

CELLULOSE DERIVED INSULATING MATERIAL FOR HEAT TRANSFER APPLICATIONS

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechanical Engineering

By

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INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A++" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of GUNASEELAN (Reg. No. 40150009) and NITIN R (Reg. No. 40150031) who carried out the project entitled "CELLULOSE DERIVED INSULATING MATERIAL FOR HEAT TRANSFER APPLICATIONS" under our supervision from December 2023 to April 2024.

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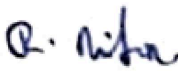
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DECLARATION

We GUNASEELAN (Reg. No. 40150009) and NITIN R (Reg. No. 40150031) hereby declare that the Project Report entitled "**CELLULOSE DERIVED INSULATING MATERIAL FOR HEAT TRANSFER APPLICATIONS**" done by us under the guidance of **Dr. S.RAM PRAKASH., M.E., Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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SIGNATURE OF THE CANDIDATES

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ABSTRACT

The research undertaken in this study aimed to develop an efficient method for producing thermal insulator from *Cenchrus purpureus*. This samples were collected from Sathyabama Institute of Science and Technology. The extraction process involves the separation of cellulose, hemicellulose, and lignin components, which are subsequently subjected to optimization techniques to enhance the yield of fermentable sugars. The *Cenchrus purpureus* contains 38.3% cellulose and 18.7% hemicellulose, The samples are prepared for proximate analysis for three different sample Biomass, Extracted cellulose, cellulose .In biomass moisture content (0.363%) , Volatile matter (2.03%), Ash content (3.481%) and fixed carbon (93.55%).and for extracted cellulose moisture content (0.9%) volatile matter (2.01%) ash content (2.9%) fixed carbon (94.19) for commercial cellulose moisture content (0) volatile matter (3.666%) ash content (2.631%),fixed carbon (93.703%) these are the analysis were done And also analysed the Density calculation for bio mass, Extracted cellulose, commercial cellulose for bio mass bulk density (0.14 kg/m³), Packed density (0.12) and hydrated density (0.33) for extracted cellulose bulk density (0.13) Packed density(0.11) Hydrated density (0.31).

And for commercial cellulose bulk density (0.12) packed density (0.10) Hydrated density (0.30). Initially confirmation of cellulose was done using the study of function groups using FITR analysis. Further characterization studies such as XRD was done to understand the crystalline structure of the cellulose extracted. And also analysed the thermal conductivity of biomass (0.073 W/m.K), extracted cellulose (0.056 W/m.K) and commercial cellulose (0.041 W/m.K).

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LIST OF ABBREVIATIONS

Co ₂	Carbon dioxide
PCM	Phase change material
TES	Thermal energy storage
GHGs	Greatest greenhouse gases
GGBFS	Granulated blast furnace slag
FA	Fly Ash
MK	Metakaolin

CHAPTER-1

INTRODUCTION

A major increase in interest in cellulose-derived insulating materials because of their remarkable thermal insulation qualities, sustainability, and adaptability to a wide range of heat transfer applications. [1] With the increasing emphasis on environmental sustainability and energy efficiency on a worldwide scale, it is critical to create novel materials made from renewable resources like cellulose.[2] In this regard, insulating materials made of cellulose present a viable way to address the problems of heat transmission and utilization of energy in a variety of industries, including aerospace and construction. These insulating materials' primary component is cellulose, a biopolymer that is widely found in plant cell walls. [3] Advanced processing methods including chemical modification, the field of nanotechnology and composite fabrication may be used to turn cellulose into insulating solutions that are extremely effective, long-lasting, and lightweight. [4] Due to their low thermal conductivity, these materials efficiently prevent heat movement by radiation, convection, and conduction, which lowers energy losses and enhances thermal comfort in industrial equipment, automobiles, and buildings. Because of their adaptability, [5] insulating materials made of cellulose may be used in a variety of thermal management situations.

These materials are essential to the wall, roof, as well as floor insulation systems used in building construction. They save heating and cooling expenses and promote [6] energy-efficient building designs. Cellulose-based insulation is essential to the automotive and aerospace sectors because it improves the thermal performance of automobiles and airplanes, which in turn improves fuel economy and passenger comfort. [7] The environmentally concerned culture of today finds cellulose-derived insulating materials even more appealing due to their sustainability qualities. [8] These materials offer a sustainable and biodegradable substitute for traditional insulation made from fossil fuels by using renewable cellulose sources as wood pulp, agricultural leftovers, or recycled paper. [9]

The energy input requirements and greenhouse gas emissions from the production of cellulose-based insulation are frequently lower, which is consistent with the concepts of environmental stewardship and the circular economy. With these strong benefits, insulating materials made of cellulose offer a convincing way to solve the problems of energy efficiency and heat transmission in a variety of applications. Because of their exceptional thermal stability, sustainability, and adaptability, they will be a key component of any future developments in thermal management systems. [10] Cellulose-based insulation has enormous potential to provide an environmentally conscious and energy-efficient building material as studies and developments in this area continue to advance. The insulation of heat in the structures can help cut down on this significant energy use for space cooling. Since the building envelope accounts for around half of heat gain, insulating it may both make a structure more energy efficient and maintain comfortable interior conditions. [11]

Given their low embodied energy, minimal environmental impact, and comparable insulation qualities to synthetic materials, renewable insulation resources like cellulose fiber should be used for insulation purposes. Every step of the process, including material manufacturing, distribution, building, and deconstruction, uses embodied energy. In comparison to non-renewable synthetic substances that produce a great deal of pollution during manufacture, natural insulating materials like cellulose fiber are significantly superior since they are sustainable, renewable, and environmentally beneficial throughout their life cycle.

Buildings are experimenting with new eco-friendly, affordable, and sustainable materials to lower energy use and negatively affect the environment. [12] One such choice for use as insulation in buildings is cellulose fiber. Recycled paper may be used to make sustainable cellulose fiber material for thermal insulation. The cellulose fiber can be utilized as a fiber board or as loose fill for insulation. [13] Since the thermal conductivity of gravity-compacted cellulose fibers in their loose condition is equivalent to that of conventional materials, they can be employed as insulation. [14] Biodegradable, renewable, and recyclable resources may be used to make environmentally friendly fiber boards from cellulose. Cellulose fiber has a poor thermal conductivity of around 0.04 W/mK. [15]

This is equivalent to current conventional and non-conventional insulating materials. [16] Hygroscopic cellulose insulations have the ability to reduce peak relative humidity by 10%, and their benefits intensify in hot and muggy outdoor environments. The diffusion coefficient of the insulating material being used determines how dynamically heat interacts with the outside environment in buildings. [17,18,19] The feasibility of natural and synthetic material insulation for use in buildings has been extensively studied; however,[20] the suitability of fibers made of cellulose for application in buildings beneath dynamic heat transfer circumstances has received less attention.

1.1 PRELIMINARY TREATMENT FOR CENCHRUS PURPUREUS

To prepare Cenchrus purpures, sometimes referred to as Napier grass, for being utilized as cellulose-derived insulating compounds for heat transfer applications, a number of actions must be taken in order to improve the raw material's insulation qualities. the right time of year, usually when the blade of grass is fully grown but not too lignified. Thorough cleaning is necessary to remove any filth, debris, or foreign objects from the gathered grass. To make processing easier, disinfected Cenchrus purpures becomes smaller segments. To encourage uniformity in the finished insulating material, the pieces should be similar in size.

Pre-Treatment: To avoid interfering with the extraction of cellulose and its insulating qualities, lignin and hemicellulose are extracted from the shredded grass using a pre-treatment procedure. Alkaline treatment, enzymatic hydrolysis, steam explosion, and other mechanical, chemical, or biologic reactions are examples of pre-treatment techniques.

Cellulose Extraction: Using an appropriate technique, such as acid hydrolysis or alkaline extraction, the pre-treated Cenchrus purpures. The cellulose was removed to improve its insulating qualities and get rid of contaminants. To increase the performance and durability of the material, modified or additions like binders or fire retardants can be added to purified cellulose in the required form, such as spreadsheets, fibers, or pellets.



