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Original Article

Applicability of demineralized milk whey powder in cooked sausage production

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Abstract

Demineralized whey powder was added to test samples at the stage of processing forcemeat in the meat mixer cutter. The product met the requirements of regulatory documents for organoleptic, physical, and chemical properties and had good commercial properties. The samples had a pleasant taste, appearance, and color and were tender with a succulent consistency. The consistency of the product remained monolithic, while its succulence and tenderness increased. However, the addition of 15% demineralized whey powder to the forcemeat resulted in excessive softening of the consistency, the appearance of fat pockets, a noticeable decrease in the meat taste of the product, and the appearance of a slightly sour taste and smell of the finished product. The introduction of demineralized whey powder into the forcemeat resulted in an increase in the relative content of nitric oxide pigments and in a reduction of residual sodium nitrite in the cooked sausage.

Keywords: milk whey, sausage production, organoleptic evaluation

1. Introduction

Currently, one of the state's priorities is involving secondary resources into the economy, which would allow not only for an increase in the profitability of enterprises, but also to solve environmental problems.

Whey is a by-product of cottage cheese, cheese, and casein production. Up to 30% of the most valuable part of milk proteins, that is immune proteins that develop protective functions of the human body and farm animals, as well as about 95% of high-quality lactose is lost with whey (Jayaprakasha & Brueckner, 1999). More than 54% of the volume of production of natural whey is cheese whey (also known as sweet whey). The second place belongs to sour whey (also known as acid whey) and no more than 1% to casein whey (Jelen, 2009; Boland, 2011).

The processing of whey in Russia, despite numerous developments in this area, is constrained for a number of reasons: little investment in the dairy industry, lack of funds for the introduction of modern technologies and the purchase of equipment, inadequate information on the benefits of whey products and promotion of a healthy lifestyle, lack of mass production of multifunctional whey-based products, and a liberal attitude of the environmental services towards dumping whey into wastewater (Capper & Cady, 2012; Kosaric & Asher, 1982).

Whey is a secondary raw material of the dairy industry. The use of whey in bakery, confectionery, and meat and dairy industries has the potential of saving flour, beet sugar, fruit juices, meat, natural milk, as well as increasing the biological value and volume of food production (Atra *et al.*, 2005; Pescuma, Valdez, & Mozzi, 2015).

Whey products used in the meat industry include sweet whey powder, whey protein concentrates (34–80% protein content), whey protein isolate (>90% protein), whey with reduced lactose content, demineralised whey, and lactose (Keaton, 1999; Prabhu, 2006). They are used especially in the production of comminuted products, such as frankfurters, sausages, mortadellas, luncheon meat, or surimi (De Wit, 2001).

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Whey protein may partially replace meat protein, as well as partially or completely substitute for soy protein and other binding agents, fillers, modified starch, and hydrocolloids (Keaton, 1999; Prabhu, 2006; Youssef & Barbut, 20 11).

Whey proteins with improved flavor and increased functionality are obtained with new technologies. While choosing a particular whey product, it is essential to match its function to the characteristics we want to achieve. For example, high protein concentrates or isolates are used to modify fat content (Prabhu, 2006). A slight increase in sweetness occurs, especially with the addition of sweet whey (which enables reduced addition of sweeteners) (Keaton, 1999). According to Keaton (1999), the properties of adding whey proteins in the processing of meat products, poultry, and fish include the water binding capacity that prevents the depletion of mass during thermal processing and storage of the product along with increased juiciness of the final product. Furthermore, whey proteins facilitate the cutting of cold meat products into slices with a higher viscosity which improves the palatable impressions of the consumer while biting and chewing the product. This is directly related to the ability of whey proteins to bind water with a high solubility in the pH range of 2–10 which is ideal for injected products. Furthermore, sodium caseinate is soluble at a pH above 5.0 while soy protein isolate is soluble only at a pH above 5.5. Also whey proteins form stable emulsions which are particularly important in the production of finely comminuted meat products, especially when the raw material is of poor quality and whey proteins may partially or completely replace other emulsifiers.

