

The design of a thermal-radiation single-drum roll dryer with a combined method of heat supply, application and cutting of the dried layer of raw materials was developed. The dryer allows obtaining a powder fraction of a semi-finished product with a solids content of 3...5 %. Such a design solution will make it possible to obtain a high-quality semi-finished product due to low-temperature drying.

The effective viscosity of the studied pastes produced by blending apple, sea buckthorn, black chokeberry, beet and pumpkin purees was determined. Adding different percentages of raw materials to apple paste increases the effective viscosity by 9...18 %. According to the results of the organoleptic evaluation, the sample with the following composition turned out to be the best: apple – 30 %, sea buckthorn – 20 %, black chokeberry – 15 %, beet – 15 % and pumpkin – 20 %. The drying time of the blended paste with a solids content of 45 % at a temperature of 65 °C and different layer thicknesses of application to the working surface (8, 6 and 4 mm) is 75, 60 and 56 min, respectively.

All the samples of pastes have a reddish-purple color with a wavelength of 610.5...614.5 nm and a tone purity of 66.5...78.8 %. The wavelength of the dried fraction is 495...615.3 nm with a tone purity of 34.3...34.8 %, from bluish-red to bluish-purple. The brightness of the samples after drying decreases within 3...4 %. The obtained color change values and drying time of the samples confirm the possibility of using the improved dryer to obtain high-quality vegetable semi-finished products of the dried fraction. The experimental data will be useful in design calculations and testing of the developed dryer in order to obtain its maximum efficiency

Keywords: structural and mechanical properties, thermal-radiation single-drum roll dryer, color characteristics, powder fraction

DEVELOPMENT OF A THERMAL-RADIATION SINGLE-DRUM ROLL DRYER FOR CONCENTRATED FOOD STUFF

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1. Introduction

An important component of the food industry of European countries is the provision of healthy nutrition based on organic raw materials in the fresh form and after gentle processing for obtaining various high-quality semi-finished products [1]. The use of combined organic powdered semi-finished products with high physiological and functional properties and the immune component will provide optimal conditions for the production of healthy food [2]. In a pandemic, the food industry must support healthy nutrition by manufacturing products to prevent immune and chronic diseases associated with environmental degradation and malnutrition [3].

Processing of organic raw materials into food and pharmaceutical products by drying, despite the energy and metal intensity of the process, provides a decrease in the volume and weight of raw materials and high quality. Forming advantages in transportation, storage and solubility of the

obtained blended organic components when adding warm water, for example during the preparation of rations by people in extreme conditions [4, 5]. Causing the need to improve the engineering and technological component and searching for innovative ways to intensify thermal-radiation drying on the basis of low-temperature regimes, taking into account the properties of complex blends of organic raw materials, ensuring high quality of the products.

An urgent task is to develop and implement modern engineering and technological solutions for improving thermal-radiation single-drum roll dryers for drying concentrates of blended organic raw materials (pastes) into powdered semi-finished products. Intensification of the method of heat supply, application and cutting of the dried layer of raw materials will ensure hardware and technological competitiveness in obtaining high-quality powdered semi-finished products, a high degree of readiness for further introduction in food and pharmaceutical technologies.

2. Literature review and problem statement

The work [6] demonstrates the potential for developing and optimizing more sustainable and efficient industrial drying technologies in the food sector that can help achieve energy reduction goals. It is shown that drum dryers are commonly used in the food industry to produce food powders from suspensions, and powders are used for many purposes, from dry beverages to instant soups, spices or flour and flavors. At the same time, current environmental policies require the formation of a sustainable food sector with reduced energy needs during processing, and especially drying operations. However, the issues related to identifying ways to implement effective drying processes for the introduction of optimal operating modes of existing drying equipment remain unresolved. The reason for this may be primarily the rapid impact of environmental factors, pandemics and obsolescence of equipment, which significantly increases the cost of the resulting powders with their quality being low. An option to overcome these difficulties may be state programs to support the modernization of the food industry, which in turn will ensure the production of high-quality organic semi-finished products with functional and physiological properties for the healthy nutrition of the world's population. The work [7] emphasizes the importance of a diet with a high content of functional and physiological substances and various vitamins of organic origin, especially in conditions of the COVID-19 pandemic. One of the sources of preventive and curative raw materials are organic fruit and berry ones. The paper [8] reveals the state of the food industry of Ukraine, indicating the development in conditions of modernization and use of domestic capacity. The paper [9] notes the need to introduce functional and physiological products of plant origin into the diet to meet consumer needs in high-quality organic products, especially in a pandemic. However, the issues of the need for technical re-equipment of the processing industry and the feasibility of forming equipment precisely for farms located in raw materials collection places remain unresolved. This may be due to the objective difficulties of modernizing existing equipment having some shortcomings in energy and metal consumption, the lack of the possibility of implementing energy-saving systems, etc., determining the expediency of research in this area.

