Coolbox Design for Traditional Fishing Vessel Using Sengon Wood (*Paraserianthes falcataria* (L.) Nielsen) Sawdust and Rice Straw Insulation

Alam Baheramsyah, Ede Mehta Wardhana, Puteri Ladikha Sihombing

***Abstract*— Increased production of Indonesia catch fish accompanied by increased use of coolbox to maintain freshness of fish. The efforts to maintain freshness of fish during this time is use a coolbox made from styrofoam which is not environmental friendly. Therefore, it is need to make cool box with environment friendly material and also effective for fish preservation . In this research, coolbox is modified with insulation based on Sengon wood sawdust (Paraserianthes falcataria (L.) Nielsen) and rice straw. Using the sawdust of sengon wood and dried straw pieces , experiments conducted to get the best composition of insulation, insulation variated with 2 different adhesives, PVAc and polyurethane .The results of the density test and thermal conductivity test, also in terms of preparation of various insulation variations, show that insulation with 66% sawdust of sengon wood; 28% straw; and 6% polyurethane adhesive is the best insulation to be used in coolbox, with thermal conductivity of 0.54 W / mK and density of 0.38 gr / cm^3. The experiment in coolbox is done for 24 hours with 48 times data retrieval. Used ice cubes with mass 2 kilograms and a tuna fish with mass 400 grams. The experimental results show the minimum temperature that can be achieved coolbox is -0.1 ° C below the surface of ice .In fish body, the lowest temperature that can be achieved is 3, 2 ° C. While in the coolbox room, the lowest temperature is 19.4 ° C. The results also show coolbox with sengon sawdust and rice straw insulation able to preserving fish for 15 hours, with weight ratio between fish and ice is 1: 5.**

Keywords— Coolbox, Insulation, Sengon Wood, Rice Straw, Thermal Conductivity

I. INTRODUCTION

Production of fish in Indonesia has increased every year. According to data from the Ministry of Marine Affairs and Fisheries Republic of Indonesia, Indonesia fisheries originally amounted to 9.93 million tons in 2015 and increased to 12.5 million tons in 2016 . The number predicted will continue to increase in the coming years. Along with the increase in the number of fish production, the government conducted a campaign to eat fish throughout the nations. This campaign began to show the achievements of success. In 2014, national fish consumption is 38.14 kilograms per capita. And in 2016 that figure reached 43.94 kilograms per capita. This increase of about 5.8 kilograms if multiplied by 250 million people of Indonesia, it can be concluded there is an increase of about 1.5 million tons in the two years.

The higher knowledge of information technology, the community will be more selective on the quality of goods to be purchased. Then fishers or fish suppliers should be more careful in presenting good quality fish for consumers. Efforts made during this day is to store the fish in a coolbox made of styrofoam . Styrofoam is a material that is harmful to the environment and also to health. In addition to containing benzene that can occur cancer, Styrofoam also contains microplastic that fish can be eaten and then eaten by humans and create many other problems . Of course, the use of styrofoam should be reduced. Therefore, need coolbox with environmental friendly material and also effective for preserve fish.

In this research, will be modified cool box with insulation based on Sengon wood sawdust (*Paraserianthes falcataria* (L.) Nielsen) and rice straw. Sengon Wood is very suitable for the needs of the industry . Compared to other types of wood, Sengon tree has a relatively fast cutting time, easy cultivation, and can grow in different types of soil . Other than that, Sengon wood is already often used for acoustic and floor panels because it is known to have good insulator properties. As for the straw, it is still rarely known that straw can keep the temperature well. But the Sasak tribe in Central Lombok has been using straw as a roof and ash straw as a hereditary floor coating. With the hot weather in Central Lombok, the situation inside the traditional house of Sasak tribe will be tempered. With the insulation of cool box made from Sengon (*Paraserianthes falcataria* (L.) Nielsen) and straw is expected to be an alternative cooling box insulation that is effective in fish preservation and also environmentally friendly.

