The object of this study is the process of making confectionery masses using the example of boiling the jam mass with the introduction of pre-dried fruit and berry raw materials, followed by boiling in a sugar syrup solution on an advanced cooking device. A feature of the improved cooking apparatus is the elimination of intermediate heat carriers, ensuring mobility, and increasing the heat exchange surface. Additional heating of the stirring device increases the total heat exchange surface by 0.23 m^2. The elimination of the steam component made it possible to install the device on a moving platform, thereby ensuring its use in small confectionery workshops.

A method of jam production with the introduction of pre-dried fruit and berry raw materials and subsequent boiling in a sugar syrup solution is proposed. A feature is preliminary drying of raw materials in a vertical cylindrical IR dryer to 25…35 % SR at a temperature of 40…55 °C, grinding to 1.0…3.0 mm, with subsequent addition to sugar syrup. Boiling of the jam mass with the introduction of plant ingredients was carried out in the temperature range of 50…60 °C in the improved mobile design of the cooking apparatus to the content of 60…75 % SR, within 10…15 minutes. The set duration of output (620 s) to the stationary mode of cooking the jam mass at a temperature of 55 °C in the improved design of the cooking apparatus, which is 30 % less. The introduction of a stirrer design with a heating surface increases the usable heating surface by 0.23 m^2, while the cooking time for jam, for example, is reduced by 26 %, and the specific heat consumption is reduced by 1.34 times. The use of an improved mobile device in the practical activities of enterprises of the industry will make it possible to reduce the time of cooking confectionery masses and improve operational indicators

Keywords: mobile cooking device, increase of heat exchange surface, jam, resource efficiency

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FEATURES OF STRUCTURAL IMPROVEMENT OF THE COOKING APPLIANCE FOR CONFECTIONERY MASS

Anatolii Kobets
Doctor of Public Administration Sciences
Rector*
Andrii Puhach
Corresponding author
Doctor of Public Administration Sciences,
Professor, Dean*
E-mail: andrijpugac437@gmail.com
Iryna Volovyk
PhD, Associate Professor
Department of Management,
Public Management and Administration*
Vira Puhach
University of Customs and Finance
Volodymyra Vernadskoho str., 2/4, Dnipro, Ukraine, 49000
*Dnipro State Agrarian and Economic University
Serhiya Yefremova str., 25, Dnipro, Ukraine, 49600

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1. Introduction

Confectionery products are characterized by the daily demand of consumer cooperatives in European countries, thereby requiring manufacturers to constantly update their technological and equipment components. In addition, many factors of today make the traditional methods of production of confectionery masses and products in general the need to use natural plant ingredients. Functional properties, original organoleptic and physicochemical properties are a feature of the use of plant ingredients. which make it possible to increase the already high physiologically functional properties of the obtained confectionery products, forming part of a sweet full-fledged diet [1].

A peculiarity of the production of confectionery masses is the need to implement resource efficiency, which is based on the recipe component and the structural design of the implementation of the heat-mass exchange manufacturing process. The recipe ingredient is characterized by the obtained functional properties on the basis of physical-chemical, rheological, and organoleptic indicators, taking into account the regime processes and should include the maximum amount of natural ingredients. And therefore, the implementation of regime parameters, in particular heat and mass exchange processes, should be implemented on innovative technological equipment to maximally preserve the initial properties of recipe ingredients – especially of plant origin [2]. Among the popular confectionery products there are various soft products with a foam-like structure (marshmallows, lozenges, cream-whipped candies, souffle-type candies, etc.) [3]. In addition, the trend of European countries is the development of craft industries for the manufacture of various products using innovative thermal equipment and additional enrichment of recipes with organic ingredients [4]. The use of herbal recipe ingredients ensures that future confectionery masses and products based on them acquire original competitive properties, expanding the assortment [5]. Therefore, research focused on improving existing technological equipment to ensure resource-efficient production of confectionery masses on mobile equipment under rational cooking modes is relevant. This will make it possible to form competitive properties of small confectionery workshops and hotel-restaurant establishments, aimed at the production of original confectionery products on improved thermal equipment for boiling confectionery masses.

2. The aim and objectives of the study

The resource efficiency of the production of confectionery masses depends on the modernity of technological and hardware solutions aimed at the production of a competitive range of confectionery products. In this regard, it is necessary to carry out a step-by-step review of the technological and hardware component for the formation of generalized innovative solutions aimed at the improvement and formation of European trends in craft production [6, 7].

