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RECYCLED POLYSTYRENE WITH UREA-FORMALDEHYDE ADDITION AS THE BINDER FOR PALMITIC ACID - IMPREGNATED PARTICLEBOARD: EFFECT OF DENSITY

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J20A0657

A report submitted in fulfilment of the requirements of the degree of Bachelor of Applied Science (Forest Resources Technology) with Honors

FACULTY OF BIOENGINEERING AND TECHNOLOGY
UNIVERSITY MALAYSIA KELANTAN
2024

DECLARATION

I declare that this thesis entitled "Recycled Polystyrene with Urea-Formaldehyde Addition as the binder for Palmitic Acid – Impregnated Particleboard: Effect of Density" is the results of my own research except as cited in the references.

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ACKNOWLEDGE

For the glory of Allah (SWT), the Most Gracious and Most Merciful. Thanks Allah (SWT); with His help, I was finally able to complete my thesis. Only with Allah (SWT) grace was, I able to persevere through various obstacles and write this thesis. Both academically and personally, I learned and grew rapidly on this journey. I am indebted to the Prophet Muhammad (SAW), whose teachings have been a constant source of direction in my life.

First and foremost, I would like to express my deepest gratitude to all those who have helped me learn new skills and cooperated in developing my understanding of my thesis, which is entitled "Recycled Polystyrene with Urea-Formaldehyde Addition as the binder for Palmitic Acid ". My sincere thanks to my project supervisor, Associate Prof. Dr. Ts. Mohd Hazim Bin Mohamad Amini, for his invaluable guidance, and unwavering support throughout the entire project. He has shown me the best way to conduct research. I appreciate his helpful.

I am also grateful to University Malaysia Kelantan for providing the necessary resources for the execution of this project. Thank all to lab/workshop assistants who gave practical guidance in making my experiment and helped complete my research. I would also like to express my sincere gratitude to my colleagues who have given me encouragement support while doing this challenging project. Really appreciate their help and towards me.

Not to be left out is my family members who always give me words of encouragement. I would like to thank my parents who gave birth and raised me. Thank them for supporting me as I continue my studies and prepare for my future, including their love, prayers, strength, and sacrifices for me. Last but not least, I wanna thank me, I wanna thank me for believing in me, I wanna thank me for doing all this hard work, I wanna thank me for having no days off, I wanna thank me for, for never quitting, I wanna thank me for always being a giver, I wanna thank me for try do more right than wrong, I wanna thank me for just being me at all times.

Recycled Polystyrene with Urea-Formaldehyde addition as the binder for Palmitic Acid - impregnated particleboard: Effect of Density

ABSTRACT

This research investigates the environmental and thermal properties of wood composites produced using polystyrene resin as an adhesive and sawdust infused with palmitic acid as a phase change material (PCM) and Urea-formaldehyde (UF) as a binder. Using rubber wood dust bound with polystyrene resin aims to reduce the environmental impact compared to conventional synthetic polymers. Furthermore, the impregnation of sawdust with palmitic acid aims to improve energy efficiency by taking advantage of the acid's phase change ability. Determine the density of 3 samples which are 0.6 g/m^3, 0.7 g/m^3 and 0.8 g/m^3 on particle board. The result of thickness swelling on sample 0.6 increased in the first 1 hour which is 12.06% from 10.32%. While 24 hours later for the 0.8 sample it only went up a little, from 17.51 to 17.55. This value is only slightly higher. This study uses bending, , water absorption, moisture content, FT-IR, TGA/DSC, and XRD on rubber sawdust using Urea-Formaldehyde as a binder along with Palmitic Acid at DT0.6, DT0.7 and DT0.8 with a weight of 5 % for UF and PA to compare all samples. Bending, wet absorption, FT-IR, TGA/DSC, and XRD were tested. Wood composite tests vary. Rubberwood dust all vary in value. For the highest moisture content (MC) which is 5.25 for the DT0.6 sample, followed by DT0.7 and DT0.8 which are 2.50 and 2.39. Particle board with more urea-formaldehyde and palmitic acid is a resin making it waterproof and better resistant in composite manufacturing. The rubber wood particle board composite will be analyzed using FT-IR, TGA, DSC, XRD analysis tests, and the wood composite test is a bending test, and a water absorption test. An important role for adhesives has been, and will continue to be played, in the effective use of wood resources, as well as in the expansion and development of the entire forest products industry as a whole.

