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Comparative Analysis of Heat Flow Rates of Seven Cold-boxes Made of Different Varieties of Wood

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Abstract: The result of the comparative analysis of seven cold-boxes made of seven varieties of wood is presented in this study. Seven geometrically the same cold-boxes for fish storage were constructed. The boxes were made of Iya, Mansonia, Araba, Iroko, Mahogany, Oriro and Akomu and labeled 1-7, respectively for easy identification. The cold-boxes are rectangular in shape with each having an internal dimension of 0.2×0.15×0.1 m with thickness of 0.025 m. Each cold-box is lined both internally and externally with aluminum foil of 1.5 mm thickness. A 2.0 kg iced Jack fish was put in each of the seven cold-boxes for 6 h (between 10.00 and 16.00 h) and a digital multimeter was used to measure the temperature of the fish inside the cold-box every 30 min for 2 consecutive days. The result of the test showed that Mansonia wood had the least heat flow rate of 28.87 W and therefore, the most effective for fish preservation, while Iroko wood had the highest heat flow rate of 91.65 W, thus the least effective, of the seven varieties, for fish preservation.

Key words: Fish preservation, wood varieties, thermal insulator, heat flow rate, cold-box

INTRODUCTION

Fish is a very good source of protein for man. It is known to contain about 15-18% of protein and about 16-33% of calcium (Ogunleye, 2006). In many countries, the bulk of fish is sold fresh for local consumption. But is an extremely perishable food, most fish become inedible within 12 h at tropical temperatures. Spoilage begins as soon as the fish dies. One way to maintain fresh fish is to keep it at a temperature that will prevent the growth of food poisoning bacteria (Peter, 1992). This is achieved by maintaining the fish at a temperature much lower than its environment. This means the fish needs to be refrigerated at temperature below 0°C.

Thermal insulation is a means of retarding the rate of heat flow from the ambient to the inside of fish preserving systems. Thermal insulators are the materials used to reduce the rate of heat transfer. Common thermal insulators are polyurethane foam, polystyrene, fibreglass, cork, wood, sawdust to mention just but a few. Factors to consider in selecting insulation material should include initial cost, effectiveness, durability, the adaptation of its form/shape to that of the fish hold and the installation methods available in each particular area (Peter, 1992).

Some of these insulating materials, like fibreglass, polyurethane foam, polystyrene, are not readily available and cost a huge foreign exchange to import them. It is therefore, necessary to carry out experimental test and comparison of thermal behaviours of various varieties of wood , which can be used to construct fish preserving systems that will be affordable to rural dwellers. The seven varieties of wood used are Iya, Mansonia, Araba, Iroko, Mahogany, Oriro and Akomu. The botanical and family names of the woods are shown in Table 1.

Table 1: Wood varieties and their botanical and family names (Awogbemi and Ogunleye, 2007)

Local name	Botanical name	Family name
Iya	Dancillia Ogea	Fabaceae
Mansonia	Mansonia Altissima	Sterculiaceae
Araba	Ceiba Pentandra	Bomb Caceae
Iroko	Milicia Excelsa	Moraceae
Mahogany	Triplochiton Sleroxylon	Meclialeae
Oriro	Antriatis Toxicaria	Moraceae
Akomu	Pycnanthus Anglolensis	Myrsticaceae

Conduction occurs when heat travel through solid medium. It is also defined, as the mechanism of molecular transport of heat in a solid at rest due to temperature difference without any movement of microscopic portion of the solid relative to one another (Karlekar and Desmond, 1982). Heat flow rate is governed by Fourier's law of heat conduction. Fourier's law can be expressed mathematically as (John *et al*., 2008):

$$q = -k\frac{dT}{dx} \quad (1)$$

Where:

- q = Heat flux ($W\ m^{-2}$)
- k = Constant of proportionality called thermal conductivity ($W\ m^{-1}.K$)
- dT = Change in Temperature (K)
- dx = Thickness of insulator (m)

MATERIALS AND METHODS

The description of the cold-box: Seven geometrically the same cold-boxes for fish storage were constructed. The cold-boxes are rectangular in shape with each having an internal dimension of 0.2×0.15×0.1 m with thickness of 0.025 m. Each cold-box is lined both internally and externally with aluminum foil of 1.5 mm thickness. There is provision for a hole of 10 mm diameter by the side of each box to insert the probe of the digital multimeter to monitor the temperature of the fish inside the box. The pictorial view of one of the cold-boxes is as shown in Fig. 1.

