International Journal of Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2023.9.4.2

Volume 9, Issue 4
April - 2023

Development and Characterization of Camel's food (*Piliostigma thonningii)* Insulator for Lagging Application

Aliyu Mohammed Lawal, and DahiruYa'u Gital,

Department of Mechanical Engineering Technology

ATAP Bauchi, Nigeria

ABSTRACT

Due to the growing concern for renewable and biodegradable thermal insulation materials motivated by the pending energy crisis, global warming and the environmental impact of the waste product after their useful life, many researchers have worked on the thermal and physical properties of various insulators without giving much consideration to the mechanical properties. Therefore, this paper proposes to investigate the mechanical properties of developed Camel's food (Piliostigma thonningii) insulator for lagging application. Camel's foot (Piliostigma thonningii L.) is a leguminous plant found growing abundantly as a wild uncultivated plant resource in many parts of Nigeria. The leaves and the bark fibers of the plant were prepared in form of insulation boards of thicknesses of 10, 20, 30 40, and 50mm using natural rubber latex as a binder. The ratio of the fiber to the binder in composition was 1:1, 1:2, 1:3 and 1:4.The test results showed that the insulation boards from bark fibers of the plant had good mechanical properties. The properties measured range as follows: ultimate tensile strength (11.66 to 6.96M. Pa); compression strength (0.09 to 0.07 M.Pa), flexural modulus (2545.96 to 2184.07 M.Pa) and flexural strength (53.09 to 29.96 M.Pa). According to the test results, it can be concluded that these insulation boards from the bark fibers of the plant had excellent mechanical properties.

Keywords: Fibre, Insulator Binder, *Piliostigma Thonningii*, Thermal insulation

1. INTRODUCTION

Insulation material is defined as any material or combination of materials which retards the flow of heat energy. In current time, there has been upsurge in the locally invented refrigerators, ice-making machines, cold storage rooms and ice coolers as a way of getting cold drinks and beverage sand for the storage of fresh food items such as fish, meat, fruit, sand, vegetables for commercial purposes. In the fabrication of these refrigerators and cold storage rooms, huge quantities of thermal insulation materials are essential. The commercially available thermal insulation materials for low temperature application are generally made of plastic foams, glass foams, mineral wools and rock wools [1]. In Nigeria, most of the designs and fabrications of these cold storage room sand refrigerators uses polyurethane and foam as the insulation materials [2].

The word "insulation" is derived from the Latin word for island (insula) describing materials which cuts off heat supply from its surrounding and was first recorded in 1870[3]. The history of thermal insulation materials is not as long as that of othermaterialsbutthenecessityofinsulationisasoldasthebuildingactivity.Themainreasonsfor the building itself was protection against the wild animals and the weather elements; cold winter sand hot summers, that is insulation from the surrounding[4].

One of the most examples of commercial thermal insulation is an inorganic material especially fiberglass. Until 1996 Bureau of Environmental Health of Thailand reported that fiberglass has an effect on human health when fiberglass is handled, cut or otherwise disturbed, people can be exposed by skin and eye contact or by breathing in fibers that have become airborne. Additionally, fiberglass can cause Emphysema and lung cancer. Therefore, many studies have been done on the development of thermal insulation materials from natural fibers used as environmental-friendly and renewable materials.

In Nigeria, the electricity sector is currently experiencing a serious crisis. With a population of over 200 million, the country generates only about 5000MW which is grossly inadequate to keep up with the demand [5].TheepilepticsupplyofelectricityhasforcedNigerianstolocallyfabricaterefrigerators and cold storage rooms for commercial use. But the operators of these systemsrely on diesel and petrol generators as the primary or back-up source of electricity to powerthemwhichisnotonlyexpensivebutasourceofenvironmentalpollution.Moreover,substantial amount of the energy generated is wasted in these systems because they are either run-insulate do under-insulated.

2. RESEARCH OBJECTIVE

The aim of this research work is to investigate the mechanical properties of a developed *Piliostigma thonningii* insulator with view to explore its potentials for use as lagging (thermal insulation) material for locally fabricated refrigerators and cold storage rooms. This can be achieved through the following objectives:

The objectives of this study are:

To investigates the mechanical properties of developed *Piliostigma thonningii* insulator.

Comparison of the mechanical characteristics of the *Piliostigma thonningii* boards with that of the commonly used low temperature thermal insulation material.

