



Journal homepage: <https://animalscience.com.ua/en>

Animal Science and Food Technology, 14(1), 49-64

Received 05.01.2023 Revised 14.01.2023 Accepted 03.02.2023

UDC 637.523.05

DOI: 10.31548/animal.1.2023.49

Application of modern technologies to improve the quality of sausage products

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Abstract. The production of sausages without the use of phosphates and sodium nitrite improves the quality and safety of the product, meeting the demand of consumers for natural and healthy food products. The purpose of the study was to investigate various technological aspects of sausage products that would improve their quality indicators, be attractive to the consumer, and have a positive impact on human health. Organoleptic qualities were evaluated by the appearance, consistency, type of minced meat on the cut, smell, taste; protein content – by Kjeldahl method; moisture content – by drying the suspension in a drying cabinet at a temperature of $103 \pm 2^\circ\text{C}$ to a constant mass; fat content – by extraction and weight Soxhlet method; moisture retention capacity – by centrifugation; penetration stress – by recalculation of penetration using a needle indenter; output of the finished product – by weighing before and after heat treatment. The

Suggested Citation:

Kryzhova, Yu., Slobodenyuk, N., & Moskalenko, I. (2023). Application of modern technologies to improve the quality of sausage products. *Animal Science and Food Technology*, 14(1), 49-64. doi: 10.31548/animal.1.2023.49.

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replacement of sodium nitrite with organic nitrite based on chard powder was studied together with a bacterial culture that, as a result of interaction, produces nitrate reductase and reduces nitrate to nitrite (samples 1, 2), in samples 3 and 4, chard powder was replaced with beet juice. All samples were pink in colour. Replacing phosphates with amylopectin starch gave the developed sausages an elastic and juicy consistency, increased the moisture retention capacity by 4.6%-6% compared to the control sample, and penetration stress by 31%-53%. The use of sous-vide technology provided the developed sausage samples with a more pronounced good taste of each recipe ingredient separately, a delicate, elastic consistency, a uniform colour on the cut, and a higher yield by 1.8%-3.3%. Replacing fatty raw materials with dietary ones, and cooking sausages in heat-resistant bags with vacuuming provided an increase in protein by 8.7%-16.7% and a reduction in fat by almost two times. The practical value of the study was to obtain a dietary product that meets the needs of modern people in a healthy diet

Keywords: sous-vide technology, amylopectin starch, phosphates, sodium nitrite, bacterial culture

Introduction

The population of Ukraine considers sausage products to be traditional food products for their taste properties and cooking speed. However, nutritionists in recent decades do not refer to this group of products as a healthy diet. The reason for this can be both the raw materials used, namely meat with signs of PSE and DFD, which has a low or high pH value, loose or hard consistency, and food additives that are used for various purposes in recipes and technologies. Therefore, such requirements of modern life encourage researchers and specialists in the meat processing industry to develop new products that would minimise the negative impact on human health, and vice versa, enrich the body with valuable substances that are components of ingredients selected according to the recipe.

The Ukrainian consumer pays attention, first of all, to the attractive appearance of the product and only after that is interested in the recipe composition (Vlasenko & Kryzhak, 2014). One of the ingredients that provide the usual pink colour to sausage products is sodium nitrite, which has both bactericidal properties and is involved in colour formation. When

salting meat raw materials, meat myoglobin is quickly oxidised by nitrite to metmyoglobin, which has a characteristic brownish-grey colour. At the intermediate stage, due to reactions, nitrosometmyoglobin is formed, which has a red colour. Nitrosometmyoglobin is reduced to a not very stable nitrosomyoglobin, which is further decomposed into globin and nitrosomyochromogen. It is this pigment, nitrosomyochromogen, that is a stable pink pigment that determines the colour of salty products. During the heat treatment of sausage products, namely, roasting boiled sausages, and frankfurters, starting from a temperature of 25-30°C, sodium nitrite breaks down, metmyoglobin is reduced to nitrosomyoglobin, providing colour formation. However, sodium nitrite has toxic properties and can participate in the synthesis of carcinogenic nitrosamines, so its amount is strictly limited (Crowe *et al.*, 2022).

The use of sodium nitrite in the meat industry has always been controversial due to the likely carcinogenic effects on health and the search for an alternative to nitrites, reducing their amount to provide antimicrobial action

and improve sensory characteristics remains a topical issue (Mynul Hasan Shakil *et al.*, 2022, Keuleyan *et al.*, 2022,). Therefore, researchers have long been engaged in the issue of replacing sodium nitrite in food production with various natural components of plant or animal origin (Vlasenko & Kryzhak, 2014, Govari & Pexara, 2015, Vlasenko and Vlasenko, 2016). This issue was part of the research work that was being done.

