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TECHNOLOGY IMPROVEMENT AND EVALUATION CONSUMER PROPERTIES OF DRY BREAKFAST

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Abstract. The assortment of ready-to-eat extruded products and the chemical composition of their ingredients according to the complex of basic and biologically active substances have been analyzed. The feasibility of developing new formulations of extruded breakfast cereals using non-traditional nut-bearing raw materials by means of adjusting the composition and types of leguminous and fruit components has been substantiated. The technology of multicomponent breakfast cereals based on wild nut-bearing raw materials of Kyrgyzstan and Ukraine, as well as cultivated types of plant crops, has been developed. The process of extrusion is improved through the use of CO₂ with partial extraction of the lipid components of the raw materials. The composition of the six introduced formulations of breakfast cereals is substantiated by predictive forecasting of biological activity and preservational ability of the main food components after technological processing and storage of the extrudates. An increased nutritional value and a decrease in amino acids limiting the biological value of their proteins in formulations with leguminous, nut-bearing and fruit-grain components are established (formulations 1–3 – reduction in lysine deficiency by 18–26%, for methionine and cystine by 12–21%; formulations 4–6 – for lysine by 22–29%, leucine and valine by 17–36%). The absence of toxic effects and the increase in the integral biological activity of the *Styloichia mytilus* test-culture in terms of its survivability by 18–31% for the developed formulations, compared with traditional extrudates, are shown. The antioxidant activity of the samples, determined volumetrically by the intensity of the isopropylbenzene oxidation, made it possible to establish the oxidation induction period and the concentration of antioxidants. According to the obtained results, the guaranteed shelf life of the developed types of dry breakfast cereals that meet safety requirements can be prolonged by 24–39% compared with the control, and the introduction of secondary raw materials to the formulations can improve technical-and-economic indicators. The nutritional and biological value, organoleptic and structural-mechanical properties, as well as the biological activity of the products developed, allow to recommend introducing them into production.

Keywords: grain legumes, fruit culture, nut raw materials, extrusion, breakfast cereals.

ВДОСКОНАЛЕННЯ ТЕХНОЛОГІЙ І ОЦІНКА СПОЖИВЧИХ ВЛАСТИВОСТЕЙ СУХИХ СНІДАНКІВ

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Анотація. Проаналізовано асортимент готових до вживання екструдованих продуктів і хімічний склад їхніх інгредієнтів за комплексом основних і біологічно активних речовин. Обґрунтовано доцільність розробки нових рецептур екструдованих сухих сніданків із використанням нетрадиційної горіхоплідної сировини, коригуванням складу та видів зернобобових і фруктових компонентів. Розроблено технологію багатокомпонентних сухих сніданків на основі дикорослої горіхоплідної сировини Киргизстану і України, а також культивованих видів рослинних культур. Проведено вдосконалення технологічного процесу екструзії шляхом використання CO₂ з частковою екстракцією ліпідних компонентів сировини. Склад розроблених шести рецептур сухих сніданків обґрунтовано предиктивним прогнозуванням біологічної активності і зберігання основних харчових компонентів після технологічної обробки і зберігання екструдатів. Встановлено підвищену харчову цінність і зниження лімітуючих амінокислот в рецептурах з бобовими, горіхоплідними і фруктовозерновими компонентами (рецептури 1–3 – зниження дефіциту за лізином на 18–26%, метіоніну і цистину на 12–21%; рецептури 4–6 – за лізином на 22–29%, лейцином і валіном на 17–36%). Показано відсутність токсичних ефектів і підвищення інтегральної біологічної активності за виживанням тест-культури *Styloichia mytilus* для розроблених рецептур на 18–31% в порівнянні з традиційними екструдатами. Антиокислювальна активність зразків, встановлена волюмометрично за інтенсивністю окислення ізопропілбензолу, дозволила встановити період індукції окислення,

концентрацію антиоксидантів. За отриманими результатами гарантований термін зберігання розроблених видів сухих сніданків, які відповідають вимогам безпеки, можна пролонгувати на 24–39% в порівнянні з контролем, а введення в рецептури вторинної сировини – поліпшити техніко-економічні показники. Харчова, біологічна цінність, органолептичні та структурно-механічні властивості, а також біологічна активність розроблених продуктів дозволяє рекомендувати їх до впровадження у виробництво.

