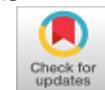


Sorption and Desorption of Medicinal Plants

Safarov J.E., Sultanova Sh.A., Dadayev G.T., Samandarov D.I.



Abstract: The sorption and desorption of medicinal plants was carried out on a vacuum installation with mercury gates and McBan quartz scales. The measurements were carried out at 293 K and a residual air pressure of 10^{-3} - 10^{-4} Pa. We studied the sorption and desorption of water vapor at 293 K for medicinal forestry plants - peppermint (*Mentha*), nettle (*Urtica*), plantain (*Plantago*) and zizifora (*Ziziphora*). The characteristics of the processes of sorption and desorption of medicinal plants were studied: it was found that the specific surface area of the capillaries is $137.26 \text{ m}^2/\text{g}$, and the total pore volume for zizifora under convective drying is $0.095 \text{ cm}^3/\text{g}$. For plantain, the characteristics of sorption and desorption were revealed: the confirmed specific surface of the capillaries is $92.10 \text{ m}^2/\text{g}$, while the total pore volume is $0.250 \text{ cm}^3/\text{g}$.

Keywords: Isotherm, Sorption, Desorption, Medicinal Plants.

I. INTRODUCTION

Medicinal plants (lat. Lantae medicinalis) - an extensive group of plants, organs or parts of which are raw materials for obtaining funds used in folk, medical or veterinary practice for therapeutic or prophylactic purposes. The most widely used medicinal plants are in traditional medicine.

When classifying the forms and types of bonds of moisture with a material, they proceed from the physical nature of the bond, which determines its qualitative characteristics, and from the bond energy, which reflects quantitative signs. The binding energy is understood as the energy that must be spent in conditions of constant temperature and moisture content to separate 1 mole of water from the material. The moisture content of a material is understood as its moisture content on a completely dry substance. Moisture content has a dimension: kg of moisture / kg of material. For free water, the binding energy is zero.

The following forms and types of bonds of moisture with the material are distinguished: 1) a chemical bond, which is characterized by hydration or crystallization; this moisture is usually not removed during the drying process;

2) physico-chemical bond, which is characteristic of all types of intracellular moisture: a) adsorption-bonded; b) osmotic-retained (moisture swelling); c) structural moisture; 3) physical and mechanical bond, which covers the moisture of macrocapillaries ($r > 10-5 \text{ cm}$) and the moisture of microcapillaries ($r < 10-5 \text{ cm}$).

The basis for dividing capillaries into macro- and microcapillaries is the commensurability of the mean free path of the vapor molecule with the radius of the capillary. The energy of the physico-mechanical bond is zero (this is free moisture), the chemical form is characterized by a sharp increase in the binding energy.

Regardless of the nature of the bond, moisture firmly bound to the material is called hygroscopic. This moisture cannot be completely removed from the material by drying. Moisture removed from the material under thermal drying is called free. By significantly increasing the temperature of the air and lowering its relative humidity, you can still remove some of the hygroscopic moisture. This part of the moisture that can still be removed by drying is called bound moisture.

Humidity of the material. In capillary-porous materials in a natural air environment there is always a certain amount of chemically unbound moisture. If a sample of the material under natural conditions is dried, its mass will decrease. The weight humidity of the material $\omega_B \%$, is determined by the ratio of the mass of moisture contained in the sample to the mass of the sample in a dry state:

$$\omega_B = M_1 - M_2 / M_2 \cdot 100, \quad (1)$$

where M_1 - wet sample weight, kg; M_2 - dry weight, kg.

Volumetric humidity $\omega_o \%$, determined by the ratio of the volume of moisture contained in the sample to the volume of the sample:

$$\omega_B = V_1 / V_2 \cdot 100, \quad (2)$$

where V_1 - the amount of moisture in the sample m^3 ; V_2 - sample volume, m^3 .

Between the weight ω_B and volumetric humidity ω_o of the material, there is a ratio:

$$\omega_B = \omega_o \rho / 1000 \cdot 100, \quad (3)$$

where ρ - the density of the material in the dry state, kg/m^3 .

In calculations, weight moisture is more often used.

With a long-term presence of a sample of material in humid air with constant temperature and relative humidity, the mass of moisture contained in the sample will become unchanged -equilibrium. With increasing relative humidity, the mass of moisture in the material increases, and with increasing temperature it decreases. This is the equilibrium moisture content of the material, corresponding to the heat-moisture state of the air, depending on the chemical composition, porosity and some other properties of the material, can be more or less.

Sorption - (from lat. Sorbeo - absorb), absorption by a solid or liquid of a substance from the environment.