Literature sources have published works on the use of blended vegetable juices with different ratios based on beetroot instead of sodium nitrite, thanks to which boiled sausages had a characteristic colour for this group of sausages, as well as the use of beet syrup (Kryzhova & Deyak, 2021).

Xu Yuning & Zhu Yinglian (2021) investigated the complete replacement of nitrite by a strain *Lactobacillus fermentum* and its positive impact on the quality and safety of Chinese fermented sausages. Results were obtained in which the strain reduced the pH and risk of food pathogens, and its ability to produce a pink colour similar to 50 mg/kg of nitrite was established, which significantly reduced the residual nitrite in sausages. It was concluded that the strain has the potential to replace nitrites for the production of sausages that will not have a negative impact on health.

M.M. Polumbrik *et al.* (2019) investigated the partial replacement of sodium nitrite in the formulation of pasteurised sausages with food blood from pig slaughter. Organoleptic parameters of sausages were not reduced.

Heat treatment of sausage products leads to the loss of meat juice, as a result of which the tissues are dehydrated, and the juiciness of products, consistency and taste decrease. As a result of cooling, freezing, and storage of steamed meat, its moisture retention capacity decreases. Therefore, in the production of

meat products, various substances are used to increase the moisture retention capacity to a level corresponding to fresh meat. Table salt cannot fully restore this ability of meat; for this purpose, phosphates are used in sausage production, which have a specific effect on muscle proteins and other components of minced meat. They also shift the pH to the alkaline side. The content of soluble proteins in meat, together with the addition of phosphates, increases the moisture retention capacity of meat, which provides a denser consistency of sausage products.

However, the presence of food phosphates in most meat products leads to an increase in the intake of phosphorus in the body, and this has a negative impact on human health. Therefore, for partial, and in some products even complete replacement of food phosphates, amylopectin starch based on waxy potatoes was used – Perfectabind C, which has a pure taste. Some studies (Kryzhova & Duzenko, 2020, Kryzhova *et al.*, 2020) prove the expediency of replacing food phosphates with amylopectin starch in order to limit the intake of phosphorus in the body and reduce the negative impact on human health.

V.S. Trokhimenko *et al.* (2018) analysed the use of food additives in the production of sausages and their effect on the human body. Researchers have noted the negative effect of phosphorus compounds, which have a carcinogenic effect, cause diarrhoea, inflammatory processes of the mucous membrane of the digestive tract, and impair the absorption of calcium, and this, in turn, leads to the deposition of calcium and phosphorus in the kidneys.

L.V. Bal'-Prylypko *et al.* (2019) studied the use of edible orange fibre instead of phosphates and other food additives in order to increase the yield of finished products and maintain high organoleptic parameters.

Sous-vide technology was used in modern establishments of the restaurant industry to

reduce the time of order fulfilment, obtaining dietary meals, simultaneous preparation of various dishes in vacuum bags in one water bath with a temperature of 85°C or using other modern equipment. Some meat products are recommended to be pre-grilled or pre-marinated or mechanically beaten before vacuum packaging to improve the texture and more pronounced taste (Kurash & Pavlyuchenko, 2015). The microbiological quality of lightly fried food was determined using sous-vide technology (Jorgensen *et al.*, 2017).

An effect was found on the sensory characteristics of pork loin, namely tenderness and juiciness, which was cooked at 60°C or 65°C for 4 hours (Kurp *et al.*, 2022).

The purpose of the study was to improve the technology of sausages recommended for healthy eating, with the replacement of food phosphates with amylopectin starch, sodium nitrite with chard powder or beet juice together with bacterial culture, using sous-vide technology.

Materials and Methods

The research was carried out during 2021 at the Department of Meat, Fish and Seafood Technology of the National University of Life and Environmental Sciences of Ukraine. At the first stage, mathematical modelling selected the recipe composition of sausages according to the balance of nutritional and biological value, which included such dietary raw materials as chicken, turkey, and rabbit meat, including grade 1 beef. Oat bran, pumpkin, linseed, and olive oil were used to enrich sausages with fibre, as well as minerals, vitamins, and fatty acids, and turmeric was used to provide antioxidant properties.

Organoleptic parameters of sausages were evaluated on a five-point scale according to requirements of DSTU 4436:2005 (2006) "Boiled sausages, sausages, meat loaves. General technical conditions". The assessment was carried

out according to the following indicators: appearance, consistency, type of minced meat on the cut, smell and taste, and size of bars.

The moisture content of sunflower seeds on the RM-450 tester was determined before and after drying, which was carried out in a drying cabinet at $t = 30^{\circ}\text{C}$ for 15 minutes.

The nitrate content was previously determined in table beets using a portable Ecovisor F4 device.