The paper [10] presents the results of analyzing the state of consumer confidence in food quality, increasing their level of conscious healthy nutrition with an analysis of cost impact in accordance with the obtained quality of food. The daily growth of consumer demand for healthy food by increasing the diversity of functional products of high quality and attractive color is shown. But there are still unresolved issues related to the importance of using high-quality raw materials for food production and the impact of operating parameters during their processing. The reason for this can be a variety of difficulties from the level of technical equipment of enterprises to a reasonable choice of raw materials used to ensure healthy nutrition. One of the options to overcome these difficulties is the introduction of innovative practical solutions for the production of high-quality products and the introduction of organic blended concentrates of a high degree of preparation, in particular in powder form, into their formulation [11]. This approach is used in [12] indicating the need to determine the structural and mechanical properties of blends for rational heat and mass transfer processes using secondary energy for technological purposes. In [13], the

importance of determining structural and mechanical properties in the production of blended pastes on the example of baby puree at a temperature of 5...65 °C is confirmed, noting the importance of the obtained data for further technological operations with the concentrate. However, the effect of the obtained structural and mechanical properties and the degree of concentration on the subsequent heat and mass transfer process of the obtained concentrates, in particular during drying, is not disclosed, which is due to the complexity of this process. All this gives grounds to assert the expediency of studies to determine the structural properties of the blended paste concentrates and the subsequent effect on the drying process when producing the powder fraction, in particular using roll dryers.

The work [14] focuses on the processing of plant raw materials that have a significant content of functional and physiological properties and vitamins and are useful for the immune system of people of any age. For example, the process of extraction of biological compounds is often replaced by drying raw materials, in particular to a powder consistency, which is of great interest to various branches of nutrition and pharmacology [15]. However, the issues related to the formation of reasonable drying and grinding processes, which significantly affect the quality indicators and biological value remain without attention [16]. This is due to the complexity of the process of manufacturing powdered semi-finished products on high-temperature equipment with complex stabilization of the temperature properties of heat sources, confirming the feasibility of research in this direction. To date, the studies of 3D printing technologies are being developed not only in the fields of mechanical engineering, medicine, but also in the food industry by studying methods for producing printing inks from food raw materials [17].

In [18], the emphasis is placed on the need to introduce alternative systems for drying food raw materials using modern heat sources with clear operating dynamics and energy-saving complexes and using solar energy. The complexity of using solar energy is due to the climatic features of the regions, which is quite feasible from a technical point of view regarding the use of energy-saving technologies with heat sources with a precisely stabilized parameter. The existing various designs of dryers in the food industry mostly have structural and technological shortcomings associated with low resource efficiency, lack of energy-saving complexes and use of high-temperature heat sources, etc. [19, 20]. One way of energy saving is the introduction of innovative actions aimed at using the secondary energy of exhaust air of Peltier elements in the power supply of fans or film heaters, which have proven their effectiveness in [21–23]. In [24], the advantages of using Peltier elements are noted, in particular, with small contact surface sizes, they provide low supply voltage or cooling of certain structural surfaces. Therefore, they are allowed in heat and mass exchangers to convert secondary energy following engineering and technological needs.

The feasibility of scientific and practical studies aimed at determining the structural and mechanical properties of blended purees from organic raw materials and semi-finished products based on them is confirmed. Production of high-quality dried powdered semi-finished products from organic raw materials using resource-efficient technologies is currently one of the priority tasks of the processing, food and pharmaceutical industries. The main structural and technological disadvantage of the heat and mass trans-

fer process, in particular drying, is the energy and metal consumption of equipment, associated with the use of a high-temperature heat-transfer steam, the complexity of application and removal of pasty semi-finished products. There is also a practical difficulty in implementing energy-saving complexes for converting secondary energy for preheating raw materials, drying primary air or obtaining low supply voltage of auxiliary structural elements of dryers. These structural and technological shortcomings significantly affect the resource efficiency of the process of drying organic raw materials in general and the quality of semi-finished products, thus requiring systematic comprehensive actions aimed at solving them. Therefore, it is expedient to develop a thermal-radiation single-drum roll dryer for drying blended organic raw materials into powdered semi-finished products with a combined method of heat supply, application and cutting of the dried product layer. It is proposed to use a modern flexible film resistance radiation electric heater (FFRREH) as a heater [25], which will provide a stable temperature and resource efficiency when eliminating steam heating systems.

