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Specific heats of some oils and a fat

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Abstract

The specific heats of some edible oils, pharmaceutical oils and a fat were measured by differential scanning calorimetry at 70–140 °C.

INTRODUCTION

Molar heat has a fundamental value in thermochemical processes. It is easy to connect the value of this function with heats of transformation: if p is a constant

$$\mathrm{d}H = \delta Q_p \tag{1}$$

then

$$C_p = \frac{\delta Q_p}{\mathrm{d}T} = \frac{\mathrm{d}H}{\mathrm{d}T} \tag{2}$$

Therefore, the C_p value is connected with molar enthalpy through eqn. (2). The value of δQ_p is dependent on the exchange of heat during transformation in elementary processes of heating or cooling, independent of their reversibility or non-reversibility. Thus, it is important to know the specific heat of edible substances at constant pressure, as these data are helpful when prolonged storage, deep-frying and other similar processes are being considered.

A scanning calorimeter is very helpful in measuring these values, being more rapid than traditional calorimetric measurements, requiring smaller sample sizes and often providing greater accuracy.

EXPERIMENTAL

Food olive oil, rape-seed oil, soybean oil, sunflower oil, lard, pharmaceutical linen oil and castor oil were used in the investigation. The refractive index, n_{D}^{20}, and fatty acid composition of the fats investigated are listed in Table 1. The fatty acid compositions of the samples were determined by

TABLE 1

The refractive index and fatty acid compositions of the edible oils investigated

Oil/fat	n_D^{20}	Saturated fatty acids		Fatty acids with double bonds			Other acids (%)
		C_4–C_{14} (%)	C_{16}–C_{22} (%)	Oleic (%)	Linoleic (%)	Linolenic (%)	
Olive	1.4705	1	8	82	4	–	–
Sunflower	1.4725	–	8	36	52	–	–
Soybean	1.4752	–	12	38	39	6	–
Rape-seed	1.4740	1	3	29	18	2	48 erucic 18 palmitooleic 40 higher non-saturated acids
Linen	1.4823	–	9	29	14	41	–
Castor	1.4800	–	4	8	3	–	84 oxyoleic acid
Lard	1.4206 [a]	3	47	51	10	–	–

[a] n_D at 40 °C.

GLC analysis [1–3]. The average composition of the investigated oils and their physicochemical values are similar to the literature values [4,5]. The specific heats were measured using a Du Pont 990 differential scanning calorimeter with a 910 thermal analyser and a normal pressure cell. Calibration of the apparatus was carried out with a high-purity indium standard. The cell calibration coefficient E was determined in the calibration procedure using the high-purity indium standard [6].

To determine C_p for each of the samples investigated, two measurements were made: the apparatus was operated under the desired conditions with empty sample and reference pans; then the sample was placed in one pan with the reference pan left empty. Both pans were closed with lids and the experiment was repeated under the same conditions as before.

The oils were homogenised at 360 K and samples weighing several milligrams were placed in aluminium pans in the calorimeter heating chamber and heated at a rate of 20 °C min^{-1}. The reference pan was empty. The measurements were performed in static air atmosphere or under nitrogen (for sunflower oil).

All the C_p values are the averages of at least three determinations.

RESULTS AND DISCUSSION

The specific heats of the investigated oils from 70 to 140 °C were calculated from the equation

$$C_p(\mathrm{JK^{-1}g^{-1}}) = \frac{60EY}{H_r m} \tag{3}$$

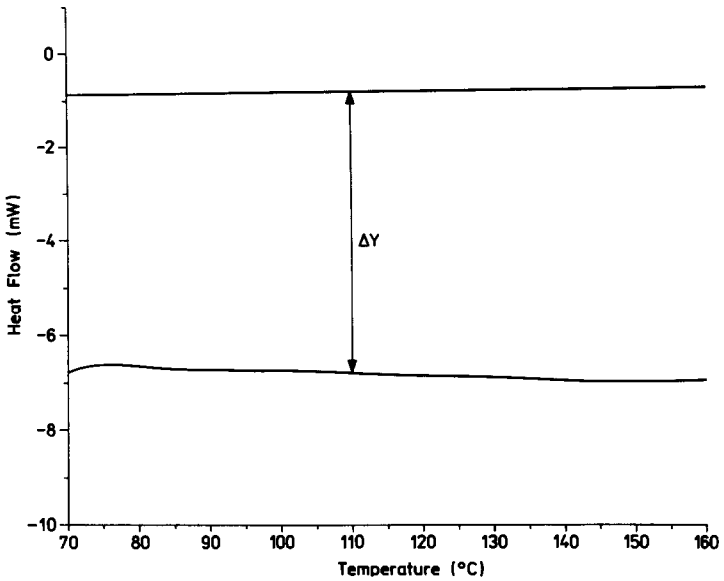

Fig. 1. Blank (top line) and sample (bottom line) DSC scans for rape-seed oil. Heating rate 20 °C min^{-1}, 9.70 mg.