For recipes No. 1 and No. 2, an activation medium was prepared: drinking water at room temperature was poured into the container, chard powder (Start STAR active NRB) was poured and bacterial culture (Start STAR NRC) was added, mixed and kept at room temperature for 24 hours. For recipes No. 3 and No. 4, the preparation of the activation medium was distinguished by replacing chard powder (Start STAR active NRB) with beet juice, which was previously brought to a boil, then cooled to a temperature of 0 – 4°C and diluted with water in a ratio of 1:1.

Before preparing the minced meat, oat bran was pre-moistened with water at room temperature for 30–40 minutes at a hydromodule of 1:4.

Fine grinding of raw materials and folding of minced meat was performed on a cutter.

After roasting, the sausages were packed in heat-resistant bags with vacuuming, then cooked in a sous-vide machine at 80°C for 15 minutes and at 60°C for 60 Minutes, followed by shock cooling, quality control, and storage in vacuum bags. In parallel, heat treatment of sausages was carried out in a thermal chamber at a temperature of $(80 \pm 5)^{\circ}\text{C}$, as well as the control sample.

Considering that the literature sources do not contain data on the temperature and duration of heat treatment of sausages using the sous-vide technology, and only cutting meat of various types and semi-finished products, for heat treatment using this technology, two

temperatures were chosen – 60°C and 80°C with a processing duration of 60 minutes and 15 minutes, respectively.

The readiness of sausages was determined when the temperature in the centre of the sausages reached 69-72°C.

The moisture content of minced meat and finished products was determined by the arbitration method, which is based on drying the samples in a drying cabinet at a temperature of $103 \pm 2^\circ\text{C}$ to a constant mass (DSTU ISO 1442:2005) (2008); active acidity (pH) – using a portable pH meter; ash content – by ozolising samples in a muffle furnace at a temperature of 600-650°C (DSTU ISO 936:2008) (2008); protein content – by Kjeldahl’s method, based on the complete mineralisation of the sample suspension with concentrated sulphuric acid in the presence of a catalyst, distillation of the resulting ammonia and determination of nitrogen content by titration using the Velp Academica device (Italy); fat content – extraction and Soxhlet weight method, which consists in removing fat using a solvent on the fat analyser Soxstek SOX 406 (China) with preliminary removal of moisture in the samples (DSTU ISO 1443:2005) (2008); moisture binding ability – by pressing, which consists in the release of water from the test sample during pressing, sorption of the released water with filter paper, determination of the amount of separated moisture by the size left on the filter paper spot area; moisture retention capacity – by centrifugation; plasticity – by spot area of minced meat formed on an ash – free filter under the action of a static

load weighing 1 kg for 10 minutes; penetration was determined on an Ulab 3-31 m penetrometer using conical and needle indentors, at the temperature of samples ($20 \pm 0.5^\circ\text{C}$), with the conversion of the penetration value of viscoplastic systems to the value of the maximum shear stress, in Pa, and elastic products – to the value penetration stress, in Pa. The salt content was determined by the Mohr method, and the yield of the finished product was determined by the ratio of the mass of minced meat to the mass of the product after heat treatment. Microbiological parameters were determined after heat treatment of sausages in accordance with the control methods given in DSTU 4436:2005 (2006) “Boiled sausages, sausages, meat loaves”. General technical conditions. “At the same time, the total content of microorganisms in 1 g of the product that can grow on the agar nutrient medium at a temperature of $(37 + 5)^\circ\text{C}$ was determined with the establishment of colonies that are visible at a five-fold increase, and the presence of *Escherichia coli* bacteria.

Results and Discussion

Previously, the nitrate content in table beets used for juice production was studied, which was 10 mg/kg at a rate of 1,400 mg/kg.

The moisture content of sunflower seeds was determined to be 8.6%. Subsequently, the seeds were dried to a moisture content of 1.4% in a drying cabinet AT $t = 30^\circ\text{C}$ for 15 minutes, then it was ground in a laboratory spice grinder and divided into sieves No. 1; 0.8; 0.5; 0.2. On the last sieve, the remainder was 38.9% (Table 1).

Table 1. Separating crushed seeds on sieves

Sieve number	Remainder on the sieve, %	Passage through a sieve, %
1	29.1	70.9
0.8	23.2	54.4
0.5	28.5	38.9
0.2	38.9	-

4 recipes of sausages were developed using chicken, turkey, grade 1 beef, rabbit meat, chard powder Start STAR active NRB, bacterial culture

Start STAR NRC, beet juice, oat bran, sunflower seeds, pumpkin, linseed, olive, dried apricots, prunes (Table 2).

