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Технологический потенциал пищевого ингредиента, полученного из подвергнутых тепловой обработке луковиц *allium sativum l.*

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Аннотация. Введение. *Черный чеснок традиционно пользуется большим спросом во многих странах мира, в том числе в России, в виду популярности гастрономического тренда паназия, в рамки которого хорошо вписывается его применение как готового к употреблению продукта питания, так и ингредиента пищевых продуктов.* ***Материалы и методы.*** *Показана возможность применения черного чеснока как ингредиента пищевых систем, однако, сведений о физическом состоянии и свойствам, в том числе обуславливающие технологическую адекватность, крайне мало и они разрознены, что обусловило цель настоящей работы – исследовать функционально-технологические свойства порошкообразного пищевого ингредиента, полученного из подвергнутых тепловой обработке луковиц Allium sativum L.* ***Результаты и обсуждение.*** *Объектами исследования послужили образцы пищевого ингредиента в виде порошка, полученные измельчением ферментированных луковиц чеснока сорта «Добрыня» урожая 2024 г. В статье приведен анализ функционально-технологических свойств порошкообразного пищевого ингредиента, полученного из подвергнутых тепловой обработке луковиц Allium sativum L. Проведенный анализ позволил сделать вывод о перспективности использования данного пищевого ингредиента в различных пищевых системах. Объектами исследования являлись образцы пищевого ингредиента, полученные ферментацией луковиц чеснока при Т=70 °С в течении 20-ти сут. (№ 1) и при Т=80 °С в течении 15-ти сут. (№ 2).* ***Заключение.*** *В ходе проведённых исследований исследованы органолептические, физико-химические и технологические свойства образцов. Показано, что по комплексу функционально-технологических свойств полученный ингредиент в виде мелкодисперсного порошка может представлять интерес для ряда пищевых технологий и систем.*

Ключевые слова: луковицы чеснока, пищевой ингредиент, тепловая обработка, порошок, функционально-технологические свойства.

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Research article

Technological potential of a food ingredient obtained from heat-treatmented allium sativum l. Bulbs

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Abstract. Introduction. *Black garlic has traditionally enjoyed great demand in many countries around the world, including Russia, due to the popularity of the pan-Asian gastronomic trend, which fits well with its use as a ready-to-eat food product and as an ingredient in food products.* ***Materials and methods.*** *The possibility of using black garlic as an ingredient in food systems is shown, however, information on its physical state and properties, including those that determine its technological adequacy, is extremely limited and scattered, which determined the purpose of this work - to study the functional and technological properties of a powdered food ingredient obtained from heat-treated Allium sativum L. bulbs.* ***Results and discussion.*** *The objects of the study were samples of the food ingredient in the form of a powder obtained by grinding fermented Dobrynya garlic bulbs harvested in 2024. The article presents an analysis of the functional and technological properties of a powdered food ingredient obtained from heat-treated Allium sativum L. bulbs. The analysis allowed us to conclude that this food ingredient has potential for use in various food systems. The objects of the study were samples of food ingredient obtained by fermentation of garlic bulbs at T=70 °C for 20 days (No. 1) and at T=80 °C for 15 days (No. 2).* ***Conclusion.*** *In the course of the studies, the organoleptic, physicochemical and technological properties of the samples were investigated. It was shown that, based on the complex of functional and technological properties, the obtained ingredient in the form of a fine powder may be of interest for a number of food technologies and systems.*

Keywords: garlic bulbs, food ingredient, heat treatment, powder, functional and technological properties.

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Introduction. In recent years, black garlic (Allium sativum L.) has traditionally enjoyed high demand in many countries worldwide, including Russia, due to the popularity of the pan-Asian gastronomic trend, which fits well with the use of black garlic as both a ready-to-eat food product and a food ingredient. Black garlic is particularly popular in Asian countries [1].

Heat treatment parameters for activating endogenous enzymes, changes in chemical composition, and their mechanisms have been described in sufficient detail in modern literature and summarized by the authors in [2], which demonstrates the positive effect of heat treatment at temperatures ranging from 40–90°C on the chemical composition, nutritional value, and organoleptic properties of the fermented product. Black garlic, for example, is distinguished not only by its color (from dark brown to black), but also by its unique and specific, pleasant taste and aroma, gelatinous texture, and soft (sometimes creamy) consistency. It is well known that, when it comes to herbs, taste is most important to consumers, often associated with food quality.

