Journal of Forests
2021 Vol. 8, No. 1, pp. 79-87.
ISSN(e): 2409-3807
ISSN(p): 2413-8398
DOI: 10.18488/journal.101.2021.81.79.87

COMPARATIVE ANALYSIS OF THERMAL RETENTION CAPACITY OF ICE CHEST WOOD COOLER STANDS MADE FROM *Pinus Caribeae and Nauclea Diderichii*

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Article History
Received: 20 January 2021
Revised: 26 February 2021
Accepted: 30 March 2021
Published: 28 April 2021

Keywords
Thermal retention
Ice chest cooler
Pinus caribeae
Nauclea diderichii
Thaw rate
Temperature loss.

ABSTRACT

The efficacy of a cooler or ice chest is measured by its preservative potentials, and how long it can make substance such as food and drinks remain hot/cold. In ensuring that an ice chest meets up to its expectation, this work investigated the construction, thaw rate and heat retention capacity of an ice chest cooler stands made from *Pinus caribeae* and *Nauclea diderichii* wood, with a view of improving its ability to maintain hotness/coldness of any substance stored in it for a longer period of time. The wood samples were machined and fabricated into a cooler stand in which plastic coolers were placed. 10kg mass of Ice block (0°C) and hot water (100°C) were used for the two tests considered in this study. Meanwhile, an ordinary cooler was used as a control. Weight reduction and thermometer were used to measure the thaw rate of the ice block and temperature loss of the water. For the ice block test, 6kg (1.8°C), 5kg (0.20°C) and 3kg (0.22°C) of ice block were left after 8 hours, while for the hot water test, water temperatures were 45°C, 25°C and 18°C after 12 hours for ice chest made from *N. diderichi*, *P. caribaea* and control respectively. The thaw rate and temperature loss was lowest for ice chest made with *N. diderichi*, thus implying that *N. diderichi* wood is a better choice for making wooden cooler stand. This study thus confirms that wood can be used to improve thermal retention capacity of ice chest cooler.

Contribution/Originality: This study is one of the few studies which have investigated the reinforcement of existing plastic cooler with wooden structure. With the aim of reducing more energy bills through constant refrigeration, this ice chest cooler will help in optimum temperature retention when cooling and heat is required.

1. INTRODUCTION

Wood is porous, as such; it has low thermal conductivity, with high thermal resistance and specific heat capacity, which are important characteristics needed in designing materials with great resistance to heat flow Ramirez-Rico, et al. [1]. Radmanović, et al. [2] stated that wood as a porous biomaterial contain small holes and spaces that can influence the mechanism of heat transfer (thermal conductivity) and specific heat capacity. The Thermal properties of wood is an essential properties considering area where they are needed in applications such as fuel conversion, building construction, and other areas of industry [3, 4]. Previous Knowledge on thermal properties of wood has helped to understand and designed model of heat transfer processes in wood and wood-products based materials. Thermal conductivity is a critical attribute when offering energy conserving building products which can be due to the fact that wood has excellent heat insulation properties [5].

The ability of a substance to resist the passage of heat, electricity, or sound can be of great advantage. Dry wood is one of the poorest conductors of heat and this characteristic renders it eminently suitable for many of the uses to which it is put every day, e.g. as a building material, as internal wall paneling, sheathing in timber-frame house construction, or external wall cladding, and as handles of cooking utensils [6].

Temperature measures the degree of hotness or coldness of a substance [7]. Products such as cooler, portable ice chest, ice box, cool box, chilly bin (in New Zealand), or esky (Australia) is used to preserve food or drink. Food and drinks are most commonly placed in these products to help the contents inside remain hot or cold for a longer time. These products are often used on picnics and on vacation or holiday. They are also used for getting cold groceries home from the store, such as keeping ice cream from melting in a hot automobile. Even without adding ice, this can be helpful, particularly if the trip home will be lengthy. Some coolers have built-in cup holders in the lid. They are usually made with interior and exterior shells of plastic, with hard foam in between. They come in sizes from small personal ones to large family ones with wheels [8].