Table 2. Sausage recipes, kg/100 kg of raw materials

Name of raw materials	Control	No. 1	No. 2	No. 3	No. 4
	%	%	%	%	%
Turkey meat		45			
Chicken meat			39	36	
Beef grade 1	35	35			85
Rabbit meat			40	40	
Milk powder	2				2
Cream 20%		2	3	3	
Chicken eggs	3	3	3	3	3
Oat bran		2	2	2	
Water for hydration		8	8	8	
Olive oil					5
Sunflower seeds		2	2		
Pumpkin oil				3	
Linseed oil		3	3		
Dried apricots				5	
Prunes					5
Fatty pork	60				
Total:	100	100	100	100	100
Auxiliary raw materials, g/100 kg of raw materials					
Table salt	2.100	2.100	2.100	2.100	2.100
Granulated sugar	120	130	120	120	120
Sodium nitrite	7.5	-	-	-	-
Ground black pepper	120	-	-	-	-
Ground white pepper	-	150	150	150	150
Ground nutmeg	40	50	50	50	50
Turmeric	-	20	20	20	20
Amylopectin starch	-	300	300	300	300
Phosphates	300	-	-	-	-
Beetroot juice	-	-	-	5.000	5.000
Chard powder	-	500	500	-	-
Bacterial culture	-	125	125	125	125

In the developed formulations, food phosphates were replaced with amylopectin starch. Instead of sodium nitrite, chard powder or beet juice was used along with bacterial culture. Sausages "Milk highest grade" were taken for control.

Chard powder was used as a natural source of nitrate, it is characterised by a high content

of minerals and nutrients, has a weak taste of its own, and is not allergenic. Due to the addition of bacterial culture to it, nitrate is reduced to nitrite during biological transformation, and natural nitrite is formed. Bacterial culture is a mixture of cultures, staphylococci and micrococci, *Staph. Carnosus* and *K. Salsicia*.

The originality of this technology, in addition to replacing phosphates and sodium nitrite, was the method of cooking sausages,

which consisted in the fact that the classic cooking method was replaced by cooking sausages using sous-vide technology (Table 3).

Table 3. Temperature conditions for cooking sausages

Test samples	Heat treatment modes	
	Temperature, °C	Duration, min
Control and developed samples	80±5	15
Sous-vide samples	60	60
Sous-vide samples	80	15

This allowed reducing technological losses in the production of sausages, discovering all the taste and aroma properties of prescription components, improving juiciness, and getting tenderness and a beautiful, uniform colour on the cut. Moreover, production using this technology reduces the contact of the finished product with the environment, which protects re-contamination during product storage, ensures uniform and more efficient heat transfer from water to the product itself, increases shelf life, increases yield due to technological processing in a hermetically sealed food bag.

The literature presents studies that most often relate to the preparation of meat or semi-finished products by the sous-vide method in the following combinations: one combination of temperature and duration, or several combinations of temperature and duration. L. Kurp *et al* (2022) present a range of parameters for cooking pork loin using the sous-vide method with the study of physicochemical, microbiological, structural, and sensory parameters. The meat was cooked at 60°C and 65°C for 4 hours. Such cutting modes provided the most attractive and acceptable sensory characteristics of pork loin, that is, the most important for perception were the texture characteristics, namely tenderness and juiciness.

In this study, the preparation of sausages in a sous-vide machine was carried out at a

temperature of 80°C for 15 minutes and 60°C for 60 minutes, determining the readiness of sausages by temperature and organoleptic indicators, and safety by microbiological indicators. The studied modes of processing sausages using sous-vide technology did not show significant differences in general appearance, colour, tenderness, taste, or aroma intensity, but sausages that were heat-treated at a lower temperature (60°C) and longer duration (60 minutes) were significantly juicier. Heat treatment of the control sample was carried out at a temperature of 85°C for 15 minutes. It was characterised by a denser consistency and did not differ in juiciness. According to L. Kurp *et al.* (2022), cooking pork loin at 75°C produced less tender meat than at lower temperatures, and according to references from other researchers (Baldwin, 2012), the softness of meat increased at temperatures between 50°C and 65°C, and then decreased with increasing temperatures to 80°C, which is also observed in this study.

The study focused on the comparative analysis of samples using bacterial culture and chard powder (samples 1 and 2), beet juice (samples 3 and 4), made using sous-vide technology, to ensure the necessary colour of sausages and other sensory indicators, which was carried out organoleptically. After production, an organoleptic evaluation of sausages was carried out on a five-point scale (Fig. 1).

