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# ANALYSIS OF EQUIPMENT FOR PRODUCING POWDERED FOOD PRODUCTS

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*The problem of rational selection of equipment for the production of powder products from high-moisture raw materials is considered, which is that in the process of drying liquid raw materials using various methods of heat supply, energy-intensive multi-unit installations are used, which is reasonable for large enterprises but not effective for small processing plants.*

***Keywords:*** *processing, food products, drying, vacuum, heat transfer, heat and mass transfer.*

# АНАЛІЗ ОБЛАДНАННЯ ДЛЯ ОТРИМАННЯ ПОРОШКОПОДІБНИХ ХАРЧОВИХ ПРОДУКТІВ

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*Енергоефективна переробка продуктів харчування, якісні характеристики зберігання є актуальним науково-технічним завданням. Із метою подовження термінів зберігання харчової сировини, отримання продукту з новими якісними властивостями використовують зневоднення, що може здійснюватися центрифугуванням, пресуванням або концентруванням із підведенням теплової енергії – випарюванням, сушінням. На сьогодні в харчовій промисловості є актуальним отримання порошкоподібних продуктів із рідкої або високовологої сировини. Порошкоподібні продукти дозволяють істотно розширити харчові ресурси, значно поліпшити асортименти нових видів харчових виробів. У них у концентрованому вигляді збережені всі інгредієнти, що входять до складу вихідної сировини. Найбільш поширеними способами сушіння рідин, що використовуються в харчовій промисловості, є кондуктивний, конвективний, сушіння під дією енергетичних полів, сублімаційний, розпилювальне сушіння, вакуумне, комбіноване. Виділяють три послідовних періоди сушіння: переміщення вологи до поверхні продукту, випаровування вологи з поверхні та переміщення вологи у вигляді пари від поверхні продукту в повітряний потік. Поєднання декількох різновидів теплового впливу на продукт дозволяє регулювати вологість усередині продукту. У таких апаратах циклічно поєднується процес конвективного або кондуктивного нагрівання, а потім вакуумування. Завдяки цьому відбувається інтенсифікація зовнішнього та внутрішнього тепломасообміну, скорочується термін перебігу процесу та попереджується перегрівання продукту. Оптимальний режим сушіння повинен здійснюватися за мінімальних витрат тепла й енергії та полягати в максимальному збереженні хіміко-технологічних показників якості сировини, що використовується для сушіння. У процесі сушіння високовологої сировини із застосуванням різних способів подачі тепла використовуються багатокорпусні установки, що призводить до значних енергозатрат. Останнім часом наукові розвідки спрямовані на вдосконалення способів сушіння, які б забезпечували максимальну ефективність харчових і смакових переваг продукту, а також високу ефективність тепломасообмінних процесів. Одним із методів вирішення цієї проблеми є використання радіаційно-конвективного способу теплопідведення у випарювально-сушильному апараті, що дозволить суттєво знизити експлуатаційні витрати на процес й отримати високоякісний порошкоподібний продукт.*

***Ключові слова:*** *переробка, продукти харчування, сушіння, вакуум, теплопідведення, тепломасообмін.*

# АНАЛИЗ ОБОРУДОВАНИЯ ДЛЯ ПОЛУЧЕНИЯ ПОРОШКООБРАЗНЫХ ПИЩЕВЫХ ПРОДУКТОВ

**В.А. Потапов, А.А. Борисова, И.П. Педорич**

*Рассмотрена проблема рационального подбора оборудования для получения порошкообразных продуктов из высоковлажного сырья, которая состоит в том, что в процессе сушки жидкого сырья с использованием различных способов подачи тепла применяются энергозатратные многокорпусные установки, что является целесообразным для предприятий большой мощности, но неэффективно для мелких перерабатывающих производств.*

***Ключевые слова:*** *переработка, продукты питания, сушка, вакуум, теплоподвод, тепломассообмен.*

**Statement of the problem.** In modern conditions, due to the rapid rise in energy prices, the problem of energy efficiency in the production and economic activity of enterprises is becoming particularly topical. At present, in the food industry, a two-stage process is usually used for the production of liquid or powdered products of high moisture: first, raw material is concentrated by vacuum evaporation, and then dried to final humidity in the spraying dryers. This technology is characterized by high energy consumption, and is economically feasible only at high productivity, which is primarily connected with technical difficulties in the operation of vacuum evaporating machines and spraying dryers for low productivity. At the same time, the demands of the equipment market require the development of compact and universal equipment, which would combine vacuum concentration and drying operations during the processing of products of low-capacity agricultural enterprises [1].

