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HEAT PUMP DRYING OF THERMOLABILE MATERIALS (MEDICINAL PLANTS)

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Keywords: drying; energy savings; heat pump; medicinal plant; rhizomes and roots of Podophyllum emodi (Podophyllum hexandrum Royle).

Abstract: Drying of medicinal plant is one of the most important processing steps, scientifically defining the quality of a finished product. The object of drying were rhizomes and roots of Podophyllum emodi, being a source podophyllotoxin. Podophyllotoxin is used as starting material in the synthesis of anticancer drugs. Experimental studies on drying were conducted in the range temperatures from 40 up to 70 °C and velocity of drying air from 2 up to 5 m/s. To study the process of heat pump drying we used an experimental setup with recirculation drying agent. The obtained data will be used for further studies: selecting process parameters of heat pump drying and working out practical recommendations for application in the industry.

Medicinal plants are sources biologically active substances. Some substances obtained from plants are not used immediately with the medical purpose, but serve as initial products for a synthesis of effective medicinal substances. In Russia, significant amounts of wild-growing and cultivated medicinal plants are prepared. Goodness of medicinal plants largely depends on observance of periods of preparation, straightening technology of gathering and a condition of drying. Biochemical processes in the collected medicinal plants in the first time proceed as in a live plant, i.e. the synthesis of biologically active substances predominates. Then, on a measure of dehydration, in connection with termination of moisture and nutrients production, the processes of interchanging are shifted aside disintegration that results in the decrease in the contents of biologically active substances in raw material. However, in some cases the processes proceeding in drying raw material, result, on the contrary, in the increase in the contents of working substances [1].

Drying of medicinal plants is one of the most important processing steps, significantly defining the quality of a finished product. Methods of drying of medicinal plants can be divided into two groups:

– Natural drying, including air–shade and solar drying. Natural drying is possible in summertime or in the regions with hot arid climate.

– Thermal drying (artificial heating). Thermal drying ensures fast dehydration and can be used under any weather conditions and in any regions.

To save, and in some cases to improve the properties of medical products during drying is possible only if optimum process and operating conditions are observed.

Small volumes of production and a variety of dried materials create complexities for the safety of required process parameters of drying. Because of a deficiency of the special drying equipment many products are dried in dryers which do not correspond to all necessary demands, therefore the quality of a finished stock is reduced, power inputs are augmented.

Today, it is necessary to solve the existing technological problems, to develop the new special equipment for drying of thermolabile medicinal herbs in production of medical specimens. Thus, we need to achieve the following goals: simplification of a manufacturing method, maintenance of the required quality of the dried up product, reduction of power inputs. These goals completely match up with the government policies: implementation of the program of technological re-equipment of the Russian pharmaceutical industry as a strategic problem of the national security of the country in the future [2]. Also, the Order of the Government of the Russian Federation authorizes the government program "Energy conservation and increase in power efficiency for the period till 2020", which basic purpose is intelligent use of fuel and energy resources at the expense of energy conservation, increased energy efficiency of different branches of economy, expansion of renewed energy sources [3].

The energy savings in drying installations have a significant potential, in connection with wide abundance of drying processes, high power consumption and insufficient engineering perfection of the used drying installations. With this purpose it is offered to use heat pumps for drying agent heat disposal [4]. Heat pump technologies are successfully applied to drying food, pharmaceutical products, biological products and others thermolabile materials [5 – 8].

The object of drying was rhizomes and roots of Podophyllum emodi, which is the source of podophyllotoxin. Podophyllotoxin is used as an initial substance during the synthesis of anticancer drugs. In the literature, very few ways of deriving podophyllotoxin have been described. Medicinal plants remain the main source of podophyllotoxin substance for the pharmaceutical industry as biotechnological and chemical ways of its production have a much lower yield of the target product and are more costly. The medical products made abroad are produced from podophyllotoxin, or its semisynthetic derivatives. In the last years, the necessity of the world pharmaceutical industry in podophyllotoxin has appreciably increased. It is connected with the growth of a number of tumoral diseases and scientific studies aimed at the creation of new semisynthetic medical products based on podophyllotoxin. Now, Russia buys specimens of podophyllotoxin manufactured in the countries of Europe, the USA, India and China [9].

