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IMPACT OF LOW-TEMPERATURE LONG-TIME PROCESSING ON QUALITY CHARACTERISTICS AND SAFETY OF WHOLE-MUSCLE PORK PRODUCTS

Olha V. Synytsia*, Lydmila H. Vinnikova, Halyna V. Shlapak, Anna S. Palamarchuk
Odesa National University of Technology, St. Kanatna, 112, Odessa, 65039, Ukraine
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Abstract

The parameters and methods of meat temperature treatment have a significant impact on its quality, biological value and technical and economic characteristics, which is of particular importance for a modern manufacturer. The development of new heat treatment modes for the production of high-quality meat products is a priority direction for the meat processing industry. Aim. Investigation of the use of low-temperature modes of processing meat raw materials on the physicochemical, technological, organoleptic properties and microbiological safety of finished cooked and cooked-smoked pork products. Methods. The developed temperature and time parameters of heat treatment of pork meat were investigated; microbiological and organoleptic studies were conducted, the yield of the finished product was calculated, amino-ammonium nitrogen, residual activity of acid phosphatase, pH and acid number were determined. Results. The developed temperature treatment parameters are sufficient for inactivating the necessary amount of microorganisms and ensuring the safety of the product. The manufactured products do not contain pathogenic and conditionally pathogenic microorganisms, and the total amount of microbiota is at a low level. Products made according to the developed thermal processing modes have significantly lower weight loss and better taste characteristics compared to control samples. The study of residual acid phosphatase activity showed that all samples underwent the necessary thermal treatment and reached culinary readiness. Conclusions. Production of whole-muscle pork products under the developed modes results in less destructive changes in protein and fat components of meat, as well as to less weight loss of the finished product with effective destruction of microorganisms.

Keywords: temperature treatment; cooking method; pork meat; microbiological characteristics; quality.

ВПЛИВ НИЗЬКОТЕМПЕРАТУРНОГО ТРИВАЛОГО ОБРОБЛЕННЯ НА ЯКІСНІ ХАРАКТЕРИСТИКИ ТА БЕЗПЕЧНІСТЬ ЦІЛЬНОМ’ЯЗОВИХ ВИРОБІВ ЗІ СВИНИНИ

Ольга В. Синиця, Людмила Г. Віннікова, Галина В. Шлапак, Анна С. Паламарчук
Одеський національний технологічний університет, вул. Канатна, 112, м. Одеса, 65039, Україна

Анотація

Параметри та способи температурного оброблення м'яса в значній мірі впливають на його якість, біологічну цінність та техніко-економічні характеристики, що має особливе значення для сучасного виробника. Розроблення нових режимів термооброблення для виготовлення високоякісних м’ясних продуктів є пріоритетним напрямком для м'ясопереробної промисловості. Мета. Дослідження використання низькотемпературних режимів оброблення м'ясної сировини на фізико-хімічні, технологічні, органолептичні властивості та мікробіологічну безпеку готових варених та копчено-варених виробів зі свинини. Вдосконалення технології варених та копчено-варених виробів зі свинини з використанням режимів низькотемпературного оброблення та проведення дослідження впливу термооброблення на фізико-хімічні, технологічні, органолептичні показники та мікробіологічну безпечність готових цільном’язових виробів зі свинини. Методи. У роботі досліджені розроблені температурно-часові параметри температурного оброблення м'яса свинини; проведені мікробіологічні та органолептичні дослідження, розраховано вихід готового продукту, визначено аміно-аміачний азот, залишкову активність кислої фосфатази, pH та кислотне число. Результати. Розроблені параметри температурного оброблення є достатніми для інактивації необхідної кількості мікроорганізмів і забезпечення безпечності продукту. Виготовлені продукти не містять патогенних та умовно патогенних мікроорганізмів, а загальна кількість мікробіоти знаходиться на низькому рівні. Продукти виготовлені за розробленими режимами температурного оброблення, мають значно менші втрати маси та кращі смакові характеристики у порівнянні із контрольними зразками.