II. METHOD

A. *Identification and Formulation of The Problem*

The formulation of the problem is the first stage in the implementation of the thesis. This stage is a very important stage, where at this stage why an existing problem must be solved so it is feasible to be material in the thesis. Searching for problems is done by digging information about problems that occur at this time. From this stage, the purpose of why this thesis is

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done can be known. In this paper, the problem to be discussed and solved is on the Design of Cooling Boxes on Traditional Fisherman's Ships Using Sengon Wood Sawdust (*Paraserianthes falcataria* (L.) Nielsen) and Rice Straw Insulation.

B. Study of Literature

In the literature study phase is looking for references problems - the problems that exist and the solution and also learn both things to be implemented in this thesis.

1. Sengon Wood

Sengon (Paraserianthes falcataria (L.) Nielsen) is grouped in the familia leguminosae with Mimosoidae subfamily. Medium to high-sized Sengon trees reaches 20-40 m and the trunk diameter can reach 70-140 cm. The sengon tree trunk has a slightly soft textured outer layer, outside it is dark gray, with transverse, centrally, thin, and 5 mm inner layers of white to pink. Sengon adapts well to barren, high-pH or salt-like soils The Sengon tree also grows well in alluvial lateritic soil and mine sandy soil.

The characteristics of sengon wood are considered very suitable for the needs of the industry today. Compared to other types of wood, Sengon trees have relatively fast cutting times, easy cultivation, and bodies in different types of soil. Sengon produces mild to moderately light wood, with a density of 320-640 kg / m³ at a moisture content of 15%. Slightly solid, fibrous straight and a little rough, but easy to work. This wood is not attacked by termites, because of the content of extractive substances in the wood.

2. Rice Straw

Straw is a vegetative part of rice plants (stems, leaves, panicle stalks) that are not collected when the rice crop is harvested. The nutrient content of rice straw depends on the fertility of the soil, the amount of fertilizer provided, the quality and quantity of irrigation water, and the climate of Straw is an organic material available in significant amounts for rice farmers. Approximately 40% N, 30-35% P, 80-85% K, and 40-50% S remain in the remaining vegetative parts of the plant. Straw is also an important source of essential nutrients such as zinc (Zn) and silicon (Si).

C. Specimen Making

For wood powder, used only sengon wood powder without mixture of other wood powder. The wood powder is sifted or separated from the remaining scraps or pieces of wood to produce fine wood powder and used rice straw that has become smaller pieces is dried in the sun for 10 hours. There are 6 variance of specimen that conducted in this experiment :

1. Specimen 1 (66% sengon wood sawdust; 28% rice straw; and 6% PVAc adhesive)
2. Specimen 2 (66% sengon wood sawdust; 28% rice straw; and 6% PVAc adhesive)
3. Specimen 3 (66% sengon wood sawdust; 28% rice straw; and 6% PVAc adhesive)
4. Specimen 3 (66% sengon wood sawdust; 28% rice straw; and 6% Polyurehane adhesive)
5. Specimen 4 (66% sengon wood sawdust; 28% rice straw; and 6% Polyurehane adhesive)
6. Specimen 5 (66% sengon wood sawdust; 28% rice straw; and 6% Polyurehane adhesive)

Presuure is applied in specimen. Press the specimen until solid and shaped according to the mold used. The pressure used is 1: 5, for example in the manufacture of specimens for this thermal conductivity testing it takes a specimen size of 79.5 cm^3 or equal to 79.5 milliliters, so the amount of mixture to be prepared is 397.5 milliliters or five times the size required. Then solidify the mixture to a size of 79.5 milliliters or the size of a mold. Drying is carried out for 7 days or until the specimen is completely dry.

D. Specimen Testing

1. Density Test

Specimen for density measurement has size 5cm ×5cm×2 cm. Mass measurements were made by weighing the specimens using the scales. Then do the density calculation using equation (1).

$$\rho = \frac{m}{V} \quad \text{.........} (1)$$

Where : ρ = density (gr/cm^3)
m = mass of specimen (gr)
V = volume of specimen (cm^3)

2. Thermal Conductivity Test

The specimen should have a flat surface on the top surface and the base of the specimen, so that the reading of the device is more accurate, then the specimen should be given 2 slits to place the thermocouple, the thermocouple will be placed on the top surface of the specimen and the side of the specimen. Specimens for thermal conductivity testing provided a basin the size of a thermocouple reaching the center of the specimen or along the specimen's radius. The shape and size of the specimen for thermal conductivity testing is shown in **Figure 3** and **Figure 4.**