3. PREVIOUS WORK

[1] Highlighted that in the low temperature insulation technology, low-cost foam and polystyrene are the most extensively used. He noted that continuous research has perfected the manufacture and utilization of these materials for specialized applications which covers clothing, industrial and residential buildings, refrigerators and ice-coolers. Hence, [2] also proposed to use the same materials in the design and adaptation of cold storage room for the umudike community and environs.

Many studies have been conducted on the development of thermal insulation materials from natural fibers such as maize husk, maize cob, groundnut shell, coconut pith and paddy straw [6], cotton seed hulls [7], durian peel and coconut coir [8], Saline Jose tall wheatgrass [9], eggplant stalks [10], tamarind hulls [11] and cotton stalk fibers [12].

[13] stated that thermal insulators are materials that are designed to have high R-value. The R-value describes the ability of materials to resist heat flow through them, the higher the R-value, the better the insulation. [14] Defined thermal insulators as materials that prevent the transfer of heat through them. They reported that the major features in all thermal insulators are their low thermal conductivity factors (k) usually lower than 0.1W/m.K. The temperature ranges within which the term “thermal insulation” will be applied is from -100^{o}F (-73^{o}C) to 1500^{o}F (815^{o}C), while applications below these temperatures are termed cryogenic and those above these temperatures are referred to as refractory [15]. When insulation is used to prevent heat loss from a process or system it is referred to as hot insulation, but when it is used to prevent heat gain to system the term cold insulation is used. Whereas when insulation is used to prevent both heat gain and loss into or from the system the term ambient insulation is normally applied [15].

4. RESEARCH METHODOLOGY

Raw materials used for this work was bark fibre of Camel’s foot(*Piliostigma thonningii*.) which was collected from Kangere Village in Bauchi Local Government Area of Bauchi State, Nigeria. Other materials include sodium hydroxide (NaOH),distilled Water, Hexamine and Pre-treated natural rubber latex all were obtained from Steve Moore Chemicals Zaria Kaduna State, Nigeria.

The equipment used in this study include an electronic weighing balance with an accuracy of 1g, arm field HT10XC heat transfer service unit alongside with HT11C computer compatible linear heat conduction apparatus. Others include unlogged Dewar flask (calorimeter) with a capacity of 500ml, magnetic stirrer, differential temperature sensors (thermocouples) with a sensitivity of 0.1^{o}C, an electric heater and a capsule made of a hollow cylindrical brass material of 25mm diameter and 50mm length, a Vanier caliper with accuracy of 0.05mm, conical flask and a standard bus bar copper, universal tensile testing machine.

The major raw materials, that is the bark fibre of Camel’s Foot (*Piliostigma thonningii* L.) was mercerized using 5%w/v Sodium Hydroxide (NaOH) solution at room temperature for 24 hours [16]. The fibres were thoroughly rinsed in a fresh tap water and air dried. The dried samples were ground into small particle sizes using a commercial grinder and used for the preparation of the particles board. A sample from the bark fibres was prepared, and stored in nylon bag.

A required quantity of the raw materials (fibres) and the binder (natural rubber) was charged into a rotating mixer and continuously mixed until the particles were thoroughly impregnated with the resin and the mixture was then poured into a prepared mould and allowed to cure under the sun. A force of 0.25kN was applied to ensure even settling of the product. Four (4) types of boards were produced from the mould with particles to binder ratios of 1:1, 1:2, 1:3 and 1:4. After forming, the board were cut into various test samples.

SAMPLE CODE	Binder Ratio
A	1:1
B	1:2
C	1:3
D	1:4
E	1:5

DOI: 10.31695/IJASRE.2023.9.4.2

The mechanical properties were evaluated following the TIS. 876-2547. Twenty-seven samples were prepared for the Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) test and forty-five samples were prepared for tensile strength perpendicular to surface test. All properties were calculated from the equations (2), (3) and (4) respectively. Each sample's results were compared with the standard

$$MOR = \frac{3F_{max}L_i}{2bt^2} \quad (1)$$

where F_{max} is the maximum load (N), l_i is the distance between knife edges (mm), b is the width of the test sample (mm) and t is the thickness of the test sample (mm).

$$MOE = \frac{pl^3}{4bt^3\, y} \quad (2)$$

where *p is the load, l* is thegauge length, b is the width (mm), t thickness (mm), y is the deflection (mm).

$$UTS = \frac{P}{bl} \quad (3)$$

Where p is the maximum load (N), b is the width (mm), l is the thickness of the sample.

