DETERMINING THE SPECIFIC HEAT OF TEA ESSENCE DRIED BY THE SUBLIMATION PROCESS

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Results are shown of a study concerning the variation of the specific heat of tea essence with temperature over the –110 to +80°C range.

In a theoretical study and analysis of the sublimation drying process, one usually considers the existence in the specimen (a food product) of two regions: the region of "dry material" and the region containing frozen vapor, both regions separated by a phase-transition interface [1].

With the thermophysical properties (specific heat, thermal conductivity, etc.) of each region individually known, it is possible to construct a physical model of the process and to perform analytical calculations.

The authors have made a study which involved measuring the specific heat of tea essence at various concentrations and of fast-dissolving tea powder with various residual moisture contents. The specific heat was measured with a dynamic calorimeter from –140 to +80°C [2]. The initial essence concentrations was varied within the 4-40% range.

The curves in Figs. 1 and 2 have been plotted on the basis of test data.

According to Fig. 1, the specific heat of tea essence decreases on the average by 20-25% as the concentration increases from 4 to 40%.

On the specific heat versus temperature curves there appears a distinct range between two points indicating the freezing temperature of tea essence.

Thus, at essence concentrations between 4 and 20% the sharp increase in the specific heat following a temperature rise from –25 to –6°C is due to crystallization of the essence, while t = –6°C is evidently the temperature at which the crystallization of tea essence containing 4% of dry material begins (cryoscopic point). For a 20% solution the cryoscopic point lies within the range $t_{cr} \cong -8$ to +10°C. For a 40% solution $t_{cr} \cong -12$ to –13°C.

The cryoscopic points obtained for the given solutions earlier by other methods confirm the validity of our conclusions.

The lower critical point evidently corresponds to the end of essence crystallization, i.e., yields an indication about the cryohydration (eutectic) point of tea essence. Thus, for essence in a 4-20% concentration these points are about –20 to –25°C, while for a 40% essence it is about –55°C.

In Fig. 1 is also shown the temperature-dependence of the specific heat for pure ice, according to the relation

$$C_{pi} = (0.0219 + 1.7662 \cdot 10^{-3} T_i) \text{ kcal/kg} \cdot \text{deg.} \quad (1)$$

This formula is valid for temperatures from 0 to –110°C [3].

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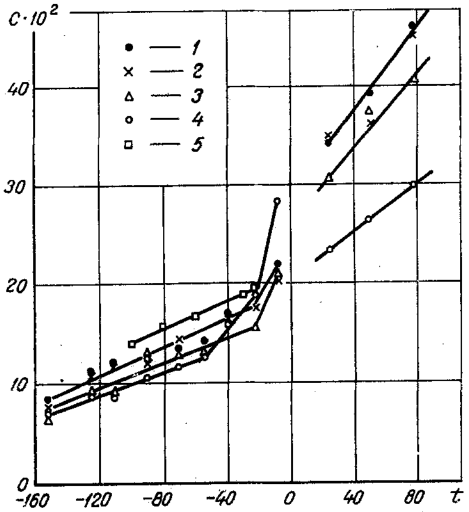

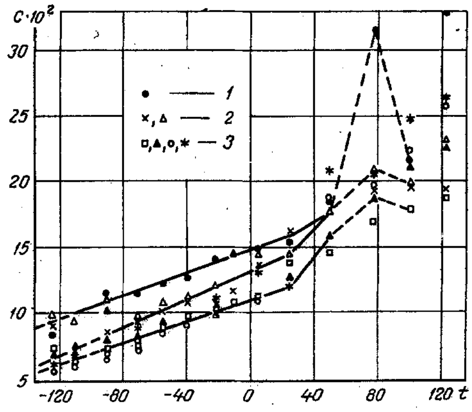

Fig. 1 Fig. 2

Fig. 1. Specific heat of tea essence C (J/kg·deg) as a function of the temperature t (°C): 1, 2) concentration of dry material 4%; 3) 20%; 4) 40%; 5) 0%.

Fig. 2. Specific heat of fast-dissolving tea powder C (J/kg·deg) as a function of the temperature t (°C): 1) moisture content 13%; 2) 8-10%; 3) 5%.

TABLE 1. Values of C_0 and K for Various Concentrations of Tea Essence

Concentration of tea essence	t=–140 – 25 °C		t=10 – 80 °C	
	C_0, J/kg·°C	K, J/kg·°C²	C_0, J/kg·°C	K, J/kg·°C²
4	–70,2	7,4	–3364	22,8
20	96,6	5,8	–1955	17,2
40	85,8	5,4	–1106	11,5

Our graphs for essence of various concentrations evidently correlate well with this equation: as the essence concentration decreases, its specific heat increases until it reaches its maximum for pure ice (0% concentration).

The mathematical relation between C and T is approximated by equations of the general form (1)

$$C_T = C_0 + KT, \qquad (2)$$

with C_0 and K values given in Table 1.

Within the temperature range from –25 to +10°C (and for 40% concentrate from –55 to +10°C) there occurs, as a result of phase transformations, a discontinuity in the functional relation.

The specific heat of fast-dissolving tea powder varies with varying moisture content (Fig. 2). Thus, as the moisture content is increased from 5 to 12%, the specific heat increases by 27-29%. As the powder temperature rises from 25 to 54°C, there occurs a jumpwise increase in the specific heat. A further temperature rise results in melting of the material.

Our measurements and analysis of the specific heat of tea essence over temperatures ranging from –110 to +80°C lead to certain general conclusions and recommendations concerning the technology of sublimation drying of tea essence under vacuum.

1. The critical points on the specific heat versus temperature curves yield an indication about the cryoscopic and cryohydration points of tea essence, which is very important for designing the mode of freezing a product by sublimation drying.

2. Knowing these points, one can solve the problem concerning the most rational initial essence concentration: thus, while at M_0 = 40% the yield of dry produce per unit surface area increases, the end-of-freezing temperature should be much lower than at M_0 = 20%: –55°C rather than –25°C.

3. In order to attain a stable mode of essence drying from an initial concentration M_0 = 4-20%, the pressure (vacuum) in the sublimation chamber should not drop below 0.1 mm Hg, which corresponds to a water-vapor saturation temperature T_S = –25°C. For an initial essence concentration M_0 = 40%, in the light of the preceding discussion, the vacuum should be much deeper: about $5 \cdot 10^{-3}$ mm Hg.

4. The surface temperature of a dry essence layer in the process of sublimation drying should not exceed 50°C. Above this temperature the material melts and releases its latent heat.

Thus, our study concerning the temperature-dependence and the concentration-dependence of the specific heat of this product provides a sound basis for recommending the technological mode not only of freezing but also of sublimation drying under vacuum.

LITERATURE CITED

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