as membrane protection activity, hypolipidemic activity, hypocholesterolemic activity, etc.

It was revealed that the developed technology, unlike conventional technologies, does not increase the initial prooxidant potential of the lipids of sunflower kernels.

Safety performance of the oil samples, obtained according to the developed technology, meet the requirements of TR TS 024/2011 "Technical regulation for oil and fat products" and TR TS 021/2011 "On the safety of food products".

In terms of safety performance the obtained protein products comply with the requirements of TP TS 024/2011 to food protein concentratesand can be ranged as food products intended for using in the technologies for the production of foodstuff as a functional ingredient.

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