5. RESULTS AND DISCUSSION

The variation of flexural strength versus binder ratio is presented in Fig 1. From the figure, it can be inferred that as the wt% of the binder ratio increases, the flexural strength decreases and becomes minimum at E. The maximum and minimum values of the flexural strength were 53.09 M.Pa and 29.96 M. Pa, respectively. In a similar work on "The effects of incineration ash filler contents on the flexural and tensile strengths" investigated by GohCheeKeong [16], it was established also, that both flexural and tensile strengths decreased with increase in incineration ash filler contents.

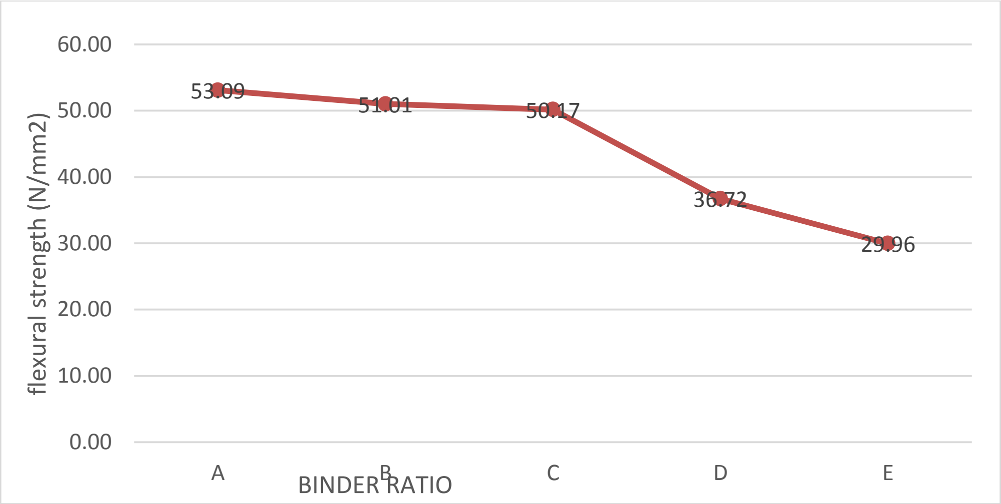

Figure 1. Effect of binder ratio on the flexural strength of Piliostigma thonningii Insulator

Increasing the binder ratio does not significantly translate into either increase or decrease in the flexural modulus of the composites from A to C. On the other hand, appreciable decrease was observed from C to E. The maximum and minimum values of 2545.69MPa and 2184.07MPa were respectively obtained at B and D

DOI: 10.31695/IJASRE.2023.9.4.2

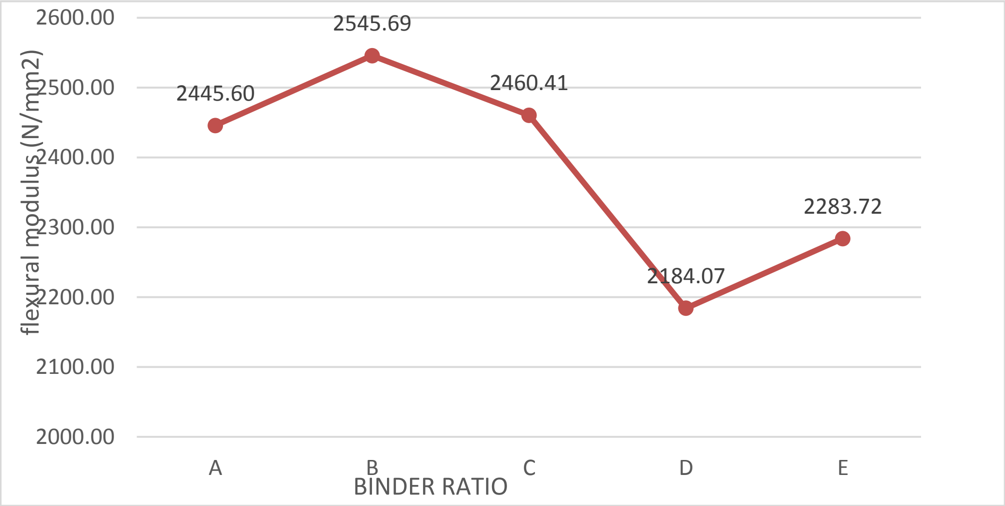

Figure2. Effect of binder ratio on the flexural modulus of Piliostigma thonningii Insulator

Figure 3, shows that the ultimate tensile strength (UTS) of the Piliostigma thonningii insulator increases from 10.45 M.Pa to 11.66 M.Pa at B and then decreases to 6.96 at C which is the lowest value.

