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Assessment of biomaterial curve drying rate (Case study: *Panax ginseng*)

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ABSTRACT

An urgent task is to study the kinetics of drying biologically active materials using the example of ginseng biomass in order to substantiate the modes of sublimate drying. To substantiate the drying modes, it is necessary to know the following main process parameters: the method of freezing an initial product; initial moisture or dry matter content of ginseng biomass; product layer thickness; the maximum permissible temperature for heating the product. Based on the curves of the kinetics of ginseng biomass drying, it was found that the drying time of ginseng biomass with a high concentration of dry substances W = 20% with the same energy supply is less than a sample with a low concentration W = 3%, but the drying rate of biomass with a lower concentration is higher. It was found that during self-freezing, the rate of moisture evaporation during this period is 3-5 times higher than during the period of sublimation, which reduces the total energy consumption for drying while maintaining high-quality indicators of the dried product. When drying thermolabile products, which include ginseng biomass, the intensity of heat supply is limited by the maximum permissible heating temperature of the material surface + 60 ^{0}C. The thickness of the product layer during drying is 10 - 11 mm, at which the specific productivity of the installation will be maximum.

Keywords: Ginseng biomass, Self-freezing, Drying kinetics, Heating temperature, Layer thickness.

INTRODUCTION

Interest in natural adaptogenic drugs never diminishes and, on the contrary, has only grown in recent years. The use of artificial medicines leads to various consequences, such as immune and vitamin deficiencies and allergies. The search for new safe means that increase the general nonspecific resistance of the organism to various unfavourable factors (stress, increased radiation, hypoxia, etc.) is an urgent task of modern pharmacology. For this purpose, adaptogens of plant origin have long been used - ginseng, *Rhodiola rosea* and others. Real ginseng (*Panax ginseng* S. A. Meu.) has been known since ancient times as a valuable remedy. They determined its potent tonic and stimulating effect on mental and physical fatigue, weakness and low blood pressure (Gammerman 1990). The tonic and stimulating properties of ginseng are based on the activity of triterpene glycosides (panaxosides A, B, C, D, E, F, G), which are tetracyclic triterpenes. The valuable properties of ginseng determine its use in medicine, food industry and other fields aimed at treating and maintaining human health and longevity. It has been established that ginseng preparations inhibit the growth of cancerous tumours and in some cases prevent disease recurrence; they are used to treat atherosclerosis, low blood pressure, heart defects, anemia, and diabetes mellitus (Kiefer & Pantuso 2003; Choi & Meyer 2008). Electro hydrodynamic drying (EHD) is a promising innovation to dry out biomaterials yet needs further advancement for mechanical use. Mathematical displaying of EHD wind current and the related fume transport, combined with the exchange measures inside the drying material, are viewed as fundamental for additional cycle advancement (Defraeye & Martynenko 2018). The capability of utilizing freeze-drying for improvement of organ-specific framework calculations for tissue designing applications, which as of recently probably won't have been viewed as plausible was approved (Brougham *et al.* 2017).

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The present and ongoing advances in information and developments, on the properties of shower dried dairy items, on the demonstrating and recreation of water move measures (drying and rehydration), and on splash drying hardware and energy utilization were inspected (Schuck *et al.* 2016). The commitments of the lipid bilayers and natural moisturizing factors (NMFs) to the obstruction properties and mechanical reactions of human of the stratum corneum (SC) were introduced (Bow *et al.* 2020). The resources of ginseng in nature are limited, and at present, the collection of wild plants in nature is prohibited by the Law of the Russian Federation. Therefore, the pharmacy network receives the root grown exclusively by plantation. The valuable medicinal properties of ginseng have led to high demand for it. However, it is not possible to fully satisfy the needs of the medical, food and cosmetic industries with this valuable medicinal raw material, since the natural resources of the root are limited, it is listed in the Red Book, and plantation cultivation is almost unprofitable due to the complexity of plant cultivation in artificially created conditions, and the slow growth of biomass root (Zhuravlev *et al.* 2003; Geng *et al.* 2010). *P. ginseng* is a plant that grows in Korea, northeastern China, and far eastern Siberia. People use the root to make medicine. Do not confuse *P. ginseng* with American ginseng, Siberian ginseng, or *P. pseudoginseng*. These are different plants with different activity. *P. ginseng* is taken by mouth to improve memory and thinking skills, Alzheimer disease, and many other conditions, but there is no good scientific evidence to support these uses. In manufacturing, *P. ginseng* is used to make soaps, cosmetics, and as a flavoring in beverages.

How does it work?

P. ginseng contains many active substances. The substances thought to be most important are called ginsenosides or panaxosides. Ginsenosides is the term coined by Asian researchers, and the term panaxosides was chosen by early Russian researchers. *P. ginseng* is often referred to as a general well-being medication, because it affects many different systems of the body.