Ключові слова: зернобобові, плодові культури, горіхова сировина, екструзія, сухі сніданки.

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Introduction. Formulation of the problem

The work is aimed at the development of new types of instant products for long-term storage, with increased nutritional value and improved functional properties.

The experience of industrialized countries showed the prospects for the production of cereals from a number of grain crops – corn, quinoa, wheat, rice, barley, etc., with the introduction of ingredients of plant and animal origin [1–4].

Creation and widespread use of a new range of healthy foods based on environmentally friendly, including wild plant materials rich in biologically valuable substances, essential nutritional components and structure-forming com-pounds is an important direction in solving the strategic tasks of the food industry of Ukraine and Kyrgyzstan [5,6].

In this regard, the improvement of the range and technology of dry breakfast cereals with a positive effect on the human body – increased nutritional and biological value, improved antioxidant characteristics and structural-mechanical properties, with prolonged period of storage is an important scientific and practical task.

Analysis of recent research and publications

Extrusion foods for a long time hold the leading positions in the market of fast food products [5,7]. Consumer cooperation enterprises prefer to produce breakfast cereals enriched with vitamin-containing raw materials and highly concentrated extracts [8–10].

The main type of dry breakfast cereal production technology is the extrusion method, which provides the modification of starch-containing raw materials and the corresponding indicators of the quality of finished products [11–13].

Thermodynamic extrusion process, combining thermal, hydraulic and mechanical processing of raw materials was known for a relatively long time [14]. Among the modes of extrusion, there are cold, warm and hot processing of plant and animal raw materials, which are carried out at a pressure of 10, 9–12, 12–20 MPa, respectively, and extruded mass moisture from 14 to 30% [15].

Grain raw materials (wheat, rice, maize, oats, etc.), the main component of which is starch, are most often extruded.

Extruded cereal-based products are beneficial to health due to the content of soluble and insoluble dietary

fibers, which, reducing cholesterol levels, reduce the risk of cardiovascular diseases, and also stabilize the digestive functions of the body, preventing diseases of the gastrointestinal tract [7].

In addition to traditional cereals, there are developments on the introduction of color pollen [16], mycelium of higher fungi (miprovit) [17] and other additional ingredients to the dry breakfast cereals.

The fruit and vegetable canning industry processes significant volumes of raw materials, the effective use of which averages 79% and 21% is waste. In particular, in Ukraine every year when processing apples, the squeezing of them is about 350 thousand tons and can be a valuable secondary raw material for various, including extruded products [18, 19].

There is evidence that, in order to obtain the desired structural and mechanical properties of extrudates, starch is introduced into their recipes. At the same time, starch does not possess those therapeutic and prophylactic properties that have pectic substances that also participate in the formation of the structure during extrusion [20].

The aim of the work is to develop a technology of multicomponent dry breakfasts of increased biological activity and prolonged period of storage based on wild nut and cultivated leguminous, fruit and cereal raw materials and its processed products.

To achieve the goal, the following **tasks** must be performed:

- 1) to monitor the recipes of dry breakfast cereals to substantiate the ingredient composition of new compositions;
- 2) to characterize the chemical composition of the potential ingredients of the recipes;
- 3) to study the biological and antioxidant activity of raw materials and compositions;
- 4) establish a set of indicators of the quality of new types of dry breakfast cereals.