Fig 1.1: Cenchrus Purpureus Cutting

Testing and Assurance of Quality: To assess the insulation's thermal conductivity, temperature stability, durability against fire, and other pertinent qualities of the insulating material made from cellulose, thoroughly test it. Put quality control procedures in place to guarantee dependability and uniformity throughout the production process. The processed cenchrus purpureus-derived insulating material is used in thermal packaging, industrial insulation, and building insulation, among other heat transfer applications. To improve performance and efficiency, continuously refine the material composition and treatment procedure based on input from testing and practical applications.

CHAPTER 2

LITERATURE SURVEY

Sen, Singh, & Kailasam (2022) Bera, C., Roy, S., & Sen, S. A summary of recent advances in cellulose aerogel composites made from biomass for use as thermal insulation. 29(9) Cellulose, 4805–4833. In order to maintain the ideal climate within a structure, thermal insulation of the building is crucial in lowering energy usage. Therefore, it is imperative to enhance the building sector's thermal insulation capabilities by facilitating energy savings by lowering the loss of energy for heating and cooling. It is commonly known that a high-quality thermally insulating material is often dependent on a number of critical factors, including low thermal conductivity, renewable resources, affordability, and environmental friendliness. In this situation, cellulose aerogel made from biomass may be a desirable substance as it meets these requirements better than alternative conventional insulating materials. High broad surface area and low heat conductivity are only two of the many excellent physical and chemical properties of cellulose aerogels. These factors make them suitable for use as an effective thermal insulating material in the building industry to reduce energy consumption. Interestingly, cellulose has the benefit of having several hydroxyl groups that are easily changed by fillers through noncovalent interactions with inorganic elements. This allows for improved mechanical and thermal stability and improved performance as a thermal insulator. The development of cellulose-based thermal insulating substances and their potential for commercialization toward practical applications have been covered in this study, taking into account the benefits of using cellulose. In addition, this work can promote the development and use of cellulose-based thermal insulators to provide insulating materials that are both affordable and sustainable.

Bera, C., Kailasam, K., Sen, S., Singh, A., & Roy, S. (2022). Utilizing iron oxide and biomass to create cellulose nanofibers and hybrid nanotechnology for thermal insulation applications. *Advances on the Nanoscale*, 4(16), 3381-3390. Environmentally friendly and reasonably priced thermally insulating materials have been more popular in recent years as a means of increasing building energy efficiency, owing to the building sector's excessive energy consumption and the

ensuing environmental problems. Because of their poor insulating efficacy and lack of biodegradability, the thermal insulating materials now accessible on the commercial market (polystyrene) are always a problem. In light of this, aerogels made from biomass are garnering a lot of attention as sustainable and renewable insulation materials. In this study, we have devised a simple method for producing cellulose nanofibers from wood pulp obtained from biomass as an economical precursor material using TEMPO-oxidation, and then adding ferrous oxide nanoparticles to create a nanohybrid. It's interesting to note that these nanohybrids largely overcome the stability and durability constraints of the currently available thermal insulation compounds by improving functional properties like hardness and flammability. Most notably, these hybrids showed extremely low thermal conductivity—as low as $0.024 \text{ W m}^{-1} \text{ K}^{-1}$ —which suggests that they have superior insulating potential than other traditional materials.

Munier, P., Apostolopoulou-Kalkavoura, V., and Bergström, L. (2021). Materials based on nanocellulose that offer thermal insulation. 33(28) of *Advanced Materials*, 2001839. Materials for thermal insulation made of renewable nanomaterials, such as nanocellulose, may lower energy usage and the construction industry's environmental effect. There have been recent reports concerning super insulation cellulose A nanomaterial (CNM)-based aerogels that are and foams that have much superior heat transmission capabilities than materials that are currently in commercial use, such as Glass wool, expanded polystyrene, and polyurethane foams have led to a sharp rise in research effort. This article describes the basic principles of porous materials' thermal conductivity. It also presents and discusses the processing, structure, and innovative CNM-based aerogels and produces an with low thermal conductivities, as well as the anisotropic heat transfer capabilities of CNMs and coatings with aligned CNMs. Anisotropic porous designs and multicomponent methods have very low thermal conductivity, which is attributed to phonon scattering and the Knudsen effect.

An, B., Ma, C., Xu, L., Zhang, and Z., Sun, J., Wu, Z., & Liu, S. (2021). Aerogel has mechanical resistance, flame resistance, and thermal insulation that is built on tubular cellulose inspired by nature. Inspired in the tubular structures seen in naturally existing thermal-insulating materials, kapok fibers were processed easily

to create tubular cellulose aerogels with enhanced mechanical resistance, thermal insulation, and flame-retardant qualities. Compared to conventional organic-inorganic composites, which are brittle, an optimized sample showed an extremely high compressive strength of 32 MPa. This material's tubular structure led to a 37.4 °C greater degree of heat preservation over that of a viscose aerogel with a different topology. Together with montmorillonite, the H_3PO_4 that broke down from $(\text{NH}_4)_2\text{HPO}_4$ throughout the formulation combined on the outermost cellulose molecules to create a tight carbon layer supported by clay that limited the spread of flames and the release of volatile chemicals. The thick carbon layer's penetration pressure was significantly decreased by the gaseous gaps in the interior tubular fibers, which also blocked heat transport channels and contained flammable volatiles. The ideal sample did not burn because of the combined influence of the layers of carbon and tubular structure, which successfully restricted the flow of oxygen, warmth, and volatiles. This work offered a simple, affordable method for creating high-strength, fire-safe, and thermally insulating aerogel with potential uses in external wall insulation and car interiors.

Moura, L. M., Coquard, R., and Baillis, D. (2015). Heat transmission in aerogels based on cellulose: analytical modeling and quantification. Researchers have looked at a straightforward analytical method for calculating the overall heat transfer inside novel cellulose-based aerogels. The model uses a cellular depiction of the nanofoam that is porous to explain the distinctive dense matrix that occurs on the nanometric scale. Heat transmission by radiation and conduction is taken into account. The conduction of heat transfer in gas is modeled using the previous mathematical correlation for the gaseous phase. To simulate the conduction movement of heat in the solid phases at the nanometric scale, new analytical formulations that employ mean free path theory in conjunction with phonon tracking technique are put out. The Rosseland approximation in conjunction with the Rayleigh scattering technique yields the radiation heat transfer contribution. Since these analytical relations allow one to compute conduction-radiation equivalency conductivity primarily a function of cell size, researchers hoping to build novel insulating organic aerogels may find them beneficial. These relations have been confirmed through experimentation phonon and optical properties of cellulose.

Jiang, S., Yu, J., Zhang, M., Li, M., Zhu, J., Ge, A., and Liu, L. (2021). Composite thermal-insulating foams made of cellulose are becoming more flexible, eco-friendly, and flame-retardant. The development of extremely porous foams with outstanding thermal insulation has led to the use of cellulose nanofibrils (CNFs) as building blocks. Regrettably, CNF foams' low mechanical performance and flammability restricted their usefulness. This approach investigated the use of nontoxic boric acid and a borate, together with the biopolymer sodium alginate, as flame suppression agents for methyltrimethoxysilane bound CNF foams. Their combined effects in keeping CNF foams from igniting were discovered. The composite foams had a significantly elevated restricted aeration rating (up to 39.5%) and se Eco-friendly foams can satisfy the requirements for energy saving, wide application, and usage safety thanks to their minimal thermal conductivity ($0.028 \text{ W m}^{-1} \text{ K}^{-1}$ at 25°C), mobility, and non-ignitability.