Furthermore, the addition of whey proteins affects the taste and improves the gelation. They can be used in the production of edible sausage casings. They are also used in the finishing of semi-products because the addition of whey has a positive effect on the adhesion of batter to portions of meat, poultry, or fish. Whey proteins may also exhibit antioxidant activity related to the oxidation of fat in pork meat and in salmon meat, or in products rich in lipids (Prabhu, 2006).

The bioavailability of whey is determined by the content of protein nitrogenous compounds, carbohydrates, lipids, mineral salts, vitamins, organic acids, enzymes, immune bodies, and microelements (Jeewanthi, Lee, & Paik, 2015; Yadav *et al.,* 2016). Thus, whey is a biologically valuable food product and the basis for production of a wide range of products.

Whey as a raw material is used in the meat industry to improve the taste of the final product, improve texture, and the quality of products in general. Whey protein binds moisture during the formation of a meat emulsion when cutting sausage forcemeat and keeps it during the subsequent heat treatment (Badpa & Ahmad, 2014b; Hanemaaijer, 1985; Smithers, 2008; Yadav *et al.,* 2015).

The complex use of raw meat material and milk whey proteins makes it possible to improve the quality of meat products. Therefore, using whey as a formula component in meat products is a topical question.

Therefore, this study aimed to investigate the effects of demineralized milk whey powder on the organoleptic properties of sausages and their nutritional value and develop a formula and technology for the production of sausages with partial replacement of raw meat material with demineralized whey powder. The goals are to obtain high-quality and safe products using raw materials rationally and reduce the cost of the finished product.

2. Materials and Methods

2.1 Materials

Demineralized milk whey powder containing 70–75% lactose (according to specification C/A No. 2600701072 6675) produced by "Baltic Food Company" (Russia) Co., Ltd. was used as the object of the study. It is a fine powder of white to cream color with a sweetish-saltish taste. The chemical composition of demineralized whey powder is shown in Table 1.

Demineralized milk whey powder was introduced into the formula of the model forcemeat system at the stage of making forcemeat from a meat mixer cutter. Minced meat without whey was used as a control sample. Control and test samples of forcemeat systems were prepared using a standard formula for sausage products (Kulikov & Postnikov, 2006).

In the course of the study, the technology and formula for cooked sausage production using demineralized milk whey powder was developed (Yetmin, Muller, & Eber, 2001). Before its use in production, whey is diluted with water at a temperature of 35–45 °C at a ratio of 1:10–12. The fatty raw material pre-ground in the meat mincing machine with hole diameters of 2–3 mm was loaded into the meat mixer cutter and processed to a paste-like state. Then the prepared whey was added and thoroughly mixed with fat for 1–2 min in the meat mixer cutter. Cold water (18–20 °C) was then added and the mixture was processed in the meat mixer cutter at the maximum speed until the emulsion was formed. The emulsion was poured into prepared containers in layers of not more than 20 cm in height and cooled at a temperature of 0–4 °C. After cooling, the emulsion should have a dense consistency. The remaining operations and modes corresponded to the traditional technological scheme for the production of cooked sausage (Kosikowski, 1979).

Control and test samples of forcemeat systems were prepared according to the formula presented in Table 2 (unified formula for “Molochnaya” cooked sausage). “Molochnaya” cooked sausage was used as the control sample. The main

Table 1. Chemical composition of demineralized milk whey powder.

Additive	Mass fraction, %				
	Water	Protein	Fat	Ash	Carbohydrate
Demineralized milk whey powder	4.10±0.06[a]	12.20±0.05[a]	1.10±0.18[b]	9.29±0.04[b]	73.31±0.02[a]

[ab] Means bearing different superscripts in a row differ significantly (P<0.05).

Table 2. Formula for control and test samples of forcemeat systems (unified formula for "Molochnaya" cooked sausage).

