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Improving the technology for the production of raw dried beef products

Larisa Bal-Prylypko*
Doctor of Technical Sciences
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-9489-8610

Mykola Nikolaenko
PhD in Technical Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-2213-4985

Oleksandr Kanishchev
Postgraduate Student
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0009-0006-5034-3695

Lyudmila Beyko
PhD in Technical Sciences, Associate Professor
Western Ukrainian National University
46009, 11 Lvivska Str., Ternopil, Ukraine
https://orcid.org/0000-0001-6211-8010

Nataliia Holembovska
PhD in Technical Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0001-8159-4020

Abstract. The relevance of this work lies in the need to reduce the negative impact on human health of sodium nitrite (food additive E250), which is added to meat products, in particular to raw dried

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*Corresponding author

sausages, in order to accelerate their maturation and give them the shades familiar to consumers. The aim of the work is to improve the technology for the production of raw dried beef products based on the use of modern biotechnological approaches, sea salt and the natural colouring agent betanin, and beetroot juice as a substitute for sodium nitrite. This goal was achieved through the implementation of a mixed salting method, whereby the surface of the meat semi-product was rubbed with a reduced amount of salt, including 0.0005 kilograms of sodium nitrite per kilogram of meat weight, compared to standard technology, and the rest of the salting mixture, which contained 0.0045 sodium nitrite, was injected deep into the semi-product as an aqueous solution. The source of nitrite was beetroot juice rich in nitrate ion, 0.03 dm^3 of which contained 0.0052 kilograms of sodium nitrate, sufficient to synthesize 0.0045 kilograms of nitrite ion per kilogram of meat raw material. The chosen salting method reduced the amount of sodium nitrite from 0.015 to 0.005 kilograms per kilogram of meat product compared to the classical method, and the addition of beetroot juice made it possible to give the product a uniform colour throughout. Contamination of the product with dangerous microflora was prevented by adding a preparation containing bacteria of the *Pediococcus acidilactici* and *Staphylococcus carnosus* strains to the syringe solution. A positive effect of *Pediococcus acidilactici* was found, which was achieved by accelerating the pH of the meat mass to 5.0 ÷ 5.5, which stopped the growth of most dangerous microorganisms, including *Shigella spp., Salmonella spp.*, *Clostridium difficile* and *Escherichia coli.* The product was protected from the development of *Listeria monocytogenes* bacteria by bacteria of the *Staphylococcus carnosus* strain. The proposed technology can be used in the food industry in the manufacture of raw meat products, which will significantly reduce the negative impact of sodium nitrite on human health

Keywords: meat products; raw dried products; beef; pickling; bacterial preparation; sodium nitrite; quality and safety of finished products

Introduction

The main areas for improving the technology of manufacturing raw smoked and raw dried products are the intensification of the technological process and the use of optimal processing modes, which ensures high nutritional value of the products. Colour is the first feature by which consumers assess the quality and suitability of meat products. If the appearance of the product is unsatisfactory, it creates the impression that the taste of the product is also unsatisfactory. Nitrite is the most common preservative in the meat industry. It improves the flavour and aroma of the product, preserves the reddish-pink colour of meat and prevents the risk of bacterial contamination of meat, but it has a negative impact on human health. That is why one of the challenges of modern nutritional science is to reduce the negative health effects of sodium nitrite (food additive E250) added to meat products, such as smoked and raw dried sausages and similar products. The negative effects of nitrites as an additive to meat were first reported in the early 1950s and 1960s, when the compound N-nitroso (NOCs) was discovered (Jin *et al*., 2018). Previous studies have suggested that nitrosamines (in particular, consumption of meat products) are associated with certain types of cancer (Gyawali & Ibrahim, 2014). Subsequently, the amount of sodium nitrite used in the production of meat products has been limited.

