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DEVELOPMENT OF EXTRUDED PRODUCTS FROM STARCH-CONTAINING RAW MATERIALS WITH VEGETABLE ADDITIVES

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Promising technology that provides a significant intensification of production processes is thermo-moisture-mechanical processing of starch-containing raw materials, carried out using extrusion techniques. Extrusion processing of starch and starch-containing raw materials allows you to get food that is completely ready to eat (snacks, breakfast cereals, cereals, etc.), instant food (semi-finished chips, puddings, drinks and jelly, soups do not require cooking). Corn contains four times more monounsaturated and 2–3 times more polyunsaturated fatty acids compared to wheat. During the production of flour, some of the fatty acids are lost. Investigated the grain of corn varieties "Dobrynya". A study of samples of the obtained extrudates based on corn grain was carried out. All indicators were determined using standard and original methods.

The developed compositions are realized in production conditions of the private enterprise. The developed products deserve due attention and are recommended for development of normative documentation on them.

Keywords: *corn, grain processing, food products, breakfast cereals, grain mixtures.*

РОЗРОБКА ЕКСТРУДОВАНИХ ПРОДУКТІВ ІЗ КРОХМАЛЕВМІСНОЇ СИРОВИНИ З РОСЛИННИМИ ДОБАВКАМИ

О.В. Буняк, С.М. Соц

Перспективною технологією, що забезпечує істотну інтенсифікацію виробничих процесів, є термовологомеханічна обробка крохмалевмісної сировини, що проводиться з використанням екструзійної техніки.

Екструзійна обробка крохмалю і крохмалевмісної сировини дозволяє отримувати продукти харчування, повністю готові до вживання (закусочні продукти, сухі сніданки, пластівці та ін.), продукти швидкого приготування (напівфабрикати чипсів, пудинги, напої й киселі, супи не потребують варіння). На підставі аналізу біохімічного складу різних сортів кукурудзи й екструдованих продуктів, визначення органолептичних показників якості нами обґрунтовано вибір зернової сировини, їх дозування, оптимальні умови отримання екструдатів та оптимізовано рецептуру. Запропоновано спосіб виробництва та рецептуру екструдованих зернових продуктів на основі зерна кукурудзи. Оптимізацію рецептури екструдатів проводили за основними показниками нутрієнтного складу, застосовуючи математичне моделювання. Використовуючи композиційні суміші на основі кукурудзяної крупи (борошна), можна збагатити екструдати незамінними для організму людини компонентами, такими як поліненасичені жирні кислоти груп ω-3 та ω-6. Зерно цукрової кукурудзи містить мінеральні речовини (кальцій, магній, калій, натрій, фосфор, хлор, сірку, залізо та ін.), крохмаль (25–37%) та водорозчинні полісахариди (19–31%). Цукрова кукурудза містить (мг%): вітаміну С 11,6–13,7; вітаміну B_1 (тіаміну) 0,16; вітаміну В (рибофлавіну) 0,11–0,12; вітаміну B_5 (ніацину) 1,97–2,25; окрім того, вітаміни B_3, B_6, Е і А (каротин), інозит, холін, біотин. Динаміку зміни органолептичних показників у баловій системі наведено на рис. 1. Інтервал зміни значень органолептичних показників становить від 0 до 5 балів: 0–1 – дуже погана якість, 1–2 – погана якість; 2–3 – середня якість; 3–4 – добра якість; 4–5 – відмінна якість. На підставі результатів дослідження рекомендований термін зберігання – 6 міс за температури (18±2) °С, вологості не більше 75% у поліпропіленовій упаковці.

Ключові слова: *кукурудза, переробка зерна, харчові продукти, сухі сніданки, зернові суміші.*

Statement of the problem. The food industry remains one of the leaders amongst industries that commission food innovations. Industry's innovation activity is aimed at using and compensation of the scientific research results and developments for the purpose of improving production technologies, updating, and increasing of food product range and enhancing its quality. At the same time, state support and innovation strategy should provide a system of organizational and economic measures to implement the latest scientific and technological achievements. Updating of production powers must be done by an accelerated withdrawal of physically worn-out and outdated equipment and commissioning new machinery, which matches world-leading examples. Notwithstanding existing problems, food production remains a powerful source for the state budget [1–3].

