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CHAPTER 3

SCIENTIFIC AND PRACTICAL JUSTIFICATION OF INNOVATIVE APPROACHES TO PRODUCTION OF MULTICOMPONENT SEMI-FINISHED PRODUCTS FOR FOOD PRODUCTS IN THE CONDITIONS OF FOOD SECURITY OF THE COUNTRY

ABSTRACT

The production of functional products in the form of independent and multicomponent compositions based on vegetable semi-finished products of a high degree of readiness for further use during the manufacture of various food products is proposed. The proposed adaptive mechanism makes it possible to simulate the competitiveness of the agro-industrial sector in the conditions of taking into account the flow parameters of traditional micro- and macro-environments for the optimal adaptation of innovative approaches when implementing resource-saving hardware and technological solutions.

A resource-saving method for the production of multi-component puree-like semi-finished products with a high degree of readiness based on own plant raw materials of apple, Jerusalem artichoke, cranberry, beetroot and hawthorn has been developed. The hardware implementation of the resource-saving method is provided by the developed author's designs of unified mobile low-temperature devices, the feature of which is the reduction of energy and metal consumption, ensuring uniformity of heat supply, stabilization of the temperature range, the possibility of using secondary heat energy. The proposed method is unified due to the implementation of the concentration process as needed in the form of a film flow (unified rotary-film apparatus), in a flow (unified tubular apparatus) and boiling in mass (unified vacuum-evaporation apparatus). Also, due to technological necessity, there is an additional technological operation of drying, which is implemented on a fundamentally new thermal radiation single-drum roller dryer.

The film-like electronic heater of the radiating type has been improved. Thanks to the improvement, the following technical properties of the film-like electronic heater of the radiating type have been achieved in terms of the maximum temperature of the working surface (40...180 °C). At the same time, the IR wavelength set from 2.0 to 15 μm with a power of up to 800 W/cm^2 and a technical efficiency factor (0.97) are optimal for heat and mass transfer processing of multicomponent vegetable semi-finished products. Thus, the reduction of: weight and specific metal capacity of the developed devices is ensured; duration of processing of thermolabile plant raw materials.

An equipment-technological line for the production of vegetable polycomponent semi-finished products with a high degree of readiness has been developed, which can be located directly on

farmland for the cultivation of natural raw materials. The practical implementation of the proposed innovative approaches in the production of semi-finished products will allow to support the own capacities of farmland, modernization of processing and production sectors of agro-industry. The resulting functional polycomponent semi-finished products will allow expanding the range of food products with an increased content of functionally physiological ingredients, predicted rheological and organoleptic properties. The introduction of developed semi-finished products into the recipes of various food products will reduce the need to use synthetic ingredients, replacing them with natural components.

KEYWORDS

Functional products, polycomponent semi-finished products with a high degree of readiness, competitiveness mechanism, concentration, drying, resource saving, film-like electronic heater of radiating type, structural and mechanical indicators, temperature field.

The implementation of scientific and practical innovative approaches in the agro-food sector is the key to the formation of food security of countries and the health of nations in the conditions of rapid adaptation of the processing and production chain to today's challenges (ecological, man-made, military, etc.). This will allow agro-industry to meet the rapidly changing needs of countries and consumer cooperatives during the production of food products and semi-finished products of increased physiological function with original rheological and organoleptic properties [1].

The use of one's own natural raw material bases (vegetable, meat, etc.) will make it possible to significantly reduce the dependence of countries in the international arena on existing import offers (recipe ingredients of synthetic origin and no benefit for human health). According to the "Sectoral Export Strategy of Ukraine for 2019–2023", the processing of natural raw materials is only 30 % of the volume of its collection from the areas of agricultural enterprises (920 thousand hectares) [2]. Today, this is explained not only by the lack of systematized, scientifically based solutions of a hardware and technological nature, regarding the processing of organic raw materials, it is especially complicated in the conditions of hostilities and the destruction of many infrastructure facilities. An important strategic task of ensuring the support of the own capacities of the agricultural sector, the processing industry and the food sector as a whole forms a strong economic export capacity of Ukraine with products of natural origin [3]. This will ensure international recognition on the world stage, prevent a food crisis in European countries and fill the country's budget, especially during full-scale military operations for rapid post-war recovery. When processing plant raw materials, attention should be paid to resource-saving processing with the use of secondary energy and the formation of rational methods of production of nutrient-based products with maximum preservation of natural properties. Ensuring the conditions for the production of our own polycomponent vegetable semi-finished products of a high degree of readiness with the subsequent introduction into the recipes of various food products, giving them predicted functional properties [4].

Traditional equipment of processing and production capacities of the agro-food sector needs modernization or the design of fundamentally new equipment to increase resource-saving operational and technological properties [5]. In particular, this applies to heat and mass exchange equipment based on intermediate coolants with increased energy and metal capacity, complicated stabilization of the temperature range and the use of additional generating devices and transportation networks. The use of heat-generating elements with fixed geometric dimensions, as well as intermediate coolants, leads to an artificial increase in the metal capacity of the equipment due to the formation of non-technological working zones. This, in turn, leads to an increase in the operational time of the devices reaching the working range and the consumption of converted thermal energy for heating the metal structures of the technological equipment of agro-industrial complexes. In addition, the existing traditional technological equipment based on the above-mentioned heat-generating elements is characterized by a low percentage of conversion of secondary thermal energy to further production needs, reducing the complex resource-efficient component of production sectors. As a result, a certain load on the country's primary resource component (gas, energy, etc.) is realized, which is difficult for the country's economy and enterprises in the conditions of full-scale military operations. Emphasizing the relevance of scientific and practical research aimed at finding, adapting and implementing innovative approaches under the conditions of comparing the technical properties of existing heat-generating elements for the formation of a resource-efficient component of heat and mass exchange equipment.

The use of traditional heat and mass exchange equipment forms the technological process and processing methods of the agro-food industry and is responsible for preserving the physiologically functional properties (quality) of the obtained natural semi-finished products and food products in general. This requires the introduction of modern innovative hardware and technological solutions based on qualitatively justified methods of heat supply, which are implemented on the main heat and mass exchange equipment with the use of gentle technological operations under the conditions of using secondary energy for production needs. Forming an urgent task of generalizing innovative hardware and technological solutions for the production of organic plant semi-finished products (dried fractional and pre-blended and powdered fractions) of a high degree of readiness. As well as food products based on them, allowing to obtain functional food rations of domestic origin under the conditions of using innovative equipment and technological approaches.

The production of health functional products by our own agro-industrial facilities in the form of independent and multi-component compositions based on vegetable semi-finished products of a high degree of readiness has a wide demand in the processing and food industries and in restaurants. In addition, it will make it possible to form a full-fledged diet in the post-pandemic and military period, thanks to the introduction of organic medical and preventive nutrition, in particular for people who are in extreme conditions (doctors, military personnel, etc.). Emphasizing the relevance of research aimed at the scientific and practical substantiation of processes and equipment for the production of organic vegetable semi-finished products of a high degree of readiness. And also, food products through the implementation of innovative energy-efficient hardware and technological

solutions aimed at obtaining products with a functional, adjustable nutrient composition from the moment of collecting raw materials to the sale of finished functional competitive products.

To solve one of the important tasks of Ukraine's national security in the conditions of military operations and rapid post-war recovery in the conditions of the majority of the population staying in extreme conditions and not having the possibility of daily full nutrition. An interdisciplinary project group was formed on the basis of the capacities of the State University of Biotechnology (Hero City Kharkiv), which, with the support of the Ministry of Education and Science of Ukraine, is implementing the state budget project "Development of hardware and technological solutions for the production of multi-purpose multicomponent organic semi-finished products and food products in the conditions of military operations and post-war reconstruction of the country". The main task of the project group is the development of innovative hardware and technological solutions for the production of multi-purpose multicomponent organic semi-finished products and food products under the conditions of using the country's own raw material base to support processing and production complexes in conditions of military operations. The obtained project solutions and results presented in the work are aimed at the possibility of further approval at the facilities of the EU countries due to the use of their own mechanisms and management systems for the organizational and legal security of agricultural enterprises of Ukraine.

