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Анотація. В статті досліджено особливості кулінарних виробів на круп'яній основі, харчова цінність яких та збалансованість нутрієнтного складу забезпечуються завдяки науково обґрунтованому підходу щодо створення полікомпонентних композицій. Показано, що багатокомпонентна рецептура, отримана шляхом математичного моделювання, ускладнює технологічний процес, за умови формування високоякісного готового продукту. Досліджено фізичні та органолептичні показники готових виробів, виготовлених на основі різних технологічних підходів. Встановлено, що поетапний технологічний процес приготування круп'яних запіканок за визначеними режимами, дотримання послідовності та тривалості технологічних операцій дозволяє сформувати високоякісний готовий продукт.

Ключові слова: круп'яні запіканки, нутрієнтна збалансованість, кулінарна готовність, в'язкість, властивості крохмалю, інсулінова відповідь продукту.

Аннотация. В статье исследованы особенности кулинарных изделий на крупяной основе, пищевая ценность которых и сбалансированность нутриентного состава обеспечиваются благодаря научно обоснованному подходу по созданию поликомпонентных композиций. Показано, что многокомпонентная рецептура, полученная путем математического моделирования, усложняет технологический процесс и условия формирования высококачественного готового продукта. Исследованы физические и органолептические показатели готовых изделий, изготовленных на основе различных технологических подходов. Установлено, что поэтапный технологический процесс приготовления крупяных запеканок согласно установленным режимам, соблюдение последовательности и продолжительности технологических операций позволяет сформировать высококачественный готовый продукт.

Ключевые слова: крупяные запеканки, нутриентная сбалансированность, кулинарная готовность, вязкость, свойства крахмала, инсулиновый ответ продукта.

THE INFLUENCE OF INGREDIENT COMPOSITION AND TECHNOLOGY ON THE FORMATION OF QUALITY OF GRAIN CASSEROLES

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Introduction

The food and restaurant industries permanently face the tasks to expand the range of food and culinary products and provide the population with high-quality and wholesome foods. Culinary dishes from cereals are an important sector of the population diet. Porridges are universal products from cereal raw materials. They are consumed in different kitchens around the world. Despite the considerable percentage of porridge consumption the derivatives of these culinary products, grain casseroles, have a limited stock. Studies on the development of the technology of the cereal-based food products with a balanced nutrient composition are of particular importance for public catering. Such studies are relevant and well-timed.

Problem statement

Expanding the range of grain casseroles and balancing nutrient composition of these food products by mathematical modeling complicate the technological process on condition of high-quality finished product formation. Development of technology for producing new types of food products from cereals involves the formation of such consumer characteristics like appearance, texture, flavor and other quality indicators. Dishes prepared according to the traditional recipes [1], are characterized by unbalanced structure, vague

taste and texture but the technological process of their production does not require special treatment. Polycomponent composition and features of raw starches substantially affect the change in the texture of food products which determines the necessity of the process adjustment.

Native biopolymers of the component composition, structure of starch grains of the grain raw materials and mass fraction of amylose determine the disintegration rate of starch granules structure and thereby the change of the rheological, taste, color and other parameters of the product. Thus, considering the basic properties of raw materials of the recipes, its changing during the technological treatment and influence on the formation of finished product multicomponent quality, it is necessary to give grounds for the technological process sequence.

Literature review

A significant segment of the food with complex recipe composition in the ordinary people diet is characterized by high organoleptic and nutritional values. It stipulates the further development towards the design of multicomponent food and culinary products [2, 3]. Development of technology for production of high-quality culinary dishes and products is possible providing systematic approach to solving problems.

The basis of the formation of complex quality indicators of food products from cereal raw materials are a number of factors that must be considered. Ingredient composition, type and mode of technological processing have direct impact on the nutritional, biological value, rheological and organoleptic characteristics of the developed products. Starch raw materials with physically inaccessible amorphous and crystalline starch types A and B are the basis of grain casseroles. These starch types are concentrated in the granules as well as in retrograde forms and vary in X-ray diffraction [4].

