STUDIES ON THERMAL DEFFUSIVITY AND CONDUCTIVITY OF FRESH AND DRY FISH

T. T. ANNAMMA & C. V. N. RAO
Central Institute of Fisheries Technology, Cochin-682011

Thermal diffusivity (α) and conductivity (K) of fresh and dry cured fish at different moisture levels were investigated by acalorimeter (regular regime) method and transient line source technique. Thermal conductivity has a linear correlation with packing density and percentage water content. K values calculated from formula method and line source technique are comparable.

INTRODUCTION

Knowledge of thermal properties of food materials is necessary either in the calculation of heat transfer in existing processes or in the development of new processing techniques. Thermal properties of biological materials have been studied by a number of workers Long(1955), Chato(1966), Cheerneeva (1956), Lentz (1961) etc. However, little information is available on the thermal conductivity (K) and diffusivity (α) values of commercially important fishes like prawn, mackerel and sardine.

This paper deals with the K & α values of mackerel and sardine in relation to their moisture contents and packing densities. Regular regime method (acalorimeter) for diffusivity measurements and transient line source technique for conductivity determinations were chosen as they are rapid and sufficiently accurate and cause minimum thermal damage of the sample. (Chaudhary *et. al.* 1969, Qashou *et. al* 1970).

MATERIALS AND METHODS

THERMAL DIFFUSIVITY: The acalorimeter method developed by Kondratev (1954) and based on the theory that when heat transfer coefficient of the surrounding medium tends to infinity, the logarithm of the rate of change of temperature becomes constant in time and space and is proportional to the thermal diffusivity of the sample, which was earlier applied in the study

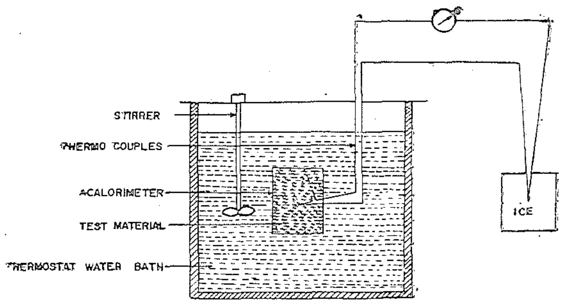

Fig. 1: Diagram of the apparatus for determining thermal diffusivity of fresh/dry minced fish

of thermo-physical characteristics of sands (Chaudhary *et. al.* 1969) was utilised in the present study of thermal diffusivity of dry and fresh fish sample.

For a finite cylinder of radius a, length 2b, the thermal diffusivity.

$$\alpha = \frac{2.3026}{f\left[\left(\frac{2.4048}{a}\right)^2 + \left(\frac{\pi}{2b}\right)^2\right]}$$

where f is the reciprocal slope of asymptote to the heating curve.

A cylindrical can of size 301 x 307 was filled with homogenised dry fish sample (or fresh) and was sealed and kept at a constant temperature 0°C overnight. It was immersed in a vigorously stirred water bath kept thermostatically at about 45°C, (T_1) and the temperature at the centre of the sample (T_2) was recorded continuously by means of copper constantan thermocouple fixed in the can earlier and a milli volt meter. The slope of the heating curve (f) was determined from the time temperature plot drawn on an inverted semi-log paper, top line numbered 1° below the water bath temperature (Stanley E. Charm 1963). The experiments were conducted at the maximum packing density and for fish at different moisture levels.

THERMEL CONDUCTIVITY (K)

The line source technique for thermal conductivity measurements is based on the theory that temperature rise at any point in an infinite solid containing a suddenly initiated, constant rate, line heat source is a function of spatial position, time, thermal properties of the solid and source strength.

K is determined from the formula.

$$K = \frac{q \ln . t_2/t_1}{4\pi(\theta_2 - \theta_1)}$$

Where θ_1 and θ_2 are the temperatures at time t_1 and t_2. q is the heat flux per unit length of wire.

The thermal probe designed for the purposes consists of a stainless steel tubing of diameter 3mm, wherein is stretched a 30 SWG constantan heater wire and a 30 SWG copper constatan thermocouple wire is placed at the centre of the