In most developing countries, forest tree seeds, food grains, fruit, vegetables, meat, poultry and fish, are very susceptible to microbial contamination and spoilage. These valuable perishable food stuffs require stringent preservation methods. One of such method is the use of ice chest freezer/cooler for the storage of food Veitmans and Grinfelds [9]. Handry, et al. [10] in his study, stated that after harvesting, forestry products like seeds and fruits, horticultural products, as well as cooked foods suffer quality degradation with time, if not properly preserved. This is because after the harvest, plants still undergo respiration and transpiration, and if not properly stored, it loses water and withers away. Likewise, foods and drinks do lose their value with time as this makes them depreciate in terms of taste, quality and appearance.

Food and drink preservers have been found to be mostly built with non woody materials like plastic, iron, Aluminum, steel, e.t.c, and as such an attempt to develop cost-effective and practical systems to reinforce existing plastic cooler with wooden structure for specific purpose of thermal retention including wall constitutions, and sheathings will go a long way to give optimum utilization of wood and possible combination with plastic if studied. It was on this bases, that this study was carried out to produce ice chest cooler from two indigenous wood species; *N. diderichii* and *P. caribaea* wood with a view to determine their thermal retention capabilities for utilization.

2. MATERIALS AND METHODS

2.1. Materials Collection

One 21-inch of *N. diderichii and P. caribaea* were felled from Ibuso-gboro village, Onigambari forest road along Ibadan-Ijebu-ode road, Ibadan, Oyo State, Nigeria. It is located on latitude 7° 25'N and Longitude 3° 55'E within the low and semi-deciduous forest belt of Nigeria. The topography of the area is generally undulating, lying at altitude between 90m and 140 meter above sea level [11]. The felled trees were processed and cut into 8 feet length. Other materials include Four (4) ½-inch brass double female connector; 30 foot tape for measurement; Bar clamps for bringing wood together ; Counter sink drill bit of size 1/8" for drilling hole joint; circular saw for cutting boards to required pieces; Screw driver; thermometer for measuring temperature differences in the ice chest cooler.

2.2. Materials Preparation

The logs were taken to the Wood processing Unit of the Department of Forestry Resources Management, University of Ibadan, Nigeria. The logs were sawn into planks of size 2" × 4" × 8' using MJ329Z trolley type of vertical wood cutting band saw machine. The wooden planks were later taken to the Industrial Development Unit of the Department of Forest Products Development and Utilization, Forestry Research Institute of Nigeria, Ibadan.

The wooden planks were cross-cut into wood pieces based on the designs layout in Figure 1 using circular saw machine of model Royek PK 300. The wood samples were stacked and conditioned at 27±2°C and 65±2 % relative humidity until their weights became stable by holding them for 10 weeks in a conditioning room. Afterwards, when the moisture content of test samples reached an average of 15%, the sawn woods were planned using Martin T51 surface planer machine. The construction of wooden cooler stand was done in accordance with Prowood [12].

2.3. Making the Frame for the Box Bottom

Miter saw was used to make straight cuts per the cut list. Long bar clamps was used to hold the box's four frame boards together, with the short ones between the long ones. A ⅛-inch combination countersink bit was used to drill two pilot holes at each joint with the frame which later secured with 1½-inch nails (Figure 2).

2.4. Slats installation for the Box Bottom

One slat was placed inside the frame and against its edge. Two pilot holes were drill through the face of the frame and into each end of the slat which were secured it to the frame with 1½-inch nails. Two more nails were added into the edge of the slat. Slat was also installed at the opposite edge in the same way.

2.5. Setting of the Bottom

The box bottom was set on the edge, while the first slat was lap over the inside of the frame. This was done at about 1 inch from a corner. The combo countersink was used with a bit to drill two staggered pilot holes so as to secure the slat with $1^{1/2}$-inch deck nails. The adjacent slat was attached using a spacer to create consistent gap. This was done till all the side slats are installed (Figure 3).

2.6. Assembling of Shelf Planks and Siding Panel

Twenty (20) planks of size 1" x 4" x $14^{1/2}$" siding panels were attached to the outside of the top and middle aprons using $1^{1/4}$" galvanized nails for each joint. Proper care was taken to ensure that the top and bottom edges of the panels and aprons were flushed with each other (Figure 4).