3.1 THE URGENCY OF FINDING INNOVATIVE APPROACHES IN THE PRODUCTION OF MULTICOMPONENT SEMI-FINISHED PRODUCTS FOR THE FOOD SECURITY OF THE COUNTRY

Today's development of Ukraine in the conditions of full-scale military actions, in addition to defensive actions, is also aimed at strengthening national agricultural and food security, which can be realized at the expense of finding and implementing innovative approaches. Ensuring daily full nutrition of all segments of the population with simultaneous support of the agricultural sector is possible by growing one's own cheaper raw material base of natural (organic) origin [6]. With further comprehensive support of the country's processing and production capacities, the formation of resource-efficient mobile heating equipment will allow at the national level to maintain a full-fledged diet of the population of European countries. Preventing a decrease in the immunity of consumers, especially people who are in extreme conditions (military personnel of the Armed Forces, peacekeepers of the Alliance countries, doctors, volunteers, internally displaced persons, etc.) by using natural ingredients of plant origin, instead of synthetic components.

The introduction of multi-purpose multicomponent organic semi-finished products and food products based on them into the diet of the population requires innovative solutions to ensure high-quality prevention of environmental and military challenges, chronic and acquired diseases and pandemics. One of the ways to achieve this is the use of the domestic organic plant raw material base with further comprehensive support of agro-production complexes of Ukraine [7, 8]. Organic plant raw materials act as a natural source of functionally physiological ingredients

of health-improving action, possessing original structural-rheological and organoleptic properties necessary for the formation of original polycomponent semi-finished products. This will make it possible to produce high-quality natural functional and specialized semi-finished products of a high degree of readiness and food products for the daily diet, providing effective resistance to environmental and military factors and infectious, bacterial, cardiovascular, oncological diseases, etc.

3.1.1 PECULIARITIES OF THE COMPETITIVENESS FORMATION IN THE CONDITIONS OF PRODUCTION OF POLYCOMPONENT SEMI-FINISHED PRODUCTS FOR FOOD PRODUCTS

The dynamic system of the world economy allows taking into account various variable factors (needs of national security, raw material base, innovativeness of technology and the agro-industrial sector, assortment and novelty of goods, interest of consumer cooperatives, etc. [9]), including:

– ecological and technogenic factors, taking into account the locality of cultivation of own raw material base, industrial capacities of processing and production complexes for obtaining food products;

– technological factors of the agricultural sector (technologies: sowing, cultivation, harvesting), features of storage, transportation and methods of processing and conditions of sale to consumers;

– technological factors of the processing and manufacturing industry (territorial dependencies of the location of the raw material base, sources of heat energy, energy and metal capacity of heat equipment and the comprehensive level of resource efficiency);

– the efficiency of combined processing of agricultural raw materials in the conditions of mobile technological lines for the production of polycomponent semi-finished products with a high degree of readiness and food products based on them.

The generalized influence of the above-mentioned factors requires a quick reaction of the agro-industry of any European country, especially in the conditions of full-scale military operations and the world food crisis, and taking into account ecological, man-made and other situations. The development of the own capacities of agro-industrial complexes of European countries is a condition for the formation of national food security and international recognition of competitiveness due to the production of products of a wide range of use and demand. Unfortunately, the production of products using traditional energy- and metal-intensive hardware and technological solutions does not fully satisfy consumer demand for quality products at favorable prices offered by the manufacturer during sales. This leads to a decrease in the profitability and payback of production, including in terms of resource consumption (initial raw materials, transportation/storage costs, processing, production, spent thermal energy sources, etc.)

The adopted competitive program "Strategy for the development of agriculture in Ukraine for 2015–2020" combines 10 important strategic and priority directions aimed at supporting and developing the agricultural sector and the general development of the agro-food industry

for the formation of national food security [10]. Taking into account the current pricing factors in the conditions of taking into account the introduction of innovative resource-saving hardware and technological solutions into the own agricultural sector to obtain a competitive range of products to increase the country's export capacity. The analysis of the existing mechanisms of the formation of the agro-industrial market allows to find the necessary components of ensuring competitive conditions, taking into account business ethics, the needs of consumer cooperatives and recognition in the international arena. The use of innovative equipment and technological solutions in the formation of complex resource-saving solutions aimed at the cultivation of one's own natural raw material base, further supply to unified mobile processing and production complexes in the conditions of the optimal ratio of price and quality of products. A rational combination of the main components aimed at:

– the development of the agricultural sector for the cultivation of its own raw material base using innovative eco-technologies (sowing, cultivation, harvesting, etc.) allows obtaining organic raw materials on the country's chernozems even in conditions of military operations;

– the development of innovative approaches to the processing sector of agro-industry in terms of the use of zero-waste technologies in the processing of plant raw materials (use of seeds, skins, suitable waste (rubbing/cutting), etc.) in general production technologies. This will make it possible to obtain special natural semi-finished products (extracts, tinctures, recipe ingredients, etc.) at the processing stage for further use in many areas (pharmaceutical, food, etc.). In addition, in most cases, the waste of the processing complex of plant raw materials contains the original micro- and macro-elements necessary for the formation of consumer immunity and the body's resistance to environmental factors;

– the development and adaptation of the production potential to the needs of Ukraine today in the conditions of full-scale military operations through the use of resource-saving technologies aimed, among other things, at reducing the energy and metal consumption of traditional equipment.

Introducing into the country's production potential innovative hardware and technological solutions for the rational processing and production of organic raw materials grown in-house. This approach will make it possible to obtain original polycomponent semi-finished products of a high degree of readiness, which will have the properties of an independent product ready for consumption or recipe ingredients of various food products. Thereby minimizing the need to use traditional synthetic foreign ingredients (flavors, dyes, etc.) for natural multifunctional components with natural physiological properties, original organoleptic and rheological properties to obtain innovative food products. However, one should remember the need to implement technological processes under rational parameters, taking into account the impact of the energy and metal consumption of the hardware component, leading to the need to implement resource-saving hardware technological solutions.

Having considered the main components of the formation of the competitiveness of the agro-industrial environment in the conditions of the production of multicomponent semi-finished products for food products in the conditions of food security of the country in the target chain, a block diagram of the adapted mechanism of competitiveness management is proposed (**Fig. 3.1**).

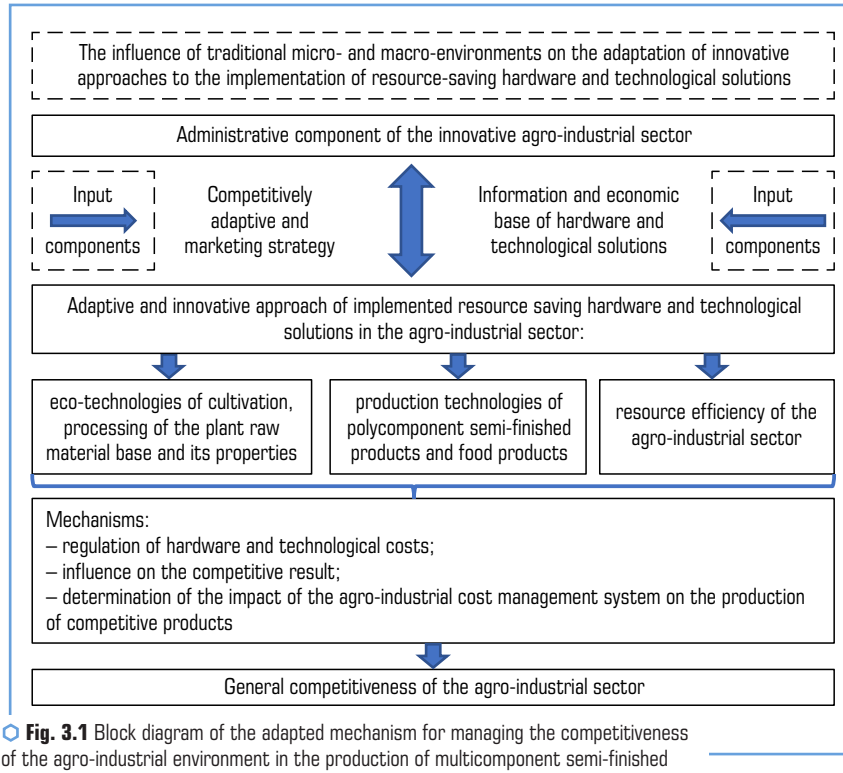


Fig. 3.1 Block diagram of the adapted mechanism for managing the competitiveness of the agro-industrial environment in the production of multicomponent semi-finished products for food products

The adaptive mechanism (**Fig. 3.1**) models the overall competitiveness of the agro-industrial sector by taking into account the parameters of the influence of traditional micro- and macro-environments on the adaptation of innovative approaches when implementing resource-saving hardware and technological solutions. The administrative component of the innovative agro-industrial sector takes into account input (resource, technological, equipment, etc.) and input (level of resource saving, originality of product range, cost, etc.) components. In the conditions of information exchange between the competitive-adaptive/marketing strategy and the information-economic base of hardware-technological solutions (technological maps, methods of processing/production, the level of efficiency of the adopted decisions, the investment-financial component of the adopted innovative approaches, etc.).

