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DETERMINATION OF THE POSSIBILITY OF USING A FUNCTIONAL APPARATUS FOR THE PRODUCTION OF MULTI-COMPONENT SEMI-FINISHED PRODUCTS WITH A HIGH DEGREE OF READINESS

The object of research is a functional apparatus for the production of paste-like and powdered vegetable semi-finished products. The problem of combined heat and mass exchange treatment of vegetable raw materials are solved by using a functional apparatus for concentration and drying for processing and production complexes, farm lands. The expected effect during the approbation of the device is predicted under the condition of a functional approach combining the processes of concentration and drying with precise control of the temperature regime due to the use of a film-like resistive electronic heater of the radiating type.

In the study, the approbation of a functional device for the production of multi-component vegetable semi-finished products of a high degree of readiness, with concentration and drying in the field of infrared heating at a temperature of 50 °C, was performed. Real-time temperature measurement was carried out by an automatic unit based on TRM, which ensured the accuracy of control at each stage. The temperature of the mashed mass during processing increased from 20.3 °C to 23.2 °C, reaching optimal conditions for forming a film with a thickness of 0.5 mm. In the rotary reboiler, the temperature in height varied from 25.7 °C to 50.1 °C, which contributed to the preservation of the properties of thermolabile raw materials. In the lower part of the apparatus, the temperature of the finished product was 49.8 °C, maintaining the necessary temperature regime for drying. The device creates a convective air flow (0.01 m/s) with the help of Peltier elements, which stabilizes the heat exchange at a temperature of 51.3 °C on the technical partition.

The practical use of the functional apparatus will allow its use at processing and production complexes and directly at the places of collection of plant raw materials for resource-efficient production of semi-finished products with a high degree of readiness. These semi-finished products can act as independent functional products for people in extreme conditions or as recipe ingredients for the recipes of various food products.

Keywords: *functional apparatus, vegetable multi-component semi-finished products, combined heat and mass exchange processing, drying in the field of infrared heating.*

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1. Introduction

Rational nutrition is becoming increasingly important due to a decrease in physical activity and the negative impact of environmental and post-pandemic factors that contribute to the development of various diseases. Innovative technological solutions make it possible to provide a diet with an increased content of natural ingredients rich in biologically active substances that strengthen immunity [1]. The production of multi-component semi-finished products with functional properties based on vegetable raw materials allows creating competitive products with predictable organoleptic characteristics that can be used both separately and as part of other food products. In work [2], it is stated that the introduction of modern resource-efficient solutions in processing processes helps preserve biologically active components of raw materials, contributing to increasing the nutritional value of products.

The work [3] considered the growing demand for natural products with functional properties, which stimulates the use of plant raw materials in the food industry. This allows replacing synthetic components and providing products with original organoleptic and rheological characteristics. Modern technologies contribute to the resource-saving production of high-quality functional products, which is especially important in extreme situations, such as natural disasters, pandemics or military conflicts. They also provide

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an opportunity to increase the efficiency of hardware and technological processes at food enterprises [4, 5].

The use of own resources for the production of functional multi-component semi-finished products with predictable structural and organoleptic properties is important in supporting the agro-industrial sector [6]. Multi-component semi-finished products made by mixing plant raw materials taking into account their functional properties have a special perspective. This approach makes it possible to obtain products that are enriched with useful ingredients, competitive and natural, which ensures a reduction in the use of synthetic additives [7, 8]. At the same time, there is a need to improve technological and hardware solutions for the processing of plant raw materials, which opens up opportunities for trial research aimed at the development of functional food products. For example, work [9] presents a method of making a multi-component fruit and vegetable paste from apple, viburnum, mountain ash, pumpkin and beet, where the recipe takes into account physiological and organoleptic properties. At the same time, the study of the influence of heat and mass transfer processing in functional mobile thermal equipment remains relevant.

The aim of research is to conduct approbation experimental and practical studies of the functional apparatus for the production of multi-component vegetable semi-finished products of a high degree of readiness (pastes/powder-like fraction).

The practical functionality of the device for the production of multi-component vegetable semi-finished products of a high degree of readiness consists in the possibility of being located in places of collection (processing) of raw materials and being equipped with rubbing machines. The structural and technological implementation allows the process of boiling to a paste-like consistency with simultaneous drying of a certain volume of paste in an IR dryer. The implementation of low-temperature heat treatment of multi-component plant raw materials will allow to obtain semi-finished products of a high degree of readiness in the form of pastes and powdery fraction. In addition, the technical passage of the puree-like mass along the inner shaft of the film apparatus allows the raw material to be heated before entering the distribution plate for the effective formation of the film flow. The use of secondary thermal energy when converted by Peltier elements ensures the autonomous operation of the fans of the IR dryer at low-voltage power supply.

