CORE
Metadata, citation and similar papers at core.ac.uk
Provided by Eastern-European Journal of Enterprise Technologies

Щоденне зростання попиту на м'ясні вироби з оригінальними смаковими властивостями обумовлює потребу в удосконаленні переробки м'ясної сировини. Це стосується не лише технології підготовки сировини, наприклад попереднього її витримування в різноманітних маринадах та приправах. Важливе значення має саме обладнання для виготовлення м'ясних виробів без скоринки.

Запропоноване інноваційне рішення з розробки апарата для низькотемпературної обробки м'ясних виробів ІЧ-випромінюванням має певні конструктивно-технологічні особливості. Завдяки легкому переміщенню в просторі забезпечується його мобільність і портативність. Використання в ролі нагрівача гнучкого плівкового резистивного електронагрівача випромінювального типу забезпечує рівномірний розподіл теплового потоку та дозволяє повторити внутрішню геометрію робочої камери апарата. Розроблене обладнання здатне працювати в щадному низькотемпературному режимі обробки (63…85 °С) зі спрощеною автоматизацією технологічного процесу. Особливістю апарата є можливість використання вторинної теплот,и яка надходить від робочого простору апарата, шляхом поглинання її поглинальним екраном. Подальше її перетворення шляхом кондуктивного теплообміну між поглинальним екраном та елементами Пельтьє, забезпечує одночасно дві конструктивні переваги. По-перше, утворюється низьковольтна напруга живлення, яка використовується для роботи витяжних вентиляторів. Виявлено, що така напруга утворюється із досягненням температури м'ясного виробу в межах 30…35 °С. По-друге, охолоджується внутрішній технічний простір, оскільки температура зовнішньої поверхні елементів Пельтьє становить 10…15 °С. Отже, зникає необхідність у теплоізоляції апарата.

Установлено, що для м'якої свинини температура обробки становить 53…80 °С із тривалістю 5,0…8,0 год; для твердої свинини 55…80 °С із тривалістю 5,0…9,5 год. Для м'яса птиці 55…80 °С із тривалістю 4,5…6,0 год; для м'якої яловичини 55…80 °С із тривалістю 5,0…8,0 год. А жорсткої яловичини відповідно 58…83 °С із тривалістю 5,0…10,0 год. Результати дегустації підтверджують оригінальні органолептичні властивості та ефективність використання апарата

Ключові слова: м'ясні напівфабрикати, низька температура, ІЧ-випромінювання, портативність, елементами Пельтьє, оригінальні властивості

UDC 637.5
DOI: 10.15587/1729-4061.2019.154950

DEVELOPMENT OF THE PLANT FOR LOW-TEMPERATURE TREATMENT OF MEAT PRODUCTS USING IR-RADIATION

An. Zahorulko
PhD, Senior Lecturer*
E-mail: zagorulkoAN@hduht.edu.ua
Al. Zagorulko
PhD, Associate Professor*
E-mail: zagorulko@hduht.edu.ua
M. Yancheva
Doctor of Technical Sciences, Professor,
Head of Department
Department of Meat Technology**
E-mail: ya.marina11.@gmail.com
M. Serik
PhD, Associate Professor,
Director of Educational and Scientific Institute
Department of Chemistry, Microbiology
and Food Hygiene
Educational and Scientific Institute of
Food Technology and Business**
E-mail: serik_m.@hduht.edu.ua
S. Sabadash
PhD, Associate Professor***
E-mail: s.v.sabadash.@ukr.net
M. Savchenko-Pererva
PhD, Associate Professor***
E-mail: marina.saw4encko2011.@gmail.com
*Department of Processes, Devices and
Automation of Food Production**
**Kharkiv State University
of Food Technology and Trade
Klochkivska str., 333, Kharkiv, Ukraine, 61051
***Department of Engineering Technology
of Food Production
Sumy National Agrarian University
H. Kondratieva str., 160, Sumy, Ukraine, 40021