3. The aim and objectives of the study

The aim of the work is to develop a thermal-radiation single-drum roll dryer for drying blended organic raw materials (pastes) into powdered semi-finished products by intensifying the method of heat supply, application and cutting of the dried layer of raw materials. This will allow resource-efficient and low-temperature processing of organic raw materials using rational design and technological conditions with a positive impact on the final quality of the dried semi-finished product.

To achieve the aim, the following objectives were set:

- to develop a model design of a thermal-radiation single-drum roll dryer for drying blended organic raw materials (pastes) into powdered semi-finished products with a modified method of heat supply, application and cutting of the dried layer of raw materials;
- to investigate the structural-mechanical and organoleptic properties of blended pastes, taking into account the developed percentage of components;
- to investigate color retention and moisture content kinetics during drying in a thermal-radiation single-drum roll dryer.

4. Materials, methods of the study of thermal-radiation drying of concentrates from organic raw materials and experimental setup

The study was carried out on the basis of the Research Center “Latest biotechnologies and equipment for food production with high health properties” of the Kharkiv State University of Food Technology and Trade (Ukraine).

To study the samples of multicomponent organic semi-finished products, the following were used: apple (Antonovka variety), sea buckthorn (Galerit variety), black chokeberry (Black-eyed variety), pumpkin (nutmeg Pearl variety), beet (Bona variety). In addition, purees, pastes and drying fractions based on them were examined. The structural and mechanical properties of blended pastes with different formulation ratios were determined. The structural and mechanical properties of the samples were determined on a “Reotest-2” rotary viscometer (Germany). The study

of the obtained organoleptic properties of the samples was carried out by an expert commission consisting of 5 members of the Kharkiv State University of Food Technology and Trade (Kharkiv, Ukraine) on a 5-point scale. The kinetics of paste drying was studied on a model setup as shown in Fig. 1. The color characteristics were examined by a colorimeter [26].

5. Determination of the effectiveness of solutions for improving the single-drum roll dryer

5.1. Development of an improved model of thermal-radiation single-drum roll dryer

The improved model of thermal-radiation single-drum roll dryer for drying pre-concentrated blended organic raw materials (pastes) into powdered semi-finished products is shown in Fig. 1. The operation of the device is as follows: blended organic paste concentrated in a rotary evaporator [27] to the solids content of 43...45 % is supplied, by means of the gear pump 1, to the coil 2 located in the inner space of the drum 3, mounted on the shaft 4, which is installed in the bearing cells 5 to provide rotary movement from the gearbox 6. Heating of the working surface of the grooved drum 3 and IR heating of the raw material layer are performed by two flexible film resistance radiation electric heaters 8. The electric heaters are located cylindrically: one in the inner space of the roll 3 drum (conductive heating); the second in the working chamber mounted on the stainless casing 9 (IR heating). The heating temperature range for the inner surface of the drum 3 of the working surface of the cylindrical working chamber 7 is 45...65 °C to provide a low-temperature treatment of the concentrated paste. To reduce heat loss, the outer surface of the cylindrical working chamber 7 is coated with heat-insulating alufom with the stainless casing 9, which simultaneously forms the body of the roll dryer mounted on the supports 10.

To ensure the supply of fresh air to the working space of the roll dryer, two forced-draught fans 11 are installed, operating independently from the conversion of secondary heat by Peltier elements 12 into low supply voltage (15...40 W). The Peltier elements are placed in the inner space of the grooved drum 3, where the temperature is constantly maintained within 65 °C. The concentrate is applied symmetrically to the grooved working surface of the drum 3 of the cone sprayer (pin) 13, the ends of which are connected to the coil 2 for uniform pumping of raw materials with the raw material layer regulator 14. The main condition for paste drying is drying for one revolution of the working surface of the drum 3 to the solids content of 3...5 %, the speed of the shaft 4 is controlled by the thyristor regulator 15.