**Review of the latest research and publications.** Recent studies have been conducted to improve methods of drying, which would ensure the maximum efficiency of the food and gustatory benefits of the product, as well as the high efficiency of the process.

For modern methods of drying [2], the intensification of heat and mass transfer processes, which is achieved in different ways, is characterized by an increase in the contact surface between the drying product and drying agent; decrease in relative humidity of the drying agent; application of combined heat supply; increasing the speed of movement of raw material and the drying agent; combination of dehydration with various technological processes: freezing, blasting, dispersing, etc.

**The objective of the research.** Analysis of the processes and equipment for obtaining a powdered product of high humidity from food raw materials.

**Presentation of the research material.** In order to extend the storage life of food raw materials, to obtain a product with new qualitative properties using dehydration, which can be done mechanically (centrifugation, pressing) or concentration with a supply of thermal energy (evaporation, drying). Quantitative ratio of water and dry matters in the product significantly influence on the choice of drying parameters and the storage conditions of a dry product [3–5].

Drying is not only a complicated process of heat and mass transfer, but also a very complicated technological process. The dried food product should possess high quality indicators, both organoleptic and physico-chemical. The method of drying depends on the properties of raw material and the final product. The optimum drying regime should be carried out with minimal losses of heat and energy, and lies in maximal maintenance of chemical and technological indicators of quality of raw materials used for drying [6].

In the process of drying from food, moisture is removed by evaporation, water vapor is released. This is a rather energy-intensive process, because the change in the aggregate state of moisture consumes a lot of heat. There are three consecutive drying periods: movement of moisture to the surface of the product, evaporation of moisture from the surface and movement of moisture in the form of vapor from the surface of the product into the air stream.

There are several classifications of drying methods on various grounds. By the way of the influence of the drying agent – natural and artificial, by pressure of air in the drying chamber – atmospheric and vacuum. By the way of heat supply to wet material the dryers are classified to: convective – thermal energy is transmitted by convection, conductive – thermal energy is transmitted by heat conduction, thermal radiation – thermal energy is transmitted by thermal emission, high-frequency – thermal energy is converted from electrical and the product is dried inside, combined – heat transfer is performed by means of combinations of the above-mentioned methods; depending on the direction of movement of the drying material and drying agent: direct-flow, reverse-current, cross-sectional; by the type of a drying agent – devices using heated air; installations using flue gases; installations used in the mixture of air with flue gases – installations using superheated steam; for circulation of a drying agent – plants with natural and forced circulation; by the method of heating drying agent – installations with steam carriers, with fire burners, with liquid fuel burners, with gas burners; on the multiplicity of using drying agent – with one-time and repeated use of heated air; by the type of a drying facility – for solid materials, liquid materials, and paste-like products; by operating mode – periodic and continuous operation. According to structural features: tunnel, chamber, tape, drum, roller, mine, and others [7].

The choice of the method of drying depends on biochemical and structural-mechanical properties of the raw material, its state when dehydrated (whole fruits, chopped, liquid products), and the properties of a final product and the economic effectiveness of the process.

One of the promising areas of drying is food powders production. Powders allow to expand food resources, significantly improve the assortment of new types of food products, in which all concentrated ingredients that are part of the raw material are preserved [8; 9]. At the same time, there are different methods of drying used to produce powders from liquid products and products of high humidity.