1. Introduction

The constant demand for meat products in many countries of the world stimulates the development of food industry by improving equipment for thermal treatment of various meat raw materials [1]. One of the major tasks of improvement of the heat treatment of meat raw materials is to reduce the technological losses of products' weight at all stages of their production with simultaneous ensuring high quality indicators. This is only possible under condition of using low-temperature treatment of meat raw materials using modern low-power and low metal consumption heating elements, specifically, based of infrared radiation. It is also possible to use various structural elements, particularly

© An. Zahorulko, Al. Zagorulko, M. Yancheva, M. Serik, S. Sabadash, M. Savchenko-Pererva, 2019

those that turn heat into the supply voltage to ensure the autonomy of the auxiliary apparatus equipment. It should be noted that low-temperature treatment of meat products in the range of 63...85 °C makes it possible to obtain high-quality semi-finished meat products even from problem meat with great content of tendons [2].

Therefore, an urgent task is to develop a modern plant for low-temperature treatment of meat products by IR-radiation. This plant must be mobile, portable and ensure high-quality manufacturing of meat products with the original organoleptic properties.

2. Literature review and problem statement

A daily increase in demand for high-quality meat semi-finished products with the original organoleptic properties among the population of many countries in the world causes the development of the meat industry in Ukraine [3, 4]. It is the taste of meat products that is the main indicator of their quality and allows increasing the market consumer demand, which prompts the need for a detailed study of the technological parameters and their impact on the finished product [5]. Therefore, there occurs the need to improve not only the technological process, but also the equipment for its implementation, since in most cases it is energy- and metal consuming and technologically outdated. In particular, the use of inertial high-temperature heaters with reflector units leads to appearance of non-uniform heat flow. This causes the formation of a crust and degrades the quality of the product, which is inadmissible during low-temperature treatment of most meat products. It is necessary to solve he problem whether it is possible to benefit from using low-temperature thermal energy for apparatus-technological purposes. To solve the existing structural and technological tasks, it is required to apply an innovative approach, developing a plant for low-temperature treatment of meat products by IR-radiation.

In most countries, there is a widespread use of low-temperature treatment of meat raw material, since it ensures obtaining high-quality culinary products with original taste properties [6]. The classic methods for low-temperature treatment of meat raw material include cooling, which has three variants: slow, fast and "shock" [7]. However, in most cases cooling is characterized by high energy consumption, technical difficulty and capital costs of its implementation, in this case, it makes it possible to obtain the product that is ready to use [8, 9]. Today a more modern method of low-temperature treatment of meat products is Sous vide, which is based on cooking food by its vacuuming and keeping in a water bath [10]. However, the technology of Sous vide has not been fully studied in terms of the influence of different technological factors on physical and chemical changes of the treated raw materials [11]. There also occur certain technical difficulties associated with using a water bath and controlling temperature and mode parameters in it. This causes a further search for the ways to improve this technology.

During manufacturing meat products, there are certain temperature dependences that characterize the degree of their culinary readiness and depend on the type of raw materials. After defrosting, raw materials get into the "danger zone", which is characterized by the temperature range from +5 to + 60 °C. To ensure the safety of meat products, they are subjected to heat treatment. In the range of treatment of 30...45 °C, there occurs fat softening, depending on the type of raw material, as well as the inevitable development of bacteria. Deceleration of the bacteria development and their dying are observed during treatment in the range of 53...58 °C. For example, beef becomes safe for consumption after being approximately for 1.5 hour at the temperature of 55 °C [12].

The basic temperature of meat products treatment is 60 °C, which leads to a change in the color of meat raw material, due to the destruction of proteins of myoglobins. Meat juice loses its coloration with simultaneous maximum destruction of bacteria. The increase in temperature up to 74 °C leads to instant destruction of bacteria and the loss of coloration, and up to 86 °C – causes collagen disintegration and gelatin formation. The temperature above 100 °C in most cases is considered not suitable for meat products treatment, because it leads to collagen boiling, the break of intercellular ties and the loss of taste properties. Meat products are considered to be safe if the following temperature is achieved in their center: for pork – 53...65 °C; for poultry – 55...80 °C, for beef (mutton) – 55...83 °C, depending on the structure [12–13].

