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MODERN TRENDS IN THE PRODUCTION OF FERMENTED MEAT PRODUCTS

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Abstract. The work generalises and analyses the main problems of manufacturing fermented meat products. These problems are dealt with in scientific papers by experts in meat processing. Today's studies by scientists all over the world are dedicated to the achievement of biological and microbiological safety, structure formation, the use of new kinds of raw materials, the specific features of colour formation, the formation of sensory properties, the improvement of the biological value of raw-smoked and dry-cured products. The work emphasises that the quality of finished products and the stability of the technological process depend on the quality of the raw materials, on the properties of their microbiota, and/or on the starter cultures of microorganisms introduced. It has been shown that the sanitary condition of raw materials can be improved and the impact of pathogenic microorganisms can be reduced by using ultrasound, hydrostatic high pressure, high-intensity pulsating electric field, cold plasma. Also, besides physical methods of processing, it is effective to use competitive microflora, extracts of spicy aromatic plants, different combinations of salting mixtures, packaging. It has been stated that the formation of the finished product structure depends on the parameters of the technological process, on the activity of exo- and endoenzymes, and on the composition according to the recipe. It has been shown that the colour of fermented meat products and its stability depend on the content of natural pigments and on the conditions of their interaction with nitrites under the action of microorganisms with nitrite reductase activity and of the pH of the environment. The possibility of obtaining a characteristic pink-red colour of meat products without using nitrites has been noted. The article presents the results of studying whether the organoleptic parameters of the finished product can be varied by modelling the ingredient composition and fermentation conditions. It has been described how new types of functional-purpose fermented meat products can be created by introducing ω-3 fatty acids, probiotics, macro and microelements, etc. into their composition.

Keywords: meat products, fermentation, starter cultures, safety, colour, biological value.

Introduction and problem statement

Meat is a multicomponent product with different functional and technological properties. Its morphological structure is inhomogeneous.

For many centuries, fermented meat products have been an important part of human nutrition. Their range is wide depending on the meat type, spices, other ingredients. Mostly, meat products are made by classical local and ethnic technologies. However, scientific knowledge is a key to obtain a safe product of high quality.

The development of food biotechnology has allowed using many biologically active components, enzyme preparations, bacterial cultures to intensify production processes and improve the quality and safety of meat products. Using a wide range of components and technologies, it is possible to influence the stability and quality of the product, despite the properties of the raw material. It is possible to create a great many different flavours, aromas, textures, and this, in turn, is of great interest to consumers, especially because it allows them to discover and experience new tasting and aromatic sensations.

Fermented meat products are delicacies, with high quality and organoleptic characteristics. They are dense in their consistency, spicy-aromatic, and taste sourish-salty. They are ingested by the human body quite well. Their structure is macroscopically homogeneous and uniform.

Ways of intensification of production, modelling the formulations, packaging and storage of fermented meat products are given much attention by scientists all over the world: J. Arnau, F. Toldrá, L. Cocolin, M. Manzano, G. Amaro-Blanco, E. Noriega, K. M. Wójciak, B.-A. Rohlík, L. G. Vinnikova, O. M. Starchevoi, H. O. Ieresko.

The production process of this type of product is time consuming and requires special attention. Thus, a specific feature of the technology of raw-smoked sausages is that they are not heat-treated while manufacturing. The full readiness of the product is a result of biochemical reactions caused by tissue and microbiological enzymes in the course of long ripening and drying. The long shelf life is due to the presence of bacteriocins produced by microorganisms, in particular lactic acid bacteria, and to a low moisture content.

That is why, the structure formation process is important. It contributes to obtaining a product with the required selling qualities, and on the other hand, it determines the product's nutritional value. Besides, the finished product has all the characteristics that make it consumable without additional cooking. When raw-smoked sausages are made, they ripen at a temperature of 20–24°C and undergo no active treatment except for drying. So, the main factor that forms the finished product is the internal changes of protein macromolecules and the causes of these changes.

Manufacture of fermented meat products takes so long mainly because the complex biochemical and microbiological processes and the product's dehydration to the required humidity are time-consuming. So, reducing the production cycle of fermented meat products is a matter of priority. One of the ways to reduce the production time of this product can be reducing the drying time.

The change in the functional and technological characterisics of raw meat (due to modern intensive methods of fattening up livestock), the increase in the cost of raw materials, and high competition in the market – all the above is a pressing problem for manufacturers worldwide. It requires innovative approaches to ensure the high quality and safety of fermented meat products. Researches in different areas are aimed at solving this task.

The purpose of the study is to determine the topical problems the fermented meat production is facing now.

The objective of the study is to analyse scientific publications devoted to studying and solving the problems of the fermented meat products technology, improving their quality, safety, and biological value.

Analysis of recent research and publications

Recently, more and more specialists have been paying attention to using bacterial preparations and various additives, essential oils, and extracts of spicy aromatic plants that provide high-quality, stable, and sanitary safe products with a longer shelf life. In today's market competition, when manufacturing these products, experts pay special attention to the following areas of research:

– biological and microbiological safety;
– structure formation;
– new types of raw materials;
– specific features of colour formation;
– the sensory properties of finished products;
– improving the biological value of the product.

The methods to achieve the biological and microbiological safety

The fermented meat products are biological systems that are affected by various environmental factors during their production. Manufacturers' main task is to make their products highly stable. When manufacturing fermented meat products, it is of primary importance to use high quality raw materials with low levels of microbiological contamination, since highly contaminated raw materials hinder fermentation significantly, which can lead to the appearance of dangerous products. In the production scheme, there is no heat treatment, and the product's readiness for consumption is achieved through endo- and exoenzyme activity.

The scientists [1] who studied the effect of primary contamination of meat raw materials in the production of Italian fermented sausages Cacciatore and Felino found that microbiological safety could be achieved by combining various factors: fermentation temperature, pH, water activity, mass fraction of *NaCl*. However, with significant primary contamination of raw materials, they have but little effect. The studies have shown that the first 48 hours of fermentation are crucial in the development of pathogenic microflora.

It is known that adding starter cultures of microorganisms in minces for raw-smoked sausages promotes fermentation and drying, improves the organoleptic characteristics of the finished products, has a tenderising effect on the muscular and connective tissues of meat, prolongs the shelf life, and improves the hygienic characteristics of products. Starter bacterial cultures are effective because they have specific and unique properties.

For natural fermentation of various foods, people, since time immemorial, have been using lactic acid bacteria (LAB) which are nonsporulating, aerotolerant, catalase-negative cocci or bacilli. During fermentation of carbohydrates, one of the metabolites of their vital activity is lactic acid. This property of theirs has a positive effect on fermented meat production, especially at the initial stage, since it causes the pH of the minced meat to decrease. LAB actively influence the formation of the flavouring properties of finished products [2]. Lactic acid microorganisms make raw-smoked sausage a product of long-term storage, as they prevent the development of unwanted microflora by producing lactic acid, hydrogen peroxide, organic acids, and antibiotic substances, bacteriocins, that inhibit the development of putrefactive microflora. Bacteriocins are ribosomally synthesised peptides, or small proteins with antimicrobial activity that are produced by bacteria. These substances actively inhibit the development of pathogens at the beginning of the stationary growth phase. The use of bacteriocins in meat products has been widely studied because they have been proved to be highly effective antimicrobial agents, mainly against L. *Monocytogenes* [2-4].

LAB-containing bacterial starter cultures and gram-positive bacteria of the genus *Staphylococcus* or *Micrococcus* are those most often used in production. Due to the adaptation of the LAB to the meat environment, they become the main, dominant microflora of the classical fermented products. LAB usually grow at the initial stages of fermentation and remain unchanged during ripening [5-8].

The researchers [9] recommend using the bioprotective properties of lactic acid bacteria in order to improve the sanitary and hygienic qualities of raw-smoked sausages, in particular, to inhibit the activity of *Listeria monocytogenes* and *Escherichia coli*. According to them, the enrichment of fermented sausages with probiotics is promising, as it promotes the growth of LAB.

The Italian scientists [7] found that in raw-smoked sausages made without using starter cultures of microorganisms, the pH did not fall below 5.6–5.7, and the water activity remained at 0.91–0.92. Most strains contained in the finished product were those of *Lactobacillus curvatus* and *Lactobacillus sakei*. But *Listeria monocytogenes*, *Salmonella spp*. and *Staphylococcus aureus* were never spotted during the ripening, which proved the product's safety.

The poultry meat is an appropriate environment for the proliferation of pathogenic microflora, so extra processing or using chemical preservatives becomes necessary. To make Tunisian fermented poultry sausage better and safer, it was suggested to use the starter culture mixtures *Lactobacillus sakei* + *Staphylococcus carnosus* or *Lactobacillus sakei* + *Staphylococcus carnosus* + *Staphylococcus xylosus* [10]. Adding these cultures allows controlling the fermentation and ripening of sausage and extends its shelf life.

It is well-known that low-frequency ultrasound (20–100 kHz) is harmful for the life of microorganisms. Due to disintegration, it causes the destruction of cells of various types, including bacteria that are harmful to human health (*Campylobacter spp.*, *Escherichia coli*, *Bacillus cereus*, etc.). Unfortunately, to achieve a sterilising effect, a very intense and long ultrasound action is required, which leads to overheating of biological structures.

The studies [11] proved how effective it was to process poultry meat by means of ultrasound with the frequency 40 kHz in a 1% lactic acid solution. The duration of the process did not exceed 6 minutes. This reduced the microbial contamination of the surface by 4 times. Similarly, to reduce the total microbial contamination of chicken meat, the scientists [12] suggested high-intensity ultrasound treatment in the presence of 0.3% oregano oil to enhance the effect of inhibition.

The effectiveness of oregano oil against mould was proved by studies of the European scientists [13]. They recommended treating the surface of Spanish dry-cured sausages with 0.1% water emulsion of oregano oil to prevent the development of surface mould. This emulsion proved highly effective in the manufacture of products with short ripening period.

Moulds are greatly responsible for microbiological contamination of meat and meat products because they produce substances harmful to the body – mycotoxins. Contamination can occur after the slaughter and later, during the technological processing and storage of finished products. The most characteristic are the mould species *Mucor*, *Penicillium*, *Aspergillus*. The most common and dangerous for people are aflatoxins, ochratoxin A, patulin, fumonisins, and others [14].

The most common ochratoxigenic mould found in fermented meat products is *Penicillium nordicum*. Spanish and German scientists' joint research studied the ability of the osmotolerant yeast *Debaryomyces hansenii* to inhibit the development of *P. nordicum*. The results of the study show that *D. hansenii* can potentially be used as a biopreservative to prevent mould development and ochratoxin A accumulation [15]. The best time for the treatment is the end of the salting process, when the value of the water activity index (a_w) is still high enough (0.94). Such treatment reduces the likely risks to consumers' health.

In the work [16], the effect is evaluated of different concentrations of *NaCl*, *KCl*, and sucrose salts on the development and production of ochratoxin A (OTA) by two strains of *Penicillium verrucosum*. The data obtained show that *KCl* and sucrose do not inhibit OTA production completely. However, the level of OTA production is much lower than when using *NaCl*. The use of KCl instead of *NaCl* is of great importance for the current tendencies to reduce the salt content in finished products and to introduce new recipe ingredients. Besides, it makes fermented sausages safer as for the OTA content.