Panax ginseng plant.

Panax ginseng root.

At present, the technology of ginseng biomass reproduction in vitro at the cellular level is widely used. Its basis is the cultivation of initial cell culture of ginseng, obtained from natural root tissues, on a medium with kinetin, followed by reseeding and selection of the grown biomass for the extraction of biologically active substances (Buntsevich 2004). The stages of the technological process for the production of biologically active drugs are as follows: obtaining and growing the biomass of plant cells and tissues - obtaining dry biomass - obtaining and controlling biologically active drugs.

At present, various methods are used for drying biological objects: spray drying, drying in fluidized and dense layers, freeze-drying (Karpov & Ulumiev 1987). For thermo-labile products, which include ginseng biomass, the method of dehydration, which ensures high quality of the resulting dry product with its preservation for a long time, is freeze-drying in a vacuum. This method is widely used for conservation and further long-term storage of various products of biological origin. Freeze-drying allows you to get dry tissues, preparations, products without losing their shape, structural integrity and, more importantly, without losing their biological activity. The main sublimation process consists of three stages: freezing, sublimation and post-drying. During the first stage, the temperature of the product drops below its solidification temperature, after which ice crystals form inside the product. Further, ice crystals disappear during the process of sublimation. This stage can have a significant impact on the level of product quality. The final stage is additional drying, carried out with the supply of heat at a temperature not exceeding + 40 °C. The purpose of this work was to study the curves of freeze-drying kinetics to substantiate the technological modes of the process.

MATERIALS AND METHODS

The object of the study was the biomass of ginseng obtained by cultivating a cell culture on a solid agar nutrient medium Murashige - Skoog. For this, callus tissue is isolated from the primary explants (root disc), cut into pieces of about 1 g, and subcultured onto a freshly prepared nutrient medium to obtain biomass, which grows disorganized. The growing cycle is 30 to 60 days. During this time, the amount of biomass in one tank increases by about 15-20 times. The duration of tissue growth (passage) ranges from 30 to 45 days (Romanov et al., 2018).

Experimental studies of freeze-drying kinetics of ginseng biomass were carried out on a practical stand, created based on a sublimation unit of the company "Stokes". The installation consists of a steel welded vacuum chamber, the inner surface of which is covered with a special material with high reflectivity. For the convenience of visual observation, there is an observation window on the chamber door. The chamber contains a freezing condenser, emitters and precision scales. The temperature of the emitters was regulated in the range from 20 ^{0}C to 200 ^{0}C and was automatically maintained by the contact device of the potentiometer with the accuracy of ± 20 C.

Ginseng biomass was applied in a thin layer into metal cuvettes with an area of 6 × 10-3 m^2. A thermocouple was placed in the centre of the cuvette to control the sample temperature. The cuvette with the sample was installed on the balance lever. After sealing the sublimation chamber and turning on the installation, the vacuum pump lowers the pressure in the chamber to 20 Pa. By creating a vacuum and partial evaporation of free moisture, the product is frozen. Most of the moisture is converted into ice crystals, after which the sublimation process begins. The wet steam, due to the action of the vacuum pump, enters the desublimator, where moisture settles in the form of ice. The air from the desublimator is discharged into the atmosphere. For the final stage of the drying process, lamps are turned on, which heat the product with infrared rays and remove the remaining moisture. The weight loss of the samples was recorded every 5 minutes. The temperature measuring unit consisted of a milliammeter, and chrome-copel thermocouples made of 0.2 mm diameter conductors. To increase the measurement limit, the milliammeter scale was 0.10 C. The temperature of the IR emitters and the temperature of the material were automatically recorded.

RESULTS AND DISCUSSION

To calculate the kinetics of freeze-drying, you need to know the following basic process parameters: the method of freezing the original product; initial moisture or dry matter content of ginseng biomass; product layer thickness; the maximum permissible temperature for heating the product. The studies of ginseng biomass as an object of drying showed that the structure of the sample changes in the process of evaporative self-freezing (Talipova & Feoktistova 2016). As shown by the structural sorption analysis, a system of large pores is formed in the sample during evaporative self-freezing, which leads to the resistance decrease of the product dry layer and to the intensification of mass transfer through the dry layer of the product. With evaporative self-freezing, the material

pp. 481~487 Received: April 24. 2020 Accepted: Aug. 19. 2020
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is cooled relatively uniformly and quickly, and during this period the sample loses up to 20% moisture. Evaporative self-freezing not only simplifies the technological process (eliminating the need to use refrigeration equipment for preliminary freezing) but also intensifies dehydration: the rate of moisture evaporation during this period is 3-5 times higher than during the sublimation period. With evaporative self-freezing, costs are reduced, since the released heat of ice melting (specific heat of crystallization) is also used during sublimation, which reduces the total energy consumption for drying while maintaining high-quality indicators of the dried product.