Thermal conductivity test in this thesis is based on ASTM E 1225 - Standard Test Method for Thermal Conductivity of Solids by Means of the Guarded Comparative-Longitudinal Heat Flow Technique. Specimen were inserted between two similar loads of

TABLE 1.
THERMAL CONDUCTIVITY OF COOPER

Material	Thermal Coductivity (W/mK)		
	300 K	400 K	500K
Pure Cooper	401	393	388

known thermal properties material (cooper) . Under equilibrium conditions, the thermal conductivity is derived from the temperature gradient measured in each specimen and the thermal conductivity of the reference material (conductor). The first step is to calculate the conductivity value of the thermal conductor based on the thermal conductivity value of copper seen in TABLE 1.

The calorific value of copper can be calculated using the equation (2)

$$Q_t = \frac{K_t \times A_t \times \Delta T_t}{L_t} \quad \text{………. (2)}$$

Where : Q_t = Heat in Cooper (W)
K_t = Thermal Conductivity of cooper (W/mK)
A_t = Area of Cooper Surface (m^2)
ΔTt = Temperature differences (°C)
L_t = Length of cooper (m)

In this experiment it is assumed that the amount of incoming heat (heat in copper) is equal to the amount of heat that comes out (heat on the specimen).

$$Q_{in} = Q_{out}$$

$$Q_{cooper} = Q_{specimen}$$

The amount of incoming heat (Qt) which can be calculated by equation (2), the thermal conductivity of the specimen can be searched by equation (3)

$$K_{sp} = \frac{Q_{sp} \times L_{sp}}{A_{sp} \times \Delta T_{sp}} \quad \text{………. (3)}$$

Where : Q_{sp} = Heat in Cooper (W)
K_{sp} = Thermal Conductivity of specimen (W/mK)
A_{sp} = Area of Specimen Surface (m^2)
ΔT_{sp} = Temperature differences (°C)
L_{sp} = Length of specimen (m)

E. Coolbox Making

At the data collecting for density and thermal conductivity stage, the best insulation material from various variations of mixture composition between Sengon sawdust (Paraserianthes falcataria (L.) Nielsen) and straw was specimen 3 with 66% of sengon wood, 28% straw, and 6% polyurethane. Cool box that will be made has dimensions as shown in **Figure 5.** For coolbox wall, resin and plywood are used as insulating coatings. The thickness of resin used is 1 mm and 4 mm plywood. While the insulation is as thick as 20 mm. Layers of coolbox wall shown in **Figure 6.**

F. Experiment

The experiment was done by comparing the performance between coolbox with sengon wood insulation and straw and coolbox made from Styrofoam. Sea fish is used as a cooling load, which is a type of tuna fish with a mass of 400 grams and also incorporated ice flake with a mass of 2.0 kilograms. Two observations will be made:

1. Cooling time

Conducted observations of the coolbox containing fish and ice wet until the coolbox space reaches 20 ° C. Temperature 20 ° C is used because at this temperature the fish can be said in fresh condition.

2. The lowest temperature that each coolbox can achieve.

In this experiment conducted the lowest temperature observations that can be achieved coolbox within 24 hours. Observation is done 30 minutes. With observation point:

- Point 1, located beneath the surface of ice
- Point 2, inside the fish body
- Point 3, located in the coolbox space

G. Data Analysis

From these data, it is analyzed based on the maximum cooling time and the lowest temperature achieved during the cooling process from both modified cool boxes and styrofoam or cork cool boxes. In the cooling time analysis of the fish preservation there will be a limit where until the fish temperature is at 20 ° C .As for the observation of the lowest temperature that can be achieved, will be observed for 24 hours with recording done every 30 minutes.

