Physico Thermal Properties of some Varieties of Fish and Meat

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The thermal conductivity and thermal diffusivity of different fish and meat varieties (Mackerel, Bolti, Sardine, Beef, Veal, Lamb) were determined by three different methods (Chato's equation, Hayakawa's method and Charm's method). The coefficient of variations for these methods were less than 1 % . This confirms the successful use of Chato's equation to estimate the thermal conductivity of fish and meat. Specific heats and densities for these varieties were also estimated and found to be in the range of available data in the literature.

INTRODUCTION

The presence of accurate and reliable data on physicothermal properties of food and food products is so important not only for the heat and mass transfer calculations during thermal processing, but also for the design of system and process equipment. A large number of scientists and investigators have covered the methods of thermal conductivity determination extensively and thoroughly Ingersoll *et al.* (1948), Carslaw and Jaeger (1959), Jakob (1958), Woodams and Nowrey (1968) and Qashou *et al.* (1972). All such methods are based on the Fourier heat conduction equation, the solution of which may be carried out under steady state conditions as in the guarded hot plate method, the concentric cylinder method, and the cocentric sphere method. The Fourier equation may also be solved under transient conditions in such a manner to facilitate the estimation of thermal conductivity or diffusivity of materials by direct measurments of temperature variations in the medium under consideration. These are also some semi imperical methods for their estimation such as: Anderson equation (1959), and Chato's equation (1966), which will be used in the present work for comparison.

MATERIALS AND METHODS

Mackerel fish (*Scomber scomberus*) caught from the high seas by the Egyptian fleet, River Nile bolti fish (*Tilapia zillii*) and sardine fish (*Sardinella spp.*) caught from Egyptian seas were obtained from local Cairo fish market. Meats of beef (lion), veal (lion) and lamb (leg) were obtained from the local market at Cairo. These different fish and meat varieties were ground and dry packed in can size 307 X 202 in order to form a cylinderical shape. No head space was allowed for.

1. Determination of thermal conductivity "K":

The thermal conductivity "K" was maesured by the following methods:

A. Using Chato's equation (1966) having the following form:

$$K = 0.0324 + 0.3294\,W \qquad (1)$$

Where:

K = thermal conductivity Btu/hr.ft.^{o}F

W = the fraction of water in the sample.

The thermal difusivity may then be calculated from:

$$\alpha = K / \rho\, C_p \qquad (2)$$

where α, K, ρ, C_p are thermal diffusivity, thermal conductivity, density and specific heat respectively.

B. Hayakawa method:

The following equations (Hayakawa, 1969) were used:

$$\mu(B) = T_r - T / T_r - T_o \qquad (3)$$

$$\alpha = Bl^2 / t \qquad (4)$$

Where:

$\mu(B)$ = dimensionless temperature at center of conductive food during heating.

T_r = retort temperature (^{o}F).

T = temperature at center of conductive food in a cylinderical can during heat processing (^{o}F).

T_o = temperature of food at zero time of heating (^{o}F).

t = heating time (min.).

B = the dimensionless Fourier number.

l = nominal height of can (in) - 3/8.

α = thermal diffusivity.

A value of μ equal to 0.1 was selected, the corresponding center temperature T was found to be 198 ^{o}F from equation (3). The heating times at that temperature were obtained from the heating curves for fish and meat given previously by El-Mansy (1975). They were 53.5, 47.5, 46.5, 52.0, 48.5, and 47.5 minutes for Mackerel, Sardine, Bolti, Beef, Veal and Lamb respectively. The value of Fourier number "B" was obtained from charts prepared by Hayakawa (1969) as a function of the dimensionless temperature "μ" and the shape factor "S" (the theoretical inside body diameter of can: nominal height less 3/8 inch). The "S" value was 0.982, the "B" value was o.183, the "l" value was 1.75 for can size 307 X 202 and μ (B) of 0.1.

Using equation (4) the resultant "α" values were calculated. The "K" values were obtained by using the following equation:

$K = \alpha \rho C_p$ ....(5)

C. Charm method:

The following equation (Charm, 1971) was used:

$\alpha = 0.398 / (1/a^2 + 0.427/b^2) f_h$ ....(6)

where:

2a = diameter of the can (inch).
2b = inside length of the can (inch).
f_h = reciprocal of slope index of heating curve (min.).

Applying equation(6) for 307X202 can the equation will be :

$\alpha = 0.398 / (1/ (\frac{3.347}{2})^2 + (\frac{1.75}{2})^2) f_h = 0.444084 f_h$

The resultant α values for different fish and meat samples are then readily obtainable using the respective values of f_h as previously given by El-Mansy (1975). Equation (5) was then used to obtain the thermal conductivity.

2. Density measurment:

A known weight of fish or meat sample (W) was transferred into a calibrated cylinder. From a burrette, a volume (V_1) of distilled water was added to a market level on the cylinder (V_2). The density (ρ) is calculated from the following equation:

$\rho = \frac{W}{V_2 - V_1}$ ....(7)

3. Determination of the specific heat (C_p):

The following equation was used to calculate specific heat (Zaitesev et al.,1969):

$C_p = W + 0.5 F + 0.36 P$ ....(8)

Where C_p is the specific heat (Btu / lb. °F) and W, F, and P are moisture, fat, and protein fractions respectively.