When drying thermolabile products, which include ginseng biomass, the intensity of heat supply is limited by the maximum permissible heating temperature of the material surface. In (Koshkalov *et al.* 2018), we found that the maximum permissible heating temperature for drying ginseng biomass should not exceed +60 ^{0}C. Fig. 1 shows the curves of the drying rate of ginseng biomass with the initial dry matter content of 3%, 10% and 20%. Freeze drying of all samples was carried out with a two-way radiation power supply under identical external conditions: the temperature of the emitters + 60 °C, the temperature of the freezing condenser -40 °C, and the pressure in the chamber is 20 Pa. We used the samples of the same size in the experiments - flat disks 80 mm in diameter and 10 mm thick.

The analysis of the drying curves showed that the drying time for ginseng biomass with a high concentration at the same energy supply is less than for a sample with a low concentration of dry substances, but the drying rate of the biomass with a lower concentration is higher. The high drying rate of ginseng biomass with an initial dry matter concentration of 3% is explained by the content of a greater amount of free moisture, as well as a lower biomass density, and, accordingly, a lower hydraulic resistance to steam movement within the product. However, the kinetics of the process is more influenced not by the supply of heat to the sublimation zone, but by the resistance of the dry layer to the removal of steam from this zone.

The vapour permeability of the sample dry layer with a dry matter content of 3% is greater than that of the sample with a dry matter concentration of 20% due to its density decrease. However, despite the drying rate decrease, the higher the initial concentration of ginseng biomass, the higher the output of the finished product from a unit of the working surface of the installation per unit of time. However, at a concentration above 20%, it becomes difficult to remove dry biomass from baking trays and to process it further.

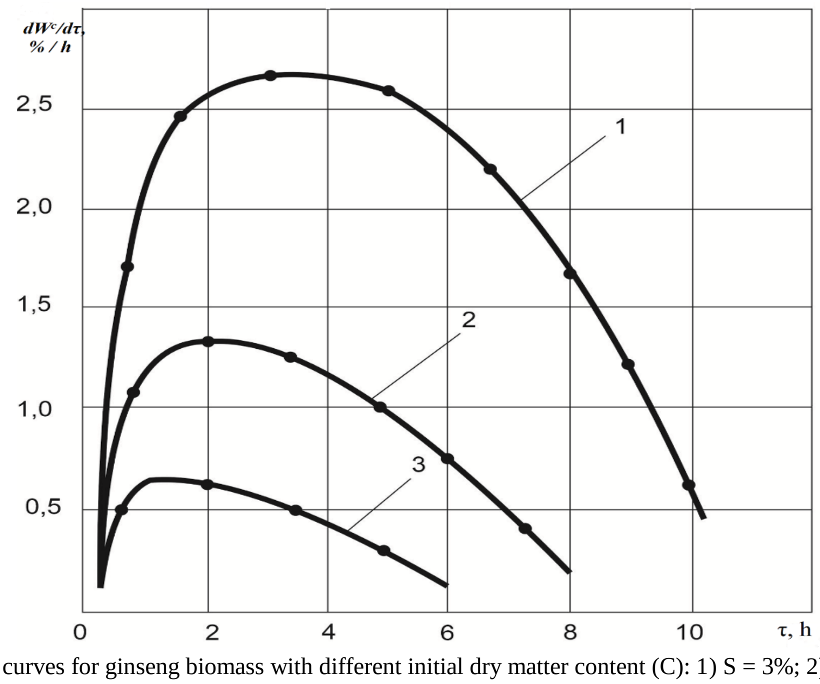

Fig. 1. Drying rate curves for ginseng biomass with different initial dry matter content (C): 1) S = 3%; 2) S = 10 %; 3) S = 20 %.

Fig. 2 shows the drying curves of ginseng biomass with different layer thicknesses (H): 5 mm, 10 mm, 15 mm and 20 mm. The initial dry matter content of all samples was 20%, the temperature of the emitters was + 60 ^{0}C.

