

This paper reports a study into the use of germinated mungbean as a promising raw material influencing the structure-forming indicators of meat systems during the production of meat-vegetable sausages. The content of iodine in the germinated mungbean and its anatomical parts has been examined using solutions of potassium iodide. A change in the phytic acid content and size of phytin globuloids has been established in mungbean malt depending on germination conditions. The influence of flour from germinated mungbean on the moisture-binding, moisture-retaining, fat-retaining abilities, as well as on the pH of meat systems based on veal meat, pork, chicken has been investigated.

The reported set of studies is important as the defined patterns could make it possible to devise technologies for meat-vegetable sausages, to expand the range of enriched meat products.

The result of this study has established that the degree of biotransformation of iodine into beans is influenced by the protein content in the native beans. Almost 90...95 % of iodine is accumulated in the cotyledons of beans in the protein fraction, 5...10 % – in sprouts and roots. The rational range of potassium iodide concentrations in the germination solution is 76.5 g per 1,000 cm<sup>3</sup>, over 48 hours. Prolonging the germination time leads to microbiological damage to the bean mass.

The germination process affects the reduction of phytic acid content, which is confirmed by a decrease in the diameter of phytin globuloids.

It is rational to use in meat systems based on pork meat and veal meat 10 % of the developed flour by reducing meat raw materials. With this ratio of formulation ingredients, the maximum increase in the moisture-binding, moisture-retaining, and fat-retaining capacities of these meat systems is achieved. In the meat systems based on chicken meat, it is possible to increase a replacement part of up to 15 %.

The reported set of studies is useful and important because it could form the basis for devising the technologies of meat-vegetable sausages to meet the needs of different segments of consumers

**Keywords:** germinated mungbean, meat-vegetable minced meat, moisture-binding capacity, moisture-retaining capacity, fat-retaining capacity, phytic acid

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# STUDYING THE INFLUENCE OF MUNGBEAN USE ON THE STRUCTURE-FORMING INDICATORS OF MEAT-PLANT SYSTEMS BASED ON VEAL, PORK, CHICKEN MEAT

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## 1. Introduction

The development of innovative technologies of sausage products is aimed at rationalizing the use of raw materi-

als [1], expanding the range [2], developing specialized types of sausages [3]. In this regard, meat-vegetable sausages may occupy a worthy place in the diet of a modern person. The inclusion of plant-based raw materials in meat systems

requires a comprehensive study since it affects the organoleptic and structure-forming quality indicators, which are known [4] to belong to the main indicators of the quality of sausage products. Particular attention when studying meat-vegetable systems should be paid to moisture-binding, moisture-retaining, fat-retaining capacities, as well as the pH of meat systems [5].

Along with this, the type of starting meat raw materials [6] is of great importance. Traditional types in the production of sausage products are the meat systems based on veal, pork, chicken, and their mixes. Chicken meat is inferior to pork and veal in terms of structure-forming and biological characteristics. It is known [7] that pork meat should not be used during the production of specialized sausage products due to the high lipid component. It has been proven [8] that calf meat has high biological indicators, mainly due to its high content of vitamin B<sub>12</sub>, but is quite expensive, which affects the purchasing power of the consumer. It is of scientific interest to conduct research aimed at studying the structure-forming indicators of meat systems based on veal, pork, chicken meat, depending on the use of plant-derived raw materials. As vegetable raw materials, it is advisable to use legumes, namely mungbean, as a source of plant protein. To reduce the anti-nutritional effect of native mungbean, it is rational to apply the germination process. Taking into consideration the fact that the protein from legume beans is capable of accumulating trace elements from solutions for germination, thereby biotransforming them into organically bound substances, it is rational to use potassium iodide (PI) as a solution for germination. This is due to the fact that PI is the maximum carrier of iodine in a substance (0.76 µg of iodine per 1 g). In the world, about 20 % of people suffer from iodine scarce conditions while the market for iodine-containing foods accounts for about 2 %.

Carrying out such a set of studies could make it possible to establish patterns that would make it possible to devise technologies for meat-vegetable sausages containing organically bound iodine. This is important because organic iodine compounds are largely biologically available with the highest degree of retention in the human body, and are non-toxic. The consumption of products to be developed should affect the increase in efficiency and the body's capacity to withstand iodine deficiency diseases.

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## 2. Literature review and problem statement

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The direction of scientific research is concentrated mainly in the production of specialized food products enriched with essential trace elements. Technologies to produce dairy products containing iodine based on goat milk [9, 10] are being developed. The disadvantage of the proposed technology is the shortage of dairy raw materials, namely goat milk, and because fermented milk products have a specific taste and smell, that is, such organoleptic indicators are not familiar to the consumer.

There are technologies [11] to produce bread containing iodine. Bread, although it refers to mass consumption products, is a carrier of gluten, which is unacceptable for people who are on specialized nutrition because of celiac disease. Another drawback in the development of iodized bread technologies is the increased carbohydrate content and reduced protein content, which can be explained by "Instagram fashion" to proper nutrition along with physical exercises in order to model body shape.

