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Efficiency of using spicy and aromatic plant ingredients in the technology of semi-smoked sausages

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Abstract. The relevance of the study lies in the need to improve the technology of semi-smoked sausages using spicy and aromatic plant ingredients, which would allow producing sausages with an extended shelf life and will help to expand the range. In order to avoid premature spoilage of sausage products or increase their consumption time, it is advisable to use a variety of food additives and antioxidants during production, with a positive effect on lipid hydrolysis and inhibition of oxidative changes in lipids. The purpose of the study was to investigate the chemical composition and freshness changes of semi-smoked sausages made using spicy and aromatic plants – thyme and caraway seeds – during storage. The following research methods were used in the study: organoleptic evaluation was carried out by appearance, cut appearance, consistency, aroma and taste; physicochemical – moisture content – by drying samples in a drying cabinet to a constant mass at a temperature of $103 \pm 2^\circ\text{C}$; fat content – by Soxhlet extraction; protein content – by Kjeldahl method; determination of table salt content – by titration of a chlorine ion in a water extract from the product with silver nitrate. When determining organoleptic parameters, it was found that the samples have rather high organoleptic properties characteristic of semi-smoked sausage according to the manufacturing technology using thyme and caraway seeds. The chemical composition study found that the moisture content of the semi-smoked sausages was 54.1-59.3%, and the protein content was 19.6-20.4%, which meets the requirements of the standard for high-grade semi-smoked sausages. In the course of research, the influence of spices on the course of product spoilage and the preservation of quality indicators in the developed sausage samples was investigated. During storage, the amount of peroxides in the sausage samples was constantly increasing, which indicates the course of oxidative processes that lead to the generation of peroxides. The practical significance of the study was to improve the organoleptic properties and expand the range of semi-smoked sausages through the use of spices

Keywords: ingredients; oxidative changes; essential oils; spices; sausages; juniper; organoleptic parameters

Introduction

The meat industry meets the population's need for biologically healthy food, especially sausages, which are of great importance for human nutrition and the production of which is the most common area of meat processing for food. In a market economy, it is particularly important to improve the traditional technology of semi-smoked sausages to obtain competitive food products.

For centuries, aromatic herbs and spices have been added to various products to improve their taste and organoleptic properties. Plant spice and aromatic raw materials contain a significant amount of antioxidants, vitamins, essential oils that can inhibit the growth and development of unwanted microflora,

including pathogenic ones. Meat systems are quite unstable and are subject to rapid microbiological influence. Issues related to spoilage of meat products during storage are relevant and require new scientific research and technological solutions. Every year in the world, up to 30% of food products are lost as a result of spoilage of manufactured products: due to microbiological spoilage and oxidative processes (Zhuk & Shevchenko, 2020).

Improvement of technical processes, management methods and storage conditions of products allows achieving stable quality of sausage products during storage. Free high-molecular saturated and unsaturated fatty acids and other hydrolysis products obtained by lipid

hydrolysis during storage of sausage products have no taste or smell, so they do not significantly affect the sensory evaluation of meat products. However, the accumulation of free fatty acids in foods causes spoilage due to oxidation.

The fat content of semi-smoked sausages is quite significant, due to the large amount of fat used in the recipe, and side lard is usually used. In this regard, oxidation processes and changes in organoleptic characteristics occur in semi-smoked sausages during production and storage. R. Domínguez *et al.* (2019) noted that the oxidation processes of lipids, proteins, pigments, and vitamins are frequent and inter-related, which negatively affects the quality of meat, including changes in colour and texture, the development of rancidity, loss of nutrients, and the appearance of toxic compounds.

Oxidative changes in sausage products primarily occur in the fat fraction. This is conditioned by increased contact with muscle tissue and the emulsification effect. L. Bal-Prylypko *et al.* (2021) noted that salting ingredients and myoglobin derivatives (iron-containing haem pigments found in meat) can contribute to oxidation, which can be active even at 0°C. In addition, the introduction of various additives into the minced meat system and increasing the temperature of the meat system also acts as a catalyst for lipid oxidation. Antioxidants are used to protect sausage products from oxidative damage, which are a component of spices and aromatic plants. The action of antioxidants is aimed at blocking active radicals in oxidative chain reactions.

P. Munekata *et al.* (2020) claim that different types of antioxidants, both synthetic and natural, can affect the chemical processes during fat oxidation. However, the global consumer community has a negative attitude towards synthetic antioxidants because of their potential harmfulness, which can lead to food poisoning and allergic reactions caused by chemical properties. The main focus is on natural antioxidants and how to get them. Theoretical

and practical aspects of the use of spice and aromatic plants are considered in numerous papers by Ukrainian and foreign researchers.

