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# HEAT CAPACITY OF MILK FAT AND OF NON-FAT DRY MILK

by

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HEAT CAPACITY OF MILK FAT AND OF NON-FAT DRY MILK

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13. ABSTRACT

It is necessary to know the specific heat capacity of milk products for many tecnnical calculations. During a study of the heat properties of ice cream, we determined the specific heat capacity of milk fat and non-fat dry milk. Mixing was used for measurement. To do this, a water calorimeter with silver 2-liter containers. The temperature of the water was measured by calibrated thermometers accurate to 0.001 degrees.

| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Heat Capacity<br>Milk Fat<br>Non-Fat Dry Milk | | | | | | |

# HEAT CAPACITY OF MILK FAT AND OF NON-FAT DRY MILK

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It is necessary to know the specific heat capacity of milk products for many technical calculations. During a study of the heat properties of ice cream, we determined the specific heat capacity of milk fat and non-fat dry milk. Mixing was used for measurement. To do this, a water calorimeter with silver 2-liter containers. The temperature of the water was measured by calibrated thermometers accurate to 0.001°.

Samples of the fat or the non-fat dry milk were loaded into brass cartridges completely closed with threaded caps with a seal. They were placed into steel cartridges, large in diameter, which were closed by rubber stoppers and they were submerged into eutestic solutions when working from negative temperatures or into a special instrument at positive temperatures.

The eutectic solutions were frozen. The temperature of the samples was 3-4° below the freezing temperature of the solutions. The samples at the low temperatures kept for 24 hours and those at temperatures above 32° kept for two hours.

The temperature of the samples being studied was fixed by a thermometer (0.1° scale spacing) located in the middle of the sample (control cartridge) that checks the temperature of the eutectic solution. As a rule, the temperatures were identical. Temperature was also checked in a steel cartridge after the sample was removed from it.

The computation of the heat capacity for the milk fat and the non-fat dry milk was done by a heat balance equation. This equation takes into consideration the latent heat of fusion in the ice in the case of non-fat dry milk.

$$c_x = \frac{(HC'' + K)\Delta t}{m(t_B - t_{np})} - \frac{K_1}{m},$$ where:

H is the weight of the water in the calorimeter (in g); C= is the negative heat capacity of the water; K is the water equivalent of the calorimeter; $\Delta t$ is the adjustment difference for the final temperatures of the main and the initial period: m is the weight of the milk fat or the non-fat dry milk (in g); $c_x$ is the specific heat capacity of the material being investigated: $K_1$ is the heat magnitude a cartridge, which is equal to the sum of the products from the weights of a cartridge and a seal to their specific heat capacities; $t_B$ is the final temperature of the water in the calorimeter (in °C); $t_{np}$ is the temperature of the sample being studied (in °C).

The latent heat of fusion in the ice r was calculated by the formula r = 79.6 + 0.6t, where t is the temperature of the eutectic.

The milk-fat sample was separated from butter employing extraction by a mixture of different volumes of sulfuric and petroleum ethers in the presence of a small amount of ammonia. After extraction the ether was distilled and the obtained milk fat had the following physicochemical properties:

freezing temperature 24°
melting temperature 30.5°
iodine number 36.1.

After the fat precipitates from the extraction of the ether mixture were separated from it and the ether was subsequently distilled, the non-fat dry milk was dried at 80°C. Milk prepared in such manner contained: fat - traces, moisture - 2.2%.

The table contains part of the experiments on the calorimetric determination of the heat capacity of milk fat and non-fat dry milk. Figures 1 and 2 show the dependence of the specific heat capacity of the studied substances upon temperature.

Heat capacity of milk fat and non-fat dry milk.

| №№ опытов (1) | Навеска вещества (в г) (2) | Температура образца (в °C) (3) | Температура воды калориметра (в °C) (4) | Поправка на радиацию (5) | Δt (в °C) (6) | c (в кал/г °C) (7) |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | | | Молочный жир (8) | | | |
| 1 | 122,05 | 74 | 38,1 | 0,057 | 1,638 | 0,524 |
| 2 | 122,05 | 65 | 32,9 | 0,052 | 1,205 | 0,507 |
| 3 | 52,34 | 54 | 33,2 | 0.010 | 0,510 | 0,488 |
| 4 | 51 82 | 50 | 33,3 | 0,013 | 0,586 | 0,473 |
| 5 | 101,16 | 30 | 21,8 | 0,027 | 0,30 | 0,433 |
| 6 | 122,05 | 1 | 19,5 | 0,001 | 1,093 | 0,883 |
| 7 | 105,66 | 0 | 18,3 | 0,010 | 0,945 | 0,833 |
| 8 | 105,66 | — 0,2 | 13,7 | 0,019 | 0,914 | 0,831 |
| 9 | 51,82 | — 2,8 | 21,1 | — | 0,813 | 0,828 |
| 10 | 105,66 | — 2,9 | 17,2 | 0,018 | 1,021 | 0,794 |
| 11 | 105,66 | — 3,8 | 15.2 | 0,013 | 0,923 | 0,765 |
| 12 | 51,82 | — 6,6 | 21,3 | 0,022 | 0,764 | 0,770 |
| 13 | 52,34 | —11,4 | 16,8 | 0,003 | 1,266 | 0,700 |
| 14 | 122,05 | —21,0 | 17,0 | 0,002 | 1,954 | 0,687 |
| 15 | 52,34 | —21,2 | 22,4 | 0,006 | 1,009 | 0,695 |
| 16 | 52,34 | —24,8 | 21,8 | 0,009 | 1,081 | 0,680 |
| | | | Молоко обезжиренное сухое (9) | | | |
| 17 | 89,06 | 35 | 23,8 | 0,020 | 0,3 | 0,362 |
| 18 | 89,06 | 3,6 | 23,1 | 0,005 | 0,42 | 0,250 |
| 19 | 89,06 | 2,0 | 20,9 | 0,007 | 0,42 | 0.244 |
| 20 | 89,06 | — 3,2 | 21,9 | — | 0,58 | 0,22[illegible] |
| 21 | 89,06 | —10,0 | 19,3 | 0,002 | 0,64 | 0,198 |
| 22 | 89,06 | —11,2 | 19,2 | 0,001 | 0,66 | 0,192 |
| 23 | 89,06 | —11,8 | 18,3 | 0,023 | 0,65 | 0,197 |