The structure that is formed as a result of specific and non-specific interactions taking place at different levels from the molecular (0.1...10 nm) to supramolecular ($2 \cdot 10^3 \dots 10^7$ nm) is an important indicator of the food quality [5]. Texture properties of food products as well as of culinary products with sufficiently high starch content largely depend on the presence of other natural polymers, physical and chemical interactions between them. Heat processing of cereals being the starch system in the protein matrix including lipid substances causes the formation of a composite microstructure. Thus swollen grain starch acts as a filler that changes the rheological properties of the generated material [6].

In addition to the rheological properties of raw materials and their impact on the texture of the finished products such factors as color, flavor and fragrance of products that are transformed during technological processing have a great importance. The influence of hydrothermal treatment on the basic properties of starch materials is shown in Figure 1. The lengthy process of hydrothermal treatment leading to a significant disintegration of starch cells causes a decrease in viscosity and thickening, enhances the absorption of moisture from the environment (water absorption), provides deepening sense of taste and flavor [7, 8].

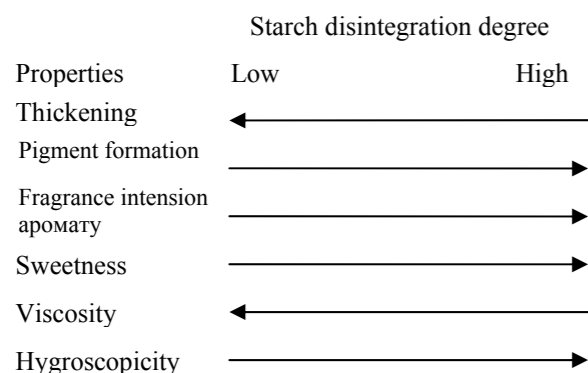


Fig. 1. Influence of the starch disintegration degree on the properties of raw materials

Such colloid-chemical changes of the properties of starch and protein components as full or partial starch gelatinization, partial hydrolysis with forming of dextrins and coagulation of proteins occur during the hydrothermal processing. In this regard, the content of water-soluble substances in the product significantly

increases, the amount of which directly depends on the properties of starch and hydrothermal treatment degree. The consistency of cereals in the result of hydrothermal treatment arises from the strength of gels formed due to the starch gelatinization, depends on the amount of water used and the cooking duration. Starches of different cereals absorb various quantity of water. For instance, buckwheat starch absorbs a minimal amount of water: 150 % (in the original mass), millet: 200 %, rice: 250 % pearl barley: 300 %. Therefore, formation of quality of food products from cereals is possible by taking into account the features of recipe components and a clear development process of cooking.

Main part

The purpose of this paper is to analyze the impact of component composition and technology of multicomponent cereal casseroles on the formation of the quality of finished products.

Objectives of the research:

- determination of the starch mass fraction content and its homopolymeric components in the recipe ingredients of casseroles;
- investigation of viscosity characteristics of cereal model systems during their hydrothermal treatment;
- determination of the duration of hydrothermal processing of cereal model systems for their culinary readiness;
- evaluation of the impact of the recommended processing methods on the formation of the casseroles' consumer characteristics.

The primary task which was to develop scientifically based composition of casseroles, has been solved by analyzing the food and biological value of raw materials recommended for the recipes. Given the need to develop products with a balanced nutrient composition and use of a wide set of raw materials (different types of cereals, nuts, candied fruits, additional flavor components, etc.) the task was solved by designing [9]. Applied principle of linear programming foresaw the introduction of the objective function (the desired ratio of proteins and carbohydrates) and a group of limitations (desired content of recipe components). As a result of the computer designing a number of multicomponent cereal-based recipes was obtained.