The most common methods of drying liquids used in the food industry are conductive, convective, drying, under the influence of energy fields, sublimation, spray drying, vacuum, combined [6; 10–12]. Drying of liquids is often carried out by a conductive method, which is based on heat transfer of the material during contact with the hot surface. For this method of drying, the air is necessary only for removal of water vapor from the dryer. Quality of the obtained dry product is characterized by high organoleptic characteristics. Advantages of conductive drying [13] are the speed, which is explained by high heat transfer coefficient between the hot surface and the material, low energy consumption and low cost of equipment. However, this method has limitations for products with low heat resistance, since under the influence of uneven heating the structure of raw materials is violated.

Convective drying is the most common method because heat comes to the surface of the product from gaseous heat carrier, which is removed from the drying chamber with evaporated moisture. At the beginning of the process, the moisture evaporates from the surface of the product, and then from its inner layers. This method is used for liquids containing thermolabile substances, since prolonged action of high temperatures leads to their inactivation. Using this method, liquids are sprayed out in a stream of hot air at a temperature of about 150 °C for 2–3 seconds. During this time, there is no overheating of the liquid. The disadvantage of spray drying is expensive equipment of large size, increased electricity costs. The disadvantage of dried products made by traditional methods of drying is their poor restoration [10].

Ultrasonic drying of liquid food products proceeds under intense acoustic oscillations. The advantages of this method include the possibility of accelerating the process by 2–6 times in comparison with the conductive method without significant raise of temperature of the material, which is especially important during the drying of thermoplastic easily oxidized products. However, this method requires the use of expensive equipment [2], which, in its turn, essentially increases the cost of manufacturing the final product.

A known method for obtaining a dry product comprising spraying a pre-condensed product with the subsequent drying of the received droplets in a stream of hot air in the presence of an acoustic field, while low-frequency harmonic oscillations are imposed on the gas-liquid mixture of the product [14]. The disadvantage of this method lies in its complexity and high level of energy consumption associated with the necessity for pre-condensation of the product, the subsequent removal of moisture by hot air, heated to 170…180 °C, which violates acoustic harmonic oscillations at a relatively low sound pressure.

One of the innovative methods of drying liquids is the method of sublimation drying [15]. The drying of frozen liquids in a freezing chamber is carried out by sublimation of ice into steam in a vacuum chamber, passing physical state of moisture in the form of water. The resulting products differ in quality, low moisture content, high amount of nutrients, solubility, nutrition, but are sensitive to moisture and oxygen. Such dryers are very complex and expensive equipment, complex in operation and have increased electricity costs.

The use of infrared radiation is a promising area in food products drying. The essence of infrared radiation is the violation of atoms and molecules, which occurs during their thermal motion. The body absorbed by such radiation will be heated due to the increase in thermal motion of its atoms and molecules. In this case, energy is transferred from a body with a large potential for heat transfer to a body with a smaller potential. As for food products, infrared radiation penetrates in them to the depth of about 6–12 mm. Not much of the emitted energy reach this place. However, it should be noted that at a depth of 6–7 mm, the temperature of the product increase, which is dried much higher than that during convective drying [18]. This happens due to the influence of infrared short-wave beams on the product that has a deeper impact on the molecular structure. The peculiarity of infrared drying of products lies in the fact that we choose such wavelength of radiation, which affects only water in the product. This radiation is not absorbed by the product itself that makes it possible to carry out the drying process at sufficiently low temperatures of 40…60 °C. Due to this, vitamins and biologically active substances are stored in the product. Therefore, the original color and taste remain unchanged. Such characteristics of the drying process of products with the use of infrared radiation lets us presuppose that this direction is currently one of the most promising among the other methods of drying food products. This method of drying preserves up to 90% of vitamins and other useful substances in the product. In order to restore all former qualities of the processed product, it is necessary to soak it for only 10–20 minutes. At the same time, organoleptic, physical and chemical indices will almost completely correspond to the source product [16; 17].

The optimum drying mode [10; 12] should ensure obtaining of the product with the best quality parameters. The quality of the final product depends on the temperature, durability and method of drying. To reduce the consumption of fuel and energy resources during the drying of liquid food products, preliminary removal of water from raw material (condensation) by evaporation in evaporating plants (multi-body or single-body with thermal compression) is used. Then the product is dried in a drying chamber, which has a device for distribution and transformation of the coolant into steam. During the work of this installation, the main amount of moisture from the substance is removed in the evaporation apparatus, and the rest – in the drying chamber using water vapor as a coolant. The disadvantage is the use of water vapor in the drying chamber that leads to an increased temperature at the outlet of the coolant.