The ISTOMA stoves for low-temperature treatment of pork are represented in the markets of modern equipment. They are designed for stewing, hot and cold smoking and even storage. According to the design and technological characteristics, they are able to ensure the reduction of losses during heat treatment, incredible taste properties and do not require pipelines [13]. For heat treatment, designers use low-temperature flexible cables that ensure the system of 3D heating instead of high-temperature electric heaters [13]. Reflector panels are used for more uniform thermal radiation in a rectangular chamber, which leads to an increase in metal consumption of the equipment. Vapor and convectomates, even with ultrasonic vibrations, are widely used in addition to these stoves [14]. However, the plants of this design are costly to maintain because of the structural implementation of processes. To some extent, it prevents their wide use, especially in the household. It causes the need for finding innovative solutions to simplify the design and technological process as a result of using more effective radiating elements. It is also appropriate to introduce the autonomy of separate units of the plant with the use of the minimum of automation or entirely without it. This will ensure the ease of maintenance, mobility, ease of use and a decrease in the cost of low-temperature plants.

Among modern energy- and metal-efficient radiating elements, a flexible film resistive electric heater of radiative type (FFREhRT) is most widely used [15]. Taking into consideration the design and technical parameters, presented in paper [16], it is the reasonable solution for the creation of modern low-temperature plants of the reflector-free type.

The autonomy of the structural elements is ensured by a variety of additional elements, such as converters, in which design and technological process and driving energy are applied. During heat treatment, the driving energy is the thermal energy, the conversion of which can later be used to ensure the autonomy of certain structural elements in combination with the plant. Peltier elements are used in most cases for the conversion of thermal energy, for example, into low-voltage of supply, and the simultaneous cooling the external structural surfaces. The advantages of these elements for the conversion of thermal energy into the supply voltage are considered in detail in paper [17], which proves the earlier hypothesis about their effective use.

Most of the existing technology and culinary equipment for low-temperature treatment of meat products is characterized by specific design and technological shortcomings. The basic among them is the use of inertia, energy- and metal-intensive heating elements with reflective units that fully do not provide uniform heat distribution. In this case, only separate plants are autonomous in terms of the use of secondary heat for technological needs. This negatively leads to a decrease in the types of meat products treatment and affects their organoleptic properties. Food industry engineers today are challenged with finding innovative design solutions to carry out low-temperature treatment of meat products. This causes the need for the development of a modern mobile and portable plant for low-temperature treatment of meat products by IR-radiation. Using this equipment, it is possible to process more kinds of meat, thereby expanding culinary products with original taste properties. And its use will be characterized by simplicity and autonomy.

3. The aim and objectives of the study

The aim of this study is to develop a modern mobile and portable resource saving plant for low-temperature treatment of meat products by IR-radiation.

To achieve the set goal, the following tasks were solved:

– to substantiate the possibility of using flexible film resistive electric heater of radiative type and Peltier elements for the development of mobile and portable resource effective plant;

– to develop recommended mode parameters of low-temperature treatment of meat products and to conduct a comparative degustation assessment;

– to establish recommended temperatures of culinary readiness of various meat products (in the center of the product) during low-temperature treatment and to perform comparative degustation assessment.

4. Materials, methods of research into multi-component natural compositions and experimental setup

Experimental-practical research aimed at the development of modern mobile and portable plant for low-temperature treatment of meat products by IR-radiation is conducted at the scientific and educational center "Innovative biotechnologies and equipment for manufacturing food products with high health properties" at Kharkiv State University of Food and Trade (Ukraine). Meat products before treatment are kept in aqueous solutions with spices, or the latter are manually applied to the surface of meat products, kept for some time and loaded to the operation chamber of the plant.