To cut the dried semi-finished product, the spring-loaded platform 16 with the cone cutting knife 17 and fluoroplastic-coated bumper 18 is used. Spring loading of the platform 16 allows adjusting the force of its pressing against the grooved working surface. The use of the cone fluoroplastic-coated bumper 18 after the cone cutting knife 17 is intended for additional guiding of the cut raw material layer and final cleaning of the grooved surface before applying a new layer of raw materials. To ensure a more uniform powder fraction of the dried semi-finished product, the toothed rolls 19 are mounted in the cutting zone, which rotate towards each other and allow adjusting the fraction due to the gap between them. The powder fraction under gravity falls into the unloading weigh hopper 20, and the moist air is removed from the roll dryer by the induced-draught fan 21.

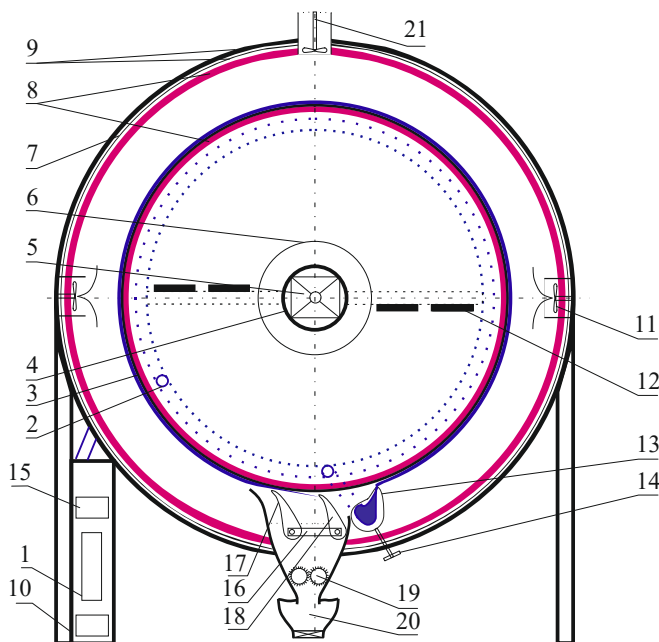


Fig. 1. Scheme of the improved model of thermal-radiation single-drum roll dryer for drying blended organic raw materials (pastes) pre-concentrated in a rotary evaporator into powdered semi-finished products: 1 – gear pump; 2 – coil; 3 – drum; 4 – shaft; 5 – bearing cells; 6 – gearbox; 7 – working chamber; 8 – flexible film resistance radiation electric heater; 9 – heat-insulating alufom stainless casing; 10 – supports; 11 – forced-draught fans; 12 – Peltier elements; 13 – cone sprayer (pin); 14 – feedstock layer regulator; 15 – thyristor regulator; 16 – spring-loaded platform; 17 – cone cutting knives; 18 – fluoroplastic-coated bumper; 19 – toothed rolls; 20 – unloading weigh hopper; 21 – induced-draught fan

5. 2. Determination of structural-mechanical and organoleptic properties of blended pastes

When drying blended pastes from organic raw materials in the thermal-radiation single-drum roll dryer, it is necessary to determine the mechanism of formation of the raw material layer on the working surface of the roll (Fig. 1, pos. 3). This can be done if the structural and mechanical properties of blended concentrates, for example, organic pastes of apple, sea buckthorn, black chokeberry, beet and pumpkin, are determined, according to their proposed formulation ratio for puree (Table 1). To control and compare the effectiveness of the selected formulation ratio and properties, apple paste (45 % solids) was used, and the test samples were pre-boiled in the rotary evaporator to a solids content of 43...45 %.

Table 1

Formulation ratio of blended organoleptic purees in different compositions

Composition	Blended composition		
	1a	1b	1c
Apple	40	30	20
Sea buckthorn	15	20	25
Black chokeberry	10	15	20
Beet	10	15	20
Pumpkin	25	20	15

The studies produced experimental characteristics of changes in the effective viscosity of blended concentrates according to the proposed formulation ratio (Table 1) from shear rate (Fig. 2).

The effective viscosity η_{ef} (Pa·s) decreases with increasing shear rate and the highest indicators of the experimental samples are: 1a – 231; 1b – 223; 1c – 212 and control – 190, respectively. Adding different percentages of raw materials to apple paste (formula, Table 1) leads to an increase in effective viscosity by 9...18 %, which is a positive factor strengthening the resulting paste structure.