The proposed adaptive and innovative approach of implementing resource-saving hardware and technological solutions in the agro-industrial sector is aimed at taking into account:

– eco-technologies of cultivation and processing of raw plant base taking into account physico-chemical, rheological and organoleptic properties;

– optimal technologies (rational methods) for the production of polycomponent semi-finished products with a high degree of readiness and food products based on them;

– innovative solutions are aimed at resource-efficient processing and reduction of energy and metal consumption for the formation of resource efficiency of technological equipment.

At the same time, the control of the effectiveness of the adaptive-innovative approach was controlled by the mechanisms of regulation of hardware and technological costs and the impact on the competitive result, with the determination of the impact of the agro-industrial cost management system on the production of competitive products. Thus, the formation of the overall competitiveness of the agro-industrial sector was achieved, in the conditions of the production of multicomponent semi-finished products and food products for the country's food security in the target chain.

The efficiency of the adapted mechanism for managing the competitiveness of the agro-industrial environment in the production of multi-component semi-finished products and food products is effective under the following conditions:

– monitoring of the agro-industrial market at the international level to obtain information on trends in target sales markets, ways to improve marketing mechanisms to improve sales approaches, including using Internet resources;

– cyclical adaptation of the administrative component of the innovative agro-industrial sector under the conditions of the use of adaptive and innovative approaches to the implementation of resource-saving equipment and technology. Taking into account the environmental, man-made, military situation, etc. and the existing demand of consumer cooperatives and production efficiency while minimizing costs, forming a competitive price value and quality of the obtained products. This approach will make it possible to form the reach of the agro-industrial sector in the conditions of full implementation of manufactured products in accordance with the implemented adaptive-innovative hardware-technological approaches, and therefore to obtain a visible effect from the capital investments of the implementation of the proposed mechanism. Resource-saving production of plant-based polycomponent semi-finished products with a high degree of readiness and various food products based on them with original nutrient composition, rheological and organoleptic properties will ensure a competitive individual approach to consumer cooperatives. Increasing the demand for the consumption of the proposed assortment of products based on plant raw materials in the conditions of a combination of economic, man-made, situational and psychological factors, taking into account the data of marketing research on the behavior of potential consumers.

3.1.2 PECULIARITIES OF USING ONE'S OWN ORGANIC PLANT RAW MATERIAL BASE IN THE CONDITIONS OF PRODUCTION OF POLYCOMPONENT SEMI-FINISHED PRODUCTS FOR FOOD PRODUCTS

Since ancient times, the territory of Ukraine has been famous for its fertile chernozems and significant volumes of its own natural raw material base, in particular plant (fruit and berry, vegetable,

grain, spicy and aromatic, etc.), which in most cases is a source of natural physiologically functional ingredients. It has specific organoleptic and rheological properties, which, under conditions of rational blending, allow creating original multicomponent compositions with increased nutrient composition [11]. The use and processing of one's own raw resources of natural raw materials grown according to today's eco-technologies provides support to domestic farms and cooperatives, forming one of the components of the country's national security. The development of the agro-industrial sector has the support of the state in various programs and strategies of Ukraine-EU development, as it is an important exporter on the international market. The introduction of full-scale military operations on the territory of Ukraine reduces the intensity of the agro-industrial sector with existing traditional complex technological solutions. The implementation of resource-saving innovative approaches of agro-industry in the production of polycomponent semi-finished products with a high degree of readiness and food products based on them will ensure own food security and stabilize the international food crisis at the expense of export capacity [12]. In addition, it will make it possible to increase competitiveness, reduce the country's dependence on the international arena from import offers in the conditions of military operations, and obtain high-quality functional products for consumer cooperatives.

Natural plant raw materials grown on the chernozems of Ukraine according to traditional eco-technologies are cheap raw materials, except for the correspondingly selective varieties, but today's genetic technologies allow reducing the final cost of cultivation due to cultivation. Grown vegetable raw materials are a natural box of physiologically functional nutrient ingredients (FNI) with original rheological and organoleptic properties, which are necessary in the daily diet of the population to support/form and strengthen the immune component. However, if to consider plant raw materials: fruit, berry, vegetable, spicy-aromatic, etc. separately, they have certain "limited" FNI. Therefore, there is a need to conduct a number of experimental and practical studies aimed at determining the effectiveness and expediency of blending in order to obtain functional multicomponent natural semi-finished products of a high degree of readiness with predicted rheological and organoleptic properties [13].

In the course of analytical and experimental-practical complex studies, sample data were obtained to determine the expediency of mixing plant raw materials taking into account the natural features of plant raw materials [14]. During the studies of the effectiveness of the production of multicomponent blends, cheap domestic pectin-containing raw materials with a significant content of dietary fibers were chosen as the main plant raw materials: apple and Jerusalem artichoke. At the same time, its rheological properties act as a control during the comparison during blending of the structural and rheological properties of the semi-finished product (puree-like/paste-like). Raw materials with high carotene-containing and saturated coloring properties and FNI were selected as additional plant raw materials that were part of the blend [15].

Blending of the puree-like semi-finished product was carried out based on the calculation of the proportion of ingredients per 100 g of the test sample. At the same time, research was carried out for 3-, 4- and 5-component samples with the aim of forming a generalized idea about the formation

of rheological, FNI and organoleptic properties. A feature of the implementation of resource-saving methods of obtaining multicomponent puree-like semi-finished products is: rational blending of plant raw materials taking into account structural-mechanical, organoleptic and FNI properties under the conditions of using low-temperature methods of blanching, concentration, drying. For example, the recipe composition (**Table 3.1**) and the proposed method of production of polycomponent semi-finished products of high degree of readiness (**Fig. 3.2**) based on apple, Jerusalem artichoke, cranberry, beetroot and hawthorn are presented.

Table 3.1 Recipe composition of the 5-component puree-like semi-finished product

Recipe and component composition, %	Polycomponent pure-like semi-finished product		
	A	B	C
Apple	20	35	45
Jerusalem artichoke	20	25	35
Cranberry	30	20	10
Beetroot	15	10	5
Hawthorn	15	10	5
Control	100	100	100

An example of the proposed resource-saving method of production of multi-component puree-like semi-finished products of a high degree of readiness based on own plant raw materials of apple, Jerusalem artichoke, cranberry, beetroot and hawthorn (harvested in the territory of the Kharkiv region in 2023). The hardware implementation of the resource-saving method is provided by pre-developed proprietary designs of unified mobile low-temperature devices, the feature of which is the reduction of energy and metal consumption, the uniformity of heat supply with a clear stabilization of the temperature range, the possibility of using secondary heat energy.