Figure 1. Specimens for Density Test

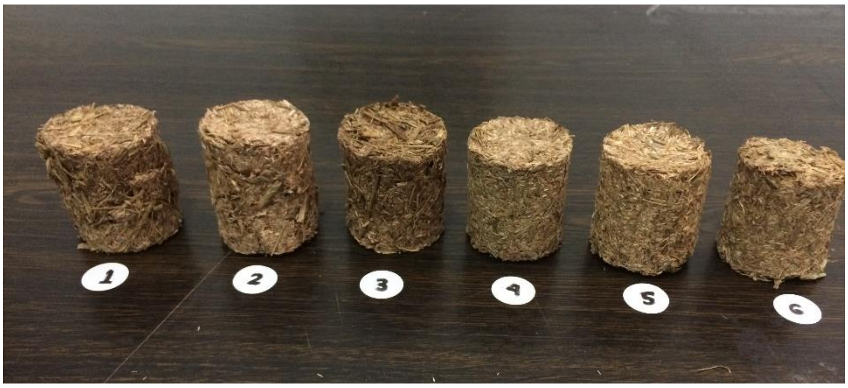

Figure 2. Specimens for Thermal Conductivity Test

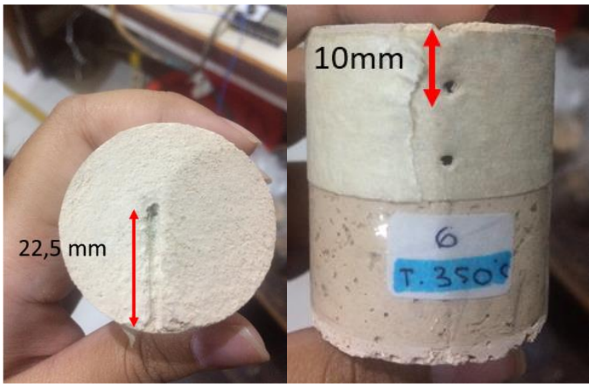

Figure 3. Specimen Preparation for Thermal Conductivity Test

Figure 4. Specimen Size for Thermal Conductivity Test

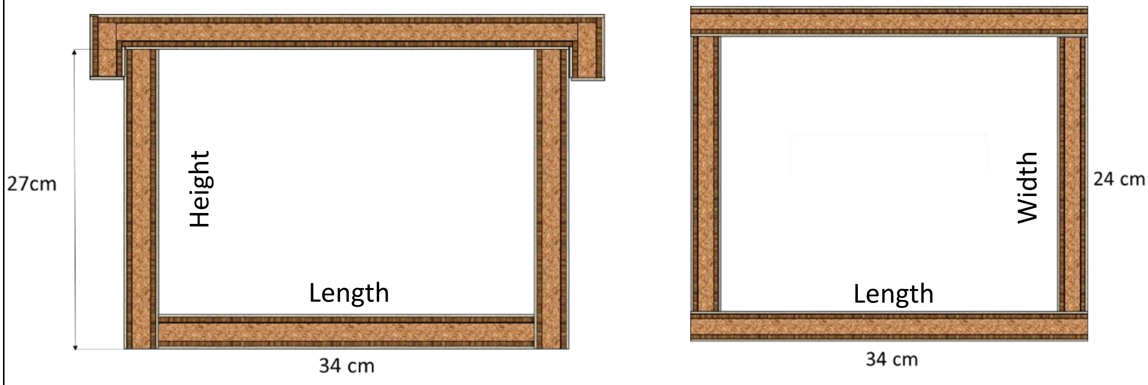

Figure 5. Coolbox dimension

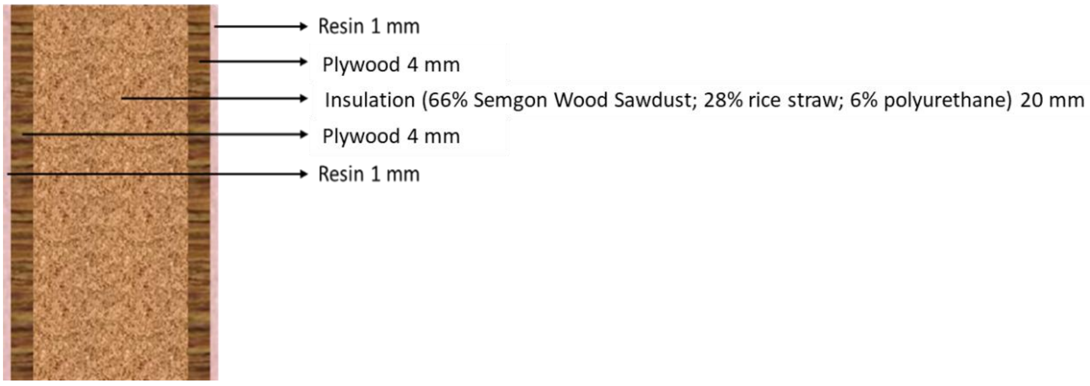

Figure 6. Layers in Coolbox Wall

TABLE 2.
DENSITY TEST RESULT

Specimen Number	Mass (gram)	Volume (cm^3)	Density (gr/cm3)
1	17	50	0.34
2	18	50	0.36
3	19	50	0.38
4	19	50	0.38
5	20	50	0.40
6	22	50	0.44

TABLE 3.
THERMAL CONDUCTIVITY TEST RESULT

Specimen Number	Thermal Conductivity (W/mK)
1	0,546101774
2	0,638683946
3	0,596418937
4	0,541414231
5	0,659583221
6	0,616567105

III. RESULTS AND DISCUSSION

A. Thermal Conductivity of Specimen Test Result

The conclusions of data collecting on the thermal conductivity of the specimens were, Specimen 4 or specimen with 66% composition of sengon wood, 28% rice straw with 6% polyurethane adhesive have the smallest thermal conductivity compared to other specimens, with a value of 0.54 W / mK. Can be seen on TABLE 2 specimens containing 66% of sengonwood powder and 28 % rice straw have smaller thermal conductivity than specimens containing 47% sawdust and 47% straw, as well as specimens containing 28% of sengon wood and 66% rice straw. From the thermal conductivity data obtained, can not be drawn conclusions about the best adhesive to be a mixture of insulation. In specimens containing 66% sengon wood and 28% straw, specimens with polyurethane adhesive had a smaller thermal conductivity value than the specimen with PVAc glue adhesive. As for the specimens containing 47% of sengon wood powder; 47% straw and specimens containing 28% sengon wood powder; 66% rice straw, the thermal conductivity value of specimens with PVAc adhesive is smaller than the specimen with polyurethane adhesive. The conclusion in the thermal conductivity test of this specimen, a specimen with the smallest thermal conductivity is specimen 4 or specimen with a composition of 66% sengon wood, 28% straw with 6%polyurethane adhesive has the smallest thermal conductivity compared to other specimens, with a value of 0.54 W / mK.