Organoleptic evaluation of the presented concentrates of blended pastes was performed to determine the optimal formulation ratio of the components (Table 2).

Table 2

Organoleptic evaluation of concentrates of blended organic pastes

Indicator	Characteristic of the blended composition		
	1a	1b	1c
Appearance	Homogeneous strained pasty mass		
Taste and smell	Pleasant harmonious taste and smell of apples, sea buckthorn and pumpkin	Pronounced taste and smell of apples and sea buckthorn, pumpkin and beets are almost not felt	Too strong smell and taste of beets; pronounced sea buckthorn
Color	reddish-purple	reddish-purple	reddish-purple
Consistency	Pasty, easily formed, does not spread when laid on a flat surface		

As a result of the analysis of structural and mechanical properties and organoleptic evaluation, sample 1b was chosen for further experiments. The formulation ratio is characterized by the introduction of 30 % apple puree, sea buckthorn – 20 %, black chokeberry – 15 %, beet – 15 % and pumpkin – 20 %. The chosen sample, along with high structural and mechanical properties, has pleasant organoleptic properties.

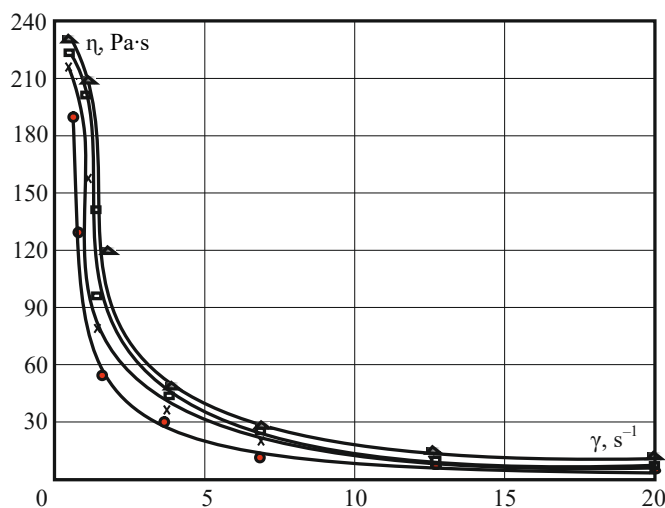


Fig. 2. Effective viscosity of blended organic paste concentrates: ● – apple paste (control); X – composition 1a; □ – composition 1b; ▲ – composition 1c

5. 3. Determination of color retention and moisture kinetics during drying in the thermal-radiation single-drum roll dryer

To determine the degree of color retention during drying, the color parameters of the samples of semi-finished products before and after treatment in the thermal-radiation single-drum roll dryer were examined. The study was performed for blended pastes made according to the formulation ratio (Table 1). Table 3 shows the color characteristics of blended compositions of organic pastes.

The predominant wavelength of the paste blend 1a is 610.5 nm, with a tone purity of 77.4 %. For the paste blends 1b – 613.2 nm, tone purity 66.5 %, and 1c – 614.5 nm, tone purity 78.8. All experimental blends of pastes were reddish-purple.

The moisture kinetics of the blended paste with a solids content of 45 % (sample 1b) at a temperature of 65 °C and an air flow rate of 0.15 m/s to a final solids content of 5 % in the single-drum roll dryer model was determined. During the studies, the thickness of the layer of the blended paste concentrate varied within 4:6:8 mm (Fig. 3).

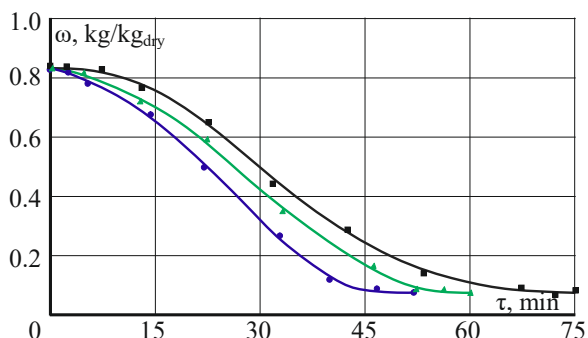


Fig. 3. Kinetics of moisture content of the blended paste with a solids content of 45 % when drying in the single-drum roll dryer with the thickness of the raw material layer: 1 – 8 mm; 2 – 6 mm; 3 – 4 mm

Analysis of the moisture kinetics of the blended paste with a solids content of 45 % indicates the possibility of implementing the drying process in the single-drum roll dryer. It was found that the drying time for a thickness of 8 mm is 75 min, for 6 mm – 60 min, and for 4 mm – 56 min, respectively. The first 5 min of drying were carried out with the switched off fan.

