Effect of cryostabilizing mixtures on quality of cooked sausages

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Abstract

Introduction. The aim of the study was to investigate the effect of binary cryostabilizing mixtures on the functional, technological structural, mechanical and sensory characteristics of cooked sausages.

Materials and methods. The cryostabilizing mixtures differed in the content of animal protein, vegetable fiber, and sodium alginate. The minced meat for sausages consisted of pork, chicken fillet, minced chicken, an emulsion of beef vein and lard (20% each). The test was performed by replacing 2.5% of the fillet in the recipe with cryostabilizers. The minced meat was cut, formed into a casing, heat-treated (to a temperature of 72 °C in the center of the product), frozen and stored at –18 °C for 30 days.

Results and discussion. Studies of the cryoprotective properties of sodium alginate, animal protein, fiber, sodium tripolyphosphate, and maltodextrin have shown their ability to reduce the cryoscopic temperature of model sausage minced systems to –2.8 °C. To enhance the effectiveness of these ingredients, their properties in binary composite mixtures were considered.

Five variants of the mixtures were used, which differed in the content of animal protein, vegetable fiber, and sodium alginate. Studies have shown that mixtures with a high content of protein and alginate provide the best functional and technological indicators: moisture binding (524–864%) and emulsifying ability (78.18–89.88%), emulsion stability (95.30–96.20%) and increased product yield (122.22–124.02%). Also, these mixtures demonstrate the lowest cryoscopic temperature (–4.58 °C and –4.62 °C) and the best sensory characteristics (juiciness, density, taste). The sensory evaluation confirmed that the sausage samples with this mixture had juiciness, dense structure, harmonious taste and aroma. Other mixtures showed certain shortcomings: samples with the highest protein and alginate content had excessive density, samples with low protein and alginate content had insufficient juiciness, and samples with the lowest protein and alginate content had poor elasticity.

Based on the results obtained, it is recommended to use a blend with an optimal protein and alginate content for the production of frozen long-term storage meat products.

Conclusions. The optimal composition of a binary cryostabilizing mixture that preserves the structure and improves the quality of cooked sausages after freezing and thawing because of the synergistic interaction between protein and polysaccharide has been determined.

Introduction

The freezing process is accompanied by the formation of ice crystals, which leads to structural changes in tissues, destruction of cell membranes and loss of product quality (Castro-Giraldez et al., 2014; Savinok et al., 2017). These changes are irreversible, reduce the sensory properties of meat products and affect their consumer value (Hlushakova et al., 2018; Ramadhan et al., 2012). This is especially true for cooked sausages, which, due to their high moisture content, are vulnerable to changes caused by freezing and thawing (Dromenko et al., 2020).

To minimize these effects, cryoprotectants are used to promote the formation of small, evenly distributed ice crystals (Ivanenko et al., 2018; Sher Ali et al., 2015). Studies have shown that combining functional ingredients such as sodium alginate, plant fibers, animal proteins, tripolyphosphate, and maltodextrin can reduce the cryoscopic temperature to – 2.8°C (Shevchenko et al., 2020; Stabnikova et al., 2022; Xianbao Sun et al., 2022). Penetrating cryoprotectants slow the growth of ice crystals inside cells, while impermeable ones act as ice blockers, reducing water diffusion across the membrane (Boutron et al., 1979; Smirnova and Boiko, 2020).

However, for cooked sausage products that are stored in a frozen state for a long time, the peculiarities of combining functional ingredients in cryostabilizing mixtures have not yet been sufficiently studied. It is important to investigate how individual ingredients (polysaccharides, proteins, phosphates, and vegetable fibers) and mixtures developed on their basis affect the functional, technological, structural, and mechanical properties of minced meat systems and ensure synergy between the recipe components. The use of optimized cryostabilizing mixtures will stabilize the fractional composition of water, promote the formation of a fine crystalline ice structure and reduce the effect of salt hyperconcentration.

The development of new functional mixtures with cryoprotective properties will also stabilize the sensory properties and improve the structure of sausages, which is especially important for products stored for a long time at temperatures below – 18°C.

The aim of the study is to investigate the effect of binary cryostabilizing mixtures based on animal protein, fiber, and alginate on the structural, mechanical, and sensory properties of cooked sausages.

Materials and methods

Materials

Cryostabilizing mixture. Composition of cryostabilizing mixtures: animal protein “ScanPro™ A-95” (Essentia) – high-functional cold-brewed animal protein made from natural food pork raw materials by mechanical and heat treatment, dietary fiber: bamboo and wheat (Shandong Jianyuan Foods Co., Ltd.), sodium alginate (E401) (Shandong Jiejing Group Corporation), tripolyphosphate, maltodextrin.

Formulation composition of the tested samples of cooked sausages. Model sausage stuffing systems were made on the basis of pork (20%), chicken fillet (20%), minced chicken (20%), beef vein emulsion (20%) and lard (20%). In the manufacture of minced meat for the experimental samples of cooked sausages, the developed cryostabilizing mixtures with different compositions of functional ingredients (Table 1) were added in the amount of 2.5% to replace 2.5% of chicken fillet, respectively.