Spray drying is one of the main methods for obtaining powdered materials from wet raw materials. This method anticipates spraying of the product with the formation of a large number of finely divided particles, which are instantly dried in a stream of hot air. The rate of the process flow under the influence of high temperature positively affects the quality of the final product. The main disadvantage of this method is large dimensions of drying facilities and increased heat consumption.

Vacuum drying is one of the rational methods, because the amount of heat required for the process reduces and, as a result, decreases the energy intensity of the process.

An installation for obtaining a dry product, which contains a multi-body vacuum evaporator and a drying chamber with a device for separating the product from the coolant and the device for heating the latter, is known. The drying chamber is equipped with a device for distribution and transformation of the coolant into steam. During the work of this installation, 80% or more of the moisture from the substance is removed in the evaporation apparatus, and the rest of the moisture – in the drying chamber using water vapor as a coolant [19]. There are some drawbacks. Use of water vapor as a coolant in a drying chamber increases the temperature at the exit of the coolant from the drying chamber that may be undesirable for thermolabile products. Decrease in the temperature by vacuuming of the drying chamber reduces density of the steam, as a result, deteriorates the process efficiency, and increases the cost of the equipment. Use of water vapor as a coolant in the drying chamber, combined with the use of the device for converting coolant into steam, leads to the fact that the start and stop of the process become complicated and stretched over time.

The installation for obtaining dry milk from "LUWA" company is known. It contains a multi-body vacuum evaporator with rotary-film apparatus, a chamber with the devices for heating and supply of the coolant and a system for cleaning the waste coolant. The rotary-film apparatus allows receiving a highly concentrated, and in some cases dry product at the outlet of the evaporator. The waste coolant after passing the purification system from solid particles of the product, taken from the drying chamber, is released into the atmosphere with a temperature, which is significantly higher than the ambient temperature leading to heat losses. The fact that the drying chamber and the multi-body vacuum evaporator are presented as separate autonomous units is one of the disadvantages of this installation that leads to the increase in a number of units of installation and metal capacity of the equipment.

There is a method for obtaining a dry milk product, which involves mixing milk with vegetable oils, vitamins, heating, homogenizing, drying, condensation of the mixture in a vacuum, while drying is carried out by spraying in a stream of air at an inlet temperature of 125…130 °C [20]. The disadvantage is the complexity and high-energy consumption due to the use of heating, condensation, spray drying in the flow of hot air.

The other method for obtaining dry milk that includes spraying of the product with subsequent drying, is characterized by spraying of the filtered steamed milk through a filter under pressure, followed by drying in a vacuum shaft [21].

As we can see, a number of different installations are known for obtaining a dry product from wet raw materials by preliminary concentration and spraying. All of them have one major drawback, which is a two-stage process: first, raw material is concentrated by vacuum evaporation, and then dried to its final humidity in spraying dryers. This technology is characterized by energy consumption and is economically feasible only in case of its high productivity, which is primarily connected with technical complexity of the operation of vacuum evaporating machines and spraying dryers with low performance [1].

Combined processes joining several methods of drying or cyclic change of modes are also of interest to scientists. The combination of several varieties of thermal effects on the product can affect humidity inside the product. Such apparatuses cyclically combine the process of convective or conductive heating and then vacuuming. Under such processes, the intensification of external and internal heat and mass transfer occurs, the term of the process shortens and the product overheating is prevented [22].

**Conclusion.** The main drawbacks of the processes of drying raw materials of high humidity applying various methods of heat supply are the use of multi-body installations that results in significant energy consumption. Modern methods of obtaining powdered products from liquid raw materials or those of high humidity are carried out by means of a two-stage process in which raw material is first concentrated by vacuum evaporation, and then dried to its final moisture. Such methods are economically feasible only under high performance that is connected with technical complexity of the operation of vacuum evaporators and spraying dryers.

