Biodegradable Thermal Insulation for Ice-Coolers

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ABSTRACT

The widespread use of non-biodegradable low temperature thermal insulation is impacting negatively on the environment with respect to disposal. In this study the effectiveness of using biodegradable locally available coconut fiber for insulation in ice-coolers was investigated. A comparative method was used to determine the effectiveness of a zinc-coated metal sheet ice-cooler with coconut fiber insulation in relation to standard commercially available Rubbermaid and polystyrene ice-cooler. The density of the coconut fiber insulation was varied from 50kg/m^3 to 95kg/m^3 for ice-coolers with wall thickness 38mm, 51mm, and 64mm, respectively. For each density the melt rate was measured and compared with the Rubbermaid and polystyrene coolers. The laboratory built ice-coolers were approximately the same volume and similar in shape to the commercial ice-coolers. From the melt rate experimental results of the three laboratory built coconut fiber insulated ice coolers the 64mm thick 95kg/m^3 density ice cooler performed the best. The 51mm and 64mm thick ice coolers performed consistently better than the Rubbermaid cooler. The 51mm and 64mm thick ice coolers performance were comparable to that of the polystyrene ice cooler.

Keywords – **Biodegradable insulation, coconut fiber, ice-cooler, thermal insulation**

1. INTRODUCTION

Daily degradation of our delicate environment is of concern to everyone. The advent of technology has brought with it glamorous new findings, luxurious facilities and exotic life stiles. However, the negative impact of technological advancement is causing serious and sometimes irreparable damage to the environment. In the field of low temperature insulation technology low-cost foam and polystyrene have been used extensively. Continuous research have perfected the manufacture and production of these materials. One can design these materials for specialized applications. Foam (rigid or flexible) is the most widely used material for low temperature insulation [1]. The wide ranging application of foam insulation covers use in clothing, air conditioning systems, commercial and residential buildings, automobile passenger compartments, refrigerators and ice coolers. The negative effects of wide spread use of non-biodegradable thermal insulation has caught up with modern society. In developing countries disposal of these materials is becoming a bigger problem daily. Discarded polystyrene does not biodegrade for hundreds of years and is resistant to photolysis [2]. Because of this stability, very little of the waste discarded in today's modern, highly engineered landfills biodegrades. Because degradation of materials creates potentially harmful liquid and gaseous by-products that could contaminate groundwater and air, today's landfills are designed to minimize contact with air and water required for degradation, thereby practically eliminating the degradation of waste [3]. Land-fills are being packed to capacity and rampant improper disposal is reeking havoc on the delicate environment.

There is an urgent need for more environmentally friendly biodegradable low temperature thermal insulation. Coconut fiber was always known for its high resilience in moist environments [4]. Before the advent of foam, coconut fiber was widely used in mattresses and cushion seats. Due to a lack of thermo-physical property data and research the possibility of using coconut fiber as an effective low temperature insulator was not explored [5, 6]. With the widespread availability of cheap foam the use of coconut fiber today is almost non-existent.

In this study the thermal insulating property of bio-degradable natural unprocessed coconut fiber was investigated. The effective insulating property was determined by a comparative method. The coconut fiber was tested in three laboratory built ice coolers and compared with two commercially available ice coolers. The commercially available coolers used were the Rubbermaid ice cooler (foam insulation) and the polystyrene ice cooler (polystyrene insulation).

2. METHODOLOGY

To investigate the thermal insulating property of coconut fiber three ice coolers were constructed from zinc-coated metal sheet. The inner shape and dimensions of the coolers were the same as the inner shape and dimensions of the Rubbermaid and polystyrene coolers. To facilitate the testing of different thicknesses of coconut fiber insulation the outer housing was constructed to accommodate 38mm, 51mm and 64mm thick insulation.

Fig. 1 shows a cross sectional view of the laboratory built ice cooler with the inner dimensions. Respective covers for the ice coolers were also constructed from zinc-coated metal sheet to accommodate 38mm, 51mm and 64mm thick insulation. The covers were designed with a 12.5mm protrusion into the ice-cooler compartment. The protrusion together with a thin rubber gasket ensured an air-tight seal at the covers (Fig. 1).

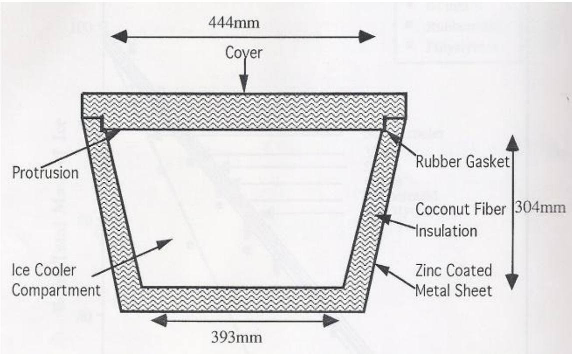

Figure 1: Cross section of laboratory built ice cooler.