It is well-known that the mass content of moisture significantly affects the microbiological stability of fermented products. The Korean scientists [17] conducted complex studies of the quality parameters of dry-cured ham with the moisture contents 35% and 45%. It was found that ham with the moisture content 45% and the water activity value 0.86–0.87 was more stable microbiologically compared to that with the moisture content 35% and the water activity 0.82–0.83, and had better quality characteristics in general.

Cutting and packaging affects the safety of meat products and reduces their shelf life because of contamination with microflora. The use of active packaging can increase the shelf life of a finished product. Active packaging systems are based on using active compounds (mainly antimicrobial and antioxidant preparations) in packaging to improve the quality and extend the shelf life of a finished product. Such compounds mostly include organic acids, chitosan, nisin, the lactoperoxidase system, and some vegetable extracts and essential oils. These strategies have been extensively studied and implemented worldwide in recent years [18-19].

The Spanish scientists [20] suggested active packaging using olive leaf alcoholic extract (0.5 cm^3 of the extract per one package of about 70 g) for vacuum packaging of dry-cured shoulders of Iberian pigs. Hydrostatic high pressure was used as additional processing. Hydrostatic high pressure processing is a non-thermal processing technology that allows inactivating pathogenic microorganisms [21]. The pressure processing was carried out with the following parameters: pressure 600 MPa, duration 7 min, water temperature for propagation of pressure 10°C. The packaging samples processed with an oil leaf extract and high pressure and the unprocessed ones were compared. The results obtained show that using an olive leaf extract in combination with high hydrostatic pressure most effectively reduces the total microbial contamination of sliced dry-cured shoulders of Iberian pigs during their vacuum packaging and further storage. The research proves how effective it is to use hydrostatic pressure of 600 MPa to reduce the total microbial contamination during vacuum packaging of sliced dry-cured ham [22].

A significant problem when manufacturing fermented meat products is their contamination by bacteria of the *Listeria* genus, the most dangerous of which is *L. monocytogenes*. They are widespread in the environment and extremely resistant. To process sliced dry-cured ham, the scientists [23] suggested applying the pressure 450 MPa (for 10 min) in combination with enterocins A and B. This allows inactivating four *L. monocytogenes* strains and prevents these pathogens' redevelopment during storage at 4°C and 12°C. However, this processing has but a little effect on other characteristics of the product (pH, a_w, colour).

To improve the microbiological safety of fermented fuet and chorizo sausages having a low-acid reaction of the environment, it is suggested to introduce starter cultures of lactic acid bacteria into the mince along with vacuum packing and high pressure processing with the following parameters with the: pressure 400 MPa; duration 10 minutes; water temperature for propagation of pressure 17°C [24].

High-intensity processing with pulsed electric fields allows inactivating microorganisms and reduces enzyme activity. This, in turn, extends the shelf life of the product without significantly affecting its characteristics. This technology belongs to the non-thermal ones. It consists in using short pulses (1 to 10 μs) of a pulsed electric field (20–80 kV/cm) with a frequency of up to 2000 Hz, with a food product placed between the two electrodes. Such treatment has demonstrated its effectiveness in inactivating such pathogens as *Listeria innocua*, *Escherichia coli*, *Salmonella Typhimurium* [25-27].

Although pulsed electric fields are only effective for fluid products, there are several concepts of how to use this technology in the meat industry. In particular, the scientists [28] found that processing frozen beef with pulsed electric fields (with the constant pulse width 20 μs, the electric field intensity 1.4 kV/cm, the constant frequency 50 Hz) allows extending the lag phase of psychrophilic bacteria, thus reducing the total microbial contamination of products during storage. A change in the membrane permeability, which results in microbial inactivation and cell disruption, can be used to accelerate mass transfer (salting, drying) [29].

The cold plasma technology can be widely used in the food industry, for example, to disinfect meat, poultry, etc. The antimicrobial effect of cold plasma depends on its source, power, duration of action, and the gas mixture used to generate plasma. The antimicrobial effect is due to the generation of various reactive oxygen and nitrogen species that cause severe oxidative damage to cellular components, which is detrimental to microorganisms. The method belongs to the non-thermal methods of disinfecting foodstuffs [30-32].

Modern processing technologies are based on the deep scientific and professional knowledge, but the contamination of meat and meat products remains a serious problem. That is why, scientists are greatly interested in finding innovative ways that can minimise the formation of, or eliminate harmful substances during processing and storage [33].

Microbial and endogenous proteolytic enzymes contribute to changes in protein during the ripening of meat and meat products. Fermented meat products, during drying and ripening, accumulate free amino acids. Their decarboxylation promotes the formation of biogenic amines (histamine, tyramine, tryptamine, phenethylamine). Studies by European scientists have established a high content of these compounds in fermented meat products, which can cause migraines, headaches, itching, high blood pressure and gastrointestinal disorders. Besides, secondary amines are likely to form, which can be nitrosated and form nitrosamines [34-37]. A way to solve this problem was suggested by the Polish scientists [38]. They recommend, when manufacturing uncured dry-fermented beef, marinating the meat with fresh whey in the presence of sea salt and glucose. This should be combined with ultrasonic treatment (with the frequency 40 kHz and acoustic power 480 W, at 4°C). The researchers found that ultrasonic treatment, while marinating the beef in whey, helped slow down the formation of histamine, cadaverine, tyramine, and putrescine.

The studies [39] provided interesting data on the formation of biogenic amine (tyramine) during fermentation. The authors found that the level of amine accumulation depended on the diameter of the product. Items with larger diameters accumulated far more amines. The researchers also proved that most amines were found in the central part of a sausage stick.

When raw meat is being minced, oxygen from the air enters the mince. This leads to faster ripening and, consequently, to a decrease in the pH and a_w. Instead, there is accumulation of lipid oxidation products (alkanes, alkenes, aldehydes, alcohols, ketones, etc.), which adversely affects the sensory perception of the finished produce, its safety and storage stability. The studies [40-41] found that the presence of *Staphylococcus xylosus* and *Staphylococcus carnosus* in the starter cultures inhibited lipid oxidation, because they produced catalase and superoxide dismutase. The Spanish researchers [42] studied the effect of *Staphylococcus carnosus* on oxidation processes in fermented meat products. To increase this effect, they suggested adding a tocopherol extract (200 mg/kg) and a celery concentrate to the formulation. The tocopherol extract was found to have a more pronounced effect on slowing down oxidation compared to the celery concentrate. At the same time, they found that this combination allowed reducing the addition of nitrite down to 70 mg/kg, without any loss in the quality and safety of the finished products. The Czech scientists [43] proved the efficiency of plant components in slowing down the oxidation processes when manufacturing and storaging fermented meat products. They suggested including a rosemary extract (0.5 g/kg) and lycopene (0.5 g/kg) in the formulation. In the course of determining the oxidation products by their interaction with thiobarbituric acid, it was found that adding simultaneously the rosemary extract and lycopene had a pronounced synergistic effect. Besides, the objective data were obtained that these additives improved the colour characteristics of the finished product.

The Russian scientists suggested using compositions of starter cultures to reduce cholesterol in meat fermented foods [44]. So, they recommended using compositions of the starter cultures *Lactobacillus sakei 105*, *Pediococcus pentosaceus 31, and Staphylococcus xylosus 45* for fermentation, in the ratio 1:1:1, respectively. Their use reduced cholesterol by 25.0–45.7% of its initial content in the environment. The ability to reduce cholesterol in vitro is a strain-specific feature of these microorganisms. This will allow expanding the circle of consumers by attracting healthy diet enthusiasts and people with lipid disorders.

Structure formation

Raw-smoked and dry-cured sausages have a macroscopically homogeneous and monolithic structure. So the process of structure formation is important and helps obtain a product with the required commercial indicators that determine its nutritional value. The structure begins forming from the moment of mincing, making forcemeat, and casing, and keeps forming throughout fermentation, drying, and smoking. The duration of manufacturing this product group is determined, first of all, by the time the complex biochemical and microbiological processes take, and by the need to achieve the prescribed moisture content. During ripening, the mince compresses, strengthens, and forms a structure that is one of the criteria of the product's readiness.

Structure formation is acted upon by two oppositely directed processes: enzymatic hydrolysis of protein components under the action of tissue and bacterial enzymes, and formation of a three-dimensional structural framework. The protein destruction leads to specific changes in the muscular fibres and to homogenisation of the mass, which increases digestibility [45]. The new bonds among protein particles and their strength contribute to the formation of the three-dimensional structure in the finished product. While raw-smoked sausages are dried, a structure with pores is formed, and the mince takes the features of a capillary-porous body. The changing of the original structure of the mince into a new one is due to the loss of the moisture content [46]. Taking the necessary structure is a complex, multiphase process that can last from a few days to several months. The work [47] names the main factors influencing structure formation: duration of mincing meat raw materials and mixing them with salt; using vacuum in the preparation of forcemeat; meat temperature; pork back-fat temperature.

The group of Spanish scientists [48] showed how the consistency of dry-cured whole-muscle products can be controlled by changing the pH values of the raw materials and the mass fraction of table salt. The dependence of the textural parameters on the pH during ripening correlated with the data obtained by the scientists in the works [49-50]. According to their studies, the lower the pH, the less is the density of the sausage structure.

According to B. Marcos et al. [24], to improve the structural characteristics of fermented sausages with low-acid reaction of the environment, it is effective to introduce lactic acid bacteria into the mince and process sausages with high hydrostatic pressure.

The authors [51] established that 3% *NaCl* in the formulations of fermented sausages could be partially replaced with a mixture of salts (1.5% NaCl+1.5% KCl). This method allows reducing the solubility of myofibrillar (from 33.6% to 27.6%) and sarcoplasmic proteins (from 9.9% to 9.3%) and obtaining products with a pronounced salty taste and less solid consistency.

An important role of exo- and endoenzymes in the destruction of sarcoplasmic and myofibrillar proteins was demonstrated in the study [52]. It was established that tissue proteases of meat raw materials played a major role at the initial stage of ripening, and at the late stages of degradation, the leading role was that of bacterial enzymes.

The study of the microstructure of myofibres in the manufacture of fermented sausages [53] shows that the formation of a secondary structure protein matrix is a prerequisite of obtaining quality products. Its formation is mainly induced by myosin and actin as a result of such technological processes as mincing, salting, and fermentation. The authors point out that these processes are stimulated by table salt and lactobacilli. They are present in the forcemeat system and have a tenderising effect on the muscular and connective tissues of meat.

Thus, the transformation of plastic-structured raw mince into a solid and at the same time homogeneous structure of finished products has three stages: dissolution of myofibrillar and sarcoplasmic proteins while mincing and salting the meat; formation of protein gel under the action of endo- and exoenzymes, and loss of moisture during the drying stage. These processes depend on complex biochemical, microbiological, and physical factors researched by many scientists.

Colour formation

The attractive and stable colour of meat products greatly influences consumers' choice. Some technological features of production, storage, and transportation can affect the colour stability of fermented meat products. Many scientists have conducted research on how to stabilise the colour and optimise the use of nitrites in fermented meat products.