There are technologies [12] where the use of flax flour in the production of meat products is proposed. The possibility of using plant raw materials in meat systems based on veal, chicken meat, and their mixes [13] has been studied.

The disadvantage of the proposed technologies is that plant raw materials are considered in terms of only improving the structure-forming characteristics of meat systems and meat-plant products. Scientists paid little attention to the study of plant raw materials and their consumer value. It is not established how many nutrients are contained in the enriching plant raw materials. A similar approach is applied in [14], which reports the results of a study that suggests the use of natural β-carotene as an additive in the production of veal-based mincemeat. The results only prove that the introduction of β-carotene leads to an increase in the moisture-binding capacity of minced meat, increases the yield of the finished product while improving the taste characteristics. A similar approach is also used in work [15] that proposed to use boiled chickpeas to improve the quality of sausage products.

Its use in the amount of 10–20 % to the mass of meat raw materials as an improver of the structure-forming characteristics of the meat product is substantiated, but the food ingredient itself has not been studied.

Work [16] paid more attention to the above issues. The scientists proposed the technology of preparation of minced meat based on pork with the introduction of pumpkin powder. It was established that it is not inferior to the control sample, and the fat content is reduced by 25 % without deterioration of structure-forming and organoleptic indicators. The researchers studied plant raw materials and found that pumpkin powder could enrich meat-vegetable products in the content of vitamin A, β-carotene, and silicon, the carrier of which it is. The disadvantage of the proposed technology is the lack of essential trace elements in the proposed technologies.

Paper [17] proposed the technology of preparing minced meat with seaweed. The proposed technique makes it possible to prepare products with an increased content of essential elements, especially iodine. However, their use in the amount exceeding 8 % by weight of the meat raw materials leads to a decrease in organoleptic indicators. The slices of finished products demonstrate greenish inclusions. Another drawback is not providing 5 % of the daily need for iodine, which is important in terms of the principles of nutriology.

An option to overcome such difficulties may be to use soy flour enriched with iodine during the germination process in potassium iodide solutions [18].

Work [10] devised the technology of boiled-smoked sausages with the addition of the flour of soy germinated in potassium iodide solutions to the basic raw material. The authors have found that the plant proteins of soy are capable of accumulating iodine from potassium iodide solution in the process of bean germination. However, the cited work has not investigated the likely anti-nourishing effect caused by legumes, mainly due to the content of phytic acid. Paper [19] describes that the phytic acid of legume beans decreases from the malting process.

Given the fact that meat-vegetable sausages may occupy a worthy place in the structure of the diet for a modern person, it is necessary to conduct research to investigate the following:

- plant raw materials;
- changes in the biochemical processes in the mungbean, depending on the germination conditions;

– the influence of the germinated mungbean on a change in the pH and structure-forming indicators of meat systems based on veal, pork, chicken meat.

The results of experimental studies are important because they could form the basis for new technologies of meat-vegetable sausages.

### 3. The aim and objectives of the study

The purpose of this study is to determine the effect of using mungbean on the structure-forming indicators of meat and plant systems based on veal, pork, chicken meat. This could make it possible to establish patterns that would be the basis for devising new technologies of specialized meat-vegetable sausages enriched with iodine.

To accomplish the aim, the following tasks have been set:

- to examine the content of iodine in the germinated mungbean of different varieties, depending on the germination conditions;
- to study the change in the content of phytic acid and the size of phytin globuloids in mungbean malt depending on the germination conditions;
- to investigate the effect of flour from germinated mungbean on the moisture-binding, moisture-retaining, fat-retaining capacities, and the pH of meat systems based on veal, pork, chicken meat.

### 4. The study materials and methods

#### 4.1. A method to study iodine content in the cotyledons, sprouts, roots, malt, and flour of mungbean

The objects of this study are the early-ripening varieties of mungbean – “Barak”, “Erdem”, “Hayam”, which were included in the State Register in 2019. The 2020 harvest from Agrotek collection farm in the city of Kyiv (Ukraine). The growing season of ripening of the early ripening varieties of mungbean is 80 days, the weight of 1,000 seeds was 65.0 g. Characteristics of the germination solutions are given in Table 1.

Table 1

Characteristics of germination solutions

Germination solution experimental sample No.	1	2	3
Substance content in solution			
PI content per 1,000 cm <sup>3</sup> H <sub>2</sub> O	15.2	38	76.5
Iodine content per 1,000 cm <sup>3</sup> H <sub>2</sub> O	20	50	100

Note: \* – 1 g PI contains 0.76 µg/g iodine

While studying the effect of flour from the germinated mungbean on the structure-forming indicators of meat systems, the study objects were model systems based on minced meat of various types of meat (veal, pork, chicken). The share of replacement was due to a decrease in the meat raw materials in quantities from 10 to 50 %.

The mass fraction of iodine was determined using the voltammetric analyzer “AVA-2” (TM Burevesnik, Russia), which is equipped with an indicator electrode, an auxiliary electrode, a comparative type electrode. A weighted portion of the sample was treated with a solution of potassium hydroxide, burned on an electric stove, and then we used the “PHOENIX” microwave ashing system (Daewoo, Chi-

na). The resulting ash was mixed in water, neutralized to pH 4...6, and centrifuged. The resulting mass was added to the electrochemical cup with a background solution and then we performed measurements. Based on the results, a mass share of iodine was calculated.