2.7. Making the Corners for the Box

One corner board was clamped in a place ensuring that it rest on the top edge of the frame and ¾ inch shy of the corner. The adjacent corner board was placed overlapping at the edge of the clamped board, and combo bit was used to drill pilot holes through its face and into the first board's edge, at the top and bottom. The corner was secured with 1½-inch nails. Then, the inside of the box was nailed with 1¼-inch nails to secure through the corner slats and into the corner boards. This was repeated for the remaining corners.

2.8. Cap Installation for the Box

Countersinks and pilot holes were drilled through the face of the cap piece and into the tops of the slats and corner boards. This was secured with 1½-inch deck screws. This was followed by installing the other long cap piece and two short ones between the long ones (Figure 5).

3. RESEARCH PROCEDURE

3.1. Temperature Retention Test – the Ice Block Test

Prior to testing, the ice chest cooler was brought to the experimental room so as to acclimatize the cooler to room temperature 7 days before use. 10 kg of 0 °C ice block were weighed and separately put into two prepared wooden ice chest coolers and ordinary plastic cooler which serve as the control. Temperature was measured and monitored with a mercury thermometer through a hole made on the wooden chest cooler and the control; this is done to avoid opening of the ice chest and cooler which may result in heat loss to the environment during measurement, as such, all the cooling boxes were closed. The holes made on the boxes were all lagged with cotton wool to prevent air/heat loss from the boxes. The cooler lids were closed promptly as opening and closing were reduced so as to keep the ice longer for the experiment. Respective thermometer readings and observations were made at every 2 hours for 6 consecutive periods to make 12 hours. The thaw rates of the ice blocks were determined from weight reduction of the ice blocks.

3.2. Temperature Retention Testing – the Hot Water Test

The wooden ice chest cooler produced was tested through pouring of boiled water (100 °C) and covered to assess the heat retention of the cooler for a period of 480 minutes (8 hours). The assessment was done through the use of 250 °C calibrated mercury thermometer. The measurement for heat retention was carried out at an interval of 30 minutes till the readings were constant. This procedure was carried out for the two wooden ice chest cooler boxes and the control. Hence, the differences in the temperature retention for the period assessed (480 minutes) were recorded.

3.3. Data Analysis

The data gotten from the experiments were subjected to Analysis of Variance (ANOVA). The follow up test was conducted to know the difference between the means using the Duncan Multiple Range Test (DMRT) at 5% probability levels.

4. RESULT AND DISCUSSION

4.1. Hot Retention Capacity– the Hot Water test

The result of hot water retention capacity of wooden ice chest coolers with that of control after 450 minutes was illustrated in Figure 6. It was observed that wooden ice chest cooler made from this study responded differently with time. The result shows that after 450 minutes of hot water exposure, the least temperature recorded was 18 °C for the control (plastic cooler without wooden stand) followed by 25 °C for *P. caribeae* ice chest cooler while the highest value recorded was 40 °C for *N. diderichii* ice chest cooler. The outcome of the result indicates that *N. diderichii* wood retained heat energy more than *P. caribeae* (Figure 6). This observation reveals that each wood species does react differently to hot water and this difference could be as a result of individual characteristics such as density, extractives and anatomical structures of each wood species. It was observed that ice chest coolers made from *N. diderichii* of higher density (650 kg/m^3) had higher heat retention capacity than *P. caribeae* of density 450 kg/m^3.

The outcome of the result also implies that *P. caribeae* had higher heat flow, thus supporting [3] who from its findings stated that density of wood can influence heat flow in wood and this implies that high density wood has good heat retention capacity. The heat retention capacity of wood can also be attributed to wood porosity, and its paucity of free electrons which are responsible for easy transmission of energy. It has been proven that the directions of heat flow through wood can vary with respect to the grain, density, quantity of extractives, defects, and moisture content [13, 14]. This result agree with previous findings that stated that wood is a poor conductor of heat and good natural insulator. This attribute has made wood to be 15 times better than masonry, 400 times better than steel, and 1,770 times better than aluminum [15].