Research materials and methods

The raw materials used were regional species of wild nut-growing raw materials – hazelnuts and walnuts, from legumes used lentils (*Lens culinaris* Medik) variety SNIM 18, from grain crops - soriz (*Sorghum oryzoidum*) variety Odes`kyi 302, oats (*Avena nuda* L.) variety Diitychnyi, chokeberry powder *Aronia melanocarpa*, CO₂-extracts of caraway seeds and amaranth meal (obtained at the Department of food and agricultural production technology of the Osh Technological

University named after Academician M.M. Adyshev), pectin extracts (obtained at the Department of bioengineering and water of the Odessa National Academy of Food Technologies) pectin extracts and secondary raw materials of apple-pectin production (dry substances 16.4%; total carbohydrate content 6.4%; pectin substances 2.36%; titrated acidity on malic acid basis 1.04%), dry cheese whey (Special Food, Ltd., Dnepr)

The main indicators of chemical composition: humidity, mass fraction of proteins, lipids, carbohydrates, mineral substances were determined by classical biochemical methods [21, 22]; integral toxicity and biological activity using the *Stylonichia mytilus* test-culture [23], amino acid composition on the «AAA 400» amino acid analyzer [24]. Amino acid score was established by a calculation method, and the amino acids limiting the biological value of proteins were determined by calculating the minimum amino acid score of C_m and the Kapacci-Linder-Warg index using the formula [25]:

$$K = 75^n \sqrt{P_{i=1}^m C_i \left(P_{j=m}^n \frac{1}{c_j} \right)} + 25 \cdot \left(2 - \frac{1 - \sum_{i=1}^n c_i a_i}{1 - \sum_{i=1}^n a_i} \right)$$

where n – the number of essential amino acids;

m – the number of essential amino acids whose content is less than in the reference («ideal») protein;

$\sum_{i=1}^n c_i a_i$ – the total content of essential amino acids in the considered protein;

$\sum_{i=1}^n a_i$ – the total content of essential amino acids in the reference («ideal») protein.

Antioxidant activity was determined by the volumetric method; the total concentration of antioxidants was estimated by the induction period of isopropylbenzene oxidation [23]. Testing was performed at initiation rate $W_i = 6,8 \cdot 10^{-5}$ mol/dm³, the initiator is azoisobutyronitrile (AIBN). The concentration of antioxidants was determined from the expression:

$$[In H] = t \cdot W_i,$$

where $[In H]$ – experimentally obtained inhibitor concentration; t – the duration of the induction period, s.

The main equipment used in the production of extrudates from the studied prescription components is a modernized extruder with CO₂ pumping (Fig. 1).

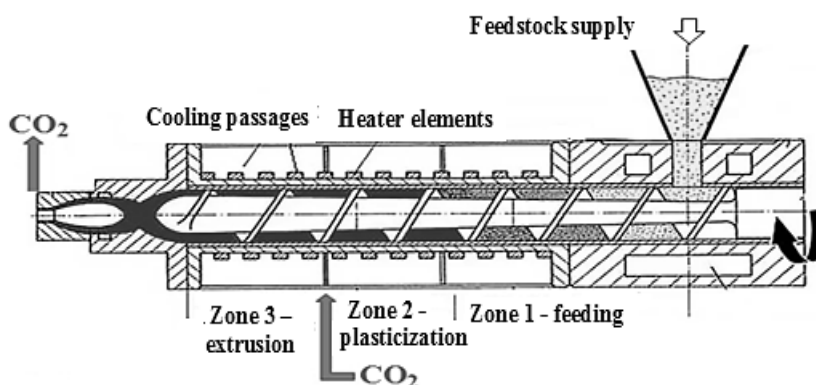


Fig. 1. Scheme of thermal zones of the extruder with CO₂-pumping

Initially, before starting it is necessary to warm up. Then the prescription ingredients are loaded into the extruder and, depending on the type of formulation, the addition of liquid components or water is carried out to a final moisture content of the mixture of 23–25%, after which the continuous operation mode of the extruder is set. The mixture loaded into the extruder is heated with a gradual increase in the temperature of the mixture through the zones of the extruder from 60–110°C and the subsequent decrease in temperature due to the supply of CO₂ to 30°C. Humidity of dry breakfast at the exit of the machine after their natural cooling should not exceed 8%. From the receiving hopper, the extrudate is conveyed to the drazer for the application of additives in the form of powdered sugar or other formulas, and then fed to the packaging.