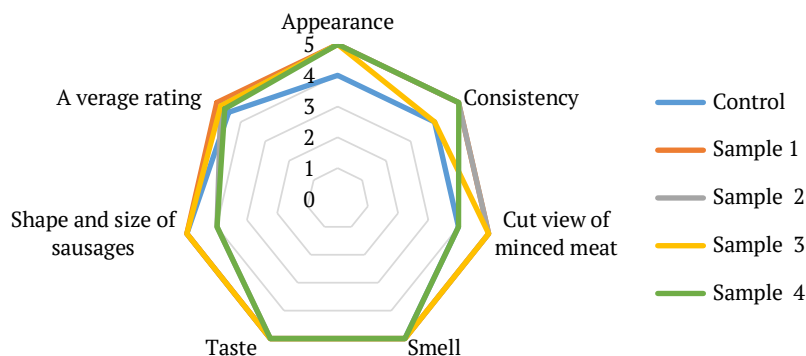


Figure 1. Organoleptic sausage evaluation profilogram

As a result of the conducted studies, a significant difference in the consistency, taste, and type of minced meat on the cut of sausages of experimental and control recipes was established. Positive changes in the organoleptic parameters of the developed sausage samples were mainly influenced by the raw material and cooking method. It was found that all samples were characterised by high taste properties due to pre-vacuuming and sealed packaging in thermal packages, which protects the evaporation of volatile aromatic substances. Samples No. 3 and No. 4 were juicier, but it was noted that all developed samples with amylopectin starch had a tender and juicy texture. They also differed in the specific taste that dried apricots and prunes gave. Sample No. 2 had a more delicate consistency than other samples due to dietary raw materials. Samples No. 1 and No. 2 had a pleasant light aroma of sunflower seeds. There was no significant difference in the organoleptic characteristics of sausages made using sous-vide technology at a temperature of 80°C or 60°C, except for juiciness. The control sample had the usual taste characteristic of sausages, without much juiciness and a pleasant aftertaste, it did not have an expressive bright colour. Chotigavin *et al.* (2023), when studying the effect of the low-temperature

long-term cooking method, sous-vide, on beef muscle properties, found that beef using sous-vide technology had higher rates of tenderness and juiciness compared to the control, which is consistent with this study.

It should be noted that all four sausage samples received a high organoleptic score and differed from the control sample in that, due to the sous-vide technology, the flavours of each recipe ingredient were clearly distinguishable. This is one of the advantages of modern new cooking technology – sous-vide technology.

In terms of colour, the best samples were No. 1 and No. 2, made with chard powder Start STAR active NRB and Start STAR NRC starter culture instead of sodium nitrite, and samples No. 3 and No. 4, in which sodium nitrite was replaced with beet juice and bacterial culture Start STAR NRC, had a more pronounced colour than is inherent in similar sausage products that are made using sodium nitrite. Most likely, this was influenced by the amount of beet juice.

O.V. Skrypyuk & Ya.M. Bychkov (2018) obtained the results of improving the structural properties of beef meat with a high connective tissue content during the heat treatment for 3,600 s using sous-vide technology, other researchers – improving sensory characteristics during stewing (Cheng *et al.*, 2022).

Scientists, using sous-vide technology for cooking, obtained a reduction in losses during cooking, better flavour and juiciness of the final product, and extended shelf life. The paper shows different processing temperatures (roast beef – 65°C, roast chicken – 60°C, roast duck – 80°C), but does not specify the duration of cutting (Kurash & Pavlyuchenko, 2015), also in the study of the effect of sous-vide technology on the quality of beef ribs received maximum tenderness, minimal impact on colour change and minimal losses during cooking (Karki *et al.*, 2022; 2023).

V.V. Vlasenko *et al.* investigated the possibility of reducing the amount of sodium nitrite through the use of bacterial cultures RCI-47 and SBI-0.5, which were introduced into the minced meat of raw smoked sausages, while maintaining high organoleptic, technological and microbiological indicators (Vlasenko & Kryzhak,

2014). The researchers concluded that the use of bifidobacteria in the production of sausages ensures the effective use of sodium nitrite in the reaction of nitrosopigment formation and allows reducing the amount of sodium nitrite to 40-50% of the generally accepted norm and obtain a product with a stable colour.

In this study, which is aimed at improving the quality characteristics of sausages, a complete replacement of sodium nitrite with bacterial culture was applied in interaction with chard powder (samples 1 and 2) and beet juice (samples 3 and 4). The colour intensity of sausages in samples with beet juice was brighter and richer than in samples with chard powder and control sample, this requires further studies on the amount of juice and shelf life.

After heat treatment, the physical and chemical parameters of sausages were analysed (Fig. 2).