2. Materials and Methods

The study of the functional apparatus for the production of multi-component plant semi-finished products of a high degree of readiness (Fig. 1) was carried out on the basis of the Scientific and Educational Center of Innovative Resource-Saving Technologies for the Processing of Organic Raw Materials into Functional Food Products, State Biotechnology University (Kharkiv, Ukraine).

The operation principle of the functional apparatus for the production of multi-component vegetable semi-finished products of a high degree of readiness is based on the step-by-step wiping of vegetable (fruits, vegetables, berries and spicy-aromatic) raw materials on the wiping machine *1* (d=0.3–1.0·10^{-3} m). After the puree-like mass enters the mixer of multi-component semi-finished products *2*, where the recipe ratio of plant raw materials is implemented to obtain functional properties.

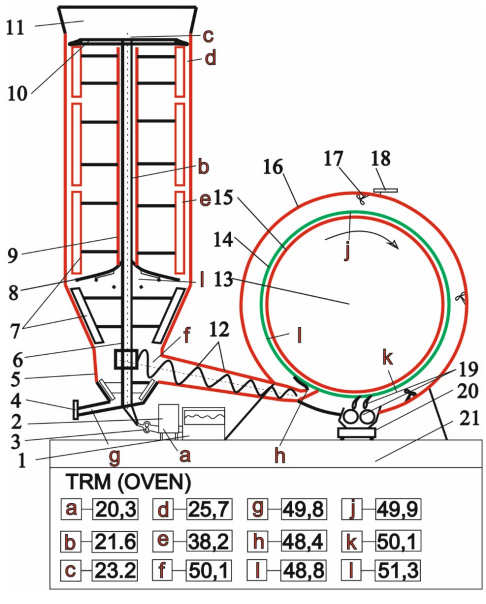

Fig. 1. Experimental scheme of the functional apparatus for the combined production of multi-component semi-finished products of a high degree of readiness (paste/powder): 1 – universal wiping machine; 2 – mixer of multi-component semi-finished products; 3 – gear pump; 4 – outlet pipe of the strip-shaped semi-finished product; 5 – body of the rotary film apparatus; 6 – hollow shaft; 7 – hinged blade with a cutting and reflecting surface; 8 – technical reflective partition with Peltier elements; 9 – screen with a heating surface (FFREHRT); 10 – distribution plate; 11 – separation technical space; 12 – dosing screw; 13 – single-drum roller IR dryer; 14 – corrugated drum of the dryer; 15 – internal drum that is heated; 16 – external heat-insulated drum with a heating surface; 17 – fan; 18 – outlet pipe of vapor-air medium; 19 – mechanism for obtaining a powdered fraction; 20 – hopper of the packaging device; 21 – control unit

The recipe multi-component puree-like mass is fed by the gear pump *3* to the hollow shaft *6*, on which the hinged blades with the cutting and reflecting surface are fixed. The use of this design of the blade makes it possible to stabilize the temperature range of the layer of the sheared film flow and direct it to the body of the rotary-film apparatus *5*, which is heated. And it also increases the film capacity when it hits the distribution plate *10*. The process of low-temperature concentration of the vegetable multi-component mass is implemented in gentle ranges (50–65 °C) taking into account the thermolabile properties of the raw material. Heating of the heating surfaces of the functional apparatus is carried out by a flexible film resistive electronic heater of the radiating type (FFREHRT) [10]. A screen with a heating surface *9* on the outer surface of the hollow shaft 6 provides additional preliminary heating of the mashed mass by 5–7 °C before entering the distribution plate *10*, increasing the film-forming ability. The vapor-air environment in the process of concentration enters the separation technical space *11* with further direction through the pipeline to the condenser of the cooler according to the classic scheme.

The lower part of the body of the rotary-film apparatus *5* is conventionally separated by a technical reflective partition with Peltier elements *8*, which prevents the direct ingress of vapor-air medium to the upper part of the apparatus. Thus, forming a conditional unloading zone of concentrated paste with a dry matter content of 25–35 % through the nozzle *4*, as well as due to the semi-central location of the dosing screw *12*, which ensures the dosing of the pasty mass entering drying. From the dosing screw *12*,

the paste-like mass enters the single-drum cylindrical IR dryer *13* and is directly injected onto the corrugated drum *14*. A feature of the heat treatment of the IR dryer is the presence of an internal drum *15* and an external heat-insulated drum *16* with heating surfaces.

The radiation drying process is carried out in gentle temperature ranges (45–60 °C) under the conditions of a free convective air environment (0.01 m/s) in the working space of the dryer. Convection of the air environment is formed in the autonomous mode due to the conversion of secondary heat energy by Peltier elements installed on the technical reflective partition *8*. At the secondary temperature of the air environment, when concentrated in gentle ranges (50–65 °C), the low-voltage supply voltage is within 3–8 W, which is enough for the autonomous operation of fans *17*. The steam-air environment from the working chamber of the dryer is discharged to the environment using the nozzle *18*. Dried raw material with a moisture content of 3–6 % enters the mechanism with cutting knives *19* to obtain a powdery fraction (0.3–0.6 mm) and then enters the hopper of the packaging device *20*.