4.2. Cold Retention Capacity – Ice Block Test

The result of temperature retention of ice chest cooler after a 12 hours (720 minutes) observation was presented in Figure 8. The values obtained for temperature of the ice block for ice chest cooler made from *N. diderichii*, *P. caribaea* and control ranged from 0.43 °C to 1.8 °C, 0.20 °C to 1.6 °C and 0.22 °C to 1.58 °C, thus representing a temperature gain of 76%, 88% and 86% respectively. The results (Figure 7) show that heat gain was least (76%) for ice chest cooler made from *N. diderichi* followed by value obtained from control (86%). The result gotten from these wooden stands compared favorably with the control ice chest cooler. Meanwhile ice chest cooler from *N. diderichi* wood compared best. This therefore implies that cold retention capacity of ice chest cooler made from *N. diderichi* wood was best due to its least heat gain.

Figure 7 shows that at 0 °C and 10kg mass of ice block during the cold measurement, the temperature drops at a lower rate for all temperature measurements for the period of 12 hours. This temperature gain might be due to change in phases from ice to vapor and to gas (sublimation process) and partly from solid to liquid or melting [10]. Values of temperature obtained after the experiment from the two ice chest samples indicate that ice chest made from the wood species had a better temperature retention capacity compared with the control. This could have been as a results of anatomical structure, density and moisture content characteristics of wood.

The weight reduction of the ice block after 12 hours was significant. For ice chest made with *N. diderichii*, the observed weight after 12 hours was 6kg, while that of *P. caribaea* was 5kg and the control 3kg. This shows that *N. diderichii* had the least thaw rate, thus implying that ice chest cooler made from this wood species can retain and maintain the temperature of a cold substance for a longer time as compared with *P. caribaea* and the control which had the highest thaw rate.

The temperature examined during this experiment could be of an assistant during the harvest period because, temperature usually are the causes of spoilage during harvest. Rapid cooling will minimize the effects of temperature thus minimizing the decay. Pathogenic bacteria will grow very slowly at temperatures below 0 °C and other decaying fungi do not grow at temperatures below 5 °C. The purpose of post-harvest handling of seeds that are recalcitrant and fruits could be savor as the wooden frame will helps to minimize respiration and transpiration, reduced wound infection that might arise during movement consequently prolong storage periods. It is also interesting to note that the wooden frames made from the two wood species used in this study has also serves as an insulation materials in the walls of the plastic cooler causing reduction in the amount of heat that enters the container and so reduce the amount of ice needed to keep the cooler chilled.

Table-1. Analysis of variance (F ratios) for thermal retention of ice chest cooler after 8 and 13 hours of hot water and ice block exposure respectively.

		T	SP	T*SP
Hot temp. retention	Sig. at 5 % level of probability	249.92*	24.73*	2.41*
Low temp. retention	Sig. at 5 % level of probability	44.22*	7.15*	0.46*

Note: *=Significant at 5% probability level (P≤ 0.05); T = (Time of observations); SP; wood Species.

The result of the analysis of variance Table 1 shows that hour of exposure, wood species and the interactions significantly influence the thermal retention capability of the ice chest produced.

5. CONCLUSION

Wooden ice chest cooler was successfully produced from *N. diderichii* and *P. carribeae* which shows their suitability for ice chest cooler production. The two wood species used to produced stands for this ice chest cooler shows a considerable positive effects on the ice chest cooler as they shows greater value in hot water retention after a considerable longer hour of examination (8 hours) when compared with the conventional cooler (control). The ice block test also indicates that the ice chest cooler can retain ice block for a period of 12 hours with high significant of retention of ice temperature.

The result in this study also shows that through the use of wooden frame as a reinforcing material, the amount of heat loss through the wall of the plastic ice chest cooler can be reduced, owing to the significant amount of ice that melted in the control over the period of examination, as such, improving on the efficiency of the icing process. Ice is used up when it removes heat energy from the materials surrounding it and also from heat energy leaking through the walls of the cooler. This cooler can be useful in the area of storage and for travel purposes to preserve vegetables, fruits and food items. As a result of this thermal retention performance of the wooden ice chest cooler produced, less energy to heat and cooling is required, which could assist in reducing energy bills.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Acknowledgement: All authors contributed equally to the conception and design of the study.