Some researchers are paying more attention to replacing sodium nitrite with plant extracts, bacteria, specific bacterial strains and high hydrostatic pressure (HHP) to remove/reduce nitrite (Holembovska *et al*., 2017;

da Silva Souza *et al.*, 2020; Macari *et al.*, 2022). Extracts and ingredients from plants are an acceptable alternative to nitrite. Some plants (herbs, vegetables, fruits, and spices) contain different types of phenolic compounds of different types, which are beneficial for human health as they have excellent free radical scavenging activity (Alahakoon *et al.*, 2018). S.K. Jin *et al.* (2018) prove that the formation of carcinogens N-nitrosamines in the interaction of sodium nitrite with amino acids found in meat and meat products and when heated can pose a potential risk of cancer development. The maximum permissible concentration of sodium nitrite residue in the manufacture of sausages is 0.005 mg/kg, and for special and baby food products – 0.003 mg/kg.

Every year, advanced technological solutions appear, new directions and trends are created. In recent years, the use of nitrites in the production of cured meat products has become an acute and complex issue due to their multifunctionality. On the one hand, nitrites have a positive effect on the colour, taste, aroma, and shelf life of meat products, while on the other hand, they can be a precursor to the formation of a powerful carcinogen, nitrosamine. The presence of free sodium nitrite in meat products poses a certain risk to human health, as nitrite is a toxic substance. Possible ways to reduce the content of sodium nitrite in meat products are of great practical importance. However, the absence of substances that can functionally replace sodium nitrite does not allow it to be excluded from the recipe and requires a search for a way to reduce its concentration in finished products.

A well-known method is the use of blood from slaughtered animals as an ingredient that can be added to cooked sausage formulations to improve the biological value of the product and increase the content of heme iron. Blood can be used effectively to colour finished products, thereby reducing the residual sodium nitrite content in gastronomic products (Khorunzha *et al.*, 2019).

The aim of the study is to improve the technology for the production of raw dried beef products using modern biotechnological approaches, sea salt, and the natural colouring agent betanin.

Literature Review

The problem of reducing the sodium nitrite content of meat products is the subject of intensive scientific research. As a compromise between the requirements of health authorities and the interests of consumers, it is sufficient to use nitrite ion in amounts ranging from 2 to 14 milligrams (3.3 to 10.0 milligrams of sodium nitrite) per kilogram of meat to achieve the desired effect. However, under such conditions, the time for preserving the desired colour is short, and therefore, according to WHO standards, in products intended for human consumption, the permissible level of nitrite ion consumption is increased to about 0.6 milligrams per kilogram of weight (about 0.5 milligrams in terms of nitrite ion), which is achieved by adding 100-150 milligrams of $NaNO_2$ to minced meat in the traditional way of consuming sausage products (Cherednichenko & Bal-Prylypko, 2020; Mushtruk *et al.*, 2023).

The problem is partially solved by adding substances with antioxidant properties to salt mixtures, for which ascorbic acid is most often used (Rosier *et al.*, 2022; Ugnivenko *et al.*, 2022). According to some studies, the negative impact of sodium nitrite in meat products is practically not felt, especially since a significant amount of this salt is bound by meat myoglobin, and after entering the body, the enzymes responsible for *NO* formation generate nitric monoxide from nitrite, where it is responsible for numerous physiological functions, including intracellular respiration (Tan *et al.*, 2022).

As a preservative, nitrite is difficult to replace because it can perform many functions simultaneously. Thus, reducing or eliminating the use of nitrite is a major challenge for the meat industry. Scientists are conducting in-depth research to investigate the antibacterial agent and organoleptic effects of various alternative compounds and technologies that can be used as substitutes for nitrite. Consequently, the production of safe meat products now plays an important role in the meat industry to be able to avoid the direct use of nitrates and nitrites. Ways to reduce the percentage of residual nitrite include the use of natural pigments of animal and vegetable origin, as well as the use of antioxidants, which can simultaneously provide the desired colouring effect while minimizing the inclusion of nitrite salts in the meat product (Bozhko *et al*., 2017). J. Haque *et al*. (2023) are wary of the use of significant amounts of sodium nitrite in mixtures used in the curing of raw meat, due to the negative impact on the body condition of living beings: for rats, the LD50 value is 180 milligrams of sodium nitrite per kilogram of body weight, for humans – 71 mg/kg.

