# THERMAL RESPONSE OF ICE CHEST COOLER REINFORCED WITH *Bambusa Vulgaris* Schrad. Ex J. C. Wendl

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**Abstract:**
*Cooling devices can be said to be efficient if its preservative potentials and retention capacity is high, this is exhibited in how long it can make substances such as food and drinks commonly placed in it remain hot/cold over a period of time. This study was then carried out to investigate the construction, thaw rate and heat retention capacity of an ice chest cooler stand reinforced and insulated with Bambusa vulgaris. The stems of B. vulgaris were cut, air dried, processed into strips and later use to reinforce a plastic cooler. A descriptive study was carried out with three replicates for each of the coolers (both bamboo insulated and the control). 5kg of Ice block and five (5) liters hot water (100$^0$C) were used and an ordinary cooler was used as a control. The thaw rate of the ice block was determined using the reduction in weight of the ice while the temperature loss of the water was measured using a well-padded thermometer inserted into the drilled hole on the ice chest. For the ice test, a maximum of 3kg (1.5$^0$C), and 1.5kg (3$^0$C) of ice block were left after 6 hours for the bamboo reinforced cooler and the control respectively, while for the hot water test, the highest water temperatures were 85$^0$C and 63$^0$C after 6hrs cooler reinforced with bamboo and the control respectively. The thaw rate and temperature loss was lowest for cooler reinforced with bamboo, thus implying bamboo as good reinforcing and insulating materials for ice chest cooler production.*

***Key words:*** *Thermal retention; Ice chest cooler; Bamboosa vulgaris; temperature.*

## INTRODUCTION

Thermal conductivity is a critical attribute when offering energy conserving structural products. This is due to the fact that wood has excellent heat insulation properties. Lower thermal conductivity values equate to greater heat insulating properties (Daniel 2010). Wood exhibits low thermal conductivity (high heat-insulating capacity) compared with materials such as metals (aluminum 204.3W/mK, iron 72.7W/mK), marble (2.08 - 2.94W/mK), glass (0.96W/mK), and concrete (1.7W/mK) (Samuel *et al*. 2012).

The importance of accurate and effective prediction of heat transfer processes in wood based products is increasing with respect to describing in-service behavior of the products especially for varying environmental conditions. Another problem related to heat transfer modeling is linked with manufacturing processes of the products, mainly due to the importance of the cooling phase. The problem of the specific heat measurements of wood based products has already been studied (Czajkowski *et al.* 2016). Data describing the thermal conductivity, obtained 40 and 50 years ago (Ward and Skaar 1963; Ten Wolde *et al.* 1988), are still frequently applied to heat transfer modeling, in spite of the fact that traditional experimental

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methods for determining the data are not capable of dealing with dependency of the properties on temperature. The steady-state method was most often applied when determining the thermal conductivity of wood-based panels. Although different modifications of experimental set ups had been made, the guarded hot plate apparatus (Speyer 1994; Sonderegger and Niemz 2009) and the heat flow meter apparatus.

*Bambusa vulgaris* (bamboo) has been one of the fastest growing plants in the world having growth up to 60cm or more in a day. Bamboo has social, economic and cultural significance and is used extensively for building materials along with thousands of uses. It is highly versatile raw material for different works. The bamboo is light weight, flexible, tough, high tensile, cheap material than the other building materials like steel. Bamboo can be used in various structural works. Bamboo structures are flexible, earthquake resistant, light weight and cheap. Bamboo can be used as reinforcement in various structural members. Bamboo is a green material for sustainable development and has various advantages. Use of bamboo may be promoted for green buildings and sustainable development (Dinesh *et al.* 2014). In fact, bamboo culture has been described as an essential part of human history and civilization, especially in Asia (Lobovikov *et al.* 2007).

Today, similar to the last 5,000 years, *B. vulgaris* is used as a primary building and structural material in many parts of the world. Currently, over 1 billion people are estimated to be living in traditional bamboo houses (Lobovikov *et al.* 2007). Lightweight and high strength bamboo stalks 4-5 inches in diameter provide structural support, and can also be lashed together to form panels used for roofing, flooring, exterior walls and partitions, doors, and window frames. Bamboo strips can be woven to form mats and window coverings. In addition, bamboo can be used for scaffolding in construction projects often to great heights. While bamboo continues to be used in these traditional ways, it has also become an essential raw material for production of modern building products (Bowyer *et al.* 2014).