Table 1

Composition of binary cryostabilizing mixtures

Ingredients	Blend 1	Blend 2	Blend 0	Blend 3	Blend 4
Sodium alginate	0.034	0.067	0.1	0.134	0.167
Animal protein	0.067	0.167	0.267	0.367	0.467
Vegetable fiber	0.05	0.08	0.12	0.15	0.180
Sodium tripolyphosphate	0.09	0.09	0.09	0.09	0.09
Maltodextrin	0.759	0.596	0.423	0.259	0.096
Total	**1**	**1**	**1**	**1**	**1**

Preparation of sausage samples. Model minced cooked sausage systems were cut with ice in a cutter to 12 °C for 15 minutes, formed into a protein sausage casing with a diameter of 60 mm and subjected to heat treatment in a thermal chamber. The program for heat treatment of cooked sausages in a natural protein casing was used until the temperature in the center reached 72 °C. The finished sausage products were cooled to 12°C for 8 hours and frozen at minus 18°C. The shelf life of the experimental sausage samples at minus 12 °C was 30 days. The heat treatment of the experimental sausage samples, until the temperature in the center reached 70 °C, was carried out after defrosting. Defrosting was made at a temperature of 20 ± 2 °C for 4 hours.

Methods for studying the properties of the cryostabilizing mixture

Determination of the pH of the mixture. The pH value was determined according to ISO 2917:1999 on a laboratory pH meter in a water extract prepared at a mixture: water ratio of 1:10. For this purpose, 5 g of the mixture was taken into a 250 ml conical flask, filled with 50 ml of distilled water and extracted for 30 min with periodic stirring. After the extraction was completed, the extract was filtered through filter paper and the pH of the filtrate was determined using a laboratory pH meter (Puolanne and Kivikari, 2000).

Determination of water-binding capacity (WBC). The moisture binding capacity of the study objects was determined by the Grau-Hamm press method in the modification of V.I. Volovinska and B.Y. Kelman (Shevchenko et al., 2021). The method is based on the release of water from a 300 mg sample during a 10-minute pressing with a 1 kg weight. The determination is made by the size of the spot that remains on the filter paper after sorption of the released moisture, outlining the contour of the spot of compressed meat with a pencil. The size of the wet spot (external) is calculated by the difference between the total spot area and the spot area formed by the meat (product). The content of the WBC was calculated by the formula:

$$WBC = \frac{(A-8.4B)\times 100}{A},$$

where: WBC – the water-binding capacity, % of total moisture; A – total moisture content in the sample, mg; B – wet spot area, cm².

Determination of moisture holding capacity (MHC). A sample of sausage product weighing 0.3-0.5 g is cut into thin slices (2 – 3 mm thick). The sample is taken directly from the middle of the product to avoid the influence of the outer layers. The sample is placed between two sheets of filter paper to ensure uniform absorption of moisture released under pressure. A weight is placed on the sample with the paper or placed in a special press. The pressure is usually 5 kg/cm² and lasts for 10 minutes. After the pressing is complete, the filter paper is weighed to determine the amount of moisture that has been released from the sample. The difference in weight between the paper before and after pressing reflects the amount of moisture lost (Barbut, 2024).

Determination of emulsion stability. The emulsion stability (ES) of the coarse raw material was determined by heating at 80°C for 30×60s and cooling with water for 15×60s. Then, four 50 ml calibrated centrifuge tubes were filled with the emulsion and centrifuged at a rotational speed of 500 s^{-1} for 5×60 s. The volume of the emulsified layer was then determined. The stability of the emulsion was calculated by the formula:

$$S = \frac{V_1}{V_2} \times 100,$$

where: V_1 – the volume of emulsified oil, ml; V_2 – total volume of the emulsion, ml.

Determination of emulsifying capacity. The emulsifying capacity (EC) was determined after centrifuging a mixture of oil, water, and emulsion at a rotation speed of 500 s^{-1} for 10×60 s. The volume of the emulsified oil was then measured, and the emulsifying capacity was calculated using the following formula:

$$EC = \frac{V_1}{V_2} \times 100,$$

where: V_1 – volume of emulsified oil, ml; V_2 – total volume of oil, ml.

Determination of the penetration stress. Penetration stress of sausage products was determined according to ISO 11036:1994 using a Brookfield DV1 digital viscometer by the depth of the indenter immersion in the test sample at 20 °C. Three measurements were made on the open surface of the sample at a distance of at least 10 mm from the edge of the product and at the maximum distance from the points of other measurements so that the deformed part of the surface did not enter the measurement area, after which the penetration value was converted to the penetration stress value.

Determination of sensory characteristics of sausages. Sensory characteristics of sausages: the method is to evaluate the quality of sausage products according to five criteria: appearance, consistency, color in the cut, smell and taste. Each of these indicators is rated on a five-point scale, where 5 is excellent and 1 is unsatisfactory. The assessment is carried out by a group of experts who analyze the product according to established parameters to determine its compliance with quality standards (Fudali et all., 2021).