Jose, J., Mathew, R. M., Vinod, V., Thomas, V., Raj, A., John, J., & Mujeeb, A. (2020). Thermal insulation made of cellulose nanofiber that is environmentally beneficial. Researchers are now interested in nano cellulose because of its intriguing qualities, which include a low degree of toxicity, availability, natural resources, biodegradability, and changeable surface chemistry. Thermal insulation made of cellulose fiber, which is often sourced from cotton, plant walls, or wood, is environmentally beneficial. The kind of cellulose nanofibers (CNFs) that are the subject of this work were produced by hydrolyzing cotton with sulfuric acid and then ultrasonically treating the cotton. If-extinguished. The foams also had high durability and bendability and were bendable. Transmission electron microscopy, also referred to as TEM, and infrared spectroscopy with Fourier transform (FTIR) were used to examine the development of CNF and its shape. The dual beaming mode-matched thermal lens approach was used to study the thermooptic properties of the prepared the sample, which, to the author's knowledge, has not yet been published. The synthesized CNFs' diffusion coefficient ($2.61 \times 10^{-8} \text{ m}^2/\text{s}$) and electrical conductivity (0.108 W/mK) results amply demonstrate the material's potential for use.

Nguyen, S. T., Ho, D. K., Du Tran, T., Thai, Q. B., Do, N. H., & Duong, H. M. (2020). Huynh, D. M. Sugarcane bagasse-based cellulose aerogels for use in heat-

insulating and oil spill cleanup applications. An economically viable and promising material for a range of uses, including oil cleanup and thermal insulation in buildings is a successfully produced byproduct of the sorghum industry found in marine habitats. The process of making biodegradable bagasse made from sugar cane aerogels involves first utilizing a polyvinyl alcohol (PVA) binding and then frozen-drying the mixture. The ultra-low the density ($[0.016-0.112]$ g/cm³), high degree of porosity ($[91.9-98.9]\%$), and extremely low temperature conductivity ($[0.031-0.042]$ W/mK) of this environmentally beneficial recycled aerogel are all present. Aerogel samples are coated with methyltrimethoxysilane (MTMS) to assess its maximum oil capacity to absorb (up to 25 g/g) and superhydrophobicity features. The biodegradable aerogel's remarkable flexibility is demonstrated by its 88 K Pa Young's modulus, which allows it to be twisted without breaking.

Chen, M., Qiu, F., Gu, B., Zhou, H., Zhang, Z., Zhang, T., & Yang, D. (2021). hybrid membrane made of cellulose with integrated functionality for applications including personal heat management. Given that too much energy was used The development of infrared thermal regulatory materials for household heat management is crucial since too much energy was used to maintain thermal convenience inside. Here, exfoliated BN nanosheets that operate (BNNS) enhanced layered double dissolution (LDH) nanosheets overlaying the outermost portion of the inorganic–organic hybridization cellulose the membrane (ICM) were assembled layer by layer to create a hybrid the membrane with heat dissipation. A single-step hydrothermal process was used to create Ni-Al LDH-coated ICM (Ni-Al-LDH/ICM). BNNS was then affixed to the outermost layer of Ni-Al-LDH/ICM to create a hybrid the membrane (BNNS/Ni-Al-LDH/ICM). With a high ultraviolet emissivity of 77%, the Ni-Al-LDH/ICM outer layer is thought to play a role in the transmission of infrared wavelengths from human beings to the surrounding atmosphere for radiation cooling. Additionally, the BNNS inner-layer has outstanding infrared transmittance. The BNNS layer also has acceptable air permeability, electric insulation, and fireresistant qualities, all of which can improve people's security and comfort in their daily lives. Therefore, there are potential uses for the BNNS/Ni-Al-LDH/ICM with integration of functions in the civil, firefighting, and aerospace domains.

Gomez, H., Maury, H., Mesa, J., and Illera, D. (2018). Trends and obstacles in using cellulose aerogels to thermal insulation in buildings. Aerogels made of cellulose have the promise to be an affordable bio-based alternative for energy efficiency in buildings. By using the Knudsen effect, low thermal conductivity levels ($<0.025 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$) are attained by reducing the contribution of the gaseous phase. Nonetheless, a number of obstacles must be addressed, including the cost and energy need for manufacture, moisture sensitivity, combustible and thermal durability. This article presents an overview and analysis of the latest developments and obstacles in the field of cellulose aerogel, which is research for thermal insulation. The information was obtained from studies that were published in the previous five years. The paper is organized into three primary sections: (i) an outline of cellulose aerogels' thermal performance; (ii) a discussion of the difficulties and potential solutions for ethanol aerogel thermal insulation; and (iii) a succinct summary of cellulose/silica aerogels.

CHAPTER-3

AIM AND SCOPE

3.1 AIM

The purpose of this work is to investigate the possibilities of materials generated from cellulose as heat transfer insulators. The goal of this study is to examine the efficiency and sustainability cellulose as thermal insulation. The objective is to evaluate the Extracted cellulose for different heat transfer applications and clarify their thermal properties, such as thermal conductivity, by thorough investigation and experimentation.

3.2 SCOPE

This study aims to conduct a development and application of cellulose-derived insulating materials for enhanced thermal performance in various heat transfer application.

Material Characterization: In order to understand the structural, mechanical, and thermal properties of the materials, cellulose-derived materials will be characterised in this study. For thorough material characterisation, methods including X-ray diffraction (XRD), and Fourier-transform infrared spectroscopy (FTIR) may be used.

Thermal Performance Evaluation: Using experimental techniques, the thermal conductivity, thermal resistance, and heat transfer characteristics of insulating materials made of cellulose will be assessed. To find out how well the materials block heat flow, heat transfer experiments under controlled settings will need to be performed.

CHAPTER 4

MATERIALS AND METHODS

4.1 SELECTION OF RAW MATERIAL

A plentiful, sustainable, and renewable source of cellulose. Wood pulp, recycled paper, hemp fibers, and agricultural wastes like bagasse or straw are common sources of cellulose. When choosing the cellulose source, take into account elements like cost, availability, and the influence on the environment. For the finished insulating material to have uniform qualities and performance, the cellulose start point must be extremely pure and consistent. Steer clear of pollutants, impurities, and changes in cellulose breakdown that might compromise the product's dependability and quality. The cellulose fibers' length and structure, since these characteristics might affect the final material's mechanical strength and ability to provide thermal insulation.

In general, longer fibers increase the material's structural integrity and offer superior insulating qualities. Low moisture content cellulose raw materials reduce the possibility of water absorption and gradual deterioration of thermal insulation effectiveness. It is better to use dry cellulose fibers as they can be processed and used in insulation goods more successfully. the requirement for chemical treatments or alterations to improve the cellulose-based insulating material's fire resistance, durability, and thermal insulation qualities.

Typical treatments that can extend the life and performance of the insulation include water repellents, flame retardants, and anti-fungal chemicals [21]. The cellulose raw material's environmental effect, taking into account energy use, release of greenhouse gases, and waste creation during manufacture and processing. Make environmentally friendly material choices and give sustainability a priority all the way through the supply chain. Compare the availability and affordability of cellulosic raw materials to those of alternative insulation choices. When choosing a supplier, compare the price of insulating material per unit of volume or weight and take handling, storage, and shipping expenses into account. As certain that the cellulose raw material of choice satisfies all applicable regulatory criteria and specifications for

thermal insulating materials. When choosing and acquiring raw materials, take into account elements like construction laws, environmental restrictions, and fire safety requirements [22]. Manufacturers may make insulation substances that offer higher efficiency of heating, environmental sustainability and cost-effectiveness for a variety of heat transfer applications by carefully evaluating these criteria and choosing premium cellulose raw ingredients. Furthermore, continued innovation and research in cellulose fabrication and insulation technologies might result in even greater gains in effectiveness and performance.

4.2 PREPARATION OF RAW MATERIAL

a. Harvesting or as Collection: Take the chosen raw material and store it in its original state. This might entail gathering cotton from fields, cutting timber from forests, or purchasing farm wastes.

b. Cleaning and Sorting: Purge the raw material of any contaminants, filth, or foreign objects. For instance, remove any leaves, bark, and other dirt if you're utilizing wood. Remove pollen and other plant material if you're using cotton.

c. Size Reduction refers to Depending on what is being done and the shape of the unprocessed substance, it could require to be chopped, crumbled, or ground into fragments in order to simplify further processing.

d. Chemical Preparation: To improve their usefulness as insulation or to change some of their qualities, some materials made of cellulose may be chemically treated. For instance, cellulose fibers can be divided into smaller parts using pulping procedures.