During heat treatment, the specific, pungent odor of fresh garlic is almost completely lost. Twenty-four aromatic compounds have been identified that determine the taste of black garlic, from which the main flavor attributes and their characteristics are formed: sour – similar to vinegar; sweet – caramel; fresh – the taste of a peeled fresh cucumber; sauce-like – soy sauce; fried – the taste of potato chips; sulfur-like – a kind of garlic taste, etc. [3]. More than 50 aromatic compounds have been identified in the aroma of black garlic, with 9 key aromatically active compounds being identified, of which they are considered very significant: allyl methyl trisulfide (boiled garlic), furaneol (caramel), diallyl disulfide (fresh garlic), (E, Z)-2,6-nonadien-1-ol (cucumber, fresh), 3-(methylthio)-propioaldehyde (boiled potato flavor) [4].

It's worth noting that the volatile aroma compounds of garlic are related not only to the heating temperature but also to the cooking methods and duration. For example, the flavor profiles of fried and baked garlic bulbs were strongly associated with thioether and pyrazine compounds, particularly 2,6-dimethylpyrazine, dimethyl trisulfide, and diallyl disulfide, which are responsible for the most prominent salty and fried (e.g., fried potato and roasted walnut) flavor notes, as well as fatty (aldehyde) and mushroomy tones [5].

As a food ingredient, black garlic is used in various dishes, sauces, dressings, marinades, etc., adding a piquant, special, and sometimes unusual, aroma.

In addition, garlic is a natural antibacterial agent, which is important for food systems susceptible to microbiological spoilage during production and storage, such as processed meat products. The ingredients used can influence the microbiota of meat products and have a positive impact on their quality and safety. The study [6] investigated the effect of black fermented garlic on the microbiological, physicochemical, and organoleptic characteristics of turkey breast muscle meatballs (test samples with the addition of 1%, 2%, 3%, and 4% of a paste obtained by grinding black garlic bulbs in a blender), replacing fresh garlic commonly used in meat products (control samples with the addition of 1%, 2%, 3%, and 4% of a paste obtained by grinding fresh garlic bulbs in a blender). The results of the study showed that the pH values (6.06, 6.02, 6.03, and 6.01 pH units) in the test samples containing black garlic were similar to the active acidity of the control group—within the 6.16 pH range—and tended to decrease during refrigeration. However, with increasing amounts of black garlic, the minced meat color also changed, becoming unacceptably dark (at 4% black garlic). Adding black garlic to poultry minced meat suppressed the total number of bacteria and Pseudomonas. It was found that using 2% black garlic produced a meat product with an acceptable flavor and aroma. The addition of 4% black garlic was unacceptable to the evaluators.

In support of the antibacterial properties of black garlic, allicin has been found to be one of the most potent inhibitors of Candida biofilms. Allicin is reported to act by inhibiting the HWP1 gene, which is important for biofilm formation (Khodavan et al., 2011). Therefore, allicin can be evaluated as a promising compound for antibiofilm drugs [7].

There is also a study demonstrating the positive effect of allicin on the preservation of freshness of cold beef at T = 4 °C, packed in gelatin film with the addition of allicin nanoparticles – W_{zein} / $W_{allicin}$ 20:1, 10:1, 8:1, 5:1, 4:1. It has been shown that the gelatin film has good mechanical properties and barrier properties, and is capable of effectively delaying the deterioration of beef quality [8].