In general, the colour of fermented meat products depends on the type of raw material, the mass fraction of adipose tissue in the recipe, and the fermentation conditions.

Traditionally, sodium nitrite solution ($NaNO_2$) is added to meat products to stabilise their colour. When it reacts with pigments of meat raw materials (myoglobin and metmyoglobin), nitrosomyoglobin is formed, which gives the products their characteristic red colour. For colour stability, at least 50% of the pigments should be bound by nitric oxide, the interaction being optimum at pH 5.2–5.7. In fermented products that are not thermally treated, this substance is formed by microbiological reduction of nitrite. The presence of sodium nitrite and its derivatives (HNO_2, NO) in fermented meat products protects them from the potential development of *Salmonella spp.*, *Staphylococcus aureus*, *Clostridium botulinum*, but has no effect on the development *of Micrococcus spp.*, *Lactobacillus spp.*, and *Enterococcus spp.* Moreover, this substance enhances the aroma of smoked products and has antioxidant properties. It should be borne in mind that $NaNO_2$ is a poisonous substance, its lethal dose for humans being 1.1 g. When manufacturing products low in table salt, it is recommended to use potassium nitrite (KNO_2). Due to the difference in the molecular weights, to achieve the same level of colouring, one needs by 30% more KNO_2 compared to $NaNO_2$ [54,37].

Taking into account the peculiarity of colour stabilisation in raw-smoked sausages, the German scientists [55] suggested using for fermentation the strains of microorganisms with high nitrate- and nitrite-reductase activities – *C. carnosus*, *C. simulans*, and *S. Saprophyticus* – for rapid formation of nitroso pigments at the initial stage of sausage ripening. In the work [41], it was proved that catalases produced by starter cultures had a positive effect on the stability of nitroso pigments.

The scientists [56] suggested using specific strains of starter cultures to reduce the nitrite content. The experiments showed that *L. fermentum* could generate NO from an alternative chemical source other than nitrate or nitrite. This property makes it possible to manufacture fermented meat without using nitrates/nitrites.

The Korean scientists [57] suggested using fermented extracts of nitrites contained in spinach in the recipes for cured meat. The nitrite extract was obtained by fermenting the spinach with a 0.1% active *Lactobacillus farciminis* culture with nitrate reductase activity. The experiments with pork proved that the extract was effective and that synthetic nitrite could be replaced with that of natural origin.

Although nitrites have numerous technological advantages, they should be used but cautiously as they are involved in the formation of carcinogenic N-nitrosamines.

The most important native pigments present in meat and meat products are biochemically bound haemin, protoporphyrin IX (PPIX), and protoporphyrin Zn (II) (Zn (II) PPIX). It used to be believed for a long time that nitrosomyoglobin was the only compound responsible for the attractive red colour of meat products. The scientists have found that the red colour of Parma ham is not due to the formation of nitrosomyoglobin: in this case, the pigment that forms the red colour is protoporphyrin Zn (II) [58-62].

The mechanism of Zn (II) PPIX action has not yet been sufficiently studied. However, it is interesting enough to inspire further research of how to replace $NaNO_2$ with a natural pigment to manufature fermented meat products.

The scientists [63] studied the influence of the meat source, pH, and production time on the formation of Zn (II) PPIX in nitrite-free fermented sausages. The study showed that longer production time and higher pH resulted in the formation of Zn (II) PPIX and PPIX and a decrease in the haem content. Protoporphyrin Zn (II), in comparison with nitrosomyoglobin, is more resistant to light and oxygen from the air, which makes its use more practical, but it forms more slowly.

Cold plasma is used to reduce microbiological contamination and make food and medicines safer. Besides, this technology can be used to manufacture nitrite-free meat products [64].

When plasma interacts with water, nitric and nitrous acids are formed in the system. Scientists studied the ability of plasma-treated water to stabilise the colour of meat products. To do this, they replaced the mass fraction of moisture prescribed in the recipe with plasma-treated water. They studied the colour in the experimental and control samples (with $NaNO_2$) spectrophotometrically. The colour of the experimental products was found to be slightly inferior to traditional nitrite-containing products (by 0.29%). These data proved that plasma-treated water could be a cost-effective alternative to synthetic nitrites in meat products. The Ames tests also proved the genotoxic safety of this replacement [65-66].

The works [67] proved that fermented beef products with the characteristic red-pink colour could be made without adding nitrites. To this end, it was suggested to kept meat, at the initial stage of production, in whey obtained when making sour milk cheese. This marinating lasted 48 hours at 2°C, and only then the meat was salted.

The same authors [68] investigated the effect of whey on the colour formation in fermented sausages. In their opinion, the stabilisation is due to the production of nitric oxide (NO) by the enzyme NO synthase that catalyses the oxidation of L-arginine to L-citrulline. Subsequently, nitrosomyoglobin is formed due to the interaction of NO with myoglobin of the raw meat. Further research in this area is sure to open up wide opportunities for manufacturing meat products without using nitrites.

Another problem is how to preserve the colour of products during their storage and sale. So, researchers pay much attention to finding appropriate packaging methods and packaging materials. The scientists [69] established that, when using vacuum or a modified gas environment during packing fermented meat products, the concentration of O_2 should be at the level 0.1–0.5%. When the oxygen level in the pack exceeds 0.5%, the colour changes significantly.

Colour formation in fermented meat products is associated with certain difficulties caused by the low temperature of the technological process, increased mass fraction of *NaCl*, decreased moisture content, pH, and a_w, etc. Therefore, further scientific research to find new approaches to these important problems is a topical issue and meets the requirements of creating innovative production technologies.

Improving the organoleptic properties

So far, no device can completely replace a human in sensory assessment of a product. Sensory evaluation is used as a scientific method to measure and analyse a product through the senses of sight, smell, touch, taste, and hearing. The first impression of a product is usually visual: one evaluates the size, shape, and colour. Then, the smell, flavour, and taste are assessed. The human mouth is a very specific tool, as it helps evaluate not only the taste, but the texture as well.

Taste formation and aroma formation are closely related to the quality of fermented products. Most flavouring substances are formed due to hydrolytic cleavage of proteins, fats, and carbohydrates under the influence of bacterial and tissue enzymes, with the formation of volatile compounds that react with oxygen and form aldehydes, ketones, volatile fatty acids, alcohols, and ethers. Acted upon by proteolytic enzymes, soluble proteins partially break down into peptides and amino acids, from which volatile fatty acids, ammonia, amines, and sulphur-containing components are formed. Influenced by microflora, carbohydrates break down, with the accumulation of lactic and other acids responsible for the sour taste and aroma that are generally typical of fermented products made by accelerated technologies. Certain compounds that react with proteins, carbohydrates, fats, and other constituents of the product form its flavour composition. The numerous components added during the manufacture (salt, spices, and their extracts, etc.) are also involved in the formation of taste and aroma [45].

The effect of nitrite on the aroma of meat products has long been known. The scientists [70] compared the effect of nitrates and nitrites on aroma formation in fermented products. They found that nitrites had a more pronounced effect on the formation of free fatty acids. On the contrary, adding nitrates results in a larger number of volatile compounds formed due to degradation of amino acids and fermentation of carbohydrates. Probably this is due to the larger population of microorganisms in these samples and the effect of nitrates on their metabolism. It should be noted that these processes are highly dependent on the conditions of ripening.

According to the researchers [71], proteolytic and lipolytic activity during ripening of fermented sausages is due to the action of endo- and exoenzymes. Some authors [72-73] believe that accumulation of free amino acids and free fatty acids during ripening of fermented sausages is due to the activity of enzymes of starter cultures.

The data obtained by the German scientists [74] prove that the level of free amino acids is significantly influenced by a number of factors. The researchers indicate that the high fermentation temperature (25°C) and nitrite content (0.3%) increase the accumulation of free amino acids. On the contrary, their production decreases with high levels of nitrates (0.2%), glucose (1.0%), table salt (3.5%), and starter cultures ($4.2 \cdot 10^7$ CFU/g).

To improve the flavour qualities of dried Cantonese sausages, the researchers [75] recommend adding up to 2% of dried straw mushrooms (Volvariella volvacea). This modification of the traditional recipe allows improving the taste and smell of the finished product. However, adding more than 4% significantly impairs its colour and texture.

Increasing the biological value

Recently, the social problems, overconsumption of products low in biologically active components, changes in nutrition habits have led to spreading of such chronic diseases as diabetes, cardiovascular disease, lipid metabolism disorders, and others. The presence of cholesterol, sugars, and, lately, high levels of salt in animal products provokes the development of these diseases and creates a negative image for consumers.

Meat and meat products play a significant role in human nutrition. According to Cabinet of Ministers Decree No. 780 of 11.10.2016, adults in Ukraine must consume at least 53 kg of meat products a year.

More and more often, consumers pay attention to products belonging to dietary, organic foods or those enriched with various biogenic substances. The following approaches can be applied in meat processing:

– natural increase of the content of a product's natural components, such as ω-3 fatty acids, calcium;

– adding compounds that are not normally contained in a certain product type, such as prebiotics;

– replacing components, macronutrients that are excessive and detrimental with compounds having the opposite effect, such as fats;

– reducing the content of specific compounds (such as fatty acids, trans fats, or food allergens) formed when processing the product, in order to reduce their harmful effects on health;

– increasing the bioavailability or stability of a component that has proved to be functionally effective;

– combination of the above methods [33].

The work [76] suggested enriching fermented sausages with calcium *Ca*. To make it more bioavailable, it was added in the form of salts (gluconate, lactate, and citrate malate). The salts were added in quantities that could provide 20–40% of the daily requirement for *Ca* when calculated per 100 g of the finished product. The enriched products had the technological and organoleptic properties characteristic of traditional products, except for calcium gluconate. In vitro experiments to determine the bioavailability showed that in the products containing lactate and potassium citrate malate, it was within 10%. So, any of them can be used to expand the range of healthy products.

High sodium chloride content in fermented meat prevents hypertensive patients worldwide from eating it. A way to solve this problem is to replace sodium, completely or partially, with other ions. However, it should be borne in mind that salt has universal properties in the technological process. It improves the texture and taste and inhibits the development of microflora [77].

To improve the safety of dry-cured sausages for human health, the researchers [78] suggested replacing 50% of salt NaCl in the recipes with KCl, $CaCl_2$, or a mixture of KCl and $CaCl_2$ (1:1). This substitution reduced the Na content in the finished product by 42%. The best sensory characteristics were those of the samples with KCl and mixtures of KCl and $CaCl_2$ introduced. Although consumers noted that the overall sensory perception in the low-sodium samples was lower, the cluster analysis and the survey conducted showed the possibility of making and selling low-sodium products. However, the Spanish researchers [79], who investigated the possibility of reducing table salt in formulations of fermented sausages, found that reducing NaCl by 16% led to a decrease in the aroma, taste, juiciness and quality in general. On the contrary, when table salt was replaced with KCl but partially (by 16%), only the aroma of the product deteriorated. According to the authors, it occurred due to a decrease in sulphur compounds and organic acids, and the accumulation of aldehydes. A possibility of reducing the concentration of salt in Spanish dry-cured ham was studied in the work [80]. Mixtures of the salts NaCl and KCl, in the ratio 50%:50%, respectively, and NaCl, KCl, $CaCl_2$, and $MgCl_2$, in the ratio 55%:25%:15%:5%, respectively, were used. The authors found that lower salt concentration required longer salting, because the parameter a_w started decreasing more slowly. No differences in the microbiological parameters were observed.