Ключові слова: температурне оброблення; спосіб приготування; м’ясо свинини; мікробіологічні показники; якість.

*Corresponding author: e-mail: oliasynytsia@gmail.com

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Introduction

The main ways to develop innovative technologies in the food industry are new food preparation technologies and the use of modern equipment, which makes it possible to improve production efficiency and product quality.

The main goals of applying new technologies in the food industry are reduction of technological losses, maximum preservation of nutritional and biological value of raw materials during thermal culinary processing, prolongation of shelf life, and ensuring high consumer properties of products [1].

In recent years, ready-to-eat foods and dishes without intensive heat treatment have become increasingly popular.

The objective of thermal treatment of meat is to achieve structural and microbiological alterations that render the meat digestible, improve its sensory properties, and ensure the safety of meat products for health throughout their shelf life [2].

Different methods of cooking meat products, temperature conditions and types of muscle result in products of different quality. Meat is cooked using different heat transfer media, such as dry-heat methods or moist heat methods such as boiling or braising. Sometimes a combination of these methods is used. The chosen heat treatment method must be appropriate for the type of meat, the amount of connective tissue, and the shape and size of the meat [3].

The heating rate of meat depends on its thermal conductivity coefficient and surface temperature. The surface temperature of the meat is influenced by the temperature of the heat source, as well as air circulation and relative humidity. [4].

The surface temperature is important for the smell, colour and taste of meat. The temperature gradient affects the rate and degree of change in the structure of proteins in meat, while the method of heat transfer affects the smell, taste and colour [3].

The quality of meat for consumers is determined by many factors, including tenderness, juiciness, taste, aroma and color of the meat product. According to most experts, taste and tenderness are the most important among these properties, especially for meat with increased toughness [5].

Improved processing methods that increase nutritional value, improve consistency and enhance desirable flavour characteristics are essential to increasing demand for meat products.

In general, optimal tenderness and juiciness, along with minimal losses during meat processing, are achieved at moderate or low temperatures. In terms of smell and taste, higher temperatures create different flavor sensations compared to low-temperature cooking. Numerous studies have shown that meat digestibility worsens with increased internal temperature [6].

A modern trend in this area is the processing of raw materials at moderate temperature modes (LT-LT processing), which allows for the production of various products such as meat, fish, poultry, gravies, and sauces while maintaining technological, structural-mechanical, and organoleptic properties, as well as microbiological safety indicators [7].

Compared to traditional cooking methods, the low temperature (50–65 °C) of the LT-LT (low temperature-long time) technology and its precise control allow for better preservation of the food's quality properties [8].

Numerous published studies [8; 9–12] have shown that LT-LT treatment improves organoleptic characteristics, reduces weight loss, and provides high nutritional and biological value to meat due to reduced losses of protein substances, vitamins, and better digestibility. It is important to note that when LT-LT processing is used, there is significant concern about the safety of the resulting product.

Our studies [13] on the effect of thermal processing on model pork samples have shown that heating the meat to a core temperature of 60°C with an exposure time of 1 hour is the optimal parameter for achieving a sufficient level of protein denaturation, microorganism inactivation, minimisation of cooking losses and achievement of culinary readiness.

The aim of this study is to investigate the influence of low-temperature modes of meat raw material processing on physicochemical, technological, organoleptic properties and microbiological safety of finished cooked and cooked-smoked pork products.

Materials and methods

In the course of the work, experimental and control samples of cooked and smoked-cooked pork loins weighing 2.5–2.8 kg and 90–95 mm in diameter were produced and a comparative analysis of the quality and safety of the finished products was carried out.

The production technology of the "Balyk" product was used as a basis, which is made from the dorsal and lumbar muscles of pork half-carcasses according to DSTU 4668:2006.
The recipe and the ratio of components are the same for both types of products. Consumption of raw materials for the production of cooked and smoked-cooked pork product 'Balyk' was carried out in accordance with the recipe (Table 1). Based on the literature and previous pilot studies, the parameters of drying, smoking and cooking of the prototypes were determined.

