# PRELIMINARY WORK ON THE SPECIFIC CONDUCTIVITY OF FISH MUSCLE

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HALIFAX, 1928

# BIOLOGICAL BOARD OF CANADA

## MANUSCRIPT REPORTS OF THE EXPERIMENTAL STATIONS

No. 22

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# Preliminary Work on the Specific Conductivity of Fish Muscle

By G. O. Langstroth B.A.

Since no measurement of the specific conductivity of fish muscle could be found in the available literature, and since this data is of importance in the understanding of refrigeration porblems, an attempt was made to obtain values.

The fish used in the preliminary experiments was Haddock, some samples of which had been frozen over night in the cold storage room at a temperature of about -17 degrees Cent. and some samples of which had not.

The apparatus consisted of a hot and a cold plate separated by a distance of about two centimeters, between which the fish was packed. The hot plate consisted of a steam box, made entirely of galvanized iron, with its outlet in the bottom to carry off all condensed steam. Its face was as near a plane surface as possible, and measured about fifteen centimeters square. The cold plate was of the same size of face, but consisted of a single piece of metal on the back of which about five feet of small diameter copper tubing was soldered so as to make good thermal contact at all points . On the ends of the copper tubing were jackets to hold the bulbs of tenth degree thermometers. This tubing was so arranged that the water could be made to enter at the centre and leave at the edge, or to enter at the edge and leave at the centre of the plate. In the centre of this plate was a metal jacket just large enough to contain the bulb of a thermometer. This jacket was soldered to the back of the plate.

Both these plates were fastened to a hard wood base in such a way that the only contact with the wood was at the bottom where two pieces about one centimeter wide held the plates up from the base. All this was surrounded by a wooden case and distance pieces were put to the backs of the plates to hold them rigid.

The box was packed very loosely with cotton wool to prevent convection currents. The experimental arrangement is shown in Fig. I.

In an actual run the plates were set up, and the distance between them measured at sixteen different systematic places, with an inside caliper. The results were averaged to give a mean plate distance, and since all measurements were made to one tenth of a millimeter, the mean distance was at least that good. In all the measurements no two series were found to differ by more than 0.01 cm.

The space between the plates was then packed quite tightly with fish, cut in thin strips. Cotton wool was placed loosely in the box and steam was passed through the steam plate. Water from a constant flow tank was passed through the cold plate tubing, where its temperature on entering and on leaving could be measured by tenth degree thermometers. The temperature of the centre of the cold plate was measured by a one degree thermometer in the jacket mentioned above.

The apparatus was allowed to come to equilibrium which was shown by the steadiness of the thermometers in the cold plate, and the temperature measurements were then taken. The amount of water flowing through in the time of the run was easily found by catching and weighing the water for this time.

Knowing the weight of water, its rise in temperature, and the time of a run, the amount of heat flowing through the fish per second could be calculated. From the dimensions of the apparatus, the temperature of the hot, and of the cold plates, the amount of heat passing per second could be calculated in terms of the specific conductivity, "K". By equating the two values, K was obtained as an average over the temperature range between that of the hot and of the cold plate.

## Measurement of Temperature Rise

The temperature rise was measured in the following way; When the thermometers showed that equilibrium had been reached, the water flowing through the tubing was caught and readings were alternately made of the inlet and outlet temperatures as fast as possible; about fifteen readings were made of each during a run of five minutes. A gradual falling off of the outlet temperature was noted as the fish became dried out near the steam plate, but all data given was taken before this effect had become noticeable. The temperatures were averaged and substracted, giving a mean value for the temperature rise of the water.

## Thickness of Fish

As before noted the thickness of the fish, (or the plate distance) was obtained at the beginning of every run as an average value.

## Plate Area

Considerable error was introduced, in finding the area of the fish between the plates. The plates themselves were 15.00 cm. square. After a run the fish was examined and a calculation made of the area uncovered around the edges. This was necessary because of the shrinkage of the fish, due to the high temperature. This correction was in general about 15 square centimeters.

## Temperature of the Plates

Due to the good insulation the temperature of the hot plate at equilibrium can probably be taken as the same as that of steam, with little likelihood of appreciable error. The steam temperature was obtained from the barometric reading in the usual manner.