G.S.B.S. de Medeiros *et al.* (2022) studied in their work the negative health effects of sodium nitrite (*food additive E*250) added to meat products, such as smoked and raw dried sausages and similar products, to accelerate their maturation and give them the usual pink to dark red colour according to the established mechanism. G. Riel *et al*. (2017) found no differences in the lightness parameter for sausages containing different amounts of parsley extract powder (PEP), but a difference was found for the parameter indicating redness. The authors concluded that the increase in yellow colour was due to the presence of plant pigments. They found that nitrite (100 or 125 mg/kg) combined with green tea catechins (300 mg/kg) protected sausages from depigmentation. P. Aliyari *et al*. (2020) found that samples (beef sausages) without nitrite but with more pomegranate peel and pistachio green onion extracts showed more yellowing than control samples with nitrite (120 ppm). F.M. Manihuruk *et al*. (2017) suggested the use of red dragon skin (*Hylocereus polyrhizus*) as a natural colourant and antioxidant.

Optimization of production technology poses a twofold task, which includes finding ways to reduce the dosage of sodium nitrite in the selected raw dried meat products and reduce the level of bacterial contamination associated with the duration of the maturation process after salting.

Materials and Methods

Experimental studies were conducted in 2023 in the laboratories of the Departments of Meat, Fish and Seafood Technology, Microbiology, Virology, and Biotechnology of the National University of Life and Environmental Sciences of Ukraine. The material used for the study was top-grade lean beef, which contains the highest relative amount of protein and, when lean meat is lean, has little adipose tissue waste. The surface of the meat was treated with a salting mixture of sea salt with additives of dextrose and sodium nitrite, and the inner layers were treated with a syringed aqueous solution of a mixture of ascorbic acid sea salt, sodium nitrite and the bacterial preparation B-LC-78.

The work was carried out using the methods generally accepted for this type of product to determine the physicochemical, organoleptic, rheological, functional, technological and microbiological quality indicators of meat products during the maturation process and ready-to-eat: the mass fraction of nitrite was determined according to DSTU ISO 2918:2005 (2007) by colouring solutions containing nitrite anion in pink-red colour of varying intensity depending on the nitrite concentration under the influence of the so-called Grissom-Ilosvay reagent; redox potential (RP) was determined by the electrometric method using the multifunctional device "Combo"; microbiological safety indicators were determined according to generally accepted methods, which included determining the number of bacteria of the Escherichia coli group (coliforms), pathogenic microorganisms, sulphite-producing clostridia and staphylococci; water activity was determined by dew point according to the method at a temperature of 25 ± 1°C (Slobodianiuk *et al.*, 2018).

The task of reducing the dosage of sodium nitrite in the product was solved in two ways. The method of dry rubbing the surface with a salt mixture, traditionally used for salting raw meat, was replaced by a mixed salting method, in which no more than 15% of the amount of salt substances used in the traditional technology, including no more than 0.0005 kilograms of sodium nitrite per kilogram of raw meat, was used to rub the surface of the meat. The rest of the substances used for salting were added in the form of an aqueous solution by introducing the bulk of them into the inner layers of meat in a state dissolved in the salting liquid, which did not require a long time for nitrate ion diffusion into the deeper layers of meat, avoided unnecessary losses due to hydrolysis on the surface, and thus ensured almost quantitative interaction with myoglobin throughout the depth of the salted product according to the mechanism shown in Figure 1. At the same time, we also avoided "over-salting" of the cornerstone layers of meat in the event of insufficient penetration of the components of the salt mixtures into the inner layers of the salted product.