Considering the fact that several kinds of cereals were mixed in designed recipes of the developed culinary products, it is important to take into account peculiarities of cooking each of them and their mixtures. Thus, determining the order of appending and length of croup hydrothermal processing and their subsequent baking one should focus on determining the impact of technological processing on the basic properties of recipe ingredients. Cereal basis of casseroles is the raw material with high content of carbohydrates, especially starch. It is necessary to take into account its characteristics (structure of starch granules, physical

properties and the presence of other nutrients and antinutrients, amylose and amylopectin ratio) and the effect of types and modes of processing technology on the change of the properties of the product. Starch content and its structural components (homopolymeric D-glucans formed from α -D-glucopyranose fragments) in the recipe ingredients are shown in Table 1.

Table 1 – Starch content and its polymeric components in the recipe components of grain-based casseroles

Recipe components	Mass fraction of starch, %	Mass fraction of amylose, %	Mass fraction of amylopectine, %
Buckwheat	54.0	20...25	75...80
Millet	53.0	10...14	86...90
Rice	60.0	15...18	82...85
Pearl barley	55.0	18...20	80...82
Wheat grits	57.0	20...25	75...80
Maize grits	59.0	25...28	72...75

It is important that amylopectin has less impact on the starch quality than amylose which largely affects the swelling ability. When "amylose-amylopectin" ratio displaces towards amylose, starch gelatinization temperature decreases, crop swelling increases and its consumer properties improve.

Conducted rheological investigations of samples (model systems) showed characteristic features in the change of cereals' viscosity during hydrothermal processing. The change of viscosity index of cereal model systems which are part of the same recipe, was determined using a rotary viscometer (hydromodulus $HM = 2$, $T = 95^\circ C$) at intervals of 5 minutes. It was established that under the same conditions and mode of technological processing rheological properties of vis-

cous cereals differ. During the hydrothermal processing viscosity of rice model system unlike buckwheat gradually decreases (Fig. 2). The reason for this is that the viscosity of systems with high starch content depends on the volume ratio and dispersed particles (swollen starch grains) deformation. The viscosity of soluble starch and the interaction between the phases have a direct impact on the formation of the rheological properties of the system. An analysis of the qualitative composition of the polymer components of casseroles showed higher mass fraction of amylose in buckwheat compared to rice. Thus, with increasing of the starch swelling due to amylose content the viscosity of buckwheat model increased, and the disintegration of the supramolecular structure of rice starch is accompanied by an exponential decrease in viscosity. Also distinctive feature of buckwheat starch is the presence of stronger bonds in polysaccharides compared to other starch crops [10]. In addition, decreasing of the swelling degree and solubility of starch in raw materials with higher starch content (rice grits) is due to the limited content of free water.

Thus, such factors as the content of starch in cereals, the mass fraction of its polymeric components, their properties and duration of hydrothermal influence determine the quality of the final product which is a viscous porridge for casserole cooking. It should be noted that the change in the rheological properties of cereals during heat treatment depends not only on the content of starch and amylose and amylopectin ratio in it. For instance, pearl barley despite the content of starch and the mass fraction of its components slightly differing from other cereals requires the longest hydrothermal treatment to achieve culinary readiness. Thus, such morphological features of the grain structure as intermolecular connections, content of fiber, (1 \rightarrow 3, 1 \rightarrow 4)- β -glucans and other nutrients have a single value.