N. Kondratiuk *et al.* (2022) investigated that the use of plant extracts from rosemary, thyme, and ginger helps maintain oxidative stability, stabilise colour parameters, and improve the technological and sensory characteristics of pickled semi-finished products. S. Hrelia & C. Angeloni (2020) confirmed that natural antioxidants undergo an intense metabolism that alters their redox potentials. In turn, K. Tzima *et al.* (2020) proved that polyphenols from black pepper, oregano, and sage can slow down the oxidative reaction, affect colour change, and alter the sensory properties of meat products.

V. Pasichnyi *et al.* (2022) found that chokeberry extracts have antioxidant activity that was comparable to blackcurrant extract in the production of semi-smoked sausages. The study showed that the addition of chokeberry extract in an amount of 0.2 to 0.5% by weight of minced meat significantly slows down the hydrolytic lipid oxidation of finished products, effectively reducing fat peroxidation. I. Simonova *et al.* (2023) investigated that extracts of chokeberry and blackcurrant berries can be a natural source of antioxidant substances, since the leaves and berries of these plants are rich in polyphenols, namely phenolic acids and flavonoids, which have strong antioxidant properties. N. Bozhko *et al.* (2020) confirmed that the addition of rosemary and cranberry extracts suppresses lipid oxidation during storage of meat products with a combined raw composition. The common disadvantages of the described extracts include a high price, different effectiveness on the course of oxidative processes at different stages of development, and insufficient antibacterial effect.

However, in the current situation, this issue requires further investigation. O. Shtonda & V. Israeli (2021) noted that many spices and aromatic plants, their extracts and essential oils, and sodium nitrite, which is included in

the composition of sausages, can act as antioxidants and slow down fat oxidation. As of 2024, the properties of various types of essential oils and their individual fractions have been studied. There are approximately 32 known types of spices that contain substances that slow down oxidation. G. Simakhina & N. Naumenko (2021; 2022) determined that the most effective are rosemary, sage, cloves, which increase resistance to fat oxidation by 15-17 times, and spices such as cardamom, anise, coriander, dill, ginger, marjoram, fennel increase resistance by 2-3 times.

Therefore, the main purpose of the study was to determine the quality indicators of sausage products and the effect of spice and aromatic plants on the lipid oxidation resistance of semi-smoked sausages during storage.

Literature Review

Currently, there are more than 200 names of spices that are used as natural flavorings and flavorings, of which just over 40 are the most popular. N. Holembovska *et al.* (2021) noted that depending on which parts of the plant are used as food additives or flavorings, spices and herbs are most often divided into seeds, fruits, flowers, leaves, roots, herbs, and bulbs. Natural spices are mostly used in dried form. Spicy plants are used both dried and fresh. Despite certain disadvantages, the use of natural spices remains quite important.

The analysis of studies shows that there is a tendency to use natural raw materials in various branches of the food industry. V. Velychko (2023) investigated the use of extracts of elderberry, blackthorn, and mountain ash in the food industry to identify their inhibitory effect on the development of free radicals. Plants have been found to contain high levels of natural antioxidants – anthocyanins and polyphenols. Multicomponent mixtures of spices are an integral part of recipes for sausage products. This ensures the production of products of stable quality and expands the range of sausage products.

I.J. Karoui *et al.* (2023) found that the use of plant raw materials (tomato pomace) is rich in valuable phytochemicals, in particular lycopene, which is an antioxidant that improves the appearance and sanitary and hygienic indicators of meat products (chicken patties). They contain substances that slow down and stop the processes of microbiological and oxidative spoilage of products, due to their harmful effects on pathogenic microflora, and slow down the growth of peroxide and acid numbers. When choosing a spice and aromatic component, special attention should be paid to the cut appearance of sausage, since some spice and aromatic plants are rich in tannins (polyatomic phenols), which have a strong antioxidant effect. Excessive use of such spices leads to product defects, i.e., black spots observed on the product cut.

In addition to spice extracts, their essential oils are widely used. F. Demarco *et al.* (2022) confirmed that rosemary and sage essential oils inhibit oxidative spoilage of food more intensively than synthetic antioxidants. S. Shityakov *et al.* (2019) found that black pepper does not affect the course of microbiological processes in spice-oil mixtures. Black pepper fruits contain essential oil up to 2.5%, the main part of it is pinene, limonene, and phellandrene, also contains choline and acetylcholine, 5-9% piperine. The active substances contained in black pepper stimulate the activity of the thyroid gland and increase oxygen consumption by tissues. Oxidative spoilage of lipids is another major cause of food quality degradation. This can lead to a loss of nutritional value and negatively affect a person's health.

R.A. Marc *et al.* (2022) studied plant spice and aromatic extracts from the stems, flowers, and leaves of rosemary, lavender, thyme and investigated their antioxidant activity. Analysing the findings, it can be concluded that plant extracts have the best antioxidant effect compared to raw materials (rosemary stems and leaves). To investigate the qualitative characteristics of the developed products, parts of

spicy plants are usually used in concentrations of 0.02%, 0.05%, 0.1%, and 0.2 %.