#### 4.2. A method to study phytic acid content and the size of phytin globuloids in mungbean malt

We determined the content of phytic acid according to the method given in work [20]. Underlying this method is the discoloration of phytic acid with a solution of the complex anion of iron disulfosalicylate to brown color. We analyzed the morphology of phytin globuloids using the microscope JSM-5610 LV (Japan), which is equipped with the system of chemical analyzers EDX JED-2201 JEOL (Japan). The experimental samples were investigated under a low vacuum mode using a detector with the reflection of electrodes.

#### 4.3. Methods to study the structure-forming indicators and pH of meat systems based on veal, pork, chicken meat

Moisture-binding capacity (MBC) was determined by the Grau-Hamm pressing method. The method implies the separation of water from a sample when pressed. The size of the area of the spot obtained on paper was used to calculate the amount of separated moisture.

Acidity (pH) was determined by the ionometric method. The method is based on the measurement of the electromotive force of the element, which consists of an electrode of comparison with the known value of the potential and an indicator electrode, the potential of which is predetermined by the concentration of hydrogen ions in an experimental sample.

Moisture-retaining capacity (MRC) was determined by a method given in [21]. Samples of minced meat weighing 200 g were canned, weighed, and exposed to heat treatment, cooled in running water to a temperature of 22...19 °C over 12...15 hours, and, at a temperature of 6...3 °C, over 24 hours. The dishes with broth were placed in the dryer and, at a temperature of 105...100 °C, brought to a constant mass. After that, calculations were performed.

Fat-retaining capacity (FRC) was determined as follows: a weighted portion of the minced meat was added to the 30 ml centrifuge test with mungbean flour malt added. That was aged in the thermostat at 20 °C, periodically stirring the suspension over 30 minutes. After that, we centrifuged it at 15,000 rpm for 15 minutes. The volume of the supernatant was measured.

To confirm the reliability of the experimental data obtained, they were statistically treated based on the results from 5...9 parallel experiments ( $p < 0.05$ ). The Microsoft Office Excel 2010 (USA) and Statistic (USA) software packages were used.

### 5. Results of studying the effect of mungbean use on the structure-forming indicators of meat-vegetable systems

#### 5.1. Investigating iodine content in the cotyledons, sprouts, roots, malt, and beans of mungbean

The results of studying the content of the mass fraction of iodine in the malt of mungbean and its anatomical parts, depending on the germination conditions, are given in Table 1.

Table 1

Content of the mass fraction of iodine in the germinated mungbean of different varieties, depending on the germination conditions

Early varieties of mungbean leguminous crop	Protein content, %	Iodine mass share, µg/g				Organoleptic indicators, points $X^1/X^2/X^3$
		0	20	50	100	
		Control	Sample 1	Sample 2	Sample 3	
The content of iodine in germinated beans in 12 hours, µg/g						
Barak	17.23	–	11	32	69	5/5/5
Erdem	23.18	traces	17	42	88	5/5/5
Khayam	14.25	–	8	25	51	5/5/5
The content of iodine in germinated beans in 24 hours, µg/g						
Barak	17.23	–	12	43	79	5/5/5
Erdem	23.18	traces	20	51	103	5/5/5
Khayam	14.25	–	9	35	61	5/5/5
The content of iodine in germinated beans in 48 hours, µg/g						
Barak	17.23	–	14	44	93	5/5/5
Erdem	23.18	traces	22	51	119	5/5/5
Khayam	14.25	–	12	41	74	5/5/5
The content of iodine in germinated beans in 72 hours, µg/g						
Barak	17.23	–	18	49	100	4/2/2
Erdem	23.18	traces	25	64	139	4/3/2
Khayam	14.25	–	10	41	79	4/2/1

Note: \* – Organoleptic indicators after:  $X^1$  – 12 hours of malting;  $X^2$  – 24 hours of malting;  $X^3$  – 48 hours of malting. The values of organoleptic indicators in points: 1 – very bad, not suitable for use – 90 % blackened, rotten beans; 2 – ≤70 % of the beans are spoiled, blackened, rotten; 3 – ≤30 % of the beans are spoiled, blackened, rotten; 4 – ≥10 % of the beans are spoiled, blackened, rotten; 5 – good without spoiled beans

Analyzing experimental studies, one can argue that the largest content of accumulated iodine is demonstrated by mungbean malt with protein content in the native beans of 23.18 % – the variety *Erdem* (Turkey). Malt of this variety had 17; 42; 88 µg/g of iodine when malting beans in carrier solutions 20, 50, 100 µg of iodine (respectively) over 12 hours. When malting for 24 hours, in carrier solutions 20; 50; 100 µg of iodine, its content in the beans of the *Erdem* variety was 20; 51; 103 mg/g of iodine (respectively). When malting over 48 hours, in carrier solutions 20; 50; 100 µg of iodine, its bean content was 22; 51; 119 mg/g of iodine (respectively). Beans of the *Erdem* variety, which germinated at the above concentrations for 72 hours, had an iodine content of 25; 64; 139 µg/g. However, according to organoleptic indicators, the samples were not suitable for use: from 10 to 70 % of blackened, rotten beans.