The control samples made according to standard technology [14] were were roasted at 50–110 °C or hot smoked at 38–55 °C, then boiled in a heating medium at 75–85 °C until the internal product temperature reached 72 °C.

The thermal processing of the experimental smoked-cooked products was carried out in three stages. First stage: The meat was heated at a heating medium temperature of 28–32 °C and a relative humidity of 35–40 % until the temperature at the least heated point of the product reached 18–22 °C. Then, the air temperature was increased to 45–50 °C with a relative humidity of 50–60 % and maintained for 30–40 minutes. Second stage: The heated meat was smoked at a temperature of 48–52 °C and a relative humidity of 50–70 % for 60–80 minutes. Third stage: The smoked meat was cooked by placing it in a cooking chamber with water at 45–50 °C, gradually increasing the heating medium temperature to 59–60 °C until the internal temperature of the meat reached 60 °C. The product processed in this way was then aged for 60 minutes.

The experimental temperature treatment modes were chosen to optimally combine microbiological safety, high quality, and minimize technological losses in the finished product. Drying at 28–32 °C followed by heating to 45–50 °C will ensure a gradual decrease in moisture without forming a hard crust, which will contribute to even smoking and preservation of juiciness. Smoking at a temperature of 48–52 °C will maintain the required level of antibacterial action of the smoking substances without excessive heating of the product. Cooking with a gradual increase in temperature to 59–60 °C will achieve the culinary readiness of the meat and effectively inactivate pathogenic microorganisms while minimizing the destruction of the protein structure. The selected parameters are based on previous studies of the effectiveness of LT-LT processing [13] and are aimed at improving the organoleptic properties (tenderness, juiciness) and reducing weight loss in the finished products.

Table 1

Recipe for whole-muscle pork products

Name of raw materials	Rate of raw materials
Unsalted Raw Material, kg (per 100 kg)	
Pork (the dorsal and lumbar muscles)	100
Spices and Seasonings, g (per 100 kg of unsalted raw material)	
Salt	2500
Sugar	300
Black pepper, ground	100
Nutmeg	60
Garlic	20
Sodium nitrite	7.5

The thermal processing of the experimental cooked products was carried out in two stages. The first stage of processing is similar to the technology for the production of experimental smoked-cooked products with one difference - processing at a temperature of 45–50 °C and relative humidity of 50–60 % was carried out for 90–120 minutes. In the second stage, the meat was cooked at a heating medium temperature of 45–50 °C and the heating medium temperature was gradually increased to 59–60 °C until the temperature in the middle of the meat reached 60 °C and the exposure was carried out for 60 minutes.

After thermal processing, all samples were cooled with cold water (10–12 °C) for 20 minutes and then with cold air until the internal temperature of the products reached 4 °C.

After the production of all samples, microbiological and organoleptic studies were conducted, the yield of the finished product was calculated, and amino-ammonia nitrogen, residual acid phosphatase activity, pH, and acid number were determined.

Microbiological studies were conducted at the Department of "Food Chemistry, Expertise, and Biotechnology" of Odesa National University of Technology (ONTU) in accordance with DSTU 8446:2015, DSTU EN 12824, GOST 30518-97,

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DSTU EN 26461-1:2002, and DSTU EN ISO 6888-1:2022. The rest of the research was carried out in the laboratories of the Department of Meat, Fish and Seafood Technology (ONTU).

The residual activity of acid phosphatase was determined in accordance with DSTU 7382:2013 and pH was determined by the potentiometric method using a Testo 205 pH meter (Germany).