Drying: To eliminate any remaining moisture content, make sure that the uncooked product is completely dried. Moisture can affect the durability of the finished insulating material by interfering with later production stages.

BIOMASS ANALYSIS: Biomass analysis was conducted to determine various parameters including moisture content, ash content, volatile matter, ash content, and fixed carbon content of the water hyacinth sample were determined following standard procedures and documented.

4.3 PROXIMATE ANALYSIS

4.3.1 Moisture Content

Water content or moisture content is the quantity of water contained in a material, such as semi solid, soil, rock, ceramics, wood, etc., and is expressed as a % ratio, which can range from 0 (completely dry) to the value of the material's porosity at saturation. It can be given on a volumetric or mass (gravimetric) basis. Procedure 2gm of Eichhornia crassipes biomass was weighed in a previously weighed empty dry crucible and preheated in an oven at 105 °C. The Eichhornia crassipes were placed in a crucible in the oven for 3 hrs. The crucible was taken out and cooled. The crucible containing the Eichhornia crassipes was then weighed till the weight change became constant. $MC = \frac{(Initial\ weight - Final\ weight)}{Initial\ Weight} * 100$ Where, IW = Mass of crucible + sample before heating (gm) FW = Mass of crucible + sample after heating (gm) Mc = Moisture Content (%)

4.3.2 Volatile Matter

Volatile matter content includes those products, exclusive of moisture given off by a material such as gas or vapor. Volatile matter is determined by heating the Eichhornia crassipes sample to 550° C and then measuring the weight loss. Procedure 2gm of Eichhornia crassipes was weighed in a previously weighed empty dry crucible and preheated in an oven at 105° C for an hour. The crucible was taken out cooled and weighed. It was then placed in a muffle furnace at 550° C for an hour. The sample is heated till the weight change becomes constant. The volatile solid content values of $VM = \frac{(Initial\ weight - Final\ weight)}{Initial\ Weight} * 100$ Where, FW = Weight of crucible + sample after heating (gm) IW = Weight of crucible + sample after ignition (gm) VM = volatile matter(%) $(Initial\ weight - Final\ weight / Initial\ Weight) * 100$

4.3.3 Ash Content

Ash content is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents. Water and other volatile materials are vaporized and organic substances are burned in the presence of oxygen in the air to carbon dioxide, water, and nitrogen. Procedure 2gm of Eichhornia crassipes was weighed in a previously empty, dry crucible and placed in

a muffle furnace set at 973 °C. The samples were placed in the furnace for 4 hours in a crucible which was then removed, and allowed to cool. The crucible along with the samples were then weighed. $AC = (Initial\ weight - Final\ weight \div Initial\ Weight) * 100$ Where, IW = Mass of crucible + sample before heating (gm) FW = Mass of crucible + sample after heating (gm) Ac = Ash Content (%)

4.3.4 Fixed Carbon

Fixed carbon represents the quantity of non-volatile carbon remaining in a coal sample. Instead of being directly measured, it is determined through calculated values derived from other parameters assessed in a proximate analysis. $100 - (Moisture\ content + volatile\ matter + ash\ content)$ [23].

4.4 ANALYSIS OF FUNCTIONAL PROPERTIES OF THE SAMPLE

The extracted cellulose underwent functional property assessment, which included determining bulk density, packed density, hydrated density.

4.4.1 Bulk Density

After the sample was completely dried, weighing 0.2g, it was placed in a 10 mL measuring cylinder and gently shaken. Subsequently, the volume of the sample was recorded to determine its bulk density. $(Bulk\ density(g/mL) = amount\ of\ sample\ (g) \div volume\ of\ sample(mL))$

4.4.2 Packed Density

0.2g of the dried sample was placed into a 10 mL graduated syringe, and pressure was applied by pushing the piston until the sample would no longer decrease in volume. The packed density was then calculated using the following method. $(Packed\ density(g/ml) = amount\ of\ sample\ (g) \div least\ volume\ of\ sample\ (mL))$

4.4.3 Hydrated Density

In a 10 mL measuring cylinder, 5 mL of distilled water was initially added. Subsequently, 0.2g of the dry sample was introduced into the cylinder, and the volume of water displaced upon adding the sample was measured. The hydrated

density was determined using the provided equation. (Hydrated density(g/mL) = sample (g) \ mL of water displaced) [24].

4.5 EXTRACTION OF DELIGNIFICATION, HOLOCELLULOSE, AND CELLULOSE

4.5.1 Removing of Lignin

1. 625ml of water
2. 25g of NaOH
3. Sample 25g

They can be combined in a beaker and placed in a 90° C autoclave for 60 minutes. then remove the liquid lignin by filtering it. Holocellulose can be found in the solid residue that remains. Clean the sample and transfer it to a beaker.

For heat transfer applications, lignin removal using cellulose-derived insulating materials might be a difficult but doable process. Plant cell walls are structurally supported by the complex polymer lignin; removing it from cellulose can improve the material's ability to withstand heat.

Chemical treatments of the cellulose feedstock are used in pulping techniques like the Kraft process and the sulphite process to dissolve lignin and remove it from the fibers made from cellulose. Although these methods can effectively remove lignin, handling chemicals carefully may be necessary [25].

Although these methods can effectively remove lignin, they may cause waste for the environment and need for cautious chemical management. Organosolv pulping is a process that breaks down lignin and separates it from cellulose by combining acids or bases with solvents made from organic matter, such as whiskey or methanol. Although these methods can effectively remove lignin, they may cause waste for the environment and need for cautious chemical management.

Organosolv pulping is a process that breaks down lignin and separates it from cellulose by combining acids or bases with solvents made from organic matter, such as whiskey or methanol.



Fig 4.1: Removing of Lignin

When compared to certain chemical pulping procedures, this approach is comparatively less harmful to the environment. such as cellulases or lignin to break down lignin alone while keeping the cellulose fibers intact. The cellulose feedstock is subjected to high-pressure steam and then quickly decomposed, causing lignin and cellulose to lose some of their structural integrity and making it easier to separate them.

This technique may be useful for keeping cellulose fibers intact while eliminating lignin. Ionic substances are salt that dissolve cellulose while leaving lignin behind [26]. They are liquid at comparatively low temperatures. Lignin may be efficiently extracted from cellulose by ionic liquid treatment, however careful solvent recovery as well as recycling may be necessary.

Bleaching: To eliminate lignin and other contaminants from cellulose fibers, bleaching procedures use oxidizing agents like hydrogen peroxide or chlorine dioxide. Bleaching can enhance the whiteness and purity of materials made from cellulose, although it could not eliminate all lignin.

Combination Techniques: By combining several treatment techniques, such as chemical pulping alongside an enzymatic procedure or steam explosion accompanied by bleaching, one may maximize lignin removal and minimize the

disadvantages of each technique separately.

When selecting a lignin removal technique for cellulose-derived insulating materials [27], it's critical to take into account the particular needs of your heat transfer application in addition to elements like cost, environmental effect, and scalability. Furthermore, in order to guarantee the finished product's quality and purity, post-treatment procedures like washing and drying could be required.

4.5.2 Separation of Holocellulose

1. 665ml of water
2. Sodium chlorite (NaClO_2) =8g
3. Glacial acetic acid =16 ml
4. Sample the impure holocellulose was then treated with glacial acetic acid and sodium chlorite was stirred using magnet for 45minutes at 90° C.