Ripe plant raw materials underwent traditional initial cleaning technological operations (washing, inspection, cutting according to technological needs, blanching). In accordance with the proposed technology, the hawthorn was kept in a 10...15 % NaCl solution with the addition of 1 % citric acid in a temperature range of 15...20 °C for 20...30 minutes to stabilize polyphenols. The selected raw materials underwent a short-term preliminary blanching operation in a universal multifunctional device [16], in particular with hot steam (103...115 °C): apple (1.5...3 min), Jerusalem artichoke (4...8 min), beetroot (8...10 min) and hawthorn (4...6 min). Blanching of cranberries was carried out with hot water for 1...2 minutes at a temperature of 85...90 °C, taking into account its natural consistency and FNI content.

Plant raw materials that have undergone the previous technological operation of blanching are sent to a universal wiping machine for wiping with the possibility of wiping components up to the size of 0.2...0.5 10^{-3} m. Waste obtained during wiping and cutting of vegetable raw

materials (skin, seed cell, bones, etc.) in order to increase the resource efficiency of the proposed technology are submitted to additional operations with drying in the IR field [12], extraction, etc. Extraction is suggested to be carried out for the first 4…8 minutes at a temperature of 70…75 °C with a further decrease in temperature to 55…70 °C. The technological operation of drying in the IR field is carried out at a temperature of 45…60 °C to the final moisture content – 6…12 % of the SR. This, in turn, makes it possible to obtain specific semi-finished products with original properties and a wide range of use in the pharmaceutical, processing and other industries in accordance with technological needs, replacing synthetic ingredients of foreign origin.

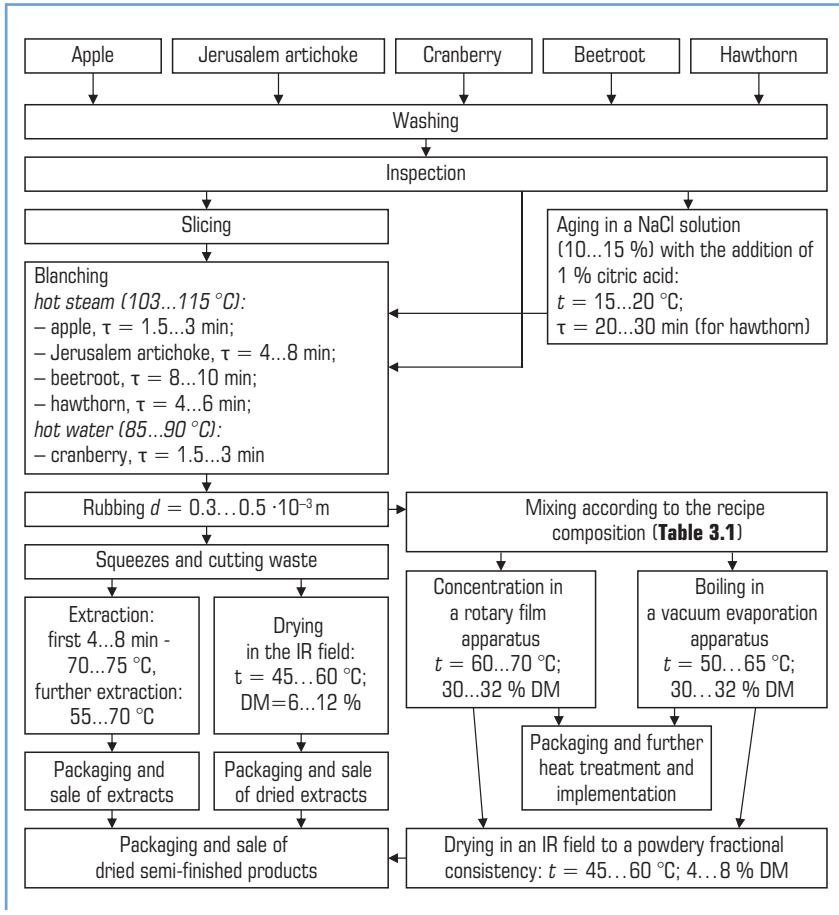


Fig. 3.2 The method of production of polycomponent semi-finished products with a high degree of readiness

After that, the homogeneous puree-like mass was sent to the mixing unit with a stabilizing thermal shell (unified reactor [17, 18]), in which the recipe mixing process of 5 components to a homogeneous state of a multi-component puree-like semi-finished product is implemented according to **Table 3.1**. A preliminary comparative analysis of organoleptic properties was carried out through evaluation by an expert group (5 people from the State Biotechnology University) of multicomponent puree-like test samples (**Table 3.2**)

Table 3.2 Results of expert assessment of organoleptic properties of multicomponent puree-like experimental samples obtained according to the recipe composition (**Table 3.1**)

Assessment index	Experimental polycomponent puree-like semi-finished product		
	A	B	C
Appearance	Homogeneous puree-like vegetable mass		
Taste and aroma	Harmonious taste of Jerusalem artichoke and apple, audible taste of cranberry, beetroot and hawthorn	Pleasant harmonious taste of Jerusalem artichoke with light notes of apple and cranberry	Pronounced smell and taste of Jerusalem artichoke in combination with apple
Color	Pronounced yellow-orange with a light red color	Pleasant yellow-light red/orange	A light shade of yellow-orange with a slight hint of red
Consistence	Homogeneous viscous consistency of uniform rheological structure		

A viscous consistency with a homogeneous rheological structure is formed as a result of mixing recipe vegetable purees into a multicomponent mass (spreading and separation of components is not observed). In terms of color and taste-aromatic indicators, blend B with the content of: apple – 35 %, Jerusalem artichoke – 25 %, cranberry – 20 %, beetroot – 10 % and hawthorn – 10 % is superior. Other experimental polycomponent puree-like semi-finished products (A and B) have more/less pronounced organoleptic properties of certain ingredients in terms of taste and color.

The formed homogeneous polycomponent puree-like mass was sent to the further technological operation of concentration. The proposed method is unified due to the implementation of the concentration process as needed in the form of a film flow (unified rotor-film apparatus [19]). The efficiency of using rotary-film evaporators is presented in experimental and practical works [20, 21]). Concentration can be carried out in a direct flow based on a film-like electric heater (unified tubular apparatus [22]) and boiling in mass (unified vacuum-evaporator apparatus [23]). The concentration process in a unified rotary-film apparatus is implemented under the conditions of a low temperature range (60...70 °C) to a paste-like state within 0.75...0.9 min., in a unified vacuum-evaporating apparatus at a temperature of 50...65 °C [24]. Regardless of the cooking method, the puree-like multicomponent mass was cooked to a pasty consistency with a content of 30–32 % DM, followed by packaging in a light-proof hermetic container with simultaneous heat treatment and sent for further sale. Packaging of the paste-like semi-finished product can be implemented in glass and

PET containers [25] depending on the technological needs and the way of use by consumer cooperatives, including significant attention is paid to the conditions of transportation/storage and use.

In order to visualize the obtained rheological properties of polycomponent semi-finished products when creating products with predicted structural and mechanical properties, it is necessary to determine them during concentration (boiling) with subsequent comparison with the control (apple puree). **Fig. 3.3** shows the properties of the ultimate shear stress of each component of the recipe composition of the future multicomponent semi-finished product (Θ, Pa).

