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STUDY OF THE PROCESSES OF MECHANICAL-THERMAL TREATMENT OF FOOD DISPERSED MATERIALS

V. A. Shulyak and D. I. Berezyuk

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The paper presents experimental data for the processes of low-temperature vacuum drying and grinding of thermolabile materials in devices with spring members.

The production of food powders from plant raw material practically always involves drying and grinding. Many types of food products, for example, fruits and vegetables rich in sugars and pectin substances do not lose plasticity when dried and therefore are susceptible to sticking and lump formation, which makes it impossible to produce finely dispersed powders. The manufacture of food products from such types of raw material necessitates the development of a special mechanization.

The review of literary sources [1] allows the conclusion that the lowest specific consumption of thermal energy on moisture desorption is provided by conductive energy supply. However, the data of technological analyses [2] attest that fruit-berry powders produced using a roller drier are characterized by low quality. This stems primarily from thermal destruction of biologically valuable substances in the dried raw material on the hot surface of the rollers. At the same time, the products obtained in vacuum freezing devices with conductive energy supply are distinguished by the highest percentage of preservation of valuable substances and receive the highest organoleptic appraisal, being the original standard of quality. This is ensured by the low temperature of the vacuum freeze drying. Thus, the combination of conductive energy supply with vacuum treatment offers a top-quality product with the lowest energy consumption on drying.

A loss of the food value of the raw material in roller and, somewhat, in vacuum freeze driers results from the prolonged high-temperature contact with a heating surface and from the oxidizing effect of air oxygen. It is possible to reduce the length of the high-temperature effect and accelerate drying via combining drying and grinding in a single reaction space.

For producing food powders, vibrovacuum mill driers are designed [3] in which grinding is effected by milling bodies and the energy for moisture desorption is supplied via conduction. Their main shortcomings are an appreciable overload of the units and parts because of the vibration of a significant mass (milling bodies, rotor, and frame of the mill drier), an insufficiently high grinding intensity, and a large number of milling bodies. Investigations [4] revealed that, with a relatively low capacity, spring members can be used with success for finely grinding food raw material. However, fluctuation in the moisture content of the plant raw material during drying can lead to an increase in its viscosity and to attainment of a critical point at which the raw material, especially rich in sugars and jellifying substances, sticks to the internal walls of the device and to the working body, and the material circulation ceases. Spring members that are distinguished by economical efficiency of grinding and offer a high degree of dispersion do not operate in this case.

The chair of heat and refrigerating engineering of the Mogilev Technological Institute developed an experimental setup for studying drying and grinding of food products. It allows simultaneous low-temperature drying and grinding of the raw material with the finished product being in the form of a finely dispersed powder. It realizes the principle of a combined mechanical-thermal effect on the dried material, namely, conductive energy supply and material grinding due to the simultaneous action of an arched spring and spherical milling bodies.

Grinding and drying are carried out in a single reaction space under vacuum. The spring and the milling bodies serve for mechanical grinding, generate vigorous circulatory flows of the material, impede lump formation,

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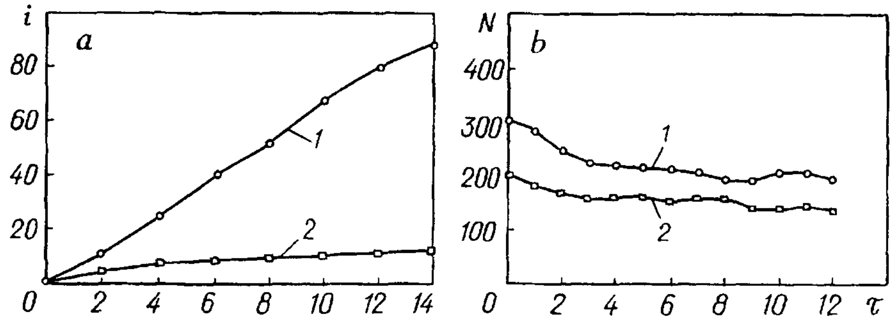

Fig. 1. Degree of grinding of the material (a) and power consumption (b) vs. treatment length: 1) with milling bodies, 2) without them. i, %; N, W; τ, min.

and ensure the formation of an additional evaporation surface, which significantly intensifies drying. Moisture desorption from the material results from conductive heat supply from the device walls. A certain portion of heat, spent on moisture desorption, is conveyed directly from the spring member. Energy is released as a consequence of elastoplastic strain of the spring and material. The moisture, removed from the material, condenses on the surface of a cooled coil-type evaporator of the refrigerator.

The setup makes it possible to carry out the processes at a residual pressure of up to 0.5 mm Hg, which significantly decreases the temperature of the raw material. Conducting the processes under vacuum precludes the oxidizing effect of air oxygen, which also upgrades the finished product. The combination of drying and grinding in a single reaction space significantly enhances and shortens drying of the raw material.

As the raw material for studying grinding and drying, we used rye, beet, carrots, and fruits of large-fruited dog rose and black-fruited aronia. The objective of the experiments on grinding was to determine a comparative characteristic of the devices with a spring member with a charge of spherical milling bodies and without it.

Initially we studied grinding of loose product, namely, rye grains. As the milling bodies, we used steel bearing spheres 7–8 mm in diameter. Prior to the experiments we measured and recorded the mass of the product considered and in the case of using milling bodies, their mass. The equivalent diameter of grains was defined as the mean of the cube root of the product of three dimensions for 100 randomly selected grains $\overline{D} = \sum_{i=1}^{n=100} (a\times b\times h)^{-1/3}/100$.