The antioxidant properties of juniper fruits were studied by American researchers Y.Y. Khatamovich *et al.* (2023). Juniper is an evergreen coniferous shrub of the cypress family, or a tree with a branched trunk. Juniper is distributed throughout the European Union, especially in mountainous areas, the United States, and Northern Asia. New juniper fruits contain a variety of vitamins, macro- and microelements. Special attention should be paid to vitamins: C (256 mg), PP (0.3 mg), vitamin E (TE) (0.3 mg), vitamin B₆ (pyridoxine) (0.1 mg), β-carotene (0.04 mg), vitamin B₂ (riboflavin) (0.02 mg), vitamin B₁ (thiamine) (0.01 mg), vitamin A (PE) (7 mcg), vitamin B₉ (folic acid) (5 mcg). It is noteworthy that juniper pods have a higher content of vitamin C than similar fruits of related species.

I. Basarab *et al.* (2021) investigated the effect of mixtures of thyme and juniper spices, their essential oils and alcohol extracts on the course of microbiological processes in pork breast. According to microbiological studies, the standard content of mesophilic-aerobic and facultative-anaerobic microorganisms was exceeded (more than 1.0×10^5 g/CCU) in breast samples with dry black pepper, and in samples with thyme and juniper in the ratios of 0.9:0.7:0.2 and 0.9:0.6:0.3. Excess of the QMA-FAnM index was also recorded in experiments using essential oils of these spices. The most intense antibacterial properties in relation to the development of microorganisms were observed in the sample using dry crushed spices of thyme and juniper in the ratio of 0.9:0.8:0.1. The use of spice and aromatic thyme and juniper plants allows increasing the shelf life of finished products.

Juniper berries have a light forest aroma and a slightly spicy, bitter-sweet taste. For this reason, they are often used as spices in the cuisines of different countries of the world. Juniper is widely distributed in the alpine region. It is

believed that the best varieties of juniper fruits can be found on the Hungarian market. Juniper berries are often sold in dried form. They are usually added to sauces and meat dishes. Due to its rich taste and aroma, juniper berries are best used in small quantities. Juniper fruits are known to be an excellent seasoning for most types of game, especially venison (combined with marjoram and black pepper), wild pigeon and wild boar meat. This spice adds a pleasant spicy taste to the famous English bull tail soup and various stews of fat beef, and can even turn ordinary lamb into wild roe deer meat. Thus, the use of spice and aromatic plants has become widespread in the technology of sausage products and various meat dishes. When used as a spice, they can give foods a taste with spicy notes. Essential oils contained in plants ensure that the proper quality of the product is preserved during storage.

Materials and Methods

The “Drohobytska” semi-smoked sausage of the highest grade was produced according to DSTU 4435:2005 (2007). The main raw material used was 100% lean pork. Variable formulations were determined to investigate the effectiveness of using parts of spice and aromatic plants in the technology of semi-smoked sausages (Table 1) The product was manufactured using the following technology: 5% of the raw materials were frozen, without being kept in salt, and ground on a laboratory cutter. Salt and sodium nitrite were added to the cutter bowl in the form of a 2.5% solution (the content of auxiliary raw materials varied in quantity according to Table 1). The remaining 95% of the meat was added in the form of pieces no larger than 2 cm and continued to be cut at low speeds for 20-30 seconds. Minced sausages were stuffed into artificial protein shells. Sausage loaves were deposited at a temperature of 2-4°C in a household refrigerator for 24 hours. The heat treatment was carried out by smoking and drying, the boiling operation was excluded: after

sedimentation, the control and 4 experimental sausage samples were fried in a drying oven at $t = 80\text{--}95^\circ\text{C}$ for 35–45 min; smoking was carried out in a smoking chamber at an initial temperature of 40°C , then every 30 min the temperature was increased by 10°C until the temperature in

the centre of the product reached $71 \pm 1^\circ\text{C}$. After smoking, the sausages were cooled to a temperature in the product thickness of no more than $4\text{--}6^\circ\text{C}$. Semi-smoked products were stored at a temperature of $2\text{--}4^\circ\text{C}$ and relative humidity of $\omega = 76 \pm 2\%$ for 20 days.

Table 1. Recipe for a spice and aromatic mixture for making semi-smoked sausages, kg per 100 kg of basic raw materials

Spices and materials	Control	Experimental samples			
		No. 1	No. 2	No. 3	No. 4
Table salt	2.5	2.5	2.5	2.5	2.5
Sodium nitrite	0.005	0.005	0.005	0.005	0.005
Granulated sugar	0.09	0.09	0.09	0.09	0.09
Ground black pepper	0.06	–	–	–	0.12
Ground allspice	0.05	–	–	–	–
Fresh garlic	0.1	–	–	–	–
Ground caraway seeds	0.05	0.1	–	–	–
Caraway essential oil	–	–	0.0075	–	–
Juniper berries	–	–	–	0.1	–

Source: recipe of the spice and aromatic composition according to DSTU 4435:2005 (2007), samples developed by the authors