Experimental methodology: A 2.0 kg of iced Jack fish (Selar crumenophthalmus) at an average temperature of -3.25°C was put inside each of the 7 cold-boxes. The cold-boxes were made of different varieties of wood namely Iya, Mansonia, Araba, Iroko, Mahogany, Oriro and Akomu and labeled 1-7, respectively for easy identification. The inside of the cold-box was cleaned with a dry clean cloth. The initial temperature of the fish and the ambient temperature were taken with the aid of a digital multimeter. The fish was put inside each of the cold-boxes and the probe of the digital multimeter inserted through the hole by the side of the box to touch the fish inside the cold-box. The temperature of the fish in each of the cold-boxes and the ambient temperature were taken every 30 min for 6 h (between 10:00 and 16:00 h) for 2 consecutives days. The experiment was carried out in a well ventilated laboratory at the University of Ado Ekiti, Nigeria, Latitude 7.5°N and Longitude 5°E in the month of August 2008.

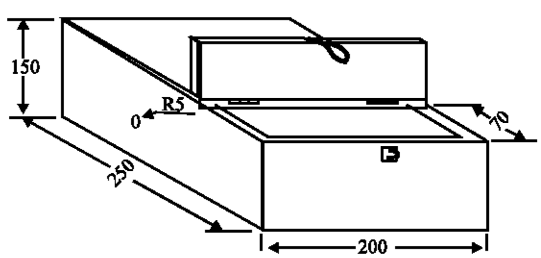

Fig. 1: Pictorial view of a cold-box for fish preservation

Determination of heat flow rates: Heat flow Q is given by

$$Q = qA \tag{2}$$

From Eq. 1, therefore

$$Q = -kA\frac{dT}{dx} \tag{3}$$

Where:

A : The area of the Cold-box = 0.13 m^2
dx : Insulation thickness = 0.025 m
k : The thermal conductivity of the various varieties of wood as determined by Awogbemi and Ogunleye, 2007.

RESULTS AND DISCUSSION

Throughout, the duration of the experiment, the Average wind velocity Va, Relative humidity Φ, Air density ρ and Specific heat capacity of air were found to be 0.1 m s^{-1}, 60%, 1.21 kg m^{-3} and 1.005 KJ Kg^{-1}, respectively.
The results are as given in Table 2-3.

Table 2 and 3 show the variations in the ambient temperature and the seven varieties of wood for days 1 and 2, respectively. The ambient temperature varies between 25.0 and 34.5°C for day 1 with the maximum temperature recorded at 15:00 h, while for day 2 the ambient temperature varies between 24:0 and 33.0°C with the maximum temperature recorded also at 15:00 h. The fish temperatures at the beginning of the experiment were -3.0 and -3.5°C for days 1 and 2, respectively.

