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DETERMINATION OF THE POSSIBILITIES OF USING THE UNIVERSAL LOW-TEMPERATURE ROTARY APPARATUS FOR THE PRODUCTION OF MEAT AND VEGETABLE PRODUCTS UNDER THE CONDITIONS OF PROVIDING UNIFORM HEAT SUPPLY

The object of research is the process of frying a meat-vegetable product in the developed universal low-temperature rotary apparatus. The problem of ensuring the uniformity of the temperature field during low-temperature processing of meat and vegetable products is solved in the developed universal low-temperature rotary apparatus. The expected effect during the approbation of the apparatus is predicted under the condition of eliminating high-temperature intermediate coolants (hot air, etc.) due to the use of a film-like resistive electronic heater of the radiating type. The temperature field is established, which confirms the uniformity of the temperature effect on meat and vegetable products, and a slight deviation within the limits of autonomous exhaust fans is not critical and within the permissible error. Also, the introduction of Peltier elements into the design of the rotary apparatus will allow converting thermal energy into a low-voltage supply voltage (3–6 W) and, already at 20 °C, ensure autonomous operation of fans. The obtained results in the form of practical implementation of the developed apparatus will allow to implement low-temperature processing of meat and vegetable products. This allows to maximally preserve the functional properties of meat raw materials and the physiological properties of vegetable semi-finished products with a high degree of readiness.

The practical implementation of the universal low-temperature rotary apparatus from the side of constructive implementation due to the use of functional containers makes it possible to obtain a wide range of assortment of meat products, both in the shell and without the shell. The elimination of high-temperature intermediate heat carriers (hot air, steam, etc.), their technical networks and generating apparatuss ensures energy and metal-intensive resource savings. In addition, the introduction of multicomponent vegetable semi-finished products of a high degree of readiness (powders, pastes, etc.) into the recipes of meat products will lead to a partial replacement of the main recipe components and an increase in the functional properties of the finished products.

Keywords: *low-temperature rotary apparatus, meat-vegetable product, polycomponent vegetable semi-finished products, temperature field.*

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1. Introduction

Meat products are produced by various technologies using heat and mass exchange equipment and occupy one of the main food chains in many countries of the world, there are also meat delicacies (ham, bread, etc.) produced using our own technologies. The relevance of meat and vegetable products is growing in the context of healthy nutrition, as they can be adapted to preserve useful properties and meet the requirements of consumer cooperatives [1]. To a certain extent, the technological quality of the production of meat and vegetable products is influenced by thermal equipment, which should meet modern resource-saving and practical properties, ensuring the high quality of the products obtained [2].

The paper [3] focuses on the expediency of low-temperature processing of meat and vegetable semi-finished products in the conditions of microbiological safety of production, but without taking into account the duration of technological operations. At the same time, the impact of the use of thermal equipment and the need for technical re-equipment of enterprises to ensure resource-saving production of high-quality meat and vegetable products are not considered.

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In particular, the work [4] presents solutions regarding the optimal conditions for heat treatment of raw meat during baking and cooking in water in the temperature range from 51 to 100 °C. However, not enough attention has been paid to the need to implement resource-saving technologies for overall process quality improvement.

The paper [5] examines aspects of healthy nutrition and safety of traditional European meat products that have unique organoleptic properties. Problems with the homogeneity of products associated with the use of classic technologies and equipment, which do not ensure the universality of production, have been identified, emphasizing the need to improve thermal equipment in accordance with modern requirements. In work [6], the combined heat and mass transfer processing of meat products using sous-vide technology is proposed as a solution to minimize technological and constructive shortcomings. Research has focused on the stages of cooking chicken breasts in a convection oven until reaching 71 °C in the center of the product, but the issues of uniformity of the temperature field remain unresolved, which requires further experimental research to improve this technology. The work [7] proposed an innovative solution for low-temperature processing of meat products using IR radiation in the range of 63–85 °C. However, the possibility of using this apparatus for other types of meat products, such as hams, pates, rolls, is not considered due to the peculiarities of its design, which requires additional research to minimize the influence of geometry on the technological process. In works [8, 9], the effectiveness of combining sous-vide technology with preliminary or final baking and compared to cooking was investigated. However, the impact of design features on the uniformity of heating is not taken into account, which confirms the need to study the design and technological impact on the process.