One of the ways of modern improvement of technologies of confectionery masses is the maximum preservation of initial properties of plant raw materials. This will preserve the functional ingredients in their natural state and form high organoleptic indicators without the use of dyes and flavorings.

This approach makes it possible to satisfy the growing consumer demand for natural confectionery products with a high content of useful substances, which has been systematically growing in countries all over the world in recent years [8]. For example, work [9] reports the results of practical research on determining the level of berry consumption depending on the consistency, seasonality, and combination with various ingredients, as a factor affecting the maintenance of the physiological properties of the body. However, practical implementation in the daily diet of each person remains an unresolved aspect. One of the reasons for this is objective difficulties in the formation of complex physiologically functional food maps for certain categories of consumers, which first of all requires complex cost studies. The simplest solution is the implementation of complex generalized methods of determining the daily norms of consumption of functional products in accordance with international standards. For example, in the course of research, the effectiveness of the consumption of 300 ml of juice-containing fruit and vegetable concentrate by volunteers consisting of 36 women and 14 men for 25 days was determined. It is advisable to consider in detail the functional properties of fruit and berry semi-finished products as a key to improving the functional properties of confectionery products. For example, work [10] proposed a method of obtaining a functional fruit and berry paste based on apple, ziziphus, and blueberry with a high content of physiologically functional ingredients. The paste was obtained under the conditions of concentration in a rotary-film apparatus at a temperature of 60...65 °C to a dry matter content (DM) of 30...32 %. The presented rheological properties of the multicomponent paste are characterized by an increase in its strength compared to the control (apple paste), in addition, the functional properties of food fibers, vitamin C and other useful micro-macroelements are increased. However, the issues related to the effectiveness of the use of vegetable pastes in confectionary products remain to be clarified, which may be related to the need for research in this area, including the creation of expert boards. In particular, work [11] evaluated the use of grape juice as a bio-ingredient and natural dye for jelly candies. The recipe composition of the obtained confectionery mass consisted of BRS Violeta grape juice, gelatin, honey, agar, and natural flavors, while the product was characterized by the concentration of the total amount of anthocyanins (mg malvidin-3,5-glucoside kg fruit-1) 686.78 with 41 % retention in relation to the concentration determined in the juice. Therefore, the use of juice in combination with other ingredients of the recipe resulted in a pleasant product with a significant concentration of anthocyanins, grape smell, and taste. This confirms the expediency of adding plant ingredients to the recipes of confectionery masses under modern conditions.

However, the question of the effectiveness of replacing traditional raw materials with vegetable ones under the conditions of ensuring the stable quality of finished products remained undefined, which is connected with the need for conducting large-scale cost studies. One of the solutions is considered in work [12] using the example of the technology of obtaining whipped candies due to the use of fruit and berry paste with rheological viscosity (498 Pa·s). It is recommended to introduce the paste into the recipe of whipped candies within 15 % of the recipe content of agar, which in turn provides original organoleptic properties, increasing the functional properties of candies.

In [13], a bioactive compound based on anthocyanins is considered under the conditions of introduction into a solid food base of Indian gooseberry (*Emblica officinalis*) using osmotic treatment. An increase in the concentration of the surrounding solution was established for the duration of reaching the equilibrium of moisture and solid matter is reduced. Therefore, the production of candies from argus is realized in 24 hours, while the traditional method takes 120 hours. However, the implementation of osmotic processing of confectionery masses requires specific equipment, and it is not established how the multicomponent nature of plant ingredients will affect the processing process. This emphasizes the expediency of conducting complex technological and design studies aimed at ensuring resource-efficient technologies for the production of confectionery masses and products. For example, work [14] reports the results of experimental implementation of the technology for the production of Turkish delight on the basis of fruit and vegetable paste, which performs the role of a functional enricher. By concentrating the paste based on apple, quince, and pumpkin (in a ratio of 30:50:20 %) in a rotary evaporator at a temperature of 60...63 °C for 30...42 seconds. Further application of the paste made it possible to reduce the amount of starch by 20 % and to obtain locum of high strength (38 kPa) and increased nutritional value. In addition to pastes, dried natural compositions are widely used, which, in addition to functional properties, are characterized by technological advantages (simpler storage conditions, easily dissolve and swell, increasing mass, etc.) [15].