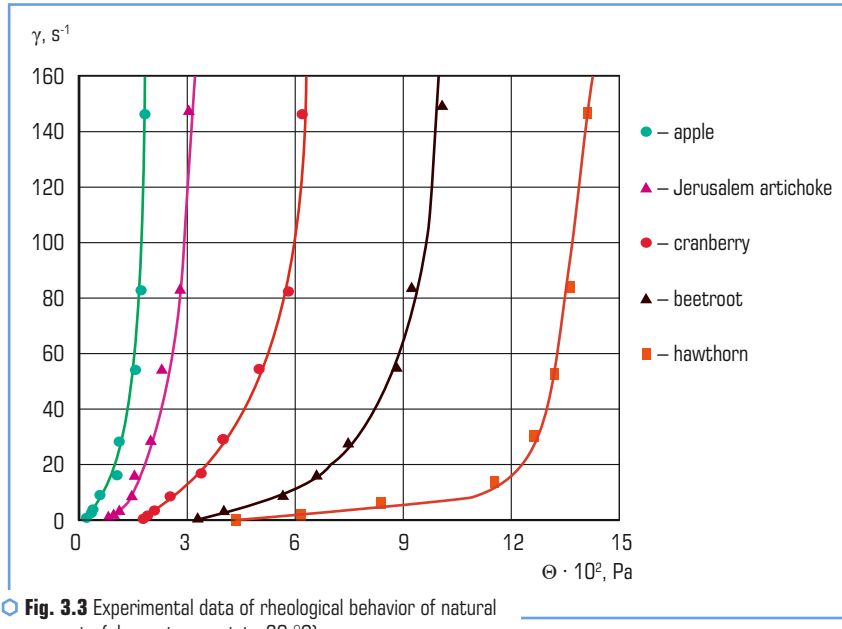


Fig. 3.3 Experimental data of rheological behavior of natural components (shear stress, at t=20 °C)

Thus, the control component of the future multicomponent puree-like composition has an ultimate shear stress of 15 Pa, Jerusalem artichoke – 320 Pa, cranberry – 70 Pa, beetroot – 85 Pa, and hawthorn – 440 Pa, respectively. In addition, for a complete picture of the rheological structure of polycomponent semi-finished products of plant origin, the dependences of dynamic viscosity on shear rate for puree and paste were obtained (**Fig. 3.4**, for the optimal blend B according to expert evaluation data, **Table 3.2**). The control was non-variable (apple puree/paste) with further comparison of the obtained rheological properties of the cooked pasty semi-finished product with a content of 30 % DM.

The analysis of the presented rheological parameters confirms the increase in the effective viscosity of the multicomponent sample B by 28 % compared to the control. In particular, test

sample B with the strength of the structure at the level of 440 Pa·s, compared to the control in the form of applesauce – 53 Pa·s. Boiling in a rotary-film apparatus at a temperature of 60 °C to 30 % DM made it possible to increase the strength by 3.4 times – 550 Pa·s, compared to the control (with apple paste 30 % DM – 175 Pa·s. Therefore, it is possible to draw a preliminary conclusion about the formation of a multicomponent plant experimental sample of high potential, increasing the effectiveness of its use as a natural additive or filler in various recipes of food products.

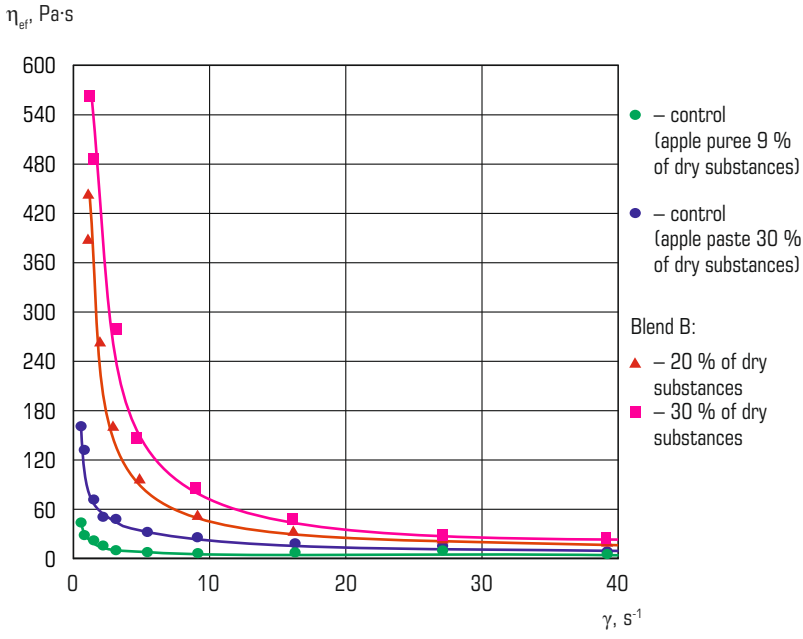


Fig. 3.4 Rheological curves of multicomponent vegetable semi-finished products (t=20 °C)

The obtained paste-like multicomponent vegetable mass is a semi-finished product of a high degree of readiness and can act as an independent product ready for direct consumption by consumer cooperatives [26]. Including by people who are in extreme conditions (military personnel, doctors, volunteers, tourists, etc.) and can be used as recipe ingredients in various food products [27], pharmaceutical products of the processing industry, etc.).

To expand the functional properties of the proposed production method, there is a possibility of drying the paste-like multicomponent products of a high degree of readiness to a powder-like

fractional consistency if technologically necessary. An additional technological operation of drying was implemented on the design of a fundamentally new thermal radiation single-drum roller dryer [28]. The peculiarity of the design is the preliminary heating of the strip-like polycomponent semi-finished product in the inner space of the corrugated drum and direct injection onto the corrugated surface by a special design of the trunnion. In addition, the device is equipped with autonomous fans to create a convective component in order to intensify the IR convective and conductive drying process. Drying in the IR field of a roller dryer to a powder-like fractional consistency is carried out under gentle temperature ranges (45…60 °C) to a dry matter content of 4…8 %. This approach will make it possible to obtain polycomponent semi-finished products of a high degree of readiness with the predicted FNI content, nutrient composition, structural-mechanical and organoleptic properties. Providing consumer cooperatives with innovative products of natural origin. The introduction of dried fractional polycomponent semi-finished products into the recipes of various food products will reduce the need to use synthetic ingredients, replacing them with natural components. To obtain a competitive range of products and to have new export capacities on international markets.

3.2 PECULIARITIES OF THE PRACTICAL IMPLEMENTATION OF PLANT RAW MATERIAL PROCESSING IN THE CONDITIONS OF THE IMPLEMENTATION OF INNOVATIVE HARDWARE AND TECHNOLOGICAL SOLUTIONS

Natural raw materials grown according to today's eco-technologies require the use of optimal methods of collection, transportation, resource-saving processing into semi-finished products of a high degree of readiness. In addition, further use in food formulations allows to artificially expand physiologically functional properties with predicted rheological and organoleptic properties [29]. However, taking into account the natural properties of plant heat-labile raw materials, there is a need to analyze traditional methods of storage and processing (**Fig. 3.5**) in order to find possible innovative approaches to resource-saving processing.

Our own vegetable raw material base for the production of polycomponent semi-finished products of a high degree of readiness is: fruits, berries, vegetables, spicy and aromatic raw materials, etc. and has traditional main methods of storage and processing. The disadvantages of the classic method of storage are:

– the need to take into account the factors of seasonality of raw materials and the expediency and efficiency of growing plant raw materials in greenhouse conditions;

– the need to create special storage conditions for plant raw materials (availability of resource-saving storage chambers and consideration of energy consumption);

– additional transport costs (from the place of collection to storage) and when moving from storage chambers to sales points in special technological modes;

– consumption of energy resources for storage, during transportation and at the time of sale.