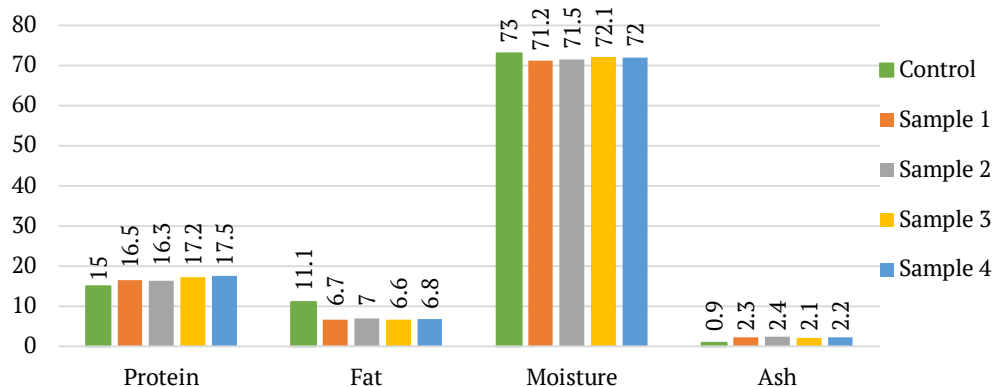


Figure 2. Physical and chemical parameters of sausages, %

The protein content in the experimental samples increased by 10% in sample No. 1, by 8.7% in sample No. 2, by 14.7% in sample No. 3, and by 16.7% in sample No. 4 compared to the control. This increase in protein content is explained by the use of raw meat in the developed samples, which is characterised by

high protein content. In sample No. 1, turkey meat was used, in sample No. 3 – chicken and rabbit, and in sample No. 4 – a larger amount of grade 1 beef. Moreover, heat treatment of sausages in vacuum bags ensured the preservation of the chemical composition of meat raw materials.

The fat content of the control sample is 38% higher on average compared to the developed samples due to fatty pork in the control and its replacement with vegetable oils in small quantities in prototypes.

The moisture content in all samples is in the range of 71.2-73.0%, which does not exceed the permissible levels for this type of product. In general, based on the results of physical

and chemical indicators, it was concluded that they met the requirements of DSTU 4436:2005 (2006) "Boiled sausages, sausages, meat loaves. General technical conditions".

An important indicator of sausage products is the moisture retention capacity, which provides them with a juicy consistency, and indicates the amount of bound moisture during heat treatment (Fig. 3).

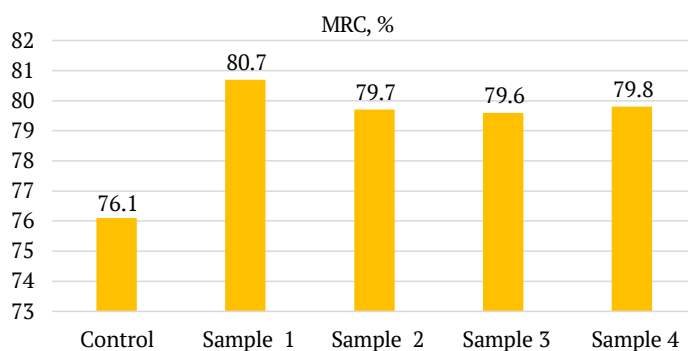


Figure 3. Moisture retention capacity of sausages, %

The moisture retention capacity of the samples with amylopectin starch increased from 4.6% to 6% compared to the control sample in which phosphates were used. This is conditioned by the increased functional and technological characteristics of amylopectin starch, which are manifested in a lower gelatinisation temperature, a sufficiently high viscosity, high moisture binding, and a high content of more than 99% amylopectin. Song *et al.* (2023) reported an improvement in water retention capacity and texture of ham from chicken breast cooked in sous-vide mode. Increasing the yield of finished products while maintaining high organoleptic characteristics, especially consistency, ensures the high economic performance of production. The yield of sausages made using classical technology and sous-vide technology was studied at different temperatures and the duration of heat treatment (Fig. 4).

The developed samples had a higher yield compared to the control by an average of 1.8% using sous-vide technology and heat treatment at 60°C and a duration of 60 minutes, and by 3.3% on average using sous-vide technology and heat treatment at 80°C and a duration of 15 minutes. Oat bran, amylopectin starch and sous-vide technology, which were applied in a complex, had a positive effect on increasing the yield. Bal'-Prylypko *et al.* (2019) noted the effect of dietary fibre on increasing the yield of meat products and the ability to bind and retain moisture.

The decrease in losses during the culinary processing of products using sous-vide technology was reported by O.H. Kurash & O.S. Pavlyuchenko (2015), L. Kurp *et al.* (2022), and a relationship was established between an increase in losses, an increase in temperature, and the duration of processing. The influence of cooking methods on the physical properties and

sensory qualities of meat (pH, cooking losses, density) was studied by A.I. Hobani *et al.* (2023). They found that cooking loss was the only parameter affected by the interaction of cooking method, temperature, and time, noting that it

did not affect the pH and activity of the water. In this study, changes in the temperature and duration of heat treatment using the sous-vide method practically did not change the pH values and water activity.