B. Density of Specimen Test Result

From the calculation of the density, can be seen that the specimen 1 with the composition of 66% sengon wood powder and 28% rice straw with 6% polyvinyl acetate adhesive (PVAc) has the smallest density of 0.34 gr / cm3, then specimen 2 with composition 47% of sengon wood powder and 47% straw with 6% polyvinyl acetate adhesive (PVAc) has the second smallest density of 0.36 gr / cm3, specimen 3 with a content composition of 28% sengon wood powder and 66% straw with 6% polyvinyl acetate adhesive (PVAc) has a density equal to specimen 4 with a composition of 66% sengon wood powder and 28% straw with 6% polyurethane adhesive of 0.38 gr / cm3, specimen 5 with a composition of 47% sengon wood powder and 47% straw with 6% polyurethane adhesive material having density of 0.40 gr / cm3, specimen 6 with a composition of 28% sengon wood powder and 66% straw with 6% polyurethane adhesive having a density of 0.44 gr / cm3 having the largest density.

From the density of the specimen calculation obtained, it can be seen that more rice straw content specimens will have a larger density than specimens containing more sengon woodpowder. Can be seen also with the same composition of sengon and strawwood powder, specimens with polyvinyl acetate adhesive (PVAc) have a density smaller than those of polyurethane adhesives.

C. Experiment Result

The experiment is done by filling the coolbox with wet ice and tuna fish. The comparison between fish and wet ice used in this experiment is 1: 5, where fish mass is 400 grams and 2000 grams of wet ice. With this comparison, the whole body of the fish has not been covered with wet ice. Wet ice covers the entire bottom surface of the fish but on the top surface of wet ice is only in the body to tail, the head not covered with wet ice.