After drying the blended compositions of organic pastes, color changes were examined to determine the effect of heat treatment efficiency on the final color (Fig. 4).

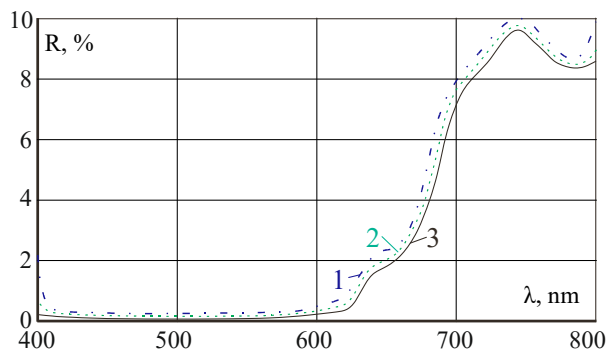


Fig. 4. Reflection spectra of the dried fraction of blended compositions: 1 – blend 1a; 2 – blend 1b; 3 – blend 1c

The obtained reflection spectra of concentrates of blended compositions (Fig. 4) indicate the presence of a blue component (z) for the blend 1a – 0.268, and for the blends 1b and 1c – 0.300 and 0.280, respectively (Table 4).

The characteristic wavelength for the blend 1a of the dried concentrate of blended compositions of organic pastes is 495 nm and corresponds to a bluish-red color with a tone purity of 34.6 %. The blends 1b and 1c have lengths of 615.3 and 572.6 nm. The tone purity of 34.6 for the blend 1b corresponds to a red-bluish color. The blend 1c is characterized by a bluish-purple color, as it has a tone purity of 34.3 %.

Table 3

Color characteristics of experimental concentrates of blended compositions of organic pastes made according to the formulation ratio

Experimental concentrates of blended compositions of organic pastes	Chromaticity coordinates			Dominant wavelength Λ_{nm}	Brightness $T, \%$	Color purity $P, \%$	Visual color evaluation of compositions
	x	y	z				
Blend 1a	3.03	2.08	0.493	610.5	36.7	77.4	reddish-purple
Blend 1b	2.77	2.04	0.689	613.2	35.1	66.5	reddish-purple
Blend 1c	3.11	1.99	0.535	614.5	35.4	78.8	reddish-purple

Table 4

Color characteristics of the experimental samples of the dried fraction of blended compositions

Samples of dried concentrates of blended compositions of organic pastes	Chromaticity coordinates			Dominant wavelength λ, nm	Brightness $T, \%$	Color purity $P, \%$	Visual color evaluation of compositions
	x	y	z				
Blend 1a	0.610	0.377	0.268	495	29.7	34.6	bluish-red
Blend 1b	0.605	0.430	0.300	615.3	31.0	34.8	red-bluish
Blend 1c	0.610	0.410	0.280	572.6	32.8	34.3	bluish-purple

Comparison of the data obtained when evaluating the colors of the blends of paste concentrates before and after drying (Tables 3, 4) show that their brightness decreases within 3...4 %. At the same time, the color purity, on the contrary, is almost halved, which is explained by the shrinkage of the blends during thermal-radiation treatment, while preserving their attractive visual color.

6. Discussion of the results of drying blended pastes in the thermal-radiation single-drum roll dryer

The thermal-radiation single-drum roll dryer provides a low-temperature combined method of heat supply (45...65 °C) in the formation of a layer of raw materials with a thickness of 3 to 8 mm and a powder fraction with a solids content of 3...5 % (Fig. 1, 3). The effective viscosity of the samples of blended organic pastes (η_{ef} , Pa·s) was determined: 1a – 231; 1b – 223; 1c – 212 and control (apple paste) – 190, respectively (Fig. 2), which indicates an increase by 9...18 %. According to the results of the organoleptic evaluation, it was determined that the paste sample with the composition: apple – 30 %, sea buckthorn – 20 %, black chokeberry – 15 %, beet – 15 % and pumpkin – 20 % has the best indicators (sample 1b, Table 2). The drying time of the paste layer at a thickness of 8 mm is 75 min, 6 mm – 60 min, and 4 mm – 56 min, respectively, for reaching the final solids content of 5 % (Fig. 3). The color tone purity 34.6 for the blend 1b corresponds to the red-bluish color. The blend 1c is characterized by a bluish-purple color, as it has a tone purity of 34.3 % (Table 4). The above allows obtaining a dried semi-finished product of high quality and attractive color due to the multicomponent blending of organic raw materials while preserving the color properties of the samples, which was revealed during the study.