Although it might be a challenging procedure, it is possible to separate hemicellulose that from cellulose in celluloid-derived insulating substances for heat transfer applications. In addition to cellulose and lignin, hemicellulose is a polymer found in plant cell walls. Pretreatment, which can include either physical, chemical, or biological techniques to break down lignin and alter the structure of the vegetative cell wall, is frequently the initial step. This stage contributes to the increased efficiency of the cellulose and hemicellulose separation process that follows. Steam detonation, acid hydrolysis, acidic hydrolysis, and oxidative techniques are common pretreatment techniques [28].

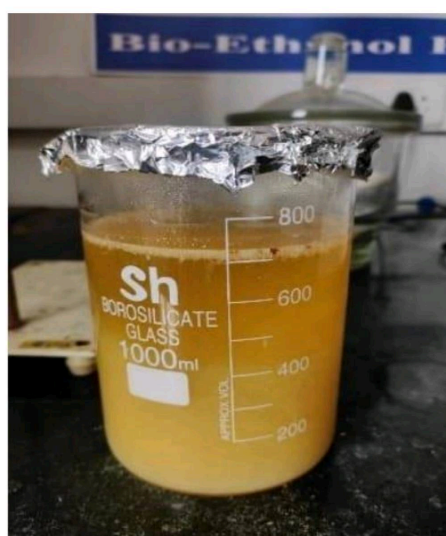


Fig.4.2: Separation of Holocellulose

Various methods can be used for this purpose:

Using solvents that selectively dissolve hemicellulose while leaving cellulose behind. For example, alkaline solutions can dissolve hemicellulose.

Enzymatic hydrolysis: Utilizing enzymes that specifically target hemicellulose bonds, leaving cellulose intact. Acidic conditions can hydrolyse hemicellulose into monomeric sugars while leaving cellulose unaffected. Separating components based on their size differences. Once fractionated, further separation of hemicellulose from the solvent or enzymatic hydrolysate may be necessary.

Techniques such as filtration, centrifugation, and evaporation can be employed depending on the specific process and materials involved [29]. The separated hemicellulose may undergo purification steps to remove any remaining impurities or solvent traces, ensuring the purity of the extracted material. The separation of hemicellulose from cellulose in cellulose-derived materials involves a combination of pretreatment, fractionation, separation, purification, and characterization steps to obtain the desired components for specific applications such as heat transfer insulation.

4.5.3 Cellulose Preparation

1. 280ml of water

2. Hydrochloric acid (HCL) = 6ml

3. Add processed sample

And keep it in heating mantle for 2 hours and wash it with hot distilled water to remove the holocellulose. And dry it cellulose will be obtained.

Cellulose-derived insulating materials are widely used for various applications, including heat transfer insulation. Cellulose, being a natural polymer found in plant cell walls, possesses excellent thermal insulation properties. The cellulose source undergoes a pulping process to separate the cellulose fibers from lignin, hemicellulose, and other impurities. This can be done through mechanical or chemical pulping methods. Chemical pulping methods, such as the Kraft process or sulfite process, are commonly used for higher purity cellulose extraction [30].



Fig. 4.3: Derived Cellulose

The extracted cellulose fibers may undergo further treatment to improve their properties. This could involve processes like bleaching to remove remaining impurities and brighten the fibers, or enzymatic treatment to modify the surface properties of the fibers. The cellulose fibers are then mixed with additives and binders to form a homogeneous mixture.

Additives may include fire retardants, water repellents, and other substances to enhance specific properties of the final product. Binders help in holding the fibers together to form a coherent structure. The mixture is formed into the desired shape using methods such as compression molding, extrusion, or casting. Compression molding is often used for producing sheets or boards, while extrusion can be employed for forming continuous shapes like pipes or films [31].

The formed cellulose material is then cured or dried to remove moisture and set the structure. This could involve processes like air drying, thermal curing, or a combination of both depending on the composition of the material. The cellulose-derived insulating material is ready, it undergoes final inspection to ensure it meets quality standards. It is then packaged appropriately for storage and transportation. Cellulose-derived insulating materials can be prepared effectively for heat transfer

applications, providing efficient thermal insulation while utilizing renewable and sustainable resources.

4.6 PROPERTIES ANALYZATION FOR DIFFERENT COMBINATION

1. Biomass=3g + Starch=3g + Water=25ml
2. Mixed (1.5g grinded cellulose and 1.5g commercial cellulose) + Starch=3g + Water=25ml
3. Grinded cellulose=3g + Starch=3g + Water=25ml
4. Commercial cellulose=3g + Starch=3g + Water=25ml

Analyzing cellulose-derived insulating materials for heat transfer applications involves considering various properties such as thermal conductivity, mechanical strength, fire resistance, and environmental impact.

Generally, biomass-derived cellulose tends to have higher thermal conductivity compared to processed cellulose due to impurities and varying fiber structures. Mixing cellulose from different sources may lead to variations in thermal conductivity depending on the ratio of each component. As the smaller particle size reduces the pathways for heat transfer.

Mechanical strength may vary depending on the source and processing method of biomass cellulose. Some biomass-derived cellulose materials may exhibit lower mechanical strength due to impurities and irregular fiber structures[32]. The mechanical strength of mixed cellulose materials can be tailored by adjusting the ratio of cellulose from different sources. Proper blending can enhance mechanical properties such as tensile strength and flexibility. Fire resistance of biomass-derived cellulose depends on the type of biomass and its inherent properties.

Some biomass materials may contain higher levels of lignin or other components that enhance fire resistance, while others may require chemical treatment for improved fire retardancy. Finely ground cellulose may exhibit improved fire resistance due to increased surface area and better distribution of fire-retardant additives if incorporated. Environmental impact depends on the sources of cellulose

and the sustainability of their production. Using recycled cellulose or waste materials can reduce environmental impact[33].

Ground cellulose derived from sustainable sources and processed using eco-friendly methods can have a minimal environmental footprint, especially if derived from recycled or waste materials. The properties of cellulose-derived insulating materials for heat transfer applications vary depending on the combination of biomass, mixed, or ground cellulose. Proper selection and processing of cellulose materials can optimize thermal conductivity, mechanical strength, fire resistance, and environmental sustainability, making them suitable for a wide range of insulation applications.

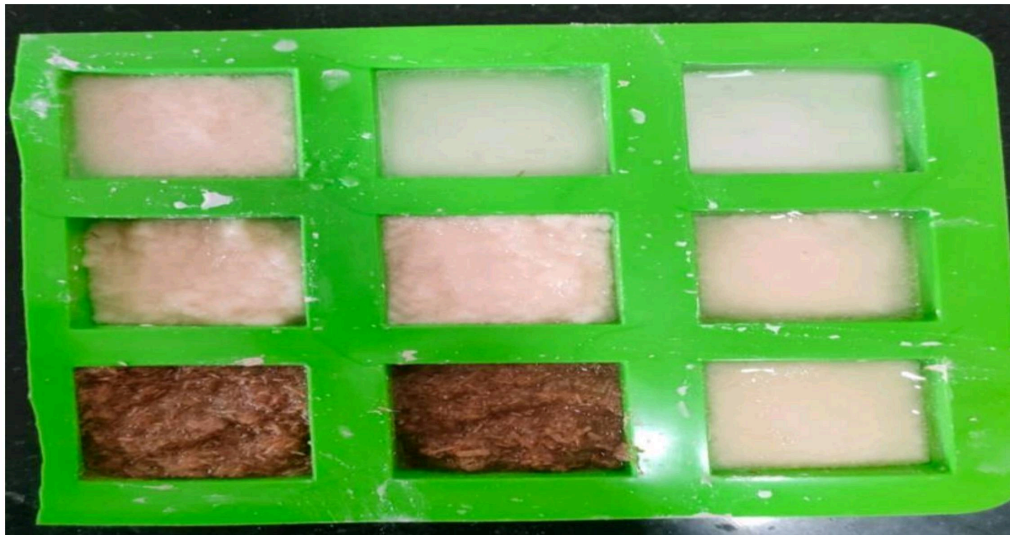


Fig. 4.4: Properties Analyzation

CHAPTER 5

RESULT AND DISCUSSION

5.1 PROXIMATE ANALYSIS

In several disciplines, including geography, planning for neighborhoods, the study of networks, and data science, proximity examination is a technique used to look at the geographical connections between distinct entities or characteristics. In a particular spatial context, it entails assessing the nearness or closeness of one item or location to another. Using fig. 1 Numerous scales, between local to worldwide, might be used for the analysis, depending on the study's goals and environment. Understanding the geographical connections between various geographic organisms, such as the separation between 2 points, the relationship between pairs of polygons, and or the connectedness of network nodes, is made easier with the aid of proximity analysis. Thermal conductivity and insulation qualities of cellulose-derived insulating materials are assessed in relation to their closeness in order to perform proximity analysis for heat transfer applications. closeness to thermal barriers or sources of heat. In environmental studies, proximity assessment is used to evaluate how human activity affects ecosystems, wildlife habitats, and natural resources.