The aim of the following study was to evaluate the effect of black garlic on the aroma profile of semi-dried fermented sucuk sausage prepared according to a traditional recipe and technology: control – 1%, 2%, and 3% crushed fresh bulbs; experimental – 1%, 2%, and 3% crushed fermented garlic bulbs. A total of 47 volatile compounds were identified in the sausage samples, including sulfur compounds, alcohols, esters, ketones, aliphatic hydrocarbons, acids, aromatic hydrocarbons, aldehydes, and terpenes. It was found that the use of black garlic in sucuk did not significantly affect the aroma content, with the exception of the content of 2-propen-1-ol, allyl methyl sulfide, methyl 2-propenyl disulfide, sabinene, β - pinene, and β - phellandrene, regardless of the amount of black garlic added. Also, the addition of 3% black garlic reduced the level of diallyl disulfide and, consequently, the pungent and spicy aroma of garlic. However, this same test sample also contained the highest level of hexanal, considered an indicator of lipid oxidation. Thus, the use of black garlic, which is considered a functional ingredient in the production of sucuk, is possible and may be an alternative product for people sensitive to the pungent aroma of garlic, but at a level of 3%, it is impractical [9].

In order to reduce the specific taste of garlic and increase the health benefits of the fermented kimchi snack, a seasoning was prepared in which fresh garlic was replaced with crushed black garlic in quantities of 25%, 50% and 75%. It was found that changes in the total number of aerobic and lactic acid bacteria were similar between the control and experimental samples during storage, changes in pH and acidity did not differ; taste and aroma also did not differ significantly between the control and experimental samples, with the exception of the color of the seasoning: thus, the color and overall acceptability of the control sample and the sample replaced with 25% black garlic were higher than those of the samples replaced with 50 and 75% black garlic [10].

Thus, the possibility of using black garlic as an ingredient in food systems has been demonstrated; however, information on its physical state and properties, including those determining its technological adequacy, is extremely limited and fragmented, which determined the purpose of this work – to investigate the functional and technological properties of a powdered food ingredient obtained from heat-treated bulbs *of Allium sativum* L.

Research materials and methods. Experimental studies were conducted in the Departments of Nutrition Technology and Biotechnology and Engineering at the Ural State University of Economics.

The objects of the study were samples of the food ingredient in the form of powder, obtained by grinding fermented garlic bulbs of the Dobrynya variety. The 2024 harvest was grown on a private farm in the Biysk district of the Altai Territory (Figure 1). To obtain fermented bulbs, the heads were cleaned of the upper several contaminated layers of husk and placed in a desiccator with water to maintain constant humidity during fermentation and prevent drying of the samples at high fermentation temperatures. The desiccator was placed in a dry-air adjustable thermostat, and garlic fermentation was carried out at t = 70 °C for 20 days (sample No. 1) and at t = 80 °C for 15 days (sample No. 2) [11].

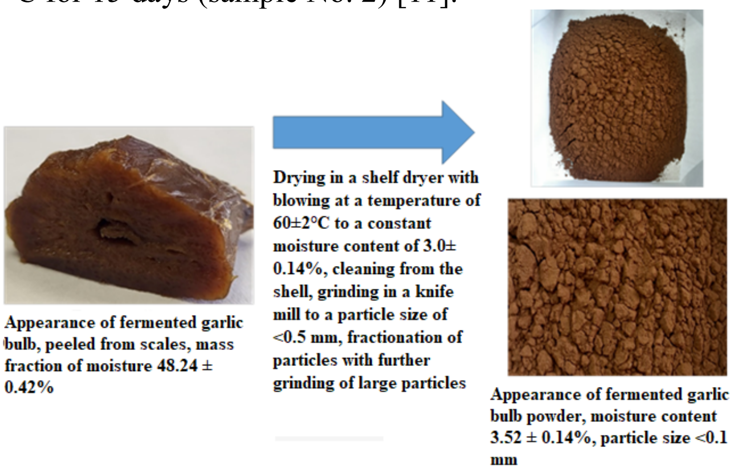

Figure 1.Visualization of the technology for obtaining a food ingredient from fermented bulbs of Allium sativum L.

Also for comparison, a dehydrated powder was obtained from peeled fresh garlic bulbs, chopped with a plastic knife and dried in a drying oven at a temperature of 70 °C to a residual moisture content of 6.8%, ground in a knife mill to a particle size of <0.1 mm .

The resulting powder samples were stored in hermetically sealed polyethylene bags until the start of the study.

The organoleptic properties of the obtained food ingredient samples were studied using tasting analysis methods in accordance with GOST 34130-2017 "Dried fruits and vegetables.