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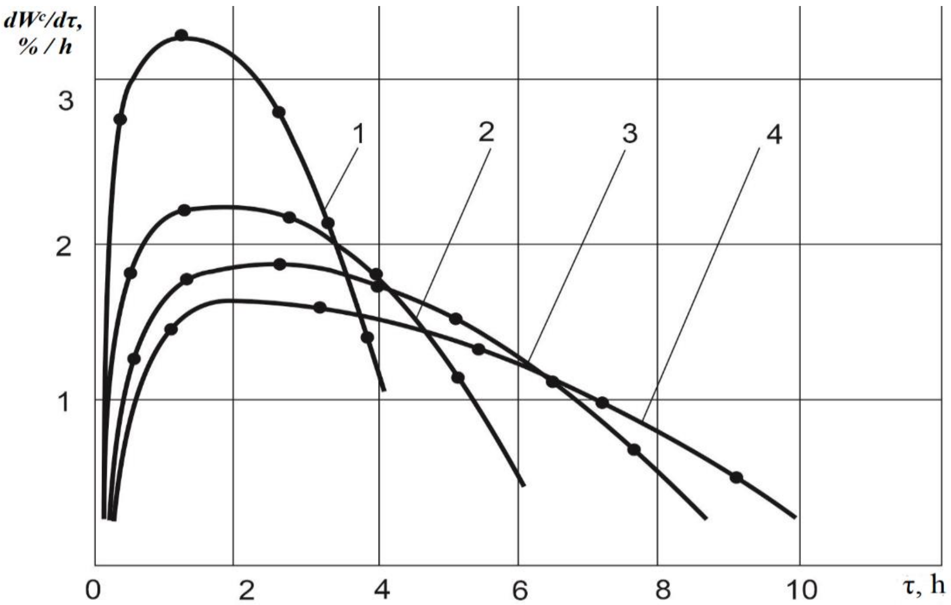

Fig. 2. Ginseng biomass drying rate curves depending on the thickness of the product layer (H): 1) H = 5 mm; 2) H = 10 mm; 3) H = 15 mm; 4) H = 20 mm.

The analysis of the drying curves shows that with the product layer thickness increase, the drying time increases from 5 hours with a layer thickness of 5 mm to 11 hours with a layer thickness of 20 mm. Thus, the drying speed is reduced. The duration of the drying process for the samples with a greater thickness increases mainly due to the increase of constant drying rate period, which depends on the amount of temperature supplied and the total amount of moisture removed during this period. The duration of drying rate decrease period increases to a lesser extent since its duration is determined mainly by the properties of the material and the form of the removed moisture bond. With the increase of the ginseng biomass layer thickness, the drying time increases, but at the same time, the yield of dry product per unit of the working surface of the installation increases per unit of time. However, with a layer thickness of more than 20 mm, the uniformity of drying is disturbed: the upper layer is burned when the lower layers are not dried.

CONCLUSIONS

It is recommended for the industrial use of freeze-drying to use the original ginseng biomass with a dry matter content of at least 20% in order to increase the yield of the finished product from a unit of the working surface of the installation per unit of time.

The recommended thickness of the product layer is 10 -11 mm, at which the specific productivity of the installation will be maximum.

SUMMARY

The main experimental regularities of freeze-drying kinetics of ginseng biomass under different conditions of the process have been established. The effect of the freezing method, the initial content of dry substances and the thickness of the product layer on the kinetics of freeze-drying is shown.

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مطالعه‌ی منحنی خشک شدن مواد زیستی (مطالعه موردی: *Panax ginseng*)

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چکیده

مطالعه‌ی سینتیک خشک سازی مواد فعال زیستی با استفاده از زی‌توده جنسینگ به‌منظور تأیید شیوه‌های خشکاندن تصعیدی لازم است. برای تأیید شیوه‌های خشک سازی، لازم است تا فراسنجه‌های اصلی در نظر گرفته شود: روش انجماد محصول اولیه، رطوبت اولیه یا مقدار ماده‌ی خشک زی‌توده ، ضخامت لایه‌ی محصول، حداکثر دمای مجاز برای حرارت دهی محصول. بر اساس منحنی‌های سینتیک خشک سازی زی‌توده جنسینگ، مشخص شد که زمان خشک سازی زی‌توده این محصول با غلظت بالای مواد خشک W = 20% با مقدار انرژی برابر، کم‌تر از نمونه‌ی با غلظت پایین ۳ ٪ است، ولی نرخ یا سرعت خشک سازی زی‌توده با غلظت کم‌تر بالاتر است. نتایج نشان داد که در طی خود انجمادی، سرعت تبخیر رطوبت در طی این زمان ۳ تا ۵ برابر بیشتر از زمان تصعید است، که این موجب کاهش مصرف انرژی کل برای خشک‌سازی، ضمن حفظ شاخص‌های کیفیتی بالای محصول خشک شده می‌شود. هنگام خشک سازی محصولات ناپایدار در مقابل حرارت که شامل زی‌توده جنسینگ نیز است، شدت عرضه‌ی دما با حداکثر دمای مجاز سطح ماده‌ی +۶۰ درجه محدود می‌شود. ضخامت لایه محصول در طی خشک‌سازی ۱۰-۱۱ میلی متر است که در آن بهره‌وری تأسیسات، حداکثر است.

*مولف مسئول

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