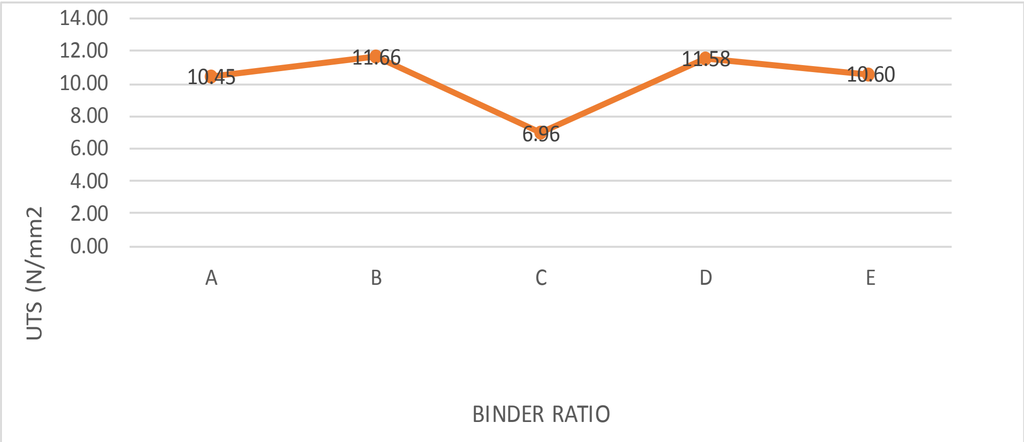

Figure 3. Effect of binder ratio on the tensile strength of Piliostigma thonningii Insulator

Figure 4 shows the graph of the effect of binder ratio on the compressive strength of the *Piliostigma thonningii* Insulator. In the graph there was little decreased in compressive strength of the composite from 0.09 to 0.07 N/mm^2

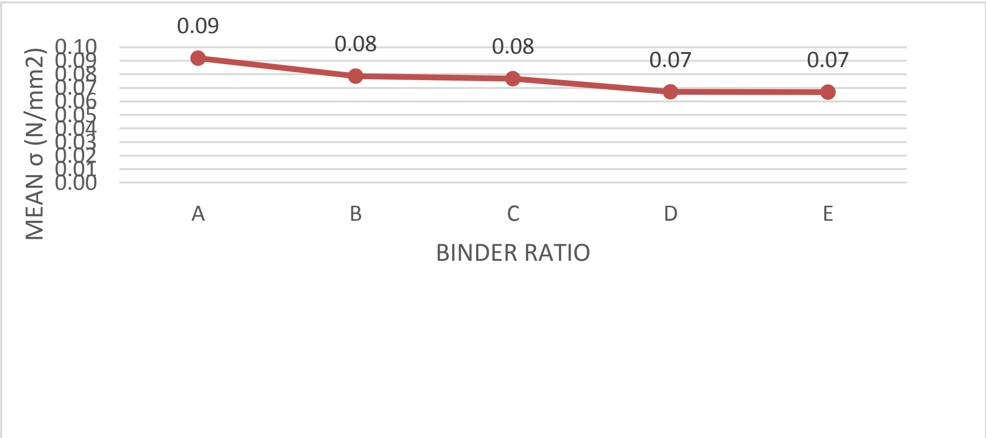

Figure 4. Effect of binder ratio on the compressive strength of Piliostigma thonningii Insulator

DOI: 10.31695/IJASRE.2023.9.4.2

CONCLUSION

The following conclusions can be drawn from the research work:

i. Increasing the binder ratio increases the tensile strength from 10.45MPa to 11.66MPa of the developed insulator.
ii. Varying the binder ratio slightly decreases the compression strength from 0.09MPa to 0.07MPa, flexural strength from 53.09 M.Pa to 29.96 M.Pa and flexural modulus from 2545.69MPa to 2184.07MPa.
iii. The bending (flexural) test shows that the developed *piliostigma thonningii* has a better bending strength. Therefore, it could be used in insulating material.
The results indicated that the thermal insulation from *Piliostigma thonningii* which bonded by natural rubber during hot pressing process have a good mechanical according to the standard of insulation board ASTM C 518.