5. Development of a plant for low-temperature treatment of meat products by IR radiation

One of the proofs that the set practical and research aim was achieved is the possibility of using modern energy and resource effective elements based on infrared emitters and Peltier elements that provide heat conversion into low voltage of supply. The results of literary and practical analysis presented in paper [17] prove the possibility and effectiveness of FFREhRT during designing low-temperature infrared plants. This is due to the design and technological properties of FFREhRT, specifically, with its low-temperature and uniform radiative thermal surface. An important characteristic is the possibility of the formation of the working surfaces of the geometrically complex forms without using additional metal structures and reflective surfaces. In this case, FFREhRT has low inertia, energy and metal effectiveness compared to other radiative heating elements.

Thermal energy conversion into low-voltage of supply due to the use of Peltier elements can ensure the autonomous operation of exhaust fans. At the same time, the use of Peltier elements can also provide cooling of the internal space of the plant, thus eliminating the need for insulation of the plant. Introduction of innovative solutions ensured the development of fundamentally new low-temperature plant. This plant is characterized by mobility, portability and practical effectiveness of use in the hotel and restaurant industry and household.

The next stage is the development of the plant for low-temperature treatment of meat products by IR-radiation (Fig. 1), consisting of the operation chamber, that includes two pivotally connected vertical thermally non-insulated semi-spherical halves: hinged 1 and fixed with counterweight 2, pivot 3, rod for meat product fixing 4, needle thermocouple (TPM) 5, connected to the thermoregulating device (measuring temperature regulator with needle thermocouple), FFREhRT 6, absorbing screen (black) 7, Peltier elements 8, exhaust fans 9, technical openings 10 and technical space, connected to cumulative capacity 11.

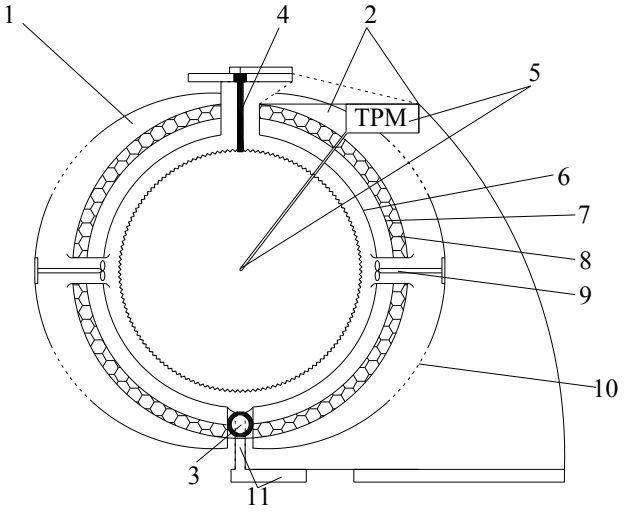

Fig. 1. Diagram of the developed plant for low-temperature treatment of meat products by IR-radiation

The plant for low-temperature treatment of meat products by IR-radiation operates as follows. First, one of the two pivotally connected vertical thermally non-insulated semispherical halves (hinged 1) opens with the help of pivot 3. After this a previously prepared meat product (of a certain geometric shape, corresponding to the geometrical shape of the zone of its location) with the help of fixing rods 4 is mounted in the plant on the vertical semi-spherical half, fixed with counterweight 2. During fixing the meat product on rod 4, needle thermocouple 5, connected to the thermo-regulating plant, is simultaneously mounted in the center of the product. Then two (1, 2) semi-spherical halves are connected by movable hinge 3. As a result of this, the zone of low-temperature treatment by infrared radiation due to FFREhRT 6, repeating the geometry of the operating chamber, is formed. In

this case, FFREhRT 6 is connected to the thermo-regulating plant with needle thermocouple 5 to control thermal treatment of the meat product.

The heat that is formed on the outer part of the FFREhRT 6 is absorbed by black absorbing screen 7. Peltier elements are located at the external side of the screen. They ensure the conversion of the heat, obtained by conductive method from absorbing screen 7, into low voltage of supply (~3...4 W), which is used for the operation of exhaust fans 9, mounted in through openings. During the research, it was discovered that the supply voltage is generated in case of reaching the temperature of a meat product within 30...35 °C. In this case, the temperature on the outer surface of Peltier elements is 10...15 °C. Exhaust fans 9 remove moist air from the operating space of the plant to the thermally non-insulated hinged halves 1, 2. Along with the transformation of voltage, Peltier elements 8 ensure simultaneous cooling of the technical space of the vertical semi-spherical halves (1, 2), thereby eliminating the need for their thermal insulation. Moist air is removed from the operating space of the plant to the thermally non-insulated halves 1 and 2 and is gradually removed to the environment through technical openings 10. Meat juice that is produced during heat treatment is removed through the technical space, connected with cumulative capacity 11, in pivot 3.