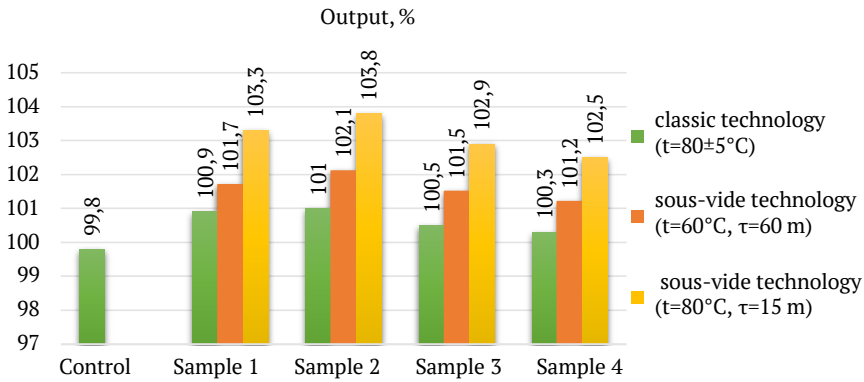


Figure 4. Sausage output, %

The change in the structure of sausages, which was influenced by oat bran, amylopectin starch, and sous-vide technology, was confirmed not only by organoleptic parameters, namely the consistency that expresses the

totality of rheological properties of the food product, but also by determining penetration on a penetrometer and converting it to the values of the maximum shear stress and penetration stress (Fig. 5).

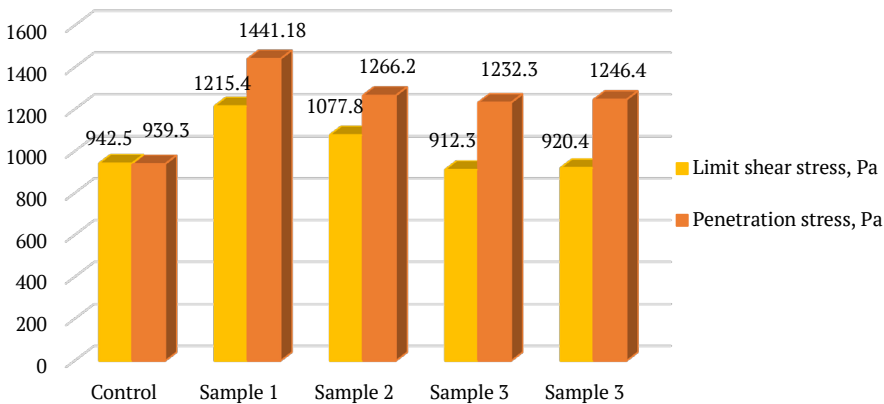


Figure 4. Boundary shear stress of viscoplastic systems and penetration stress of sausages

The studies showed that samples No. 1 and No. 2 had a more elastic consistency, which was facilitated, most likely, by a complex of compo-

nents, namely, bacterial culture, oat bran, and amylopectin starch. The penetration stress of these samples is the highest, while samples

No. 3 and No. 4 had a lower penetration stress value, these samples had a more delicate consistency, which may have been the result of using beet juice instead of chard powder, which, in addition to being high in nitrate, contains many minerals and nutrients. Samples of sausages that were cooked for 15 minutes at a higher temperature (80°C) had a more elastic consistency than samples that were cooked for 60 minutes at a lower temperature (60°C), their penetration stress was lower. This is consistent with the results given by L. Kurp, who investigated the effect of sous-vide technology on improving the texture of pork loin (Kurp *et al.*, 2022). The most tender meat was obtained at temperatures of 60°C and 65°C with a shorter cooking time of 3 hours. It was suggested that the softening of meat that was cooked longer was supported by the activity of internal proteases that remained active at lower temperatures. It was also found that with the same cooking time, lower losses were established at a lower cooking temperature. Structural changes in meat proteins under the influence of heat treatment probably played a crucial role in the formation of sausage tenderness.

Investigation of the influence of temperature and time on the culinary properties of pork loin, processed by sous-vide technology conducted by Hwang *et al.*, showed an advantage in obtaining tender meat compared to traditional cooking, which was confirmed by lower shear force indicators. However, the shear force during sous-vide processing did not show any patterns in terms of temperature or time (Hwang *et al.*, 2019).

The fact that semi-finished products made using sous-vide technology had an extended shelf life was described by O.H. Kurash and O.S. Pavlichenko (2015).