There is increasing interest in products that have a functional purpose in the society [1]. A promising technology that provides significant intensification of production processes is thermal-hydromechanical

treatment of starch-containing raw materials, which is carried out using extrusion technic [1; 2].

Extrusion is characterized by a simultaneous impact on the processed material of moisture, heat, mechanical stresses of various kinds. Extrusion is a highly efficient, zero-waste, short-term technological process, and extruder is considered as a universal biochemical reactor by many researchers [4].

The uniqueness of extrusion method lies in the possibility in not only using a wide scope of traditional for our country types and features starch-containing raw materials, but in the possibility to obtain products of various structure and forms (ready-to-eat products, products of children's therapeutic and preventive nutrition, semi-finished products, modified starches, etc.) [4; 5].

Extrusion processing of starch and starch-containing raw materials allows us to obtain completely ready-to-eat food products (snack products, cereals, cornflakes etc.) instant products (semi-finished chips, puddings, drinks, soups that do not require boiling) [6; 7].

Review of the latest research and publication. The works on designing food products for pre-school and school-age children are especially relevant today. We can explain this by the fact that the resources of some kinds of raw materials are limited, especially considering usage only organic batches, this affects child nutrition products range. Therefore, the task of finding new sources of raw materials that are quite widespread, relatively inexpensive, not inferior to the traditional types of raw material in nutritional value is current. Intensively conducting works nowadays are works on the expanding range of new types of functional cereals such as flour mixtures, bakery, pasta, and confectionery products, food concentrates enhanced by the additives received from medical plants, vegetables, fruits, etc. The active work in this direction is being performed by such scientist as: I.V. Syromakhin, V.M. Kovbasa, V.I. Drobot, H.B. Rudavska, N.V. Prytulska, K.G. Iorgachova, V.O. Morgun, L.V. Kapreliants, G.F. Kozlov, N.K. Cherno, A. Wisman, W. Bergthaller, L. Haxaire and other [7–12]. Today, more and more new varieties of corn are included in the register of varieties of agricultural plants in Ukraine, but the possibility of their use in the food, food-concentrate and processing industries is not studied enough.

Cereal products consist of nutrients that are necessary for maintaining the normal functioning of the human body (macro and microelements, vitamins, enzymes, dietary fiber, phospholipids, and other biologically active substances). However, they are low in protein and therefore are characterized by a large number of limited amino acids [13–15].

The objective of the research. The aim of the work is to obtain extruded products based on corn grain and to determine their quality indicators. To achieve the goal, the following tasks are formulated:

– development of technology for extrudates from corn grits;

– development of recipe composition for corn extruded products;

– study of quality indicators of the obtained extruded products;

– determination of the optimal storage conditions for the developed extruded products.

Presentation of the research material. Based on biochemical content analyses of different corn varieties and extruded products, identifying organoleptic quality characteristics we justified choice of the cereal raw material, its dosage, extruders production optimal conditions, and improved their formula.

We suggested the production method and formula of extruded cereal products on the basis of corn grain [16; 17].

According to the assigned tasks, we performed in the laboratory technological process of production of cereals and extruded materials during the processing of corn grain using the MHP method with schemes represented in the pic. Grain purification and fractioning, separation of grinding products was performed on the sieves and metal woven sieves.

Preparation, processing of corn grain, and obtaining extrudates were performed according to the schemes presented in the Fig. 1–3.

Fort the production of corn snacks we used the following equipment:

– Laboratory extruder (PE, Germany), laboratory grinder, electric weights (Rotex RSK 10-P, China);

– to determine the degree of digestibility: a device for determining digestibility *in vitro* – spectrophotometer (V-1100D, China); laboratory mill.

Fort the research we used following raw materials: sugar corn (GOST 6002), barley (DSTU 3769), carrot (DSTU 7035:2009), licorice root (GOST 22839-88).

We have conducted extrudates formula improvement based on the main nutrient characteristic of the content using mathematical modeling [18]. Mathematic modeling was performed by linear programming using editor MS Excel 2010 [19; 20].

We have been assigned to design ingredients composition for the production of extruded cereal products, in which, employing inserting new components, we needed to ensure the increase of nutrient and biological values of the final product as well as expanding of the product range.