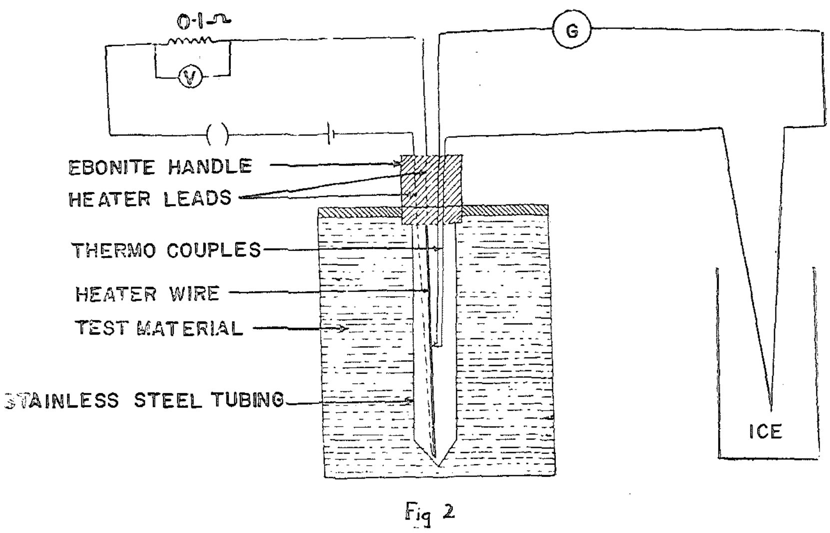

Fig. 2. Diagram of the apparatus for determining thermal conductivity of fresh / dry minced fish.

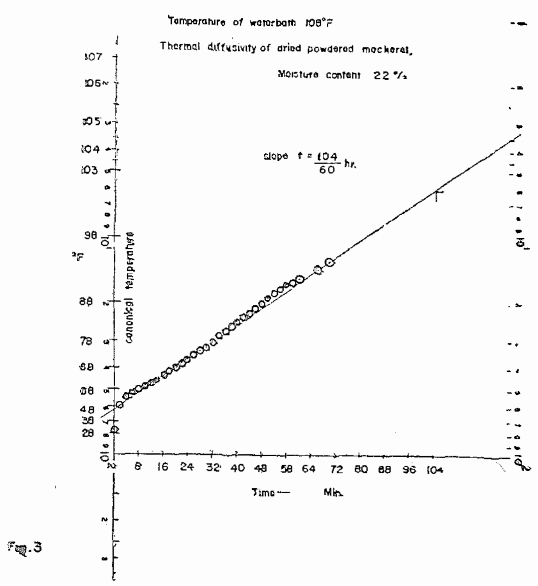

Fig. 3. Thermal diffusivity of dried powdered mackerel (moisture content 22%)

heater. The heater element was supplied with a steady power from a low voltage D. C. power source. The probe was pierced vertically in the centre of a can (size 301 x 409) filled with homogenised dry fish/fresh fish sample and the temperature was recorded for 5/10 minutes by means of the thermo couple and a galvanometer. The current flowing through the heater wire was calculated by measuring the voltage drop across a standard resistance of 0.1 ohm connected in series with heater wire. The experiments were repeated for different species of fish at different moisture levels and packing densities. Each experiment was repeated for 2 current levels and average K values of each moisture are presented.

RESULTS & DISCUSSION

Figure 3 is the semi-log graph drawn between canonical temperature and time for the thermal diffusivity measurements. f value in the present case is $\frac{104}{60}$ hrs.

Figure 4 is the plot between the temperature of the probe and time taken in natural logarithms for two current levels 2 amps. and 3 amps. in the line source method. The results on thermal diffusivity and moisture content at the maximum packing density for fish, mackerel

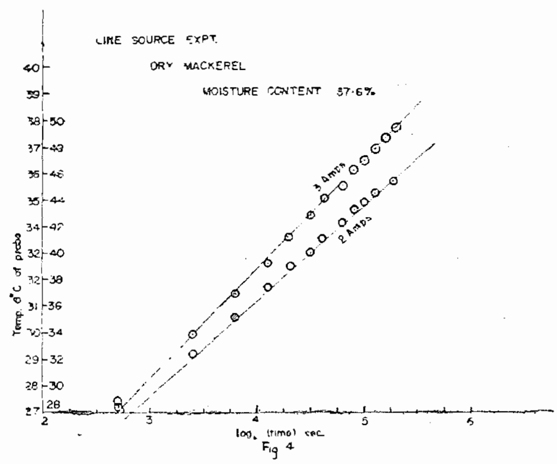

Fig. 4. Line source experiment. Dry mackerel moisture content 37.6%

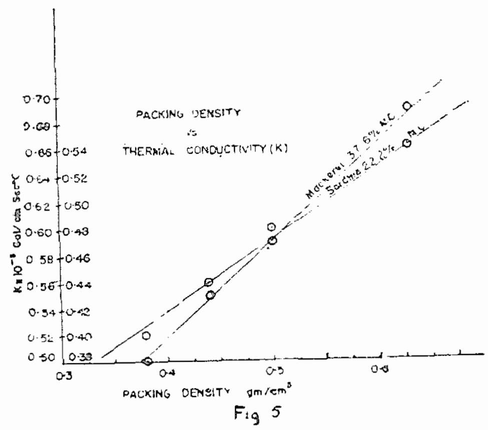

Fig. 5. Packing density Vs. Thermal conductivity obtained by line source experiment

and sardine, are given in Table I. Figure 5 and Table 2 give the data of thermal conductivity versus packing density at various moisture levels. There is a linear relationship between thermal conductivity and packing density at any moistute level.