Investigations of small agricultural processing companies demonstrated an urgent need for small-sized equipment, in which the processes of vacuum concentration and drying could be effectively combined.

One of the prospective methods for solving this scientific and technical task is the use of the method of radiation-convection heat transfer in an evaporative-drying apparatus that will sufficiently reduce operational expenses of the process and obtain a high-quality powdered product [22].

## Список джерел інформації / References

1. Потапов В. О. Аналіз способів сушіння для отримання порошкоподібних харчових продуктів / В. О. Потапов, І. П. Педорич // Хімічна технологія та інженерія : міжнар. наук.-практ. конф., 26–30 червня 2017 р. – Львів : Львівська політехніка, 2017. – С. 181–182.

Potapov, V.O., Pedorych, I.P. (2017), “Analysis of Drying Techniques for Powdered Food Products", *Chemical Technology and Engineering: International Scientific and Practical Conference* [“Analiz sposobiv sushinnya dlya otrymannya poroshkopodibnykh kharchovykh produktiv" Khimichna tekhnolohiya ta inzheneriya: Mizhnarodna naukovo-praktychna konferentsiya], June 26–30, Lviv Polytechnic, Lviv, pp. 181-182.

2. Fellows, P. (1988), *Food Processing Technology: Principles and Practice*, Chichester, U.K., Fills Horwood.

3. Атаназевич В. И. Сушка пищевых продуктов / В. И. Атаназевич. – М. : ДеЛи, 2000. – 295 с.

Atanazevich, V.I. (2000), *Drying of food products* [*Sushka pishchevykh produktov*], DeLi, Moscow, 295 p.

4. Бачурская Л. Д. Технология пищевых концентратов / Л. Д. Бачурская, В. Н. Гуляев. – М. : Пищевая пром-сть, 1970. – 312 с.

Bachurskaya, L.D., Gulyaev, V.N. (1970), *Technology of food concentrates* [*Tekhnologiya pishchevykh kontsentratov*], Food industry, Moscow, 312 p.

5. Гуляев В. Н. Технология пищевых концентратов / В. Н. Гуляев. – М. : Легкая и пищевая пром-сть, 1981. – 207 с.

Gulyaev, V.N. (1981), *Technology of food concentrates* [*Tekhnologiya pishchevykh kontsentratov*], Light and food industry, Moscow, 207 p.

6. Cook, E.M., Du Mont, J.D. (1991), *Process Drying Practice,* NY, McGraw-Hill.

7. Киселева Т. Ф. Технология сушки : учебно-методический комплекс / Т. Ф. Киселева. – Кемерово, 2007. – 117 с.

Kiseleva, T.F. (2007), *Drying technology: Educational and methodical complex* [*Tekhnologiya sushki: Uchebno-metodicheskiy kompleks*], Kemerovo, 117 p.

8. Кабанов Л. А. Сравнительная характеристика плодово-ягодных порошков выработанных различными методами сушки / Л. А. Кабанов, Б. В. Карабуля // Консервная и овощесушильная промышленность. – Москва, 1983. – Вып. 5. – С. 23–25.

Kabanov, L.A., Karabulya, B.V. (1983), "Comparative characteristics of fruit and berry powders produced by various drying methods", *Canning and vegetable-drying industry* ["Sravnitel'naya kharakteristika plodovo-yagodnykh poroshkov vyrabotannykh razlichnymi metodami sushki", *Konservnaya i ovoshchesushil'naya promyshlennost'*], Moscow, Iss. 5, pp. 23-25.

9. Потапов В. О. Аналіз сировини, процесів та обладнання для отримання харчових порошків / В. О. Потапов, В. В. Євлаш, І. П. Педорич // Удосконалення процесів і обладнання харчових і хімічних виробництв : матеріали XVII Міжнар. наук.-практ. конф., 3–8 вересня 2018 р. – Одеса : ОНАХТ, 2018. – С. 149–152.