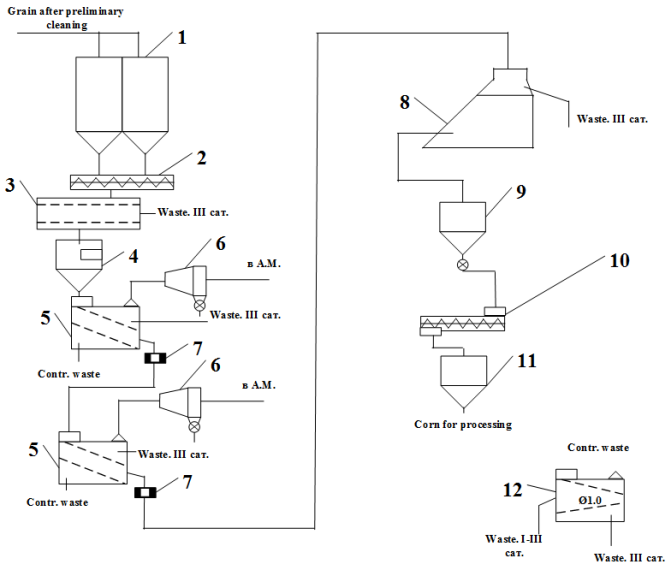


Fig. 1. Flow chart of preparation for processing corn grain: 1 – bunkers; 2 – auger; 3 – scalper; 4 – scales; 5 – sieve-air separator; 6 – horizontal cyclone; 7 – magnetic separator; 8 – stone sampler; 9 – hopper; 10 – moisturizing apparatus; 11 – bins for moistened grain

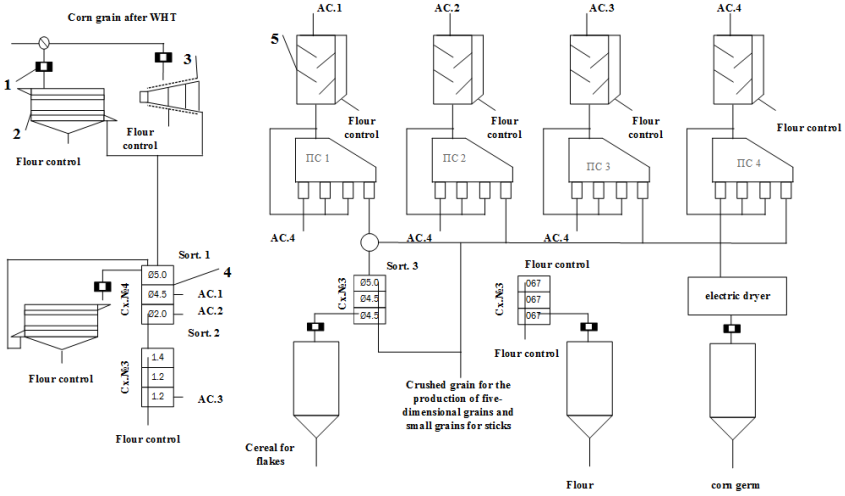


Fig. 2. Technological scheme of grinding corn and embryo selection: 1 – magnetic separator; 2 – two-rotor crusher; 3 – derminator; 4 – grain sieving; 5 – aspiration column; 6 – pneumatic sorting table

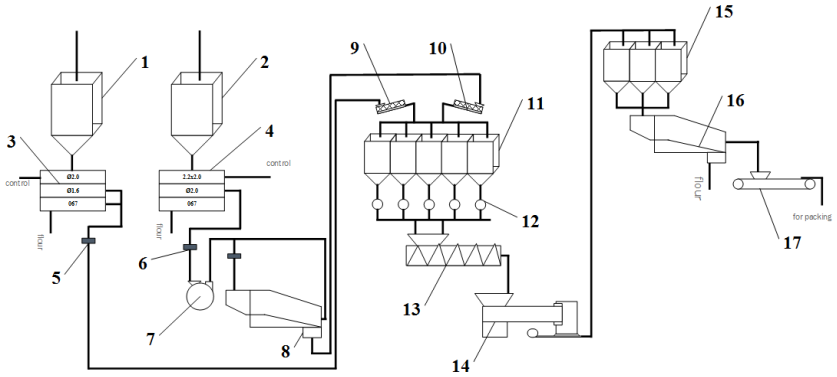


Fig. 3. Technological scheme for the production of extrudates from combined cereal raw materials: 1, 2 – bunkers; 3, 4 – sieving; 5, 6 – magnetic column; 7 – crusher; 8 – sifter; 9, 10 – moisturizing machine; 11 – bunkers; 12 – dispensers; 13 – mixer; 14 – extruder; 15 – bunkers; 16 – sifter; 17 – conveyor