Keywords: Rubber Wood Dust, recycled polytyrene waste, Urea-formaldehyde, phase change material (palmitic acid), rubber sawdust test is FT-IR, TGA, XRD, and wood composite test is bending test, thickness swelling, water absorption and moisture content

Polistirena kitar semula dengan tambahan Urea-Formaldehid sebagai pengikat untuk Asid Palmitik - papan partikel yang diresapi: Kesan Ketumpatan

ABSTRAK

Penyelidikan ini menyiasat sifat alam sekitar dan terma komposit kayu yang dihasilkan menggunakan resin polistirena sebagai pelekat dan habuk papan yang diselitkan dengan asid palmitik sebagai bahan perubahan fasa (PCM) serta Urea-formaldehid (UF) sebgai pengikat. Menggunakan habuk kayu getah yang diikat dengan resin polistirena bertujuan untuk mengurangkan kesan alam sekitar berbanding polimer sintetik konvensional. Tambahan pula, impregnasi habuk papan dengan asid palmitik bertujuan untuk meningkatkan kecekapan tenaga dengan memanfaatkan keupayaan perubahan asid. Menentukan ketumpatan 3 sampel iaitu 0.6 g/m^3, 0.7 g/m^3 dan 0.8 g/m^3 ke atas papan partikel. Keputusan thickness swelling pada sampel 0.6 meningkat pada 1 jam yang pertama iaitu 12.06% daripada 10.32%. Manakala pada 24 jam kemudian untuk sampel 0.8 hanyak naik sedikit iaitu dari 17.51 hingga 17.55. Nilai ini hanya menaik sedikit. Kajian ini menggunakan lenturan, , penyerapan air, kandungan lembapan, FT-IR, TGA/DSC, dan XRD pada habuk papan getah menggunakan Urea-Formaldehyde sebagai pengikat yang mengandungi Palmitic Acid pada DT0.6, DT0.7 dan DT0.8 dengan berat 5. % bagi UF dan PA untuk menggabungkan semua sampel. Lenturan, penyerapan basah, FT-IR, TGA/DSC, dan XRD telah diuji. Ujian komposit kayu berbeza-beza. Rubberwood dust semuanya berbeza-beza nilai. Bagi kandungan lembapan (MC) tertinggi iaitu 5.25 bagi sampel DT0.6, diikuti dengan DT0.7 dan DT0.8 iaitu 2.50 dan 2.39. Papan partikel dengan lebih banyak urea-formaldehyde dan palmitic acid adalah resin menjadikan kalis air dan tahan lebih baik dalam pembuatan komposit. Komposit papan partikel kayu getah akan dianalisis menggunakan ujian analisis FT-IR, TGA, DSC, XRD, dan ujian komposit kayu ialah ujian lenturan, dan ujian penyerapan air. Peranan penting untuk pelekat telah, dan akan terus dimainkan, dalam penggunaan sumber kayu yang berkesan, serta dalam pembangunan dan pembangunan keseluruhan industri hasil hutan secara keseluruhan.

Kata kunci: Habuk Kayu Getah, sisa politirena kitar semula, Urea-formaldehid, bahan perubahan fasa (asid palmitik), ujian habuk papan getah ialah FT-IR, TGA, XRD, dan ujian komposit kayu ialah lenturan, bengkak ketebalan, penyerapan udara dan kandungan lembapan

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LIST OF SYMBOLS

°C	Degree Celcius
θ	Teta
%	Percentage
Mw	Medium wave
J·g-1	Heat
g/cm^3	Gram per cubic me

LIST OF ABBREVIATION

PS	Polystyrene
PCM	Phase Change Material
CO2	Carbon dioxide
CH4	Methane
N20	Nitrous oxide
FT-IR	Fourier transform infrared spectroscopy
UF	Urea formaldehyde
MDF	Medium density fibreboard
TGA	Thermogravimetric analysis
DSC	Differential scanning calorimetric
XRD	X-ray diffraction
G	Gram
CM^2	Centimetres cubic
kV	Thousand volt
Cm	Centrimetres
Kg	Kilogram
Mm	Millimeter
Min	Minutes
M	Mass
DT	Density
J-g-1	Heat

CHAPTER 1

1.0 INTRODUCTION

1.1 Background of study

Polystyrene (PS) is an aromatic polymer formed from the aromatic monomer styrene, a liquid hydrocarbon that is commercially manufactured from petroleum. Since it was first commercially produced in 1930, it has been applied to a wide range of commercial, packaging and building purposes (Farrelly & Shaw, 2017). Although the effects will be bad for human health, causing pollution to the environment, but the usage of polystyrene has grown in many nations. Styrene, the primary component of polystyrene, has been identified by the World Health Organization's International Agency for Research on Cancer as a probable carcinogen with potential health risks for humans. The disposal of polystyrene requires many procedures and is affordable due to its non-biodegradable nature, and it needs to be recycled to reduce the lessen on the environment.