Inferior in the content of accumulation of iodine is the mungbean variety *Barak* (Turkey). The protein content in the native beans of the *Barak* variety was 17.23 %. The *Barak* bean malt had 11; 32; 69 µg/g of iodine when malting beans in carrier solutions 20, 50, 100 µg of iodine (respectively) for 12 hours. When malting for 24 hours in carrier solutions 20; 50; 100 µg of iodine, its content in the beans of the variety *Barak* was 12; 43; 79 µg/g. When malting for 48 hours, in carrier solutions 20; 50; 100 µg of iodine, its content in the beans of the variety *Barak* was 14; 44; 93 mg/g of iodine (respectively). The beans of the *Barak* variety, which germinated at the above concentrations for 72 hours, had an iodine content of 18; 49; 100 µg/g. According to organoleptic indicators, the bean mass was not suitable for use: ≤70 % of blackened, rotten beans.

The lowest capacity for the accumulation of a trace element (iodine) from the solution is demonstrated by the mungbean variety *Khayam* (Turkey), with protein content in the native beans of 14.25 %. The malt of this variety had 8; 25; 51 µg/g of iodine, when malting beans in carrier

solutions 20, 50, 100 µg of iodine (respectively) for 12 hours. When malting for 24 hours, in carrier solutions 20; 50; 100 µg of iodine, its content in the beans of the *Khayam* variety was 9; 35; 61 mg/g of iodine (respectively). When malting for 48 hours in carrier solutions 20; 50; 100 µg of iodine, its content in the beans of the *Khayam* variety was 14; 44; 93 mg/g of iodine (respectively). The *Khayam* beans, which germinated at the above concentrations for 72 hours, had an iodine content of 10; 41; 79 µg/g. However, there was a sharp deterioration in organoleptic indicators. The bean mass was not suitable for use: 90 % of beans were blackened, rotten.

The issue characterizing the effectiveness of using our seminal advance is determining the degree of localization of iodine in the protein fraction. This is important because organic iodine compounds have the greatest bioavailability and degree of retention in the human body and are non-toxic, which significantly reduces the risk of intoxication in case of overdose.

It was considered relevant to conduct research aimed at studying the distribution of iodine by anatomical parts of sprouted beans, malt, and flour on its basis.

This approach would make it possible during the production of germinated flour to use those parts of beans that limit the maximum amount of iodine. The content of iodine in the cotyledons, sprouts, malt, and flour of mungbean is given in Table 2. We used the early ripening mungbean varieties *Erdem* and *Khayam*; the period of cultivation is 2020 on black soils in Kyiv oblast (Ukraine).

Our experiment has established that the beans of early ripening varieties of the mungbean leguminous crop can accumulate iodine, during germination, from solutions where potassium iodide was used as a carrier of iodine.

Analyzing the content of iodine in the anatomical parts of sprouted beans, it was established that iodine accumulation occurs in bean cotyledons in the protein fraction. The bean cotyledons of the *Barak*, *Erdem*, *Khayam* varieties

contain 90; 110; 70 µg/g of iodine (respectively). Whereas the sprouts of the above varieties contain only 3; 9; 4 µg/g of iodine. We found minor iodine losses within 5 % when the flour was made. Our results indicate a high degree of conversion of iodine into an organic form during the germination of mungbean in PI solutions. And the production of flour allows using it as a food ingredient when making many meals and products. Flour is the most used nutritional ingredient for 64 % of people of different nationalities. Our experimental results and parameters formed the basis for devising a technological scheme to produce mungbean flour enriched with iodine. A distinctive feature, in contrast to control technology, is that the beans are soaked in a solution of potassium iodide with a concentration of iodine in the solution of 100 µg/g over 48 hours. The technological scheme does not require additional equipment.

Table 2

Iodine content in the cotyledons, sprouts, roots, malt, and flour of mungbean

An early variety of mungbean leguminous crop	Iodine content, µg/g dry substance			
	Cotyledons	Sprouts, roots	Malt	Flour
<i>Barak</i> , germinated in water	traces	–	–	–
<i>Barak</i> , germinated in PI solution	90±0.2	3±0.2	93±0.3	91±0.3
<i>Erdem</i> , germinated in water	1±0.2	–	–	–
<i>Erdem</i> , germinated in PI solution	110±0.2	9±0.3	119±0.3	114±0.3
<i>Khayam</i> , germinated in PI solution	traces	–	–	–
<i>Khayam</i> , germinated in PI solution	70±0.3	4±0.2	74±0.3	72±0.3

Note: Beans were soaked for 48 hours, the concentration of PI was 76.5 g/1,000 cm<sup>3</sup> H<sub>2</sub>O. The content of iodine in solution is 100 µg. Malt – whole beans (cotyledons and sprouts). Flour – whole beans (cotyledons and sprouts), which were dried at a temperature of 100 °C to a moisture content of 7 %, grounded to the particle size of 0.2...0.4 mm

One of the issues of scientific interest is the content of phytic acid in the examined objects. It is known that legume beans contain phytic acid in the amount of 0.5 to 20 µg/100 g. Paper [22] found that the daily consumption of phytic acid in the amount of more than 5 g within 20 days significantly worsens the nutraceutical status and biological effect on the human body. It has been proven in [23] that this is because phytic acid, getting with food to the human body, is able to form complexes with iron, zinc, calcium, and magnesium in an insoluble form in the intestines and stomach. The human body cannot use those substances to meet physiological needs and removes them together with metabolic products.