The positive experience gained regarding the effectiveness of using plant ingredients as functional enrichers of confectionery products allows us to use this direction to obtain new competitive products.

However, resource-efficient processing of plant raw materials requires the use of innovative heat and mass exchange equipment. It is advisable to consider the possible structural defects of technological equipment for the production of confectionery masses and vegetable semi-finished products. In most cases, vacuum evaporators, rotary evaporators, and dryers of various designs are used to obtain high-quality concentrated and dried semi-finished products. Thus, work [16] reports the experimental and practical results of improving the design of a rotary film evaporator for obtaining competitive fruit and berry pastes. A feature of the design is the reduced metal capacity compared to the basic vacuum-evaporator due to the elimination of the component of the intermediate heat carrier through the use of flexible electric heaters. Such a design solution made it possible to reduce the specific energy consumption for heating the puree

entering the cooking process (547 kJ/kg in 75 s compared to the basic design – 1090 kJ/kg. However, issues related to the peculiarity of the implementation of the cooking process of vegetable raw materials remained unresolved under gentle regime parameters, this is related to the probable complexity of technological implementation of the process, since it is a long operation. One of the solutions is given in work [17] and is aimed at boiling plant raw materials in an evaporation apparatus in the temperature range of 15...35 °C under replacement conditions vapor component to electromagnetic waves. One of the solutions for determining and increasing the heat transfer coefficient in a rotary-film apparatus with an improved design of a film-forming element that is additionally heated is presented in [18]. The use of a reflective surface that is additionally heated to stabilize the hydraulic movement of a shear wave flow by the account of the reflective surface of a certain geometric shape for the forced direction of the raw material that is cut onto the heating surface. In the course of research, a criterion equation was obtained, and the usable heat exchange surface was increased – 0.75 m^2. This led to a decrease in the duration of the temperature effect on the raw materials (the process lasted 200 s), thus confirming the effectiveness of the introduction of electric heating when boiling plant raw materials. The effectiveness of additional heating of the surfaces of mixing devices in cooking processes is also emphasized, which can be adapted to the process of cooking confectionery masses with detailed research, emphasizing the relevance of research in this area.

Possibilities of forming portable structural properties of resource-efficient equipment are a relevant engineering trend today. In particular, the portability (mobility) of structural implementation is one of the main directions of development of European craft confectionery industries. 3D printing technologies are also widely used, for which the use of mobile resource-efficient equipment is relevant, which confirms the feasibility of engineering research in this area. Thus, work [19] emphasizes a revolutionary approach to 3D food printing technologies in the gastronomic world, offering individual meals. Therefore, it is necessary to analyze possible ways of forming the mobile properties of boiling devices under conditions of elimination of intermediate components, which is relevant for craft industries and hotel-restaurant complexes. One of the solutions is given in work [20], in which the process of cooking fruit and berry mixture in an improved design of a vacuum-evaporating apparatus that can be used for cooking confectionery masses is considered. It is noted that traditional boiling reactors have intermediate heat carriers, significant energy and metal consumption, the difficulty of stabilizing the temperature field under the conditions of a significant duration of the process, which prevents ensuring mobility, resource efficiency and reducing the quality of the obtained products. At the same time, replacing the steam jacket with a film-like resistive electronic heater of the radiating type with the simultaneous use of a unified stirrer to increase the usable heat exchange surface by 0.6 m^2 increases the total heat exchange area to 2.8 m^2. Emphasizing the effectiveness of its use for the processes of cooking vegetable raw materials, and therefore the effectiveness of the proposed solutions in the improvement of cooking devices for confectionery masses with the simultaneous possibility of heat treatment of vegetable raw materials.

In [21], attention is focused on compliance with the microbiological safety of chocolate products due to the consistent application of the HACCP concept and compliance with mandatory programs to ensure production and agricultural practices during the technological cycle. This includes not only the final stages of chocolate processing but also begins with the level and sources of agricultural raw materials used in the production of chocolate, such as cocoa, nuts, vegetables, berries, etc. This emphasizes the relevance of the production of resource-efficient mobile equipment for the full realization of the process of production of confectionery masses in a separate technological equipment under the conditions of rational regimes. For example, work [22] presents an improved design of a tempering machine for heating marshmallow mixture, which is characterized by the elimination of the traditional steam jacket and the introduction of electric heating with the simultaneous provision of additional heating of the stirring device. A decrease in the duration of heating the mixture at a temperature of 75 °C was established for 530 s, and in the analog with a steam jacket, 645 s, respectively, the specific costs for heating raw materials were also reduced. This confirms the effectiveness and expediency of adapting similar structural movements on the cooking apparatus of confectionery masses under the conditions of conducting basic experimental and practical research.