KEY: (1) Experiment No.; (2) Weighed portion of matter (in g); (3) Temperature of sample (in °C); (4) Water temperature in calorimeter (in °C); (5) Correction for radiation; (6) Δt (in °C); (7) c (in cal/g °C); (8) Milk fat; (9) Non-fat dry milk.

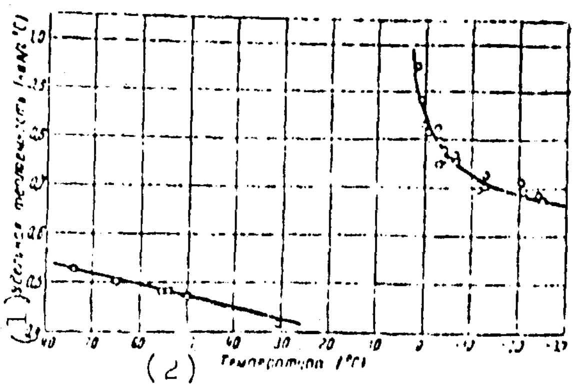

Fig. 1. Dependence of the heat capacity of milk fat upon temperature.

KEY: (1) Specific heat capacity (cal/g °C); (2) Temperature, (°C).

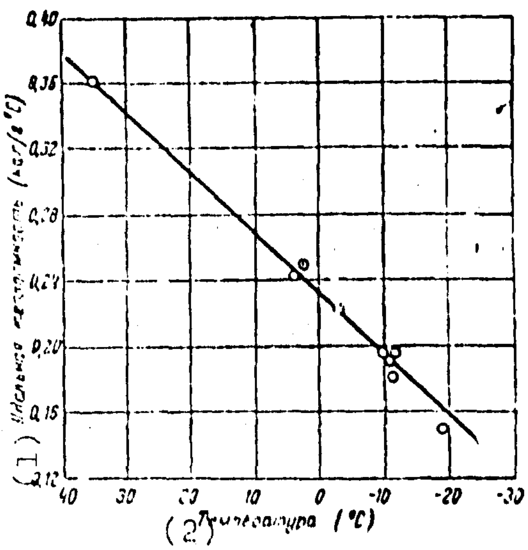


Fig. 2. Dependence of the heat capacity of non-fat dry milk upon temperature.

KEY: (1) Specific heat capacity (cal/g °C); (2) Temperature (°C).

Determination of the heat capacity of milk fat is encumbered by the crystallization process of its individual components, which is lengthy not only in time but also in the rather wide temperature interval. Thus, the glycerides of fat have the following melting temperatures: tristearin +71°, tripalmitin +65°, trimyristin +55° and triolein -5°. It has been established by the investigations of many authors that complete crystallization of fat is accomplished in the course of four hours from the instant it begins to cool. In our experiments the samples kept 24 hours.

Also the nonuniformity of the temperature distribution in the studied sample affects the accuracy of the findings. Since fat refers to poor heat conductors, temperature equilibrium in a calorimeter is established very fast. This leads to great heat losses. The calculation of these losses by common formulas is difficult and possibly is not quite accurate.

The heat capacity of milk fat in liquid form was determined at a water temperature in the calorimeter no lower than 32°. In the experiments where the fat was in solid form, water temperature in the calorimeter was not lower than the solidification temperature of the fat.

The approximation of the water temperature of the calorimeter to the freezing or melting temperature of the fat affects specific heat capacity, since the latent heat of fusion in the individual components of fat is not used in the calculation (experiments Nos. 9, 12 and 15).

From the presented table and Fig. 1, it follows that a linear function is observed between its specific heat capacity and temperature at temperatures above the melting temperature of the fat. This function can be expressed by the following equation derived on the basis of experimental data:

$$c_{ж} = 0{,}368 + 0{,}0021t,$$ where:

t is the temperature of the fat (above the melting temperature).

When the aggregation state of the fat is changed, i.e., after transformation into the solid state, the linear function between heat capacity and temperature is disrupted and can be expressed by an exponential function equation of the following type:

$$c_{тв} = 0{,}67 + 0{,}18e^{0{,}1t},$$ where:

t is the temperature of the fat (below the freezing temperature), e is the base of natural logarithms.

As follows from the table and Fig. 2, for the specific heat capacity of non-fat dry milk and for milk fat higher than the melting temperature, a linear function of temperature is characteristic. This function can be expressed by the equation:

$$c = 0{,}236 + 0{,}0038t;$$ where:

t is the temperature of non-fat dry milk.