To fulfil the tasks set, studies were carried out according to the relevant standard methods: the following were examined by sensory evaluation: appearance, cut appearance, aroma, taste, colour according to DSTU 4435:2005 (2007) “Smoked sausages”. Evaluation of indicators was carried out in the following order: appearance, colour on cut, consistency, aroma, and taste. Before tasting, the twine was removed from the sausage, the ends of the shell were cut off and dried with a towel. The colour, texture, and distribution of ingredients were evaluated after cutting the sausage loaves by diameter. The shell was removed from half of it, determining the appearance and taste, noting the condition of the crust, minced meat outside, and in the middle of the loaf. Samples of sausage products were cut into thin slices, ensuring hygiene rules. The length of the slice was 8 cm and corresponded to the full sample of the sample, that is, its commercial type and grade. Sausage products were cut at an acute angle to obtain wider slices. The position of the

sausage loaf (or its vertical half) varied depending on the cutting angle, which was from 45 to 60° . The thickness of the slices was 2–3 mm.

Special knives with 250 mm long blades were used for cutting prototypes of sausage products. Moisture content – by drying the suspension to a constant mass and calculating the weight fraction of dry substances according to DSTU ISO 1442:2005 (2005). The protein content was determined by the Kjeldahl method according to ISO 1871:2009 (2009). This method is an arbitration, the essence of which is that proteins and other organic food components are broken down in concentrated sulphuric acid in the presence of a catalyst; the ammonia formed during the mineralisation of the components is distilled and absorbed by the acid; the next step included the titration of the excess acid with alkalis. The proportion of fat in the samples was determined by DSTU 8380:2015 (2017). The essence of the method was to wash out fats using a solvent from a paper sleeve, into which the dried suspension of the product was previously

added. Petroleum ether was used as a solvent. After extraction, the difference in the mass of the sleeve before and after extraction was determined. The results of the conducted studies were processed by statistical analysis methods.

Results

Product quality is determined by their characteristics, i.e., quality indicators, including sensory evaluation. Sensory analysis methods provide a fast, objective, and reliable overall impression of product quality. Organoleptic

analysis allows quickly and purposefully influencing all stages of food production. The results of sensory evaluation in most cases were final and decisive in determining the quality of raw materials and products. Organoleptic evaluation of product quality indicators can be differentiated (according to individual quality indicators) or complex, considering the values of all indicators of the product under study. The results of the tasting evaluation showed that the tested samples had fairly high sensory indicators, as shown in Table 2.

Table 2. Organoleptic evaluation of sausage products, in points

Sample name	Appearance	Cut appearance	Smell	Taste	Consistency	Overall score, points
Control	4.5±0.2	4.5±0.2	5.0±0.2	5.0±0.1	5.0±0.2	4.83±0.2
No. 1	4.5±0.2	4.5±0.2	5.0±0.1	4.5±0.1	5.0±0.1	4.68±0.2
No. 2	4.5±0.2	4.5±0.2	5.0±0.1	4.8±0.2	5.0±0.1	4.75±0.2
No. 3	4.5±0.2	4.5±0.2	5.0±0.2	5.0±0.2	5.0±0.2	4.78±0.2
No. 4	4.5±0.2	4.5±0.2	5.0±0.2	4.8±0.2	5.0±0.2	4.77±0.2

Source: developed by the authors

When evaluating the appearance of all samples of sausage products, the surface of the loaves was clean, dry, without stains, lumps, damage to the shell and minced meat. Evaluating the cut appearance of semi-smoked sausages, it was found that the minced meat is evenly mixed, pink in colour, and pieces of pork are visible. The taste of the products was pleasant, moderately salty, in sample No. 4 slightly sharp, with the smell of garlic in the control sample; samples No. 1 and No. 2 had strongly pronounced aroma of caraway seeds; sample No. 3 was characterised by a pronounced aroma of spices and smoke. All samples had no extraneous aroma and taste. The consistency in all the samples produced was quite elastic.

The appearance of the product was most influenced by the following factors: the correct order of introduction of minced meat components and the execution of the technological process in compliance with all parameters – temperature, humidity, duration of processing,

air speed. At the same time, salt-soluble proteins swell, colour stabilises, and taste is developed. The surface of the sausage loaves was visually clean and dry, without damaged shells and minced meat.

Such an indicator as the consistency of sausage characterises not only the ease of cutting the product, but also the fact that the minced meat does not stick to the knife blade, and the degree to which the product is finished. The results of the study showed that the consistency of all the sausage samples under study was elastic and dense. When examining the sausages on the cut – the appearance of minced meat was light pink, uniformly mixed with the inclusion of small pieces of pork. Taste and aroma determined the attractiveness of the product to consumers. The aroma and taste of the products was pleasant, characteristic of sausages of this type, with a pronounced aroma of spices and smoke. The taste was moderately salty and spicy, inherent in semi-smoked sausage products.