Potapov, V.O., Evlash, V.V., Pedorych, I.P. (2018), "Analysis of raw materials, processes and equipment for the production of food powders", *Improvement of processes and equipment of food and chemical industries*: *Materials of the XVII International Scientific and Practical Conference* ["Analiz syrovyny, protsesiv ta obladnannya dlya otrymannya kharchovykh poroshkiv", *Udoskonalennya protsesiv i obladnannya kharchovykh i khimichnykh vyrobnytstv Materialy XVII Mizhnarodnoyi naukovo-praktychnoyi konferentsiyi*], September 3–8, ONACHT, Odesa, pp. 149-152.

10. Черевко О. І. Процеси і апарати харчових виробництв / О. І. Черевко, А. М. Поперечний. – Харків : Світ книги, 2014. – Розд. 6. – С. 440–449.

Cherevko, O.I., Poperechnyi, A.M. (2014), *Processes and apparatuses of food industries* [*Protsesy i aparaty kharchovykh vyrobnytstv*], World Book, Kharkiv, Part. 6, pp. 440-449.

11. Keey, R.B. (1991), *Drying of Loose and Perticulate Materials,* H.Y, Himisphere.

12. Потапов В. О. Аналіз перспективних напрямків отримання порошків харчових продуктів / В. О. Потапов, І. П. Педорич // Проблеми енергоефективності та якості в процесах сушіння харчової сировини : Всеукр. наук.-практ. конф., присвячена 50-річчю заснування Харківського державного університету харчування та торгівлі, 1–2 червня 2017 р. : [тези] / редкол. : О. І. Черевко [та ін.]. – Х. : ХДУХТ, 2017. – С. 61–62.

Potapov, V.O., Pedorych, I.P. (2017), "Analysis of promising directions for obtaining food powders", *Problems of energy efficiency and quality in the processes* *of drying of food raw materials. Allukr. science-practice Conference dedicated to the 50th anniversary of the foundation of Kharkiv State University of Food and Trade, June 1-2* [“Analiz perspektyvnykh napryamkiv otrymannya poroshkiv kharchovykh produktiv”, *Problemy enerhoefektyvnosti ta yakosti v protsesakh sushinnya kharchovoyi syrovyny: Vseukr. nauk.-prakt. konf., prysvyachena 50-richchyu zasnuvannya Kharkivskoho derzhavnoho universytetu kharchuvannya ta torhivli, 1–2 chervnya*: tezy], KhDUHT, Kharkiv, pp. 61-62.

13. Красников В. В. Кондуктивная сушка / В. В. Красников. – М. : Энергия, 1973.

Krasnikov, V.V. (1973), *Conductive Drying* [*Konduktivnaya sushka*], Energy, Moscow.

14. Пат. РФ МПК A23C 1/04. Способ получения сухого молока, молочных и молокосодержащих продуктов / Борисов Ю. Я., Плановский А. А. – № 2127526 ; опубл. 20.03.99.

Borisov, Yu.Ya, Planovsky, A.A. (1999), *Method for producing dry milk, dairy and milk-containing products* [*Sposob polucheniya sukhogo moloka, molochnykh i molokosoderzhashchikh produktov*], RF. Pat. 2127526.

15. Гинзбург А. С. Основы теории и техники сушки пищевых продуктов / А. С. Гинзбург. – М. : Пищевая промышленность, 1973. – 528 с.

Ginzburg, A.S. (1973), *Fundamentals of the theory and technology of drying food products* [*Osnovy teorii i tekhniki sushki pishchevykh produktov*], Food industry, Moscow, 528 p.

16. Лыков А. В. Теория сушки / А. В. Лыков. – М. : Энергия, 1968.

Lykov, A.V. (1968), *Theory of drying* [*Teoriya sushki*], Energy, Moscow.

17. Лыков А. П. Тепломассообмен: Справочник / А. П. Лыков. – М. : Энергия, 1978.

Lykov, A.P. (1978), *Heat and mass transfer: a Handbook* [*Teplomassoobmen: Spravochnik*], Energy, Moscow.

18. Лебедев Е. И. Комплексное использование сырья в пищевой промышленности / Е. И. Лебедев. – Москва, 1982.

Lebedev, E.I. (1982), *Complex use of raw materials in the food industry* [*Kompleksnoye ispol'zovaniye syr'ya v pishchevoy promyshlennosti*], Moscow.