The process of low-temperature treatment of meat culinary product by IR- radiation is completed with achievement of the temperature in the range from 63 °C to 85 °C in the middle of the product. In this case, thermocouple 5 automatically disables FFREhRT 6. A decrease in the temperature of FFREhRT 6 leads to a decrease in the value of converted low-voltage of supply that causes autonomous turning off exhaust fans 9. After this the thermally non-insulated hinged half 1 opens using movable pivot 3 and finished products are removed from fixing rod 4.

In order to prove in practice obtaining the uniform distribution of the heat flow from FFREhRT and to ensure uniform heating of meat products, the measuring complex based on a spherical grid with located inside thermocouples was used in the developed plant. In this case, the thermocouples were connected to a personal computer (PC) and the measurement device "TPM". According to the obtained results, FFREhRT ensures the uniform distribution of the heat flow without formation of a crust on the surface of meat products.

Taking into consideration the data as temperatures of readiness in the center of meat products, preliminary presented in analysis, the study of previously prepared various meat raw materials (pork, poultry, etc.) of the spherical shape with the diameter of 0.1±0.01 m was carried out. After loading them to the operation chamber of the developed plant, they were thermally treated until reaching the temperature of culinary readiness of the product. Specifically, the temperatures from 53 to 85 °C in the center of the product were reached, depending on the type of raw materials. The process of low-temperature treatment on the example of pork fillet; pork for fry; duck breast; mutton tenderloin and other tough beef is shown in Fig. 2.

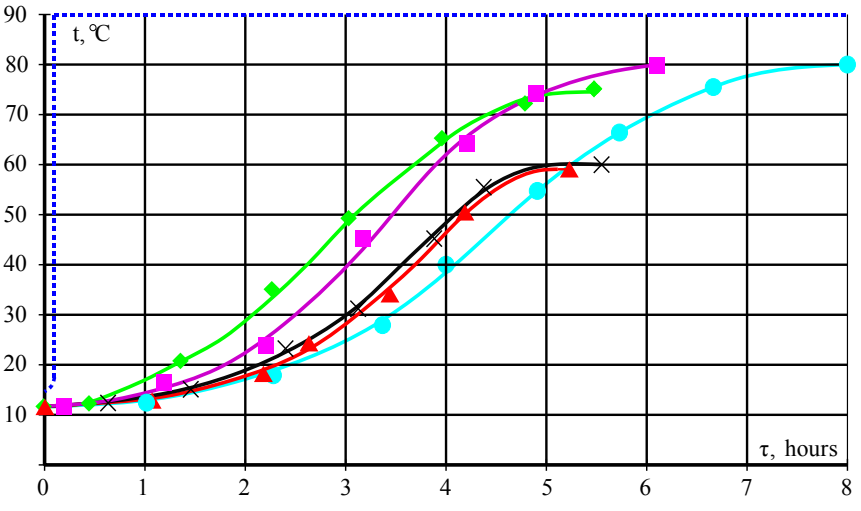

Fig. 2. Diagram of low-temperature treatment of meat raw material under condition of achieving culinary readiness at the temperature in the center of the product: – duration of reaching operation temperature (90 °C); by FFREhRT; – pork fillet; – pork for fry; – duck breast; – mutton tenderloin; – other tough beef

As the diagram shows, the operating temperature proposed for the plant FFREhRT (90 °C) can be reached in 5 minutes, it is equal to the temperature in the operating chamber. Previously prepared spherical meat products had the initial temperature of 12 °C. It was found that pork fillet reaches 58 °C in the center of the product in 5.2 h; pork for roasts, respectively, reaches 80 °C in 8 h; duck breast meat (80 °C in 6 h); mutton tenderloin (60 °C in 5.5 h); any other tough beef, (80 °C in 6.2 hours). In addition to the studies, presented in the diagram (Fig. 2), other kinds of meat products were studied under conditions of achieving culinary readiness to establish their required safe temperature in the center (Table 1). It should be noted that due to using FFREhRT in the developed plant, the low-temperature treatment of meat products, maximum preservation of their natural properties, juiciness and, first of all, safety are ensured.

