Analysis of efficiency of production of sausage products using non-traditional vegetable raw materials

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Abstract. The article is devoted to the problem of balanced nutrition in modern living conditions. The lack of vitamins, micro and macro elements negatively affects human health. Currently, much attention is paid to the problem of nutrition – new enriched products appear on the shelves, and consumers are increasingly paying attention to their composition and nutritional value. The creation of meat products intended for the prevention and treatment of diseases is an actual direction in the food industry, which has extremely important practical and social significance. The purpose of this work is to increase the nutritional value of sausages by using secondary products of regional plant materials – powdered mustard cake. By steaming the cake, the allyl mustard oil is removed, which gives a specific smell and a burning taste. The resulting additive with a residual essential oil content of not more than 0.05-0.1% is considered suitable for use in the technology of enriched meat products. As a result of the studies, the addition of processed mustard cake in the amount of 6-8 kg per 100 kg of raw meat to cooked and semi-smoked sausages positively affected the functional and technological parameters of the minced systems, as well as the main quality indicators developed in the framework of the experimental prototypes. The use of the indicated plant component in the formulations made it possible to increase the yield of the finished product, as well as to increase the stability of the minced system: in cooked sausages by 6%, in semi-smoked sausages – by 1%. A study of the biological value of protein showed an increase in this indicator in the studied product samples: in cooked sausages, this indicator increased by 1.9%, and in half-cooked sausages by 5.7%. In the test samples, essential amino acids are in more balanced proportions due to the high biological value of the protein.

1. Introduction

Nutrition has the most significant impact on human health and life. Lack of vitamins, macro- and microelements in the diet negatively affects the body. At present, much attention is paid to human nutrition – new fortified foods regularly appear on the shelves, and consumers increasingly pay attention to their composition and nutritional value. An important place in the grocery basket is occupied by meat products. Being a product of animal origin, meat contains animal protein, which is most fully absorbed by the body, as well as many nutrients necessary for the body.

The creation of meat products intended for the prevention, treatment and prevention of diseases is a progressive direction in the food industry, which has extremely important practical and social value [1, 2].
The volume of the world market of enriched and functional products in 2010 amounted to almost $160 billion, while back in 2004 this indicator was in the region of $30 billion. The global market for enriched products is developing rapidly, increasing annually by 15-20%. Innovative food products with functional properties, made from natural raw materials, will not only provide consumers with a healthy diet, but also guarantee manufacturers increased competitive status and access to a world-class market.

In the production of sausages, an important role is played by substances that ensure the stabilization of meat emulsions at the stages of grinding and cutting. The main builders used in the meat industry are wheat flour, soy flour, soy isolates, etc. Proteins and starch, which are part of the flour, play a significant role in the formation and stabilization of meat emulsion. Proteins soluble in the aqueous phase of the emulsion act as surfactants that facilitate the emulsification process.

The purpose of this work is to increase the nutritional value of sausage products by using mustard seeds processed in solid formulations (powdered mustard cake obtained in the production of mustard oil), as well as achieving product quality stability with storage. The development of a method for the production of sausages according to advanced recipes using regional raw materials of the Volgograd region is very relevant and appropriate from the point of view of rational use of raw materials of the food industry.

2. Materials and methods
Experimental studies were carried out on the basis of the complex analytical laboratory of the Federal State Budget Scientific Institution "Volga Research Institute for the Production and Processing of Meat and Dairy Products" and the laboratory of the department of "Technology of Food Production" of Volgograd State Technical University (Volgograd, Russia). The experiment was carried out in accordance with the scheme shown in figure 1.