Results of the research and their discussion

For the development of dry breakfast cereal recipes, various types of raw materials were monitored as

sources of irreplaceable nutrition factors, biologically active substances, antioxidant compounds that increase the period of storage. The introduction of individual components of the recipe was based on: - the availability of raw materials of the regions and their non-prevalence as ingredients of breakfast cereals, - features of the biochemical composition of raw materials, allowing to obtain products with high biological, structural-mechanical and antioxidant properties, - ability to maintain high nutritional value during storage. Preliminary monitoring identified individual ingredients, investigated their biochemical composition for a number of indicators, as well as tested their biological activity and antioxidant properties.

From these positions, wild species of nuts, legumes and cereals, fruit and secondary raw materials, obtained mainly on an industrial scale, were selected. The main indicators of their chemical composition are given in Table 1.

Table 1 – The chemical composition of the components of the recipes, %

Types of raw materials	Water	Proteins	Lipids	Carbohydrates	Pectic substances	Mineral substances
Bean and grain crops						
Lentils (SNIM 18)	13.8	23.1	1.7	46.2	-	2.1
Oats (Dietychnyi)	12.8	11.9	6.2	58.7	-	1.9
Soriz (Odes'kyi 302)	13.2	12.0	2.9	54.6	-	3.1
Nuts						
Walnuts after CO ₂ treatment	3.8	16.2	40.8	11.1	-	1.8
Hazelnut	5.5	15.6	62.5	9.5	-	2.2
Fruit and secondary raw materials						
Chokeberry powder (Aronia melanocarpa)	8.6	11.6	2.8	62.5	4.9	8.2
Apple malt pomace	74.2	2.9	0.4	15.8	7.4	1.2
CO ₂ -amaranth meal	-	23.9	0.1	63.1	5.8	4.8
Pectin concentrate	77.5	1.4	1.8	16.2	2.4	1.4
Dry cheese whey	5.7	3.2	1.8	73.1	-	7.9

As can be seen from the Table 1 results, both legumes and nut crops contain significant amounts of protein. In this regard, the biological value of the protein components of the recipes was determined by the results of their amino acid analysis. It has been established that limiting the biological value of proteins of potential prescription components according to the results of the calculation of the amino acid score are:

- for walnuts – lysine (64%), for hazelnuts – methionine + cystine (57%), lysine (68%);

- for legumes and grain crops: lentils – methionine + cystine (65%), oats – lysine (62%), soriz – lysine (69%). Analysis of amino acid scores showed the expediency of using legumes and some types of nut raw materials to increase the biological value of a multicomponent extruded product, since the amino acid score of lentil proteins for lysine is 126.1%. The assessment of the biological value of proteins from the point of view of their amino acid composition by the Kapacci, Linder and Warg method, which is a mathematical combination of the essential and non-essential amino acid scores, also confirms the expediency of introducing the proposed ingredients into the cereal recipes to improve the balance of amino acids.

Predictably substantiated regulated structure-mechanical properties by preliminary research of the degree of swelling and ability to absorb water. Judge by the results obtained, the highest rates are characterized by apple-malt pomace, for which the degree of swelling and water absorption are respectively 11.6 cm³/g and 12.0 g/g of dry product, slightly lower in chokeberry powder (9.8 cm³/g and 10.3 g/g of dry product) and low rates (2.8 cm³/g and 2.4 g/g of dry product) have lentils, oats and soriz.

Legumes, nuts, fruit and cereal ingredients were represented into the composition of the formulation of extruded products. The components that provide the organoleptic properties of the finished product as structure, color, taste and aroma also presented. Preliminary experiments showed the expediency of introducing selected components in a specific

quantitative composition, which allows obtain a product that has not only high nutritional value, but also the required structural and mechanical properties. As early as in 1994, studies by L.M. Pylypenko, and later V.V. Martirosyan (2013) and V.V. Litvyak (2013), it was shown that thermal processing during extrusion leads to the formation of biocomposite complexes, which can have pectin-protein and starch-lipid-protein compositions [4,26]. At the same time, the fractional composition of protein substances of the raw material, which is dominated by glutelins and proteins of solid residue, has, for example, zein, a ratio of the major and minor axes of molecules of 20 or more relative units, the molecules of which resemble needles or short filaments, which leads to low thermally properties unlike globular proteins. That is why we recommended such combinations of types and concentrations of leguminous raw materials in recipes (48–57%) with nut, fruit ingredients and secondary raw materials. Table 2 shows the prescription composition of dry breakfast cereals.