To measure amino-ammoniacal nitrogen [15], a 20 g sample of meat was mixed with 100 ml of distilled water and left to stand for 15 minutes, stirring every 5 minutes. The mixture was then filtered and 10 cm^3 of the resulting extract was placed in a flask. 40 cm^3 of distilled water was added along with three drops of a 1 % alcoholic solution of phenolphthalein were added. The extract was neutralized with a 0.1 mol/dm^3 sodium hydroxide solution until a faint pink color appeared. Next, 10 cm^3 of formalin, previously neutralized with phenolphthalein, was introduced into the flask, and the contents were titrated with a 0.1 mol/dm^3 sodium hydroxide solution until a faint pink tint was observed.

The acid number was determined using a method based on titration of free fatty acids in an alcohol-ether fat solution with an aqueous potassium hydroxide solution until a persistent pink color appeared for 1 minute, in accordance with DSTU EN ISO 660:2019.

Results and their discussion

Traditionally, in the production technology of most meat products, heating to an internal temperature of 70±2 °C is sufficient for inactivating the required number of microorganisms. Such processing modes ensure the inactivation of spoilage-causing microorganisms (Pseudomonas, Lactobacillus) as well as dangerous pathogens such as Escherichia coli, Salmonella, Campylobacter, Staphylococcus aureus, and Listeria monocytogenes [16; 17].

To verify the safety of the manufactured products, microbiological studies of the qualitative and quantitative composition of the microbiota of whole-muscle pork products made according to standard and developed heat treatment modes were carried out (table 2). The studies were carried out before thermal processing and after the production of the finished products, without subjecting them to packaging.

Table 2

Results of microbiological studies

Name of the indicator	Before thermal processing	Experimental samples		Control samples	
		cooked meat	smoked-cooked meat	cooked meat	smoked-cooked meat
1	2	3	4	5	6
MAOAnM, CFU in 1 g	$7{,}5\cdot10^2$	$2{,}5\cdot10^1$	< 10	$1{,}5\cdot10^1$	< 10
ECBG in 1 g	not found	not found	not found	not found	not found
Sulfite reducing Clostridia in 1 g	not found	not found	not found	not found	not found
Pathogenic microorganisms including Salmonella in 25 g	not found	not found	not found	not found	not found
St. aureus in 1 g	not found	not found	not found	not found	not found

The analysis of microbial conditions in raw materials and manufactured whole-muscle products showed that the developed temperature treatment modes are just as effective against meat-environment microorganisms as traditional methods. The produced products do not contain pathogenic and conditionally pathogenic microorganisms, and the total viable microbial count is at a low level.

The samples subjected to smoking have a lower level of residual microbiota due to the antibacterial properties of smoking substances.

In the process of heat treatment of meat, its native properties are lost as a result of changes in the initial configuration of protein molecules, which causes changes in hydration and moisture retention, which in turn affects the juiciness and tenderness of the finished product [18; 19].

The release of moisture from meat during the temperature treatment process is accompanied by the loss of nutrients that pass into the cooking environment, which negatively affects the nutritional value of the finished product.

Mass loss during thermal processing is a critical factor, as it determines the technological yield and affects the product's cost. Therefore, comparative studies were conducted to evaluate

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the impact of the developed heat treatment modes on the yield of the final product (Fig. 1).