Ingredient	Control sample	Sample No. 1	Sample No. 2	Sample No. 3
	Unsalted raw material, kg / 100 kg			
Trimmed beef, grade 1	30	30	30	30
Trimmed semi-fat pork	49	44	39	34
Fat pork	20	20	20	20
Demineralized milk whey powder	-	5	10	15
Pasteurized milk	1	1	1	1
Total	100	100	100	100
Spices and additives, g / 100 kg of unsalted raw material				
Food salt	1900	1900	1900	1900
Sodium nitrite	7.5	7.5	7.5	7.5
«Milk» complex flavor-aromatic additive	950	950	950	950

formula components are trimmed beef, grade 1 (30 kg), trimmed semi-fat pork (49 kg), fat pork (20 kg), pasteurized milk (1 kg), and the additional components are food salt (1900 g), sodium nitrite (7.5 g), and a milk complex flavor-aromatic additive (950 g) (Table 2).

The formula of the same "Molochnaya" cooked sausage was used for test samples, but the equivalent amount of trimmed semi-fat pork was replaced with demineralized whey powder. Under laboratory condidtions 3 sausages were produced for each sample, weighing 200 g for a total of 12 sausages. Ready cooked sausages were also used as the object of the study. They were tested for organoleptic, physical, and chemical properties, as well as for the content of residual sodium nitrite and nitrosopigments.

2.2 Methods

The diagram of the experiments is given in Figure 1. The mass fraction of moisture was determined by drying the sample weight with sand to the constant mass at 103±2 °C according to Russian State Standard GOST 33319-2015 (National Institute of Standard, 2018a). for meat and meat products and the method to determine moisture content.

The mass fraction of protein was determined by a Kjeldahl-based method of the sample's mineralization and photometric measurement of the indophenol blue color intensity, which is proportional to the amount of ammonia in the mineralase according to Russian State Standard GOST 25011-81 (Meat and meat products, Method of protein determination) (National Institute of Standard, 2018b).

The mass fraction of fat was determined by the extraction method using the Soxhlet extractor according to GOST 23042-2015 (Meat and meat products, Methods of fat determination) (National Institute of Standard, 2018c).

The mass fraction of ash was determined by drying, charring, and ashing at a temperature of 550±25 °C of the test sample and subsequent calculation of the total ash mass fraction according to GOST 31727-2012 (Meat and meat products, Determination of total ash) (National Institute of Standard, 2018d).

The mass fraction of lactose was determined by a method based on a polarimetric measurement of the lactose concentration in a dry whey solution after protein precipitation with special reagents and separating them by filtration according to GOST R 51259-99 (Milk and milk products, Method for determination of lactose and galactose content) (National Institute of Standard, 2018e).

The total chloride content was determined by the potentiometric method and expressed as the mass fraction of sodium chloride in percent according to GOST R 51444-99 (ISO 1841-2-96) (Meat and meat products, Potentiometric method for determination of chloride content) (National Institute of Standard, 2018f).