At the same time, we abandoned the use of sodium nitrite in favour of nitrate, which is present in large quantities in a dissolved state in beetroot juice. This method of salting reduced the irreversible loss of nitrite due to the evaporation of nitric oxide (II) as a result of the slow diffusion of $NaNO_2$ into the deeper layers of the meat raw material, which is characterized by its acidic properties:

$$NaNO_2 + H+ \rightarrow HNO_2 + Na+$$
$$3\ HNO_2 \rightarrow HNO_3 + 2\ NO\uparrow + H_2O.$$

After the salting was completed, the mixture was kept for 3 days to ripen the meat component, cut into flakes 6-7 millimetres thick and dried in the open air without access to direct sunlight at a temperature of up to 40°C until the mass fraction of moisture decreased by no more than 20%. Next, pieces of the dried product were cut into flakes 6-7 millimetres thick, sprinkled with a mixture of spices and transferred to a consumer transport container.

Results and Discussion

A series of studies showed that the proposed salting method significantly reduced the amount of nitrite ion used in salting by three times, while bringing the colour of the finished raw dried product closer to the usual consumer colour throughout the thickness due to the natural colouring agent betanin present in beetroot juice. Based on a series of studies, it was determined that a sufficient level of myoglobin binding to nitroso-myoglobin is achieved when the total processing of meat raw materials is 0.005 kilograms of $NaNO_2$, for which it was sufficient to use 0.0052 kilograms of sodium nitrate (an amount equivalent to 0.045 kg of sodium nitrite after reduction of nitrate contained in 0.03 dm^3 of beetroot juice with an actual content of 1.45 g/dm^3 of $NaNO_3$. The process of nitrate reduction to nitrite was significantly accelerated by the addition of ascorbic acid to the salt mixture as a substance with reducing properties, as indirectly evidenced by the redox potential of the meat system, while the corresponding characteristic of the control sample systematically increased upon contact with air oxygen (Fig. 1).

The analysis of the transformations shown in Figure 1 allows concluding that the end product of nitrate and nitrite metabolism in the human body is nitrogen monoxide, and the constant intake of nitrate/nitrite with food can cause systemic irritation of the mucous membranes of the gastrointestinal tract due to the formation of free radicals and a mixture of nitrate and nitrite acids. The optimization of production technology has a twofold task, which includes finding ways to reduce the dosage of sodium nitrite in the selected raw dried meat products and to reduce the level of their bacterial contamination associated with the duration of the maturation process after salting.

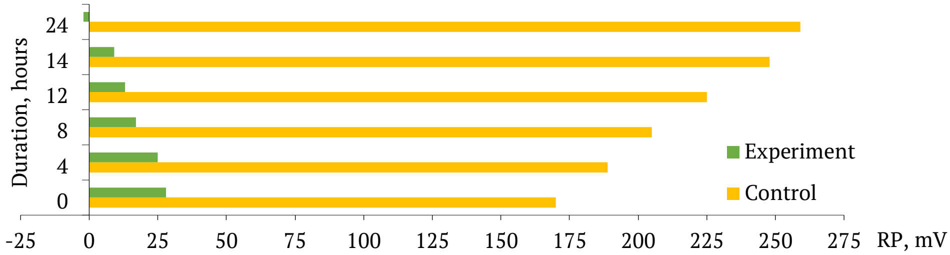

Figure 1. Dynamics of changes in the redox potential of raw dried meat flakes during the salting process

Source: developed by the authors

Salting by the proposed method also made it possible to virtually stop the process of microbiological contamination of the entire mass of the freshly salted product with toxicogenic and hazardous microorganisms, which is insufficient when salting by the classical method of adding sodium nitrite to the salting mixture, which, in addition to participating in the formation of the desired colour of the finished product, also inhibits the vital activity of microorganisms, both harmful and beneficial. However, due to the toxicity of nitrite and its insufficient antibacterial activity, the possibility of reducing the level of contamination of meat products with harmful and toxicogenic microorganisms of the genera *Pediococcus acidilactic*i and *Staphylococcus carnosus* as components of the bacterial preparation B-LC-78 was tested.