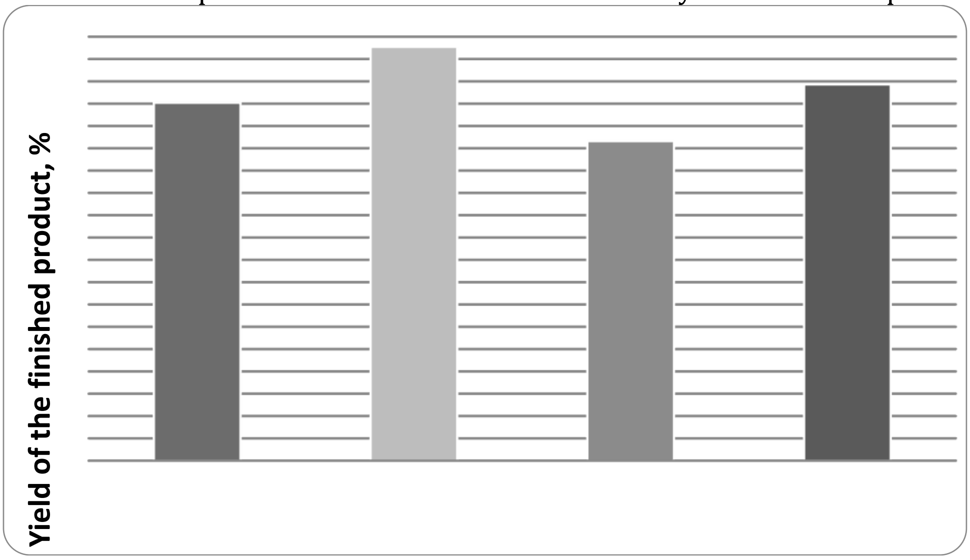

Fig. 1. Finished product yield after heat treatment: control cooked meat (1); experimental cooked meat (2); control smoked-cooked meat (3); experimental smoked-cooked meat (4)

Analysis of the results showed that the products made according to the developed temperature treatment modes have significantly lower weight losses compared to control samples of pork products. This pattern aligns with data from various studies conducted by foreign researchers [20; 22]. The experimental cooked samples are characterised by the highest yield of the finished product (92.7 %), which is 12.5 % higher than that of control cooked samples. The smoked-cooked meats had a slightly lower yield than the cooked ones.

The lower weight loss observed when using the developed processing modes is attributed to the fact that, during slow heating of meat to a temperature of 59–60 °C, protein denaturation occurs gradually and less intensively. This helps preserve the structure of muscle fibers and maintains their ability to retain moisture. In contrast, traditional heating to 72 °C causes proteins to denature quickly and abruptly, leading to significant displacement of internal moisture.

To assess the effectiveness of the developed modes and compare them with traditional thermal processing parameters, physicochemical and technological indicators were determined, specifically amino-ammonia nitrogen levels, residual acid phosphatase activity, acid number, and active acidity (pH) (table 3).

The study of amino-ammonia nitrogen showed that the samples processed at higher temperatures had a higher amount of it, which indicates a deepening of the process of protein destruction. It was found that the experimental cooked and smoked-cooked samples of balyks had a minimal increase in amino-ammonia nitrogen by 4.6 % and 4.9 %, respectively.

The results of the residual acid phosphatase activity study showed that all samples underwent the necessary temperature treatment (phenol mass fraction not exceeding 0.006 %) and reached a state of culinary readiness.

The data of Table 3 show that the active acidity shifts toward the alkaline side during temperature treatment, but the difference between the control and experimental samples is not significant.

Table 3

Physicochemical indicators of whole-muscle pork products

Name of the indicator	Before thermal processing	Experimental samples		Control samples	
		cooked meat	smoked-cooked meat	cooked meat	smoked-cooked meat
1	2	3	4	5	6
Amino-ammonia nitrogen, mg/%	36.2±0.1	37.9±0.1	38.0±0.2	38.7±0.2	40.1±0.1
Residual acid phosphatase activity, % phenol	-	0.0058± 0.0001	0.0055± 0.0001	0.0046± 0.0002	0.0049± 0.0001
pH	5.82±0.02	5.99±0.01	6.0±0.02	6.08±0.03	6.05±0.01
Acid number, mg KOH/g	1.30±0.03	1.41±0.01	1.39±0.02	1.52±0.02	1.48±0.01

An important factor in the choice of technology and processing parameters is the impact of modes on the fat component of the product.

Samples processed according to the developed modes have lower acid number and exhibit less hydrothermal fat breakdown. Compared to the original raw material, the acid number of the cooked control samples increased by 0.22 mg KOH/g, while it increased by only 0.11 mg KOH/g in the experimental samples. The acid number of the control smoked-cooked samples was 6.4 % higher than that of the experimental ones.

Taking into account the primary importance of organoleptic characteristics in the formation of consumer properties, the organoleptic evaluation of the experimental and control samples of balyks was carried out on a five-point scale (Fig. 2.)