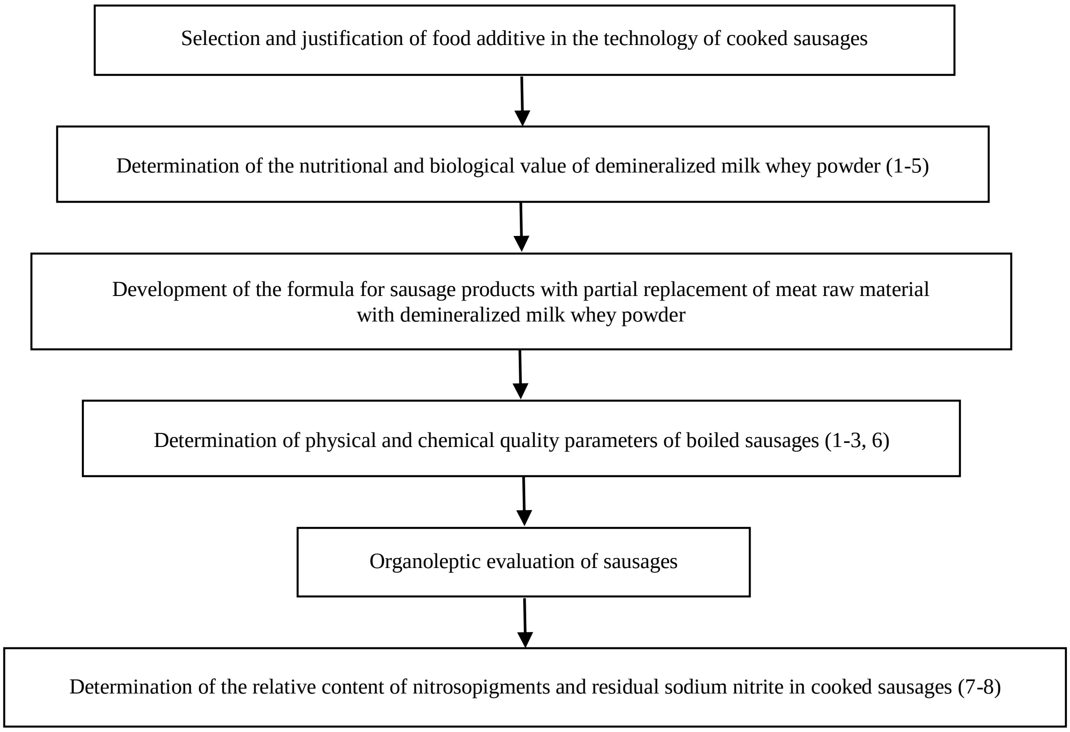
The content of sodium nitrite was determined by a method based on reaction with N-(1naphthyl)-ethylenediamine dihydrochloride reagent and sulphanilamide in a protein-free filtrate and subsequent photocolorimetric determination of the color intensity according to GOST 8558.1-78 (Meat products, Methods for determination of nitrite, Revisions 1 and 2) (National Institute of Standard, 2018g).

The content of nitric oxide pigment content was determined following this procedure. Five grams of the test sample was placed in a glass tube (25×145 mm), adding 20 mL of 94% aqueous acetone solution and homogenized in a teflon-in-glass homogenizer for 2 min. The contents of the tube were immediately filtered through paper filter into a 50 mL measuring flask. The tube was thoroughly rinsed with an 80% aqueous solution of acetone and filtered through the same filter. The precipitate was washed several times with a solution of 80% acetone and then the volume of solution was brought to the mark using the same solution. The acetone solution must be completely transparent before measuring the optical density. A cloudy solution can be clarified by adding 1 mL of trichlorethylene by shaking it with glass wool.

The solutions of nitric oxide pigments are stable within 30 min after adding an aqueous solution of 94% acetone. After extraction, measurements should be done as soon as possible (Skurikhin & Tutelian, 1998).

The optical density of the solutions was measured on a spectrophotometer at a wavelength of 540 nm relative to an 80% aqueous solution of acetone (Skurikhin & Tutelian, 1998).

The sensory evaluation of products was performed by 35 consumers in individual booths at room temperature



Parameters under study:
1 - mass fraction of moisture
2 - mass fraction of protein
3 - mass fraction of fat
4 - mass fraction of ash
5 - mass fraction of carbohydrates
6 - mass fraction of sodium chloride
7 - content of nitrosopigments
8 – content of sodium nitrite

Figure 1. Diagram of the experiments

using white light. The samples were served in disposable white plastic cups, identified by three-digit numbers, and randomly arranged. The results were statistically analyzed by means of the table for the ordering test of Newell and Mac Farlane, which defines the value of critical differences between the total ordering at level of 5% (Newell & Mac Farlane, 1987).

Shortly after, external appearance, appearance on the cut, smell, taste, consistency, succulence and chewability of the sausages were evaluated using a nine-point hedonic scale, where the extremes corresponded to 9 = liked extremely, 8 = liked very much, 7 = liked moderately, 6 = liked slightly, 5 = neither liked nor disliked, 4 = disliked slightly, 3 = disliked moderately, 2 = disliked much, and 1 = disliked extremely.

2.3 Statistical analysis

All measurements were repeated three times. The statistical analysis was performed using Microsoft Excel XP and Statistica 8.0. Statistical error did not exceed 5% (with a 95% confidence level). Analysis of variance (ANOVA) was performed with significance ($P<0.05$), the results were compared using the Tukey test ($P<0.05$) and bilateral Dunnett's test (ICS 95%). The latter statistical analysis was done using XLSTAT.

