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ANALYSIS OF STABLE PHASE CHANGE MATERIAL MADE USING RUBBERWOOD BIOCHAR FOR THERMAL ENERGY STORAGE

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Abstract:

This work analyses the stability of phase change materials after being mixed with rubber wood biochar for thermal energy storage. Globally, stable phase change materials are receiving increased attention as it provides better functionality specifically to regulate temperature changes during diurnal temperature fluctuations in building construction elements. This study focuses on conducting three main sections, to obtain the optimum impregnation percentage of rubberwood for the phase change material to achieve effective impregnation, to evaluate the effect of phase change material on the heat transfer properties of wood composites, and to measure the physical and mechanical properties of wood composites with shape-stabilized palmitic acid/decanoic acid as phase change material. Rubberwood particles were pyrolyzed before mixed with palmitic acid and decanoic acid, respectively. Testing of leakage and thermal conductivity were carried out for both mixtures. Mechanical evaluation on wood composites made with the wood mixtures were recorded.

Keyword:

Biochar, Decanoic Acid, Palmitic Acid, Phase Change Material, Wood Composite.

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Introduction

The use of energy is growing worldwide. People were captivated by the building structure's usage of energy-regulating elements. Heat can be stored and released by a phase change material at any time of day or night. This is a possible method of producing energy-efficient building materials for the construction of green buildings. The problem is that when this medium is heated, it tends to evaporate.

A more complete history may have been necessary for the initial discovery and use of phase change materials. It's possible that people have either used these drugs without understanding their nature or have been unaware of them from the beginning of human intelligence. However, as science and industry have advanced, their methods of storing and releasing thermal energy have been investigated since the discovery of sensible or latent energies and the heat capacity of materials. The first report on the finding of phase transition material that could be utilized in energy storage applications was given by Alan Tower Waterman of Yale University at the beginning of the 20th century [Mohsen M. (2018)]. An integral part of renewable energy is energy storage. Energy can be stored mechanically (e.g., pressurised air, flywheel, etc.), electrically (e.g., double-layer capacitors), chemically (e.g., fuels), electrochemically e.g., batteries), or thermally [Vakhshouri AR. (2020)].

Phase change materials (PCMs) are latent thermal energy storage materials that can control daytime and nighttime temperature variations in building components. Nearly majority of the focus in academic research is on PCM encapsulation in manufactured porous structural materials like wallboard, plaster, and cement. One has created a unique thermal insulating material using wood chips, high-density polyethylene, and micro-encapsulated PCM [Jesuarockiam N. (2019)]. Utilizing PCMs incorporated into construction materials to effectively store thermal energy and manage available energy resources in a reasonable manner [Sulaiman NS. (2022)]. With daily increases in energy consumption and expenses, there is growing interest in developing and comprehending PCM encapsulated in building materials. Wood materials are particularly attractive for PCM encapsulations since they are cheap and commonly used in constructions for a variety of purposes (floors, ceilings, walls, etc.). However, wood has long been known to provide special compounds to enhance its properties because it is a porous natural substance [Temiz A. (2020)]. Compared to traditional synthetic fillers, natural fibres are more affordable, less abrasive, renewable, and biodegradable [Tabarsa T. (2011)].

Phase change materials (PCMs) have been researched and used extensively globally in recent years due to their advanced properties, such as tiny size transition, high thermal density, and maintained phase change temperature [Satya G N. (2022)]. Additionally, the system's energy efficiency can be increased by using PCMs. The main types of PCMs are eutectic, organic, and

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inorganic. Compared to the other two PCMs, organic PCMs have a large latent heat capacity, outstanding thermal stability, and are environmentally friendly [Wan Y-c. (2019)].

Direct composite mixing with a hot polymer is not feasible due to the nature of the PCM. The phase change material should be microencapsulated with polymers prior to being embedded in a wood composite. The impact and dependability of using rubberwood and palmitic acid together as a stable phase change material will be examined in this study. The effectiveness of wood as one of the suggested thermal energy storage materials for the microencapsulation technique will also be confirmed by this effort.