Therefore, in most cases, traditional heating equipment uses intermediate heat carriers (hot steam, organosilicon substances, etc.), which require the use of steam generators, technical networks for them, and have difficult operating conditions. There is a difficulty in controlling the temperature range and stabilizing the uniformity of the cooking of confectionery masses due to the inertia of the control object, which leads to the loss of nutritional properties. The existing technical networks of heating equipment at large confectionary factories do not have the portability, and as a result, the mobility necessary for craft productions.

3. The aim and objectives of the study

The purpose of our research is the implementation of innovative hardware solutions aimed at structural improvement of cooking apparatus for confectionery masses. The peculiarity of the solution is the formation of a resource-efficient approach to reducing the metal content of traditional devices by eliminating the steam generator, heat networks, shut-off fittings, and ensuring the mobility of the structure. The installation of an improved cooking device on a mobile platform will allow its use in small confectionery enterprises and hotel and restaurant complexes for the production of confectionery masses with their own hands – increasing competitiveness.

To achieve the goal, the following tasks were set:

– to develop an improved design of a mobile cooking device for confectionery masses;

– to carry out experimental and practical testing of the improved design of the mobile cooking device on the example of the implementation of the process of boiling the jam mass obtained by the improved method;

– to confirm the effectiveness of the implemented structural solutions in comparison with the basic design according to technological and structural parameters.

4. The study materials and methods

The object of the study is the process of making confectionery masses using the example of boiling the jam

mass with the introduction of pre-dried fruit and berry raw materials, followed by boiling in a sugar syrup solution on an improved mobile cooking device. Experimental and practical implementation of structural solutions will ensure a reduction in the energy and metal consumption of devices due to the use of a conductive method of heat supply from electric heaters, and installation on a mobile platform forms portability and structural advantages of use.

The research hypothesis is the possibility of eliminating the component of intermediate heat carriers, ensuring mobility, and increasing the heat exchange surface. This will make it possible to increase the total heat exchange surface, install the device on a moving platform, thereby ensuring mobility, which comprehensively contributes to increasing resource efficiency. Another assumption of the study is to improve the efficiency of the cooking apparatus due to the use of electric heat supply with a simplified automation scheme.

Experimental and practical tests were carried out at the laboratory facilities of the State Biotechnology University (DBTU, Kharkiv, Ukraine). The improved design of the mobile cooking apparatus for confectionery masses of various recipes is equipped with automation equipment from the company "Oven" (Kharkiv, Ukraine). This made it possible to implement high-quality control of temperature parameters, the frequency of rotation of the stirring device and control of the operation of the automatic unloading device. The presented description of the structure of the improved mobile cooking apparatus allows one to completely restore the process of cooking jam masses obtained by the improved method and meet the traditional requirements of experimental and practical testing based on standard methods. The machine-technological advantages of the design solutions were determined by a comparative analysis with the traditional 28-A cooking apparatus with a mechanical stirrer [23].

5. Research into the competitiveness of the structural improvement of the mobile cooking apparatus for confectionery masses

5. 1. Development of an improved model design of a mobile cooking apparatus for confectionery masses

The proposed structural and technological solutions are aimed at reducing the generalized indicators of energy and metal capacity of cooking apparatus for confectionery masses for use in mobile workshops and hotel-restaurant complexes. The basic component of the improvement is aimed at increasing resource-efficient indicators due to the elimination of energy and metal consumption (elimination: steam generator, technical network, steam jacket and shut-off steam fittings), which was implemented due to the use of electric heaters. To reduce the thermostable effect of the usable heat exchange surface of the cooking apparatus on the temperature range and technological duration of the heat treatment of confectionery masses, an increase in the heat exchange surface was implemented due to additional heating of the mixing device.