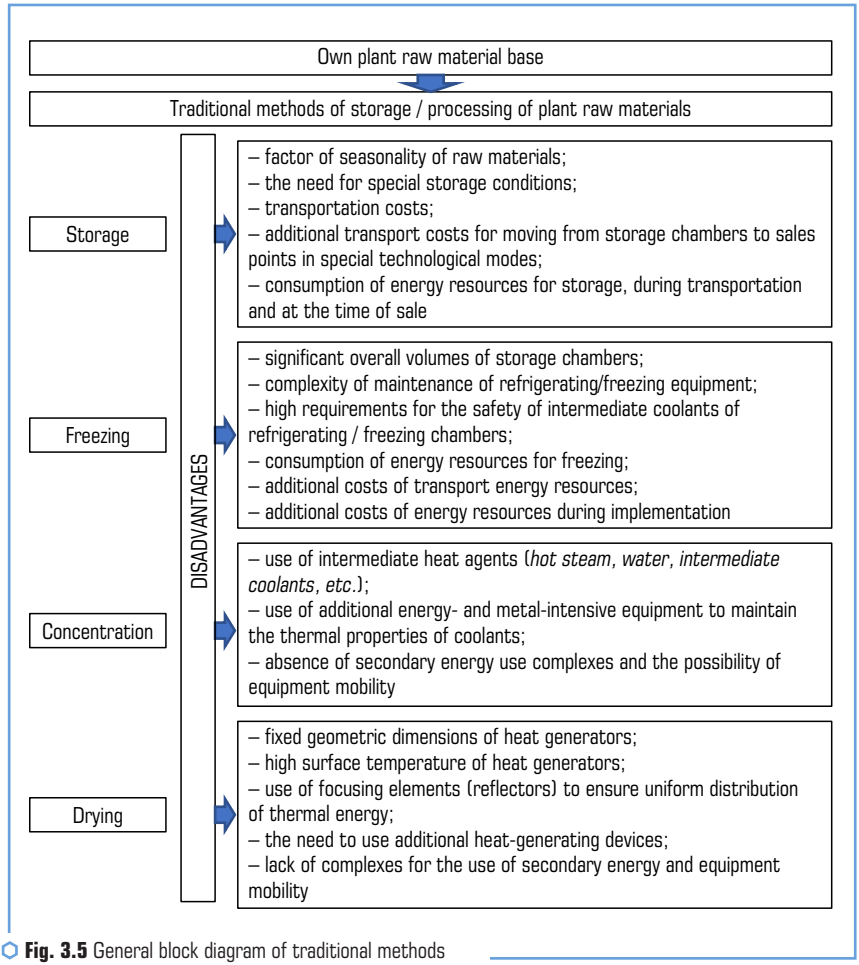


Fig. 3.5 General block diagram of traditional methods of storage/processing of plant raw materials

The technological process of freezing, including sublimation, has the following disadvantages:

– significant overall volumes of storage chambers and chambers for sublimation of plant raw materials;

– complexity of technical maintenance of refrigerating, freezing and sublimation equipment;

– high requirements for the safety of intermediate coolants of the equipment;

– costs of energy resources for freezing/sublimation and additional costs of transport energy resources and during frozen products.

Among the heat and mass transfer technological processes, concentration and drying (convective, conductive, microwave, infrared, etc.) are promising for the processing of plant raw materials [30], but they also have certain disadvantages related to design features:

– the use of intermediate heating agents (hot steam, water, intermediate coolants, etc.), which require the use of additional energy- and metal-intensive equipment to maintain the thermal properties of coolants;

– fixed geometric dimensions of heat generators and the use of technical networks for their transportation, including the need to use focusing elements (reflectors) to ensure uniform distribution of thermal energy on receiving surfaces (working chambers);

– lack of complexes for the use of secondary thermal energy and the possibility of equipment mobility due to the above-mentioned structural shortcomings.

Therefore, classic storage and freezing operations have more difficult conditions for the implementation of innovative approaches to intensification of equipment and technological approaches, in contrast to methods of concentration and drying. However, in order to find innovative approaches, in particular in the direction of constructive improvement of the equipment, it is necessary to consider the features of heat-generating elements. This approach will make it possible to substantiate optimal heat-generating elements that can allow: minimize (eliminate) the use of intermediate coolants with technical networks; to form rational working chambers with uniform distribution of thermal energy throughout the entire volume. This will, to some extent, increase resource efficiency and the possibility of finding ways to use secondary heat resources for production needs. The search for innovative approaches to the constructive improvement of heat and mass exchange equipment will simultaneously provide the possibility of realizing low-temperature gentle temperature ranges of processing, which is necessary for the maximum preservation of natural FNI of heat-labile plant raw materials.

Let's consider the features of the use of radiant-type electric heat-generating elements available on the market (**Fig. 3.6**) with the establishment of design advantages [31] for further use in equipment for concentrating (boiling) and drying multicomponent semi-finished products of a high degree of readiness.

Taking into account the data of the comparative analysis of the technical properties of electric heaters of the radiating type, it is possible to form an idea of the possibility and effectiveness of their use in the designs of heat and mass exchange devices for drying and concentrating polycomponent vegetable semi-finished products. The use of: tubular electric heaters, quartz lamps and ceramic electric heaters is complicated by their thermophysical parameters, in particular the working temperature of the surfaces (900…1900 °C), this requires their distance from the receiving surface when drying thermolabile raw materials. In addition, the above-mentioned radiant heaters have certain requirements for the location (horizontal for tubular quartz lamps), also according to the analysis, the heaters need a protective-focusing screen, simultaneously acting as a distributing element of heat flows. The removal of heaters from the receiving surfaces and the need to use protective focusing screens artificially increases the non-technological zones of the drying equipment with a simultaneous increase in the energy and metal capacity of the structure. In contrast to the

film-like electronic heater of the radiating type, the flexibility allows repetition of the geometric shapes of the devices under the conditions of a maximum bending radius of up to 15°, and therefore eliminates non-technological zones in conditions of uniform distribution of heat flow. The electric heater is repairable with no metal capacity, clear heating dynamics and stabilization of the temperature range in conditions of ensuring the repetition of the geometry of the working chambers. During the experimental and practical use, actions were taken to improve the basic design of the film-like electronic heater of the radiating type. In particular, according to the known structure, the heater consists of a flexible electrical insulating film (dielectric substrate) on the surface of which a resistive element with a coating thickness based on conductive nichrome paste is applied using vacuum spraying. The application of the paste was carried out in the form of sequentially connected rectangular strips, which are located perpendicular to the tires, equipped with leads for connecting to the power grid [32]. At the same time, it is equipped with additional lower and upper layers of flexible electrical insulating film, provided that the thickness of the resistive layer is: from 1.5 μm to 4.5 μm; from 5.0 μm to 8.5 μm and from 9.0 μm to 16 μm. Spraying is carried out by vacuum spraying with screen printing technology according to the given geometry of the future heating (working) surfaces. And the additional lower layer of the flexible electrical insulating film is made in the form of applied liquid thermal insulation with a low coefficient of thermal conductivity.

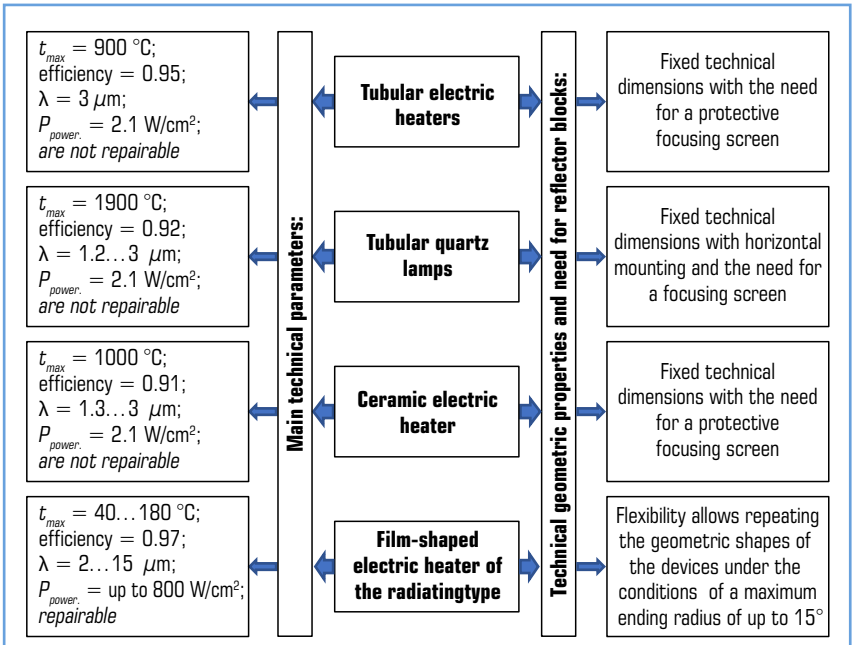


Fig. 3.6 Comparative analysis of the technical properties of radiant-type electric heaters

The schematic view of the improved film-like electronic heater of the radiating type is shown in **Fig. 3.7**.