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Sorption and desorption of medicinal plants

The main types of sorption are adsorption, absorption, chemisorption. The absorbing body is called a sorbent, the absorbed one is called a sorbate (sorbate). The most important solid sorbents capable of regeneration and used in technology are activated carbons, silica gel, zeolites, ion exchangers. Sorption in hydrometallurgy is the absorption of valuable components (U, Au, Mo) from solutions or pulps during the leaching of ores and concentrates.

Distinguish between the absorption of the entire volume of the liquid sorbent (absorption), as well as the solid or melt (occlusion) and the surface layer of the sorbent (adsorption). Sorption due to the interaction of a chemical type between the surface of a solid sorbent and a sorbate is called chemisorption. During vapor sorption by solids, capillary condensation often occurs. Usually, several sorption processes occur simultaneously.

Sorption refers to the effect of absorption or adsorption:

- absorption - volumetric fusion of two substances in different aggregate states (e.g. liquids absorbed by solids or gases, gases absorbed by liquids, etc.).

- adsorption - the physical adhesion of ions and molecules on the surface of a body of another state (for example, reagents are adsorbed to the whole surface of the catalyst).

II. EXPERIMENTAL AND RESULTS PART

The reverse process of isolation is called desorption. The pattern of change in the equilibrium moisture content of the material in air with a constant temperature and increasing relative humidity is expressed by the sorption isotherm. Sorption studies of medicinal plants were carried out on a vacuum installation with mercury gates and McBan quartz scales. The measurements were carried out at 293 K and a residual air pressure of 10^{-3} - 10^{-4} Pa.

We studied the sorption and desorption of water vapor at 293 K for medicinal forestry plants - mint (*Mentha*), nettle (*Urtica*), plantain (*Plantago*), and zizifora (*Ziziphora*). The data obtained are shown in table 1.

Table 1. Sorption and desorption of water vapor by samples of medicinal plants in forestry

Sample	№1 Mint (<i>Mentha</i>)		№2 Nettle (<i>Urtica</i>)		№3 Plantain (<i>Plantago</i>)		№4 Zizifora (<i>Ziziphora</i>)	
	Sorption, %	Desorp-ti on, %	Sorption, %	Desorp-ti on, %	Sorption, %	Desorp-ti on, %	Sorption, %	Desorp-ti on, %
Relative humidity, %	Sorption, %	Desorp-ti on, %	Sorption, %	Desorp-ti on, %	Sorption, %	Desorp-ti on, %	Sorption, %	Desorp-ti on, %
10	0,00	0,30	0,00	2,40	0,00	0,8	0,00	2,5
30	0,10	0,50	0,25	4,00	0,16	0,9	0,31	4,72
50	0,30	0,95	0,40	6,60	0,35	1,7	0,60	7,4
65	0,80	1,90	1,40	9,90	0,84	1,97	1,91	12,2
80	1,70	3,80	3,20	15,40	1,9	3,88	4,87	17,6
90	3,60	7,20	11,50	21,00	3,58	8,20	12,7	21,2
100	9,50	9,50	24,00	24,00	18,50	18,50	19,43	19,43

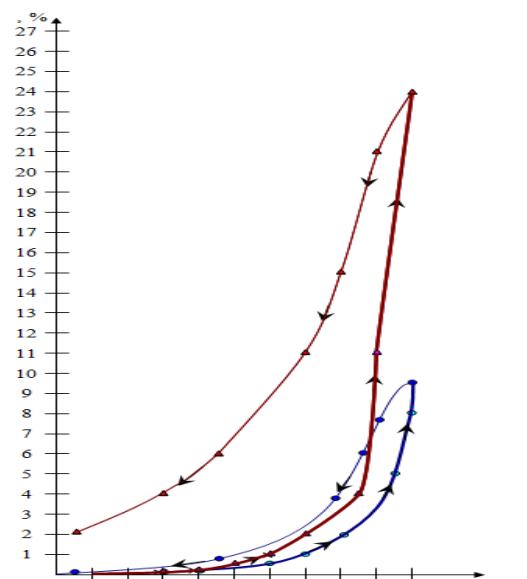
As can be seen from the table, the sorption capacity in all three samples increases after 80% relative humidity. Comparison of the studied samples shows that the tendency to sorption of water vapor in mint (*Mentha*) - №1 is the lowest compared to nettle (*Urtica*) - №2 samples, which is apparently due to the influence of the drying temperature.

Isothermal isotherm curves of isothermal sorption and desorption at a temperature of 293 K for dried medicinal plants in forestry using experimental mint and nettle as an example (Fig. 1).

From the curve of the sorption and desorption isotherms, it is possible to determine the equilibrium humidity, and also to establish to what humidity it is necessary to dry the material so that during storage it does not increase its humidity due to sorption from the air [1-2].

The maximum humidity that the material can have due to sorption of steam from the environment (maximum sorption capacity at $\varphi=100\%$) is called the hygroscopic humidity W . It can be determined on the graph of the sorption isotherm from the point of intersection of the isotherm with the line $\varphi=100\%$. The higher the hygroscopic humidity of the material, the more moisture it can absorb from the air during storage.