![Figure 1](image)

**Figure 1.** Scheme of experimental studies.

The objects of study are samples of sausage products, the development of which was carried out on the basis of the Volga Research Institute of Production and Processing of Meat and Dairy Products and the Technology of Food Production Department of Volgograd State Technical University in accordance with optimized formulations based on the developed technology based on literature and patent data [3-7].
Sampling and analysis of the properties of powdered mustard cake (protein mustard structurant according to TU No. 9146-049-10514645-02) was carried out according to the following methods: GOST 13979.0-86 "Cake, meal and mustard powder. Acceptance rules and sampling methods", moisture determination and volatile substances according to GOST R 54705-2011; determination of the mass fraction of fat and extractive substances according to GOST 13979.2-94; determination of the total mass fraction of soluble proteins according to GOST 13979.3-68; fiber – GOST 32749-2014, determination of color and smell, the amount of dark inclusions and small things according to GOST 13979.4-68; determination of ash according to GOST 13979.6-69. Determination of the content of essential mustard oil (allyl oil, AITC) before and after its steaming from mustard seed products was carried out according to GOST 13979.7-78. The remaining indicators (the content of minerals, toxic elements, etc.) – according to generally accepted methods for the analysis of animal feed.

The selection and preparation of samples of sausages for laboratory studies was carried out according to a single method in accordance with the requirements of GOST R 51447-99 (ISO 3100-1-91). The determination of organoleptic indicators was carried out according to the requirements of GOST 9959-2015; GOST R 53159-2008; GOST R 53161-2008. Mass fraction of fat was determined according to GOST 23042-2015; protein – GOST 25011-2017; mineral substances – GOST 31727-2012, the pH of the samples of minced meat and sausages using a pH meter (using a piercing electrode).

The energy value of the samples (kcal / 100 g) was determined by the calculation method, based on the fact that the caloric content of nutrients (1 g of fat – 9 kcal, 1 g of protein – 4 kcal and 1 g of carbohydrates – 3.75 kcal) was multiplied by the percentage the content of relevant nutrients.

The study of functional and technological indicators (moisture-binding, water-retaining, fat-holding, emulsifying ability) was carried out by sequential determination in a single sample (method P.M. Salavatulina and others).

The amino acid composition of the builder and the sausage samples were determined using the Aracus amino acid analyzer in accordance with the instructions for the device.

Amino acid score was determined as the ratio of the content of a specific amino acid in 1 g of the protein of the test sample to the content of this amino acid in 1 g of the reference protein [1].

The difference coefficient of amino acid scores (KRAS, %) was calculated by the formula:

\[
KRAS = \frac{\sum_{i=1}^{n} (C_i - 100)}{n}
\]

where \( C_i \) is the amino acid rate of the i-th indispensable amino acid,%;
\( n \) is the amount of essential amino acids.

The biological value (BV,%) of the protein was calculated by the formula:

\[
BV = 100 - KRAS.
\]

The research materials were processed by the method of variation statistics using the Microsoft Office software package on a PC.

3. Results and its discussion

In the course of scientific research, a method for the production of sausage products was developed, which includes the introduction of an additive based on oilseed processing products at the stage of minced meat cutting. As a structurant, it is proposed to introduce a product of processing mustard seeds, a powdered mustard cake obtained in the production of mustard oil, into a mixture of ingredients of a traditional sausage recipe at the cutting stage [8]. Pre-mustard cake will go through the stage of removing the essential oil by steaming in the reactor.

3.1. The technology for producing cake with a low content of allyl mustard oil

As you know, the processing of mustard cake by steaming using the existing technology is an energy-intensive and labor-intensive process, the implementation of this technology requires the availability of technological and analytical control over the quality of the obtained additives. Therefore, an improved
technology was chosen that was implemented in the open joint-stock company VMEZ "Sarepta", Volgograd.

The technology for producing a high-protein additive from mustard cake with a low content of allyl mustard oil is as follows. 300 l of water was poured into the reactor, heated to 35-50 °C, and with a constantly working stirrer, 100 kg of mustard cake were poured. The hydrolysis time of sinigrin is 15 minutes at a temperature of not more than 50 °C. To remove allyl mustard oil, the suspension was purged with air.