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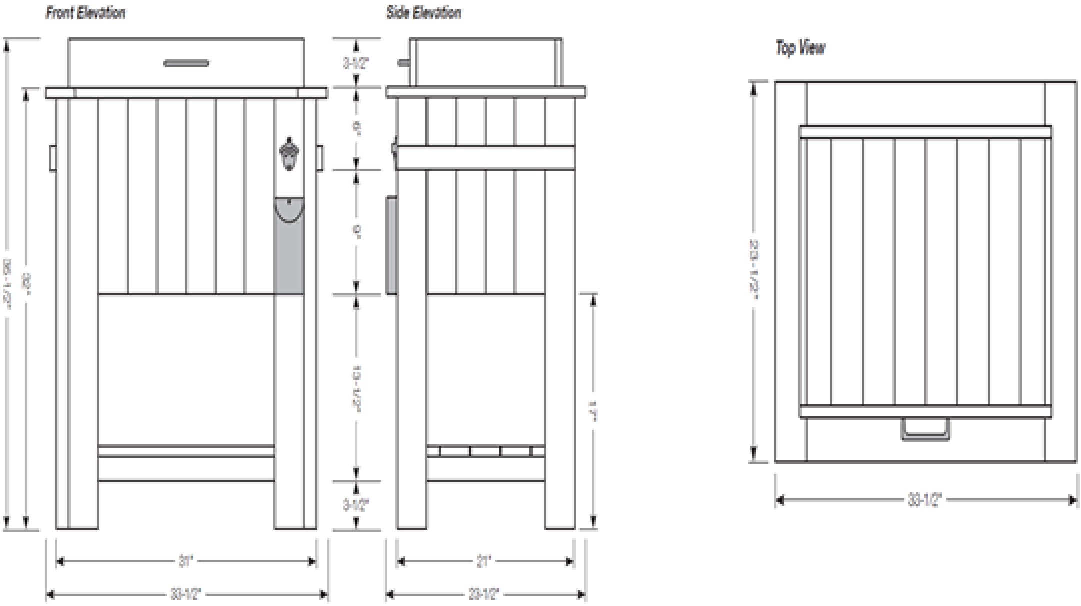

Figure-1. Front, side and top view elevation of the ice chest box [12].

Source: Prowood [12].

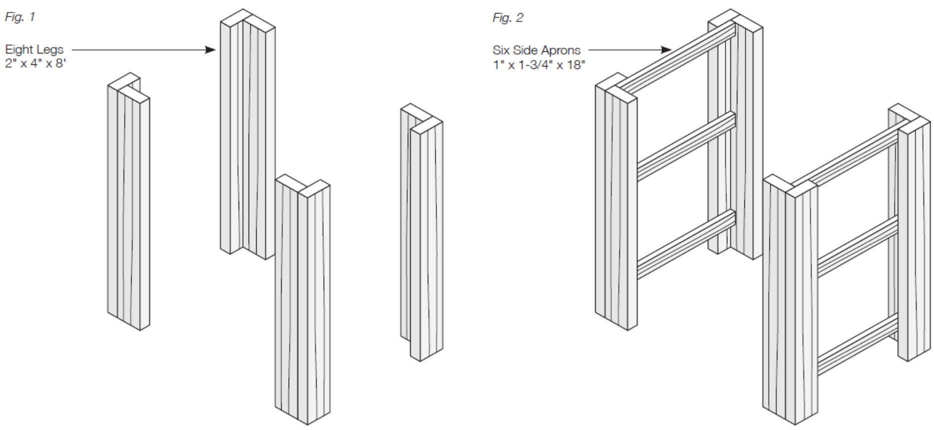

Figure-2. Assembling of legs and side aprons [12].

Source: Prowood [12].