The analysis of isotherms of sorption and desorption is of great importance for clarifying the characteristics of the forms of moisture-material bonds. Knowledge of the hydrothermal equilibrium state is necessary to select the optimal drying and storage regime for the material.



●№1 mint (*Mentha*); ▲№2 nettle (*Urtica*)
where, P/P_0 - relative humidity

Fig. 1. Isotherms of sorption and desorption

From the experimental data of the sorption curves obtained by us, it can be seen that of the studied forestry plants have the highest hygroscopicity.

We also studied the desorption of water vapor. The data obtained show a change in the structure of drugs, accompanied by the appearance of hysteresis.

According to the classification of Dubinin and Kiselev, the second type of sorbents is microporous sorbents with a pore radius of up to 16 Å. Such thin pores are inaccessible to the

penetration of large sorbate molecules and a large number of small molecules. Microporous sorbents are characterized by G-shaped isotherms, which are formed not as a result of saturation of the surface with sorbate molecules, but due to the inaccessibility of thin pores for the penetration of a large number of molecules into them [3-4].

Next, we studied the kinetics of sorption and desorption of water vapor of medicinal plants of forestry at 293 K. The data obtained are shown in table 2 and in figure 1.

Table 2. Kinetics of vapor sorption by samples of dried medicinal plants

Sample							
№1 Mint (<i>Mentha</i>)		№2 Nettle (<i>Urtica</i>)		№3 Plantain (<i>Plantago</i>)		№4 Zizifora (<i>Ziziphora</i>)	
Sorption, %	Time, h	Sorption, %	Time, h	Sorption, %	Time, h	Sorption, %	Time, h
0,0	2	0,0	2	0,0	2	0,0	2
0,31	4	0,65	4	0,34	4	0,71	4
0,67	6	1,25	6	0,72	6	1,1	6
1,21	8	2,27	8	1,36	8	2,23	8
1,42	10	3,64	10	1,44	10	2,7	10
1,85	12	4,85	12	2,05	12	4,5	12
2,25	14	6,3	14	2,37	14	6,8	14
3,0	16	7,74	16	3,47	16	8,4	16
3,90	18	9,87	18	4,86	18	9,89	18
5,5	20	14,60	20	7,23	22	15,0	20
9,0	25	24,5	25	9,0	25	23,7	25

Based on the isotherm, the sorption of water vapor is calculated according to the BET equation (Brunauer, Emmett, Teller): S_{sp} - specific surface, W_0 - total pore volume and radius of submicroscopic capillaries - r_k .

$$S_{sp} = \frac{x_m}{M} \cdot N_A \cdot A_m \cdot 10^{-20}$$

$$W_0 = \frac{a}{d}$$

where, a is the mass of the adsorbate taken at $P/P_0=1$, d is the density of the adsorbate

$$r_k = \frac{2 \cdot W_0}{S_{y\partial}} \cdot 10^{-4}$$

The capillary-porous structure of samples of dried medicinal plants upon desorption of water vapor, 25 °C is given in table. 3.

Table 3. Capillary-porous structure of samples of dried medicinal plants

Sample	№1 Mint (<i>Mentha</i>)	№2 Nettle (<i>Urtica</i>)	№3 Plantain (<i>Plantago</i>)	№4 Zizifora (<i>Ziziphora</i>)
Monolayer capacity	0,0390	0,0262	0,41	0,0221
Specific surface area S_{sp} , m^2/g	137,26	92,10	138,84	90,19
Total pore volume W_0 , cm^3/g	0,095	0,250	0,166	0,287
Capillary radius, r_k , Å	13,8	54,3	15,02	36,7

The change in the total pore volume with a change in the relative pressure of water vapor at 25 °C is given in table 4.

Table 4. Change in total pore volume

№1 Mint (<i>Mentha</i>)						
Relative pressure, %	30	50	65	80	90	100
Total pore volume, W_0 , cm^3/g	0,001	0,003	0,008	0,017	0,036	0,095
№2 Nettle (<i>Urtica</i>)						
Relative pressure, %	30	50	65	80	90	100
Total pore volume, W_0 , cm^3/g	0,0025	0,004	0,014	0,032	0,115	0,250
№3 Plantain (<i>Plantago</i>)						
Relative pressure, %	30	50	65	80	90	100
Total pore volume, W_0 , cm^3/g	0,023	0,004	0,012	0,024	0,038	0,114
№4 Zizifora (<i>Ziziphora</i>)						
Relative pressure, %	30	50	65	80	90	100
Total pore volume, W_0 , cm^3/g	0,0021	0,003	0,013	0,034	0,119	0,287

a methodology for calculating an industrial water-convection convection drying plant has been developed.

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