The assigned task was completed by the composition [16; 17] of the ingredients which contained corn cereal and grain product with additionally added ground licorice root and blanched carrot root, as for the cereal component, it contained hull-less barley cereal with following mass ratio in %:

– corn cereal 75–80;
– hull-less barley cereals 15–20;
– ground licorice root 1–2;
– blanched and ground carrot root 2–4.

Using the sweet corn cereal, which contains a lot of protein (sugars) allows us to avoid usage of sugar and sugar powder in the production process. Sweet corn grain contains mineral substances (calcium, magnesium, potassium, sodium, phosphorus, chlorine, sulfur, iron, etc.), starch (25–37%), and water-soluble polysaccharides (19–31%). Sugarcane contains (in mg%): Vitamin C 11.6–13.7; Vitamin B_1 (thiamine) 0.16; Vitamin B (riboflavin) 0.11–0.12; Vitamin B_5 (Niacin) 1.97–2.25; in addition – vitamins B_3, B_6, inositol, choline, biotin, E and A (carotene) [21; 22].

Licorice root contains vitamins, minerals and other biologically active compounds, as well as natural amino acids, polysaccharides, essential oils, resins and tannins. It is used in the food industry as a sweetener of natural origin. The use of licorice root enhances the nutrition properties of the product – gives a sweet taste, as well as enriches with vitamins (A, E, B_1, B_2, B_6, B_9, PP, beta-carotene), macro- (phosphorus, calcium,

magnesium, sodium, potassium) and microelements (iron, iodine, manganese, fluorine, etc.) [23].

The use of hull-less barley cereal increases the nutrition properties of the product and enriches it with microelements. Hull-less barley grain contains a complex of vitamin E +, magnesium +, omega-3 fats, as well as a large amount of ß-glucan, which helps to cleanse the body of cholesterol, slag, and toxins, as well as having strengthening and immunostimulant effect on the body [24; 25].

The addition of blanched ground carrot root into the content of the mixture increases the nutrition properties of the final product, giving it a special taste, aroma, and color, as well as adds vitamins and minerals. Carotene contained in carrots in large quantities, promotes the normalization of metabolism, affects the physical and mental state of the human body, normalizes the functions of the organs of vision, has antioxidant properties, cleanses the body of toxins and slags [26; 27].

Extruded cereal product with mentioned formula is produced according to the following technology.

Sweet corn cereal, rice cereal, wheat cereal, and ground licorice root undergo control sifting and purification from metal admixtures, mix, and load mixture to the extruder with simultaneous addition of the water in the amount of 15–20% mass from the general amount of mixture. The extrusion process results in a dough-like substance. During the pressing through forming openings we obtain endless harnesses 8–10 thick mm, which should be cut in separate products with knife installed in the outline border of the matrix. Then products undergo a high-temperature drying process with 100…200 °C within 1–1.5 minutes until the moist level becomes 3–5%, after that they are transferred to a container for the conditioning, where the will be left for 16–18 hours for the gradual reduction of products humidity and fragility stabilization [16].

This study also examined the nutritional composition of developed corn sticks.

The results presented in the table show that the developed products have a high content of protein substances, which is quite important from the point of view of meeting the needs of the modern human body.

It should be noted that the developed products are distinguished by a fairly high content of all the main micronutrients necessary for the human body, namely calcium, phosphorus and potassium (Table 2).

Table 1

Macronutrient composition of corn sticks (g / 100 g)

Name of macronutrients	Control	"Kukurudzianka"	"Kukurudzianka+"
Humidity	6.0	5.0	3.0
Protein	10.9	12.5	19.5
Fat	5.6	2.8	2.1
Carbohydrates	78.4	63.2	63.7
Ash	2.4	1.7	2.15