It supports land management, planning for conservation, and risk assessment. the cellulose-derived material's thermal conductivity utilizing accepted methods such the transient plane source method, shielded hot plate method, or hot disk method. Important information on the material's heat conductivity will be obtained from this test. The insulating material made of cellulose will be near the heat source. This may be placed close to or in immediate proximity with an energy source (such as a hot water pipe). computational simulations or mathematical models to estimate the heat transfer through the vicinity of the insulating material and the heat source.

Table 5.1: Result Proximity Analysis

Properties (Percentage)	Elephant grass	Extracted cellulose	Commercial Cellulose
Moisture Content	0.363	0.9	0
Ash Content	3.481	2.9	2.631
Volatile Matter	2.603	2.01	3.666
Fixed Carbon	93.55	94.19	93.705

The material's surface area, temperature gradient, and thermal conductivity are all important variables to take into account. This entails figuring out how well a material resists heat transfer by taking into account both its thickness and thermal conductivity. Optimize the cellulose-derived insulating material's closeness to the heat source based on the analysis's findings to achieve the highest possible efficiency in heat transfer reduction.

Proximity analysis is useful in emergency response planning and disaster management because it may be used to pinpoint dangerous regions, vital infrastructure, and evacuation routes. It facilitates preparing for emergencies and the effective use of resources. A flexible method for analyzing spatial relationships, trends, and interactions, proximity analysis is applied in many different fields to provide insights that help with planning and decision-making.

5.2 DENSITY CALCULATION

You must take into account both the density of cellulose and any other materials or additives inside the insulation when determining the weight of cellulose-derived insulation substances for heat transfer applications. The elements that comprise the insulating substance. Although cellulose fibers make up the majority of cellulose insulation, binders and fire retardants may also be added. the various component densities. The density of cellulose fibers is normally between 1.5 and 1.6 grams per centimeter of surface area (g/cm^3).

This is accomplished by aggregating the results of multiplying each component's density by its volume percentage in the mixture. For example, you would compute the average, weighted, density if the material consisted of 90% cellulose fibers and 10% binder.

$$\text{Density}_{\text{mixture}} = \sum (\text{Density}_{\text{Component}} \times \text{Volume fraction}_{\text{Component}})$$

Table 5.2: Result of Bulk Density

Properties	Biomass	Extracted Cellulose	Commercial Cellulose
Bulk Density	0.14	0.13	0.12
Packed Density	0.12	0.11	0.10
Hydrated Density	0.33	0.31	0.30

The packing of cellulose fibers can vary based on the production method, from loose to dense. The material's total density is influenced by the packing density. Include whatever information you have about the packing frequency in your computation. A percentage is frequently used to represent packing density.

5.3 FTIR

Biomass-derived cellulose, extracted cellulose, and commercial cellulose are three distinct sources of cellulose-derived insulating materials for heat transfer applications. Each source possesses unique properties and characteristics that influence its suitability and performance in insulation.

Biomass-derived cellulose may exhibit variations in thermal conductivity, density, porosity, and mechanical strength based on the specific raw materials and processing techniques employed. And one of the techniques is FTIR. Elephant grass biomass can be analysed using Fourier Transform Infrared Spectroscopy (FTIR) to gain important insights into its chemical composition and determine whether it is suitable for use in thermal insulator applications in the biomass ftir result.