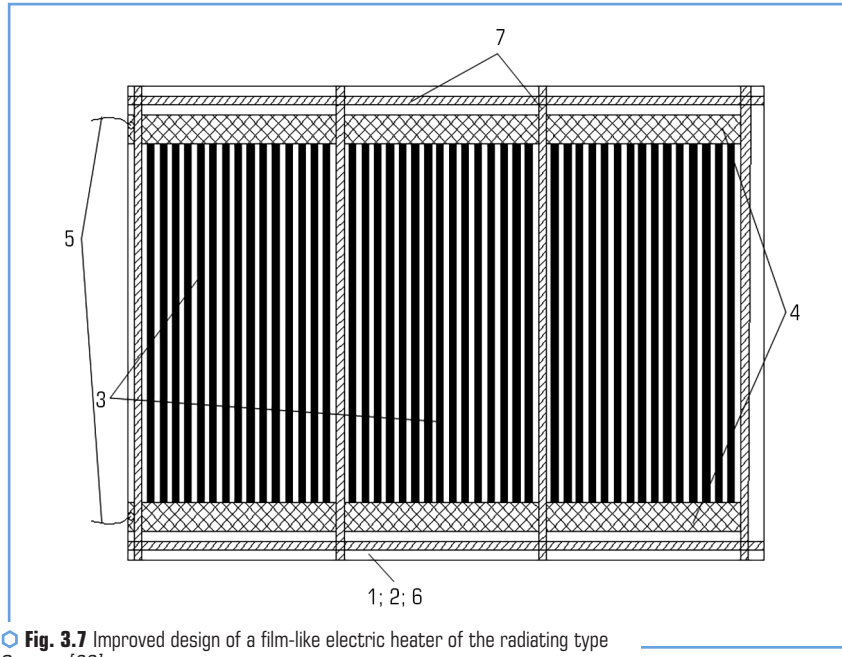


Fig. 3.7 Improved design of a film-like electric heater of the radiating type
Source: [32]

The technical result achieved when using a film-like electronic heater of the radiating type is: increase in electrical safety, reliability, hardware and technological strength, heat conservation, flexibility; fixed geometry of the heating plane, different absorption length of the radiating wave from 1.5 μm to 4.5 μm; from 5.0 μm to 8.5 μm and from 9.0 μm to 16 μm and electrical safety during operation of heating of domestic, economic and industrial premises, low-temperature heat and mass exchange equipment of the processing and food industry, in "warm floor" systems and rooms with high humidity and able to work submerged.

Thanks to the improvement, the following technical properties of the film-like electronic heater of the radiating type were achieved in terms of the maximum temperature of the working surface (40...180 °C). At the same time, the IR wavelength set from 2.0 to 15 μm with a power of up to 800 W/cm^2 and a technical efficiency factor (0.97) are optimal for heat and mass transfer processing of multicomponent vegetable semi-finished products. Confirming the effectiveness of use for drying equipment with the need for further confirmation of the effectiveness of use in heat and mass exchange equipment for the concentration of plant raw materials.

The implementation of innovative approaches consisting in the use of film-like electronic heaters of the radiating type will allow to eliminate the need for the use of intermediate coolants and technical networks in the equipment for heat-mass exchange processing of multicomponent vegetable semi-finished products. reduction of energy and metal intensity. It will create the possibility of mobility of the equipment, the simplicity of its design, its operational properties and, in general, will allow to increase the resource efficiency of the processes of concentration and drying of plant raw materials in conditions of low temperature ranges. An example of the effectiveness of improving thermal equipment for boiling multicomponent raw materials of plant origin by replacing the traditional steam heat supply with a film-like electronic heater of the radiating type is the comparative characteristics of the improved boiler compared to the basic design of MZS-320 (**Table 3.3**).

Table 3.3 Comparative characteristics of the improved boiler based on a film-like electronic heater of the radiating type in comparison with the basic design of the MZS-320 with an intermediate steam coolant

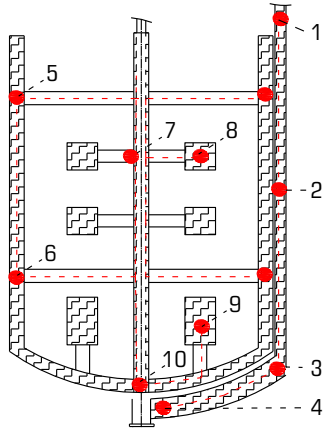
Energy losses	MZS-320	Improved steamer
Device weight	$m^*=1700$ kg	$m=m_{MZS\text{-}320}-m_{jacket}+m_{FFREHRT}=$ $=1700-620+20=1100$ kg
Specific costs	$Q_s=Q/m=1120798/1600=700$ kJ/kg	$Q_s=Q/m=651137/1600=406$ kJ/kg
Duration of processing	$\tau=Q/F\cdot k\cdot\Delta t=$ $=1191033/3.7\cdot1454\cdot91=4065$ s	$\tau=Q/F\cdot k\cdot\Delta t=$ $=1969245/4.15\cdot1454\cdot91=3586$ s
Heat exchange surface area	$F^*=3.7$ m^3	$F=F_{MZS\text{-}320}+F_{stirrer}=3.7+0.45=4.15$ m^3
Heating the device	$Q_{heat.}=m_1\cdot c_c\cdot(t_2'-t_1')+m_1\cdot c_c\cdot(t_2''-t_1'')=$ $=900\cdot0.48\times(52-25)+$ $+620\cdot0.48\cdot(142+80)=33452$ kJ	$Q_{heat.}=m_1\cdot c_c\cdot(t_2'-t_1')=$ $=900\cdot0.48\cdot(52-25)=$ $=11664$ kJ
Heating the product	$Q_{pr=}m\cdot c\cdot(t_e-t_b)=$ $=1600\cdot3.7\cdot(52-40)=2552$ kJ	$Q_{pr}=m\cdot c\cdot(t_e-t_b)=$ $=1600\cdot3.7\cdot(52-40)=72552$ kJ
Total number	$Q_{tot}=2053504$ kJ	$Q_{tot}=2009433$ kJ
Specific metal capacity of the device	$m=M/F=1700/3.7=459$ kg/m^2	$m=M/F=1100/4.15=265$ kg/m^2

**Note: calculated data are presented as an example based on previous experimental and practical results*
Source: [23, 33]

The analysis of comparative data confirms the effectiveness of using a film-like electronic heater of the radiating type in heat and mass exchange equipment when replacing intermediate coolants. Thus, a reduction in: weight and specific metal capacity of the device is ensured; duration of processing of thermolabile plant raw materials. At the same time, the peculiarities of the use of a film-like electronic heater of the radiating type make it possible to improve the design of moving devices of heat and mass exchange equipment for boiling (concentration)

multicomponent semi-finished products. This is achieved by introducing a film-like electronic heater of the radiating type into the inner space of the mixing devices and installing additional heating and contact surfaces. Such actions make it possible to artificially increase the useful surface of thermal devices and intensify the dynamics of uniform heating of raw materials with simultaneous mixing, and therefore, a reduction in the duration of the product's stay in the working space of the device is ensured.

To confirm the uniformity of the heat flow distribution in the improved boiler based on the film-like electronic heater of the radiating type under the conditions of additional heating of the unified stirring device, a fragment of the device's working chamber and thermocouple data are given (**Fig. 3.8**).



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1	140.0	7	136.0
2	135.6	8	136.5
3	136.1	9	136.2
4	136.3	10	135.8
5	135.0	11	-.-
6	135.2	12	-.-

Fig. 3.8 A fragment of the working chamber of an improved boiler based on a film-like electronic heater of the radiating type and a diagram of the placement of thermocouples with their data under the conditions of setting the electronic heater to be turned off at 140 °C
**Note: uniformity studies were carried out in laboratory conditions in real time (the error of thermocouple data is within acceptable limits)*
Source: [23]

The obtained data confirm the effectiveness of using a film-like electronic heater of the radiating type in the heat-mass exchange structures of devices for boiling (concentration).

Taking into account previously obtained experimental-practical and analytical data on the effectiveness of creating multicomponent semi-finished products of own plant origin and rheological behavior of natural raw materials during blending. There is a need for the formation of a resource-saving equipment and technological line for the production of vegetable polycomponent semi-finished products with a high degree of readiness.