In this experiment, there are three temperature observation points in the coolbox. Point 1 is at the bottom of the coolbox, used to measure the temperature of the wet ice inside the coolbox, point 2 is in the fish body by piercing the fish and inserting the thermometer inside, and point 3 is on the coolbox wall used to set the coolbox room temperature.

Figure 7. explains graph of temperature change at point 1, which shows the change of ice in the coolbox with the insulation of sawdust sengon wood and straw and coolbox with the insulation of styrofoam. In the 0th minute or first data retrieval, coolbox with sengon sawdust and sawdust insulations indicates that the wet-ice temperature is -0.1 ° C, the temperature is smaller than the wet ice temperature of the styrofoam coolbox of 0.1 ° C. This condition continues until the 60th minute, where the temperature of wet ice inside the coolbox with the insulation of sawdust sengon and straw is lower than the coolbox with Styrofoam insulation. Then in the 90th to 150th minute, both coolboxes have the same temperature at point 1. The initial condition occurs again in the 180 to 240 minutes, the coolbox with the insulation of sawdust sengon and the hay shows a lower temperature. The temperature difference in the two coolboxes is not too large, the average difference between the two temperatures is 0.2 ° C.

After 1050 minutes, thermometer on the coolbox with insulation sawdust sengon wood and straw shows lower numbers than coolbox with Styrofoam insulation. Until 48th, the thermometer in the coolbox with sawdust and sengon sawdust still shows lower temperatures on wet ice. Of the 48 wet ice temperature data retrieval times in the coolbox, 19 data showed wet ice temperatures in the coolbox with sawdust sawdust and straw insulation lower than temperatures in coolbox with Styrofoam insulation, and as many as 29 data indicated that temperatures in the coolbox with Styrofoam insulation is lower as seen in **Figure 7**. Thus, from overall temperature data retrieval at point 1 or temperature on wet ice, coolbox with Styrofoam insulation is superior to coolbox with sengon sawdust and rice straw insulation.

Point 2 is inside the fish body. In this experiment used tuna fish with mass 500 grams then perforated in the middle of the fish as a place to measure temperature. **Figure 8.** shows temperature changes in the fish body inside the coolbox with insulation of sawdust sengon wood and straw and coolbox with Styrofoam insulation. The fish put in the coolbox has the same temperature as the ambient temperature, so it can be seen in the first take of the fish at a temperature that is not too low. In coolbox with sengon sawdust insulation and straw the initial temperature is 5.1 ° C and in coolbox with styrofoam insulation of 3.4 ° C. Then at the second data collection or at minute 30, there was a 0.9 ° C temperature drop in the coolbox with the insulation of sawdust pine wood and straw and 1.6 ° C on coolbox with Styrofoam insulation.The parameters used for comparison of the two coolboxes are preservation time until the temperature shows 20 ° C. In coolbox with sawdust sawdust and sengon insulation, a temperature of 20 ° C is seen exactly at 900 minutes or 15 hours after the first data retrieval. As for coolbox with new styrofoam insulation putting 20,6 ° C at minute 960 or 16 hours after taking the first data which previously 19 ° C at minute 930.

The observation point 3 is on the coolbox wall. The thermometer is mounted 10cm below the top surface of the coolbox to read the coolbox room temperature. **Figure 9.** shows the change in temperature of the coolbox space for 24 hours in the coolbox with insulation of sawdust sengon wood and straw and coolbox with Styrofoam insulation. In coolbox with sengon wood sawdust insulation and straw the initial temperature is 24.2 ° C and in coolbox with Styrofoam insulation of 20.2 ° C. The second temperature of the coolbox can be seen always in tandem with either a decrease or an increase in temperature. The most drastic decline in coolbox with sengon sawdust and sawdust insulation occurred in the 30th minute, where there was a temperature drop of 3.1 ° C where the wet ice began cooling the coolbox space. While on the coolbox with Styrofoam insulation also happened the most drastic decrease at minute 30, where there was a decrease of 1.5 ° C. Decrease in temperature continues until the data up to 14, the second coolbox slowly experienced a rise in temperature at 420 minutes or on the 15th data collection. At the point of observation 3, there is no difference in temperature is too large, the difference in temperature on both coolbox average of 1.26 ° C. Up to 960 turns, 3 point temperature on coolbox with sengon sawdust and straw insulation lower than coolbox with Styrofoam insulation up to 48 data retrieval. From all data collection there are 16 data showing room temperature inside coolbox with insulation of sawdust sengon and straw is lower than temperature in coolbox with Styrofoam insulation, and as many as 32 data indicates that temperatures on coolbox with Styrofoam insulation are lower as seen in **Figure 9.**