Determination of cryoscopic temperature. The cryoscopic temperature was determined by the classical cryoscopic method, which is a method of determining the freezing point of a solution compared to a pure solvent (Fikiin et al., 1998). The test sample with cryostabilizers was cooled in a cryoscope. The temperature difference between the freezing of the pure solvent and the solution was used to evaluate the effect of cryostabilizing additives. The calculations were performed according to Raoul's formula:

$$\Delta T_f = K_f \cdot m,$$

where: ΔT_f is the decrease in freezing point, °C; K_f is the cryoscopic constant of the solvent, °C·kg/mol; m is the mole fraction of the solution, mol/kg.

Statistical analysis

The statistical analysis of the results was carried out with Microsoft Excel program. All determinations were performed at least in triplicate. Values of different parameters were presented as the average (mean) ± standard deviation.

Results and discussion

Analysis and development of ingredient composition of cryostabilizing mixtures

At the first stage, the cryoprotective ability of various functional ingredients (sodium alginate, animal protein, vegetable fiber, tripolyphosphate, maltodextrin) was investigated when added to cooked sausage minced meat before freezing. The results of studies characterizing the change in cryoscopic temperature in model minced sausage systems under the influence of functional ingredients are shown in Figure 1.

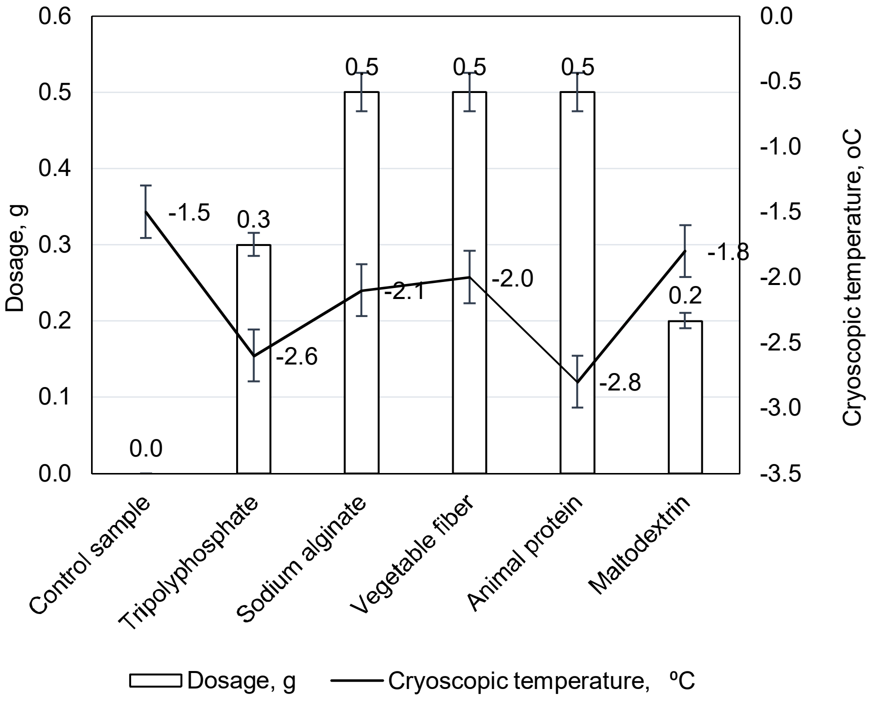

Figure 1. Changes in cryoscopic temperature in minced sausage systems for cooked sausages depending on the influence of functional ingredients

As can be seen from the data in Figure 2, all the studied ingredients are capable of reducing the cryoscopic temperature of model meat systems compared to the control sample, with values ranging from –1.8 °C to –2.8 °C. The use of cryoprotective complex mixtures in model meat systems reduces the cryoscopic temperature by 2.09–2.81 °C, decreases the mass fraction of frozen moisture by 0.9%, and increases water-holding capacity by 5.3–9.7%

compared to the control sample, which positively affects the quality indicators of the final products (Skochko et al., 2018). The obtained results indicate the potential of using the selected functional ingredients as substances aimed at stabilizing meat systems and providing cryoprotection against the effects of low temperatures.

However, the use of individual functional ingredients can reduce the cryoscopic temperature of the meat mixture during freezing to values close to –2 °C, which is insufficient for the long-term storage of cooked sausages in a frozen state. Therefore, based on previous studies (Keniyz, 2014; Shevchenko and Tunik, 2024), we conditionally adopted the formulation of five binary cryostabilizing mixtures with different ratios of ingredients based on animal protein, plant fibers, phosphates, and sodium alginate (Table 1). Protein ingredients of animal and plant origin in cryostabilizing mixtures, as high-molecular compounds, are capable of reducing the rate of crystal growth and protecting muscle tissue cells from osmotic and temperature fluctuations (Skochko et al., 2018). In addition, the cryoprotective effect of polysaccharides can stabilize the functional properties of meat systems during freezing and thawing (Yancheva et al., 2014a).