Probiotics are living microorganisms that, when added in adequate quantities, have a beneficial effect on the host's health and can be incorporated into various foods [81]. Fermented meat products can contain a lot of viable lactic acid bacteria, so a lot of attention has recently been given to using these foods as carriers of probiotic cultures. A probiotic culture must be well adapted to the product's manufacturing conditions, and be resistant to other endogenous factors of the meat source. Besides, it should not affect the organoleptic characteristics.

The scientists [82] tested the strains with probiotic properties of *L. rhamnosus GG, LC-705, E-97800*, and *L. plantarum E-98098*, in order to organise the production of dry-cured sausages with probiotic properties. The finished products had typical technological and organoleptic qualities. The number of lactic acid bacteria reached 8–9 log CFU/g. Another group of researchers [83] suggested using strains with probiotic properties of *Lb plantarum/pentosus* (MF1291, MF1298, MF1300) as starter cultures for Scandinavian-type fermented sausages. The number of lactic acid bacteria in the finished product reached $4.7 \cdot 107–2.9 \cdot 10^8$ CFU/g.

Most peptides produced by protein fermentation belong to functional food ingredients. Numerous peptides have been found that have diverse effects on the human body [54,84-85]. They can have immunostimulatory, antimicrobial, antioxidant, antithrombotic effects, reduce blood pressure, etc. Since meat is a natural source of protein, using fermented meat products as a source of biologically active peptides makes it possible to create new functional meat products [86-87].

In order to improve the nutritional properties and biological value of fermented sausages, the researchers [88] suggested including the following ingredients in their composition: selenium-containing yeast, iodised salt, flaxseed emulsion (containing ω-6/ω-3 fatty acids), and lyophilised water extract of Melissa officinalis L. (containing antioxidants). Products made with these components have the same organoleptic properties as traditional products do. However, consuming 50 g of these products provides the body with 100% of the daily selenium need, and with 70% of the iodine need. The ratio of ω-6/ω-3 fatty acids decreased from 15.7 (in traditional products) to 1.96 (in fermented sausages with modified composition).

A team of researchers [89] suggested enriching fermented sausages with deodorised fish oil as a source of ω-3 fatty acids. Emulsified deodorised fish oil was used to substitute 25% of fatty pork in the recipe. To prevent the development of active oxidation processes, a mixture of antioxidants (1 g/kg of butylhydroxytoluene and 100 mg/kg of butylhydroxyanisole) was added into the formulation. The finished product contained no compounds that would have indicated oxidative deterioration of fats. The ratio of ω-6/ω-3 fatty acids was 2.97. The organoleptic characteristics of the products containing fish oil did not differ from those of traditional products. Another group of researchers [90] used encapsulated fish oil to regulate the ratio of ω-6/ω-3 fatty acids in Dutch-style fermented sausages. When the 15–30% of pork back-fat prescribed in the recipe was replaced with encapsulated fish oil, the ratio of ω-6/ω-3 decreased from 8.49 (in traditional products) to 0.90–2.47 (in modified products). Both groups of researchers pointed out how practical it was to use fish oil to enrich fermented sausages with ω-3 fatty acids. This approach opens up great opportunities for developing new types of functional fermented meat products.

Most studies of the manufacture of functional fermented meat products are aimed primarily at improving their composition by introducing one or more functional ingredients. Meat and meat products play an important role in human nutrition due to a high content of nutrients. However, most consumers do not consider these products to be functional because of the image of industrially processed meat as unhealthy food.

Conclusion

The analysis of numerous scientific publications shows the considerable interest of researchers all over the world to the problems of fermented meat production and shows that this direction will remain relevant and progressive for a long time. In the manufacture of fermented meat products, their quality and safety depend on many external (technological parameters of production, composition and enzymatic properties of starter microflora, the presence of smoking) and internal (type and quality of the meat source, pH, a_w, microbiota of the meat, ingredients of the formulations, etc.) factors. Each factor should be analysed individually, and all of them should be researched comprehensively to establish synergistic or antagonistic interactions. The globalisation opens up the opportunities to research and analyse products that have been produced in different regions of the planet from ancient times and to give scientific reasons to their qualities. Development of technologies and equipment allows us to improve technological processes and apply new processing methods.

Referenses:

1. Mataragas M, Bellio A, Rovetto F, Astegiano S, Decastelli L, Cocolin L. Risk-based control of food-borne pathogens Listeria monocytogenes and Salmonella enterica in the Italian fermented sausages Cacciatore and Felino. Meat Sci. 2015 May; 103:39-45. https://doi.org/10.1016/j.meatsci.2015.01.002
2. De Souza Barbosa M, Todorov SD, Ivanova I, Chobert J-M, Haertlé T, De Melo Franco BDG. Improving safety of salami by application of bacteriocins produced by an autochthonous Lactobacillus curvatus isolate. Food Microbiol. 2015 Apr; 46:254-262. https://doi: 10.1016/j.fm.2014.08.004
3. Nieto-Lozano JC, Reguera-Useros JI, Peláez-Martínez MC, Hardisson de la Torre AH. Bacteriocinogenic activity from starter culture used in Spanish meat industry. Meat science. 2002; 62(2):237-243. https://doi: 10.1016/S0309-1740(01)00252-2
4. Zhu M, Du M, Cordray J, Ahn DU. Control of Listeria monocytogenes Contamination in Ready-to-Eat Meat Products. Compr Rev Food Sci Food Saf. 2005 Nov; 4(2):34-42. https://doi.org/10.1111/j.1541-4337.2005.tb00071.x
5. Cocolin L, Manzano M, Cantoni C, Comi G. Denaturing Gradient Gel Electrophoresis Analysis of the 16S rRNA Gene V1 Region To Monitor Dynamic Changes in the Bacterial Population during Fermentation of Italian Sausages. Appl Environ Microbiol. 2001 Nov; 67(11):5113-5121. https://doi.org/10.1128/AEM.67.11.5113–5121.2001
6. Cocolin L, Manzano M, Aggio D, Carlo C, Comi G. A novel polymerase chain reaction (PCR) – Denaturing gradient gel electrophoresis (DGGE) for the identification of Micrococcaceae strains involved in meat fermentations. Its application to naturally fermented Italian sausages. Meat Science. 2001 May; 58(1):59-64. https://doi.org/10.1016/s0309-1740(00)00131-5
7. Comi G, Urso R, Iacumin L, Rantsiou K, Cattaneo P, Cantoni C, Cocolin L. Characterisation of naturally fermented sausages produced in the North East of Italy. Meat Sci. 2005 Mar; 69(3):381-392. https://doi.org/10.1016/j.meatsci.2004.08.007
8. Ieresko HO, Lyzova VIu, Voitsekhivska LU, Starchevoi OM. Udoskonalennia tekhnolohii vyrobnytstva fermentovanykh kovbas z vykorystanniam kompozytsiinykh dobavok. Visnyk ahrarnoi nauky. 2007; 6:66-69.
9. Työppönen S, Petäjä E, Mattila-Sandholm T. Bioprotectives and probiotics for dry sausages. Int J Food Micro-biol. 2003 Jun; 83(3):233-244. https://doi.org/10.1016/s0168-1605(02)00379-3
10. El Adab S, Essid I, Hassouna M. Microbiological, biochemical and textural characteristics of a tunisian dry fermented poultry meat sausage inoculated with selected starter cultures. J Food Saf. 2015 Dec; 35(1):75-85. https://doi.org/10.1111/jfs.12164