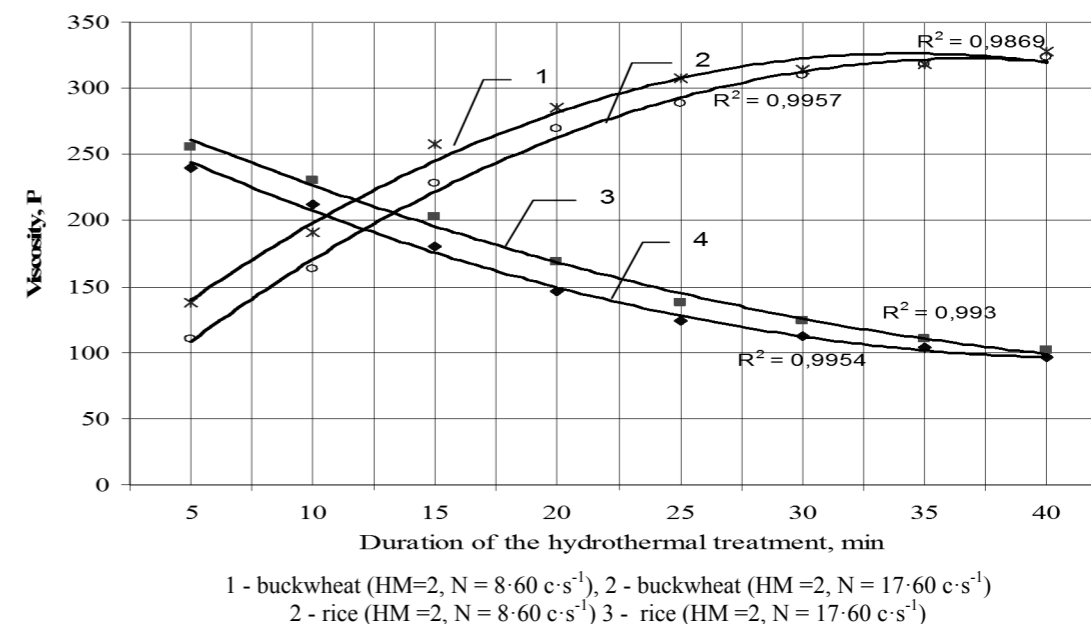


Fig. 2. Influence of hydrothermal treatment on the viscosity of cereal model systems

Determination of hardness change of examined cereals (proof of culinary readiness) under the same conditions of hydrothermal processing allows setting the desired duration of the process. Completion of the process corresponds to the time at which the hardness value of cereals is in the range of 4...6 °F degrees (Fig. 3). Achieving this indicator examined cereals assume texture desired for casseroles cooking, distinctive taste and pleasant smell. Continued hydrothermal influence on cereal samples is accompanied by undesirable changes in the rheological properties: buckwheat becomes too viscous and rice grains lose their shape, assuming puree consistency. In addition, excessive heat exposure can lead to irreversible processes in raw protein molecules, such as the initial stage of proteolysis which may cause a decrease in the digestibility of protein nitrogen.

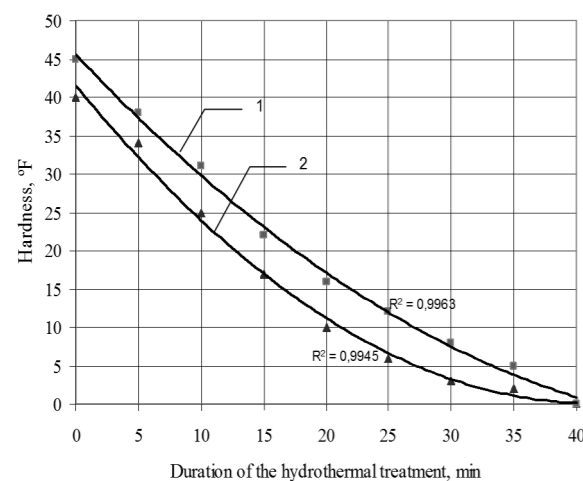


Fig. 3. Influence of hydrothermal treatment on the hardness of grits
1 – buckwheat, 2 – rice

Thus, during the preparation of several combined cereals should be carried out according to the characteristics of the raw materials: swelling and cooking speed. Based on the research results the technologies of grain casseroles with different component composition are developed by linear programming (Gantt chart). It allows to determine the time and sequence of appending components [11].

As stated above, colloid-chemical changes of the properties of starch and protein components occur during the hydrothermal processing of cereals. Such colloid-chemical changes of the properties of starch and protein components as full or partial starch gelatinization, partial hydrolysis with forming of dextrans and coagulation of proteins occur during the hydrothermal processing. In this regard, the content of water-soluble substances in the product significantly increases. The amount of these substances is directly dependent on the properties of starch and degree of hydrothermal treatment. It was established that with increas-

ing moisture content of cereals (78...81 % for viscous porridges) the number of their water-soluble substances increases by 17...39 %. The increase of water-soluble substances in porridges (compared with raw materials) is mainly caused by dissolving of starch polysaccharides during starch gelatinization and the dissolution of the mucilaginous materials and other substances. The more water is absorbed by starch, which is gelatinized, the more amylose is dissolved and more peptized amylopectin is formed.