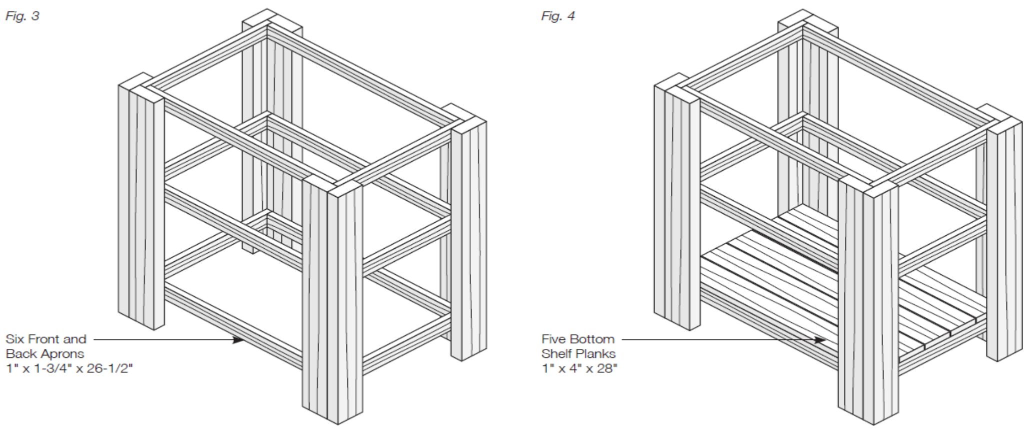

Figure-3. Installing front and back apron and bottom shelf planks [12].

Source: Prowood [12].

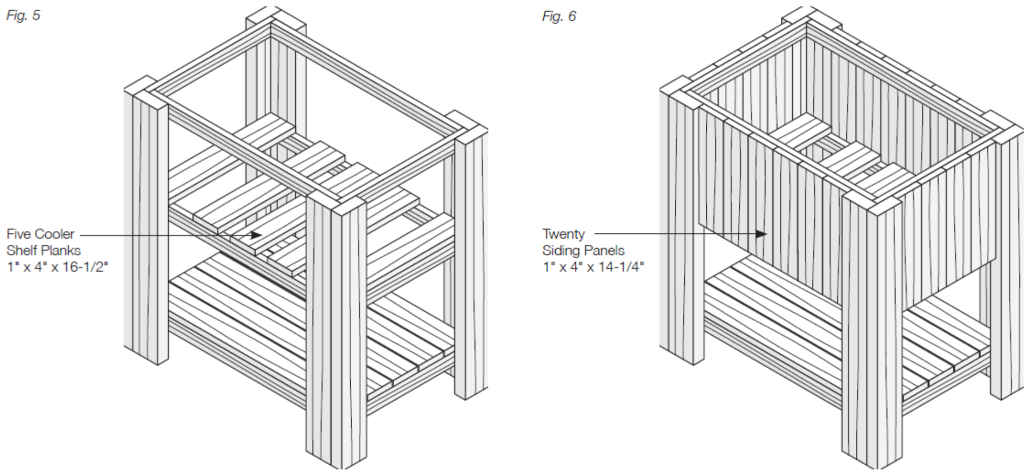

Figure-4. Assembling of shelf planks and siding panel [12].

Source: Prowood [12].

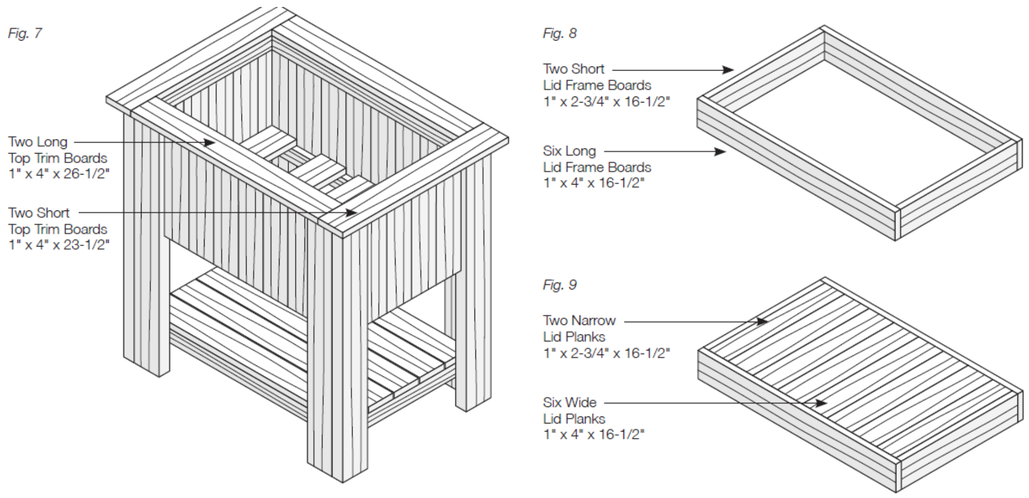

Figure-5. Assembling the top and frame boards [12].