11. Kordowska-Wiater M, Stasiak D. Effect of ultrasound on survival of Gram-negative bacteria on chicken skin surface. Bull Vet Inst in Pulawy. 2011 Jan; 55(2):207-210.
12. Piñon MI, Alarcon-Rojo AD, Renteria AL, Mendez G, Janacua-Vidales H. Reduction of microorganisms in marinated poultry breast using oregano essential oil and power ultrasound. Acta Alimentaria. 2015 Dec; 44(4):527-533. https://doi.org/10.1556/066.2015.44.0024
13. Martín-Sánchez AM, Chaves-López C, Sendra E, Sayas E, Fenández-López J, Pérez-Álvarez JÁ. Lipolysis, proteolysis and sensory characteristics of a Spanish fermented dry-cured meat product (salchichón) with oregano essential oil used as surface mold inhibitor. Meat Science. 2011 Sept; 89(1):35-44. https://doi.org/10.1016/j.meatsci.2011.03.018
14. World Health Organization (WHO). Mycotoxins [Internet]. Geneva: WHO; 2018. Available from: https://www.who.int/news-room/fact-sheets/detail/mycotoxins
15. Andrade MJ, Thorsen L, Rodríguez A, Córdoba JJ, Jespersen L. Inhibition of ochratoxigenic moulds by Debaryomyces hansenii strains for biopreservation of dry-cured meat products. Int J Food Microbiol. 2014 Jan; 170:70-77. https://doi.org/10.1016/j.ijfoodmicro.2013.11.004
16. Andrade MJ, Peromingo B, Rodríguez M, Rodríguez A. Effect of cured meat product ingredients on the Penicillium verrucosum growth and ochratoxin A production. Food Control. 2019 Feb; 96:310-317. https://doi.org/10.1016/j.foodcont.2018.09.014
17. Jin S-K, Shin D-K, Hur I-C. Effects of Moisture Content on Quality Characteristics of Dry-Cured Ham during Storage. Korean J Food Sci Anim Resour. 2011 Oct; 31(5):756-762. http://dx.do.org/10.5851/kosfa.2011.31.5.756
18. Coma V. Bioactive packaging technologies for extended shelf life of meat-based products. Meat Sci. 2008 Jan-Feb; 78(1–2):90-103. https://doi.org/10.1016/j.meatsci.2007.07.035
19. Campos CA, Gerschenson LN, Flores SK. Development of Edible Films and Coatings with Antimicrobial Activity. Food Bioprocess Technol. 2011 Aug; 4:849-875. https://doi.org/10.1007/s11947-010-0434-1
20. Amaro-Blanco G, Delgado-Adámez J, Martín MJ, Ramírez R. Active packaging using an olive leaf extract and high pressure processing for the preservation of sliced dry-cured shoulders from Iberian pigs. Innov Food Sci Emerg Technol. 2018 Feb; 45:1-9. https://doi.org/10.1016/j.ifset.2017.09.017
21. Ferreira M, Almeida A, Delgadillo I, Saraiva J, Cunha Â. Susceptibility of Listeria monocytogenes to high pressure processing: A review. Food Reviews International. 2016; 32(4):377-399. http://dx.doi.org/10.1080/87559129.2015.1094816
22. Clariana M, Guerrero L, Sárraga C, Díaz I, Valero Á, García-Regueiro JA. Influence of high pressure application on the nutritional, sensory and microbiological characteristics of sliced skin vacuum packed dry-cured ham. Effects along the storage period. Innov Food Sci Emerg Technol. 2011 Oct; 12(4):456–65. https://doi.org/10.1016/j.ifset.2010.12.008
23. Pérez-Baltar A, Serrano A, Bravo D, Montiel R, Medina M. Combined Effect of High Pressure Processing with Enterocins or Thymol on the Inactivation of Listeria monocytogenes and the Characteristics of Sliced Dry-cured Ham. Food Bioprocess Technol. 2019 Feb; 12(2):288-297. https://doi.org/10.1007/s11947-018-2212-4
24. Marcos B, Aymerich T, Guàrdia MD, Garriga M. Assessment of high hydrostatic pressure and starter culture on the quality properties of low-acid fermented sausages. Meat science. 2007 May; 76:46-53. https://doi.org/10.1016/j.meatsci.2006.09.020
25. Toepfl S, Siemer C, Saldaña-Navarro G, Heinz V. Overview of Pulsed Electric Fields Processing for Food. Emerg Technol Food Process (Second editional). 2014 Jan; 93-114. https://doi.org/10.1016/B978-0-12-411479-1.00006-1
26. Barba FJ, Parniakov O, Pereira SA, Wiktor A, Grimi N, Boussetta N, et all. Current applications and new opportunities for the use of pulsed electric fields in food science and industry. Food Res Int. 2015 Nov; 77:773-798. https://doi.org/10.1016/j.foodres.2015.09.015
27. Mosqueda-Melgar J, Elez-Martinez P, Raybaudi-Massilia R, Martin-Belloso O. Effects of Pulsed Electric Fields on Pathogenic Microorganisms of Major Concern in Fluid Foods: A Review. Critical reviews in food science and nutrition. 2008 Aug; 48(8):747-759. https://doi.org/10.1080/10408390701691000
28. Faridnia F, Ma QL, Bremer PJ., Burritt DJ, Hamid N, Oey I. Effect of freezing as pre-treatment prior to pulsed electric field processing on quality traits of beef muscles. Innovative Food Science & Emerging Technologies. 2015 May; 29:31-40. https://doi.org/10.1016/j.ifset.2014.09.007
29. Cummins EJ, Lyng JG, editors. Emerging Technologies in Meat Processing: Production, Processing and Technology. John Wiley & Sons; 2016.
30. Fernández A, Noriega E, Thompson A. Inactivation of Salmonella enterica serovar Typhimurium on fresh produce by cold atmospheric gas plasma technology. Food Microbiology. 2013 Feb; 33(1):24-29. https://doi.org/10.1016/j.fm.2012.08.007
31. Noriega E, Shama G, Laca A, Díaz M, Kong MG. Cold atmospheric gas plasma disinfection of chicken meat and chicken skin contaminated with Listeria innocua. Food Microbiology. 2011 Oct; 28(7):1293-1300. https://doi.org/10.1016/j.fm.2011.05.007
32. Ziuzina D, Patil S, Cullen PJ, Keener KM, Bourke P. Atmospheric cold plasma inactivation of Escherichia coli, Salmonella enterica serovar Typhimurium and Listeria monocytogenes inoculated on fresh produce. Food Microbiology. 2014 Sept; 42:109-116. https://doi.org/10.1016/j.fm.2014.02.007
33. Toldrá F, Nollet LML, editors. Advanced Technologies for Meat Processing. 2nd Edition. Boca Raton. London, New York: Taylor & Francis Group; 2017.
34. Smith TA. Amines in food. Food Chemistry. 1981 March; 6(3):169-200. https://doi.org/10.1016/0308-8146(81)90008-X
35. Santos MHS. Biogenic amines: their importance in foods. International Journal of Food Microbiology. 1996 Apr; 29(2-3):213-231. https://doi.org/10.1016/0168-1605(95)00032-1
36. Scientific Opinion on risk based control of biogenic amine formation in fermented foods. EFSA Journal. 2011 Oct; 9(10):2393 [93 pp.] https://doi.org/10.2903/j.efsa.2011.2393
37. Feiner G. Meat products handbook : practical science and technology. Cambridge, England: Woodhead Publishing; 2006.
38. Wójciak KM, Stasiak DM, Stadnik J, Ferysiuk K, Kononiuk A. The influence of sonication time on the biogenic amines formation as a critical point in uncured dry-fermented beef manufacturing. International Journal of Food Science & Technology. 2019; 54:75-83. https://doi.org/10.1111/ijfs.13906
39. Bover-Cid S, Schoppen S, Izquierdo-Pulido M, Vidal-Carou M. Relationship between biogenic amine contents and the size of dry fermented sausages. Meat Science. 1999 Apr; 51(4):305-311. https://doi.org/10.1016/S0309-1740(98)00120-X
40. Barrière C, Centeno D, Lebert A, Leroy-Sátrin S, Berdaguá JL, Talon R. Roles of superoxide dismutase and catalase of Staphylococcus xylosus in the inhibition of linoleic acid oxidation. FEMS Microbiology Letters. 2001 June; 201(2):181-185. ttps://doi.org/10.1111/j.1574-6968.2001.tb10754.x
41. Barriere C, Leroy-Setrin S, Talon R. Characterization of catalase and superoxide dismutase in Staphylococcus carnosus 833 strain. Journal of Applied Microbiology. 2001 Apr; 91(3):514-519. https://doi.org/10.1046/j.1365-2672.2001.01411.x
42. Magrinyà N, Bou R, Tres A, Rius N, Codony R, Guardiola F. Effect of Tocopherol Extract, Staphylococcus carnosus Culture, and Celery Concentrate Addition on Quality Parameters of Organic and Conventional Dry-Cured Sausages. Journal of Agricultural and Food Chemistry. 2009 Oct; 57(19):8963-8972. https://doi.org/10.1021/jf901104h

43. Rohlík B-A, Pipek P, Pánek J. The effect of natural antioxidants on the colour and lipid stability of paprika salami. Czech J. Food Sci. 2013; 31(4):307-312. https://doi.org/10.17221/327/2012-CJFS
44. Klabukova DL, Kolotvina SV, Titov EI, Mashenczeva NG. Izuchenie vliyaniya kompoziczii startovy`kh kul`tur na uroven` kholesterina v fermentirovanny`kh myasny`kh produktakh. Voprosy` pitaniya. 2017; 86(8):82-90.
45. Vinnikova LG. Tekhnolohiya myasnykh produktov. Teoreticheskie osnovy i prakticheskie rekomendatsii. Kiev: Osvita Ukrayini; 2017.
46. Saccani G, Fornelli G, Zanardi E. Characterization of Textural Properties and Changes of Myofibrillar and Sarcoplasmic Proteins in Salame Felino During Ripening. International Journal of Food Properties. 2013 May; 16(7):1460-1471. https://doi.org/10.1080/10942912.2011.595027
47. Van't Hooft B-J. Development of binding and structure in semi-dry fermented sausages: a multifactorial approach. Summary. Utrecht University; 1999.
48. Ruiz-Ramírez J, Arnau J, Serra X, Gou P. Relationship between water content, NaCl content, pH and texture parameters in dry-cured muscles. Meat Science. 2005 Aug; 70(4):579-587. https://doi.org/10.1016/j.meatsci.2005.02.007
49. Spaziani M, Torre MD, Stecchini ML. Changes of physicochemical, microbiological, and textural properties during ripening of Italian low-acid sausages. Proteolysis, sensory and volatile profiles. Meat Science. 2009 Jan; 81(1):77-85. https://doi.org/10.1016/j.meatsci.2008.06.017
50. Hughes M, Kerry J, Arendt E, Kenneally P, McSweeney P L, O'Neill E. Characterization of proteolysis during the ripening of semi-dry fermented sausages. Meat Science. 2002 Oct; 62(2):205-216. https://doi.org/10.1016/S0309-1740(01)00248-0
51. Ibañez C, Quintanilla L, Cid C, Astiasarán I, Bello J. Dry fermented sausages elaborated with Lactobacillus plantarum-staphylococcus carnosus. Part II: Effect of partial replacement of NaCl with KCl on the proteolytic and insolubilization processes. Meat Science. 1997 July; 46(3):277-284. https://doi.org/10.1016/S0309-1740(97)00022-3
52. Molly K, Demeyer D, Johansson G, Raemaekers M, Ghistelinck M, Geenen I. The importance of meat enzymes in ripening and flavour generation in dry fermented sausages. First results of a European project. Food Chemistry. 1997 August; 59(4):539-545. https://doi.org/10.1016/S0308-8146(97)00004-6
53. Katsaras K, Budras K-D. Microstructure of fermented sausage. Meat Science. 1992; 31(2):121-34. https://doi.org/10.1016/0309-1740(92)90032-Y
54. Toldrá F, Reig M. Innovations for healthier processed meats. Trends in Food Science & Technology. 2011 Sept; 22(9):517-522. https://doi.org/10.1016/j.tifs.2011.08.007
55. Gøtterup J, Olsen K, Knøchel S, Tjener K, Stahnke LH, Møller JKS. Colour formation in fermented sausages by meat-associated staphylococci with different nitrite- and nitrate-reductase activities. Meat Science. 2008 Apr; 78(4):492-501. https://doi.org/10.1016/j.meatsci.2007.07.023
56. Møller JKS, Jensen JS, Skibsted LH, Knöchel S. Microbial formation of nitrite-cured pigment, nitrosylmyoglobin, from metmyoglobin in model systems and smoked fermented sausages by Lactobacillus fermentum strains and a commercial starter culture. European Food Research and Technology. 2003 March; 216(6):463-469. https://doi.org/10.1007/s00217-003-0681-8
57. Kim T-K, Kim Y-B, Jeon K-H, Park J-D, Sung J-M, Choi H-W, et al. Effect of Fermented Spinach as Sources of Pre-Converted Nitrite on Color Development of Cured Pork Loin. Korean Journal for Food Science of Animal Resources. 2017 Feb; 37(1):105-113. http://dx.doi.org/10.5851/kosfa.2017.37.1.105
58. Nollet LM, Toldrá F, Benjakul S, Paliyath G, Hui YH. Food biochemistry and food processing. John Wiley & Sons; 2012.
59. Wakamatsu J, Nishimura T, Hattori A. A Zn–porphyrin complex contributes to bright red color in Parma ham. Meat Science. 2004 May; 67(1):95-100. https://doi.org/10.1016/j.meatsci.2003.09.012
60. Wakamatsu J, Odagiri H, Nishimura T, Hattori A. Quantitative determination of Zn protoporphyrin IX, heme and protoporphyrin IX in Parma ham by HPLC. Meat Science. 2009 May; 82(1):139-142. https://doi.org/10.1016/j.meatsci.2008.12.011
61. Wakamatsu J, Okui J, Ikeda Y, Nishimura T, Hattori A. Establishment of a model experiment system to elucidate the mechanism by which Zn–protoporphyrin IX is formed in nitrite-free dry-cured ham. Meat Science. 2004 Oct; 68(2):313-317. https://doi.org/10.1016/j.meatsci.2004.03.014
62. De Maere H, Jaros M, Dziewięcka M, De Mey E, Fraeye I, Sajewicz M, Paelinck H, Kowalska T. Determination of hemin, protoporphyrin ix, and zinc (II) protoporphyrin IX in parma ham using thin layer chromatography. Journal of Liquid Chromatography & Related Technologies. 2014; 37(20):2971-2979. https://doi.org/10.1080/10739149.2014.906995
63. De Maere H, Chollet S, De Brabanter J, Michiels C, Paelinck H, Fraeye I. Influence of meat source, pH and production time on zinc protoporphyrin IX formation as natural colouring agent in nitrite-free dry fermented sausages. Meat Science. 2018 Jan; 135:46-53. https://doi.org/10.1016/j.meatsci.2017.08.024
64. Kim HJ, Sung NY, Yong HI, Kim H, Lim Y, Ko KH, et al. Mutagenicity and immune toxicity of emulsion-type sausage cured with plasma-treated water. Korean journal for food science of animal resources. 2016 Aug; 36(4):494-498. https://doi.org/10.5851/kosfa.2016.36.4.494
65. Jung S, Kim HJ, Park S, Yong HI, Choe JH, et al. Color developing capacity of plasma-treated water as a source of nitrite for meat curing. Korean journal for food science of animal resources. 2015 Oct; 35(5):703-706. https://doi.org/10.5851/kosfa.2015.35.5.703
66. Yong HI, Park J, Kim H-J, Jung S, Park S, et al. An innovative curing process with plasma-treated water for production of loin ham and for its quality and safety. Plasma Processes and Polymers. 2017; 15(2): 1-9. e1700050, https://doi.org/10.1002/ppap.201700050
67. Wójciak KM, Krajmas P, Solska E, Dolatowski ZJ. Application of acid whey and set milk to marinate beef with reference to quality parameters and product safety. Acta Sci. Pol. Technol. Aliment. 2015 Oct-Dec; 14(4):293-302. https://doi.org/10.17306/J.AFS.2015.4.30
68. Wójciak KM, Dolatowski ZJ. Effect of acid whey on nitrosylmyoglobin concentration in uncured fermented sausage. LWT – Food Science and Technology. 2015; 64(2):713-719. http://dx.doi.org/10.1016/j.lwt.2015.06.009
69. Møller JK, Jensen JS, Olsen MB, Skibsted LH, Bertelsen G. Effect of residual oxygen on colour stability during chill storage of sliced, pasteurised ham packaged in modified atmosphere. Meat Science. 2000 April; 54(4):399-405. https://doi.org/10.1016/S0309-1740(99)00116-3
70. Marco A, Navarro JL, Flores M. The influence of nitrite and nitrate on microbial, chemical and sensory parameters of slow dry fermented sausage. Meat Science. 2006 Aug; 73(4):660-673. DOI:10.1016/j.meatsci.2006.03.011
71. Casaburi A, Aristoy M-C, Cavella S, Di Monaco R, Ercolini D, et al. Biochemical and sensory characteristics of traditional fermented sausages of Vallo di Diano (Southern Italy) as affected by the use of starter cultures. Meat Science. 2007 June; 76(2):295-307. https://doi.org/10.1016/j.meatsci.2006.11.011
72. Aro Aro JM, Nyam-Osor P, Tsuji K, Shimada K, Fukushima M, Sekikawa M. The effect of starter cultures on proteolytic changes and amino acid content in fermented sausages. Food Chemistry. 2010 March; 119(1):279-285. https://doi.org/10.1016/j.foodchem.2009.06.025