In the absence of the smell inherent in table mustard, a suspension sample was taken for analysis to determine the residual content of essential oil. When the residual essential oil content is not more than 0.05-0.1%, the suspension is considered suitable for use in the technology of enriched meat products, it is dried in a tunnel dryer. For drying, a kapron cloth was used, on which the suspension was uniformly applied. The layer thickness is not more than 2 mm, the temperature of the supplied air for drying is not more than 80 ° C. The quality of the products obtained is homogeneous, in contrast to the traditional method of steaming the cake, each batch is controlled by the Quality Control Department for compliance with the requirements of regulatory documents.

Powdered mustard cake obtained in the production of mustard oil, followed by removal of allyl mustard oil from it (protein mustard structurant according to TU No. 9146-049-10514645-02) used in the inventive method for the production of sausages, has the quality indicators presented in table 1.

| Name of indicator | Indicator value |
|-------------------|-----------------|
| Appearance        | Fine yellow-green powder |
| Taste             | Peculiar to mustard cake without a specific mustard taste |
| Smell             | Peculiar to mustard cake without specific mustard and other extraneous odors |

Physico-chemical indicators (in terms of absolutely dry matter):

| Indicator value | Mass fraction of moisture,%, no more | Mass fraction of allyl isothiocyanate,%, no more | Mass fraction of crude fat,%, not less than | Mass fraction of crude protein,%, not less than | Mass fraction of crude fiber,%, no more | Mass fraction of total ash,%, no more | Oiliness, | Essential oils, % |
|-----------------|-------------------------------------|-----------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|-----------------------------------------|----------|------------------|
|                 | 7.0                                 | 0.1                                           | 12.0                                     | 30.0                                     | 5.0                                      | 6.0                                      | 7.5-11.5% | 1.0-3.0          |

Powdered mustard cake is a rich source of nutrients and has an amino acid composition that is practically indistinguishable from the amino acid composition of mustard seeds. In addition, residual essential oils of powdered mustard cake obtained in the production of mustard oil contain up to 40% allyl mustard oil and up to 50% crotonyl mustard oil, which inhibit the development of putrefactive microorganisms and contribute to a longer storage of products; in particular, it is assumed that this effect will be preserved in the production of cooked and semi-smoked sausages [7, 9, 10].

Allyl mustard oil is formed from sinigrin under the influence of the enzyme myrosinase at a temperature of 25-50° C and a sufficient amount of moisture. These components are contained in mustard seeds and are isolated from each other; in the absence of at least one of three factors – the presence of myrosinase, moisture, and elevated temperature – the formation of allyl mustard oil from sinigrin does not occur [11]. The presence of a large amount of allyl mustard oil in the finished meal is unacceptable, since it is one of the poisonous essential oils and, when ingested, can cause inflammation of the digestive system and kidneys.

Powdered mustard cake significantly surpasses soy flour in fat and water retention, which is explained by the structural composition of its constituent proteins. So, the water-holding capacity of soy
flour is 2.9 ± 0.2 g of water / g of the drug, and the water-holding capacity of powdered mustard cake is 6.0 ± 0.3 g of water / g of the drug, which is 2 times more. There are significantly more such water-soluble proteins in mustard oilcake than in soy protein isolate. Also, the protein fraction of powdered mustard cake plays the role of a thickener in the aqueous phase, which increases the sedimentation stability of the emulsion [3, 12]. The process of formation of protein gels is associated with thermal denaturation, i.e., with the destruction of the native three-dimensional structure of the protein and the release of polypeptide chains, which upon subsequent cooling of the emulsion form a spatial network stabilized mainly due to hydrophobic interactions.

3.2. Recipes and technology of cooked and semi-smoked sausages with the addition of powdered mustard

After conducting a series of experiments, the optimal recipe composition of finished products (sausage samples) was established using mustard cake as a structuring agent [13]. Control samples were developed using soy protein (table 2).