The aim of research is to conduct approbation studies of the developed universal low-temperature rotary apparatus for the production of meat and vegetable products under the conditions of ensuring uniform heat supply and the use of secondary heat energy for production and technical needs.

The practical implementation of the universal low-temperature rotary apparatus from the side of constructive implementation due to the use of functional containers makes it possible to obtain a wide range of assortment of meat products, both in the shell and without the shell. The elimination of high-temperature intermediate heat carriers (hot air, steam, etc.), their technical networks and generating apparatuss ensures energy and metal-intensive resource savings. In addition, the introduction of multi-component vegetable semi-finished products of a high degree of readiness (powders, pastes, etc.) into the recipes of meat products will lead to a partial replacement of the main recipe components and an increase in the functional properties of the finished products.

2. Materials and Methods

Experimental and practical testing of the developed universal low-temperature rotary apparatus for the production of meat and vegetable products (Fig. 1) was carried out in the laboratory conditions of the State Biotechnology University (Kharkiv, Ukraine).

The principle of operation of the universal low-temperature rotary apparatus for the production of meat and vegetable products consists in the preliminary preparation of the meat and vegetable product for heat treatment in the shell or by loading technological variable functional containers 6. Loading of functional containers 6 is realized by opening the side cover of the apparatus 11, which is fixed on the mechanism for opening the side wall of the apparatus 14. The replaceable functional containers 6 are attached in the working space on the perforated drum 4 with the help of a quick-release mechanism 5. After that, the operator sets the required temperature range for the heat treatment of meat and vegetable products on the control unit temperature range 8, followed by heat treatment.

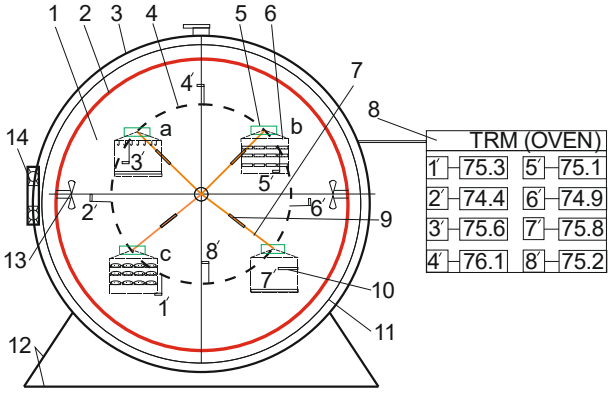

Fig. 1. Experimental scheme of the universal low-temperature rotary apparatus for the production of meat and vegetable products: 1 – working space of the apparatus; 2 – film-like resistive electric heater of the radiating type (FLREHRT [10]); 3 – protective screen with a reflective aluminum heat-insulating surface; 4 – perforated working drum; 5 – quick release mechanism; 6 – variable functional containers (a, b and c); 7 – internal edges of the perforated working drum; 8 – temperature field control unit; 9 – Peltier elements; 10 (7′) – needle thermocouple; 11 – side cover of the apparatus; 12 – racks; 13 – autonomous exhaust fan; 14 – mechanism for opening the side wall of the apparatus

The design of the apparatus has a protective screen with a reflective aluminum heat-insulating surface 3 to reduce heat loss to the environment. In order to increase the resource efficiency of the heat and mass exchange equipment for technical production needs, with the help of Peltier elements 9, the conversion of secondary thermal energy into low-voltage power supply for the operation of autonomous exhaust fans 13 is realized. The design of the perforated working drum 4 has internal edges 7, in the center of which Peltier elements 9 are located. the constructive solution allows rational use of the working space of the apparatus without creating additional non-technological zones and without hindering the spread of the temperature field in the form of IR rays.

Control of the uniformity of the temperature range in the working chamber of the apparatus is measured by thermocouples: 1′–8′. The temperature control in the center of the loaf of meat product is carried out using a needle thermocouple 10 (7′) and when the selected technological value is reached, the product is considered culinary ready.