3. Results and Discussion

The results of the study of the chemical composition of demineralized milk whey powder revealed that the mass fractions of protein, fat, moisture, and ash were 12.2%, 1.1%, 4.1%, and 9.29%, respectively (Table 1). As can be seen from the table, demineralized milk whey powder is rich in protein, which is able to enhance the functional and technological properties of the meat system during sausage production.

The chemical compositions of the products in each recipe are shown in Table 3. Replacement of meat raw material (trimmed semi-fat pork) by demineralized whey powder amounts from 5% to 15% not only did not worsen the quality of the cooked sausages, but increased the protein content and reduced the fat content (Table 3). The introduction of whey proteins into the forcemeat instead of a part of meat raw material caused an increase in the moisture-binding and moisture-retaining capacity of the forcemeat and a reduction in losses during heat treatment. This can be explained by the effect of

Table 3. Chemical quality indicators of cooked sausage.

Indicator	Characteristics and value for sausage			
	Control sample	Sample No.1	Sample No.2	Sample No.3
Mass fraction of moisture, %	68.6±1.47^{a}	66.1±1.51^{a}	64.3±1.22^{ab}	61.7±1.39^{b}
Mass fraction of food salt, %	1.99±0.71^{a}	1.95±0.83^{a}	1.93±0.99^{ab}	1.93±0.90^{b}
Mass fraction of protein, %	16.9±0.89^{a}	18.3±0.74^{a}	19.5±0.85^{ab}	21.4±0.64^{b}
Mass fraction of fat, %	20.1±1.02^{a}	17.9±1.40^{a}	16.1±1.15^{ab}	14.4±1.04^{b}
Yield of product, %	107	111	115	117

^{ab} Means bearing different superscripts in a row differ significantly ($P<0.05$).

serum proteins and calcium, which while interacting with muscle proteins, "cross-link" between protein molecules and form the so-called "protein matrix", helping to reduce loosely bound moisture and increase the moisture-binding system on the whole (Youssef & Barbut, 2011).

The dynamics of a decrease in the mass fraction of moisture correlates to the pH value. With a decrease in the hydrogen index in the control and test samples, a corresponding decrease in the mass fraction of moisture was observed. The most significant decrease in the mass fraction of moisture was observed in test sample No. 3.

After the heat treatment, the test samples turned out to be more elastic in consistency than the control. This is due to the fact that the introduction of whey powder to the cooked sausage at the stage of mincing in the meat mixer cutter instead of meat raw material helps to densify the stuffing mix. This is explained by the influence of Ca^{2+} ions on the processes of the structure formation of meat systems and the improvement of their functional and technological properties (Postnikov & Ryzhinkova, 2009).

Based on the study of the quality, it was determined that demineralized milk whey powder in the amounts of 5%, 10%, and 15% in samples 1, 2, and 3, respectively, did not adversely affect the organoleptic properties of the finished products. The samples had a pleasant taste, appearance, and color on the cut side and were tender with a succulent consistency. The consistency of the products remained monolithic, while their succulence and tenderness increased (Figure 2).

Demineralized milk whey powder has a peculiar taste due to a large amount of lactose and high acidity. Therefore, the introduction of whey powder into the formula added sourness which made the taste of the cooked sausage of test sample No. 3 less pronounced at an average score of 7.2±0.73 which was less than test sample No. 2 by 0.72 points ($P\leq0.05$). The presence of lactic acid in the whey powder did not fully reveal the gustatory advantages of the finished product and there was no reliable difference between test sample No. 1 and the control. At the same time, the taste panel gave a high score to test sample No. 3 for external appearance (8.7±0.91) and appearance on the cut side (8.6±0.88). Test sample No. 3 had a cleaner and drier surface due to a decrease in the mass fraction of moisture. Also, the forcemeat on the cut side of sample No. 3 had a more attractive pink color due to the intensified color formation reaction with the 15% replacement of meat raw material with the demineralized whey powder.