The introduction of *Staphylococcus carnosus* bacteria into food products since the 1950s has shown no signs of a dangerous effect on consumer health. Their use also helps to improve the flavour of meat products and provides a strong antagonistic effect against *Listeria monocytogenes*. The main reason for choosing the *Pediococcus acidilactici* strain, which is capable of synthesizing bacteriocins of the pediocin class, which are harmful to numerous microorganisms that are dangerous to health, including *Shigella spp., Salmonella spp., Clostridium difficile, Escherichia coli*, is that they quickly achieve pH values close to 5.0, at which the rate of reproduction of dangerous strains of microorganisms is minimal. The addition of a bacterial preparation has a positive effect on product safety, as the period of bacterial growth of the bacteria it contains is much shorter than that of the vast majority of undesirable microflora. The kinetics of the reproduction of lactic acid bacteria compared to the control, where this process occurs much more slowly, is shown in Figure 2.

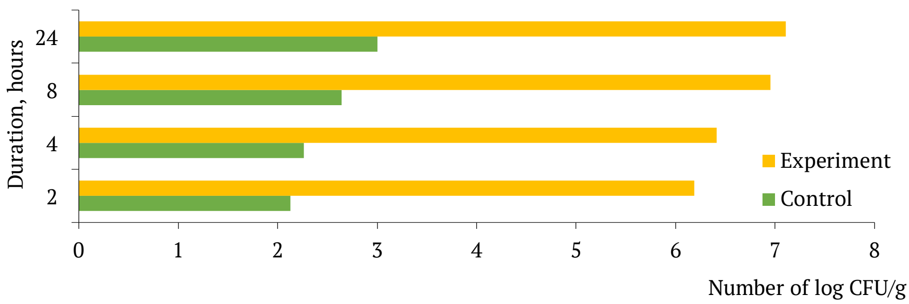

Figure 2. Dynamics of changes in the number of lactic acid bacteria during salting of raw beef

Source: developed by the authors

The dynamics of changes in the composition of hazardous microflora was studied within 72 hours in relation to bacteria of the Escherichia coli group (*E. coli*), mesophilic aerobic and facultative anaerobic microorganisms (MAFAM), salmonellae, bacteria of the Staphylococcus aureus strain, moulds, and yeasts. The determined indicators showed a practical stop to the growth of pathogenic microorganisms, and an increase in the number of bacteria of the E. coli group was detected only in relation to control samples (Table 1).

Table 1. *Dynamics of changes in microbiological indicators of control and experimental samples of meat flakes during 72 hours of salting*

	Duration of pickling, hours				
	2	12	24	48	72
Escherichia coli bacteria					
Control	$1.0 \cdot 10^1$	$1.0 \cdot 10^1$	$1.0 \cdot 10^1$	$1.0 \cdot 10^2$	$1.0 \cdot 10^3$
Experiment	$1.0 \cdot 10^1$	$1.0 \cdot 10^1$	$1.0 \cdot 10^1$	$1.0 \cdot 10^1$	$1.0 \cdot 10^1$
Mold/yeast					
Control	$1.0 \cdot 10^3$	$1.0 \cdot 10^3$	$1.2 \cdot 10^3$	$1.4 \cdot 10^3$	$1.5 \cdot 10^3$
Experiment	$1.0 \cdot 10^3$	$1.0 \cdot 10^3$	$1.1 \cdot 10^3$	$1.2 \cdot 10^3$	$1.2 \cdot 10^3$

Source: developed by the authors

After 3 days of maturation of the salted meat component, the pieces of meat were cut into flakes 6-7 millimetres thick and laid out for drying at a temperature not exceeding 40 ^{0}C without direct sunlight until a residual water content of about 20% was reached within 4 days. After completion of the production cycle, the flakes were sprinkled with a mixture of spices and left for storage for 180 days. The kinetics of water activity changes in the control and test samples of beef flakes are shown in Figure 3.