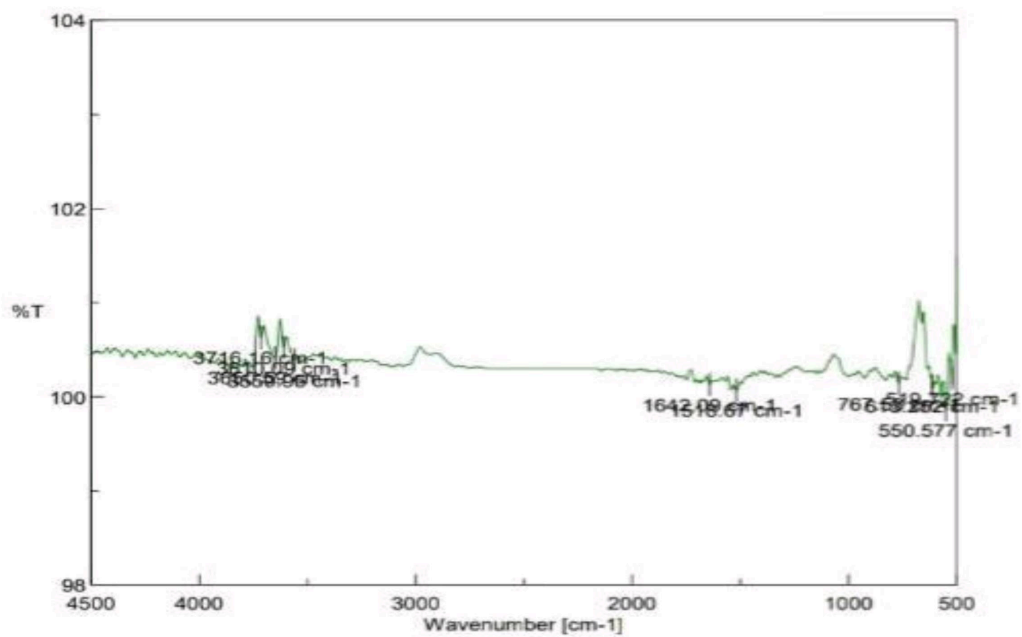


Fig. 5.1: Biomass-derived Cellulose FTIR Result

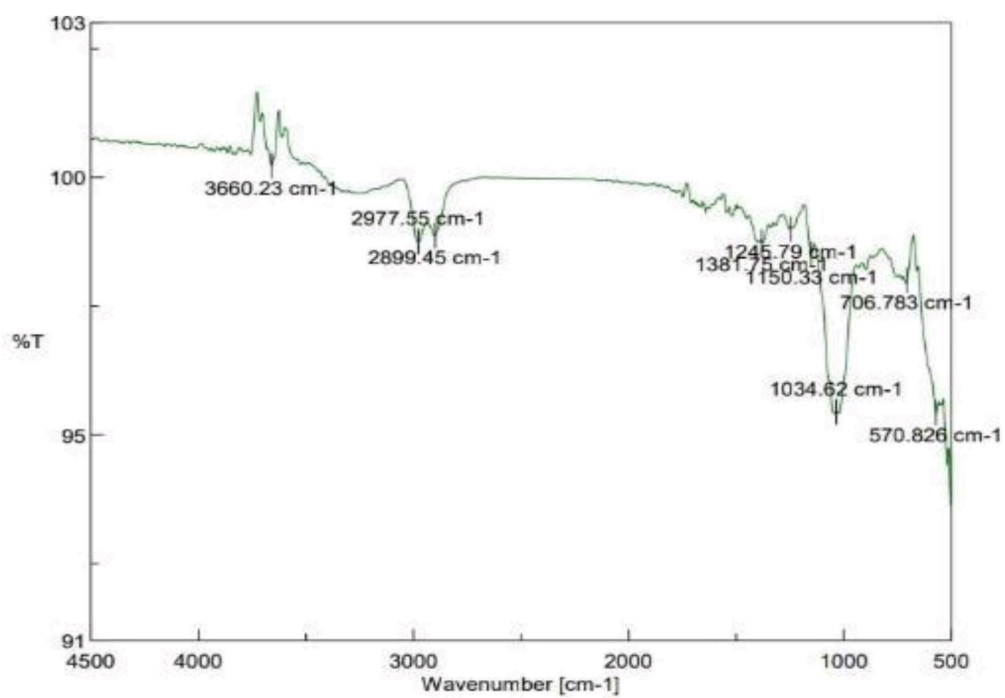


Fig. 5.2: Extracted Cellulose FTIR Result

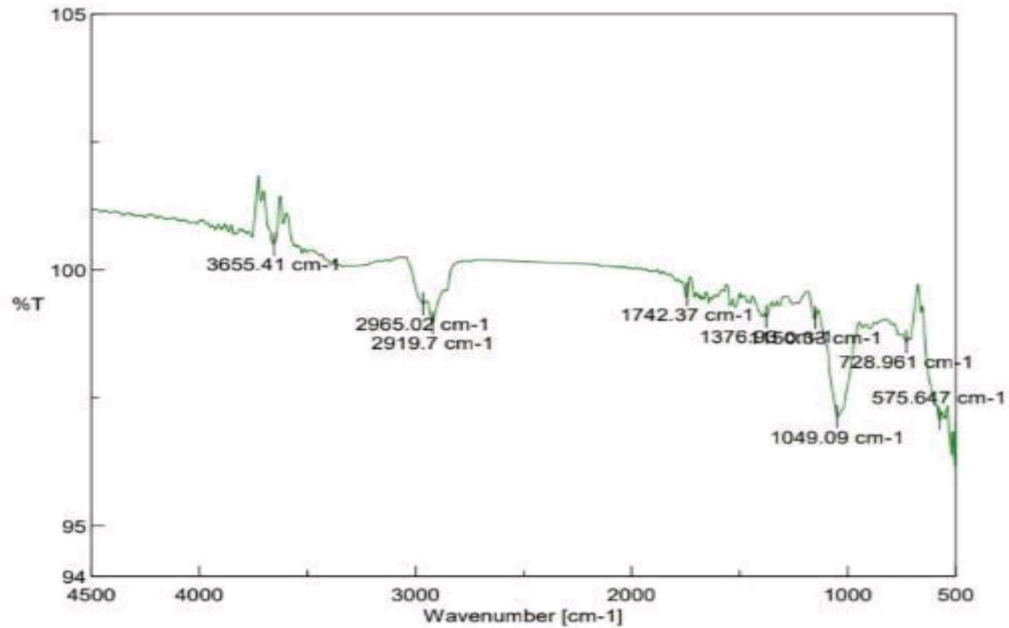


Fig. 5.3: Commercial Cellulose FTIR Result

The wavelength range of approximately 1520 to 1650 indicates the presence of lignin components in the biomass sample. However, extracted cellulose does not exhibit peaks within this range, suggesting the effectiveness of the pre-treatment process. This observation is further confirmed by the absence of similar peaks in commercially available cellulose samples. Overall, FTIR results indicate effectiveness in removing lignin from the extracted sample.

Overall, cellulose-derived insulating materials offer promising solutions for heat transfer applications due to their renewable nature, thermal insulation properties, and environmental sustainability. The choice of biomass-derived, extracted, or commercial cellulose depends on factors such as availability, cost, performance requirements, and environmental considerations. Further research and development efforts are needed to optimize cellulose-derived insulation materials for various applications and to enhance their overall performance and sustainability.

5.4 XRD RESULT

XRD analysis of elephant grass biomass can provide information about its crystalline structure, primarily reflecting the cellulose content and potentially other crystalline phases present. It is essential for understanding the biomass's properties and its suitability for various applications, including bioenergy, bio composite materials, and biorefinery processes.