**5. 2. Studying a change in the content of phytic acid and the size of phytin globoloids in mungbean flour depending on germination conditions**

It was established [24] that phytic acid is distributed throughout the entire cotyledon with cells in the aleurone layer of the phytin globoloid. The results of changes in phytic acid and diameter of phytin globoloids depending on germination solutions are shown in Table 3 and in Fig. 1.

During the experiment, we worked with the mungbean of the early-ripening variety *Erdem* cropped in 2020. The beans were soaked for 48 hours, the concentration of PI was 76.5 g/1,000 cm<sup>3</sup> H<sub>2</sub>O. The cotyledons were separated from the shells, sprouts, roots. They were dried at a temperature of 100 °C, up to a moisture content of 7 %, (Sample *c*). Sample *b* was prepared using the above technological operations, the difference was that water was used as a solution for germination.

Table 3

Studying changes in phytic acid content and diameter of phytin globoloids depending on mungbean germination solutions

Sample	Phytic acid content, mg/100 g	Phytin globoloid (d), µm
Flour from the non-germinated mungbean	5.8±0.02	5.1±0.01
Flour from the mungbean germinated in water	2.4±0.01	4.2±0.01
Flour from the mungbean germinated in PI solution (76.5 g 1,000 cm <sup>3</sup> H <sub>2</sub> O)	1.9±0.01	3.3±0.01

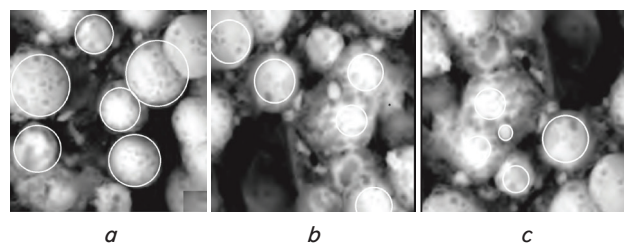


Fig. 1. Investigation of changes in the diameter of phytin globoloids depending on the solutions for mungbean germination: *a* – flour from non-germinated mungbean; *b* – flour from the mungbean germinated in water; *c* – flour from the mungbean germinated in a solution of PI. Photographs of phytin globoloids are magnified 3,500 times

It is established that the content of phytic acid in flour, made from the native beans of mungbean is 5.8 mg/100 g. The content of phytic acid in the flour of beans that were germinated reduces by 3.4 mg/100 g compared to the germination in water, and by 3.9 mg/100 g compared to the germination in a solution containing PI.

Phytic acid in legume beans is found in phytin globoloids. Reducing the size of phytic globoloids is symbiotic with phytic acid content. Our study of changes in the diameter of phytin globoloids has established that they are reduced by 0.9 µm when germinated in water and by 1.8 µm when germinated in PI solution.

Paper [25] reported similar results. When devising technology for meat-vegetable sausages, we suggest using the germinated legume malt as it has been proven that the germination process affects the splitting of phytic acid due to an increase in phytase activity.

**5. 3. Studying the influence of flour made from germinated mungbean on structure-forming indicators**

We have investigated the moisture-binding, moisture-retaining, fat-retaining capacities, and changes in the pH of meat systems based on chicken meat, veal, pork depending on the proportion of replacement of meat raw materials with mungbean flour whose beans were germinated in PI solutions. The results of our research are shown in Fig. 2–5.

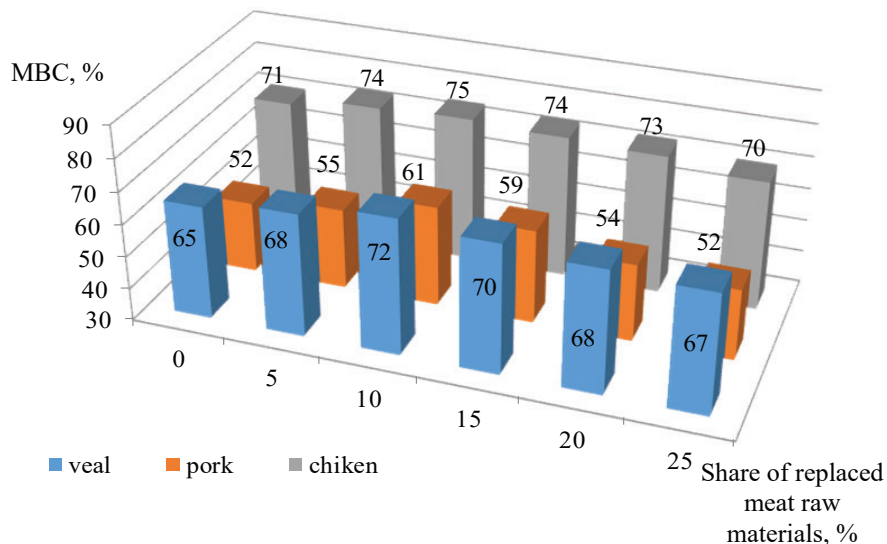


Fig. 2. Moisture-binding capacity of meat systems depending on the proportion of meat raw materials replaced with mungbean flour