3.2.1 PRACTICAL IMPLEMENTATION OF THE EQUIPMENT-TECHNOLOGICAL LINE FOR THE PRODUCTION OF VEGETABLE POLYCOMPONENT SEMI-FINISHED PRODUCTS WITH A HIGH DEGREE OF READINESS

The production of vegetable polydopamine semi-finished products of a high degree of readiness obtained from own raw materials grown according to today's eco-technologies and collected in the fields of the front-line Kharkiv region corresponds to the previously proposed method (**Fig. 3.2**). Most of the heat and mass exchange equipment used in the proposed method and equipment-technological line has a proprietary character in terms of improvement and creation of fundamentally new equipment with the main equipment-technological advantages:

– liquidation of the component of intermediate heat carriers (steam generators, steam jacket and technical networks) of heat and oil exchange equipment for the processing of vegetable raw materials;

– the use of a film-like electronic heater of the radiating type as a heat-generating element under the conditions of repeating the geometry of the working chambers to ensure a uniform distribution of the heat flow in the IR wave range $\lambda=2...16$ μm;

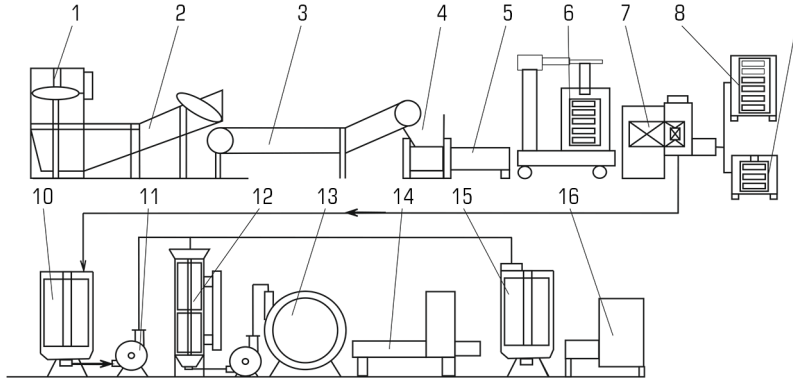
– the use of a film-like electronic heater of the radiating type to increase the useful heat exchange surface of the heat and mass exchange equipment by introducing mixing devices of the heater into the inner space and installing additional heating and contact surfaces;

– the use of a film-like electronic heater of the radiating type allows to implement low-temperature modes of processing natural polycomponent raw materials for maximum preservation of FFI and organoleptic properties;

– the use of a film-like electronic heater of the radiating type made it possible to create a fundamentally new mobile universal device for preliminary thermal operations (blanching, extraction, boiling, aging, etc.).

The general view of the equipment and technological line for the production of vegetable polycomponent semi-finished products with a high degree of readiness is shown in **Fig. 3.9**.

The equipment-technological line for the production of vegetable polycomponent semi-finished products with a high degree of readiness works according to the proposed method (**Fig. 3.2**) and can be located directly on farmland for growing natural raw materials. This became possible due to the implementation of innovative approaches in the field of improvement of the presented heat and mass exchange equipment, which is characterized by mobility, ease of operation, and resource saving in the agro-industrial sector. The practical implementation of the proposed innovative approaches in the production of polycomponent semi-finished products will allow to support the own capacities of farmland, modernization of the processing and production sectors of agro-industry. The obtained functional polycomponent semi-finished products of a high degree of readiness will allow to expand the range of food products with an increased content of FFI, predicted rheological and organoleptic properties.



1 – container dumper; 2 – conveyor washing machine; 3 – inspection roller conveyor; 4 – machine for preliminary cutting of vegetable raw materials; 5 – technological table with storage trays; 6 – universal multifunctional device; 7 – universal wiping machine; 8 – periodic IR dryer for plant extracts; 9 – extraction unit; 10 – unified reactor; 11 – gear pump; 12 – unified rotary film apparatus; 13 – thermal radiation single-drum roller dryer; 15 – unified vacuum evaporation apparatus; 14 and 16 – packing machines

Fig. 3.9 Equipment and technology line for the production of vegetable polycomponent semi-finished products with a high degree of readiness

Due to its operational and technical properties, the film-shaped electronic heater of the radiating type can be used directly in portable and mobile equipment of hotel and restaurant complexes and in the home. For example, the author's team designed a number of technological equipment for low-temperature processing of meat products in the recipe of which natural plant raw materials were added [34–38]. This, in turn, according to the equipment component, made it possible to preserve the natural properties of natural raw materials as much as possible under the conditions of minimizing intensive juice losses during frying. The surface of the meat delicacies had an optimal crust, or even without it, depending on the type of raw material and product. And from the technological side, meat products with natural vegetable raw materials and multicomponent dried semi-finished products were characterized by original organoleptic properties. In addition, the introduction of dried fractional semi-finished products into the recipes of fried meat products allows to increase the volume of raw materials and replace a certain share of recipe ingredients, in particular bread. This becomes possible because, in addition to the concentrated content of FFI, dried semi-finished products have good water-absorbing abilities, allowing them to be saturated with the liquid-fat component during the preparation of minced meat, and to release it during the frying process, preventing the product from drying out.

Taking into account the above information, it is possible to state the effectiveness of the proposed innovative approaches to the production of multicomponent semi-finished products of

a high degree of readiness with the possibility of effective use in the recipes of various food products. The obtained polycomponent semi-finished products are widely used in confectionery products, which is confirmed by a number of author's studies of the team, confirming the perspective of research in this direction. In turn, let's also support hotel and restaurant complexes to meet the needs of consumer cooperatives with the simultaneous expansion of the range of our own competitive semi-finished products of a high degree of readiness and food products based on them. Therefore, it will ensure the targeted national security of the country in the conditions of full-scale military operations and support of the world's food needs on the international market.

CONCLUSIONS

An urgent task has been formed to generalize innovative hardware and technological solutions for the production of organic plant semi-finished products (dried fractional and powdered fractions) of a high degree of readiness. The production of functional health products in the form of independent and multicomponent compositions based on plant semi-finished products of a high degree of readiness for further use in various industries during the manufacture of food products is proposed. The proposed adaptive mechanism for modeling the competitiveness of the agro-industrial sector in the conditions of taking into account the parameters of the flow of traditional micro- and macro-environments for the optimal adaptation of innovative approaches when implementing resource-saving hardware and technological solutions.

A resource-saving method for the production of multi-component pureed semi-finished products with a high degree of readiness based on own plant raw materials of apple, Jerusalem artichoke, cranberry, beetroot and hawthorn is presented. The hardware implementation of the resource-saving method is provided by the developed author's designs of unified mobile low-temperature devices, the feature of which is the reduction of energy and metal consumption, ensuring uniformity of heat supply, stabilization of the temperature range, the possibility of using secondary heat energy. The proposed method is unified due to the implementation of the concentration process as needed in the form of a film flow (unified rotary-film apparatus), in a flow (unified tubular apparatus) and boiling in mass (unified vacuum-evaporation apparatus). Also, due to technological necessity, there is an additional technological operation of drying, which is implemented on a fundamentally new thermal radiation single-drum roller dryer.

A film-like electronic heater of the radiating type has been developed. The technical result achieved when using a film-like electronic heater of the radiating type is: increase in electrical safety, reliability, hardware and technological strength, heat conservation, flexibility; fixed geometry of the heating plane, different absorption length of the radiating wave from 1.5 μm to 4.5 μm; from 5.0 μm to 8.5 μm and from 9.0 μm to 16 μm and electrical safety during operation of heating of domestic, economic and industrial premises, low-temperature heat and mass exchange equipment

of the processing and food industry, in "warm floor" systems and rooms with high humidity and able to work submerged.

An equipment-technological line for the production of vegetable polycomponent semi-finished products with a high degree of readiness has been developed, which can be located directly on farmland for the cultivation of natural raw materials. The practical implementation of the proposed innovative approaches in the production of polycomponent semi-finished products will allow to support the own capacities of farmland, modernization of the processing and production sectors of agro-industry. The obtained functional polycomponent semi-finished products of a high degree of readiness will allow to expand the range of food products with an increased content of functionally physiological ingredients, predicted rheological and organoleptic properties. The introduction of developed semi-finished products into the recipes of various food products will reduce the need to use synthetic ingredients, replacing them with natural components.

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