Table 2. The recipe of the samples.

| Component                        | Quantity, kg / 100 kg during production: |
|----------------------------------|------------------------------------------|
|                                  | boiled sausage products                  |
|                                  | Unsalted raw materials, kg / 100 kg     |
|                                  | Control samples No. 1                    |
|                                  | Prototypes No. 1                         |
|                                  | half-smoked sausage products             |
|                                  | Control samples No. 2                    |
|                                  | Prototypes No. 2                         |
| Veined beef of 1 grade           | 35.0                                     |
| Fat veined pork                  | 32.0                                     |
| Veined pork bold                 | –                                        |
| Wheat flour or potato starch     | –                                        |
| Soy protein isolated             | 6.0                                      |
| brand Supro                      | –                                        |
| Powdered mustard cake (hydrated) | –                                        |
| Water for hydration              | 24.0                                     |
| Spices and materials, g / 100 kg unsalted raw materials | |
| Nitrite salt                     | 2500                                     |
| Granulated sugar or glucose      | 300                                      |
| Ground black or white pepper     | 100                                      |
| Ground red pepper                | 50                                       |
| Coriander                        | 50                                       |
| Freshly chopped minced garlic    | 200                                      |
| Sodium ascorbate or ascorbic acid| 50                                       |
| Food Phosphates                  | 300                                      |

At the stage of optimization of the formulation of prototypes, as well as to analyze the effectiveness of using the structure-forming agent – mustard cake – in the manufacture of sausages, we studied the influence of this raw material on the technological properties of minced systems, organoleptic, physico-chemical characteristics and other quality indicators of the finished product.
The technology of control and experimental samples No. 1 (cooked sausages grade 1) is as follows [14]. Beef is crushed on a spinning top with a diameter of lattice holes of 2-3 mm and salted at the rate of 2.5 kg of nitrite salt per 100 kg of meat for 12-24 hours. Fatty pork is ground on a spinning top with a diameter of lattice holes of 16-25 mm and salted at the rate of 2.5 kg of nitrite salt per 100 kg of meat for 24-28 hours.

In the cutter lay nonfat raw materials (beef), cut for 3-4 minutes. Then, without stopping the cutter, 6 kg of hydrated soy protein or 8 kg of hydrated powder cake are added, as well as wheat flour (or potato starch) in an amount of 3.0 kg. Next, fatty raw materials (pork), sugar, spices, seasonings and spices (according to the recipe) are introduced into the cutter, continue to cut for 4 minutes. When processing meat on a cutter, the optimum temperature of the meat is 8-12°C. In order to prevent overheating of the meat, cold water or ice is added to the cutter.

The pork belly is filled with the obtained meat, the loaves obtained are sedimented for 24 hours at 0-4°C. Then the loaves are sent for thermal treatment. The loaves are fried at 90-110°C until the temperature in the center of the loaf reaches 45°C and the surface of the loaf becomes red (110 min).

The production technology of control and prototypes No. 2 (semi-smoked sausages grade 1) is as follows [12]. Veined meat raw materials (beef of the first grade and pork semi-fat) in pieces or chopped on a top with a diameter of lattice holes of 16-25 mm are salted at the rate of 100 kg of raw meat 3 kg of nitrite salt. Salted raw materials are kept at a temperature of 2-4°C in pieces for up to 2 days.

Next, the salted raw material is ground: beef on a top with a diameter of lattice holes of 2-3 mm, pork – with a diameter of lattice holes of 25 mm. The ground beef is mixed in the mixer for 2-3 minutes, adding spices, nitrite salt (based on unsalted raw materials), as well as previously hydrated isolated soy protein. According to the recipe for prototype No. 2, instead of soy protein, hydrated powdered mustard cake is added.

After processing the beef with the indicated components (according to the recipe), blended pork in the form of meal (25 mm) is added to the mixer and stirred for 2-3 minutes until evenly distributed in the minced meat.