According to the data presented in Table 2, it can be seen that “Drohobytka” sausage (control) received the highest score in terms of organoleptic evaluation indicators with a total score of 4.83, and sample No. 3 with juniper berries. The lowest rating was given to sample No. 1, which

contains only caraway seeds spice. To identify differences in the quality of the developed products, the sensory evaluation was supplemented with the creation of a profilogram, which allows visually presenting the overall comparative sensory evaluation of samples (Fig. 1).

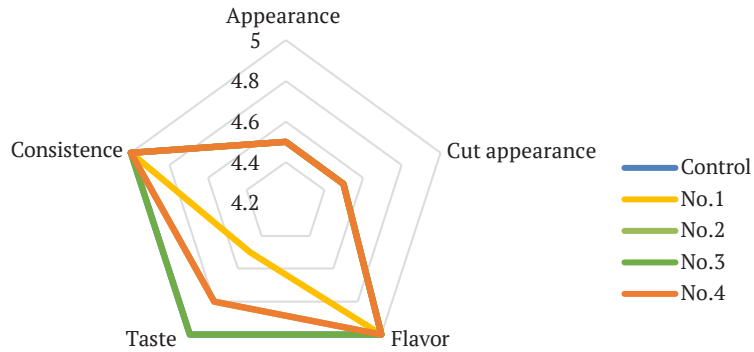


Figure 1. Organoleptic parameters of experimental sausages

Source: developed by the authors

The obtained data summarise that in terms of sensory indicators, sausage products containing various spice and aromatic plants are as close as possible to sausages that are made according to standard recipes. One of the most important stages of product development is the study of its chemical composition. The results

of studies showed that the moisture content in the samples of semi-smoked sausages ranged from 54.1 to 59.3%, which did not exceed the standards (Table 3). According to this indicator, they meet the requirements of the state standard for the “Drohobytka” semi-smoked sausages.

Table 3. Chemical composition of semi-smoked sausages

Indicator	Standard (according to DSTU 4435:2005, 2007), %	Control	Experimental samples			
			No. 1	No. 2	No. 3	No. 4
Content: moisture	not more than 60	54.9±0.23	54.1±0.12	54.2±0.15	56.5±0.22	59.3±0.18
protein	not less than 13	20.1±0.21	19.7±0.17	20.4±0.16	19.6±0.17	20.0±0.20
fat	not more than 45	22.8±0.28	22.1±0.13	23.8±0.28	24.1±0.15	22.8±0.21
table salt	not more than 4.5	4.3±0.05	4.2±0.06	4.1±0.05	4.2±0.06	4.3±0.05

Source: developed by the authors

When making sausages, with the exception of spice and aromatic components, no changes were made in the recipe, so the differences between the control and experimental samples fluctuated within the margin of error. In sausage products, the protein content corresponded to the standard values and ranged from 19.6 to

20.4%, fat – from 22.8 to 24.1% and salt – from 4.1 to 4.3%. When making sausage products, one of the most important factors that must be considered is the possibility of maintaining the quality characteristics of the product throughout the entire shelf life. It is well known that the rate of fat oxidation depends on their

interaction with air oxygen. The resistance of fats to oxidation is mainly determined by their fatty acid composition. In sausage products, this is directly related to technological changes in meat raw materials.

The shelf life of semi-smoked sausages is determined by indicators that do not change during storage – these are sensory and physico-chemical indicators. Microbiological indicators change and characterise the oxidative transformation of products. Therefore, the further study was to determine the changes in the criteria of fat oxidation and microbiological parameters in the developed semi-smoked sausages during storage. Ready-made sausages were stored at a temperature of 0...6°C and relative humidity of 75 ± 3% for 15 days. Determination of the acid and peroxide numbers of experimental sausage products was carried out after production and during storage, using “Semi-smoked sausage” sausage as control. Hydrolytic and oxidative changes in lipids that occur during long-term storage are usually not caused by microorganisms. However, lipolytic bacteria, mould fungi, and other microorganisms contain enzyme systems that cause hydrolysis and oxidative conversion of lipids. These microbial lipases actively catalyse lipid hydrolysis. Unsaturated

fatty acids and short-chain saturated fatty acids are the most sensitive to oxidative conversion. High-molecular fatty acids are more resistant to such changes.

During storage of the product in fats, hydrolysis took place, the depth of which is determined by the content of free fatty acids and is characterised by the value of the acid number. Hydrolysed fats are well absorbed by the human body, but fatty acids formed in large quantities during deep hydrolysis contribute to the development of oxidation processes. As a result of the conducted studies, a link was revealed between the meat raw materials used and the influence of spice and aromatic components on the process of spoilage of the product, and the preservation of the quality indicators of the sausages under study. Long-term storage of semi-smoked sausages can lead to fat hydrolysis processes, which leads to the accumulation of free fatty acids.

It is known that increasing the temperature increases the strength of hydrolytic enzymes, which leads to the accumulation of free fatty acids in fat. The investigation of changes in the acid number was carried out immediately after sausage production and during storage at a temperature of 0 to 6°C on the 5th, 10th, and 15th days (Table 4).