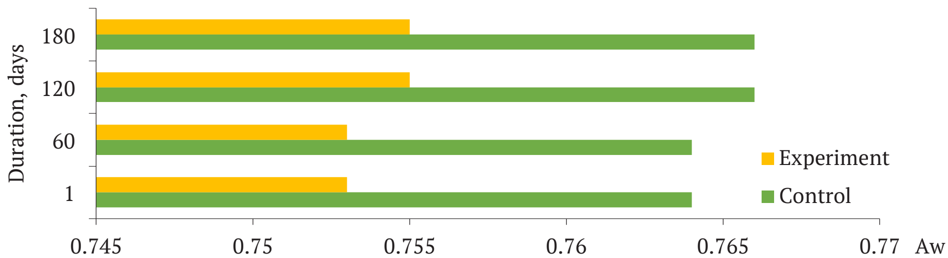

Figure 3. Dynamics of changes in water activity in samples of raw dried beef flakes during long-term storage

Source: developed by the authors

The data obtained indicate a higher level of safety of the control composition samples in terms of the probability of reproduction of hazardous microflora. The tendency of a faster decrease in the level of water activity in the product of the experimental composition compared to the control can be explained by the higher content of microorganisms introduced with the starter cultures, the proteolytic activity of which contributes to the swelling of elastin and collagen. Based on the results, it was found that the introduction of the bacterial preparation B-LC-78 into the mixture used to salt almost pure meat raw materials in terms of bacterial contamination leads to the practical absence of harmful microflora, respectively, and an increase in the level of bacterial safety of the product both immediately after the completion of the manufacturing process and during prolonged ageing of the product (Table 2). The raw dried beef flakes were free of Escherichia coli, pathogenic microorganisms, sulphite-producing clostridia, *L. Monocytogenes, Staph. Aureus*, which indicates that the test samples are safe and suitable for consumption.

Table 2. *Microbiological indicators of the safety of the experimental sample of raw dried beef flakes*

Indicator	The content of dangerous microorganisms	Method of determination
Escherichia coli (coliforms), in 1.0 g	Not found	ISO 4831:2006
Pathogenic microorganisms, including salmonella, in 25 g		ISO 6579-1:2017
Sulphite reducing agents clostridia, in 0.1 g	Not found	ISO 15213:2003
L. monocytogenes, in 25 g		ISO 11290-1:2017
Staph. aureus, in 1.0 g		GOST 10444.2-94

Source: research conducted by the authors

According to microbiological criteria, all sausage samples meet the requirements of the current regulatory documents. The finished product does not contain bacteria belonging to the *E. coli* group, the Salmonella genus or sulphite-producingclostridia. Relevant studies were carried out by L. Bal-Prylypko *et al*. (2022) on the example of mixtures of standard (control) and experimental composition (Table 3):

Table 3. *Composition of the standard salt mixture, kg/100 kg of meat*

The name of the component	Control	Experiment
Kitchen salt	3.5	–
Sea salt	–	3.1
Water	–	6.4
A mixture of spices	1.2	1.2
Sodium nitrite	0.015	0.005
Beet juice	–	0.03
Dextrose (glucose)	1.0	0.65
Sodium isoascorbate	0.07	–
Ascorbic acid	–	0.085
Bacterial preparation B-LC-78	–	0.018

Source: L. Bal-Prylypko *et al*. (2022)

Similar studies were conducted by J. Haque *et al*. (2023), who investigated fermented sausages using accelerated technology. The results of their research showed that the use of accelerated technology for the production of fermented sausages does not affect the microbiological safety of products and can significantly reduce the drying time of the product. The data obtained indicate that at a low level of bacterial contamination of meat raw materials, the same product safety is achieved as when using the traditional process.

M. Shynkaruk & O. Baluk (2021) addressed the problem of improving the quality of cured meat products using starter cultures. In the development of meat product technology, there is a tendency to use food additives made from plant materials in combination with starter cultures to improve the quality of finished products. To reproduce the colour of meat products, starter cultures should contain denitrifying bacteria. The biological basis for the formation of sausages as a food product is lactic acid bacteria, which contribute to the biotransformation of the main components of meat with the formation of compounds that determine the smell, taste, aroma, and consistency; changes in the physicochemical parameters of minced meat, which can lead to the growth of bacteria that cause meat spoilage. The use of sourdough starter cultures in the production of meat products not only reduces the time of the technological process, but also ensures the microbiological safety of the finished product.