A quality evaluation of the finished sausages at the end of the technological process showed that the sausage casing of all samples fit tightly to the surface of the product. Therefore, the sausage loaves were of the same shape, clean, and dry without any damage of the casing and without un-smoked spots, flowed minced meat, water or fat pockets (Shipulin & Akhmetshina, 2010).

Replacement of 5% and 10% of meat raw material by whey powder in the formula of "Molochnaya" cooked sausage did not introduce any specific odors into the sausage product since there were no significant differences between the control and test samples No. 1 and No. 2. However, the addition of 15% demineralized whey powder to the forcemeat resulted in excessive softening of the consistency, a noticeable decrease in the meat taste of the products, and the appearance of a slightly sour taste and smell of the finished product. Thus, it is optimal to replace meat raw materials with demineralized whey powder in the amounts of 5% and 10%. The organoleptic evaluation of the samples is shown in Figure 3.

During the next stage of the study, the samples were tested for the content of nitric oxide pigments and the content of residual sodium nitrite. The information concerning the effect of sodium nitrite reduction on the state of heme pigments in the control and test samples of boiled sausage using demineralized whey powder is presented in Table 4. The introduction of demineralized whey powder to the forcemeat resulted in an increase in the relative content of nitric oxide pigments and in the reduction of residual sodium nitrite in the

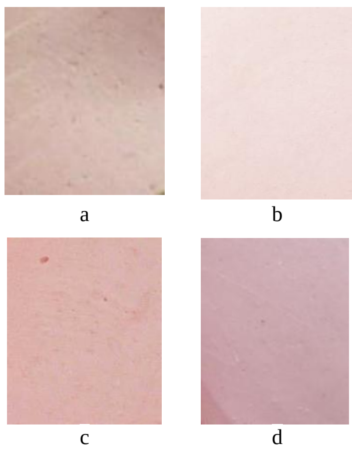


Figure 2. Photos of control and test samples of the sausages: a) control, b) experiment No.1, c) experiment No. 2, d) experiment No. 3.

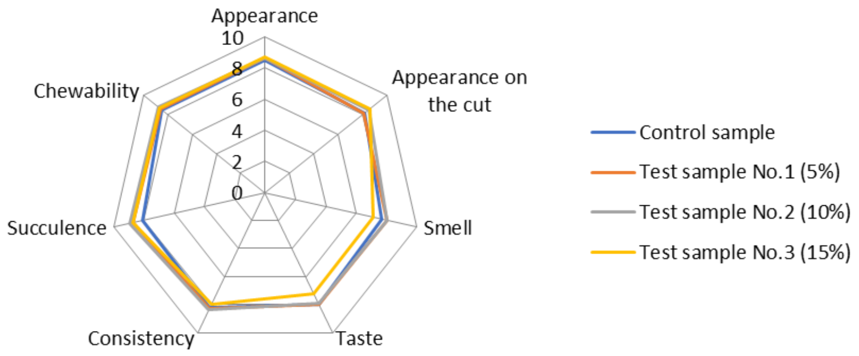


Figure 3. Organoleptic evaluation of sausage samples.

Table 4. Estimation of the content of nitrosopigments and sodium nitrite in sausage products.

Characteristics	Control sample	Sample No.1	Sample No.2	Sample No.3
The content of nitrosopigments (% of total pigments)	76.3±1.43[a]	82.2±1.59[a]	81.5±1.70[ab]	80.4±1.65[b]
Content of residual sodium nitrite, mg%	3.6±0.53[a]	2.8±0.44[a]	1.4±0.43[ab]	1.3±1.65[b]

[ab] Means bearing different superscripts in a row differ significantly ($P<0.05$).

cooked sausage (Table 4). Thus, the content of nitric oxide pigments in the control sample was 76.3% of total pigment, whereas in all test samples this value increased. The content of nitric oxide pigments in the control and test samples correlated with the index of residual sodium nitrite. The residual sodium nitrite decreased in the test samples compared to the control which indicated an increase in the safety level of the finished product.