Study of functional and technological properties of cryostabilizing mixtures

At the next stage, the functional properties of the cryostabilizing mixtures of the proposed composition were studied to evaluate their possible impact on the functional and technological properties of model minced meat systems and finished cooked sausage products. The obtained research results are shown in Table 2.

Table 2

Functional and technological properties (FTP) of cryostabilizing mixtures of different composition

Indicators	**Samples of crystallizing compound with different formulations**				
	Blend 1	**Blend 2**	**Blend 0**	**Blend 3**	**Blend 4**
pH mixtures	9.57±0.14	9.83±0.21	9.63±0.17	9.32±0.19	9.15±0.27
Moisture-binding capacity, %.	104±3.62	270±6.14	320±9.60	524±13.70	864±23.50
Penetration stress, g	48.3±1.75	62.1±1.95	68.1±2.16	78.32±3.08	69.2±2.07

The study of functional and technological properties (FTP) of models of sausage minced systems using 2.5% cryostabilizing mixtures to assess their effect on the technological properties of minced systems is presented in Table 3.

According to the results of FTP studies, model minced meat systems with 2.5% cryostabilizing mixtures of different ingredient composition had higher moisture binding, emulsifying ability, and emulsion stability compared to the control. This is due to the fact that at the gelling temperature of the selected polysaccharides close to the denaturation temperature of meat proteins, the water separated from the proteins is absorbed by the protein-polysaccharide complexes that make up the cryostabilizing mixtures (Tomaniak et al., 1998; Shevchenko and Skochko, 2018).

Table 3
FTP of model minced meat systems and samples of cooked sausages with 2.5% cryostabilizing mixtures of different ingredient composition

Indicators	Cryostabilization mixtures				
	Blend 1	**Blend 2**	**Blend 0**	**Blend 3**	**Blend 4**
pH emulsions	6.1±0.14	6.1±0.21	6.3±0.17	6.2±0.19	6.2±0.18
Moisture binding capacity, %	10.6±0.32	18.2±0.64	22.1±0.92	28.6±0.96	33.8±1.02
Moisture retention capacity, %	41.7±1.05	48.9 ±1.16	69.7±2.12	72.01±2.80	83.6±3.04
Fat retention holding capacity, %	66.82±2.18	70.60±2.82	74.40±3.10	77.32±2.46	78.68±2.94
Emulsifying ability, %	69.90±2.24	72.10±3.36	76.46±2.82	78.18±3.14	89.88±3.34
Emulsion stability, %	82.40±3.15	86.20±3.10	91.20±3.56	95.30±3.75	96.20±3.81
Penetration stress, %	44.1±0.95	50.2±1.95	62.8±2.06	80.2±3.18	63.9±2.07
Output, %	110.02±3.1	110.84±4.3	118.16±4.9	122.22±5.1	124.02±5.3

An important indicator that determines the quality characteristics of cooked sausages is the stability of minced meat systems. Crystallizing mixtures are a key tool in preserving the structure and properties of meat products (Petracci et al., 2013). The presence of hydrophilic and hydrophobic groups in protein molecules causes the orientation of polar groups to water and non-polar groups to fat, which results in the formation of an interfacial adsorption layer in the minced protein emulsion (Boutron et al., 1979). This indicator characterizes the strength of the formed interfacial layers at the fat-water interface (Castro-Giraldez et al., 2014). The results of the study indicate an increase in the stability of minced meat systems in sausage samples using 2.5% cryostabilizing mixtures Blend 0, Blend 3 and Blend 4, which contain a higher amount of animal protein, sodium alginate and plant fibers in the composition.

The determination of losses during heat treatment of the experimental samples of cooked sausages showed that the highest yield (122.22 – 124.02 %) was characteristic of sausage samples with 2.5% cryostabilizing mixtures Blend 3 and Blend 4, which contain a larger amount of protein-polysaccharide complexes. Due to their ability to reduce the formation of large ice crystals, stabilize proteins and retain moisture, they minimize product quality losses during long-term storage at low temperatures (Yancheva et all., 2014b).

Significant changes in physicochemical and sensory properties after freezing and thawing, including reduced juiciness, fragility of the structure, and lower product yield (110.02 – 110.84%), were characteristic of sausage samples containing a smaller amount of components with moisture-retaining properties Blend 1 and Blend 0.

Studies have confirmed that the use of a mixture with a high content of proteins and polysaccharides significantly improves the quality of cooked sausages in terms of functional and technological indicators, in particular moisture and fat retention, which contributes to an increase in the yield of finished products.

Study of structural and mechanical properties of model sausage samples

The shear stress of the model samples of cooked sausages with cryostabilizing mixtures of different ingredient composition was measured using a Brookfield DV1 viscometer (Figure 2).