Methodology

Materials

Samples of rubberwood were gathered at a nearby wood processing plant in Bukit Perawas, Jeli, Kelantan, Malaysia. Local vendors provided ethanol, palmitic acid, unsaturated polyester (UPE) resin (Reversol P9565), methyl ethyl ketone peroxide (MEKP), and cobalt naphthalene (Revertex Malaysia Sdn. Bhd.). The characteristics of UPE are displayed in Table 1.

Table 1. The Properties of Upe by Revertex (Malaysia)

Viscosity(cp)	Density (g/cm^3)	Volume shrinkage (%)	Gel time at 25°C (min)	Tensile strength (MPa)	Tensile Modulus (GPa)	Elongation (%)
200 - 300	1.2	8.7	12 - 15	63.9 - 72	3.40 – 3.59	2.5 – 3.1

Sample Preparations

Particles of rubberwood were oven-dried for a full day at 100°C. Rubberwood particles were heated to 500°C for 60 minutes in a furnace to create biochar. Additionally, raw rubberwood particles were made for the control sample. In order to maximize the absorption of the phase change materials, palmitic acid was impregnated by heating wood particles in a water bath at 100°C [Amini MHM. (2022)]. The precalculated proportions of PCM and UPE were thoroughly mixed with an accelerator agent (MEKP) and catalyst agent (cobalt naphthalene) to prepare the composite. Using a hot press with five tons of pressure, the mixture was cured for fifteen minutes at 120°C. The composition of each form of composite is displayed in Table 2.

Table 2. Composition Of Wood and Palmitic Acid of Each Sample

Samples (biochar)	Palmitic acid composition (%)	Wood compositions (g)
TRB1	10	20
TRB2	20	20
TRB3	30	20
TRB4	40	20
TRB5	0	20

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Samples (particle)	Palmitic acid composition (%)	Wood compositions (g)
TRP1	10	20
TRP2	20	20
TRP3	30	20
TRP4	40	20
TRP5	0	20
		20

*TRB = Rubberwood biochar composite; TRP = Raw rubberwood particle composite

Testing Procedures

Characterisation

Fourier transform infrared spectroscopy (FT-IR) was used to obtain the Fourier transform infrared patterns of the composites. A Mettler Toledo TGA/DSC2 was used to perform the thermal analysis of PCM composites with a pure nitrogen flow at 20 millilitres per minute and a heating rate constant of 10 degrees Celsius per minute. Samples weighing around 2.5 mg were put into a tiny crucible and cooked at temperatures between 25 and 600 degrees Celsius. The purpose of the investigation was to assess how phase change material affected the heat transfer characteristics of wood composites. Thermal stability and weight loss were measured using thermogravimetric analysis. With a heating rate of 10 °C per minute and a protective gas of high-quality nitrogen (purity of 99.99%), the testing temperature ranged from 30 °C to 800 °C. Differential scanning calorimetry (DSC) was used to examine the composites' phase transition temperature and latent heat.

Results and Discussions

Thermal Gravimetric Analysis (TGA)

For form-stable phase change materials used in latent heat storage applications, thermal stability is essential. The weight loss process of the composite as the temperature rises was measured using TGA analysis. The prepared wood composites' TGA curves are displayed in Figure 1. According to the curves displayed, degradation happened in two steps: the sample broke down between 160 and 170 degrees Celsius, then degraded once more to a significantly steeper curve that began from 300 to 420 degrees Celsius before a sustained loss at 450 degrees. For TRB2, they displayed a steep turn that was more noticeable at first, followed by a steep that was comparable to other samples. For TRB3, there was a slight steep curve at 140°C, which was followed by a steady weight loss. From 300°C to 400°C, the curve became substantially steeper, and at 450°C, it ended with a steady weight loss. Tight weight loss curves were seen in TRP3/TRP5 at 170°C, followed by a steeper curve beginning at 300°C. Sample TRB5/TRP1 was thought to have a useful practical application in thermal energy storage due to its favourable thermal stability below 152°C. According to research [Wan Y-c (2019).], the early biochar breakdown temperature of this sample was 150°C.