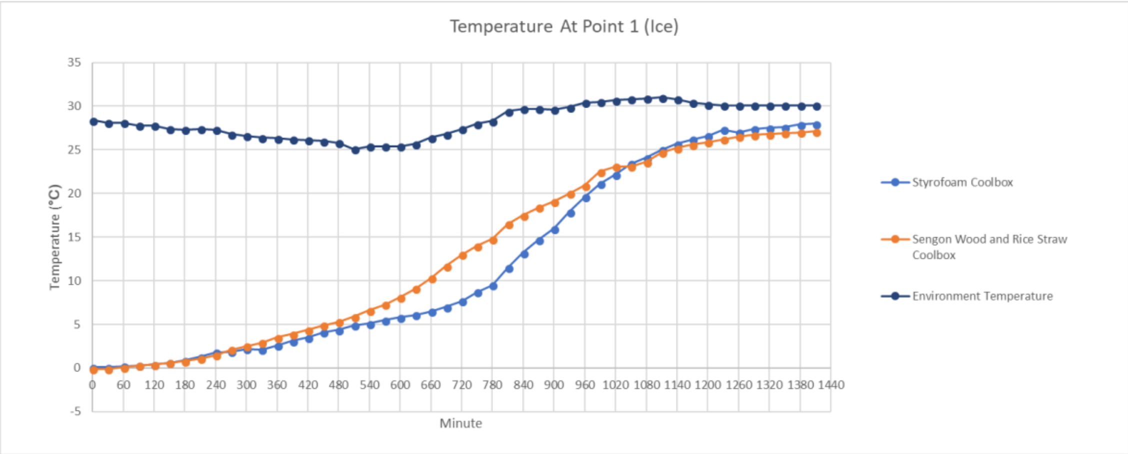

Figure 7. Graph of Temperature Changes at Point 1 (Ice)

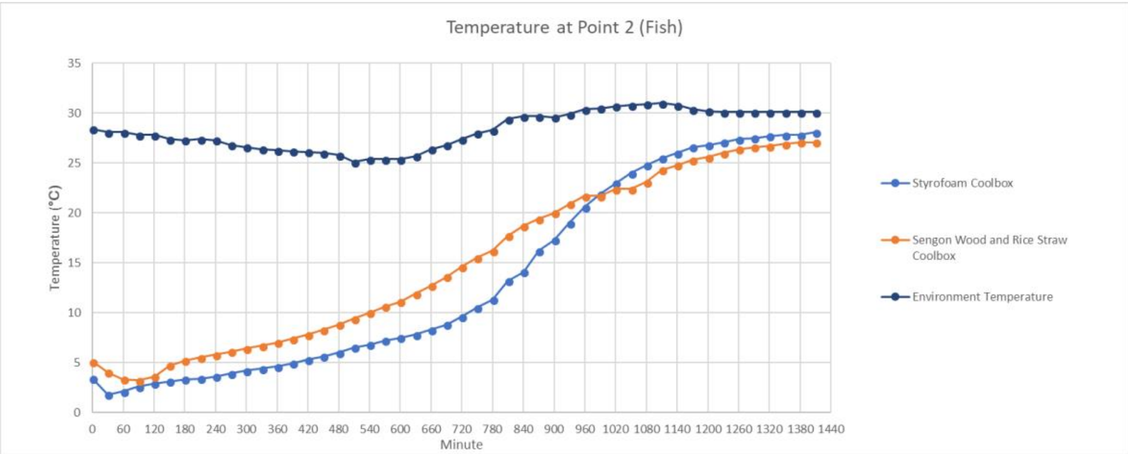

Figure 8. Graph of Temperature Changes at Point 2 (Fish)