The use of Phase Change Material (PCM) as a latent heat storage medium is a good technique to save energy. High energy storage density and isothermal properties were the advantages of PCM. PCM has been widely used in heat pumps, solar systems, and spacecraft applications to store latent heat. Due to its large capacity for energy storage during melting and solidification, PCMs are used to reduce cooling and heating loads across the building envelope, resulting in adequate thermal comfort (QudamaAl-Yasiri, 2021). It also can absorb and release energy making it an effective technique for saving energy and maintaining isothermal conditions (Liu et al., 2022). This is the way to reduce energy consumption in building and construction industry by using PCM in industry.

1.2 Problem Statement

Nowadays, polystyrene is the main source of packaging and it is widely used all over the world. Products consisting of PS are used in various applications including building insulation, plastic utensils and packaging materials (Khan et al., 2023). Because of its widespread use, polystyrene has a harmful influence on both human beings and the environment. It poses significant environmental concerns due to its slow rate of degradation and potential to release hazardous chemicals when burned. Especially in terms of pollution, where non-biodegradable polystyrene is allowed to accumulate.

Therefore, the inclusion of palmitic acid in wood, UF and also PS that has been dissolved with acetone in the creation of this particle board as a material impregnated with PCM, on the other hand is one of the innovations that can be used to recycle polystyrene while reducing pollution such as air pollution and environmental pollution around.

1.3 Expected Output

In this research project, particle board can be prepared with PCM that has impregnated polystyrene as a binder. Palmitic acid as phase change material (PCM) and acetone will be used as the primary ingredients in the preparation of the structure and properties of this wood. We know that adhesives are important for the efficient use of wood resources, as well as growth and development, and the forest products sector. The adhesive bonding of solid wood and wood particles of varying sizes is an important aspect of producing modern wood products for buildings, furniture, and other uses. Therefore, it is hoped that with this combination will be able to positively improve the physical and mechanical properties and the density of article boards made using recycled PS that can be evaluated well.

1.4 Objective

i. To prepare wood composite of different target density made using polystyrene/Urea-Formaldehyde mixture as a binder with palmitic acid and it’s characteristic/properties.
ii. To study the performance of different adhesive density on particle board.

1.5 Scope of Study

The scope of this study is to see the possibility of using recycled polystyrene with the addition of UF as a binding material for PCM to store thermal energy in building applications. This study will look at the properties and characteristics of recycled polystyrene as a binder. The effect of using palmitic acid in impregnated particle board, such as energy capacity and the effect of use, put the board through bending, compression and tension tests. In addition, the project also includes to evaluate the perspective for recycled polystyrene impregnated particleboard with UF addition as a binder for PCM and to optimize the manufacturing process. A comparison with other materials used for thermal energy storage in building applications will be made.

This project also, can run some tests to further study the mechanical and physical properties. These physical and mechanical properties can be determined by the workability and durability of the material when used for example to make furniture such as tables. The mechanical properties of materials can be determined through tests carried out on specimens such as tension and flexibility.

Overall, the findings of this work can explain the practicality and potential of using recycled polystyrene with the addition of UF as a binding material for PCM in building applications.

1.6 Significant of Study

Particleboard is now available in a variety of materials, patterns and styles to enable the manufacture and design of modern furniture. For example, it is often used in interior applications such as veneer substrates and furniture. Particleboard is cheaper than other engineered woods, easy to handle and manufacture, and versatile. Other particle boards may meet the requirements of certain construction applications such as moisture resistance, fire resistance, acoustic insulation, etc. Particleboard can also be used with other materials, such as veneer, plastic or paper.

The goal of this research is to create a low-cost and environmentally friendly PCM-impregnated particle board with recycled polystyrene with the addition of UF as a binder. This is because PCM is for heat storage while PS is for environmentally friendly binders. In this study, the thermal and mechanical properties of particleboard, including compressive and flexural strength, thermal conductivity, and thermal stability, will also be investigated. By optimizing the production process by changing the particle size, the amount of binder, and the pressing conditions, it is possible to produce article boards of the desired quality. This research will show that using recycled polystyrene with the addition of UF as a binder for PCM-impregnated particleboard can provide a sustainable alternative for thermal energy storage in construction applications.