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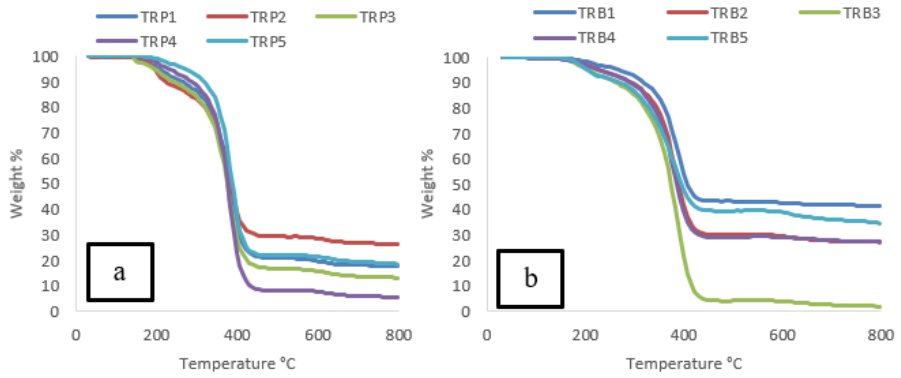

Figure 1. Thermogravimetry Curves Of (A) Produced Biochar (Trb) And (B) Raw Particles (Trp)

Differential Scanning Calorimetry (DSC) Analysis

The DSC graph of various rubberwood biochar and particle samples is displayed in Figure 2. According to the graph, every sample releases heat as soon as the temperature increases. The average heat flux of TRB1, TRB4, and TRB5 was closer, ranging from 30°C to 45°C. When compared to other rubberwood particles and biochar, TRB3 and TRP3 exhibited the maximum heat flux. The PA: RB/RP ratio, which was 6:4 in the previous phase, was the same for both TRB3 and TRP3. Analysis was conducted on temperatures ranging from 30 to 200 degrees Celsius, taking into account the ultimate product's working temperature. The samples were found to have heat-absorptive properties between these temperatures, which is a crucial component of a material for latent heat storage.

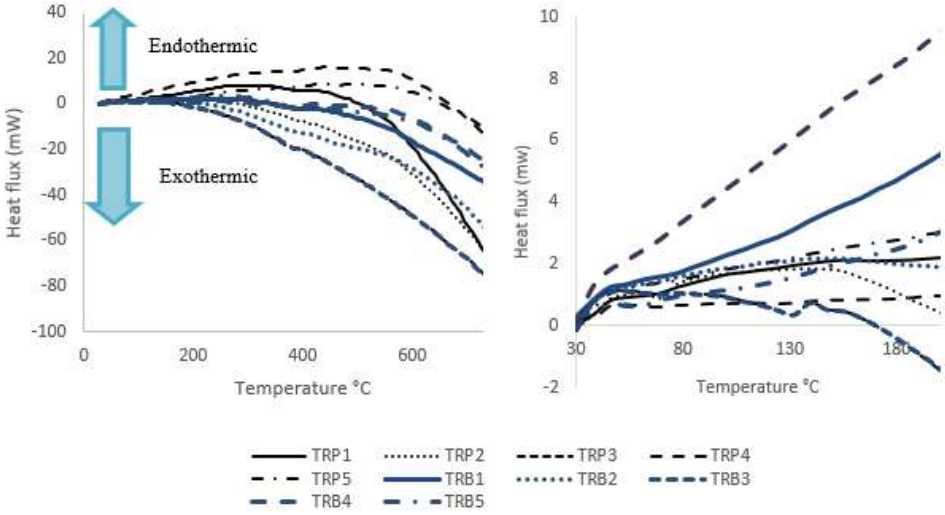

Figure 2. DSC Curves of All Samples at Full Temperature Sweep (Left) And Close-Up Between 30 °C To 200 °C (Right)

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Fourier Transform Infrared Spectroscopy (FT-IR) Analysis

All five rubberwood biochar (TRB) show a near identical number of peaks. Additionally, each of the five pyrolyzed rubberwood particles (TRP) displays the most prevalent compound that could be present in the samples. Since the final peak of all ten samples has more than five peaks, it is regarded as a complicated sample. Every conceivable material's look is displayed in Table 2. The findings suggested that a main alcohol, secondary alcohol, alkane, and esters made up the PCM's functional group. Wood samples were combined with palmitic acid using primary alcohol (ethanol), an organic molecule. Its primary purpose is to provide as fuel for the fermentation process, which produces carbon dioxide and water. As an aside, alkanes are found in a wide variety of different biological materials. By demonstrating the carbon and energy source, it primarily serves metabolic and ecological purposes.