73. Zhao L, Jin Y, Ma C, Song H, Li H, Wang Z, et al. Physico-chemical characteristics and free fatty acid composition of dry fermented mutton sausages as affected by the use of various combinations of starter cultures and spices. Meat Science. 2011 Aug; 88(4):761-766. https://doi.org/10.1016/j.meatsci.2011.03.010
74. Waade C, Stahnke LH. Dried sausages fermented with staphylococcus xylosus at different temperatures and with different ingredient levels. Part IV. Amino acid profile. Meat Science. 1997 May; 46(1):101-114. https://doi.org/10.1016/S0309-1740(96)00089-7
75. Wang X, Zhou P, Cheng J, Chen Z, Liu X. Use of straw mushrooms (Volvariella volvacea) for the enhancement of physicochemical, nutritional and sensory profiles of Cantonese sausages. Meat Science. 2018 Dec; 146:18-25. https://doi.org/10.1016/j.meatsci.2018.07.033
76. Soto AM, Garcia ML, Selgas MD. Technological and Sensory Properties of Calcium-Enriched Dry Fermented Sausages: A Study of the Calcium Bioavailability. Journal of Food Quality. 2016 Oct; 39(5):476-486. https://doi.org/10.1111/jfq.12223
77. Ruusunen M, Puolanne E. Reducing sodium intake from meat products. Meat Science. 2005 Jul; 70(3):531-541. https://doi.org/10.1016/j.meatsci.2004.07.016
78. Dos Santos BA, Campagnol PCB, da Cruz AG, Morgano MA, Wagner R, Pollonio MAR. Is There a Potential Consumer Market for Low-Sodium Fermented Sausages? Journal of Food Science. 2015 March; 80(5):1093-1099. https://doi.org/10.1111/1750-3841.12847
79. Corral S, Salvador A, Flores M. Salt reduction in slow fermented sausages affects the generation of aroma active compounds. Meat Science. 2013 March; 93(3):776-785. https://doi.org/10.1016/j.meatsci.2012.11.040
80. Blesa E, Aliño M, Barat JM, Grau R, Toldrá F, Pagán MJ. Microbiology and physico-chemical changes of dry-cured ham during the post-salting stage as affected by partial replacement of NaCl by other salts. Meat Science. 2008 Jan-Feb; 78(1-2):135-142. https://doi.org/10.1016/j.meatsci.2007.07.008
81. Guarner F, Aamir G. Khan AG, Garisch J, Eliakim R, Gangl A, et al. Probiotyky ta prebiotyky. World Gastroenterology Organization [Internet]. 2008 [cited 2019 Mar 13]. Available from: http://www.worldgastroenterology.org/UserFiles/file/guidelines/probiotics-russian-2008.pdf
82. Erkkilä S, Petäjä E, Eerola S, Lilleberg L, Mattila-Sandholm T, Suihko M-L. Flavour profiles of dry sausages fermented by selected novel meat starter cultures. Meat Science. 2001 June; 58(2):111-116. https://doi.org/10.1016/S0309-1740(00)00135-2
83. Klingberg TD, Axelsson L, Naterstad K, Elsser D, Budde BB. Identification of potential probiotic starter cultures for Scandinavian-type fermented sausages. International Journal of Food Microbiology. 2006 Jan; 105(3):419-431. https://doi.org/10.1016/j.ijfoodmicro.2005.03.020
84. Hettiarachchy NS, Sato K, Marshall MR, Kannan A. Bioactive food proteins and peptides: applications in human health. Boca Raton: CRC Press; 2011.
85. Owusu-Apenten R. Bioactive Peptides. Boca Raton: CRC Press; 2010.
86. Nollet L. M. L., Toldrá F. Advanced technologies for meat processing. 1st Edition. CRC Press; 2006.
87. Mudgil D., Barak S. Functional foods: sources and health benefits. Jodhpur, India: Scientific Publishers; 2017.
88. Garcia-Iniguez de Ciriano M, Larequi E, Rehecho S, Calvo MI, Cavero RY, Navarro-Blasco I, et al. Selenium, iodine, omega-3 PUFA and natural antioxidant from melissa officinalis L.: A combination of components from healthier dry fermented sausages formulation. Meat Science. 2010 Jun; 85(2):274-279. https://doi.org/10.1016/j.meatsci.2010.01.012
89. Valencia I, Ansorena D, Astiasarán I. Nutritional and sensory properties of dry fermented sausages enriched with n−3 PUFAs. Meat Science. 2006 Apr; 72(4):727-733. https://doi.org/10.1016/j.meatsci.2005.09.022
90. Josquin NM, Linssen JPH, Houben JH. Quality characteristics of Dutch-style fermented sausages manufactured with partial replacement of pork back-fat with pure, pre-emulsified or encapsulated fish oil. Meat Science. 2012 Jan; 90(1):81-86. https://doi.org/10.1016/j.meatsci.2011.06.001

СУЧАСНІ ТЕНДЕНЦІЇ У ВИРОБНИЦТВІ ФЕРМЕНТОВАНИХ М'ЯСНИХ ПРОДУКТІВ

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Анотація. Роботу присвячено узагальненню й аналізу основних проблем виробництва ферментованих м'ясопродуктів, відображених в наукових публікаціях фахівців м'ясопереробної галузі. Сучасні дослідження науковців у всьому світі присвячено досягненню біо- та мікробіологічної безпеки, структуроутворенню, використанню нових видів сировини, особливостям кольороутворення, формуванню сенсорних властивостей, підвищенню біологічної цінності сирокопчених і сиров'ялених виробів. У роботі підкреслено, що якість готової продукції та стабільність проведення технологічного процесу залежать від якості сировини, властивостей власної мікробіоти сировини та/або внесених стартових культур мікроорганізмів. Висвітлено можливість покращення санітарного стану сировини і зменшення впливу патогенних мікроорганізмів за рахунок використання ультразвуку, гідростатичного високого тиску, високоінтенсивного пульсуючого електричного поля, холодної плазми. Також, окрім фізичних методів обробки, ефективним є використання конкуруючої мікрофлори, екстрактів пряно-ароматичних рослин, комбінування солильних сумішей, пакування. Вказано, що формування структури готової продукції залежить від параметрів проведення технологічного процесу, діяльності екзо- та ендоферментів та рецептурного складу. Відображено, що колір ферментованих м'ясопродуктів і його стабільність залежать від вмісту природних пігментів та умов їхньої взаємодії з нітритами під дією мікроорганізмів з нітритредуктазною активністю і pH середовища. Відмічено можливість отримання характерного рожево-червоного кольору м'ясопродуктів без використання нітритів. Наведено результати досліджень можливості варіювання органолептичних показників готової продукції за рахунок моделювання інгредієнтного складу та умов ферментації. Висвітлено можливість створення нових видів ферментованих м'ясопродуктів функціонального призначення за рахунок введення до їх складу ω-3 жирних кислот, пробіотиків, макро-, мікроелементів тощо.

