ABOUT PORE STRUCTURE OF SUGAR BEET PULP

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INTRODUCTION

Our task was to study low-temperature drying modes of plant material, required to obtain more detailed information on the mechanism of internal heat and mass transfer during the drying process. The object of research was selected – beet pulp, byproduct of sugar production. Based on the structure of the sugar beet tissue, referred to as pulp dispersed strongly structured products with low porosity, which do not crack during drying. [1]

1. MATERIALS AND METHODS

Method of prof. P. Lutsik [2] was used to determine the structural characteristics of the pulp. This method is suitable for both rigid bodies with solid skeleton and bodies which are limited to swell in a state of hygroscopic swelling.

The experimentally obtained beet pulp isotherms [3] identify the following characteristics: micro-pore volume, integral differential distribution curves of micro-pores radiuses, effective pore radius, surface area, etc. It was assumed that the pulp is a partially porous water-swellable material, and the micro-pores are cylindrical. For the calculation were used the desorption curves, corresponding to pores completely filled with liquid and moisture meniscus of spherical shape. Micro-pores radiuses were determined using the equation Thomson-Kelvin.

Micro-pore volume filled with moisture, was determined by multiplying the number of adsorbed moisture at given $\varphi = \frac{p}{p_0}$ on the molar volume of water.

Integral F(r) micro-pore distribution function:

$$F(r) = U / U_{max}$$

where U and U_{max} are Integral F(r) micro-pore distribution function:

$$F(r) = U / U_{max}$$

where U and U_{max} are the equilibrium and maximum (hygroscopic) moisture content of pulp at given value $\varphi = 1$.

Figure 1 shows the integral curves F (r) for the distribution of micro-pores of the size of pulp at different temperatures T 1 - 298 2 - 232 3 - 343 K.

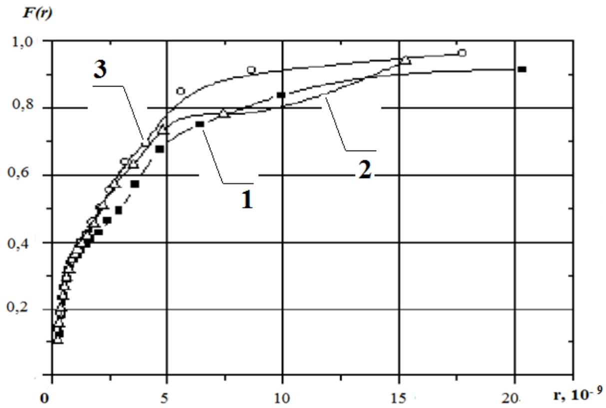

Figure 1. Integral F (r) distribution curve of micro-pore radiuses for beet pulp at temperatures T: 1 – 298; 2 – 323; 3 - 343 K.

As can be seen from the figure, the micro-pore volume increases dramatically, ranging from minimum values $r_o \approx 7 \cdot 10^{-10} m$ to $r \approx 60 \cdot 10^{-10} m$. Further cumulative distribution does not change significantly and is close to a linear distribution with growth values *r*.

Differential distribution function *f(r)* of micro-pores was found as the derivative of the cumulative distribution $f(r)=dF(r)/dr$. Calculations were carried out by discrete differentiation using OriginPro. Differential distribution curves *f(r)* of micro-pores on their radiuses in the beet pulp, are shown in Fig. 2.

As can be seen from figure 2, the maximum values of all curves reach minimum values when $7 \cdot 10^{-10} m \le r \le 12 \cdot 10^{-10}$ *m*. This indicates that the pulp has the largest number of micro-pores of that size. Curve 1 at $T = 298$ *K* shows small peaks at $r \approx 13 \cdot 10^{-10}$ *m* and $r \approx 37 \cdot 10^{-10}$ *m*, covering a wider range of radiuses. Increasing the temperature of the research object leads to the appearance of minor peaks (curves 2 and 3 in Fig. 2) which shifts to smaller radiuses of micro-pores. Last, in our opinion, can be explained by the shrinkage of the skeleton beet chips with increasing its temperature, and hence a decrease in the equilibrium moisture content.

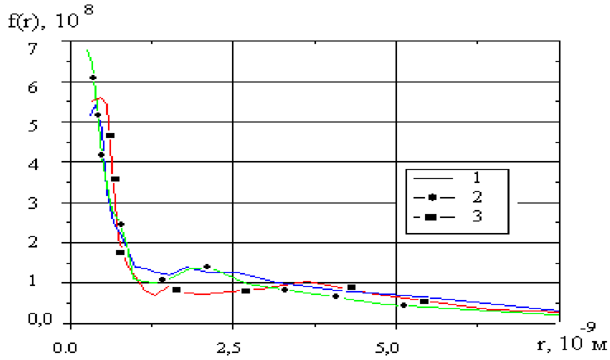

Figure 2. Differential f (r) curve distribution for the micro-pore radiuses beet pulp at temperatures T1 – 298, T2 – 323, T3 – 343 K.

The size of the equivalent radius r_e [4] of molecular vapor flow determined by using one of the methods of the approximate integration, has units of length and depends on the distribution curve of pore radius:

$$r_e = \frac{\int_{r_o}^{r_{max}} r^2 f(r) dr}{r_{max} - r_o}$$

where r_o is the minimum radius of micro-pores; r_{max} – the maximum radius of micro-pores; *f(r)* – the differential micro-pores distribution curve. Results are presented in Table 1.

Table 1. Equivalent radius r_e of beet pulp pores.

T, K	***298***	***323***	***343***
$r_e, 10^{-10}$ m	11,32	11,10	8,10

The amount of adsorbed moisture in poly-molecular layer u_p, as well as the maximum hygroscopic moisture condition $u_г$, was found on desorption isotherm curve. The indicated isotherm was also built in the coordinates BET [5] and more accurately find moisture monolayer u_m.

The calculated values of these quantities for sugar beet pulp: u_m=0,04 kg/kg, u_p≈0,14 kg/kg, u_g=0,40 kg/kg – at temperature 298K; u_m=0,038 kg/kg, u_p≈0,11 кg/кg, u_g=0,294 kg/kg – at temperature 323 K; u_m=0,03 kg/kg, $u_п$≈0,9 kg/kg, $u_г$=0,26 kg/kg – at temperature 343K. In industrial rotary dryers, beet pulp is dried to a water content u=0,115 kg/kg (W=13 %). Thus, in the drying process removes all the capillary moisture, and only a minor part of the moisture poly-molecular layer adsorption.

2. CONCLUSION

The data on the moisture monolayer u_m allowed evaluating the specific surface of micro-pores. The value for the specific surface area of beet pulp at 298, 323 and 343 K are 141,8 m^2/g 134,8 m^2/g and 106,4 m^2/g, respectively.

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