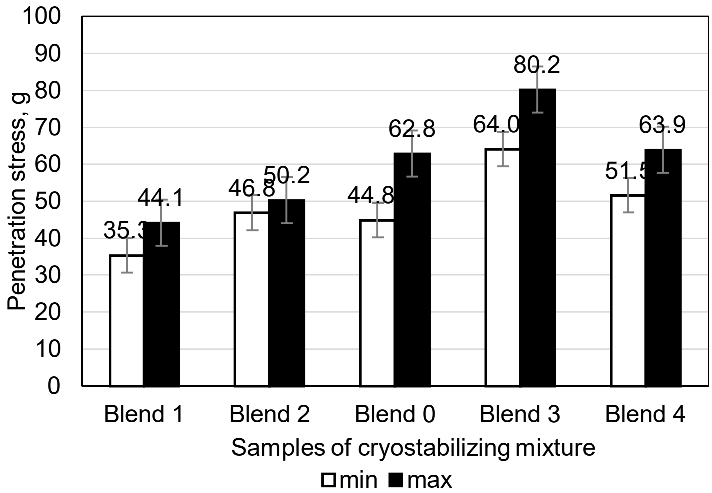

Figure 2. Changes in penetration stress of model samples of cooked sausages depending on the composition of cryostabilizing mixtures

Sausages with the cryostabilizing mixture Blend 3 had the highest values of shear stress – 80.2 g, which significantly exceeded the results of the other samples. Samples of sausages with the cryostabilizing mixture Blend 2 also had high values of shear stress – 50.2 g, although slightly lower than those with the mixture Blend 3, which indicates the ability of both mixtures to increase the stability of the minced systems of cooked sausages. Samples of sausages with the cryostabilizing mixture Blend 4 had average values of shear stress – 63.9 g, but significantly better than those of samples of sausages with cryostabilizing mixtures Blend 1 and Blend 0 – 50.2 g and 44.1 g, respectively. This indicates the insufficiently high functionality of the ingredient composition of the composite mixtures Blend 1 and Blend 0 and their low ability to stabilize the minced systems of cooked sausages, as well as the lower efficiency of the ingredient composition compared to the composition of the cryostabilizing mixtures Blend 3, Blend 4 and Blend 2.

Thus, the results of measuring the shear stress of the experimental samples of cooked sausages on the Brookfield DV1 viscometer showed that the most optimal is the ingredient composition of the composite mixture Blend 3, the use of which in the composition of cooked sausages contributes to the formation of their best structural properties, which confirms the high functionality of its composition as a cryostabilizing mixture for cooked sausages.

Sensory properties of model cooked sausage samples

According to the results of the sensory study of model samples of cooked sausages with different formulations of the cryostabilizing mixture, it was found that the best sensory characteristics were observed in sausage samples with the Blend 3 mixture, which contains a sufficient amount of proteins and polysaccharides. This confirms the high results of the functional, technological and rheological properties of the model sausage samples, and indicates that this composition of the mixture is the most optimal for ensuring high sensory quality indicators of sausage products.

This is in line with studies Tomaniak et al. (1998), which showed that polysaccharides improve the texture and juiciness of meat products. However, studies Yancheva et al. (2014b) have shown that a combination of polysaccharides and proteins can reduce the cryoscopic temperature to – 5.0 ºC. This suggests that there is a potential for further improvement of the mixtures. However, it is important to keep in mind that excessive amounts of polysaccharides, such as sodium alginate, can lead to an excessively thick texture and a deterioration in the product's taste. Therefore, optimizing the composition of mixtures should take into account the balance between the effectiveness of cryoprotective properties and sensory characteristics.

Samples of sausages made from the cryostabilizing mixture Blend 3 were characterized by a satisfactory appearance, uniform color on the cut, dense structure and juicy texture. They also had an expressive aroma and harmonious taste, which ensured their overall high rating (Figure 3). The optimal dosage of sodium alginate in Blend 3 is a key factor in ensuring high quality sausages. It gives the product a good structure, juiciness and stability, without adversely affecting the taste. An excessive amount of sodium alginate could lead to an overly dense or "rubbery" texture, as well as an unpleasant aftertaste. This makes Blend 3 an ideal choice for the production of cooked sausages with high sensory characteristics.

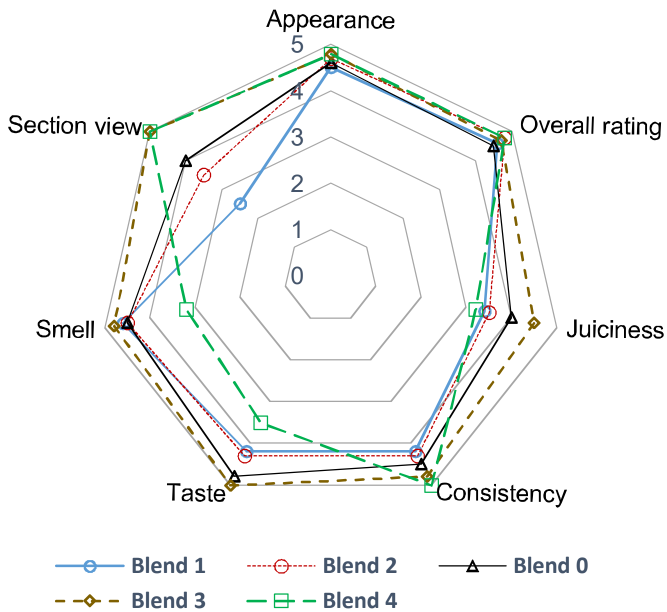

Figure 3. Quality profiles of model cooked sausages samples by sensory characteristics and recipe composition