TABLE I

VARIATION OF MOISTURE CONTENT WITH THERMAL DIFFUSIVITY

Sample	Moisture content %	Thermal diffusivity for maximum packing density cm²/sec.
Mackerel (Fresh)	78.9	1.332×10^{-3}
,, (Dry)	57.1	0.7960×10^{-3}
,, ,,	48.9	0.7660×10^{-3}
,, ,,	37.6	0.7485×10^{-3}
,, ,,	22.0	0.6982×10^{-3}
Sardine (Fresh)	77.6	1.136×10^{-3}
,, (Dry)	50.4	0.7685×10^{-3}
,, ,,	42.6	$0,7504 \times 10^{-3}$
,, ,,	37.6	0.7050×10^{-3}
,, ,,	22.2	0.6486×10^{-3}

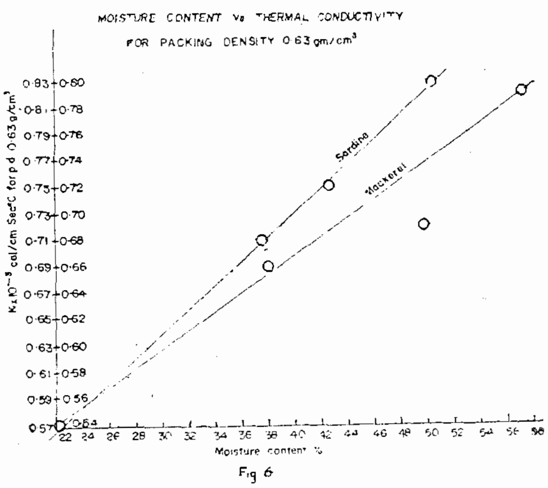

Fig. 6. Moisture content Vs. thermal conductivity for packing density 0.63 gm./cm³ obtained by line source experiment.

Linear correlation was reported (Chato 1966) between K and moisture represented by the equation $K = 0.0324 + 0.3294\,W$, where W is the weight fraction of water in fish. This equation was applied in the present study and K values determined by line source techniques are comparable to K obtained by Chato's formula method within experimental errors. These results obtained by formula method and line source technique are nearly comparable, as the same packing density is not possible at various moisture levels, which gives rise to maximum experimental error. Thermal conductivity also varies linearly with moisture content upto about 55% (Fig. 6).

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TABLE II

COMPARATIVE DATA ON THERMAL CONDUCTIVITY VALUES FROM PROBE METHOD AND FORMULA METHOD

Sample	Moisture content %	Packing density gm/cm	Thermal conductivity K by probe expt. cal/Sec cm °C at 45-50°C.	Thermal conductivity K in BTU/hr ft. °F (probe method	Thermal conductivity K according to formula 0.0324+0.3294W
Mackerel (Fresh)	78.9	Maximum	1.391×10^{-3}	0.3364	0.2922
Mackerel (Dry)	57.1	0.63	0.7828×10^{-3}	0.2004	0.2204
,, ,,	48.9	0.63	0.7179×10^{-3}	0.1736	0.1935
,, ,,	38.0	0.63	0.6940×10^{-3}	0.1678	0.1575
,, ,,	—	0.50	0.5880×10^{-3}	0.1421	—
,, ,,	—	0.44	0.5486×10^{-3}	0.1327	—
,, ,,	—	0.38	0.5002×10^{-3}	0.1210	—
,, ,,	22.0	0.63	0.5741×10^{-3}	0.1389	0.1053
,, ,,	—	0.50	0.5290×10^{-3}	0.1279	—
,, ,,	—	0.44	0.4958×10^{-3}	0.1199	—
,, ,,	—	0.38	0.4665×10^{-3}	0.1128	—
Sardine (Fresh	77.6	Maximum	1.444×10^{-3}	0.3492	0.2880
,, (Dry)	50.4	0.63	0.8026×10^{-3}	0.1941	0.1984
,, ,,	42.6	0.63	0.7184×10^{-3}	0.1738	0.1727
,, ,,	—	0.50	0.6566×10^{-3}	0.1589	—
,, ,,	37.6	0.63	0.6762×10^{-3}	0.1636	0.1563
,, ,,	—	0.50	0.5714×10^{-3}	0.1380	—
,, ,,	22.2	0.63	0.5356×10^{-3}	0.1296	0.1155
,, ,,	—	0.50	0.4782×10^{-3}	0.1157	—
,, ,,	—	a.44	0.4352×10^{-3}	0.1053	—
,, ,,	—	0.38	0.3972×10^{-3}	0.0967	—

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