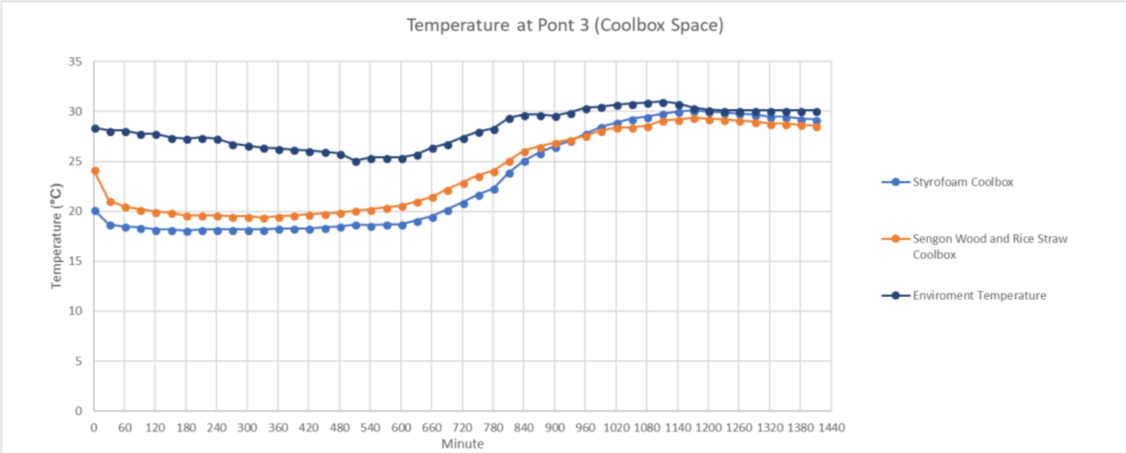

Figure 9. Graph of Temperature Changes at Point 3 (Coolbox Space)

Temperature changes has been observed at some point in the coolbox with sawdust of sengon and rice straw and comparing the temperature change and duration of fish preservation with styrofoam coolbox, it is concluded that coolbox with insulation of sawdust sengon and straw is no better than coolbox with styrofoam insulation. From the rate of temperature change, Styrofoam coolbox is able to maintain better temperature than coolbox with the insulation of sawdust sengon wood and straw. Although at ambient temperatures above 30 ° C coolbox with Styrofoam insulation has increased temperature significantly while coolbox with sengon sawdust and straw insulation tend to be better in maintaining temperature inside coolbox, but overall experiment coolbox with Styrofoam insulation is superior to coolbox with insulation of sawdust sengon wood and straw.

The thermal conductivity of the material greatly influences the heat transfer process, the thermal conductivity of the sengon sawdust and the hay used in the coolbox has a value of 0.54 W / mK while the styrofoam thermal conductivity has a value of 0.3 W / mK. So it can be concluded that styrofoam has better insulator properties.

IV. Conclusion

Insulation with base material sawdust sengon wood and rice straw used for making coolbox has composition 66% sengon wood sawdust, 28% rice straw, and 6% polyurethane adhesive. After conducting insulation thermal conductivity testing, the result is 0.54 W / mK. The insulation of the sengon wood powder and the straw used in the manufacture of coolbox has a density of 0.38 gr / cm^3. The addition of polyurethane adhesives below 6% can not be done because it causes sengon sawdust and straw can not bind well.The experimental results on the coolbox show a temperature of 20 ° C on the 31^{st} data retrieval meaning that coolbox with sengon sawdust and rice straw insulation able to preserve fish for 15 hours, with weight ratio between fish with wet ice of 1: 5. The minimum temperature that the coolbox can achieve is -0.1 ° C at point 1 or below the wet ice surface in the first thirty minutes after the fish and wet ice are included in the coolbox. At point 2 or on the fish body, the lowest temperature that can be reached is 3.2 ° C at 1 hour 30 minutes after the fish and ice are included in the coolbox. While in the coolbox room or point 3, the lowest temperature is 19.4 ° C at 5 hours 30 minutes after the fish and ice are included in the coolbox.

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