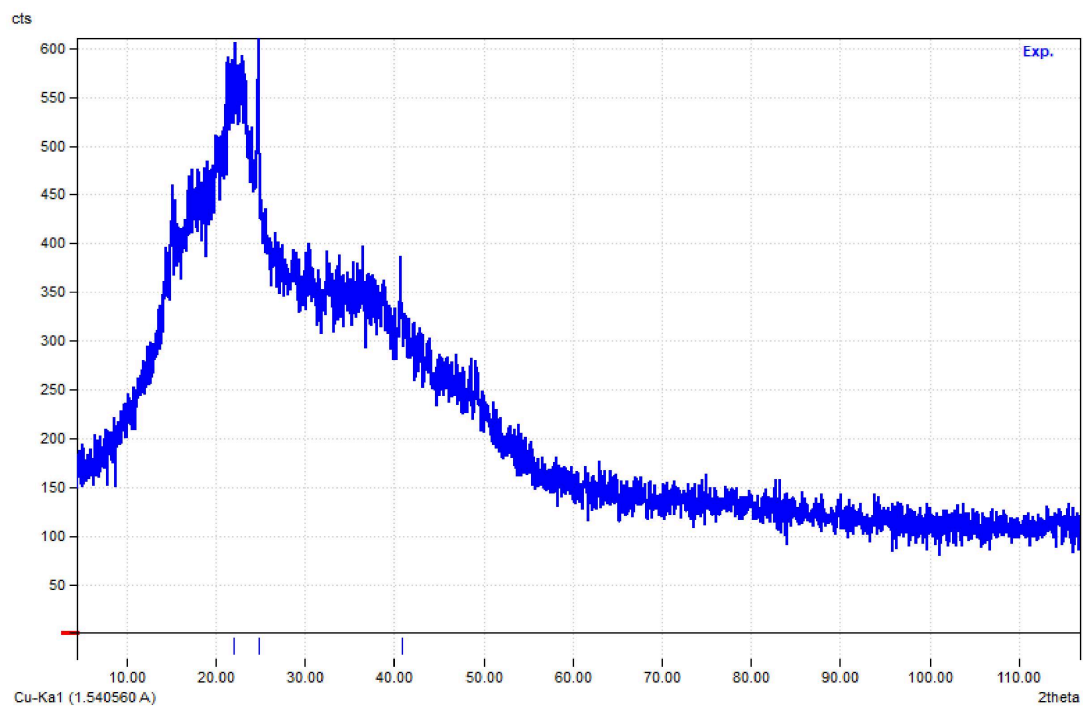


Fig. 5.4 Biomass XRD Result

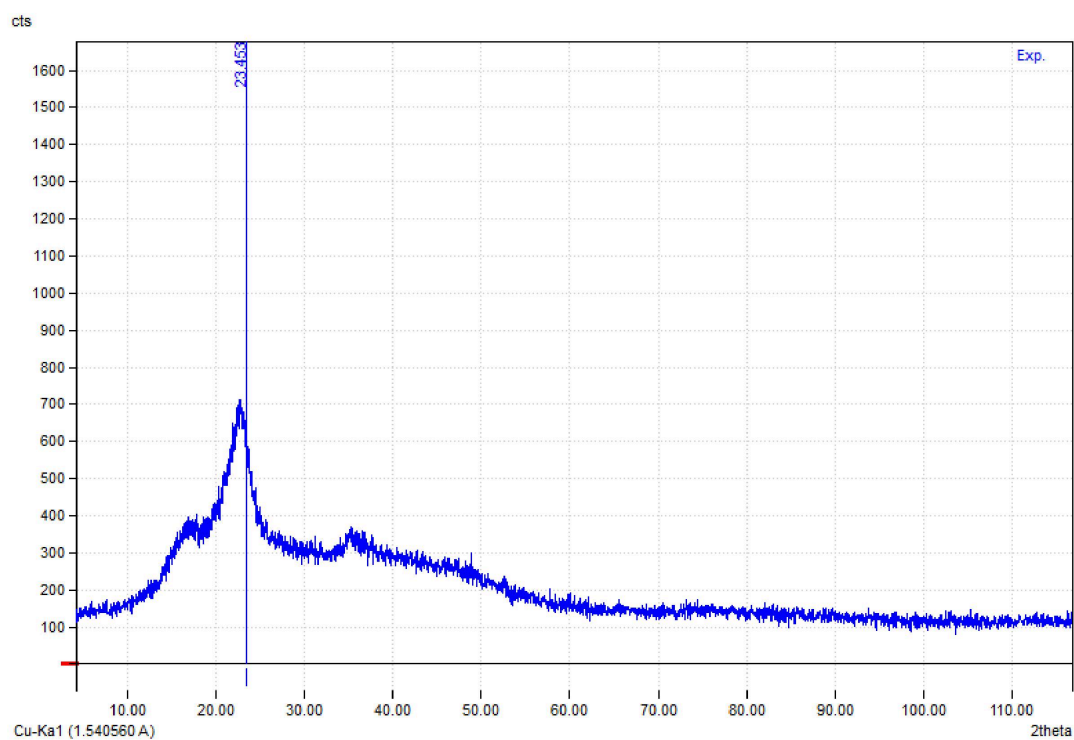


Fig. 5.5: Extracted Cellulose XRD Result

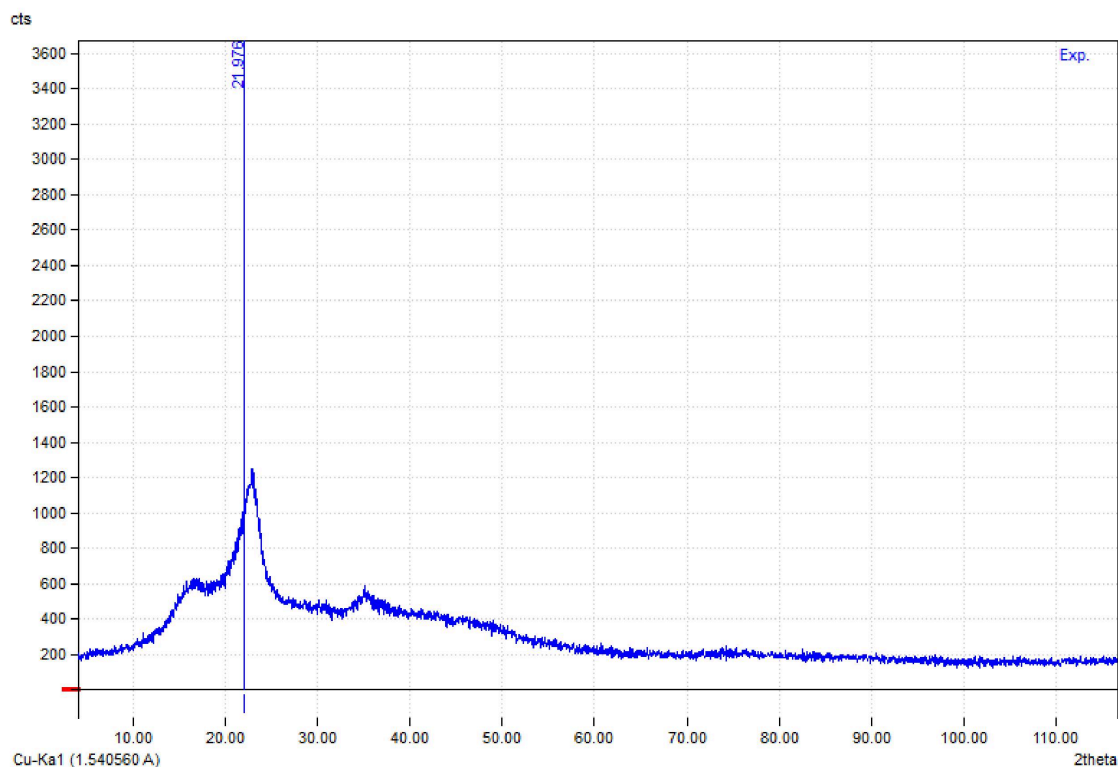


Fig.5.6: Commercial Cellulose XRD Result

XRD analysis was carried out to investigate the formation of the pure cellulose (extracted) thermal insulator which compared to biomass thermal insulator commercial cellulose thermal insulator. The XRD pattern of biomass thermal insulator, pure cellulose (extracted) and commercial cellulose thermal insulator are shown in Fig. XRD showed the characteristic peaks at 22.09, 24.90 and 40.85 representing the characteristic peaks of biomass thermal insulator. The peaks of pure cellulose (extracted) around 23.45 and the peaks of commercial cellulose shows around 21.98. However, other peaks at 24.90 and 40.85 present in the biomass cellulose thermal insulator were disappeared in pure cellulose (extracted) and commercial cellulose thermal insulator, which could be due to the formation of intermediate phases in the presence of the highly alkaline solution of NaOH during the synthesis of the pure cellulose (extracted). These phases exhibited a low crystalline structure with weak diffraction peaks in the XRD pattern of the cellulose.

5.5 THERMAL CONDUCTIVITY

Biomass materials are used as insulation in various applications such as construction, and thermal management systems. Thermal conductivity testing helps the effectiveness of biomass-based insulation in resisting heat transfer. A low thermal conductivity indicates better insulation performance, as it means the material can impede the flow of heat more effectively.

Thermal conductivity testing for biomass is essential for evaluating insulation performance, selecting suitable materials, optimizing processing methods, ensuring product quality, fostering innovation, and promoting sustainability in various industries

For a material to be classified as a thermal insulator, its thermal conductivity value (λ) must be less than $0.1 \text{ W m}^{-1} \text{ K}^{-1}$. In our sample thermal conductivity of biomass (0.073 W/m.K), extracted cellulose (0.056 W/m.K) and commercial cellulose (0.041 W/m.K). This result indicates effectiveness of insulating capacity of biomass, and extracted cellulose.

Table 5.3: Thermal Conductivity for Samples

SAMPLE	THERMAL CONDUCTIVITY (W/m.K)
Bio Mass	0.073 W/m.K
Extracted Cellulose	0.056 W/m.K
Commercial Cellulose	0.041 W/m.K

CHAPTER-6

SUMMARY AND CONCLUSION

In conclusion, the research and development of cellulose-derived insulating materials for heat transfer applications represents a significant stride towards sustainable and efficient thermal management solutions. The utilization of cellulose, a renewable and abundant natural resource, offers a promising avenue for addressing the growing demand for environmentally friendly insulation materials. Through comprehensive experimentation and analysis, this study has demonstrated the feasibility and potential of cellulose-derived materials as effective thermal insulators.

The inherent properties of cellulose, including low thermal conductivity and biodegradability, make it an attractive candidate for a wide range of heat transfer applications, spanning from building insulation to industrial processes. Advancements in manufacturing techniques and material processing have enabled the optimization of cellulose-based insulation materials for enhanced thermal performance, durability, and cost-effectiveness.

By exploring innovative fabrication methods and incorporating additives or treatments to mitigate challenges such as moisture absorption and fire resistance, researchers have made significant strides in overcoming the limitations associated with cellulose-derived materials.

The application of cellulose-derived insulating materials holds great promise in addressing key challenges in heat transfer applications, including energy efficiency, environmental impact, and sustainability. By providing effective thermal insulation, these materials can contribute to reduced energy consumption, lower greenhouse gas emissions, and improved indoor comfort and air quality.

The scalability and affordability of cellulose-derived insulation materials make them accessible to a wide range of industries and consumers, further driving

their adoption and widespread use. As the demand for sustainable building materials and energy-efficient solutions continues to grow, cellulose-derived insulating materials are poised to play a crucial role in shaping the future of thermal management technologies.

In conclusion, the development and utilization of cellulose-derived insulating materials represents a promising avenue for advancing sustainable and efficient heat transfer applications. Through ongoing research, innovation, and collaboration across academia, industry, and government sectors, we can harness the full potential of cellulose-based materials to address global challenges related to energy efficiency, climate change, and environmental sustainability.

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