According to the literature (Kulikov & Postnikov, 2006; Postnikov, 2007; Postnikov & Ryzhinkova, 2009; Shipulin & Akhmetshina, 2010), the introduction of lactose into forcemeat results in an increase in the nitrosopigments content, which is due to better conditions for the reduction of sodium nitrite and its binding by muscle proteins under the influence of lactose, which has a higher reduction ability in comparison with sucrose. The decrease in the amount of residual sodium nitrite is also associated with the action of lactose. Lactose increases the degree of transformation of sodium nitrite and its binding to muscle proteins and contributes to improved color of the product and increased safety. This may be due to the fact that lactose in demineralized whey powder leads to more intensive oxidoreduction changes in sodium nitrite with reduction to nitrogen oxide and the formation of more nitrosopigments which reduces the likelihood of obtaining nitrosamines (Kulikov & Postnikov, 2006; Shipulin & Akhmetshina, 2010).

Barybina and Postnikov (2002), as well as Omarov and Shlykov (2011) in their studies established a positive effect of lactose on the reduction of residual sodium nitrite content in cooked sausages by 50–55%. The introduction of milk and cheese whey into the formula reduces the content of residual sodium nitrite in cooked sausages by 10–30%. Accordingly, the oxidative process parameters change. When monocomponents (lactose) are introduced into the system, the peroxide value in the cooked sausage samples is reduced by 20%, but when the composition (whey) is introduced, this value is reduced by 50%. At the same time, there is a significant acceleration of the transformation of sodium nitrite in the processes of color formation of meat products, including whey proteins and lactose (whey), which is important from the point of view of improving the safety of meat products produced with nitrite additives. It was noted that an increase in the mass fraction of whey is accompanied by an increase in the intensity of the color of the cooked sausage, which indicates a positive effect of the additive on the formation of nitrosopigments. Probably, lactate ions, acting as competitors to the oxidizer (oxygen of the air), contribute to the formation of nitrosomyoglobin and nitrosogemochromogen which have pinkish-red and pinkish colors, respectively, and interfere with the oxidation of nitrosopigments. In addition, a more acidic medium of the whey excessively intensifies the disintegration of nitrite and can lead to a loss of nitric oxide.

The optimal amount of meat raw material to be replaced by demineralized milk whey powder is 10%. The use of demineralized milk whey powder in the amount of 10% instead of meat raw material improves the color characteristics of the finished product, allows for a reduction in the amount of residual nitrite while increasing the relative content of nitrosopigments, improves the organoleptic characteristics of finished products, enhances the production process of cooked sausages, and provides a product with high consumer properties.

4. Conclusions

According to the test results of the chemical composition of demineralized whey powder, the mass fractions of protein, fat, moisture, and ash in whey were found to be 12. 2%, 1.1%, 4.1%, and 9.29%. Whey powder is rich in protein and it hardly contains any fat but contains minerals. The objective of this study was to cook sausages according to a unified formula with different amounts of demineralized milk whey powder as a substitute of meat raw material. The sausages were then tested for organoleptic, physical and chemical properties, residual nitrite content, and nitrosopigments. The taste panel gave a high score to test sample No. 3 (with 15% of substitute) for external appearance (8.7±0.91) and appearance on the cut side (8.6±0.88). However, sample No. 3 resulted in excessive softening of the consistency, a noticeable decrease in the meat taste of the products, and the appearance of a slightly sour taste and smell of the finished product. Thus, the optimal replacement percentages should be 5% and 10%. Using whey protein at 10% yielded the best results for replacement as all attributes were good and acceptable. The use of demineralized milk whey powder in the amount of 10% instead of meat raw material improves the color characteristics of the finished product and reduces the amount of residual nitrite while increasing the relative content of nitrosopigments. Moreover, the use of whey protein also reduced the amount of sodium nitrite because the lactose in the forcemeat results in an increase in the nitrosopigments content, which is due to the better conditions for the reduction of sodium nitrite and its binding by muscle proteins under the influence of lactose, which has a higher reduction ability in comparison with sucrose. The addition of whey protein replacement resulted in the reduction of residual sodium nitrite with increased nitric oxide pigments in the final products.

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