HYGROSCOPIC PROPERTIES OF BIOLOGICAL MATERIALS AND THE BINDING ENERGY OF MOISTURE*

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The binding energy of moisture with biological materials is determined from sorption isotherms for yeast at different temperatures.

Modern drying theory is based on the theory of heat and mass transfer and the concept of forms of moisture bonds with materials. Drying of moist materials is a thermophysical process in which the form of binding of moisture with the material is important. Therefore, discovery of the drying mechanism and its molecular nature is necessary for establishing scientifically substantiated optimum drying conditions.

Most microbiological preparations subject to drying are suspensions, whose dispersion medium is, in turn, a solution of organic and inorganic compounds. A microbial cell itself also contains 80–85% water. Some of the water is free and some is bound. Any decrease in the amount of water in the cell brings about drastic changes in the whole colloidal system. Protein compounds are basic components of a bacterial cell, and therefore too large losses of water result in coagulation of the protein, which is an irreversible process equivalent to death of the cells.

The drying process must not disturb the ability of the cell to metabolize; however, suppression of the life cycle does not always lead to death of the cell, and inactivation only occurs in the case of irreversible changes in the cell structure.

The objective of drying of living microorganisms is to suppress the life processes in the cells by decreasing the water content to a level at which the cells become "anabiotic."

The word "anabiosis" usually means temporary cessation of life processes or their deep suppression, after which the cells can be fully resuscitated.

It is known that the presence of a certain amount of water in a cell is a necessary condition for nutrition and respiration of microbes. According to E. V. Maistrakh [1], up to 35% of the entire amount of water can be removed from a living cell. In the process of adaptation to unfavorable living conditions, many microorganisms lose a certain percentage of water.

The question of the state of the vital functions in freeze-dried microorganisms has not been answered so far. Some researchers believe that freeze-drying terminates completely the metabolic processes in microorganisms, while others suggest that freeze-drying deeply suppresses the life processes.

Drying and dehydration processes can be theoretically substantiated and the time and energy necessary for water removal from biomass can be evaluated accurately only with complete knowledge of the properties of bound water contained in the cell.

At present P. A. Rebinder [2] and S. M. Lipatov [3] have developed the concept of forms of moisture bonds with capillary-porous colloid materials. In the drying of moist materials the moisture bond with the solid skeleton is disturbed and this distortion consumes some energy. With this in view, the forms of moisture bond are classified on the basis of the value of the binding energy in accordance with Rebinder’s scheme.

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As is known, the vapor pressure over the surface of moist materials decreases due to the moisture bond with the material and the free energy decreases accordingly. It is natural that the stronger the moisture bond, the higher the binding energy. Binding of moisture with the material is accompanied by evolution of heat, and therefore some work is to be done to detach absorbed water molecules from the surface, and it is this work that characterizes the strength of the moisture bond with the material.

Consequently, the stronger the moisture bond, the higher the value of $P_v$ and, on the other hand, for free water $P_v$ can reach $P_s$ and $\varphi$ becomes equal to unity and the energy is equal to zero. In drying the moisture content of the material decreases continuously and starting from a certain moment (from the hygroscopic moisture content), the water vapor pressure over the material surface diminishes gradually, while the binding energy rises, i.e., it rises as $\varphi$ falls. In the hygroscopic region the binding energy can be determined from sorption isotherms, i.e., from the relation $u_e = f(\varphi)$.

We investigated the hygroscopic properties of biological materials by the vacuum sorption method, because the popular strain-gauge technique requires a long experimentation time and can induce decomposition of the biological materials studied.

Decomposition can be accompanied by an increase in the material weight, and byproducts of the biochemical process can accumulate during experimentation. Therefore we used the vacuum sorption method to find the relation $u_e = f(\varphi)$ for biological preparations. The gravimetric method with the use of a McBain quartz balance allowed us to carry out investigations at low water vapor pressures (1.33-1333.2 N/m$^2$) in a fairly broad temperature range (20-90°C).