Experimental and practical testing of structural solutions was implemented on the basis of the developed model design of the mobile cooking apparatus for confectionery masses (Fig. 1). The heating of the working chamber 14 is carried out by a film-like resistive electric heater of the radiating type (FREhRT [24]) with a heat-insulating surface 1. In addition, the inner surface of the mixing device 2 is also additionally heated by FREhRT 1, providing an increase in the heat exchange surface by 0.23 m^2 to stabilize the temperature range of the internal layers of confectionery masses during boiling. And also intensifies the thermal process under the conditions of reducing the duration of stay of the food mass in the working space of device 14.

Boiling of confectionery masses in cooking devices is carried out in accordance with technological maps in compliance with technological mode parameters, and the confectionery mass ready for further implementation is unloaded from the working chamber 14. The improved model design of the cooking device is equipped with a discharge nozzle with automatic valves 3, which are controlled by the control unit 10, upon reaching the technological duration of boiling certain confectionery masses. The shaft of the mixing device 2 rotates in the supporting bearing units 4 and is connected to the motor compartment 6 with further control/regulation on the control unit 10 of the frequency of rotation of the device 2.

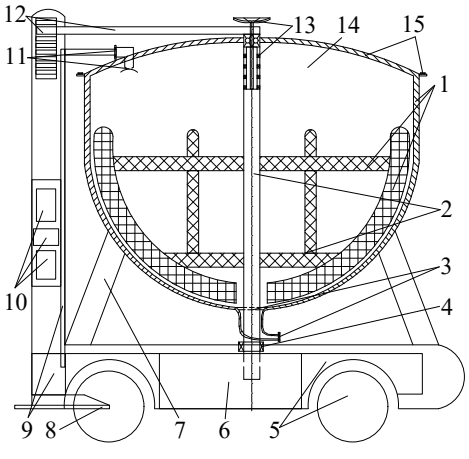

Fig. 1. Scheme of the improved model design of the mobile cooking apparatus for confectionery masses: 1 — a film-like resistive electronic heater of the radiating type (FREhRT) with a heat-insulating surface; 2 — mixing device with an artificially increased heat exchange surface heated by an electric heater (1); 3 — unloading nozzle with automatic valves; 4 — resistance bearing units; 5 — mobile platform; 6 — engine compartment; 7 — stable; 8 — mechanical rolling lock; 9 — vacuum compartment with a flexible rubber vacuum line; 10 — control unit (temperature; frequency of rotation of the stirring device (2); vacuuming; depressurization valve; automatic latch of the unloading nozzle (3)); 11 — quick-removable nozzle of the vacuum main with a droplet reflector; 12 — lid lifting mechanism with stirrer (15); 13 — pressure relief valve in the working chamber (14); 14 — working chamber; 15 — cover with quick-release fasteners

The elimination of traditional energy- and metal-intensive components (steam jacket, steam generator, and technical networks) of cooking apparatus for confectionery masses made it possible to install an improved apparatus on a mobile platform 5 with a safety mechanical locking device for rolling 8. Ensuring the mobility of the equipment, in addition to increasing the resource efficiency indicators, made it possible to increase the competitiveness of the equipment due to the possibility of use in small confectionery shops and

hotel and restaurant complexes for the direct production of sweets in accordance with the needs of consumers.

Unlike the traditional 28-A boiler with a mechanical stirrer, the improved model design is additionally equipped with vacuum technology to reduce the temperature impact when boiling confectionery masses. The vacuum department 9 is installed in the mobile platform 5 and is equipped with a flexible rubber vacuum line connecting to the quick-removable nozzle of the vacuum line 11, which is additionally equipped with a drop deflector to prevent steam from entering the vacuum system. Control of the vacuum level is implemented by the control unit 10. After the technological implementation of the cooking of confectionery masses, the cooking apparatus is equipped with an automatic pressure relief valve 13 in the working chamber 14. This occurs under the conditions of turning the working shaft of the valve until it coincides with the technical holes, thereby supplying air to the working chamber. In addition, the mobile platform 5 is equipped with a lifting mechanism 12, which allows one to lift cover 15 with quick-release fasteners.