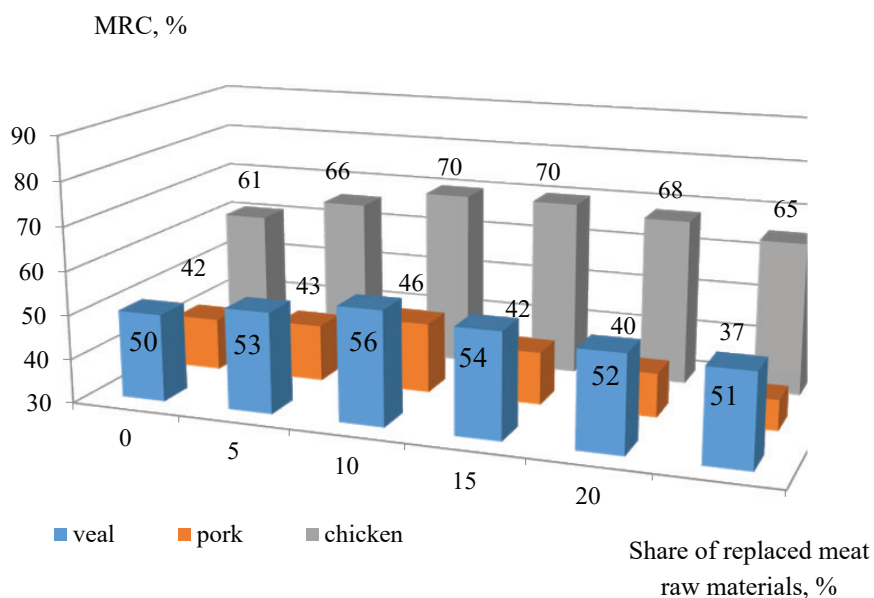


Fig. 3. Moisture-retaining capacity of meat systems depending on the proportion of meat raw materials replaced with mungbean flour

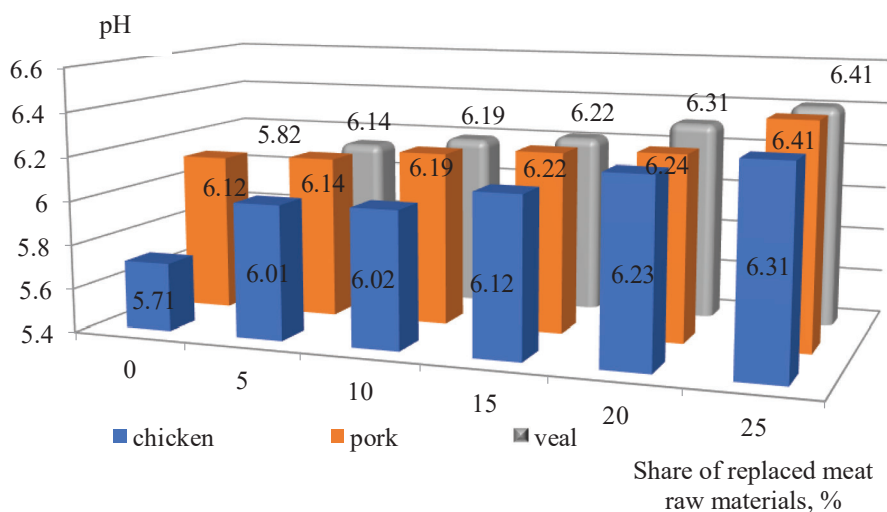


Fig. 4. Change in the pH of meat systems depending on the proportion of meat raw materials replaced with mungbean flour