19. Пат. РФ МПК B01D 1/24, B01D 1/26. Установка для получения сухого продукта / Александров В. М., Колобов В. И., Тихонов В. А., Чижик Ю. Л., Герасимов В. Я., Картавцев А. В., Кругликова А. М. – № 2022607 ; опубл. 15.11.94.

Aleksandrov, V.M., Kolobov, V.I., Tikhonov, V.A., Chizhik, Yu.L., Gerasimov, V.Ya., Kartavtsev, A.V., Kruglikova, A.M. (1994), *Installation for the production of a dry product* [*Ustanovka dlya polucheniya sukhogo produkta*], RF. Pat. 2022607.

20. Пат. РФ МПК A23C 9/00, A23C 9/158, A23C 11/04. Способ получения сухого молочного продукта / Маслобоев Ю. А. – № 2116032 ; опубл. 27.07.98.

Masloboev, Yu.A. (1998), *Method for Producing a Dry Milk Product* [*Sposob polucheniya sukhogo molochnogo produkta*], RF. Pat. 2116032.

21. Пат. РФ МПК A23C 1/14, A23C 9/00. Способ получения сухого молока / Кашурин С. Ю. – № 2485785 ; опубл. 27.06.13.

Kashurin, S.Yu. (2013), *Method for obtaining dry milk* [*Sposob polucheniya sukhogo moloka*], RF. Pat. 2485785.

22. Выбор рационального тепло-массобменного процесса получения диетической добавки «Нутрио-Гем» / В. А. Потапов, В. В. Евлаш, Н. М. Цуркан, И. П. Педорич // Удосконалення процесів і обладнання харчових та хімічних виробництв. – Одеса, 2016. – С. 66–70.

Potapov, V.A., Evlash, V.V., Turcan, N.M., Pedorich, I.P. (2016), "Choice of rational heat and mass exchange process for obtaining Nutrio-Gem dietary supplement", *Improvement of processes and equipment of food and chemical manufactures* ["Vybor ratsyonalnoho teplo-massobmennoho protsessa poluchenyya dyetycheskoy dobavky «Nutryo-Hem", *Udoskonalennya protsesiv i obladnannya kharchovykh ta khimichnykh vyrobnytstv*], ONACHT, Odesa, pp. 66-70.

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# DEVELOPMENT OF EQUIPMENT FOR IMPLEMENTATION OF THE COMBINED PROCESS OF JERUSALEM ARTICHOKE PEELING

**D. Dmytrevskyi, D. Horielkov, R. Lazurenko, O. Procenko**

*Qualitative indicators of raw materials are analyzed. The necessity of preserving the vitamin and mineral content of Jerusalem artichoke tubers during processing is proved. The analysis of the basic methods of realization of process of cleaning of vegetable raw materials is presented; their main advantages and disadvantages are analyzed. The device for the combined cleaning of Jerusalem artichoke tubers has been designed. The machine design is described in detail. Main advantages of using the developed machine are identified.*

***Keywords:*** *Jerusalem artichoke, combined peeling machine, heat treatment, mechanical treatment, quality of peeling, percentage of loss of raw materials.*

# РОЗРОБКА ОБЛАДНАННЯ ДЛЯ РЕАЛІЗАЦІЇ КОМБІНОВАНОГО СПОСОБУ ОЧИЩЕННЯ БУЛЬБ ТОПІНАМБУРА

**Д.В. Дмитревський, Д.В. Горєлков, Р.С. Лазуренко, О.І. Проценко**

*Розвиток та вдосконалення процесу очищення рослинної сировини є актуальним науково-технічним завданням. Одним із найбільш перспективних напрямків інтенсифікації процесу очищення овочів є розробка комбінованих процесів їх переробки. Удосконалення процесу очищення бульб засноване на поєднанні процесу попередньої термообробки топінамбура парою та процесу подальшого механічного доочищення. Доведено необхідність створення обладнання для реалізації комбінованого процесу очищення овочів. Проведено експериментальні дослідження для вивчення впливу параметрів процесу*