At the same time, other samples had certain shortcomings: samples of sausages with Blend 4 had an excessively dense texture and less pronounced taste, which negatively affected the overall score; samples of sausages with Blend 1 and 2 were characterized by a split structure, insufficient juiciness and weaker flavor, which made them less attractive to consumers. Samples of sausages with Blend 1 had a pleasant odor, but their texture was not dense and the taste did not meet expectations. Samples of sausages with Blend 0, which were used as a base recipe, demonstrated average performance in all characteristics, but did not stand out with any particular advantages.

Thus, samples of cooked sausages with a cryostabilizing mixture containing sodium alginate 0.134 g and protein 0.367 g (Blend 3) best meet the requirements for sensory quality indicators, combining sufficient juiciness, structural strength, elastic texture, distinct aroma, and balanced taste (Figure 4).

Blend 1 Blend 2 Blend 0 Blend 3 Blend 4

Figure 4. Model cooked sausages samples after defrosting

Water activity and cryoscopic temperature

The cryoscopic temperature and water activity (a_w) are important indicators that allow us to assess the stability of the product during storage, its consistency and susceptibility to microbiological spoilage. The use of cryostabilizing mixtures Blend 4 and Blend 3 in model minced sausage systems for cooked sausages contributed to the maximum reduction of the cryoscopic temperature from – 4.62 °C to – 4.58 °C, which correlated with rather low values of water activity (0.940 and 0.948, respectively) in the experimental sausage samples. This indicates the ability of these mixtures to positively affect the preservation of the structure of sausages in the frozen state and after defrosting and greater microbiological stability during storage. This effect is achieved due to the synergy between the components of the mixtures (protein, alginate, phosphates), which provides better water binding, emulsion stabilization and the formation of a fine crystalline ice structure.

The cryostabilizing blend Blend 0 ranks in the middle in terms of its properties, demonstrating a compromise between the two parameters. The use of cryostabilizing mixtures Blend 2 and Blend 1 in model minced meat systems is less effective due to the relatively low values of cryoscopic temperature (– 3.82 ºC and – 3.76 ºC) and water activity of cooked sausages (0.936 and 0.928) (Figure 5).

The use of more effective cryostabilizing mixtures (Blend 4 or Blend 3) ensures better quality of cooked sausages during freezing and storage, contributing to the preservation of their structure, as evidenced by the results of the sensory evaluation (Figure 4). Due to the optimally selected composition of the mixture: alginate, animal protein, phosphate and fiber, which reduce the freezing point of water in the minced meat system, water binding and the formation of small ice crystals occur, which affect the cryoscopic temperature and water activity (a_w) in minced meat systems.

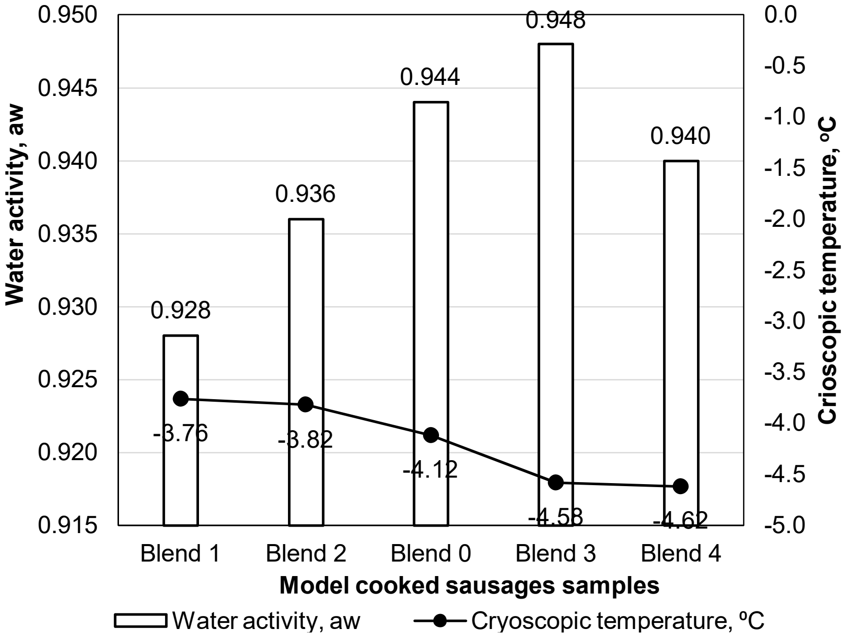

Figure 5. Cryoscopic temperature and water activity of cooked sausage with 2.5% cryostabilizing mixtures of different ingredient compositions

Effectiveness of the cryostabilizing mixture

The use of cryostabilizing mixtures, in particular Blend 3, improves the quality of minced meat systems during freezing and thawing. The blend helps to reduce moisture loss and structure stratification, which has a positive effect on the texture, emulsion stability and sensory properties of cooked sausages.