To confirm the feasibility of the phased appending of cereals on the stage of hydrothermal processing the comparative organoleptic evaluation of two samples was conducted. Recipe composition of the samples was the same: millet (28.0 %), buckwheat (19.7 %), rice (12.0 %), eggs (27.0 %), candied ginger (5.0 %), butter (4.0 %), sugar (3.0 %), turmeric (1.0 %), vanilla sugar (0.3 %). Technology of cooking grain casseroles provided to obtain viscous cereals ($T = 96...98\text{ }^{\circ}\text{C}$, $\tau = 30\text{ min}$), further appending of whipped raw eggs, butter, candied ginger, sugar, egg oiling of the surface and baking ($T = 180...190\text{ }^{\circ}\text{C}$, $\tau = 30\text{ min}$). The difference of technology was the first step which was cooking viscous porridge with a recommended composition of grits. The first model involved the simultaneous cooking of cereals, the second involved the phased cooking according to the developed technology.

Organoleptic evaluation confirmed the feasibility of using the recommended sequence of technological operations when cooking casseroles. Improvement of rheological properties (texture and porosity) with basic sensory quality (Fig. 4) indices gives an attractive appearance to the finished product.

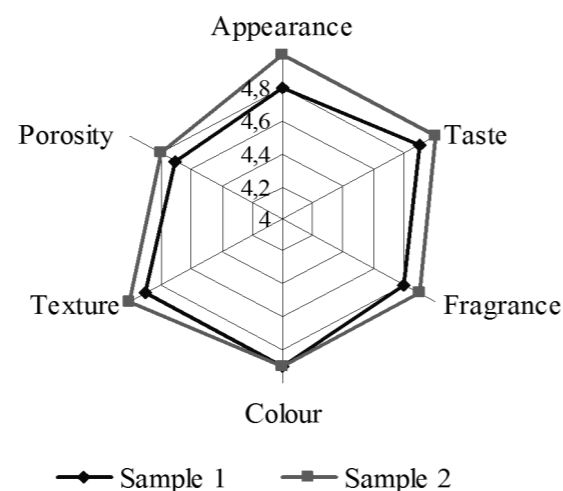


Fig. 4. Organoleptic evaluation of grain casseroles cooked according to different modes of technological treatment

The combination of these features creates high consumer properties of food products, helping to attract additional customers. This is also due to the fact, that casseroles prepared according to the recommended

Conclusions

Determining the impact of the basic properties of starch raw materials on the formation of a complex quality index of casseroles is important in terms of science-based approach to the production of food products and dishes. It is shown that the choice of modes and the sequence of manufacturing operations to produce multicomponent products with desirable properties (texture, organoleptic characteristics) should be based on the established relationships. It was established that the combination of raw materials with high content of carbohydrate biopolymers reduces the insulin response in human body. Thus, the scientific justification and compliance of recipe composition, mode, duration and sequence of manufacturing operations of cooking multicomponent cereal-based casseroles enhances the complex quality index of finished products.

mode are better absorbed in the body. Carbohydrates of the cereal components are characterized by low splitting velocity, and therefore do not cause a sharp rise in blood glucose concentration. It promotes the normal production of insulin by the body. Systematic consumption of foods with a low glycemic index and glycemic load reduces the risk of diabetes, obesity and other diseases [12]. The decrease in glycemic response of developed dishes is due to polymer composition of starch raw materials, namely amylose and amylopectin ratio. Thus, the glycemic response decreases with an increase in the proportion of amylose. In addition, encapsulation of starch as a result of the interaction of dietary fiber and protein during hydrothermal processing of cereals reduces the availability of starch to the action of α -amylase, and at the same time the glycemic response of the product.

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