Ключові слова: м'ясні продукти, ферментація, стартові культури, безпека, колір, біологічна цінність

Список літератури:

1. Risk-based control of food-borne pathogens *Listeria monocytogenes* and *Salmonella enterica* in the Italian fermented sausages Cacciatore and Felino / Mataragas M. et al. // Meat Scince. 2015. Vol. 103. P. 39-45. https://doi.org/10.1016/j.meatsci.2015.01.002
2. Improving safety of salami by application of bacteriocins produced by an autochthonous *Lactobacillus curvatus* isolate / De Souza Barbosa M. et al. // Food Microbiol. 2015. Vol. 46. P.254-262. https://doi: 10.1016/j.fm.2014.08.004
3. Bacteriocinogenic activity from starter culture used in Spanish meat industry / C Nieto-Lozano J. et al. // Meat science. 2002. Vol. 62. P. 237-243. https://doi: 10.1016/S0309-1740(01)00252-2
4. Control of *Listeria monocytogenes* Contamination in Ready-to-Eat / Zhu M. et al. // Meat Products. Compr Rev Food Sci Food Saf. 2005. Vol. 4, No. 2. P. 34-42. https://doi.org/10.1111/j.1541-4337.2005.tb00071.x
5. Denaturing Gradient Gel Electrophoresis Analysis of the 16S rRNA Gene V1 Region To Monitor Dynamic Changes in the Bacterial Population during Fermentation of Italian Sausages / Cocolin L. et al. // Appl Environ Microbiol. 2001. Vol. 67, No. 11. P. 5113-5121. DOI: 10.1128/AEM.67.11.5113-5121.2001
6. A novel polymerase chain reaction (PCR) – Denaturing gradient gel electrophoresis (DGGE) for the identification of Micrococcaceae strains involved in meat fermentations. Its application to naturally fermented Italian sausages / Cocolin L. // Meat Science. 2001. Vol. 58, No. 1. P. 59-64. DOI: 10.1016/s0309-1740(00)00131-5
7. Characterisation of naturally fermented sausages produced in the North East of Italy / Comi G. et al. // Meat Sci. 2005. Vol. 69, No. 3. P. 381-92. https://doi.org/10.1016/j.meatsci.2004.08.007
8. Удосконалення технології виробництва ферментованих ковбас з використанням композиційних добавок / Єресько Г.О. та ін. // Вісник аграрної науки. 2007. № 6. С. 66-69.
9. Työppönen S., Petäjä E., Mattila-Sandholm T. Bioprotectives and probiotics for dry sausages // Int J Food Microbiol. 2003. Vol. 83, No. 3. P. 233–44. DOI:10.1016/s0168-1605(02)00379-3
10. El Adab S., Essid I., Hassouna M. Microbiological, biochemical and textural characteristics of a tunisian dry fermented poultry meat sausage inoculated with selected starter cultures // J Food Saf. 2015. Vol. 35, No. 1. P. 75-85. DOI: 10.1111/jfs.12164
11. Kordowska-Wiater M., Stasiak D. Effect of ultrasound on survival of Gram-negative bacteria on chicken skin surface // Bull Vet Inst in Pulawy. 2011. Vol. 55, No. 2. P. 207-210.
12. Reduction of microorganisms in marinated poultry breast using oregano essential oil and power ultrasound / Piñon M.I. et al. // Acta Alimentaria. 2015. Vol. 44, No. 4. P. 527-533. DOI: 10.1556/066.2015.44.0024
13. Lipolysis, proteolysis and sensory characteristics of a Spanish fermented dry-cured meat product (salchichón) with oregano essential oil used as surface mold inhibitor / Martín-Sánchez A.M. et al. // Meat Science. 2011. Vol. 89, No. 1. P. 35-44. https://doi.org/10.1016/j.meatsci.2011.03.018
14. World Health Organization (WHO). Mycotoxins // Geneva: WHO; 2018. URL: https://www.who.int/news-room/fact-sheets/detail/mycotoxins (viewed on: 25.04.2019).
15. Inhibition of ochratoxigenic moulds by *Debaryomyces hansenii* strains for biopreservation of dry-cured meat products / Andrade M.J. et al. // Int J Food Microbiol. 2014. Vol. 170. P. 70-77. https://doi.org/10.1016/j.ijfoodmicro.2013.11.004
16. Effect of cured meat product ingredients on the *Penicillium verrucosum* growth and ochratoxin A production / Andrade M.J. et al. // Food Control. 2019. Vol. 96. P. 310-317. https://doi.org/10.1016/j.foodcont.2018.09.014
17. Jin S.-K., Shin D.-K., Hur I.-C. Effects of Moisture Content on Quality Characteristics of Dry-Cured Ham during Storage // Korean J. Food Sci Anim Resour. 2011. Vol. 31, No. 5. P. 756-762. DOI http://dx.do.org/10.5851/kosfa.2011.31.5.756
18. Coma V. Bioactive packaging technologies for extended shelf life of meat-based products // Meat Sci. 2008. Vol. 78, No. 1–2. P. 90-103. https://doi.org/10.1016/j.meatsci.2007.07.035
19. Campos C.A., Gerschenson L.N., Flores S.K. Development of Edible Films and Coatings with Antimicrobial Activity // Food Bioprocess Technol. 2011. Vol. 4. P. 849-875. https://doi.org/10.1007/s11947-010-0434-1
20. Active packaging using an olive leaf extract and high pressure processing for the preservation of sliced dry-cured shoulders from Iberian pigs / Amaro-Blanco G. et al. // Innov Food Sci Emerg Technol. 2018. Vol. 45. P. 1-9. https://doi.org/10.1016/j.ifset.2017.09.017
21. Susceptibility of *Listeria monocytogenes* to high pressure processing: A review / Ferreira M. et al. // Food Reviews International. 2016. Vol. 32, No. 4. P. 377-399. http://dx.doi.org/10.1080/87559129.2015.1094816
22. Influence of high pressure application on the nutritional, sensory and microbiological characteristics of sliced skin vacuum packed dry-cured ham. Effects along the storage period /Clariana M. et al. // Innov Food Sci Emerg Technol. 2011. Vol. 12, No. 4. P. 456-465. https://doi.org/10.1016/j.ifset.2010.12.008
23. Combined Effect of High Pressure Processing with Enterocins or Thymol on the Inactivation of *Listeria monocytogenes* and the Characteristics of Sliced Dry-cured Ham / Pérez-Baltar A. et al. // Food Bioprocess Technol. 2019. Vol. 12, No. 2. P. 288-297. https://doi.org/10.1007/s11947-018-2212-4
24. Assessment of high hydrostatic pressure and starter culture on the quality properties of low-acid fermented sausages / Marcos B. et al. // Meat science. 2007. Vol. 76. P. 46-53. https://doi.org/10.1016/j.meatsci.2006.09.020
25. Overview of Pulsed Electric Fields Processing for Food / Toepfl S. et al. // Emerg Technol Food Process (Second editional). 2014. P. 93-114. https://doi.org/10.1016/B978-0-12-411479-1.00006-1
26. Current applications and new opportunities for the use of pulsed electric fields in food science and industry / Barba F.J. et al. // Food Res Int. 2015. Vol. 77. P. 773-798. https://doi.org/10.1016/j.foodres.2015.09.015
27. Effects of Pulsed Electric Fields on Pathogenic Microorganisms of Major Concern in Fluid Foods: A Review / Mosqueda-Melgar J. et al. // Critical reviews in food science and nutrition. 2008. Vol. 48, No. 8. P. 747-759. https://doi.org/10.1080/10408390701691000
28. Effect of freezing as pre-treatment prior to pulsed electric field processing on quality traits of beef muscles / Faridnia F. et al. // Innovative Food Science & Emerging Technologies. 2015. Vol. 29. P. 31-40. https://doi.org/10.1016/j.ifset.2014.09.007
29. Cummins E.J., Lyng J.G. Emerging Technologies in Meat Processing: Production, Processing and Technology. John Wiley & Sons, 2016. 448 p.
30. Fernández A., Noriega E., Thompson A. Inactivation of *Salmonella enterica* serovar Typhimurium on fresh produce by cold atmospheric gas plasma technology // Food Microbiology. 2013. Vol. 33, No. 1. P. 24-29. https://doi.org/10.1016/j.fm.2012.08.007
31. Cold atmospheric gas plasma disinfection of chicken meat and chicken skin contaminated with *Listeria innocua* / Noriega E. et al. // Food Microbiology. 2011. Vol. 28, No. 7. P. 1293-1300. https://doi.org/10.1016/j.fm.2011.05.007
32. Atmospheric cold plasma inactivation of *Escherichia coli*, *Salmonella enterica* serovar Typhimurium and *Listeria monocytogenes* inoculated on fresh produce / Ziuzina D. et al. // Food Microbiology. 2014. Vol. 42. P. 109-116. https://doi.org/10.1016/j.fm.2014.02.007
33. Toldrá F., Nollet L.M.L. Advanced Technologies for Meat Processing. 2nd Edition. Boca Raton. London, New York: Taylor & Francis Group, 2017. 721 p.
34. Smith T.A. Amines in food // Food Chemistry. 1981. Vol. 6, No. 3. P. 169-200. https://doi.org/10.1016/0308-8146(81)90008-X