Table 2

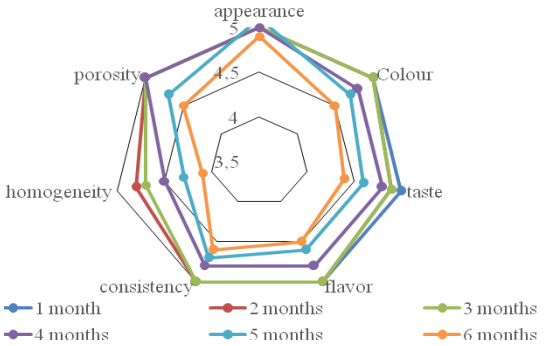
The degree of satisfaction of the daily human need for essential vitamins, % (when consuming 100 g of sticks)

Vitamins	Daily rate, мg	"Kukurudzianka"		"Kukurudzianka+"	
		Sticks, in 100g	Satisfaction with daily needs, %	Sticks, in 100 g	Satisfaction with daily needs, %
A	0.1	0.08	76.62	0.08	80.00
B_1	1.5	0.22	14.93	0.29	19.27
B_2	1.8	0.25	13.82	0.28	15.31
B_6	0.2	0.15	75.76	0.65	79.25
E	15	0.44	2.93	0.56	3.73
PP	20	4.78	23.90	5.475	27.38
C	80	0.61	0.77	0.65	0.81
Calcium (Ca)	3000	314.74	10.5	392.63	13.1
Magnesium (Mg)	800	99.89	12.5	127.75	16.0
Phosphorus (P)	400	255.32	63.8	297.95	74.5
Potassium (K)	2500	181.97	7.3	212.38	8.5
Sodium (Na)	400	99.89	25.0	52.36	13.1
Iron (Fe)	18	2.67	14.8	3.48	19.3

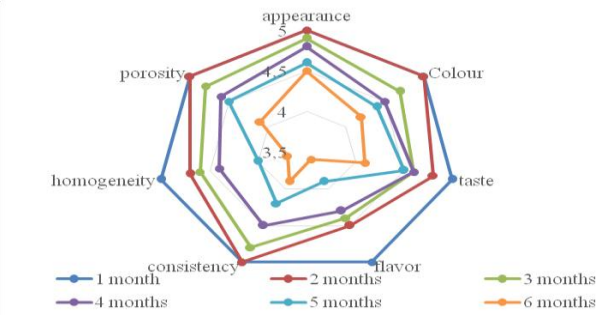
As can be seen from the above data, when using composite mixtures based on corn grits (flour), it is possible to enrich the extrudates with essential components for the human body.

On the basis of the conducted microbiological researches it is established that at storage of the developed extrudates in unregulated conditions, these products have rather quite good quantitative and qualitative indicators [28].

The dynamics of changes in organoleptic parameters in the point system is shown in Fig. 4. Intervals of changes in the values of organoleptic indicators were assigned from 0 to 5 points: 0–1 – very poor quality, 1–2 – poor quality; 2–3 – medium quality; 3–4 – good quality; 4–5 – excellent quality.



a – snacks "Kukurudzyanka +"



b – snacks "Kukurudzyanka"

Fig. 4. Dynamics of changes in sensory parameters of corn snacks during storage: a – snacks "Kukurudzyanka +"; b – snacks "Kukurudzyanka"

Based on the research done, a shelf life of 6 months at a temperature of (18 ± 2) ^{o}C) and a relative humidity of not more than 75% can be recommended.

Conclusion. 1. Technological schemes for producing corn grits and extrudates based on them have been developed.

2. Formulations of extruded products based on corn grain have been developed. Optimization of extrudate recipes was carried out using the table processor Solver (MS Excel 2010), the optimal content of all components was established. This made it possible to obtain products balanced in biological value and improved consumer properties, namely corn sticks "Kukurudzianka" and "Kukurudzianka +".

3. The chemical composition of the developed corn sticks was investigated. Proven to be balanced in terms of essential nutrient content. It was found that the protein content in the developed extrudates "Kukurudzianka" and "Kukurudzianka +" is 12.5 and 19.5 g / 100 g, respectively. The carbohydrate content of the developed products is 63.2 and 63.7 g / 100 g "Kukurudzianka" and "Kukurudzianka +" respectively.

4. The optimal storage periods for cereal and extruded products from starch-containing grain raw materials have been determined, during which there is a decrease in organoleptic characteristics and significant changes in physical and chemical properties, namely, within 6 months in unregulated conditions (relative air humidity 75–80%, air temperature 18±20 ^{o}C) environment with intact packaging.

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