The composite wavelengths were found to be distributed between 2914.80 cm-1 and 2847.70 cm-1 during this test (Figure 3). For cellulose and lignin, the band was found at around 2925 cm-1 and 2844 cm-1, respectively, and was attributed to -CH2 stretching in alkyl groups [Jutharat I. (2021)]. The following wavelengths were caused by C=O stretching at 1716.09 cm-1, -OH bending at 1697.67 cm-1, -CH bending at 1068.01 cm-1, and out-of-plane -CH bending at 741.44 cm-1 [Esmaeili E. (2021)].

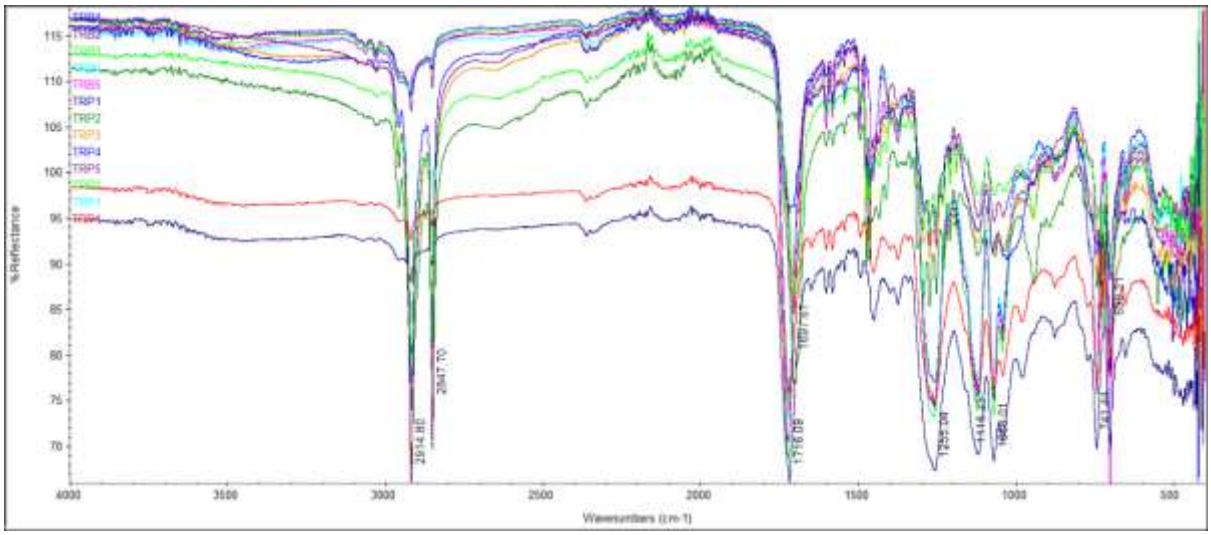

Figure 3. FT-IR Spectra of All Samples

Table 3. FT-IR Properties of Wood Composite Samples

Absorptions (cm^{-1})	Appearance	Functional group	Compound class
2914.80	Strong, broad	-CH_2 stretching	Alkyl cellulose
2847.70	medium	-CH_2 stretching	Alkyl lignin
1716.09	Strong	C=O stretching	Conjugated acid, aldehyde
1697.67	Medium	O-H bending	Alkane
1255.04	Strong	C-O, C-N stretching	Aromatic amine, aromatic ester, alkyl aryl ether

1068.01	Strong	C-H bending	Primary alcohol
741.44	Strong	C-H bending	Monosubstituted
698.21		C-H bending	Benzene derivative

Conclusion

By impregnating rubberwood biochar or particles as the shape-stabilizing matrix for the palmitic acid, a potential form-stable phase change material comprising palmitic acid/rubberwood and palmitic acid/rubberwood biochar was created. The samples were evaluated using Fourier-transform infrared analysis (FT-IR), differential scanning calorimetry analysis (DSC), and thermogravimetry analysis (TGA). DSC research revealed that the samples had a heat-absorptive characteristic between 30 and 200 degrees Celsius, which is a crucial component of a material for latent heat storage. The fact that the raw material was extracted from rubberwood forest leftovers, which is inexpensive, safe for the environment, and easy to create, is another benefit of this product. As a result, the composite created in this study had a great deal of potential for use in thermal energy storage.