To investigate the insulating properties of coconut fiber the cavity between the inner and outer housing of the ice coolers were filled with coconut fiber packed at various densities. The densities tested were 50kg/m^3, 65kg/m^3, 80kg/m^3, and 95kg/m^3. This density range was chosen since it is within the optimum density range for coconut fiber insulation [7].

To measure the effective insulating properties of the coconut fiber ice coolers the melt rate of ice was monitored. Identical specimens of ice in both shape and size were used in each ice cooler (Fig. 2).


Figure 2: Ice specimen used to monitor melt rate.

For each test density experiments were conducted with the 38mm, 51mm, and 64mm thick coconut fiber insulated ice coolers together with the Rubbermaid ice cooler (Fig. 3) and the polystyrene ice cooler (Fig. 4).


Figure 3: Rubbermaid ice cooler.


Figure 4: Polystyrene ice cooler.

One ice specimen was also placed in an open container on the test bench and was also monitored for each test run. Under these conditions for each test run all the specimens were subjected to the same environmental conditions.

At pre-set intervals the ice containers from each cooler was removed and the water (melted ice) drained and weighed. The ice was replaced in their respective containers and checked at the next pre-set time. The melt rate of the ice in each ice cooler and the specimen without an ice cooler was monitored over a twenty hour period. This test procedure was repeated for each test density of coconut fiber insulation.

3. INSTRUMENTATION

The scale used for the weight measurement of the ice samples was a Scientech Series 5000 electronic balance. The measurement range of this instrument was 0 to 5 kg with an accuracy of $\pm$ 0.005g and a resolution of 0.01g.

4. EXPERIMENTAL RESULTS

The melt rate of ice in each ice cooler was measured by subtracting the weight of the drained water from the mass of ice each time. One set of results for the test density 50kg/m^3 coconut fiber insulation ice coolers is given in Table 1. The percentage of the total mass of ice remaining was calculated from the measured results.

Table 2 shows the calculated results for the 50kg/m^3 coconut fiber insulation ice cooler tests. The calculated test data was used to plot respective graphs of percentage of total mass of ice versus time for each ice cooler at the various test densities. A typical set of graphs of the 50 kg/m^3 coconut fiber ice cooler test results from Table 2 is shown in Fig.5. The computer generated best fit line using the method of least squares and the corresponding linear equation was obtained for each test and the gradient of the best fit line provided an indication of the melt rate. Similar tables and graphs were obtained for each of the respective test with 65 kg/m^3, 80 kg/m^3 and 95 kg/m^3 density coconut fiber insulation ice coolers and the respective melt rate obtained from the best fit line. Table 3 gives a summary of the melt rate results for the various test densities.

Table 1: Mass of Ice Remaining in Ice Cooler with Time
Coconut Fiber Insulation at 50 kg/m^3

		Mass of ice remaining with time (measured values)					
Test No.	Time Elapsed (hours)	No ice cooler (g)	38 mm ice cooler (g)	51mm ice cooler (g)	64 mm ice cooler (g)	Rubbermaid ice cooler (g)	Polystyrene ice cooler (g)
1	0.0	1396.6	1377.6	1365.6	1383.9	1362.0	1378.5
2	1.5	1255.2	1342.8	1325.8	1342.0	1294.4	1338.1
3	3.0	987.1	1179.9	1171.2	1165.6	1120.9	1197.9
4	4.5	775.4	1043.9	1041.2	1034.1	987.5	1070.6
5	6.0	592.7	918.7	924.6	911.6	865.9	951.3
6	7.5	437.9	802.4	812.3	796.1	744.6	841.3
7	9.0	254.2	701.2	711.8	693.8	637.4	734.8
8	12.0	0.0	532.0	511.2	535.5	477.5	569.5
9	17.0	0.0	217.3	259.8	238.5	184.4	268.4
10	20.0	0.0	92.0	115.0	116.3	77.3	134.9

Table 2: Mass of Ice Remaining in Ice Cooler with Time
Coconut Fiber Insulation at 50 kg/m^3

		Percentage of total mass of ice remaining with time (calculated values)					
Test No.	Time Elapsed (hours)	No ice cooler (g)	38 mm ice cooler (g)	51mm ice cooler (g)	64 mm ice cooler (g)	Rubbermaid ice cooler (g)	Polystyrene ice cooler (g)
1	0.0	100.00	100.00	100.00	100.00	100.00	100.00
2	1.5	89.51	87.41	97.01	96.09	94.91	96.99
3	3.0	69.89	85.26	85.37	83.81	81.81	86.55
4	4.5	54.32	75.12	75.54	74.85	71.75	77.08
5	6.0	40.89	65.78	66.92	64.96	62.58	68.20
6	7.5	29.51	57.11	58.39	56.40	53.42	60.00
7	9.0	16.00	49.56	50.81	48.81	45.34	52.07
8	12.0	0.00	36.94	38.72	37.07	36.00	37.77
9	17.0	0.00	13.48	16.80	15.03	11.16	17.36
10	20.0	0.00	4.13	5.90	5.96	3.09	7.41