The use of the parameters obtained during experimental and practical research provides for manufacturing of a variety of meat products with the original taste properties: tenderness, juiciness, lack of impurities, and smell of real meat. If it is difficult to meet the required parameters, we recommend taking meat after deep freezing. We also carried out the test studies aimed at the improvement of flavor properties of manufactures meat products due to the introduction of organic additives into the middle of the product.

As an example, we take the meat product with the addition of organic dried apricots and prunes (Fig. 3) and made its comparative degustation evaluation with the one purchased in trade network "TM Meat Standard" (Table 2).

The results of the visual and comparative degustation assessment prove the high quality of the developed product, a homogenous structure with the pleasant uniform color without formation of a crust. An additive of organic dried apricots and prunes retains its natural color and taste after thermal treatment.

As a result of the research, we obtained the generalizing recommended mode parameters of low-temperature treatment of meat products, which ensure obtaining high-quality products with the original taste properties. This proves the effectiveness of further use of the developed plant at the institutions of the hotel and restaurant industry and household. The

advantages of the plant include, first and foremost, mobility, portability, resource efficiency, reducing the temperature influence on the raw material through the use of FFREhRT. In addition, it is important to ensure the autonomy of operation of exhaust fans through the use of secondary heat, in this case, the necessity to use insulation materials disappears.

Table 1

Temperature of culinary readiness of various meat products (in the center of the product) under condition of their low-temperature treatment in the plant (product diameter is 0.1±0.01 m)

Type of meat raw material	Temperature of culinary readiness of the product (in the center of the product), °C	Duration of thermal treatment, h
Pork (tender meat)		
Meat from ribs	53...64	5.0...6.1
Fillet	52...58	5.0...5.2
Other	60...80	5.0...8.0
Pork (tough meat)		
Chop	55...59	5.0...6.5
Meat for fry	60...80	6.0...8.0
Other	65...80	5.5....9.5
Poultry		
Fillet and chicken breasts	65...71	4.5....5.0
Fillet and turkey breasts	76...80	5.0....5.2
Fillet and duck breasts	75...80	5.6...6.0
Beef or mutton (tender meat)		
Fillet	55...60	5.0
Tenderloin		5.5
Chop		5.0
Other	62...80	5.0...8.0
Beef or mutton (tough meat)		
Breast	58...60	5.0...6.0
Other	60...83	6.0...10

Table 2

The results of degustation assessment of meat products

Sample of meat product	Appearance	Consistency	Taste	Natural color	Smell
Meat product obtained in the plant for low-temperature treatment by IR-radiation	5	5	5	5	5
Purchased in a trade network (baked ham)	5	4	4	4	5

a *b*

Fig. 3. Photographs of meat product with the addition of dried organic raw materials, obtained in plant for the low-temperature treatment of meat products by IR-radiation: *a* — whole meat product; *b* — meat product that is cut through the center

6. Discussion of results obtained when making meat products in the developed plant

The results of the study prove the design and technological effectiveness of using the plant for low-temperature treatment of meat products by IR-radiation, specifically, ensuring the production of high-quality meat products with high organoleptic properties. The implemented innovative approach during designing the plant made it possible to reduce its energy and metal consumption, to achieve uniform heat flow due to the use of FFREhRT and obtaining low voltage of supply from the Peltier elements as a result of conversion of the secondary heat. The use of these plants is promising due to their mobility and portability.

The proposed plant provides energy efficient sparing low-temperature treatment, which generally provides the best taste properties of meat raw material, such as tenderness and juiciness.