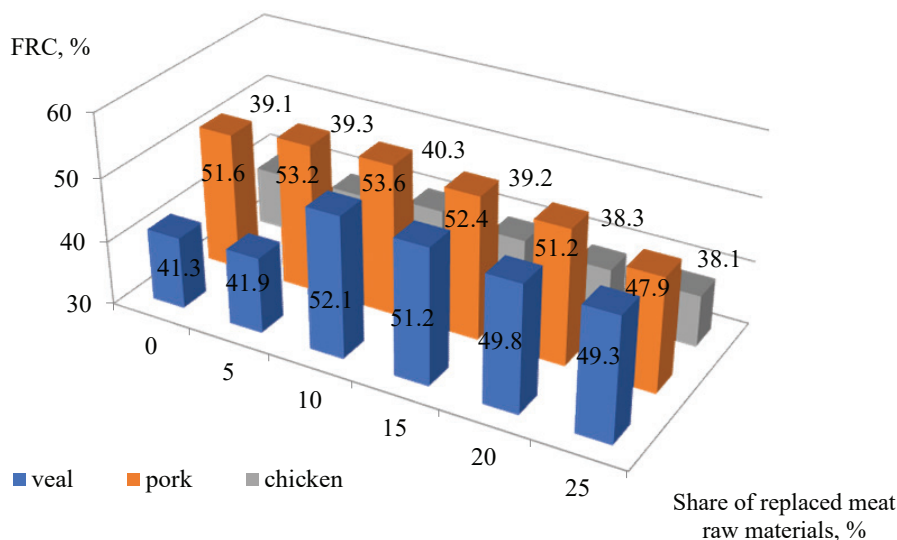


Fig. 5. Fat-retaining capacity of meat systems depending on the proportion of meat raw materials replaced with mungbean flour

The experimental data shown in Fig. 2, 3 indicate an increase in the moisture-binding and moisture-retaining capacity when replacing meat raw materials with the developed flour in the amount of 10 %. In the meat systems based on chicken meat, veal, pork, there is an increase in moisture-binding capacity by 4, 7, 9 %, respectively, relative to control samples. The moisture-retaining capacity increases by 9, 6, 4 % in the meat systems based on chicken meat, veal, pork (respectively), relative to control samples. With an increase in the proportion of replaced meat raw materials with the developed flour to 15 %, the meat systems based on veal and pork demonstrate a decrease in the indicators studied.

In the meat systems based on chicken meat, the maximum moisture-retaining capacity is observed in the range of 10...15 % of the share of meat raw materials replaced with the developed flour.

We have established a change in the pH of meat systems depending on the proportion of the meat raw materials replaced with mungbean flour, whose beans were germinated in the PI solution. It was determined that the introduction of the developed flour with a replaced share of 5...25 % contributes to the pH shift from 5.9...6.05 to 6.25...6.43.

Our study of the fat-retaining capacity of meat systems depending on the proportion of replaced meat raw materials using the developed flour indicates a positive effect at a replacement share of 10 %. The fat-retaining capacity increases by 1.2; 10.8; 2.0 % in the meat systems based on chicken meat, veal, pork (respectively), relative to control samples. With an increase in the share of the meat raw materials replaced with the developed flour from 15 to 25 %, there is a decrease in the FRC of meat systems.

## 6. Discussion of results of studying the use of flour made from mungbean malt on the structure-forming indicators of meat systems

The content of iodine in the flour of germinated mungbean and its anatomical parts was studied, depending on the germination conditions. It was established that the rational range of PI concentrations in the germination solution is 76.5 g per 1,000 cm<sup>3</sup>, over 48 hours. Increasing the germination time leads to microbiological damage to the bean

mass, which becomes unusable (Table 1). It was determined that mungbean can concentrate iodine from the germination solution whose content depends on the protein content in the native beans. We assume that potassium iodine solutions affect the permeability of mungbean cell membranes, contribute to the loosening of their shells, which leads to active diffusion of iodine ions from the solution into the inner space of the seeds. After examining the distribution of iodine through the anatomical parts of sprouted beans, malt, and the flour based on it (Table 2), it was established that iodine accumulation occurs in bean cotyledons and is more than 95 %.

That indicates a high degree of conversion of iodine into an organic form during germination in the PI solution. Our data correlate with those in [26], which investigated a change in the biochemical processes in chickpea seeds during their germination in a solution of sodium hydro selenite, as well with those reported in work [27], which describes a study of changes in the biochemical processes in soybeans during their germination in potassium iodide solution. This can be explained by the formation of new bio-accessible organic iodine and selenium-containing compounds in a metabolized form, which can be achieved during the malting process using mineral solutions.

Our study of changes in the content of phytic acid in the flour made from native and germinated mungbean has shown that its content is influenced by the germination process (Table 3). Bean germination solutions containing PI, when compared with control, reduce the content of phytic acid in the flour made from germinated mungbean by 67 %. The reduction in phytic acid content was confirmed by a decrease in the diameter of the phytin globoloid (Fig. 1).

That can be explained by enzymatic transformations during the soaking and germination of beans.

It is known [28] that soaking and germinating legume beans cause enzymatical transformations and splitting of phytic acid by activating phytase. Activated phytase enzymatically splits phytic acid, which reduces its anti-nourishing effect. The splitting of phytic acid occurs with the formation of free phosphate ions, which are available for absorption when entering the body.

Similar substantiations of the results of scientific research are described in paper [29], whose authors studied

the biological effect on the body of pigs exerted by the consumption of legumes and products of their processing. They searched to reduce the anti-nourishing effect caused by oligosaccharides, phytic acid, trypsin inhibitors. It was determined that the process of soaking and germination causes a decrease in the negative charge of phytic acid molecules, and as a result, the loss of the capacity to block proteins before digestion and absorption of amino acids and minerals [30, 31].

Fig. 2, 3 demonstrate that the maximum increase in moisture-binding and moisture-retaining capacity is achieved when replacing 10 % of meat raw materials with the developed flour. The above concentration shows the same maximum efficiency in the meat systems based on veal meat, pork. However, in the meat systems based on chicken meat, the proportion of replacement can be up to 15 %, with which there is no decrease in MRC.