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CHAPTER 2

2.0 LITERATURE REVIEW

Due to environmental concerns and the need for resource efficiency, the use of recycled materials and sustainable binder systems in the production of PCM has attracted a lot of attention. This literature review aims to explore existing research and studies related to the use of recycled polystyrene (PS) with the addition of UF as a binder for the production of PCM. Over the past few years, the use of PCM in building applications has received significant attention (Jelle & Kalnæs, 2017). This is because of its ability to store and release heat energy.

2.1 Polystyrene (PS)

Polymerization of styrene results in PS, a hard, stiff, brilliantly transparent synthetic resin. It is often used as trays and rigid containers, disposable tableware, and foam cups, plates and bowls in the food service sector. PS also copolymerized, or mixed with other polymers, providing hardness and rigidity to some important plastic and rubber products (Kara Rogers, 2023). This makes PS a non-biodegradable product because it is part of the plastic and takes time to dispose of. PS recycling is an alternative that will be used. Various researchers investigated looked into the possibility of making value-added wood composites by employing polystyrene as a binder (Foti et al., 2022). With this PS recycling, it is an alternative that will be used.

2.2 Problem Polystyrene

When polystyrene breaks down slowly, it can leak chemicals into the environment that will cause damage if it is disposed of improperly. The manufacture of polystyrene contributes a lot to global warming and is basically non-biodegradable, taking hundreds or even thousands of years to break down (Uppala & Muthukumaran, 2022). PS is easily carried by the wind and litters the streets or eventually pollutes aquatic bodies, even if it has been disposed of in a landfill (Rubio & Rubio, 2021). Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_{2O}) are examples of these emissions (Sulaiman & Mohamad Amini, 2022). However, using recycled PS with UF and PCM as binders contributes to waste reduction and promotes a circular economy. By reusing PS waste, the environmental impact associated with its disposal is minimized. Furthermore, the addition of UF resin, a sustainable and readily available material, is in line with sustainability goals and supports the development of environmentally friendly PCM materials.

2.3 Urea-formaldehyde (UF)

In the wood industry, the most used adhesive is UF resin. It is a water-based polymer resin made from urea and formaldehyde under acid or alkali catalysis (Li & Zhang, 2021). UF is mostly utilised in protective finishes, adhesive component materials, and mould. In addition, it is available at a low price, good technological characteristics, the absence of color in the cured polymer, hardness, low curing temperature, resistance to abrasion and microorganisms are urea formaldehyde of exceptional quality and good thermal properties. UF can cause various diseases, the symptoms of which can have adverse effects on health. Long-term exposure to high levels of UF can lead to cancer and lung disease. By reducing formaldehyde and adding polystyrene to further strengthen the particle board.

2.4 Rubber Wood (Hevea Brasiliensis)

Hevea Brasiliensis, often known as rubberwood. It is a huge evergreen tree that may grow up to 40 meters tall, has a straight trunk up to 50 cm in diameter and branches out at the top to produce a dense canopy. Hevea Brasiliensis, often know as rubberwood, is native to Brunei, Cambodia, India, Indonesia, Laos, Myanmar, Thailand and Vietnam (MTC Wood Wizard, 2024). Hevea Brasiliensis is classified as follows:

- ➢ Kingdom: Plantae
- ➢ Phylum: Spermatophyta
- ➢ Subphylum: Angiospermae
- ➢ Class: Dicotyledonae
- ➢ Family: Euphorbiaceae
- ➢ Genus: Hevea
- ➢ Species: Hevea brasiliensis

1a: Rubber tree
1b: Rubber tree latex
1c: Rubber tree seed

Figure 1: Picture of rubber tree, rubber tree latex and rubber tree seed

2.5 Phase Change Material (PCM)

PCM is a practical method to control thermal conditions because it can store and transmit latent heat energy within a certain temperature range. It releases and stores heat through chemical connections. When a substance changes from liquid to solid or solid to liquid, heat energy is released. The use of PCM in wood is driven by the need for energy control in the building sector because high energy consumption leads to the release of greenhouse gases and other pollutants. PCM is used in latent heat storage systems (Hailu, 2021) it should have certain desired kinetic, thermodynamic and chemical properties.