35. Santos M.H.S. Biogenic amines: their importance in foods // International Journal of Food Microbiology. 1996. Vol. 29, Vol. 2–3. P. 213-231. https://doi.org/10.1016/0168-1605(95)00032-1
36. Scientific Opinion on risk based control of biogenic amine formation in fermented foods // EFSA Journal. 2011. Vol. 9, No. 10. P. 2393 [93 pp.] https://doi.org/10.2903/j.efsa.2011.2393
37. Feiner G. Meat products handbook : practical science and technology. Cambridge, England: Woodhead Publishing; 2006. 672 p.
38. The influence of sonication time on the biogenic amines formation as a critical point in uncured dry-fermented beef manufacturing / Wójciak K.M. et al. // International Journal of Food Science & Technology. 2019. Vol. 54. P. 75-83. https://doi.org/10.1111/ijfs.13906
39. Relationship between biogenic amine contents and the size of dry fermented sausages / Bover-Cid S. et al. // Meat Science. 1999. Vol. 51, No. 4. P. 305-311. https://doi.org/10.1016/S0309-1740(98)00120-X
40. Roles of superoxide dismutase and catalase of Staphylococcus xylosus in the inhibition of linoleic acid oxidation / Barrière C. et al. // FEMS Microbiology Letters. 2001. Vol. 201, No. 2. P. 181-185. DOI:10.1111/j.1574-6968.2001.tb10754.x
41. Barriere C., Leroy-Setrin S., Talon R. Characterization of catalase and superoxide dismutase in *Staphylococcus carnosus* 833 strain // Journal of Applied Microbiology. 2001. Vol. 91, No. 3. P. 514-519. DOI:10.1046/j.1365-2672.2001.01411.x
42. Effect of Tocopherol Extract, *Staphylococcus carnosus* Culture, and Celery Concentrate Addition on Quality Parameters of Organic and Conventional Dry-Cured Sausages / Magrinyà N. et al. // Journal of Agricultural and Food Chemistry. 2009. Vol. 57, No. 19. P. 8963-8972. DOI: 10.1021/jf901104h
43. Rohlík B.-A., Pipek P., Pánek J. The effect of natural antioxidants on the colour and lipid stability of paprika salami // Czech J. Food Sci. 2013. Vol. 31, No. 4. P. 307-312. https://doi.org/10.17221/327/2012-CJFS
44. Изучение влияния композиций стартовых культур на уровень холестерина в ферментированных мясных продуктах / Клабукова Д.Л. и др. // Вопросы питания. 2017. Т.86, № 8 С.82-90.
45. Винникова Л.Г. Технология мясных продуктов. Теоретические основы и практические рекомендации: учебник. Киев: Освіта України, 2017. 364 с.
46. Saccani G., Fornelli G., Zanardi E. Characterization of Textural Properties and Changes of Myofibrillar and Sarcoplasmic Proteins inSalame Felino During Ripening // International Journal of Food Properties. 2013. Vol. 16, No. 7. P. 1460-1471. https://doi.org/10.1080/10942912.2011.595027
47. Van't Hooft B.-J. Development of binding and structure in semi-dry fermented sausages: a multifactorial approach. Summary. Utrecht University, 1999. 173 p.
48. Relationship between water content, NaCl content, pH and texture parameters in dry-cured muscles /Ruiz-Ramírez J. et al. // Meat Science. 2005. Vol. 70. No. 4. P. 579-587. https://doi.org/10.1016/j.meatsci.2005.02.007
49. Spaziani M., Torre M.D., Stecchini M.L. Changes of physicochemical, microbiological, and textural properties during ripening of Italian low-acid sausages. Proteolysis, sensory and volatile profiles // Meat Science. 2009. Vol. 81. No. 1. P. 77-85. DOI:10.1016/j.meatsci.2008.06.017
50. Characterization of proteolysis during the ripening of semi-dry fermented sausages / Hughes M. et al. // Meat Science. 2002. Vol. 62. No. 2. P. 205-216. https://doi.org/10.1016/S0309-1740(01)00248-0
51. Dry fermented sausages elaborated with Lactobacillus plantarum-staphylococcus carnosus. Part II: Effect of partial replacement of NaCl with KCl on the proteolytic and insolubilization processes / Ibañez C. et al. // Meat Science. 1997. Vol. 46. No. 3. P. 277-284. https://doi.org/10.1016/S0309-1740(97)00022-3
52. The importance of meat enzymes in ripening and flavour generation in dry fermented sausages. First results of a European project / Molly K. et al. // Food Chemistry. 1997. Vol. 59. No. 4. P. 539-545. https://doi.org/10.1016/S0308-8146(97)00004-6
53. Katsaras K., Budras K.-D. Microstructure of fermented sausage // Meat Science. 1992. Vol. 31. No. 2. P. 121-134. https://doi.org/10.1016/0309-1740(92)90032-Y
54. Toldrá F., Reig M. Innovations for healthier processed meats. Trends in Food Science & Technology. 2011. Vol. 22. No. 9. P. 517-522. https://doi.org/10.1016/j.tifs.2011.08.007
55. Colour formation in fermented sausages by meat-associated staphylococci with different nitrite- and nitrate-reductase activities / Gøtterup J. et al. // Meat Science. 2008. Vol. 78. No. 4. P. 492-501. DOI:10.1016/j.meatsci.2007.07.023
56. Microbial formation of nitrite-cured pigment, nitrosylmyoglobin, from metmyoglobin in model systems and smoked fermented sausages by Lactobacillus fermentum strains and a commercial starter culture / Møller J.K.S. et al. // European Food Research and Technology. 2003. Vol. 216. No. 6. P. 463-469. DOI: 10.1007/s00217-003-0681-8
57. Effect of Fermented Spinach as Sources of Pre-Converted Nitrite on Color Development of Cured Pork Loin / Kim T.-K. et al. // Korean Journal for Food Science of Animal Resources. 2017. Vol. 37. No. 1. P. 105-113. http://dx.doi.org/10.5851/kosfa.2017.37.1.105
58. Nollet L.M. et al. Food biochemistry and food processing. John Wiley & Sons, 2012. 912 p.
59. Wakamatsu J., Nishimura T., Hattori A. A Zn–porphyrin complex contributes to bright red color in Parma ham // Meat Science. 2004. Vol. 67. No. 1. P. 95-100. DOI:10.1016/j.meatsci.2003.09.012
60. Quantitative determination of Zn protoporphyrin IX, heme and protoporphyrin IX in Parma ham by HPLC / Wakamatsu J. et al. // Meat Science. 2009. Vol. 82. No. 1. P. 139-142. DOI:10.1016/j.meatsci.2008.12.011
61. Establishment of a model experiment system to elucidate the mechanism by which Zn–protoporphyrin IX is formed in nitrite-free dry-cured ham / Wakamatsu J. et al. // Meat Science. 2004. Vol. 68. No. 2. P. 313-317. DOI:10.1016/j.meatsci.2004.03.014
62. Determination of hemin, protoporphyrin ix, and zinc(II) protoporphyrin IX in parma ham using thin layer chromatography / De Maere H. et al. // Journal of Liquid Chromatography & Related Technologies. 2014, Vol. 37. No. 20. P. 2971-2979. https://doi.org/10.1080/10739149.2014.906995
63. Influence of meat source, pH and production time on zinc protoporphyrin IX formation as natural colouring agent in nitrite-free dry fermented sausages / De Maere H. et al. // Meat Science. 2018. Vol. 135. P. 46-53. DOI:10.1016/j.meatsci.2017.08.024
64. Mutagenicity and immune toxicity of emulsion-type sausage cured with plasma-treated water / Kim H.J. et al. // Korean journal for food science of animal resources. 2016. Vol. 36. No. 4. P. 494-498. DOI:10.5851/kosfa.2016.36.4.494
65. Color developing capacity of plasma-treated water as a source of nitrite for meat curing / Jung S. et al. // Korean journal for food science of animal resources. 2015. Vol. 35. No. 5. P. 703-706. DOI:10.5851/kosfa.2015.35.5.703
66. An innovative curing process with plasma-treated water for production of loin ham and for its quality and safety / Yong H.I. et al. // Plasma Processes and Polymers. 2017. Vol. 15. No. 2. P. 1-9. e1700050, https://doi.org/10.1002/ppap.201700050
67. Application of acid whey and set milk to marinate beef with reference to quality parameters and product safety / Wójciak K.M. et al. // Acta Sci. Pol. Technol. Aliment. 2015. Vol. 14. No. 4. P. 293-302. DOI:10.17306/J.AFS.2015.4.30
68. Wójciak K.M., Dolatowski Z.J. Effect of acid whey on nitrosylmyoglobin concentration in uncured fermented sausage // LWT – Food Science and Technology. 2015. Vol. 64. No. 2. P. 713-719. http://dx.doi.org/10.1016/j.lwt.2015.06.009
69. Effect of residual oxygen on colour stability during chill storage of sliced, pasteurised ham packaged in modified atmosphere / Møller J.K. et al. // Meat Science. 2000. Vol. 54. No. 4. P. 399-405. https://doi.org/10.1016/S0309-1740(99)00116-3

70. Marco A., Navarro J.L., Flores M. The influence of nitrite and nitrate on microbial, chemical and sensory parameters of slow dry fermented sausage // Meat Science. 2006. Vol. 73. No. 4. P. 660-673. DOI:10.1016/j.meatsci.2006.03.011
71. Biochemical and sensory characteristics of traditional fermented sausages of Vallo di Diano (Southern Italy) as affected by the use of starter cultures / Casaburi A. et al. // Meat Science. 2007. Vol. 76. No. 2. P. 295-307. https://doi.org/10.1016/j.meatsci.2006.11.011
72. The effect of starter cultures on proteolytic changes and amino acid content in fermented sausages / Aro Aro J.M. et al. // Food Chemistry. 2010. Vol. 119. No. 1. P. 279-285. https://doi.org/10.1016/j.foodchem.2009.06.025
73. Physico-chemical characteristics and free fatty acid composition of dry fermented mutton sausages as affected by the use of various combinations of starter cultures and spices / Zhao L. et al. // Meat Science. 2011. Vol. 88. No. 4. P. 761-766. https://doi.org/10.1016/j.meatsci.2011.03.010
74. Waade C., Stahnke L.H. Dried sausages fermented with staphylococcus xylosus at different temperatures and with different ingredient levels. Part IV. Amino acid profile. Meat Science. 1997. Vol. 46. No. 1. P. 101-114. https://doi.org/10.1016/S0309-1740(96)00089-7
75. Use of straw mushrooms (Volvariella volvacea) for the enhancement of physicochemical, nutritional and sensory profiles of Cantonese sausages / Wang X. et al. // Meat Science. 2018. Vol. 146. P. 18-25. https://doi.org/10.1016/j.meatsci.2018.07.033
76. Soto A.M., Garcia M.L., Selgas M.D. Technological and Sensory Properties of Calcium-Enriched Dry Fermented Sausages: A Study of the Calcium Bioavailability // Journal of Food Quality. 2016. Vol. 39. No. 5. P. 476-486. https://doi.org/10.1111/jfq.12223
77. Ruusunen M., Puolanne E. Reducing sodium intake from meat products // Meat Science. 2005. Vol. 70. No. 3. P. 531-541. https://doi.org/10.1016/j.meatsci.2004.07.016
78. Is There a Potential Consumer Market for Low-Sodium Fermented Sausages? / Dos Santos B.A. et al. // Journal of Food Science. 2015. Vol. 80. No. 5. P S1093-S1099. https://doi.org/10.1111/1750-3841.12847
79. Corral S., Salvador A., Flores M. Salt reduction in slow fermented sausages affects the generation of aroma active compounds // Meat Science. 2013. Vol. 93. No. 3. P. 776-785. https://doi.org/10.1016/j.meatsci.2012.11.040
80. Microbiology and physico-chemical changes of dry-cured ham during the post-salting stage as affected by partial replacement of NaCl by other salts / Blesa E. et al. // Meat Science. 2008. Vol. 78. No. 1-2. P. 135-142. https://doi.org/10.1016/j.meatsci.2007.07.008
81. Пробиотики и пребиотики. /Guarner F. et al. // World Gastroenterology Organisation. 2008. URL: http://www.worldgastroenterology.org/UserFiles/file/guidelines/probiotics-russian-2008.pdf (viewed on: 25.04.2019).
82. Flavour profiles of dry sausages fermented by selected novel meat starter cultures / Erkkilä S. et al. // Meat Science. 2001. Vol. 58. No. 2. P. 111-116. DOI: 10.1016/S0309-1740(00)00135-2
83. Identification of potential probiotic starter cultures for Scandinavian-type fermented sausages / Klingberg T.D. et al. // International Journal of Food Microbiology. 2006. Vol. 105. No. 3. P. 419-431. DOI: 10.1016/j.ijfoodmicro.2005.03.020
84. Bioactive food proteins and peptides: applications in human health / Hettiarachchy N.S. et al.// Boca Raton: CRC Press, 2011. 368 p.
85. Owusu-Apenten R. Bioactive Peptides. Boca Raton: CRC Press, 2010. 414 p.
86. Nollet L. M. L., Toldrá F. Advanced technologies for meat processing. 1st Edition. CRC Press, 2006. 483 p.
87. Mudgil D., Barak S. Functional foods: sources and health benefits. Jodhpur, India: Scientific Publishers. 2017. 396 p.
88. Selenium, iodine, omega-3 PUFA and natural antioxidant from melissa officinalis L.: A combination of components from healthier dry fermented sausages formulation / Garcia-Iniguez de Ciriano M. et al. // Meat Science. 2010. Vol. 85. No. 2. P. 274-279. doi:10.1016/j.meatsci.2010.01.012
89. Valencia I., Ansorena D., Astiasarán I. Nutritional and sensory properties of dry fermented sausages enriched with n−3 PUFAs // Meat Science. 2006. Vol. 72. No. 4. P. 727-733. https://doi.org/10.1016/j.meatsci.2005.09.022
90. Josquin N.M., Linssen J.P.H., Houben J.H. Quality characteristics of Dutch-style fermented sausages manufactured with partial replacement of pork back-fat with pure, pre-emulsified or encapsulated fish oil // Meat Science. 2012. Vol. 90. No. 1. P. 81-86. DOI:10.1016/j.meatsci.2011.06.001