The peculiarity of the proposed methods is the use of multicomponent blends from organic raw materials, which will ensure the production of semi-finished products with functional and physiological properties, which is relevant in pandemics and environmental degradation. The layout of equipment for the dehydration of blended organic semi-finished products, namely the rotary film evaporator and the developed dryer, allows eliminating storage tanks for pre-storage of the paste in process lines in the conditions of its heating. It should be noted that most existing roll dryers are characterized by metal-intensive structures, high energy consumption, smearing of raw materials is carried out by partial immersion of the drum in the tank, and hot steam is used as a heat-transfer medium, which reduces their efficiency [6, 28].

During the study, the main limitations were the use of the specified organic raw materials for the production of samples of blended semi-finished products and the drying temperature (45...65 °C) in the thermal-radiation single-drum roll dryer. The disadvantage of the study is the difficulty of controlling the pumping of raw materials on the working surface through the pin when using the gear pump to generate the pumping pressure. One of the ways to eliminate this is to ensure uniform pumping of raw materials directly from the paste concentrator to the dryer to form a stable flow of raw materials through the pin with the same productivity of the devices.

The development of further research may aim to compare the efficiency of design solutions with existing industrial analogues of dryers, but it should be understood that they are mostly high-temperature due to the use of hot heat-transfer

media. Thus, research will be aimed at identifying a combination of a system of supplying blended pastes from the rotary evaporator directly to the supercharger of the thermal-radiation roll dryer, ensuring the elimination of the pump and storage tanks. However, this area of research will require computer modeling of the process first to reduce the cost of practical research for presenting the implementation of heat and mass transfer processes using physical and mathematical modeling.

7. Conclusions

1. The model design of thermal-radiation single-drum roll dryer, characterized by the combined method of heat supply, formation of a paste layer with a thickness of 4 to 8 mm on the working surface of the roll and method of cutting the dried layer of raw materials was improved. The dryer allows obtaining a powder fraction of the fruit and vegetable semi-finished product with a solids content of 3...5 % of the original paste content of 45 % at low temperatures of 45...65 °C.

2. Structural and mechanical properties of blended apple, sea buckthorn, black chokeberry, beet and pumpkin pastes, in accordance with the developed percentage ratio of components were determined. The effective viscosity η_{ef} (Pa·s) of the samples was revealed: 1a – 231; 1b – 223; 1c – 212 and control (apple paste) – 190, respectively. Adding different percentages of raw materials to apple paste increases the effective viscosity by 9...18 %, which is a positive factor strengthening the resulting paste structure. According to the results of the organoleptic evaluation, the best sample of paste with the following composition was found: apple – 30 %, sea buckthorn – 20 %, black chokeberry – 15 %, beet – 15 % and pumpkin – 20 % (sample 1b).

3. Drying time of the blend 1b with 45 % solids with a thickness of 8 mm is 75 min, 6 mm – 60 min, and 4 mm – 56 min, respectively (final content of the semi-finished product – 5 % solids). The drying process was carried out at a temperature of 65 °C and an air flow rate of 0.15 m/s. The color change of the samples before and after drying was studied. The predominant wavelength for blending paste 1b is 613.2 nm, with a tone purity of 66.5 %. For the paste blend 1a – 610.5, tone purity 77.4 %, and 1c – 614.5 nm, tone purity 78.8 %. The experimental blends of pastes had a reddish-purple color.

The characteristic wavelength for the blend 1b of the dried fraction is 615.3 nm, which corresponds to a bluish-red color with a tone purity of 34.8 %. The blends 1a and 1c have lengths of 495 and 572.6 nm. The tone purity of 34.6 for the blend 1b corresponds to a reddish-bluish color. The blend 1c is characterized by a bluish-purple color, as it has a tone purity of 34.3 %. So, the brightness of the pastes before and after drying decreases within 3...4 %. At the same time, the color purity, on the contrary, decreases almost by half, which is explained by the shrinkage of the blends during thermal-radiation treatment, while preserving their attractive visual color and confirms the effectiveness of the decisions made.

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