M. Stoica *et al.* (2022) examined the impact of plant powders. extracts and plasma to replace all or part of conventional $NaNO_2$ in meat products. The authors also presented the functionality of $NaNO_2$ in meat products and the costs of its replacement. E. Vossen & S. De Smet (2015) showed the effect of $NaNO_2$ on protein oxidation. In addition, the potential use of 3-nitrotyrosine as a specific marker for reactive nitrogen species-mediated nitration was investigated. Overall, no clear antioxidant effect of $NaNO_2$ against carbonyl formation in the isolates was observed. 3-Nitrotyrosine was present in all samples, but no clear effect of $NaNO_2$ addition or oxidation time was observed. G. Ma *et al.* (2022) studied the effects of low doses of sodium nitrite on meat colour, myoglobin oxygenation status, myoglobin aggregation and myoglobin structure using infrared spectroscopy. The results showed that the redness index of meat increased continuously compared to the control after the addition of low dose sodium nitrite. The results indicate that low doses of sodium nitrite promoted the dynamic transformation of the nitrosylated myoglobin peptide fragment, which in turn preserved the colour of the meat.

Similar studies on microbiological safety indicators in finished products were conducted by B. Łaszkiewicz *et al.* (2021). Different groups of bacteria were tested, and it was found that a number of factors dramatically affect the bacteriostatic effect of sodium nitrite. The pH of the medium influenced the level of nitrite causing inhibition, thus tending to confirm the hypothesis that unbound nitric acid is the active form. During autoclaving, the anaerobic growth of *Staphylococcus aureus, Streptococcus salivarius,* and *Streptococcus mitis* was inhibited by significantly lower nitrite levels than if glucose had been added to the medium after autoclaving. X. Wang *et al*. (2022) studied the effect of different sodium nitrite concentrations on the quality and protein oxidation of salted meat during 21 days of beef curing. Their results showed that the carbonyl group, dithirosine, and surface hydrophobicity of salted meat were significantly reduced by the addition of sodium nitrite. At the same time, total nitrogen and aerobic plate content decreased significantly, while pH values increased significantly with increasing nitrite concentration compared to the control group. Importantly, this phenomenon was also observed in salted meat treated with low doses of sodium nitrite. Consequently, they also found that the quality of salted beef can be improved by adding low doses of sodium nitrite to inhibit protein oxidation during the curing process.

Conclusions

A method for the production of raw dried beef flakes by treating the surface with a mixture of sea salt, dextrose and sodium nitrite, and the inner layers of meat raw materials by syringing a salting liquid containing sea salt, ascorbic acid, dextrose, sodium nitrite, beetroot juice and bacterial preparation B-LC-78 was investigated. It has been shown that the use of a combined salting method, which involves the introduction of beetroot juice containing nitrite ion obtained by reducing the nitrate ion of the inherent juice with ascorbic acid, into the syringe salting solution, allowed for a threefold reduction in the dosage of nitrite ion and improved the colour characteristics of the product due to the presence of the natural colourant betanin in beetroot juice, which is similar in colour to the colour of cured meat products. The presence of a bacterial preparation containing bacteria of the *Pediococcus acidilactici* and *Staphylococcus carnosus* strains in the solution allowed almost completely stopping the development of pathogens and toxicogenic microorganisms in the mass, which suggests an increase in the level of bacterial safety of the product both after the manufacturing process and after prolonged exposure of the finished product. The dynamics of changes in the water activity in the product of the prototype sample is explained by the higher content of introduced microorganisms, the proteolytic activity of which contributes to the swelling of elastin and collagen, which indicates a higher level of safety of the control samples in terms of the probability of reproduction of hazardous microflora.