5. 2. Approbation of the model design of the mobile cooking apparatus for boiling the jam mass

Confectionery masses are characterized by a variety of assortments, which are realized according to traditional and improved technological and equipment solutions and have, accordingly, different physical-chemical and rheological manufacturing properties. However, the main attention is directed to the implementation of high-quality resource-efficient heat and mass exchange processing in compliance with regulatory parameters, especially if plant raw materials are used in the recipe composition of confectionery masses to obtain functional products. The proposed increase in the usable heat exchange surface, implemented in the improved mobile design of the cooking apparatus, allows the internal layers of the mass to be heated due to the improved design of the stirring device.

In order to test the effectiveness of using a mobile cooking device, it is proposed to preliminarily improve the method of obtaining jam mass based on vegetable raw materials, in order to improve the functional properties of the product. The method is based on the use of gentle heat regimes for cooking the jam mass with the introduction of fractional pre-dried fruit and berry raw materials, followed by cooking in a sugar syrup solution to increase the functional value and organic properties.

The production technique involves the use of ripe fruit and berry, vegetable raw materials, which previously underwent the initial stages of technological processing (washing, inspection, etc.), and if necessary, machines for slicing into a certain geometric shape were provided. Pre-prepared plant raw materials were sent for pre-drying to a vertical cylindrical IR dryer to a final moisture content of 25–35 % dry matter (DM) at a temperature of 40–55 °C. After that, the pre-dried plant material was crushed on a universal crusher to an average particle size of 1.0...3.0 mm, with subsequent addition to sugar syrup. In addition to the recipe mass, citric acid was added, and the boiling process was carried out in the temperature range of 50...60 °C in the improved mobile design of the boiling device. The technological process of boiling was carried out until the mass of the jam with a dry matter content of 60...75 % was reached within 10...15 minutes, ensuring the formation of a homogeneous rheological consistency. The boiled mass underwent a technological pasteurization operation in a tubular pasteurization apparatus [25] at a temperature of 88 °C, followed by packaging, storage, and sale. Preliminary drying and grinding helps to increase the diffusion of sugar syrup due to faster absorption by the cells of the plant raw materials of the syrup and its larger available surface.

The effectiveness of the use of the improved mobile design of the cooking apparatus under the conditions of a comparative analysis of the kinetics of heating the jam mass with the introduction of vegetable ingredients into the sugar syrup with the basic design of the cooking boiler 28-A was determined (Fig. 2).

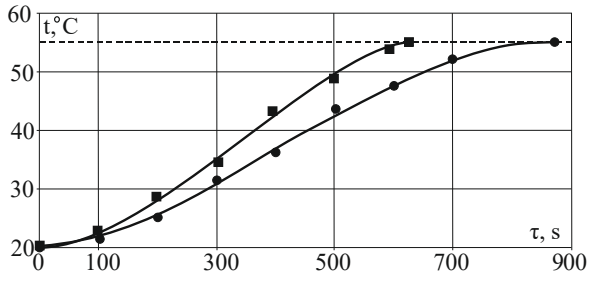

Fig. 2. Experimental results of the kinetics of heating the jam mass with the introduction of vegetable ingredients into the sugar syrup: ■ — improved mobile structure of the cooking apparatus; ● — basic boiler 28-A

Analysis of our data reveals that it takes 620 s to switch to the stationary mode of cooking the jam mass at 55 °C in the improved mobile design of the cooking apparatus, which is 30 % less than the duration in the basic cooking boiler 28-A. The implementation of the preparation of confectionery masses with the simultaneous introduction of plant ingredients requires the use of rational resource-efficient technologies, which is also reflected in the generalized technological recommendations for the production of glazing masses for wafers, cones, etc. [26].

5. 3. Comparative analysis of technological and structural parameters of the model structure with the basic apparatus

A comparison of the improved model design of the mobile cooking apparatus for confectionery masses with the basic design was carried out by calculation. Comparative calculation indicators are summarized in Table 1 (calculations were carried out under the conditions of vacuuming the equipment, heat loss to the environment is not taken into account).

The results of the indicators summarized in Table 1 show the improvement of the efficiency of using the improved model design of the mobile cooking device for confectionery masses compared to the basic design. The main indicators of resource conservation have been improved, namely specific heat consumption and specific metal capacity, which are reduced by 1.34 and 2.10 times from the basic design, respectively. Along with this, the operational performance of the proposed cooking apparatus has been improved due to the use of electric heat supply with a simplified automation scheme, in contrast to steam heating in the basic design. The introduction of a stirrer design with a heating surface increases the usable heating surface by 0.23 m^2, while the cooking time for jam, for example, is reduced by 26 %. Thanks to our practical research, the technical characteristics of the improved model design of the mobile cooking apparatus for confectionery masses have been established (Table 2).