2.6 Particleboard

Engineered wood products produced from a wood product is particle board. It is heated in a hot press at a certain pressure and temperature until it bonds with a synthetic resin or another appropriate binder. Rubber (*Hevea brasiliensis*), a medium-density hardwood with a whitish natural color, is utilized as the primary raw material in Southeast Asia for the manufacture of particle board. In the production of particleboard, adhesives containing UF are employed. Amino plastic resins from non-renewable petrochemical sources, like UF, are the ones that are most frequently used as adhesives in the production of particleboard (Lee et al., 2022).

2.7 Goal of Research

The goal of this research was to demonstrate the potential of recycled polystyrene with UF as a suitable binding substance for PCM production. While avoiding waste reduction and environmental sustainability, the addition of UF resin can improve the mechanical strength, thermal properties, and stability of PCM materials. The economic ability of this fastening system can further support its practical application in various industries. Future research can concentrate on optimizing the composition and properties of PCM materials combining recycled PS with UF resin, as well as exploring other issues including fire resistance and scalability for industrial manufacturing.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Materials preperation

Polystyrene (PS) will be obtained local residents of Jeli, Kelantan. Palmitic acid as the phase change material (PCM) and urea-formaldehyde resin (UF) will be obtained from the wood workshop and laboratory, while rubber wood (*Hevea brasiliensis*) will be obtained from Evergreen Rubberwood Products Sdn Bhd, Jeli, Kelantan. Wood, polystyrene (PS), urea-formaldehyde resin (UF), acetone and palmitic acid (PCM) are the raw materials that will be used in this study. Before the particle board making operation, the wood dust and polystyrene will be crushed to obtain particles size range. FTIR, TGA, DSC, and XRD analyses will be used to characterized the PCM composite.

3.2 Method

Rubber wood dust, polystyrene, acetone, urea-formaldehyde, palmitic acid were the main raw materials used in this investigation. Before the grinding process could been started, the rubberwood had been chopped and dried. It was intended to passed the collected dust through a filter in ordered to acquire particles that fell within a smaller size range. Rubber wood particleboard composites had been analyzed used FT-IR, TGA/DSC and XRD analysis. Polystyrene will be dissolved with acetone, Uerea-formaldehyde is and adhesives, Palmitic acid is the essence of Phase Change Material and all of this will be mixed with wood dust (rubberwood). Next, the mixture will be pressed into a hot press machine and it will become a square shape for 10 minutes at a temperature of 150℃. The density for the particle board manufacturing process is 0.6 g/m^3, 0.7 g/m^3 and 0.8 g/m^3. The density of range depending on the air-dry state of the wood is often mentioned in the description of the wood itself. Light, heavy and very heavy are all terms used to characterize the weight of wood, and these classifications are based on the following categorization system.

3.2.1 Development of bio-adhesive

Any material that can bind materials together functionally by surface attachment that deters separation is considered adhesive (Pike, 2022). Adhesives have played an important role in the effective use of wood resources and in the development and growth of the forest products sector. The adhesive bonding of solid wood and wood particles of varying sizes is an important variable for the development of useful contemporary wood products, whether they are used for building, furniture or other purposes.

In this study, urea-formaldehyde is an adhesive that will be mixed into a mixture of rubber wood dust and polystyrene that has been diluted by palmitic acid. This can further strengthen the bond in making particleboard.

3.3 Evaluation of particleboard made using bioadhesive as the binder

3.3.1 Preparation of bioadhesives

Rubber wood dust, polystyrene, acetone, urea-formaldehyde, palmitic acid were the main raw materials used in this investigation. Before the grinding process could been started, the rubberwood had been chopped and dried. It was intended to passed the collected dust through a filter in ordered to acquire particles that fell within a lowered size range. Rubber wood particleboard composites had been analyzed used FT-IR, TGA/DSC and XRD analysis

3.3.2 Particleboard making

Rubber wood (*Hevea brasiliensis*) is a wood particle that will be made and obtained from Evergreen Rubberwood Products Sdn Bhd, Jeli, Kelantan. Each piece of wood will be ground and filtered until it is crushed to remove small particles that can affect the particle board. Then, polystyrene will be mixed with acetone before being mixed with wood particles, palmitic acid and UF to produce particle board. After that, it is placed manually in a mound of size 30 cm x 30 cm by 10 cm with a density of 0.6 g/m^3, 0.7 g/m^3, and 0.8 g/m^3 for each particle board to be produced. For 2 minutes, the mat was pre-pressed at 500kg/cm2 will be hot-pressed for 10 minutes in 180 ^{o}C.