4. Moisture, fat, and protein determination:

The moisture content was determined at 105 °C until the weight became constant; fat content was determined using Soxhelt method, and protein was determined by Keljdahl method. These determinations were carried out according to A.O.A.C. (1975).

RESULTS AND DISCUSSION

The physico-thermal properties of any product depend greatly on its chemical composition. Table (1) gives the values of moisture, fat and protein contents in various samples of fish and meat (Mackerel, Sardine, Bolti, Beef, Veal and Lamb).

Experimental determination of thermal conductivities "K" requires the knowledge of density (ρ), specific heat (C_p) and thermal diffusivity (α), that is:

$K = \alpha \rho C_p$ .... (5)

Density and specific heat were determined as mentioned before. Their values for Mackerel, Sardine, Bolti, Beef, Veal, and Lamb are included in table (1).

It can be seen from the same table that the increase in moisture and decrease in fat contents for various fish and meat varieties are accompanied by high values of density and specific heat.

For fish, the specific heat range (0.759 to 0.875 Btu / lb. °F) was comparable to those reported by Zaitesev et al. (1969) (0.74 to 0.91 Btu / lb. °F). Moreover, the density range (67.400 to 68.149 lb / ft^3) was very close to that given by the same author (65.55 to 67.42 lb /ft^3). In the case of meat, similar agreement of the data given in Table (1) were reported in the literature. For instance, the specific heat range was(0.767 to 0.832 Btu / lb. °F) fitted to the range mentioned by Charm (1971) (0.48 to 0.93 Btu / lb. °F); while the density value of 67.42 lb / ft^3 (according to Poppendick et al., 1966) was within the presently determined range (66.299 to 67.692 lb / ft^3).

The thermal conductivities and thermal diffusivities obtained by the forementioned methods are given in Tables (2 and 3) respectively. The thermal conductivity value for fish (0.2688 Btu / hr. ft. °F) as reported by Zaitesev et al. (1969) was found to be within the calculated thermal conductivity values (0.2233 - 0.2979 Btu / hr. ft. °F), while for meat the obtained range (0.2080 to 0.2530 Btu / hr. ft. °F) were very close to the range (0.2080 to 0.2530 Btu / hr. ft. °F) as determined by Qashou et al. (1970). The thermal conductivity value for meat (0.3077 Btu / hr. ft. °F) as reported by Lawrie (1974) was higher than the obtained range. This may be due the variation in the chemical composition of meat.

The maximum coefficient of variability in thermal conductivities as obtained by the three methods was 0.81 %, while that for thermal diffusivities was 0.82 %. Because of the insignificance of these variations, average values are considered for use.

Table (1) : Physico - Chemical properties of fish and meat varieties.

Variety	Moisture %	Fat %	Protein %	Specific heat B.t.u/lb. °F	Density Lb/ft³	K av. *	∝ av. **
Mackerel	58.09	22.00	19.00	0.759	67.400	0.2233	0.01048
Sardine	73.05	9.01	16.87	0.836	67.525	0.2752	0.01170
Bolti	80.10	3.06	16.32	0.875	68.149	0.2979	0.01199
Beef	59.10	23.90	15.95	0.767	66.299	0.2265	0.01069
Veal	70.90	10.20	18.10	0.825	67.092	0.2653	0.01149
Lamb	72.90	8.00	17.50	0.832	67.692	0.2746	0.01170

* Obtained from table (2)

** Obtained from table (3)

Table (2): Thermal conductivity of fish and meat varieties (B.t.u/ hr . ft. °F).

Variety	Chato's equation	Hayakawa's method	Charm's method	Average	Coefficient of variability %
Mackerel	0.2237	0.2237	0.2227	0.2233	0.19
Sardine	0.2730	0.2776	0.2750	0.2752	0.68
Bolti	0.2962	0.2994	0.2980	0.2979	0.44
Beef	0.2271	0.2284	0.220	0.2265	0.81
Veal	0.2659	0.2666	0.2627	0.2653	0.64
Lamb	0.2725	0.2769	0.2743	0.2746	0.66

Table (3): Thermal diffusivity (inch/min) of fish and meat varieties.

Variety	Chato's equation	Hayakawa's method	Charm's method	Average	Coefficient of variability %
Mackerel	0.01050	0.01048	0.01045	0.01048	0.20
Sardine	0.01161	0.01180	0.01169	0.01170	0.42
Bolti	0.01192	0.01205	0.01200	0.01199	0.45
Beef	0.01071	0.01078	0.01057	0.01069	0.82
Veal	0.01152	0.01156	0.01139	0.01149	0.6[illegible]
Lamb	0.01161	0.01180	0.01169	0.01170	0.67

N.B. The coefficient of variability has been calculated according to Kram r and Twigg (1962).

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