Table 1

Calculation indicators of the improved model design of the mobile cooking apparatus

Indicator	Boiling apparatus 28-A	Model sample of the cooking apparatus
Area of the working surface	F^*=0.65 m^2	$F=F^*+F_{stirrers}$=0.65+0.23=0.88 m^2
Mass	m^*=450 kg	$m=m^*-m_{shirts}+m_{FREhRT}$=450–164+5=291 kg
Specific heat consumption for heating	$q_{heating}=Q/m_p$=37 568.46/195=192.6 kJ/kg	$q_{heating}=Q/m_p$=27 969.9/195=143.4 kJ/kg
Specific metal capacity	$M=m^*/F$=450/0.65=692 kg/m^2	$M=m/F$=291/0.88=330 kg/m^2
The heat of heating the device	$Q_{ap}=m_1\cdot c_c(t_2-t_1)+m_2\cdot c_c(t_3-t_1)$=238·0.48(55–20)+ +164·0.48(143–20)=3998.4+9682.56=13 680.96 kJ	$Q_{ap}=m_1\cdot c_c(t_2-t_1)$=243·0.48(55–20)= 4 082.4 kJ
The heat of heating the jam	$Q_{pr}=m_p\cdot c\cdot(t_k-t_n)$=195·3.5·(55–20)=23 887.5 kJ	$Q_{pr}=m_p\cdot c\cdot(t_k-t_n)$=195·3.5·(55–20)=23 887.5 kJ
Final heat consumption	Q_{gen}=135 143.4 kJ	Q_{gen}=135 227.4 kJ
Boiling time	$\tau=Q/F\cdot k\cdot\Delta t$=135 143.4/0.65·1454·88=1624 s	$\tau=Q/F\cdot k\cdot\Delta t$=135 227.4/0.88·1454·88=1200 s

Note: Information on the basic design of 28-A is taken from [23]*

Table 2

Basic technical characteristics of the model design of the mobile cooking apparatus for confectionery masses

Model index	Parameter
Working volume, m^3	0.15
Working surface of the bowl heating, m^2	0.65
Stirrer heating surface, m^2	0.23
Stirrer drive power, kW	1.0
Surface temperature, °C	to 125
Stirrer rotation frequency, min^{-1}	48
Weight, kg	291

Our data confirm the effectiveness of the proposed design solutions for improving the cooking apparatus of confectionery masses and the formation of a resource-efficient approach to reduce the metal capacity of traditional apparatus, increase the total heat exchange surface, and ensure the mobility of the structure. This will allow the device to be used also at small confectionery enterprises and hotel-restaurant establishments for the production of confectionery masses – increasing competitiveness.

6. Discussion of the effectiveness of implementing the improved design of the mobile cooking device for confectionery masses

The introduction of portable designs of resource-efficient equipment meets the needs of European craft confectionery industries [19], and therefore requires the search for innovative engineering solutions to improve traditional equipment. The following are used for boiling vegetable ingredients: vacuum evaporation and film apparatuses, reactors, cooking apparatuses [20], in which the cooking of confectionery masses is also realized. And so there is a process of combining those technological operations in a single hardware solution, but there is a need to eliminate intermediate heat carriers. For example, work [22] presents an improved design of a tempering machine for heating marshmallow mixture, which is characterized by the elimination of the traditional steam jacket and the introduction of electric heating with the simultaneous provision of additional heating of the stirring device. However, the researchers do not provide complete data on the effectiveness of boiling confectionery masses with organic ingredients, although they offer an effective solution for heating the device. However, the proposed structural solution does not have a portable mobile platform, reducing its competitive advantage. It should be noted that the use of a mobile advanced cooking apparatus is expedient to use in combination with modern technologies of packaging in various containers with the use of automated systems for its production, which meets the international requirements HACCP.