Source: Prowood [12].

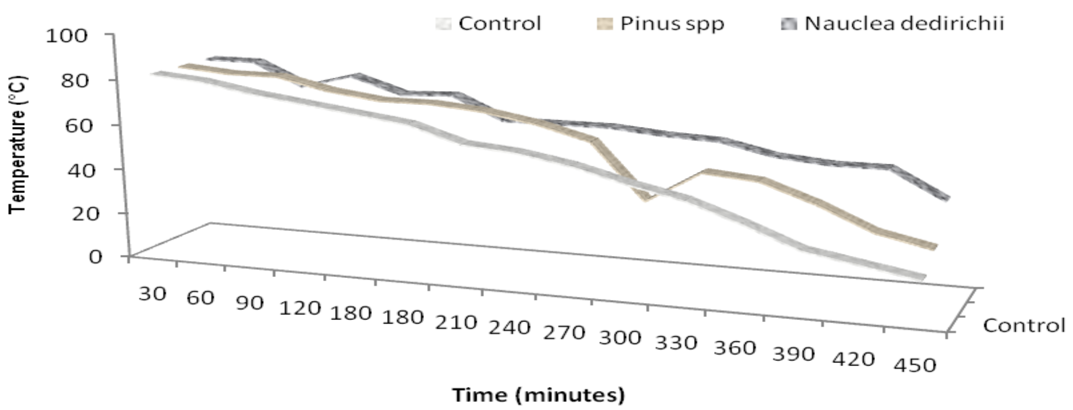

Figure-6. Temperature loss with respect to time.

Source: Prowood [12].

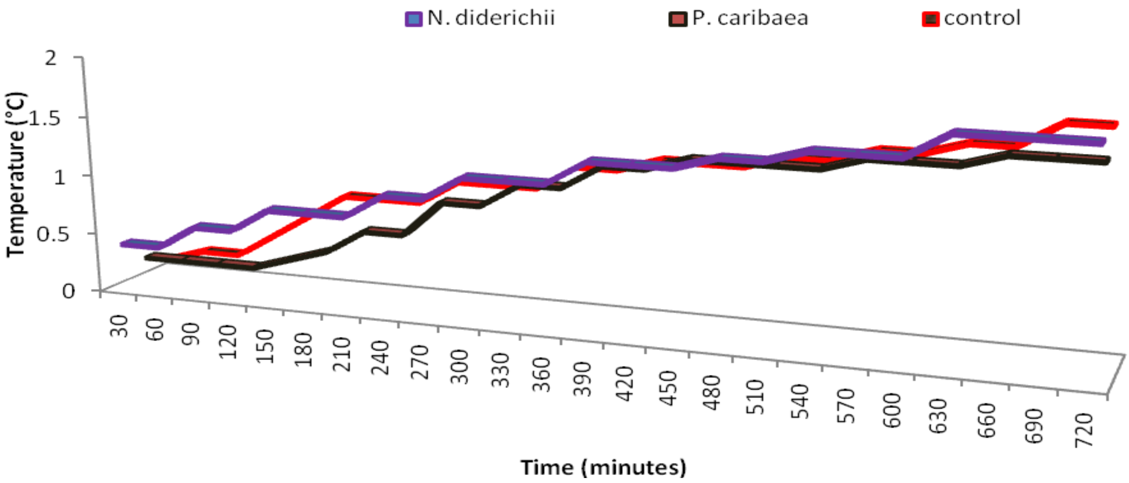

Figure-7. Temperature gain with respect to time.

Figure-8. Complete assembled stands ice chest wood cooler.