Various meat raw materials (pork, poultry, beef, etc.) were used in the research on the quality of heat treatment of meat and vegetable products. As a plant component, plant polycomponent dried fractions of a high degree of readiness based on Jerusalem artichoke, carrots, zucchini, apples, beets, etc., which are characterized by a high content of physiologically functional ingredients, were used. A multi-component approach allows to realize the formation

of the optimal composition of a vegetable semi-finished product for further inclusion in the recipes of meat and vegetable products for artificial enrichment with natural ingredients and partial replacement of the main recipe components (meat, bread, etc.).

3. Results and Discussion

During the experimental and practical testing of the developed universal low-temperature rotary device for the production of meat and vegetable products using thermocouples 1/–8/ connected to the temperature field control unit 8, the uniformity of heat supply was confirmed. Temperature control in the center of the experimental loaf of meat product is carried out with the help of a needle thermocouple (Fig. 1, item 10, where item 7/ is a control thermocouple with a set technological temperature at the level of 75 °C). Minor deviations in the temperature range on thermocouples 2/ and 6/ can be explained by the operation of autonomous exhaust fans 13. In general, the obtained temperature range data confirm the uniformity of the temperature field, and minor deviations are within the limits of experimental and practical approbation and are permissible.

The structural structure of variable functional containers 6 is aimed at the simultaneous implementation of heat and mass exchange processing of a wide range of meat and vegetable products. The use of functional containers with hooks (Fig. 1, item a) allows heat treatment of casing (sausage, etc.) products, and a technical collection container is mounted in the lower part of the container to collect possible juice-containing fraction. The functional container with press forms (Fig. 1, item b) is intended for heat treatment of products in various geometric designs (bread, loaves, etc.). Functional containers (Fig. 1, item c) are designed for obtaining products in functionally closed environments, thereby obtaining juicy products without excess skin, unlike traditional frying with two-operation flipping.

Peltier elements 9 located on the inner edges 7 of the perforated working drum 4 allow the temperature of the working chamber to be converted into a low-voltage supply voltage (3–6 W) when the temperature in the chamber rises to a value of 20 °C. Thus, creating a convective component in the IR field from a film-like resistive electric heater of the radiating type (FLREHRT, 2), providing additional movement of air flows without using electricity for the operation of exhaust fans.

The practical implementation of the developed universal low-temperature rotary device for the production of meat and vegetable products will allow the device to be used in hotel and restaurant complexes, mobile production facilities. In particular, for quick preparation of meat and vegetable products for people in extreme conditions (displaced persons, volunteers, military and others). In addition, due to the ease of use of the device, it can also be used at the processing facilities of the meat industry during the creation of a mini-shop for the production of functional products.

Currently, one of the limitations is the need to conduct a wide range of experimental and practical studies to form generalized technological maps of heat and mass transfer processing of various assortments of functional meat and vegetable products. However, the work is conducted even in the conditions of experimental and practical research in the front-line territory of the city of Kharkiv and the region, which in turn will make it possible to support production facilities and obtain functional meat and vegetable products for the full diet of consumer cooperatives in many countries.

4. Conclusions

The universal low-temperature rotary device for the production of meat and vegetable products was tested. A feature of the device is the absence of high-temperature intermediate coolants (hot air, etc.) due to the use of a film-like resistive electronic heater of the radiating type. A temperature field has been established, which confirms the uniformity of the temperature effect on meat and vegetable products, and a slight deviation within the limits of autonomous exhaust fans is not critical and within the limits of permissible error. The use of Peltier elements made it possible to convert thermal energy into a low-voltage supply voltage (3–6 W) and to ensure autonomous operation of fans already at 20 °C. Temperature control in the center of the experimental loaf of meat product is carried out with the help of a needle thermocouple (Fig. 1, item 10, where item 7/ is a control thermocouple with a set technological temperature at the level of 75 °C). The obtained results in the form of practical implementation of the developed device will allow to implement low-temperature processing of meat and vegetable products. This allows to maximally preserve the functional properties of meat raw materials and the physiological properties of vegetable semi-finished products with a high degree of readiness.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, including financial, personal, authorship, or any other nature that could affect the research and its results presented in this article.

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The study was conducted without financial support.

Data availability

The manuscript has no associated data

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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