Microbiological studies of the developed sausages were carried out immediately after

heat treatment and storage for 48 hours in thermal packages at a temperature of 0-4°C. Studies have shown that the amount of mesophilic aerobic and facultative anaerobic microorganisms, CFU in 1 g of the product, did not exceed the permissible norms, and no bacteria of the *E. coli* group or pathogenic microorganisms were detected per 1 g of product, which confirmed the safety and high quality of the developed products. In addition, prototypes of sausages with the addition of chard powder Start STAR Activ NRB, beet juice and bacterial culture Start STAR NRC had better microbiological indicators compared to the control. This is conditioned by the fact that the bacteria present in the bacterial culture have an antagonistic effect on pathogenic and opportunistic microorganisms.

Conclusions

The use of modern technologies to improve the quality indicators of sausages provided for the use of dietary raw materials, namely chicken, turkey, and rabbit meat instead of fatty pork. As a result, an increase in protein content was achieved by 8.7%-16.7%. In addition, the production of sausages in sealed bags with vacuuming had a positive effect on this indicator. Replacing raw meat with less fat, and using small amounts of vegetable oil reduced fat almost twice without changes in taste properties. The addition of amylopectin starch to the recipe, which had a positive impact on the consistency, increased the moisture retention capacity, and made it possible to produce sausages that do not have the effect of accumulating unwanted phosphorus in the body, which is possible when using phosphates. Due to the exclusion of sodium nitrite from the formulation and its replacement with chard powder and starting culture, the possibility of dangerous N-nitrosamines synthesised from nitrite in the human body is excluded. A positive solution was the use of

sous-vide technology, which provided extremely high taste properties to the developed sausage samples due to better heat exchange of the wet environment in a sealed bag, a feeling of full taste, extreme juiciness, lower nutrient losses, a higher yield compared to the control sample by 1.8% during heat treatment at 60°C for 60 minutes and by 3.3% during heat treatment at 80°C for 15 minutes. Oat bran, which, like other similar dietary fibres, is widely used in the production of both semi-finished products and sausage products to provide the necessary structure, save meat raw materials and increase the economic performance of production. The results confirmed that the developed

sausages can be used in the dietary nutrition of people or in general as more “healthy” products.

The study on this topic has prospects for further research on partial or complete replacement of sodium nitrite, the use of beet juice, and the use of sous-vide technology in the production of sausage products, determining temperature intervals and processing duration, extending shelf life.

Acknowledgements

None.

Conflict of Interest

None.

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Застосування сучасних технологій у покращенні якості ковбасних продуктів

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Анотація. Виробництво сосисок без застосування фосфатів та нітриту натрію покращує якість та безпечність продукту, відповідаючи попиту споживачів на натуральні та здорові харчові продукти. Метою роботи було вивчення різних технологічних аспектів ковбасних продуктів, які підвищили їх показники якості, були б привабливими для споживача і мали позитивний вплив на здоров'я людини. Органолептичну оцінку визначали за зовнішнім виглядом, консистенцією, виглядом фаршу на розрізі, запахом, смаком; вміст білка – методом К'ельдаля; вміст вологи – висушуванням наважки в сушильній шафі за температури

103 ± 2 °C до постійної маси; вміст жиру – екстракційно-ваговим методом Соклета; вологоутримуючу здатність – центрифугуванням; пенетраційну напругу – перерахунком пенетрації з використанням голкового індентора; вихід готового продукту – зважуванням до і після термічного оброблення. Досліджено заміну нітриту натрію органічним нітритом на основі порошку мангольда разом з бактеріальною культурою, яка в результаті взаємодії виробляє нітратредуктазу та відновлює нітрат до нітриту (зразки 1, 2), в зразках 3, 4 – порошок мангольда замінено буряковим соком. Усі зразки мали рожеве забарвлення. Заміна фосфатів амілопектиновим крохмалем надала розробленим сосискам пружної та соковитої консистенції, підвищила вологоутримуючу здатність на 4,6 %-6 % порівняно з контрольним зразком та пенетраційну напругу на 31 %-53 %. Застосування sous-vide технології забезпечило розробленим зразкам сосисок більш виражений гарний смак кожного рецептурного інгредієнта окремо, ніжну, пружну консистенцію, однорідний колір на розрізі, вищий вихід на 1,8 %-3,3 %. Заміна жирної сировини дієтичною, варіння сосисок в термостійких пакетах з вакуумуванням забезпечили підвищення білка на 8,7 %-16,7 % та зниження жиру майже в два рази. Практична цінність дослідження полягала в отриманні дієтичного продукту, який відповідає потребам сучасної людини у здоровому харчуванні

Ключові слова: sous-vide технологія; амілопектиновий крохмаль; фосфати; нітрит натрію; бактеріальна культура