The processes of low-temperature treatment of meat products in the vapor-convectomate by heating the operating chamber with high-temperature heaters were preliminarily studied. However, a certain difficulty of technical maintenance of these plants, the inertia of heating elements, metal consumption and high cost prevent their wide use. That is why we proposed the innovative solution for the development of the plant for low-temperature treatment of meat products by IR-radiation to ensure mobility, portability, and ease of use. The plant will be characterized by reduced price and is recommended to be used in the hospitality industry and the household.

The merit of this study compared to the existing analogues is primarily the creation of the innovative design and technological solution with the intensification of low-temperature treatment of meat products. This will ensure the expansion of the range of models of existing equipment for low-temperature treatment of meat products and increase their assortment due to the fuller use of raw materials. The introduction of the developed plant to the hotel and restaurant industry and households will provide a qualitative approach to low-temperature treatment of meat products at all stages of production of high-quality semi-finished products with the original taste properties.

The use of the plant for low-temperature treatment of meat products by the infrared radiation does not require special expertise. This is due to the fact that the use of FFREhRT with its properties and of Peltier elements provides ease of use, maintenance, autonomy and mobility. Special attention should be paid only to the previous preparations of meat products before their low-temperature treatment, because the quality of the products is affected not only by the characteristics of the plant, but also the raw material selected for the production.

The use of FFREhRT, as well as the possibilities of converting the secondary heat into low voltage of supply by Peltier elements, will generally provide low- temperature treatment of meat products, simplicity and portability of the plant.

Among the restrictions that are possible during these studies, it is possible to point out the necessity of formation of the spherical shape of the meat product in order to ensure uniform heat treatment. The shortcomings of the study include an insignificant change in the shape of meat products during heat treatment.

Subsequently, we are planning to carry out more detailed research to determine and test low-temperature mode pa-

rameters of heat treatment of various meat products in the designed plant.

7. Conclusions

1. The plant for low-temperature treatment of meat products by IR-radiation using FFREhRT is characterized by low inertia, energy efficiency, a simplified circuit of control of the technological process. It provides a repetition of the inner semispherical operation chamber of the plant. The use of Peltier element provides an autonomous operation of exhaust fans and eliminates the need for heat insulation of the plant, reducing its metal consumption. Peltier elements ensure a low voltage of supply if a meat product achieves the temperature within 35...40 °C. In this case, the temperature on their outer surface is 15...20 °C. The plant is resource effective due to more sparing temperature treatment of meat products for retaining their original taste properties.

2. The recommended temperatures of culinary readiness of various meat products (in the center of the product) were determined under conditions of their low-temperature treatment in the plant For tender pork, the treatment temperature is 53...80 °C with the duration of 5.0...8.0 hours; for tough pork, it is 55...80 °C with the duration of 5.0...9.5 hours; for poultry, it is 65...80 °C with the duration of 4.5...6.0 hours; for tender beef, it is 55...80 °C with the duration of 5.0...8.0 hours; for tough beef, respectively, it is 58...83 °C with the duration of 5.0...10.0 hours. The results of degustation comparison of the meat samples prove high organoleptic properties of the studied sample.