Table 4. Investigation of the dynamics of the acid number in naturally smoked sausages during the shelf life, mg KOH, $M \pm m$

Sample	Storage period, days			
	0	5	10	15
Control	1.9±0.03	3.0±0.01	4.3±0.02	4.7±0.01
No. 1	1.9±0.01	2.9±0.02	4.2±0.01	4.7±0.01
No. 2	1.9±0.04	3.2±0.01	4.5±0.02	4.6±0.01
No. 3	2.0± 0.02	2.7±0.02	3.9±0.01	4.5±0.01
No. 4	1.9±0.01	3.2±0.01	4.7±0.03	5.5±0.01

Source: developed by the authors

The results of a study of the dynamics of the acid number showed that in the first half of the shelf life, the amount of free fatty acids increases sharply. By the end of the storage period, their accumulation continued and dou-

bled. However, the course varied in intensity depending on the product recipe. Thus, the least significant increase in the acid number was observed in sample No. 3 with the addition of juniper berries. At the end of the shelf life,

this figure was 4.5 mg KOH. When using caraway seeds and caraway essential oil in semi-smoked sausages, it was found that the acid

number was lower than in the control sample, but higher than in sausages with juniper and black pepper (Fig. 2).

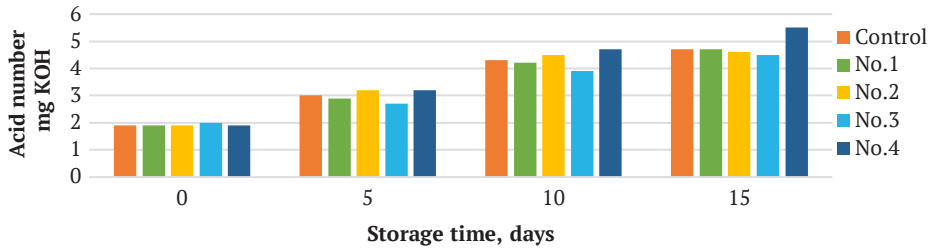


Figure 2. Dynamics of changes in the acid number in semi-smoked sausages during storage
Source: developed by the authors

During storage, the peroxide number of semi-smoked sausages is steadily increasing. This indicates that there is an oxidation process that leads to the generation of peroxide. However, under the same storage conditions,

the strength of increasing the peroxide number is different. At a storage temperature of 0...6 °C after 5 days in the control sample, the peroxide number was 0.04% J₂, for 10 days – 0.08% J₂, and at the end of 15 days – 0.1% J₂ (Table 5, Fig. 3).

Table 5. Dynamics of changes in the peroxide number in semi-smoked sausages during storage, % J₂ M ± m

Samples	Shelf life, days			
	0	5	10	15
Control	0.01 ± 0.03	0.04 ± 0.03	0.08 ± 0.01	0.1 ± 0.02
No. 1	0.01 ± 0.02	0.03 ± 0.2	0.06 ± 0.01	0.09 ± 0.01
No. 2	0.01 ± 0.01	0.02 ± 0.0	0.05 ± 0.04	0.09 ± 0.02
No. 3	0.01 ± 0.01	0.02 ± 0.02	0.04 ± 0.05	0.08 ± 0.01
No. 4	0.01 ± 0.04	0.05 ± 0.01	0.08 ± 0.2	0.12 ± 0.02

Source: developed by the authors

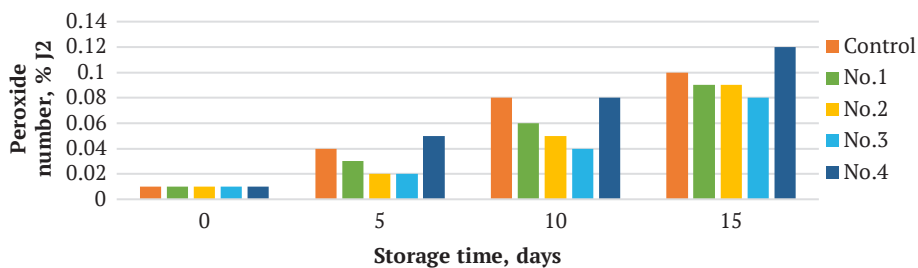


Figure 3. Results of changes in the peroxide number in semi-smoked sausages during storage
Source: developed by the authors

The indicator of the peroxide number of fat is less in the samples for the use of juniper berries – after 5 days of storage, it was 0.02 % J_2 , after 10 – 0.04% J_2 , and after 15 – 0.08% J_2 . In semi-smoked sausages with the use of caraway seeds and essential oil, this indicator was higher than in sausages with juniper berries, but lower compared to the control sample (Fig. 3).