Drying of rhizomes and roots of Podophyllum emodi was carried out on the convective dryer with the drying agent recirculation up to final moisture content of 4 – 15 %. Drying parameters ranges as follows: temperature (40, 50, 60 and 70 °C) and air velocity (between 2 and 5 m/s). The results of the experiments of drying of rhizomes and roots of Podophyllum emodi at velocity of drying air of 2 m/s are presented in Fig. 1 and in Table.

From the reduced data it is seen, that the increase in the temperature of drying agent considerably (by several times) decreases the time of drying, but the contents of podophyllotoxin insignificantly decreases. The smaller contents of podophyllotoxin under the increase in the temperature is the more likely it is connected with its oxidation.

The increase in the velocity of drying air practically did not influence the period of drying, for example, the increase in the velocity up to 5 m/s reduced the time of drying by no more than 5 % from the reduced one that is explained y almost complete degeneration of 1 drying period.

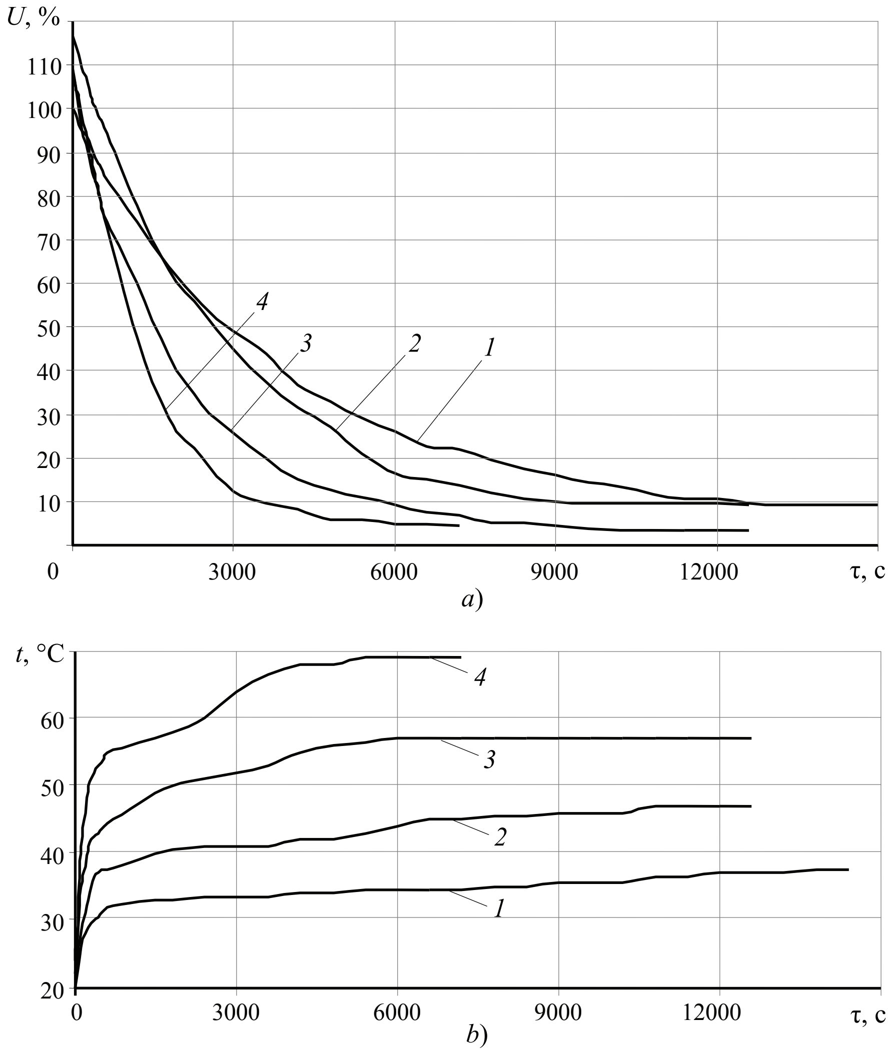

Fig. 1. Dependence of the moisture content (*a*) and temperatures (*b*) of rhizomes and roots of Podophyllum emodi from the drying time at temperature of drying air, °C:
1 – 40; *2* – 50; *3* – 60; *4* – 70