References

1. Prodovol'stvennyy prognoz // Prodovol'stvennaya i sel'skohozyaystvennaya organizaciya Ob'edinennyh Naciy. 2018. URL: http://www.fao.org/3/CA0910RU/ca0910ru.pdf
2. Innovacionnye tekhnologii v oblasti pishchevyh produktov i produkcii obshchestvennogo pitaniya funkcional'nogo i specializirovannogo naznacheniya: kollektivnaya monografiya / N. V. Pankova (Ed.). Sankt-Peterburg: Izd-vo «LEMA», 2012. 314 p.
3. Mostenska T. Stan ta perspektyvy rozvytku rynku prodovolchykh tovariv v Ukraini // Kharchova i pererobna promyslovist. 2009. Issue 1. P. 8–12.
4. Balansy ta spozhyvannia osnovnykh produktiv kharchuvannia naselenniam Ukrainy: statystychnyi zbirnyk / N. S. Vlasenko (Ed.). Kyiv: Derzhavna sluzhba statystyky Ukrainy, 2013. 56 p.
5. Kanokruangrong S., Birch J., El-Din Ahmed Bekhit A. Processing Effects on Meat Flavor // Encyclopedia of Food Chemistry. 2019. P. 302–308. doi: https://doi.org/10.1016/b978-0-08-100596-5.21861-1
6. Dominguez-Hernandez E., Salaseviciene A., Ertbjerg P. Low-temperature long-time cooking of meat: Eating quality and underlying mechanisms // Meat Science. 2018. Vol. 143. P. 104–113. doi: https://doi.org/10.1016/j.meatsci.2018.04.032
7. Savinok O., Kuzelov A. Influence of ways of cooling on functional properties of pork // Scientific Works of University of Food Technologies. 2015. Vol. LXII. P. 149–152.
8. Onyshchenko V. M., Hrynchenko N. H., Bolshakov V. A. Improvement of frozen poultry storage technology // Eastern-European Journal of Enterprise Technologies. 2015. Vol. 6, Issue 10 (78). P. 37–41. doi: https://doi.org/10.15587/1729-4061.2015.54656
9. Development of a physical-mathematical model for the process of crystallization of meat systems / Yancheva M., Dromenko O., Potapov V., Grinchenko O., Zhelieva T. // Eastern-European Journal of Enterprise Technologies. 2018. Vol. 1, Issue 11 (91). P. 50–55. doi: https://doi.org/10.15587/1729-4061.2018.120793
10. Roascio-Albistur A., Gámbaro A. Consumer perception of a non-traditional market on sous-vide dishes // International Journal of Gastronomy and Food Science. 2018. Vol. 11. P. 20–24. doi: https://doi.org/10.1016/j.ijgfs.2017.10.002
11. Effects of sous-vide method at different temperatures, times and vacuum degrees on the quality, structural, and microbiological properties of pork ham / Jeong K., O H., Shin S. Y., Kim Y.-S. // Meat Science. 2018. Vol. 143. P. 1–7. doi: https://doi.org/10.1016/j.meatsci.2018.04.010
12. Innovacionnye tekhnologii v proizvodstve kulinarnoy produkcii: ucheb. pos. Sankt-Peterburg, 2014. 80 p.
13. Zonin V. G. Sovremennoe proizvodstvo kolbasnyh i solenokopchenyh izdeliy. Sankt-Peterburg: Professiya, 2006. 224 p.
14. Pech' tomleniya, goryachego i holodnogo kopcheniya, hraneniya. URL: http://www.istoma.com
15. Verboloz E. I., Romanchikov S. A. Features of the low-temperature heat treatment of meat products in a combi steamer with the imposition of ultrasonic vibrations // Proceedings of the Voronezh State University of Engineering Technologies. 2017. Vol. 79, Issue 3. P. 35–41. doi: https://doi.org/10.20914/2310-1202-2017-3-35-41
16. Zahorulko O. Ye., Zahorulko A. M. Hnuchkyi plivkovyi rezystyvnyi elektronahrivach vyprominiuiuchoho typu: Pat. No. 108041 UA. No. u201600827; declareted: 02.02.2016; published: 24.06.2016, Bul. No. 12. URL: http://uapatents.com/5-108041-gnuchkijj-plivkovijj-rezistivnijj-elektronagrivach-viprominyuyuchogo-tipu.html
17. Improvement of IR emitter to create non-reflector dryer for plant raw materials / Kiptelaya L., Zahorulko A., Zagorulko A., Liashenko B. // Technology audit and production reserves. 2017. Vol. 2, Issue 3 (34). P. 17–22. doi: https://doi.org/10.15587/2312-8372.2017.98068
18. A three-dimensional model for thermoelectric generator and the influence of Peltier effect on the performance and heat transfer / Liao M., He Z., Jiang C., Fan X., Li Y., Qi F. // Applied Thermal Engineering. 2018. Vol. 133. P. 493–500. doi: https://doi.org/10.1016/j.applthermaleng.2018.01.080