REFERENCES

[1] Manohar, K. (2013). Biodegradable Thermal Insulation for Ice-coolers. *International Journalof Modern Engineering Research* (IJMER), 1 (2), 559-563

[2] Ugwu, H.U. and Ogbonnaya, E. A. (2012). Design and Adaptation of a Commercial Cold Storage Room for Umudike Community and Environs. *IOSR Journal of Engineering*, 2 (5), 1234-1250

[3] Bhatia, A. (2010). *Overview of Insulation Materials*. Continuing Education and DevelopmentInc. NewYork.RetrievedJanuary2,2023,from:www.cedengineering.com/.../Overview%20of%20Insulation%20Materials

[4] Bozsaky, D. (2010). The historical development of thermal insulation materials. *Periodicapolytechnica*, 41 (2), 49-56. Research Article, Retrieved March 18, 2013, from: http://www.pp.bme.hu/ar

[5] United Nations Development Program (UNDP), (2010). *Promoting Energy efficiency inResidential and public sector in Nigeria, Project Document*. Retrieved March 18,2023 from: www.ng.undp.org/**energy**/Training_Manual_EE_Project_Reviewed

[6] N. E. Alias *et al.*, "Electrical characterization of n-type cylindrical gate all around nanowire junctionless transistor with SiO2 and high-k dielectrics," in *2020 IEEE International Conference on Semiconductor Electronics (ICSE)*, 2020, pp. 13-16: IEEE.

[7] Sampathrajan A, Vijayaraghavan NC, Swaminathan KR. Mechanical and thermal properties of particle boards made from farm residues. *Bioresource Technology* 1992;**40**:249-251

[8] Gurjar RM. Effect of different binders on properties of particle board from cotton seed hulls with emphasis on water repellency. *Bioresource Technology* 1995;**43**:177-178.

[9] Khedari J, Noppanun N, Jongjit H, Sarocha C. New low-cost insulating particleboards from mixture of durian peel and coconut coir. *Building and Environment* 2004; **39:59**-65

[10] Zheng Y, Pan Z, Zhang R, Jerkins BM. Particleboard quality characteristics of saline jose tall wheatgrass and chemical treatment effect. *Bioresource Technology* 2007;**98**:1304-1310.

[11] Guntekin E, Karakus B. Feasibility of using eggplant (*Solanum melongena*) stalks in the production of experimental particleboard. *Ind Crop Prod* 2008;**27**:354-358.

[12] Rachtanapun P, Loiloes K, Jaikeankeaw D. Effects of blended starch adhesive contents and particle size of tamarind hulls on properties of particleboard. *Proceedings of 48thKasetsart University Annual Conference: Agro-industry, February 3-5, 2010,Bangkok, Thailand*. 117-123.

[13] Kenneth, H. (2010). *Insulating to Reduce Heating Cost*. North Dakota State University Extension Services. North Dakota State University, Fargo, North Dakota 58105. Retrieved from: www.ag.ndsu.edu/pubs/yf/home/ae1368.**pdf**

[14] Anastasios, K., Papadopoulos, A. and Anastasellos, D. (2003). *Heat Transfer Phenomena inFibrous Insulating Materials*. Laboratory of Heat Transfer and EnvironmentalEngineering, Aristotle University, Thessaloniki. Retrieved March 22, 2013 from http://aix.meng.auth.gr

[15] Bhatia, A. (2010). *Overview of Insulation Materials*. Continuing Education and Development Inc. New York. Retrieved January 12, 2023, from: www.cedengineering.com/.../**Overview**%20of%20**Insulation**%20**Materials**

[16] Jayabal, S., Sathiyamurthy, S., Loganathan, K.T. and Kalyanasundarama, S. (2012). Effect of Soaking Time and Concentration of NaOH Solution on Mechanical Properties of Coir-Polyester Composite. Bull. Mater. Sci., 35(4), 567-574. Indian Academy of Sciences

DOI: 10.31695/IJASRE.2023.9.4.2