The resulting minced meat is mixed well and introduced into artificial casings to form loaves, which are subjected to heat treatment – roasting, cooking, smoking according to the modes of production of semi-smoked sausages until the moisture content in the finished product is 30%.

Functional and technological characteristics of minced meat and the main indicators of the quality of the studied samples are presented in tables 3 and 4.

Table 3. Functional-technological and physico-chemical properties of the samples.

| Indicator value | cooked sausages | semi-smoked sausages |
|-----------------|-----------------|----------------------|
|                 | Control samples No. 1 | Prototypes No. 1 | Control samples No. 2 | Prototypes No. 2 |
| Content         |                 |                     |                     |                     |
| water, %        | 69.1            | 70.2                | 44.6                | 44.8                |
| Protein, %      | 12.3            | 12.7                | 16.2                | 17.0                |
| fat, %          | 14.5            | 13.8                | 33.8                | 33.1                |
| minerals, %     | 2.3             | 2.8                 | 4.3                 | 4.5                 |
| Energy value, kcal / 100 gr | **179.7** | **184.0** | **369.0** | **375.5** |
| mince system pH | 6.25            | 6.27                | 6.27                | 6.28                |
| finished product pH | 6.27             | 6.30                | 6.29                | 6.30                |
| Output, %       | 110.0           | 114.0               | 80.0                | 82.0                |
water holding capacity
minced meat, % to total moisture
Stability of minced meat emulsion, %

| Indicator                                | cooked sausages | semi-smoked sausages |
|------------------------------------------|-----------------|----------------------|
|                                          | Indicator value | Indicator value      |
|                                          | cooked sausages | semi-smoked sausages |
|                                          | Control samples | Control samples      |
|                                          | Prototypes No. 1| Prototypes No. 2     |
|                                          | Prototypes No. 2| Prototypes No. 2     |
| Organoleptic indicators                  | good presentation, cut minced meat of a pale pink color, evenly colored, has a specific taste characteristic of cooked sausage | good presentation, no broth and greasy swelling, the sausage texture is elastic, delicate, cut, minced meat of pink color, evenly colored, has a specific pleasant taste | good presentation, pleasant taste with a pronounced aroma of spices and garlic, without extraneous odor and taste | good presentation, pleasant taste with a pronounced aroma of spices and garlic, without extraneous odor and taste |
| Duration and storage conditions          | sausage quality is stored during storage for 5-6 days at a temperature not exceeding +4°C | sausage quality is preserved during storage for 10 days, which is 4 days longer than sausage prepared according to the traditional recipe | the shelf life at a temperature of no higher than 6°C and a relative humidity of 75-78% is 20 days, which is 5 days longer than that of semi-smoked sausages cooked according to traditional recipes |

These indicators of table 4 indicate the effectiveness of the simulated formulations. The experimental samples of cooked sausages had a higher yield compared to the control ones – by 4.0%, semi-smoked sausages – by 2.0% and the best organoleptic rating (table 4).

Table 4. Quality indicators of the samples.

3.3. The biological value of cooked and semi-smoked sausages

The biological value of proteins is determined by the balance of amino acid composition and the attackability of proteins by digestive tract enzymes (digestibility) [1].

The biological value of a protein by its amino acid composition can be estimated by comparing it with the amino acid composition of a reference protein, which is balanced and ideally matches the needs of the human body for each irreplaceable amino acid. For an adult, the FAO / WHO Committee amino acid scale is used as a "reference" protein [1, 3].