Table 1: Particleboard for Recycled PS with UF addition as the binder for PCM

	Ratio (%)			
Board	**Wood (g)**	**Polystyrene (g)**	**Urea-Formaldehyde (g)**	**Palmitic Acid (g)**
Sample 1 (0.6)	540	81	27	27
Sample 2 (0.7)	630	94.5	31.5	31.5
Sample 3 (0.8)	720	108	36	36

$$\text{Density} = \frac{\text{m}}{\text{v}}$$

For this table 1, formula that been using is Density = m (mass) devide by v (volume).

3.4 Charecterizations

I. Thermogravimetric analysis & Differential scanning calorimetric (TGA/DSC)

TGA is an analytical technique used to determine a material’s thermal stability or a critical laboratory tool for determining material properties and its fraction of volatile components by monitoring the weight change that occurs as a sample is heated at a constant pace. TGA is a technique for determining the properties of materials used in environmental, food, pharmaceutical, and petrochemical applications. Position-independent weighing, an automatic internal calibration weight with a wide measurement range, the best minimum weight performance, and the highest weighing accuracy and precision are all features of the weighing technology known as TGA/DSC. TGA/DSC will be performed (SDT Q600-TA Instruments) at a heating rate of 10°C/min from room temperature to 800°C.

II. Fourier-transform infrared (FT-IR) machine

FTIR spectra can be used to determine the composition of solids, liquids and gases. FTIR provides highly specific information, allowing accurate discrimination between comparable materials. Because of its speed and sensitivity, FTIR analysis is beneficial for advanced research and screening. FTIR is frequently used to assess the quality of incoming/outgoing materials, analyze small portions of materials to identify contaminants, analyze thin films and coatings, monitor emissions, and analyze failures. In most cases, the information content is quite specific, allowing for fine differentiation between similar elements. The FT-IR machine (IRAffnity-1S) will scan from 400-4000 cm^{-1} while it is in powder form.

III. X-ray diffraction (XRD)

A technique for examining the atomic or molecular structure of materials is known as XRD. It is non-destructive and functions best with fully or partially crystalline materials (Dancahill, 2022). The crystalline index of the wood sample used in this study was assessed in order to determine the phase, structure, crystal orientation, and other structural parameters such as average stretch, grain size, crystallinity and crystal defects. The analysis will be done using XRD equipment (Rigaku model, Japan) with Cu K at 35 kV and 30 mA, and it will be done in the range of 5 to 70 (2) diffraction angles at a scan rate of 0.04/min.

3.5 Evaluation of properties of particleboard

Manufactured particleboards were evaluated for their physical and mechanical properties as shown in the following subchapters.

3.5.1 Moisture content of particleboard

By using the method described in the Japanese Standard (JIS A 5908, 2003), the moisture content will be determined. In order to achieve an initial weight of at least 20g, the particleboard sample will be cut according to the dimensions of 10mm by 10mm for the thickness of the board. The sample will be weighed according to its initial weight. it was dried overnight in an oven set at 102 °C. It is then weighed to its final weight after cooling in a desiccator. Until the final weight stabilizes, the procedure will be repeated. The test was run three times, and the equation was used to determine the results.

$$\text{Moisture content, \%} = \frac{\mathrm{m_H} - \mathrm{m_0}}{\mathrm{m_0}} \times 100$$

mH (test piece's initial mass (g) before drying) and m0 (test piece's mass (g) after drying).

3.5.2 Density of particle board

Using a modified sample dimension and the Japanese Standard (JIS A 5908, 2003), the density of particleboards was determined. Particleboards were cut to 10 mm x 10 mm thickness. The test item is an overnight condition at a temperature of 25°C and a humidity of 50% in an air-conditioned room. A calliper was used to measure the sample's dimensions once more, and an analytical balance was used to weigh it. The equation was used to calculate the density.

$$Density\ (kg.m^{-3}), \rho = \frac{m}{b_1 \times b_2 \times t}$$

t (test piece's thickness), b_1 (test piece's width), b_2 (length), and m (mass of the test piece).