Table 2: Temperature measurement for day 1

Local time t (h)	Ambient temperature t_a(°C)	Fish temperature t_f (°C) for the seven varieties of wood						
		Iya	Mansonia	Araba	Iroko	Mahogany	Oriro	Akomu
10:00	25.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
10:30	25.5	-2.5	-2.7	-2.7	-1.5	-2.7	-2.5	-2.2
11:00	26.5	-1.5	-2.2	-1.2	1.1	-1.5	-1.2	-1.0
11:30	25.5	-1	-1.8	0.5	3.4	-1.2	1.0	1.5
12:00	26.0	0.5	-0.8	2.0	5.7	1.0	3.0	4.0
12:30	27.0	3.0	2.0	3.5	7.0	3.5	4.8	5.5
13:00	27.5	7.0	4.0	6.0	9.3	6.8	7.4	7.6
13:30	28.0	8.2	5.5	9.2	11.0	8.9	9.8	9.5
14:00	30.5	10.0	7.0	11.0	13.4	10.5	11.0	11.7
14:30	32.2	12.0	8.5	13.2	15.0	12.5	13.5	13.0
15:00	34.5	13.1	11.5	15.0	17.3	13.6	15.5	14.5
15:30	32.0	15.0	13.0	17.0	20.0	15.5	18.5	18.0
16:00	31.0	15.0	13.0	17.0	20.0	15.5	18.5	18.0

Table 3:Temperature measurement for day 2

Local time t (h)	Ambient temperature t_a(°C)	Fish Temperature t_f (°C) for the seven varieties of wood						
		Iya	Mansonia	Araba	Iroko	Mahogany	Oriro	Akomu
10:00	24.0	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5
10:30	24.0	-2.1	-2.8	-2.5	-1.0	-2.0	-1.4	-2.0
11:00	25.5	-0.1	-0.5	0.0	1.0	-0.3	0.7	0.2
11:30	25.0	1.5	1.2	0.9	2.3	1.5	2.0	1.7
12:00	26.0	3.1	2.6	3.5	5.0	3.2	4.3	3.8
12:30	26.0	4.7	4.2	4.9	7.0	4.6	5.5	5.0
13:00	27.5	5.2	5.6	6.0	9.8	6.0	7.0	6.6
13:30	28.0	7.0	6.5	8.7	12.0	7.6	10.0	9.2
14:00	30.5	8.1	7.0	10.0	13.3	9.0	12.0	11.6
14:30	32.0	10.0	8.3	12.0	15.0	10.5	13.6	13.0
15:00	33.0	11.4	9.4	13.0	17.5	11.6	15.4	14.6
15:30	31.0	12.0	10.0	13.5	18.0	12.5	16.0	15.0
16:00	30.0	12.0	10.0	13.5	18.0	12.5	16.0	15.0