As part of the study, the content of essential amino acids in the product was analyzed, the amino acid rate, the coefficient of difference of amino acid scores (KRAS) and the biological value (BV) of the protein were calculated. The content of essential amino acids in the experimental samples in comparison with the control are presented in table 5.
Table 5. The amino acid content in the samples.

| Amino acid | cooked sausages | semi-smoked sausages |
|------------|-----------------|----------------------|
|            | Control samples  | Prototypes No. 1     | Control samples  | Prototypes No. 2 |
|            | No. 1            | No. 1                | No. 2            | No. 2            |
| Valine     | 688              | 722                  | 1072             | 1170             |
| Leucine+isoleucine | 1420          | 1590                | 1765             | 1899             |
| Lysine     | 896              | 922                  | 1180             | 1244             |
| Methionine | 390              | 406                  | 308              | 335              |
| Threonine  | 602              | 621                  | 580              | 622              |
| Tryptophan | 164              | 178                  | 228              | 248              |
| Phenylalanine | 532            | 552                  | 503              | 551              |

According to the calculations (table 6), it is seen that, in general, the amino acid rate of the experimental samples is higher than the control. The limiting amino acid in boiled sausage samples is phenylalanine. It should be noted that proteins can have several limiting amino acids, in this case they include phenylalanine and methionine.

Table 6. Amino acid rate.

| Amino acid   | cooked sausages | semi-smoked sausages |
|--------------|-----------------|----------------------|
|              | Control samples No. 1 | Prototypes No. 1 | Control samples No. 2 | Prototypes No. 2 |
| Valine       | 112             | 114                  | 132               | 138              |
| Leucine+isoleucine | 105            | 114                  | 99                | 102              |
| Lysine       | 132             | 132                  | 132               | 133              |
| Methionine   | 91              | 91                   | 54                | 56               |
| Threonine    | 122             | 122                  | 90                | 91               |
| Tryptophan   | 133             | 140                  | 141               | 146              |
| Phenylalanine| 72              | 72                   | 52                | 54               |

The amino acid difference coefficient (KRAS) shows an excess of essential amino acids that are not used for plastic needs. KRAS control and prototype boiled sausages amounted to 26.3% and 24.4%; half-smoked sausages – 35.1% and 29.5%, respectively.

Based on the KRAS value, the biological value of the protein was calculated. The BV of the control and experimental samples of cooked sausages was 73.7% and 75.6%; semi-smoked sausages – 64.8% and 70.5%, respectively.

If a protein is characterized by low biological activity, that is, it contains an incomplete set of essential amino acids, then it must be present in large quantities in the diet in order to ensure the physiological needs for essential amino acids contained in a minimal amount. In this case, the remaining amino acids will be ingested in excess of excess requirements. Excess amino acids will undergo deamination in the liver and turn into glycogen or fat.

Thus, it follows from the calculation results that in the experimental sausage samples, essential amino acids are in more balanced proportions, since the BV index is closer to the ideal characteristic of biological value equal to 100%.

4. Conclusion
The result of the research is the development of a method for the production of sausage products, including the introduction of additives based on vegetable oilseed processing products at the stage of
chopping the minced meat, characterized in that the powdered mustard cake obtained in the production of mustard oil, passed a steaming step to remove allyl mustard oil.

According to the research results, the use of powdered mustard cake in the amount of 6-8 kg per 100 kg of raw meat in the production technology of cooked and semi-smoked sausages positively affected the functional and technological indicators of the minced systems, as well as the main quality indicators developed within the framework of experimental prototypes. The use of the indicated plant component in the formulations allowed to increase the yield of the finished product – cooked sausages by 4.0%, and half-smoked sausages by 2.0%, and also to increase the stability of the minced system, which is one of the key indicators in the production technology cooked and smoked sausages.

At the same time, according to the results of the study of the amino acid composition, it was concluded that the used structure-forming agent – powder-like mustard cake – positively affects the amino acid composition of the products, which is confirmed by studies of biological value. Thus, the biological value of the studied samples of cooked sausages is 1.9% higher than the control, the use of mustard cake in the production of semi-smoked sausages contributes to an increase in the biological value of the product by 5.7%.

The developed recipes for cooked and semi-smoked sausages as a whole make it possible to obtain a product with high nutritional and biological value and can be recommended for implementation in the production with the aim of expanding the range of sausages.

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