The temperature of the cold plate was harder to measure accurately. By changing the inlet ~~and the inlet~~ and the outlet, the centre of the plate could be made to become the hottest of the coldest part of the plate. It was found that over the range of rates of flow used the hottest part of the plate was constantly higher than the outlet temperature by a definite amount even when the outlet temperature was changed by two or three degrees. The coldest part of the plate which was measured for each run, was of course somewhat higher than the inlet temperature. The temperature of the cold plate was then calculated as follows: The hottest part of the plate was found to be 2.0°C. higher than the outlet temperature in the preliminary experiments over a wide range of temperature. The coldest part of the plate was measured for each run. Since the outlet temperature for each run was measured, the hottest part of the plate was found by adding to the mean of the outlet temperature 2.0°C. The temperature of the coldest and of the hottest parts were then averaged to give a mean value for the temperature of the plate.

The time of a run was taken as the time during which the water passing through the tubing was being caught.

If M be the amount of water caught in a time "t" and if $\theta$ be the difference in temperature between the inlet and the outlet then the amount of heat passing per second is on the average.

$$H = \frac{M \times \theta}{t}$$

If "A" be the area of the plates, "d" the distance between them, "T" the difference in temperature of the plates, and "K" the specific conductivity, then the heat flowing across per second is given by:

$$H = \frac{K \times A \times T}{d}$$

Equating the two we get;

$$\frac{M \times Q}{t} = \frac{K \times A \times T}{d}$$

which is the equation used.

The following example of a typical calculation will show the method;

| | |
|---|---|
| Wt. of beaker and water | 700.3 gm. |
| Wt. of beaker | 131.7 |
| Wt. of water | 568.6 |
| Barometric pressure | 76.7 cm. |
| Boiling point of water | 100.2°C. |
| Time of flow | 240.0 sec. |
| Average plate distance | 2.20 cm. |
| Area of fish | 225.0-20.6 = 204.4 |
| Average temperature of cold plate | $\frac{27.3+24.3}{2}$ = 25.8°C. |

| Outlet Temp. | Inlet Temp. |
|---|---|
| 25.30 | 20.30 |
| 25.30 | 20.30 |
| 25.30 | 20.30 |
| 25.29 | 20.30 |
| 25.30 | 20.30 |
| 25.31 | 20.30 |
| 25.30 | 20.30 |
| 25.30 | 20.30 |
| 25.28 | 20.30 |
| 25.29 | 20.30 |
| 25.28 | 20.30 |
| 25.26 | 20.30 |
| 25.25 | 20.30 |
| 25.20 | 20.30 |
| 25.28 | 20.30 |

Temp. rise 25.28 - 20.30 4.98

Temp. drop between plates 74.4

Substituting these values in the expression given;

$$\frac{568.6 \times 4.98}{240.0} = \frac{K \times 204.4 \times 74.4}{2.20}$$

Whence K is given; i.e.

$$K = 0.00171 \ \frac{\text{cal.}}{\text{sec. deg. cm.}}$$

In the foregoing it was assumed that all the heat crossing the fish goes to heat the water. This is not strictly true, but the conductivity of air (still), is so small compared to that of the fish that boundary effects have been neglected.. No appreciable amount of heat would be conducted by the very small pieces of wood in contact with the metal.

The fish used was in some cases obtained unfrozen and in others it was air frozen. In some cases two runs were made with the same piece of fish, one immediately following the other.

The results obtained were as shown below:

| HIGH TEMP. | LOW TEMP. | SPEC. CONDUCTIVITY |
|---|---|---|
| 100.0 | 30.1 | 0.00162 |
| 100.0 | 28.7 | 0.00163 |
| 100.1 | 24.0 | 0.00171 |
| 100.1 | 25.0 | 0.00157 |
| 100.1 | 27.4 | 0.00167 |
| 100.1 | 26.4 | 0.00162 |
| 100.2 | 25.8 | 0.00171 |
| 100.2 | 25.3 | 0.00159 |
| 100.2 | 25.5 | 0.00170 |
| 100.2 | 25.6 | 0.00158 |

The average value for the conductivity over the range of 100 to 25 degrees Centigrade is therefore.

$$K = 0.00164 \pm 0.00004 \ \frac{\text{cal.}}{\text{sec. deg. cm.}}$$

The errors are;

| | | |
|---|---|---|
| In 204.4 | $<5.0$ | $<2.5$ % |
| 240.0 | $<0.4$ | $<0.2$ % |
| 75.4 | $<0.7$ | $<1.0$ % |
| 2.20 | $<0.1$ | $<0.5$ % |
| 568.6 | $<.2$ | |
| 4.98 | $<0.05$ | $<1.0$ % |

Giving in the result

Error in K $<5.2$ % in a single reading.

The error in the average of ten is therefore given by

Error in average K $<1.8$ %