During experimental and practical research, the model design of the mobile cooking apparatus for confectionery masses was improved (Fig. 1). The difference from the traditional equipment is the elimination of the component of intermediate heat carriers and the increase of the heat exchange surface due to the heating of FREhRT (Fig. 1, item 1), including the inner surface of the stirring device. Additional heating of the inner surface of the mixing device (Fig. 1, item 2) increases the total heat exchange surface to 0.23 m^2 (prototype – 0.65 m^2). The elimination of the steam component made it possible to install the device on a mobile platform (Fig. 1, item 6), thereby providing the possibility of use in small confectionery workshops and hotel and restaurant establishments.

The peculiarity of the method of production of the jam mass with the addition of dried fruit and berry raw materials followed by boiling in a sugar syrup solution is preliminary drying in a vertical infrared dryer to 25...35 % DM at a temperature of 40...55 °C. After that, it was crushed to 1.0...3.0 mm, with subsequent addition to sugar syrup. The process of boiling the jam mass with vegetable ingredients was carried out in the range of 50...60 °C in an advanced cooking apparatus to a content of 60...75 % DM, within 5...10 minutes. The set duration of output (620 s) to the stationary mode of cooking the jam mass at a temperature of 55 °C in the improved design of the cooking device, which is 30 % less than the duration in the basic design.

The use of electric heating by a modern film heater with the simultaneous introduction of stirrer heating makes it possible to reduce the specific heat consumption by 1.34 times, and the specific metal capacity by 2.10 times. This confirms the expediency of the implemented engineering solutions. One of the limitations can be considered the need to stabilize the temperature of the working surface. The shortcoming of our experimental and practical studies is the need to carry out regular work on the unloading nozzle installed in the device of automatic valves after a long period of downtime of the device without technological maintenance. However, this does not in any way affect the obtained competitive properties of the equipment, and neglecting

the recommendations specified in the work description can only lead to a decrease in technological and operational properties. Adherence to the recommended properties will ensure an efficient resource-efficient production process of confectionery masses, including various jam masses with the addition of pre-dried fruit and berry raw materials followed by boiling in sugar syrup. However, this will be possible only under the conditions of using the designed model structure of the mobile cooking apparatus.

Further experimental and practical research will be aimed at the development of generalized procedures for determining resource-efficient methods of production of various confectionery masses on the improved design of a mobile cooking apparatus and finding the possibility of introducing resource-saving means.

7. Conclusions

1. The technological and structural feature of the developed and improved design of the mobile cooking apparatus for confectionery masses, in contrast to traditional equipment, is the elimination of the component of intermediate heat carriers, ensuring mobility and increasing the heat exchange surface. This became possible due to the use as a heater of the working chamber and the inner surface of the stirring device of a film-like resistive electric heater of the radiating type, which led to a decrease in the overall energy and metal capacity of the device. Additional heating of the inner surface of the mixing device increases the total heat exchange surface by 0.23 m^2 (prototype – 0.65 m^2). The elimination of the steam component made it possible to install the device on a moving platform, thereby ensuring its use in small confectionery workshops and hotel and restaurant establishments.

2. A technique for producing jam with the introduction of pre-dried fruit and berry raw materials with subsequent boiling in a sugar syrup solution is proposed. A special feature is preliminary drying of vegetable raw materials in a vertical cylindrical IR dryer to 25...35 % DM at a temperature of 40...55 °C. After that, the pre-dried raw materials were crushed on a universal crushing device to 1.0...3.0 mm, with subsequent addition to sugar syrup. The process of boiling the jam mass with the introduction of vegetable ingredients was implemented in the temperature range of 50...60 °C in the improved mobile structure of the cooking apparatus to the content of 60...75 % DM, within 10...15 minutes. The set duration of output (620 s) to the stationary mode of cooking the jam mass at a temperature of 55 °C in the improved design of the cooking device was established, which is 30 % less than the duration in the basic design.

3. The efficiency of the advanced cooking apparatus is improved due to the use of electric heat supply with a simplified automation scheme, as opposed to steam heating in the basic design. The introduction of a stirrer design with a heating surface increases the usable heating surface by 0.23 m^2, while the cooking time for jam, for example, is reduced by 26 %, and the specific heat consumption is reduced by 1.34 times. Thanks to our practical research, the main technical characteristics of the improved model design of the mobile cooking apparatus for confectionery masses have been established.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

All data are available in the main text of the manuscript.

Use of artificial intelligence

The authors used artificial intelligence technologies within acceptable limits to provide their own verified data, which is described in the research methodology section.

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