An increase in the peroxide number of sausage products leads to the appearance of an unpleasant smell and taste. Signs of spoilage occur when the level of peroxide in the product reaches 0.2% J_2 . Although the regulation does not set a maximum permissible peroxide number for fat in sausage products, it is important for assessing the safety of this type of product.

Discussion

The use of plant extracts to preserve meat opens up broad prospects for extending its shelf life. Research conducted by G. Manassis *et al.* (2020) indicates the potential of biologically active compounds found in plant raw materials to reduce the oxidative processes that occur in meat during storage. This is especially important because fat oxidation can lead to discolouration of the meat, loss of taste, and an increased risk of spoilage. When choosing a suitable supplement for a meat product, it is necessary to consider the amount of active ingredients in the extract, the composition of the product itself, the fat content, and the ratio of saturated and unsaturated fatty acids. This helps ensure the optimal effectiveness of the antioxidant preparation. The results of studies on the acid number obtained by L. Tamkutė *et al.* (2021), confirm that triglyceride breakdown products accumulate gradually during meat storage, reaching their maximum value by the end of the shelf life. This indicates the need to use effective antioxidants to prevent the rapid breakdown of lipids and ensure the longest possible shelf life of meat without loss of quality. According to V. Pasichnyi *et al.* (2022), the addition of aronia and black currant extracts to

minced semi-smoked sausages reduces microbiological contamination and has a bacteriostatic effect. The addition of aronia extract in the amount of 0.2-0.5% by weight of meat significantly slows down the hydrolytic oxidation of lipids in heat-treated products, effectively suppresses fat peroxidation. The use of black currant extract also has an antioxidant effect, but is weaker. Stabilisation of lipid peroxidation in semi-smoked sausages gives the effect of inhibiting the development of secondary oxidation products, which is confirmed by the results of studies. Due to the inhibition of hydrolysis of triacylglycerols, the concentration of free fatty acids was reduced. This was conditioned by the high oxidative capacity of flavonoids in the berry extract, which was confirmed by studies.

The study by N. Bozhko *et al.* (2019) proved that the addition of rosemary and cranberry extracts inhibits lipid oxidation during storage of meat-containing bread with a combined raw composition. The common disadvantages of the extracts used include a high price, different efficiency in passing through different stages of the oxidation process, insufficient antimicrobial action, etc. Analysis of the kinetics of the acid number of experimental samples showed that the addition of spice and aromatic plants inhibits peroxidation. Oxidation was observed after the first 5 days of storage. This is because the components of berries prevent the binding of active oxygen to fatty acid radicals and free radical oxidation is suppressed. This happens in the case of using juniper berries in a prototype.

Compounds that demonstrate the antioxidant activity of juniper berries are responsible for slowing down oxidative processes in experimental sample No. 3. And the potential of using this spice and aromatic raw material and products made from it (essential oil) in the production of semi-smoked sausages to improve their quality, which is consistent with the findings of B. Šojić *et al.* (2017). The use of natural antioxidants to reduce the consumption of synthetic supplements and produce cleaner meat prod-

ucts can be considered as one of the promising alternatives. M. Glisic *et al.* (2023) summarised data on the obtained natural antioxidants from agro-industrial by-products and their inclusion in various meat product formulations. This allows slowing down the oxidation of lipids and proteins, which is one of the main reasons for the deterioration of the quality of meat and meat products during technological processing and storage. The use of natural antioxidants has several benefits. Firstly, they are more natural and safe to consume, as they are obtained from natural sources such as fruits, vegetables, or vegetable oils. This is especially important for consumers who avoid synthetic additives in their food. Secondly, the use of natural antioxidants helps to reduce environmental impacts and promotes the use of agro-industrial by-products, such as waste from fruit and vegetable processing. This can help reduce waste in the food industry and support sustainable development. The findings of this study indicate the effectiveness of using natural antioxidants in various types of meat products, such as sausages, ham, etc. Their addition helps maintain the quality and duration of storage of meat products, and increases their resistance to oxidation, which can be especially important in the case of long-term storage or transportation.

H. Alkhattat *et al.* (2022) found the antioxidant and antimicrobial effects of thyme against various microorganisms. These studies were conducted to investigate the effect of thyme water-alcohol extract on the quality of ground beef. The results of antimicrobial analysis of water and alcohol extracts of thyme in various concentrations showed that the water extract had a significant inhibitory effect on the growth of a wide range of bacteria compared to the alcohol extract. Thus, water-based thyme extracts can be effective and promising as preservatives for meat and its products, especially in high concentrations, to inhibit bacterial growth. The study by R. Tshabalala *et al.* (2021) focused on three aspects: isolation and molecular

identification of bacteria from meat; determination of the antimicrobial activity of spices against pathogens; evaluation of the organoleptic properties of meat with spices. Spice extracts were tested by disk diffusion to determine their inhibitory ability. The results show that clove and black cumin extracts have shown excellent antibacterial effects against most pathogenic bacteria. Cloves showed the highest inhibition zone of 18 mm against *E. coli*. Clove extract was the largest inhibitor, followed by black cumin, while thyme and cinnamon extracts showed weak antibacterial effects against the strains studied.