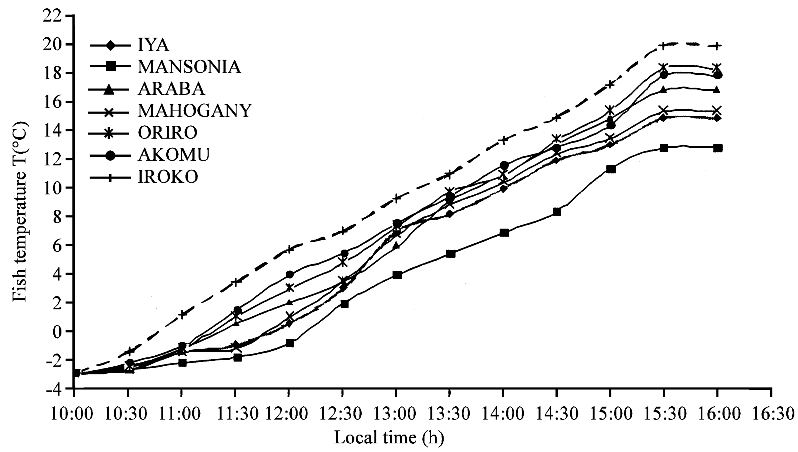

Fig. 2: The plot of fish temperature T (°C) against local time t(h) for day 1

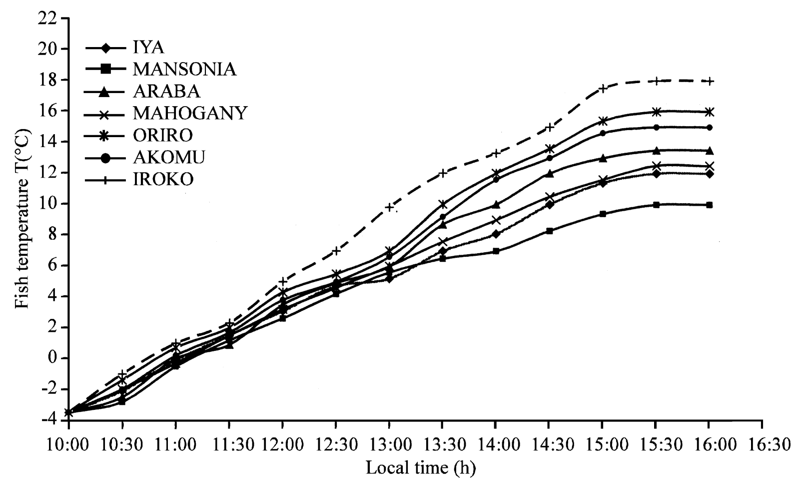

Fig. 3: The plot of fish temperature T (°C) against local time t(h) for day 2

The starting fish temperature was -3.0°C. The fish temperature had risen to 15, 13, 17, 20, 15.5, 18.5 and 18°C for Iya, Mansonia, Araba, Iroko, Mahogany, Oriro and Akomu, respectively for day 1 as shown in Table 2. For day 2, however, the temperature rose from initial value of -3.5-12°C, 10, 13.5, 18, 12.5, 16 and 15°C for Iya, Mansonia, Araba, Iroko, Mahogany, Oriro and Akomu, respectively as shown in Table 3.

Table 4: Heat flow rate for the seven varieties of wood

Wood	Heat flow rate (W)
Iya	31.93
Mansonia	28.87
Araba	34.55
Iroko	91.65
Mahogany	32.12
Oriro	37.62
Akomu	36.17

Fig. 4: Heat flow rate of wood

Where, 1 = Iya wood; 2 = Mansonia wood; 3 = Araba wood; 4 = Iroko wood; 5 = Mahogany wood; 6 = Oriro wood; 7 = Akomu wood.

Figure 2 and 3 showed the plot of fish temperature against local time for days 1 and 2, respectively. The Fig. 2 show the rate, at, which the temperature of the fish inside the cold-boxes increases with time. It revealed that the fish inside the box made of Iroko has the highest rate of temperature increment while, the fish inside the box made of Mansonia has the least rate of temperature increment for both day 1 and 2. Table 4 shows that Iroko has the highest heat flow rate followed by Oriro, Akomu, Araba, Mahogany, Iya and Mansonia in that order. This is also, clearly shown in Fig. 4.

CONCLUSION

This research has revealed that wood can be used to construct cold-box for fish preservation but with varied degree of effectiveness. Mansonia is the most suitable wood variety for construction of cold-box, followed by Mahogany, Iya, Araba, Akomu, Oriro and Iroko in that order. In other words, Iroko wood is found not to be effective as material for the construction of cold box for fish preservation because of its high heat flow rate. Thus, the high cost of procuring synthetic lagging materials like polystyrene, polyurethane foam and fibreglass can be saved by using Mansonia wood, which is cheap and locally available. This will no doubt be of great use to both rural and urban dwellers, who always demand for fresh fish for consumption.

REFERENCES

Awogbemi, O. and I.O. Ogunleye, 2007. Determination of thermo-physical properties of eight varieties of sawdust. J. Res. Eng., 4 (4): 9-11.

Karlekar, B.V. and R.M. Desmond, 1982. Heat Transfer. 2nd Edn. West Publishing Company, New York, pp: 45.

John, H., I.V. Lienhard, H. John and V. Lienhard, 2008. A Heat Transfer Textbook. 3rd Edn. Phlogiston Press, Cambrigde, pp: 10.

Ogunleye, I.O., 2006. Preservation of fish through solar drying. J. Sci. Technol. Res., 5 (3): 1-2.

Peter, F., 1992. Fish and Fish products. Available from www.fao.org/Wairdocs.