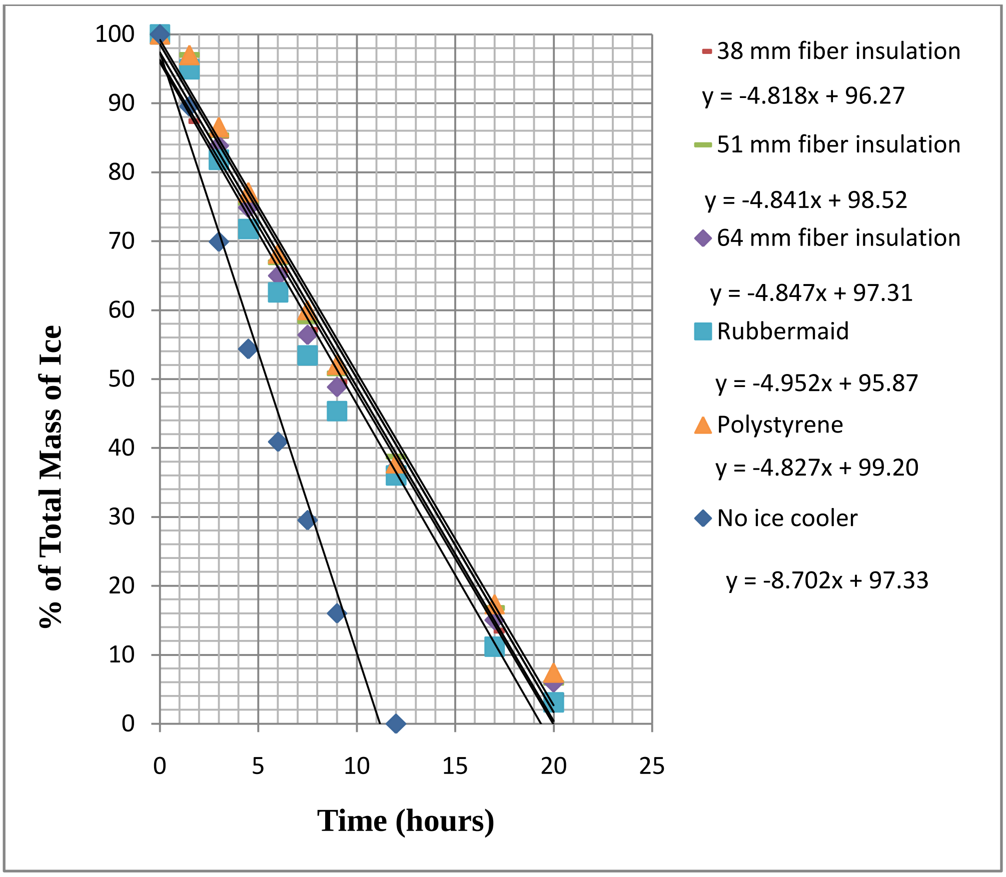

Figure 5: Graph of melt rate with time for test with coconut fiber insulation at 50 kg/m^3 density.

Table 3: Melt Rate of Ice Experimental Results

Ice Cooler Type	Melt Rate of Ice (% of total mass per hour)			
	Coconut Fiber Insulated Ice Coolers			
	50 kg/m^3	65 kg/m^3	80 kg/m^3	95 kg/m^3
Coconut fiber 38 mm thick insulation	4.818	4.892	4.818	4.705
Coconut fiber 51 mm thick insulation	4.841	4.866	4.731	4.509
Coconut fiber 64 mm thick insulation	4.847	4.673	4.808	4.480
No ice cooler	8.702	8.752	8.800	8.791
	Reference ice coolers under similar test conditions			
Rubbermaid ice cooler	4.952	4.955	4.995	4.814
Polystyrene ice cooler	4.827	4.827	4.777	4.797

5. DISCUSSION AND CONCLUSIONS

Using a comparative method to investigate the thermal insulating property of coconut fiber in ice coolers eliminated experimental errors due to uncontrollable environmental conditions. Monitoring the melt rate of the ice coolers for each density test run simultaneously provided data which can be directly compared.

Test results of percentage total mass of ice versus time (typical graph shown in Fig. 5) showed an initial slower melt rate with time over the first two hours with a gradual increase. Over the next ten hours the melt rate remained fairly constant. For the last eight hours the melt rate showed a small (< 2%) variation.

For the first two hours the slow melt rate can be attributed to thermal system being in a transition state. The constant melt rate over the next ten hours indicated that equilibrium conditions were established during this period. The small decrease in melt rate during the last eight hours was due to the falling ambient temperature during the night.

From the melt rate of the three laboratory built coconut fiber insulated ice coolers the 64mm thick $95kg/m^3$ density ice cooler performed the best. The 51mm and 64mm thick ice coolers performed consistently better than the Rubbermaid cooler. The 51mm and 64mm thick ice coolers performance were comparable to that of the polystyrene ice cooler.

Comparing the melt rate of ice under similar conditions without any ice cooler showed close to 50% reduction in the melt rate. The experimental data showed that coconut fiber insulated ice coolers can be as effective as the commercially available ice coolers.

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