Prospects for future research include conducting comprehensive analyses of bacterial preparations in comparison with other bacterial preparations, their impact on pH reduction, microflora, and the formation of a distinct taste and structure of raw dried sausages due to the development of microflora. This technology can be implemented in the food industry in the manufacture of meat snack products and will significantly reduce the negative impact of sodium nitrite on human health, but these studies require further refinement.

Acknowledgements

None.

Conflict of Interest

None.

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Удосконалення технології виготовлення сиров'ялених продуктів з яловичини

Лариса Вацлавівна Баль-Прилипко

Доктор технічних наук
Національний університет біоресурсів і природокористування України
03041, вул. Героїв оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-9489-8610

Микола Станіславович Ніколаєнко

Кандидат технічних наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-2213-4985

Олександр Петрович Каніщев

Аспірант
Національний університет біоресурсів і природокористування України
03041, вул. Героїв оборони, 15, м. Київ, Україна
https://orcid.org/0009-0006-5034-3695

Людмила Анатоліївна Бейко

Кандидат технічних наук, доцент
Західноукраїнський національний університет
46009, вул. Львівська, 11, м. Тернопіль, Україна
https://orcid.org/0000-0001-6211-8010

Наталія Володимирівна Голембовська

Кандидат технічних наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв оборони, 15, м. Київ, Україна
https://orcid.org/0000-0001-8159-4020

Анотація. Актуальність роботи полягає у необхідності зменшення негативного впливу на стан здоров'я людини нітриту натрію (харчової добавки Е250), який додають у м'ясні продукти, зокрема в сиров'ялені ковбаси, з метою прискорення процесів їх визрівання та надання звичних споживачам відтінків. Мета роботи полягає в удосконаленні технології виготовлення сиров'ялених продуктів з яловичини, яка базується на використанні сучасних біотехнологічних підходів, морської солі та природного барвника бетаніну та бурякового соку, як замінника нітриту натрію. Реалізація поставленої мети відбувалась шляхом реалізації змішаного способу посолу, за яким поверхню м'ясного напівпродукту натирали зменшеною до 15 %, порівняно із стандартною технологією, кількістю використовуваних для солей, у тому числі 0,0005 кілограма нітриту натрію на кілограм м'ясної маси, а іншу частину посолочної суміші, яка містила 0,0045 нітриту натрію, шприцювали вглиб напівпродукту у вигляді водного розчину. Джерелом нітриту був багатий нітрат-іоном буряковий сік 0,03 дм^3 якого містили 0,0052 кілограми нітрату натрію достатнього для синтезу 0,0045 кілограму нітрит-іону на кілограм м'ясної сировини. Обраний спосіб соління дозволив зменшити порівняно з класичним методом кількість нітриту натрію з 0,015 до 0,005 кілограма на кілограм м’ясного продукту, а додавання бурякового соку дозволило надати продукту рівномірного забарвлення по всій товщині. Забруднення продукту небезпечною мікрофлорою попереджували додаванням у шприцювальний розчин препарату, який містив бактерії штамів *Pediococcus acidilactici* та *Staphylococcus carnosus*. Встановлено позитивний ефект від застосування *Pediococcus acidilactici*, який досягався прискореним доведенням pH м’ясної маси до 5,0 ÷ 5,5, за якого припинялось розмноження більшості небезпечних мікроорганізмів, зокрема *Shigella spp*., *Salmonella spp*., *Clostridium difficile* та *Escherichia coli*. Захист продукту від розвитку бактерій *Listeria monocytogenes* відбувався за допомогою бактерій штаму *Staphylococcus carnosus*. Запропонована технологія може бути використана в харчовій промисловості під час виготовлення сиров’ялених м’ясних продуктів, що сутєво знизить негативний вплив нітриту натрію на здоров’я людини

Ключові слова: м’ясні продукти; сиров’ялені продукти; яловичина; соління; бактеріальний препарат; нітрит натрію; якість та безпека готових виробів