The proposed functional apparatus allows for the production of multi-component vegetable semi-finished products of a high degree of readiness, which can be used both as an independent product and as a recipe ingredient. At the same time, the introduction of a multi-component semi-finished product into the recipes of food products allows to increase the functionality of the obtained products with predicted rheological and organoleptic properties, to replace a certain share of the main recipe ingredient and to reduce the dependence on synthetic ingredients.

3. Results and Discussion

Approbation of the functional apparatus was carried out at the temperature of concentration and drying in the IR field at a temperature of 50 °C. With the measurement of temperature changes in real time due to the automatic control unit 20 based on the TRM of the "OVEN" (Kharkiv, Ukraine) company, which is connected to thermocouples from *a* to *l*. It was established that the temperature of the pureed vegetable mass after rubbing corresponds to the ambient temperature (20.3 °C). When the mass passes through the hollow shaft *6*, it is additionally heated by a screen with a heating surface 9 based on FFREHRT. Consequently, the mass is heated to 21.6 °C (thermocouple *b*, the middle of the boiler height section) and 23.2 °C (thermocouple *c*, the upper point of film flow formation) on the distribution plate *10*. This, in turn, makes it possible to increase the film-forming ability of the vegetable pureed mass. The film-like flow from the distribution plate (thickness 0.5 mm) enters the working surface of the rotary evaporator, where it concentrates for 0.85 s. At the same time, along the geometrical surface of the rotary cooker, the layer of vegetable mass is simultaneously cut and, accordingly, moved to the lower part of the apparatus by hinged blades with a cutting and reflecting surface *7*. The change in the temperature range of the vegetable mass along the height of the rotary cooker corresponded to the values for thermocouples: *d* – 25.7 °C, *e* – 38.2 °C and *f* – 50.1 °C, confirming compliance set temperature range. The pasty semi-finished product is discharged from the rotary reboiler with a temperature of 49.8 °C (thermocouple – *g*) and enters for further technological implementation. The structure of the lower part of the functional apparatus provides for a partial flow of the concentrated mass to the dosing screw *12* and an adjustable injection of the mass onto the corrugated drum of the dryer *14* (temperature of the mass 48.9 °C, thermocouple – *h*), the temperature decrease is explained by the movement along the dosing channel. The values of the thermocouples: *j* (49.9 °C) and, respectively, – *k* (50.1 °C), confirm compliance with the operating temperature range, which in turn forms gentle temperature ranges for processing thermolabile raw materials and clear dynamics of heat treatment. The functional device allows to create the necessary convective component of the air flow (0.01 m/s) in the working chamber of the dryer under the conditions of conversion of the secondary heat of concentration by Peltier elements installed on the technical reflective partition *8*. At the operational boiling temperature of 50 °C, the temperature on the technical reflective partition with elements Peltier *8* is 51.3 °C and the conversion produces a low-voltage supply voltage within 8 W, which is enough for autonomous operation of fans *17*.

The practical use of the functional apparatus will allow its use at processing and production complexes and directly at the places of collection of plant raw materials for resource-efficient production of semi-finished products with a high degree of readiness. These semi-finished products can act as independent functional products for people in extreme conditions or as recipe ingredients for the recipes of various food products.

Among the limitations, one can note the need to conduct a number of experimental and practical studies on the technological component (ratio of multi-component semi-finished products in the composition, regime parameters, rheological and organoleptic properties). This, in turn, will make it possible to obtain a generalized base for resource-saving processing of plant raw materials, even in the conditions of conducting research in the front-line territory of the Kharkiv region, and therefore support the production capacity of farmland and processing complexes.

4. Conclusions

Approbation of the functional device took place at a temperature of 50 °C with real-time monitoring of changes thanks to an automatic control unit based on thermocouples. It was established that the temperature of the mashed mass after preliminary wiping was 20.3 °C and gradually increased to 50.1 °C, providing optimal conditions for film formation and product concentration. After that, the mass enters the corrugated drum of the dryer, where the temperature is maintained in the range of 48.9–50.1 °C, maintaining the stability of the technological process. The equipment creates the necessary air flow and uses secondary heat, ensuring autonomous operation of the dryer. The functional apparatus is suitable for use at processing plants and raw material collection sites, providing resource-saving production of finished semi-finished products that can be used as functional products or ingredients in other products. Additional experiments will help clarify the parameters of the regime for optimal processing of vegetable raw materials and support of farms even in the front-line zones.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal,

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authorship, or any other, that could affect the study and its results presented in this article.

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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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