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Ethics Statement: Option B (For Studies Not Involving Human or Animal Subjects) This study did not involve any human participants, animals, or sensitive data requiring ethical approval. The authors confirm that the research was conducted in accordance with accepted academic integrity and ethical publishing standards.

Author Contribution Statement: All authors contributed significantly to the development of this manuscript. [Author 1] was responsible for the conceptualization, methodology, and overall supervision of the study. [Author 2] handled data collection, analysis, and interpretation of results. [Author 3] contributed to the literature review, drafting, and critical revision of the manuscript. All authors read and approved the final version of the manuscript prior to submission.

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References

Amini MHM, Temiz A, Hekimoğlu G, Demirel GK, Sarı A. Properties of Scots pine wood impregnated with capric acid for potential energy saving building material. Holzforschung. 2022;76(8):744-53.

Esmaeili E, Rounaghi SA, Eckert J. Mechanochemical synthesis of rosin-modified montmorillonite: A breakthrough approach to the next generation of OMMT/Rubber nanocomposites. Nanomaterials. 2021;11(8):1974.

Jelena L. (2023). Natural Rubber Composites Using Hydrothermally Carbonized Hardwood Waste Biomass as a Partial Reinforcing Filler—Part II: Mechanical, Thermal and Ageing (Chemical) Properties. Polymers 2023, 15, 2397.

Jesuarockiam N. (2019). Jesuarockiam N, Jawaid M, Zainudin ES, Thariq Hameed Sultan M, Yahaya R. Enhanced thermal and dynamic mechanical properties of synthetic/natural hybrid composites with graphene nanoplateletes. Polymers. 2019;11(7):1085.

Jutharat I. (2021). The Characteristics of Natural Rubber Composites with Klason Lignin as a Green Reinforcing Filler: Thermal Stability, Mechanical and Dynamical Properties. Polymers 2021, 13, 1109.

Lijuan P. (2021). In Polymerization of Environment Friendly Melamine-Urea- Glyoxal Resin in Rubber Wood for Improved Physical and Mechanical Properties. Hindawi International Journal of Polymer Science Volume 2021

Mohsen M. (2018). Introductory Chapter: Phase Change Material. In: Mohsen M, editor. Phase Change Materials and Their Applications. Rijeka: IntechOpen; 2018. p. Ch. 1.

Satya G N. (2022). Preparation and Characterisation of Wood Polymer Composites Using Sustainable Raw Materials. Polymers 2022, 14, 3183.

Su-Gwang Jeong (2012). Performance evaluation of the microencapsulated PCM for wood-based flooring application. Energy Conversion and Management. Elsevier.

Sulaiman NS. (2022). Sulaiman NS, Mohamad Amini MH. Review on the Phase Change Materials in Wood for Thermal Regulative Wood-Based Products. Forests [Internet]. 2022; 13(10).

Suresh K. (2017). Experimental investigations on the thermophysical properties of CuO-palmitic acid phase change material for heating applications. J Therm Anal Calorim (2017) 129:1647–1657

Tabarsa T. (2011). Tabarsa T, Khanjanzadeh H, Pirayesh H. Manufacturing of wood-plastic composite from completely recycled materials. Key engineering materials. 2011; 471: 62-6.

Temiz A. (2020). Temiz A, Hekimoğlu G, Köse Demirel G, Sarı A, Mohamad Amini MH. Phase change material impregnated wood for passive thermal management of timber buildings. International Journal of Energy Research. 2020;44(13):10495-505.

Vakhshouri AR. (2020). Paraffin as phase change material. Paraffin Overview. 2020:1-23.

Wan Y-c. (2019). Wan Y-c, Chen Y, Cui Z-x, Ding H, Gao S-f, Han Z, Gao J-k. A promising form-stable phase change material prepared using cost effective pinecone biochar as the matrix of palmitic acid for thermal energy storage. Scientific reports. 2019;9(1):11535.