Test methods" in the following order: appearance, color, consistency, odor, and taste (purity, intensity, and foreign tastes and odors).

The physicochemical parameters of the samples were determined using standard methods according to GOST 34131-2017: mass fraction of moisture (%), mass fraction of mineral impurities (%) – according to GOST 25555.3-82 “Processed fruit and vegetable products. Methods for determining mineral impurities”.

Polyphenol content was determined using the Folin-Ciocalteu method (calculated as gallic acid) according to GOST 55488–2013 "Propolis. Method for Determining Polyphenols." For this purpose, alcohol extracts of dried garlic were prepared at a concentration of 1 g per 100 ml of 96% ethyl alcohol. The analysis was performed using a Shimadzu UV-1800 dual-beam spectrophotometer.

The technological properties of powdered food ingredient samples were determined using the following methods: swelling capacity - by infusing a 1% aqueous suspension in a graduated cylinder for 24 hours. Swelling capacity was estimated as the maximum amount of water that an object can absorb and retain before reaching dynamic equilibrium, divided by the mass of the sample [12]; wettability The powder density (in seconds) is determined by measuring the time of complete wetting of 10 g of a sample placed in a 250 ml beaker containing 100 ml of distilled water at T = 25 °C according to [13]. To determine the bulk density (kg/dm^3), 20 g of powder was loaded into a 100 ml graduated cylinder, the loaded cylinder was lowered 70 times onto a 15 cm high rubber mat and the final volume was recorded for use in calculations according to [14]. The water holding capacity (WHC), g water / g product, was defined as the amount of water adsorbed and retained by the raw material component during the infusion and centrifugation of the aqueous suspension. The fat holding capacity (FHC), g vegetable oil / g product, was determined by the amount of vegetable oil retained by the raw material component after infusion and centrifugation [15].

Research results and discussion. In the first stage, the organoleptic properties of food ingredient samples (Table 1) and the physicochemical properties determining the sample quality and added benefits (Table 2) were determined.

Table 1 – Organoleptic properties of food ingredient samples

Indicator	Sample characteristics		Fresh garlic powder
	No. 1	No. 2	
Appearance, color and consistency	A finely dispersed homogeneous powder without foreign impurities and particles of scales and bottoms, a beautiful brown color (visually similar to powdered instant coffee), free-flowing, tactilely similar to starch, hygroscopic	Finely dispersed homogeneous powder without foreign impurities and particles of scales and bottoms, dark brown in color, free-flowing, similar to starch when tactilely felt, hygroscopic	A homogeneous powder without foreign impurities and particles of scales and bottoms, cream-colored, free-flowing
Smell	distinct, pleasant, subtle, specific – with caramel tones, without foreign odors	distinct, specific - with burnt tones, without foreign odors	Characteristic of fresh garlic, without foreign odors
Taste	Distinctive, specific – sweetish, fried (potato chips), without any foreign flavors	Distinctive, specific – sweetish, with a predominance of burnt sugar tones, without any foreign flavors	Sharp garlicky flavor typical of fresh garlic, without any foreign flavors

2 – Physicochemical characteristics of food ingredient samples

Indicator	Sample characteristics	
	No. 1	No. 2
Mass fraction of moisture, %	3.52±0.14	3.10±0.11
Mass fraction of mineral impurities, % no more than 0.01	Not found	
Polyphenol content, mg/g	0.168±0.003	0.146±0.003

Based on the data in Table 1, sample No. 1 has acceptable organoleptic characteristics, therefore only this sample was subjected to the study of technological properties (Table 3).

The obtained values of the indicators determining technological adequacy are presented in Table 3.

Table 3 – Technological properties of a food ingredient sample obtained by heat treatment at t=70 °C

Indicator	Sample characteristics
Swelling capacity, cm3 / g	1.00
Bulk density, kg/dm³	23:00
Wettability, s	32
Water holding capacity (WHC), g water/g product	6.00
Fat holding capacity (FHC), g vegetable oil/g product	3.20

The data presented in Table 1 demonstrate that heat treatment, which initiates non-microbial fermentation of garlic bulbs, significantly alters their organoleptic properties. Essentially, a new food ingredient has been created, distinguished by its attractive brown color, distinct and distinctive aroma—with caramel tones—and a sweet, fried (potato chip) flavor. This allows this ingredient to be used in various food systems chosen by consumers who are hesitant to consume products containing fresh garlic due to its specific and highly persistent breath odor. In the mouth, hydrogen sulfide compounds in garlic form methyl mercaptan, which causes an unpleasant odor.