The mechanism of MRC formation in meat systems is associated with the formation of hydrocolloids of the gel type. Proteins remain in the state of gels only in the presence of a stabilizing factor [32]; in the studied meat systems, the mungbean flour developed in this study could serve as one. The assumption is based on the fact that functional groups of meat proteins are able to interact with isothiocyanates, phenolic and indole compounds of plant raw materials. As a result, a spatial flexible matrix is created that retains a significant part of the water with substances dissolved in it; as a result, there is an increase in MRC.

It is known [33] that MBC, MRC, FRC are affected by pH. The initial pH value of the studied meat systems ranged within 5.9...6.05 depending on the type of meat, the pH of the developed flour is 6.6. With an increase in the proportion of the meat raw materials replaced with the developed flour, a pH shifts to 6.20...6.43 depending on the type of meat and replacement share (Fig. 4). Thus, when the pH shifts by an average of 0.38 units of measurement from the initial value, the charge of the protein molecule increases, as a result, the solubility of proteins increases. The pH increase is heading towards a certain maximum value, at which the maximum solubility of the protein is observed with the corresponding maximum increase in MRC and FRC. With a further increase in the proportion of replaced meat raw materials, the studied indicators are reduced, which correlates with a decrease in pH. With an increase in the share of the meat raw materials replaced with the developed flour from 15 to 25 %, there is a decrease in the FRC of meat systems (Fig. 5).

Thus, it is rational, in the meat systems based on veal meat, pork, to use 10 % of the flour from germinated mungbean, by reducing meat raw materials. Further increase in the content of flour from germinated mungbean does not contribute to the stabilization of meat systems; minced meat becomes non-plastic, not monolithic, free moisture appears.

There are certain limitations of our research related to that the rational range of concentrations of potassium iodide in the germination solution should be up to 76.5 g per 1,000 cm<sup>3</sup>. It is rational to germinate beans for 48 hours. Increasing the germination time leads to microbiological damage to the bean mass; as a result, it would lead to a deterioration in the organoleptic indicators of the finished product.

The prospect of further research is the development of formulations and technologies for meat-vegetable sausages, the study of their indicators of quality and content of iodine when their expiration date is reached. This is an opportunity

to establish the recommended amount of consumption of the developed products by persons with iodine deficiency and for the prevention of endocrine disorders.

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## 7. Conclusions

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1. It has been established that the degree of accumulation of iodine is influenced by the protein content in the native beans. The highest content of accumulated iodine was determined in the germinated mungbean of the *Erdem* variety with protein content in the native beans of 23.18 %. The malt of this variety contained 88; 103; 119; 139 µg/g of iodine when malting the beans in a carrier solution of 100 µg of iodine over 12; 24; 48; 72 hours (respectively). The mungbean variety *Barak* with protein content in native beans of 17.23 % demonstrated a lower capacity to accumulating a trace element (iodine) from the solution compared to that of the *Erdem* variety. The *Barak* variety mungbean malt contained 69; 79; 93; 100 µg/g of iodine when malting the beans in a carrier solution of 100 µg of iodine over 12; 24; 48; 72 hours (respectively). The *Khayam* variety mungbean malt with protein content in the native beans of 14.25 % contained 51; 61; 74; 79 µg/g of iodine when malting the beans in a carrier solution of 100 µg of iodine over 12; 24; 48; 72 hours (respectively). It is rational to perform the germination process for 48 hours. Increasing the germination time to 72 hours leads to microbiological damage to the bean mass, which becomes unusable. It was established that 90...97 % of iodine is accumulated in cotyledons, malt, mungbean flour, and, in the range of 3...10 %, iodine is accumulated in sprouts and roots. The rational range of PI concentrations in the germination solution is 76.5 g per 1,000 cm<sup>3</sup>, over 48 hours.

2. It was established that the content of phytic acid in the flour made from native mungbean beans is 5.8 mg/100 g while in the flour whose beans were germinated in water the content of phytic acid reduced by 3.4 mg/100 g. The content of phytic acid in the flour when the beans were germinated in a solution of PI reduced by 3.9 mg/100 g compared to the flour made from native mungbean. Our results have been confirmed by a decrease in the diameter of phytin globuloids in the beans. The reduction of phytin globuloids by 0.9 µm due to the germination in water, and by 1.8 µm due to the germination in PI solution, was established.

3. It was found that the maximum increase in moisture-binding and moisture-retaining capacity is achieved when replacing 10 % of the meat raw materials with the developed flour. The share of the meat raw materials replaced with the developed flour by 10 % shows the same maximum efficiency in meat systems based on veal and pork meat but, in the meat systems based on chicken meat, a replacement proportion can be up to 15 %. With an increase in the share of the meat raw materials replaced with the developed flour to 15 to 25 %, there is a decrease in the meat systems' FRC. Thus, it is rational, in the meat systems based on veal meat, pork, to use 10 % of flour from germinated mungbean, by reducing meat raw materials.

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