Bamboo is one of the oldest structural materials used by man in many part of the world. The reduction in timber reserves and the awareness of deforestation problems caused by crops have increased interest for bamboos forest which is fast-growing resources (Shiembo 1986). This is a multifunctional plant: it is solicited in the protection of the environment (water and soil conservation) and nutrition (Tangka 2001); the petiole designated as African bamboo (Ingram *et al.* 2010) and the raw leaves are used as building materials (Tangka *et al.* 2001). Bamboo has been used over the years because it is relatively cheap, readily available, and fast growing plants that can meet the need for broad construction. So many studies has been carried out on bamboo, but the study of insulation properties and applications as a raw material for insulation materials for products like cooler is very limited. It is an underutilized and neglected material, so that its full potential is not used. Further studies are needed to assist and promote its application in the modern world.

The increasing demand for tropical wood products leads to expand trade offers, as well as knowledge of the characteristics of non-wood such as its physical, mechanical, thermal and technological properties. This is a reason to perform determinations of thermal properties of non-wood intended to house a chest cooler. In fact, one exotic (*Pinus caribaea*) and indigenous wood (*Nauclea diderichii*) species are sufficiently tested by Adelusi *et al.* (2021), but there has not been any reliable information about non-wood such as bamboo for housing cooler with a reason to conserve heat flow. Thus, there is need to further explore intensively and extensively bamboo potentials in the area of using it as insulation materials and to provide comprehensive data with an expectation for making the design standards.

## MATERIALS AND METHODS

### Materials collection

The materials used for determining the thermal retention capacity of *B. vulgaris* for reinforcing plastic ice chest cooler are; *B. vulgaris* stems, 30 foot tape for measurement, circular saw, 1’’ and 2’’ nails, connector, Bar clamps, Counter sink drill bit (1/8”), ice block and thermometer.

### Materials Preparation

The stems of *Bamboosa vulgaris* were collected from Moore plantation, Odo-Ona, Apata, Ibadan. The stems were air dried and later processed into strips at the wood processing unit of the Department of Wood and Paper Technology, Federal College of Forestry, Ibadan. The strips were cut (Fig. 1) and planned for surface smoothening and later taken to the circular saw machine for cutting based on the cutting list design for this study as previously described by *Jieyu* et al*. (2021)*.

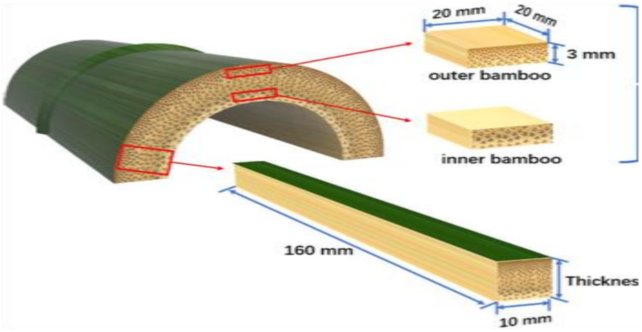


*Fig. 1.*
*Strips Collection method from the stem.*

*Fig. 2.*
*Assembling of side aprons using Bamboo strips.*

*Fig. 3.*
*Complete assembled reinforced ice chest cooler.*


***Fig. 4.***
***B. vulgaris reinforced plastic cooler.***

## RESEARCH METHODOLOGY

### Research Method

In this study, a descriptive study was carried out with three replicates for each of the ice chest cooler (both bamboo insulated and control). Measurements of temperature (ice and hot water) were carried out in the ice chambers.

### Research procedure

### Ice Block Testing

Two boxes were prepared for this study. One plastic cooler reinforced with bamboo; the other was without reinforcement (control). Ice block of 2.74 kg was weighed and collected into two (2) groups. Each ice block was placed into each of the two cooling boxes. After that, thermometer was put into each of the two cooling boxes and then all of cooling boxes were closed. Observations were made every 1 hour for 6 consecutive period making six (6) hours. Observations of weight loss with temperature range were done calculating the difference in weight before and after the 6 hours observations.