The synergy of protein and polysaccharide components ensures the formation of protein-polysaccharide complexes, stabilizes the water-fat emulsion and improves the consistency of the products. The cryostabilizing mixture also demonstrates high functional and technological properties, such as moisture retention, stability and emulsifying ability, which is confirmed by positive results of sensory tests.

The results showed a decrease in cryoscopic temperature to – 4.62 ºC and – 4.58 ºC for Blend 4 and Blend 3. These values are in line with the research of Skochko et al. (2018), who also found that the use of cryoprotective blends reduces the cryoscopic temperature by 2.09 – 2.81 ºC. The practical use of a cryostabilizing mixture based on the optimal ratio of components in the Blend 3 recipe in the production of cooked sausages can increase the yield of finished products by 10%. Due to the stability of the water-fat emulsion and preservation of the product texture, the finished products meet high quality standards, retain a uniform color, harmonious taste and aroma, which makes them competitive in the market. Thus, Blend 3 cryostabilizing mix can be recommended for wide application in the industrial production of frozen sausage products, as it improves quality, reduces losses and increases consumer appeal.

The use of the composite mixtures of the proposed composition can be recommended for the industrial production of cooked sausages, sausages and bratwursts. The use of the proposed mixtures increases the stability of sensory characteristics: the products have an elastic consistency, harmonious taste and aroma, even after prolonged storage at low temperatures and subsequent defrosting, which increases their competitiveness in the market.

Thus, the research results confirm the feasibility of using the cryostabilizing mixture in the production of sausages. Its use improves the stabilization of minced meat systems and ensures effective cryostability of products during freezing and thawing and long-term storage at low temperatures; also, the cryostabilizing mixture avoids the formation of large ice crystals that destroy the structure of minced meat, reducing its moisture retention and sensory properties.

Based on this study, two main areas of implementation of the cryostabilizing mixture in the production of cooked sausages for long-term storage can be identified: stabilization of the functional and technological properties of minced meat and raw meat during production; cryoprotection of finished sausage products during storage and export in a frozen state, and preservation of sensory characteristics after defrosting and further use.

Conclusions

1. The cryostabilizing mixture with a high content of animal protein and alginate (Blend 3) contains the most preferable combination of proteins, polysaccharides and other functional ingredients and demonstrates the best balance between the stability of minced meat systems of cooked sausages and their sensory properties. Its formulation is promising for use in the production of industrial cryostabilizing mixtures.
2. The complex use of the cryostabilizing mixture, using a combination of ingredients (sodium alginate, animal protein, vegetable fiber, tripolyphosphate, and maltodextrin) has proven effective in improving the functional properties of cooked sausages. The combination of animal protein and polysaccharides ensures the stability of the product structure and minimizes moisture and fat loss during freezing and thawing.
3. The use of the cryostabilizing mixture Blend 3 improves the quality of cooked sausages for export and long-term storage at low temperatures, ensuring the stability of their structure and sensory characteristics.

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References

Barbut S. (2024), Measuring water holding capacity in poultry meat, *Poultry Science*, 103(5), 103577, https://doi.org/10.1016/j.psj.2024.103577

Boutron P., Kaufmann A. (1979), Stability of the amorphous state in the system water-glycerol-ethylene glycol, *Cryobiology*, 16(1), pp. 83–89. https://doi.org/10.1016/0011-2240(79)90015-4

Castro-Giraldez M., Balaguer N., Hinarejos E., Fito P.J. (2014), Thermodynamic approach of meat freezing process, *Innovative Food Science & Emerging Technologies,* 23, pp. 138–145, https://doi.org/10.1016/j.ifset.2014.03.007

Dromenko O., Potapov V., Yancheva M., Onishchenko V., Bolshakova V., Inzhyyants A. (2021), Research into the thermophysical characteristics of muscle and adipose tissues in the freezing-thawing process, *Food Science and Technology,* 15(3), pp. 40–51, https://doi.org/10.15673/fst.v15i3.2120

Fudali A., Chełmecka I., Salejda A.M., Krasnowska G. (2021), Microbiological safety and sensory quality of homogenized sausages manufactured with commercial functional additives, *Applied Sciences,* 11(11), 11662, https://doi.org/10.3390/app112411662

Fikiin K.A. (1998), Ice content prediction methods during food freezing: A survey of the Eastern European literature, *Journal of Food Engineering*, 38(3), pp. 331–339, https://doi.org/10.1016/S0260-8774(98)00120-4

Hlushakova Y.V., Petrenko I.O. (2018), Research of cryoprotective properties of biopolysaccharide mixtures in meat systems, *Scientific Works of NUFT*, 5, pp. 25–30.