The quality of the powder samples under study was confirmed experimentally: as can be seen from the data in Table 2, the mass fraction of moisture was 3.52% and 3.10% in samples No. 1 and No. 2, respectively, which did not exceed the 8.0% required for food powders; no mineral or foreign impurities were detected.

It is worth noting that the biochemical parameters of fresh garlic powder sold in retail under the brands Indana, Granda, Every Day, Kamis [16] are known, the average values are: ash content 3.36%, polyphenol content - 506 mg-eq GA/100 g , sugars - 69.1%, water-soluble substances - 34.6%, antioxidant activity - 3230 mg-eq GA/100 g. In the work [17] the content of allicin in dried garlic powder extracts is given - from traces in darker samples to 1.1-4.8 mg / g in creamy-golden and 7.3 mg / g in white powder. Remezova I.P. and co-authors determined the content of the main biologically active components of garlic, %: the amount of sulfur-containing compounds - 1.05, flavonoids - 0.013, ascorbic acid - 10.55, chlorophyll - 2.37 [18].

However, no information on technological properties is provided, which further confirms the relevance and practical significance of the research conducted. To effectively use dry ingredients (powders), they must be pre-hydrated, taking into account key technological properties that ultimately determine their effectiveness in food systems/food products.

Bulk density is a clear indicator of powder properties, as it is a complex characteristic dependent on shape, particle size distribution, density, moisture content, and dispersion of powders, among other factors. This property is important for many food industry processes, as it allows for control of product consistency and influences the structure of finished products. Bulk density also influences flowability and can characterize it. The data in Table 3 shows that the food ingredient sample under study, with a bulk density of 23.0 kg/m³, is characterized as lightweight (ρн < 600 kg/m³), which will ensure highly accurate dosing of this raw material during food preparation.

One of the important requirements for a dry food ingredient is its rapid and easy reconstitution in water, including the absence of clumping upon contact with water. The first step in powder rehydration is wetting. Powder wettability is typically characterized by wetting time, measured in seconds. The value for this indicator for the sample was 32 seconds. It is known that finely dispersed powders are generally less wettable than agglomerated powders (with larger particles).

It should be noted that the swelling capacity and water holding capacity (WHC) of fine powders in food systems characterize their ability to bind and retain water, while the fat holding capacity (FHC) characterizes their ability to bind and retain fat. The swelling capacity of the sample was 1.0 cm3 / g, which is comparable to that of wheat flour [12].

Of great importance for food components is the WHC, on which the consistency, moisture content and yield of the finished product depend. As follows from Table 3, the WHC value is 6.0 g/g, which indicates a fairly good ability to absorb and retain moisture and is in good agreement with the literature data on the study of the functional and technological properties of vegetable powders from beets (6.7 g/g), carrots (9.8 g/g) and carrot pomace (8.68-9.05 g/g), pumpkin (6.0 g/g) and red sweet pepper (6.2 g/g) [19, 20]. The sample is also hygroscopic.

Taking into account that the obtained food ingredient is planned for use in various food systems, including those based on fat, for example: emulsion sauces, etc., the value of FHC, which is an important characteristic of raw ingredients, was determined to be 3.20 g/g, which is an average value when compared with the value of a similar indicator of the polysaccharide extract from flax seeds of the Caesar variety - 8.0 g/g [21].

Conclusion. The functional and technological properties of a powdered food ingredient obtained from heat-treated *Allium sativum L. bulbs* were studied. It was shown that, based on a combination of functional and technological properties, the resulting finely dispersed powder ingredient may be of interest for a number of food technologies and systems. Knowledge of the technological properties allows one to predict the behavior of the studied food ingredient in food systems during processing and storage of finished products.

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