### Hot Water Testing

The ice chest cooler produced was tested for temperature holding through pouring of hot water into the boxes at a temperature of 90°C and covered to assess the thermal (hotness) retention for a period of 6 hours (360 minutes). The assessment was done through the use of 100°C calibrated thermometer. The measurement for heat retention was carried out at an interval of 1 hour. This procedure was carried out for the control (plastic cooler without reinforcement). The differences in the temperature retention for the period assessed was used to plot a line graph to show heat flow and dissipation from the two cooler assessed.

### Data analysis

The data gotten from the experiment was 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.

## RESULTS AND DISCUSSION
### Hot Water Retention Capacity

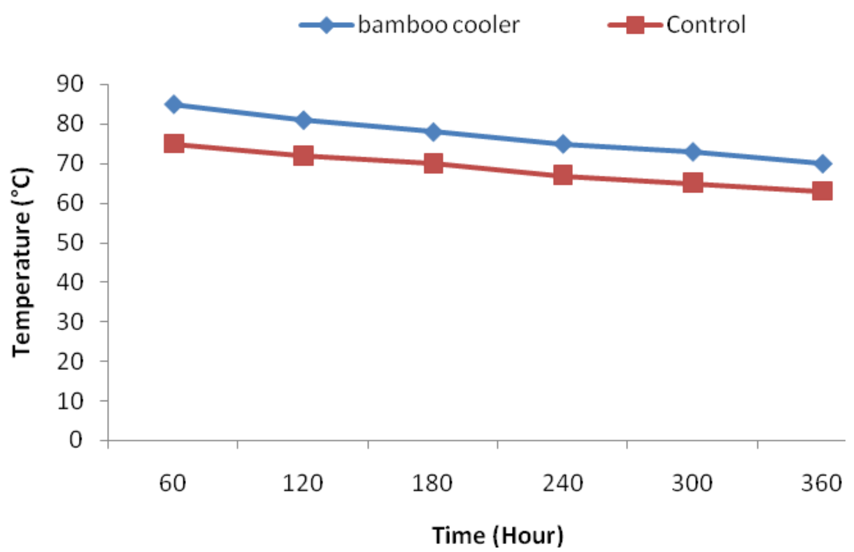


***Fig. 5.***
***Heat loss with respect to time.***

The result of the hot water retention capacity of ice chest cooler after 6 hours observations is presented in Fig. 5. The result showed that the bamboo reinforced coolers respond differently with time compared to control. The result shows that after 6 hours of hot water exposure, the least thermal retention (63°C) was recorded in the control i.e., the conventional plastic cooler, while plastic cooler reinforced with bamboo had 70°C at the end of the experiment. The highest value of 85°C was recorded with the cooler reinforced with bamboo.

The result indicates that cooler reinforced with bamboo retained heat energy more than the control. This observation reveals that heat does not easily pass through the bamboo fibre. This suggested that bamboo material has good thermal insulation, which is similar to wood (Shah *et al.* 2019). This result could also be attributed to bamboo been a natural fibrous insulator. Commonwealth of Australia (2008) described fibrous materials as a natural insulator due to air pockets within its cellular structure. As a result of this, thermal performance of the bamboo reinforced cooler products will require less energy to heat and cool, thus, resulting in reduced energy bills. In addition, bamboo is hygroscopic and has the ability to exchange moisture with the surrounding air which provides a buffer against short-term changes in humidity and temperature (Adelusi *et al.* 2021).

*Table 1*
***Analysis of variance (F. ratios) for thermal retention of wooden cooler after 6 hours of hot water exposure***

| SV | SS | DF | MS | F |
|---|---|---|---|---|
| Between Groups | 82.51 | 1 | 82.51 | 2.11* |
| Within Groups | 1335.24 | 34 | 39.27 | |
| Total | 1417.74 | 35 | | |

**Note** *= Significant difference at 5% probability

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The result of the analysis of variance (Table 1) shows that there is significant difference between the bamboo reinforced cooler and the control (Plastic cooler).