Dry breakfasts made according to the recipe have an attractive appearance, optimal structural and mechanical properties, pleasant light-pink (product according to recipes 1–3) or light amber (product according to 4–6 recipes) color and harmonious, specific taste, they are characterized by higher structural-mechanical properties than extrudates regulated for extrudates, especially recipes 5 and 6. All kinds of recipes with a maximum 10 point assessment of organoleptic properties received 8.7–10.0 points.

Traditional dry breakfast technology is based on such traditional technological operations as screening, magnetic cleaning, conditioning, moistening, mixing with other ingredients, extracting, molding, applying additives, packaging, labeling and storage. In the implementation of the technological process in classical installations, the heating occurs to high temperatures (170–190°C) and pressure, while the mass in the form of threads is squeezed through the matrix. The developed technology of obtaining dry breakfast provides for similar processes in the preparation of flour from lentils,

oats and soriz with the addition of the necessary ingredients in the recipe and then the resulting mass is sent to extrusion using CO₂ at a temperature of 60–110°C.

Existing technological regimes reduce the nutritional value and limit the introduction to the recipe of dry breakfast ingredients containing in their composition oxidant-and thermolabile biologically active compounds, as well as aromatic and color-forming substances causing the organoleptic properties of the finished product. The development of dry breakfast in a modernized production extruder allows to achieve an increase in the nutritional value of the product by reducing the temperature and the protective effect of

CO₂. The expediency of the developed formulations and technologies was judged by the results of a study of a set of indicators of biochemical composition, safety and biological properties, as well as the persistence of the product.

Antioxidant activity is an indicator of the detoxifying ability of the product, since the mechanism of toxic action is manifested in the ability to activate the processes of lipid peroxidation as a universal pathogenetic link in the development of a number of diseases. The results of the study of the antioxidant and biological activities of the developed types of products are given in Table 3.

Table 2 – Composition of the recipes of breakfast cereal,%

Name of raw materials	Recipe 1	Recipe 2	Recipe 3	Recipe 4	Recipe 5	Recipe 6
Oatmeal flour	40.0	45.0	50.0	-	-	-
Soriz flour	-	-	-	40.0	45.0	48.0
Lentil flour	8.0	7.0	6.0	12.0	10.0	9.0
Chokeberry powder (Aronia melanocarpa)	6.0	7.0	5.0	-	-	-
Walnuts after CO ₂ treatment	7.0	6.0	6.0	5.0	8.0	6.0
Hazelnut	-	-	-	5.0	5.0	5.0
CO ₂ -extract of cumin	0.001	0.003	0.005	-	-	-
Dry cheese whey	6.5	8.0	5.0	6.0	4.0	5.0
Powdered sugar	12.0	8.0	7.5	-	-	-
CO ₂ -amaranth meal	3.5	4.9	5.5	-	-	-
Apple malt pomace	-	-	-	8.0	6.5	6.0
Pectin concentrate	-	-	-	to 100 %	to 100 %	to 100 %
Water	to 100 %	to 100 %	to 100 %	-	-	-

Table 3 – The total concentration of antioxidants and the biological activity of the developed types of products

Recipe	Induction period, s	[In H], mol / dm ³	Biological activity, %
Control – Corn sticks*	65	0.44·10 ⁻⁵	100
Recipe 1	480	3.26·10 ⁻⁵	127
Recipe 2	450	3.06·10 ⁻⁵	121
Recipe 3	440	2.99·10 ⁻⁵	118
Recipe 4	530	3.60·10 ⁻⁵	131
Recipe 5	520	3.54·10 ⁻⁵	126
Recipe 6	505	3.43·10 ⁻⁵	124

* State standard of Ukraine 2903: 2005 Dry breakfast food concentrates

The features of designed dry breakfast cereals, as follows from the Table 3, their significant antioxidant activity applies. The observed increased induction period of the oxidation process in comparison with the control is due to the significant concentration of oxidation inhibitors contained in the components of the recipes. This allows to extend the period of storage of dry breakfast cereals by 24–39% compared to that regulated for traditional extrudates as corn sticks [27-29].