Results of experiments

Temperature of drying air, °C	Initial moisture content, %	Final moisture content, %	Time before reaching of moisture content, s	Time before reaching moisture content of 10 %, s	Podophyllotoxin content, %
40	100	8.0	14985	12600	3.28
50	116	8.6	12600	9000	3.24
60	108	4.2	12600	5400	3.17
70	108	4.3	7290	3600	3.13

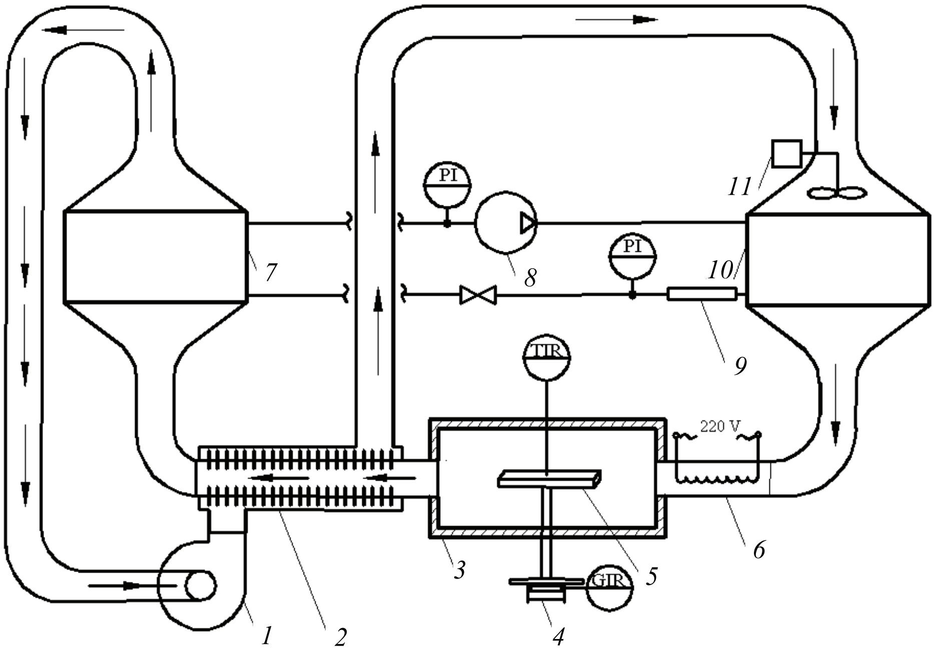

Fig. 2. The scheme of the experimental setup:
1 – fan; *2* – recuperative heat exchanger; *3* – drying chamber; *4* – balance;
5 – dried sample; *6* – hot-air heater; *7* – evaporator; *8* – compressor;
9 – filter-drier; *10* – condenser; *11* – additional fan

To determine the effect of the type of drying agent on the final content of podophyllotoxin we used nitrogen instead of air for drying of similar roots. Drying was conducted at 70 °C. The concentration of podophyllotoxin in roots reached 3.44%, which was higher than during drying in air even at 40 °C. Drying time in nitrogen did not differ from the drying time in the air at the same 70 °C, which may be due to identical kinetics of drying.

For the investigation of the kinetics of drying by using a drying agent, which differs in composition from air (nitrogen, carbon dioxide, etc.), we used an experimental installation with recirculation of the drying agent comprised of the following elements: a heat pump; a drying chamber; a heater for additional heating; a recuperative heat exchanger (Fig. 2). The possibility of varying the speed of the drying agent ranged from 0.5 to 10 m/s, the heater power was in the range from 0.1 to 1 kW [10].