Ivanenko O.V., Petrova L.M. (2018), Influence of cryoprotectors on the quality of meat products after freezing, *Scientific Works of NUFT*, 24, pp. 45–52.

Keniyz N.V. (2014), *Technology of frozen semi-finished products using cryoprotectants,* Saarbrücken, Germany, Palmarium Academic Publishing, pp. 112–119.

Petracci M., Bianchi M., Mudalal S., Cavani C. (2013), Functional ingredients for poultry meat products, *Trends in Food Science & Technology,* 33(1), pp. 27–39.

Puolanne E., Kivikari R. (2000), Determination of the buffering capacity of postrigor meat, *Meat Science,* 56, pp. 7–13, https://doi.org/10.1016/S0309-1740(00)00007-3

Ramadhan K., Huda N., Ahmad R. (2012), Freeze-thaw stability of duck surimi-like materials with different cryoprotectants added, *Poultry Science*, 91(7), pp. 1703–1708, https://doi.org/10.3382/ps.2011-01926

Savinok O., Pastyukov S., Kuzelov A., Shepelenko D. (2017), Sensory and functional parameters of sausages with reduced sodium nitrite content, *Scientific Works of University of Food Technologies*, 64(1), pp. 32–40.

Semenenko O. M., Ivanenko A. P. (2018), Scientific and practical bases of freezing and cold processing of meat and meat products, *Bulletin of Sumy National Agrarian University,* 12, pp. 89–95.

Stabnikova O., Danylenko S., Kryzhska T., Shang F., Duan Z. (2022), Effects of different phosphate content on the quality of wheat bran chicken sausage, *Ukrainian Food Journal,* 11(4), pp. 588–600, https://doi.org/10.24263/2304-974X-2022-11-4-8

Shevchenko I., Polishchuk G., Kotliar Y., Osmak T., Skochko A. (2020), Prospects of using the crystobilizing protein-polysaccharide composition to manufacture semi-finished chopped meat products, *Food Science and Technology*, 14(1), pp. 134–141, https://doi.org/10.15673/fst.v14i1.1642

Shevchenko I., Polishchuk G., Topchii O., Kotliar Ye., Osmak T. (2021), Improving the technology of restructured ham-type products from turkey meat and pse pork, *Food Science and Technology,* 15(4), pp. 106–115, https://doi.org/10.15673/fst.v15i4.2125

Shevchenko I., Skochko A. (2018), Advantages of using proteins in the production of truncated semi-finished products, *Journal of Faculty of Food Engineering*, Stefan cel Mare University of Suceava, 12(3), pp. 272–277

Shevchenko I., Tunik O. (2024), Cryoprotective properties of functional mixtures in cooked sausage products, *Ukrainian Journal of Food Science*, 13(3), pp. 33–44, https://doi.org/10.24263/2310-1008-2024-12-1-5

Sher Ali, Zhang W., Rajput N., Khan M.A., Li C., Zhou G. (2015), Effect of multiple freeze–thaw cycles on the quality of chicken breast meat, *Food Chemistry*, 173, pp. 808–814, https://doi.org/10.1016/j.foodchem.2014.09.095

Skochko O., Druhoveiko V., Shevchenko I., Maslikov M. (2018), The study of cryoprotective properties of protein-polysaccharide mixtures in the composition of chopped semi-finished products, *Scientific Works of NUFT,* 24(5), pp. 203–207.

Skochko, O., Shevchenko, I., Polichuk, G., Paska, M. (2018), The estimation of effects of food cryoprotectors on quality indicators of semi-finished products,*Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Food Technologies*, 20(90), pp. 27–31. https://doi.org/10.32718/nvlvet9006

Smirnova T.A., Boiko D.Yu. (2020), Use of combined cryoprotectors to improve the stability of meat products during low-temperature storage. *Meat and Meat Products Technology,* 5, pp. 78–85.

Tomaniak A., Tyszkiewicz I., Komosa J. (1998), Cryoprotectants for frozen red meats, *Meat Science*, 50(3), pp. 365–371, https://doi.org/10.1016/S0309-1740(98)00043-6

Yancheva M.O., Bolshakova V.A., Zheleva T.S. (2014a), Study of hydrocolloids properties during the freezing-thawing process, *Kharchova Promyslovist (Food Industry),* 16, pp. 42–45, http://nbuv.gov.ua/UJRN/Khp_2014_16_11

Yancheva M., Zheleva T., Pogozhych N., Hrynchenko A. (2014b), Cryoscopy research of solutions of food ingredients of polysaccharide nature, *Eastern-European Journal of Enterprise Technologies,* 2(12), pp. 84, https://doi.org/10.15587/1729-4061.2014.23513

Sun X., Wu Y., Song Z., Chen X. (2022), A review of natural polysaccharides for food cryoprotection: Ice crystals inhibition and cryo-stabilization, *Bioactive Carbohydrates and Dietary Fibre,* 27, 100291, https://doi.org/10.1016/j.bcdf.2021.100291

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