From the samples obtained experimentally we selected a representative sample and isolated a 100 g weighed sample. A dispersion (granulometric) composition of a weighed sample was identified with the aid of a standard set of metal-woven sieves. On the basis of the sizing data we constructed histograms of the passage and sieve residue as functions of the sieve mesh dimensions $R = f(d)$ and $D = f(d)$, and determined the median diameter of the sample particles d_{med}. As a result, we established time dependences for the degree of grinding of the material i, namely, $i = f(\tau)$, where $i = \overline{D}/d_{\mathrm{med}}$, and for the power consumption, $N = f(\tau)$.

The data were approximated using an APRROX program, and on their basis the energy intensity of grinding was calculated via integrating the approximated function $E = \int_0^{\tau_i} f(\tau)d\tau$, where τ_i is the grinding time in which a reference degree of grinding was attained, $i_{\mathrm{ref}} = \overline{D}/d_{\mathrm{med}} = 10$.

Comparing the degrees of grinding of the material as functions of the time for the process with and without milling bodies (Fig. 1a) reveals that the intensity of grinding of the product in the first case is markedly higher. This allows the conclusion that it is reasonable to use fine-grinding devices based on mills with a spring member and with a charge of milling bodies. It follows from the plots of the power consumption vs. the grinding time (Fig. 1b) that the power consumption for grinding with a spherical charge is higher. However, due to a high rate of the process with a spherical charge, the required power consumption on grinding rye to a reference degree $i = 10$ is 2.4 times smaller than in the case with no milling bodies.

Grinding of pasty materials was studied using beet passed through a high-speed knife grinder. It was established experimentally that lump-forming pasty materials poorly lend themselves to grinding in the devices

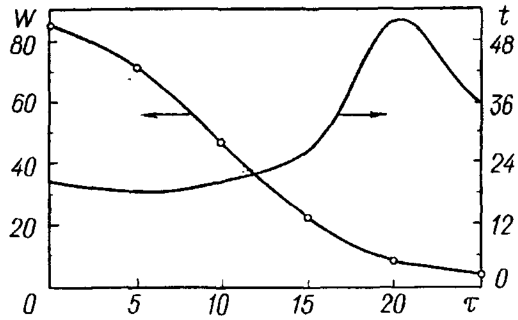

Fig. 2. Variation in moisture content and temperature of the material during drying. W, %; t, °C.

with a spring member, since the material gets hung up and does not get to the grinding zone. With grinding with a spherical charge, the milling bodies involve the material in circulation, and as the material is dried, it sloughs off and is ground to powder. Thus, charging with spherical milling bodies allows grinding of pasty, lump-forming, and susceptible-to-sticking materials in devices with spring members.

Experimental investigations of mechanical-thermal treatment were aimed at ascertaining the possibility of manufacturing food powders from various types of thermolabile food products. Using garden beet as the raw material we managed to produce finely dispersed high-quality food products from blanched, moist, and also dried raw material. Relying on the experimental data we ascertained the possibility of manufacturing high-quality finely dispersed food powders from thermolabile products of plant origin. It is found that producing high-quality powder from raw material rich in sugars requires that the product be cooled at the end of drying.

The samples of finely dispersed powders of garden beet had a 20–120 μm particle size, a pleasant rose color, and a weak beet flavor. When dissolved in water, the powder gives hues from crimson to deep cherry without brown undertones. On the basis of the experimental data we constructed a curve of the drying rate and a drying thermogram (Fig. 2) and determined the specific moisture removal from the heating surface from the equations of material and heat balance.

An optimal relationship between the quality of the finished product and the energy intensity is achieved with a certain rate of the processes of mechanical-thermal treatment. This rate depends on the rotation frequency and the profile of the spring, on the number of milling bodies, and on a single charge of the raw material. The drying rate relates to the pressure in a working volume and to the temperature of the heating and cooled surfaces. Variation of these parameters allows flexible control of the treatment of the raw material and manufacture of a product of the required quality from various raw materials. In the experiments on beet grinding and drying, the pressure in the working volume was maintained at 1–2 kPa, the temperature of the heat carrier varied from 75 to 95°C, and the boiling temperature of the coolant in the condenser coil ranged from −5 to −10°C. The specific moisture removal was 18–20 kg/m^2, which is comparable with similar characteristics of roller driers [1]. The heat flux supplied directly from a mechanical stimulator attains 10% of the entire energy spent on moisture desorption from the material.

The experiments demonstrated that such devices are reasonable to use for producing finely dispersed food powders from valuable types of raw material unstable at high temperatures, for example, for manufacturing natural medicines, dyes, and flavors.

NOTATION

D, mean equivalent diameter of a particle prior to grinding, d_{med}, median diameter of the material particles after grinding; i, degree of grinding of the material; i_{ref}, reference degree of grinding; τ, time; a, b, h, particle dimensions; N, power; W, moisture content; t, temperature.

REFERENCES

1. A. S. Ginsburg, *Basics of the Theory and Technology of Drying Food Products* [in Russian], Moscow (1973).
2. P. A. Kabanov and B. V. Karabulya, *Konservn. Ovoshchesush. Promyshl.*, No. 6, 23-25 (1982).
3. É. A. Galikberov, N. A. Nikolaev, and N. Z. Galikberova, *Pishch. Prom.*, No. 9, 32 (1995).
4. V. A. Shulyak, L. A. Sivachenko, and D. I. Berezyuk, *Proc. Int. Sci. Tech. Conf.* "Current State of Flour-Grinding and Prospects for Its Development 'Mill-97'" [in Russian], Moscow (1997), p. 132.