Due to the rather spicy taste and aroma, these spices are used in small quantities in minced meat systems and sausage products. As of 2024, quite a few studies have been conducted on the effects of the antioxidant and antimicrobial effects of berries and juniper berry extract. Currently, the antioxidant potential of extracts, essential oils, and oleoresins in meat products has been studied and confirmed. Using natural sources as antioxidants is an alternative to synthetic antioxidants. Their antioxidant capacity is associated with a high content of phenols. Thus, the inclusion of active components of spice and aromatic plants in the composition of sausage recipes will slow down oxidative processes and extend the shelf life of products.

Conclusions

One of the most promising areas of search for new antioxidants is the study of various biologically active substances in natural raw materials. Thus, the range of plants rich in antioxidants is rapidly expanding, both to protect food products from non-enzymatic oxidation, and to provide them with the development and production of functional food products containing antioxidant components.

Based on comprehensive studies, a comparative evaluation of the quality of sausages made using a variety of spicy and aromatic ingredients according to the traditional recipe of the “Drohobytska” high-grade sausage was

carried out. The sensory performance of sausage products using various spice and aromatic components is high and as close as possible to products made using standard technology. The protein content in sausage products corresponded to the standard values, ranging from 19.6 to 20.4%, fat – from 22.8 to 23.8%, and salt – from 4.1 to 4.3 %. It was found that the use of juniper berries in the technology of semi-smoked sausages reduces the accumulation of products of peroxidation of free fatty acids. When studying changes in acid and peroxide numbers during storage at temperatures from 0 to 6°C, an increase in indicators was observed in all samples on day 5, but in the control sample and in sample No. 3 made with juniper berries, this indicator was slightly lower.

Prospects for further research consist in a comprehensive analysis of juniper berries in comparison with other spices, their impact on changes in physicochemical and microbiological parameters. Preventing lipid oxidation in meat products with antioxidants found in

plant-based raw materials not only improves the quality of food, but is also important for the health of people who consume the food. Although the human body is equipped with various defence mechanisms, including antioxidant enzymes and antioxidant compounds, maintaining an oxidant/antioxidant balance in favour of antioxidants by consuming more antioxidants through food and avoiding oxidative processes in food or pro-oxidants are the best methods to reduce oxidative stress in the human body. In the aggregate of the obtained research results, it can be concluded that sausage products with the use of various spice and aromatic plants have high quality indicators at the level of a traditional product. This makes it rational to introduce this technology in industry.

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Conflict of Interest

None.

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Ефективність використання пряно-ароматичних рослинних інгредієнтів у технології напівкопчених ковбас

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Анотація. Актуальність роботи полягає в необхідності удосконалення технології напівкопчених ковбас із використанням пряно-ароматичних рослинних інгредієнтів, що дозволить отримати ковбаси з подовженим терміном придатності та сприятиме розширенню асортименту. Щоб уникнути передчасного псування ковбасних виробів або збільшити їх терміни споживання доцільно використовувати під час виробництва різноманітні харчові добавки і антиоксиданти, з позитивним впливом на гідроліз ліпідів і гальмуванням окислювальних змін у ліпідах. Метою роботи було дослідження хімічного складу та зміни свіжості напівкопчених ковбас, виготовлених з використанням пряно-ароматичних рослин: чебрецю та кмину під час зберігання. У роботі використовували такі методи дослідження: органолептичну оцінку проводили за зовнішнім виглядом, виглядом на розрізі, консистенцією, ароматом та смаком; фізико-хімічні – вміст вологи – методом висушування зразків в сушильній шафі до постійної маси при температурі $103 \pm 2^\circ\text{C}$; вміст жиру – методом Сокслета; вміст білка – методом К'ельдаля, визначення вмісту кухонної

солі – методом титруванням іону хлору у водяній витяжці із продукту азотнокислотним сріблом. При визначенні органолептичних показників було встановлено, що зразки мають досить високі органолептичні властивості характерні для напівкопченої ковбаси за технологією виготовлення з використанням чебрецю та кмину. В результаті дослідження хімічного складу було визначено, що вміст води в напівкопчених ковбас складає 54,1-59,3 %, вміст білку – 19,6-20,4 %, що відповідає вимогам стандарту для напівкопчених ковбас вищого сорту. В ході досліджень було вивчено вплив прянощів на перебіг псування продукту та збереження показників якості в розроблених зразках ковбас. Під час зберігання кількість пероксидів у зразках ковбасних виробів постійно зростала, що свідчить про протікання окислювальних процесів, які призводять до утворення пероксидів. Практичне значення проведених досліджень полягає в покращенні органолептичних властивостей та розширенні асортименту напівкопчених ковбас за рахунок використання прянощів

Ключові слова: інгредієнти; окисні зміни; ефірні масла; прянощі; ковбасні вироби; ялівець; органолептичні показники