Judging by the results of the survival of the *Styloichia mytilus* test-culture with biotesting, the developed recipes compared with the control have increased biological activity and the absence of integral toxic effects.

The analysis of the biological value as a characteristic of the protein components that make up the developed types of dry breakfast also showed an increased balance of essential amino acids for lysine by 18–26%, methionine and cystine by 12–21% in formulations 1–3; for lysine by 22–29% in formulations 4–6, as well as a decrease in the deficiency in leucine and valine by 17–36% in formulations with legumes and fruit and vegetable components.

Characteristics of the developed dry breakfast cereals for biochemical composition, structural and mechanical properties are given in Table 4.

The coefficient of dilation of more than 3 for extruded products indicates its porous macrostructure and satisfactory structural and mechanical properties. The maximum dilation coefficient equal to 3.70 had an extrusion product made according to the recipe № 5 with the introduction of apple malt pomace and pectin concentrate. The product with the addition of black chokeberry powder and CO₂-meal of amaranth was practically not inferior to it (recipe № 1).

As follows from Table 4, indicators of swelling and water-retaining power of samples of dry breakfast cereals testify to the improved properties of extruded products with legumes, nut and fruit-grain components. This is probably due to the formation of protein-polysaccharide complexes with increased hydration capacity, which led to an increase in swelling and water-retaining power of extrudates.

Table 4 – Consumer properties of dry breakfast cereals

Parameters	Control		Recipe 1	Recipe 2	Recipe 3	Recipe 4	Recipe 5	Recipe 6
	Unglazed rice shaped products	Corn sticks						
Humidity, %	7.3	6.5	7.95	7.02	6.50	7.60	7.80	7.10
Proteins, %	5.7	6.9	12.56	12.09	12.89	15.41	15.71	15.20
Lipids, %	11.7	15.0	9.16	8.40	8.60	12.58	15.03	13.10
Carbohydrates, %	67.9	65.4	66.31	66.84	59.73	58.94	57.40	58.75
Minerals, %	2.4	2.14	2.53	2.75	2.54	2.6	2.55	2.66
L-ascorbic acid, 10 ⁻³ %	-	-	11.30	13.10	9.85	8.41	7.50	7.10
Coefficient of dilation	2.91	3.12	3.41	3.24	3.15	3.38	3.70	3.31
Swelling, cm ³ /g	5.25	6.32	7.23	7.04	6.50	7.48	8.12	7.81
Water-retaining power, %	301	332	342	317	308	351	375	364

Accordingly, new types of extruded products have been developed as dry breakfast cereals with legumes, nut and fruit and grain components, which are characterized by high nutritional value and balance of the composition, lack of integral toxic effects and increased biological activity, significant antioxidant properties, and increased biological value. This allowed us to prolong the traditional storage time of dry breakfast cereals, use secondary raw materials, and improve the organoleptic and structural-mechanical characteristics of the finished product.

Conclusion

Monitoring the range of instant products showed the feasibility of developing new recipes of extruded cereals using non-traditional nut-bearing raw materials, adjusting the composition and types of leguminous and fruit components.

Based on the study of a set of quality and safety indicators, the ingredient composition of the recipes is justified, which allows to increase the nutritional value and balance of products, reduce the deficit of amino acids limiting the biological value of their proteins, to increase the integral biological activity of extrudates by 18–31%, to establish the absence of toxic effects and increase their concentration antioxidants.

Improving the process of extrusion by using CO₂ and the characteristics of the ingredient composition of the recipes made it possible to prolong the shelf life by 24–39% in comparison with the traditional period of storage for break-fast cereals.

Developed new types of dry breakfast cereals contain valuable secondary raw materials, are characterized by increased nutritional and biological value, improved organoleptic and structural-mechanical properties and can be recommended for introduction into production when creating a new range of healthy food products.

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