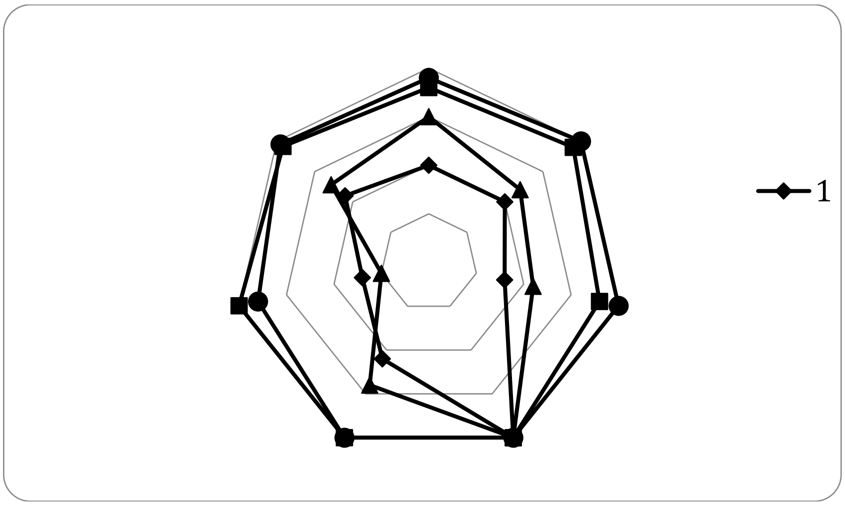

Fig. 2. Profilogram of control of organoleptic parameters of cooked meat (1); experimental cooked meat (2); control smoked-cooked meat (3); experimental smoked-cooked meat (4)

The data of the organoleptic analysis showed that the products made according to the developed modes had a more attractive appearance and better taste. This is the reason for the higher overall scores, which were 4.91 and 4.95 for the cooked and smoked-cooked experimental samples, respectively, and 4.10 and 4.28 for the control samples.

During the taste evaluation of the products, the “tenderness” parameter was assessed separately. The results of the organoleptic studies showed that the experimental samples were more tender and juicy, which contributed to their higher taste scores.

In terms of juiciness, the smoked-cooked samples had slightly lower scores than the cooked ones, which can be attributed to a higher degree of moisture loss during the smoking process due to the additional effect of temperature and prolonged contact with air of lower humidity. However, even the smoked-cooked and cooked experimental samples were superior in juiciness compared to the corresponding control samples, indicating the effectiveness of the developed processing modes in preserving the tenderness and juiciness of the product.

The results of the consistency study of pork products showed that the control samples had a tougher consistency compared to the test products, which is consistent with the results of similar foreign studies [23–26]. The more tender consistency of the experimental products can be explained by less thermal destruction of structural proteins and connective tissue under slow heating conditions, which minimized excessive fiber compaction and contributed to the formation of a more tender texture in the finished product.

There were no significant differences in the intensity of the aroma of the products. Both the experimental and control smoked-cooked samples had a pronounced smoky aroma.

Conclusions

The obtained results allow us to conclude about the superiority of the developed thermal processing modes, as they resulted in minimal destructive changes in proteins and fat component, as well as to less weight loss in the final product, while ensuring effective elimination of microorganisms.

It has been established that the use of low-temperature processing with heating to a temperature in the middle of the product of 60 °C and exposure for 60 min at a temperature of 60 °C of the heating medium leads to:

– production of microbiologically safe products;

– reduction of weight loss by 12.5 % for cooked and 12.7 % for smoked-cooked pork products;

– reduction of residual acid phosphatase activity to 0.0058 % phenol for cooked and 0.0055 % phenol for smoked-cooked products;

– more tender and juicy taste of cooked and smoked-cooked meat.

Prospects for further research are to study the influence of the developed thermal treatment modes on the nutritional and biological value of finished pork products and determining their shelf life.

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