where C_p is the specific heat, E is the coefficient of the cell calibration (1.08), H_r is the heating rate (°C min^{-1}), Y is the y-axis range setting, i.e. the measured difference in the positions of the blank/sample thermograms (mW) at the desired temperature T and m is the sample mass (mg); Fig. 1.

The masses of the empty sample and reference pans used were almost identical. All the experimental values of C_p are listed in Table 2. The experimental values of C_p were correlated with the equation

$$C_p = \sum_{i=1}^{3} A_i T^i \tag{4}$$

where A_i are coefficients of eqn. (4) at temperature T (K). The coefficients A_i and standard deviations s obtained by the least-squares method are listed in Table 3.

There are no C_p values listed in the literature for linen or castor oils. At temperatures above 100 °C, sunflower oil undergoes autooxidation and, therefore, it was investigated in nitrogen atmosphere.

For all the investigated oils, the specific heats do not vary substantially and their values can be used for engineering design purposes.

We conclude that it is not possible to compare directly our values of C_p for the investigated oils with those of other authors, because the investigated materials have specific characters; however, our data are similar to data reported in refs. 4–6.

TABLE 2

Specific heats C_p for edible oils at 70–140 °C

Temperature (°C)	C_p ($J\,K^{-1}g^{-1}$)	Temperature (°C)	C_p ($J\,K^{-1}g^{-1}$)
Olive oil		*Soybean oil*	
70	2.072	70	2.056
75	2.011	75	2.001
80	2.040	80	2.000
85	2.042	85	2.015
90	2.046	90	2.025
95	2.059	95	2.036
100	2.074	100	2.047
105	2.094	105	2.057
110	2.111	110	2.061
115	2.132	115	2.084
120	2.139	120	2.098
125	2.079	125	2.106
130	2.145	130	2.117
135	2.148	135	2.130
140	2.153	140	2.142
Sunflower oil		*Rape oil*	
70	2.084	70	1.976
75	2.090	75	1.926
80	2.117	80	1.939
85	2.138	85	1.962
90	2.151	90	1.969
95	2.160	95	1.998
100	2.173	100	1.980
105	2.173	105	1.987
110	2.183	110	1.998
115	2.184	115	2.013
120	2.182	120	2.124
125	2.182	125	2.030
130	2.179	130	2.036
		135	2.048
		140	2.061
Linen oil		*Lard*	
70	2.084	70	1.925
75	2.078	75	1.876
80	2.114	80	1.872
85	2.097	85	1.880
90	2.106	90	1.877
95	2.112	95	1.881
100	2.119	100	1.885
105	2.132	105	1.890
110	2.140	110	1.986
115	2.150	115	1.906
120	2.155	120	1.907
125	2.157	125	1.901
130	2.160	130	1.902
135	2.164	135	1.904
140	2.170	140	1.904

TABLE 2 (continued)

Temperature (°C)	C_p ($J K^{-1} g^{-1}$)
Castor oil	
70	2.261
75	2.279
80	2.284
85	2.298
90	2.306
95	2.310
100	2.317
105	2.324
110	2.329
115	2.342
120	2.347
125	2.350
130	2.380
135	2.357
140	2.364

TABLE 3

Smoothing coefficients A_i and standard deviations s for the edible oils investigated

Edible oil	A_1	A_2	A_3	s
Olive	1.9518	0.0006	6.2992	0.047
Sunflower	1.5951	0.0097	−0.000	0.010
Soybean	2.1339	−0.0034	0.000	0.039
Rape	1.9339	−0.0005	0.000	0.029
Linen	1.9460	0.0022	−4.3697	0.018
Castor	2.0676	0.0035	−0.000	0.004
Lard	2.0849	−0.0043	0.000	0.065

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