**Cold Retention Capacity – Ice Block Test**

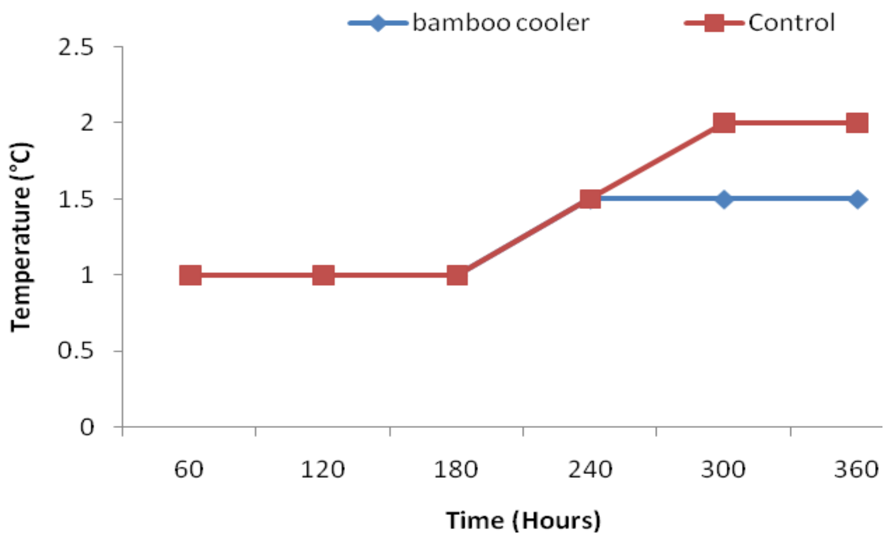


***Fig. 6.***
***Heat gain with respect to time.***

The result of the cold retention capacity of ice chest cooler after 360 minutes (6 hours) observations is presented in Fig. 6. The highest heat gain capacity of *B. vulgaris* reinforced plastic cooler and the control ice chest cooler is between 1.5°C and 2°C respectively.

Fig. 6 shows that with 2.74kg mass of ice block during the cold measurement, the temperature drops at a lower rate for all temperature measurements for the period of 6 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 (Handry *et al.* 2014). The result obtained after the experiment from the reinforced and control samples indicate that cooler made from the bamboo species had a better temperature retention capacity compared with the control. This could have been as a result of anatomical structure and moisture content characteristics of bamboo. This also corroborates the findings of Kusano *et al*. (2008) who reported that PLA-bamboo "green" composites have excellent insulation properties and its thermal conductivity depends on the direction of fiber alignment as well as the direction of stacking.

The results obtained is also in agreement with what was obtained by Shah *et al*. (2019) who found out that the thermal conductivity of untreated outer and inner bamboo was almost the same suggesting bamboo material has good thermal insulation, which is similar to wood. The thermal conductivity of bamboosa was said to be influenced by many factors including crystallization area, moisture content and density (Yang *et al.* 2011, Liu *et al*. 2012).

## CONCLUSION

Plastic ice chest cooler was successfully was successfully Bamboo in this study, and thus makes bamboo a good reinforcing and insulating materials for ice chest cooler production. The ice chest produced from the bamboo shows a considerable effect on the plastic cooler reinforced as they shows reasonable hot retention value in hot water test after a considerable longer hour of examination (6 hours) when compared with the conventional cooler. The ice block test also indicates that bamboo reinforced cooler can retain ice block for a period more than 6 hours with high significant of retention of ice temperature.

The temperature examined during this experiment will go a long way in assisting users during the harvest period because, temperature usually are the causes of spoilage during harvest. Because of its temperature moderation and control, rapid cooling examined during this study will go a long way to minimize the effects of temperature influx thus minimizing the decay as 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 is to minimize respiration and transpiration, preventing wound infection and prolong their storage periods.

It is also interesting to note that the bamboo frame used as a reinforcement frames 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. This cooler can easily be provided for storage and travel purposes because it is cheap, easy to make and practical in use.

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