The installation operates as follows. Wet warm drying agent goes out of the drying chamber *3*, passes through the heat exchanger *2* where it gives off a part of the heat, and acts in the heat exchanger-evaporator *7*. Dehumidification occurs at the expense of downturn of the temperature of drying agent below the temperature of a dew-point because of evaporation of a refrigerant in the intertube space. The drained cold drying agent passes in succession through the heat exchangers *2* and *10*. Heating of drying agent to the temperature close to reference temperature of drying, occurs in the heat exchanger *10* at the expense of condensation of a refrigerant in the tube space. Constant temperature drying agent at the entrance to the drying chamber is ensured by the heat supply of hot-air through the heater *6*. Circulation of drying agent occurs at the expense of the fan *1* and the additional fan *11*.

The described installation will allow obtaining data on the kinetics of drying, selecting process parameters of heat pump drying, and working out practical recommendations for the application in the industry.

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Сушка с тепловым насосом термолабильных материалов (на примере лекарственного растительного сырья)

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Ключевые слова: корневища с корнями подофилла гималайского; лекарственное растительное сырье; сушка; тепловой насос; энергосбережение.

Аннотация: Сушка лекарственных растений является одной из наиболее важных технологических операций, существенным образом определяющих качество готовой продукции. Объектом сушки выступали корневища с корнями подофилла гималайского, являющиеся источником подофиллотоксина. Подофиллотоксин используется в качестве исходного вещества при синтезе противоопухолевых препаратов. Экспериментальные исследования по сушке проводились в диапазоне температур от 40 до 70 ºС и скорости сушильного агента от 2 до 5 м/с. Создана экспериментальная установка с рециркуляцией сушильного агента, для исследования процесса сушки с тепловым насосом. Полученные данные планируется использовать для дальнейших исследований: обоснования технологических параметров процесса сушки с тепловым насосом и выработки практических рекомендаций для применения в промышленности.

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Trocknen mit der thermischen Pumpe der thermolabilen Materialien (am Beispiel des medikamentösen Pflanzenrohstoffs)

Zusammenfassung: Das Trocknen der Arzneipflanzen ist eine der wichtigsten technologischen Operationen, die wesentlich die Qualität der Fertigware bestimmen. Als Objekt des Trocknens wurden die Wurzelstöcke mit den Wurzeln des Himalayapodophyls, der die Quelle des Podophyllotoxines ist, genommen. Das Podophyllotoxin wird als Ausgangsstoff bei der Synthese der antineoplastischen Präparate verwendet. Die experimentalen Forschungen nach dem Trocknen wurden im Umfang der Temperaturen von 40 bis zu 70 ºC und bei der Geschwindigkeit des Trockenagenten von 2 bis zu 5 m/S durchgeführt. Es ist die experimentale Anlage mit der Rezirkulation des Trockenagenten für die Forschung des Prozesses des Trocknens

mit der thermischen Pumpe geschaffen. Die bekommenen Daten wird es geplant, für die weiteren Forschungen zu verwenden: die Begründungen der technologischen Parameter des Prozesses des Trocknens mit der thermischen Pumpe und der Leistung der praktischen Empfehlungen für die Anwendung in der Industrie.

Séchage avec la pompe thermique des matériaux thermolabiles (à l'exemple de la matière végétale médicinale)

Résumé: Le séchage des plantes médicinales est une importante opération technologique qui définit la qualité des produits. En qualité de l'objet du séchage sont pris les rhizomes avec les racines de Podophyllum d'Himalaya, source de Podophyllotoxin qui est utilisé comme source initiale lors de la synthès des appareils antitumorales. Les études expérimentales s'effectuaient dans une gamme de température de 40 jusqu'à 70 C et la vitesse de l'agent de séchage de 2 à 5 m/s. Est créée une installation expérimentale avec le recyclage de l'agent de séchage avec une pompe thermique. Les données reçus peuvent être utilisées pour les études ultérieurs.

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