3.5.3 Thickness swelling and water absorption of particle board

Particleboard thickness swelling following immersion in water was determined using Japanese Standard (JIS A 5908, 2003). Particleboard test pieces that were 30 millimeters by 30 millimeters in size were cut, and they were condition for 24 hours at 25 °C and 50% relative humidity. The sample's length, width, and thickness were all measured, its weight was determined, and it was then immersed in water. The extra water was removed after 24hours and the dimensions following water immersion were measured. With weighing test pieces, the amount of water absorbed will be determined. The capacity to absorb water and thickness swelling were calculated using the equation below.

$$Swelling\ or\ Water\ absorbtion, \% = \frac{m_i - m_0}{m_0} \times 100$$

m0 (measurement before immersion), mi (measurement after immersion).

3.5.4 Bending strength of particle board

The bending strength of particleboards was evaluated using the Japanese Standard method (JIS A 5908, 2003). Particleboards were cut to dimensions of 200 mm by 50 mm and then dried at a temperature of 25 °C and a relative humidity of 50%. The Instron Tensile Machine Model 5582 received the test component and mounted it on it. For the testing, the loading rate was set at 10 mm/min.

$$E_m = \frac{l_1^3\ (F_2 - F_1)}{4\ bt^3\ (a_2 - a_1)}$$

Where the elasticity modulus = Em (in N/mm^2)

l1 is the distance between the centers of the supports, in millimeters

b is the test piece's width in millimeter

t is the test piece's thickness in millimeter

The load increment on the load-deflection curve's straight line part is expressed, in N, as F2 - F1. F1 must be around 10% of the maximum load, and F2 must be around 40%.

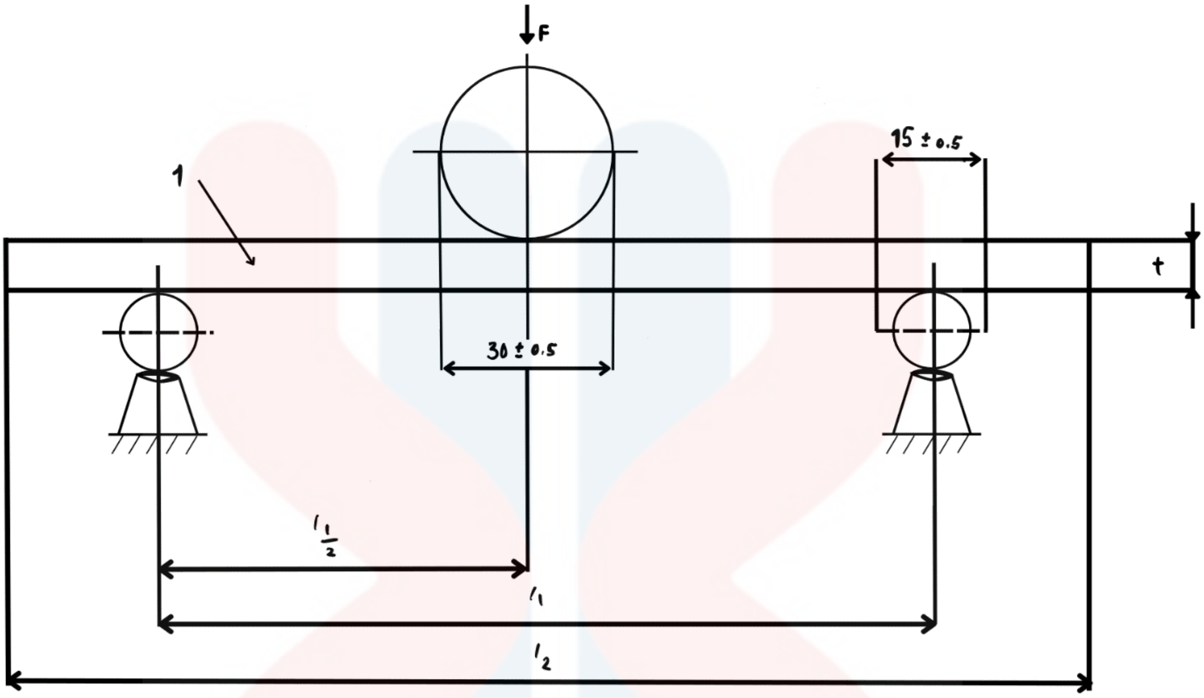
The increment of deflection at the test piece's midpoint (equivalent to F2 - F1) is expressed as a2 - a1

and bending strength

$$Bending\ strength, f_m(Nmm^{-2}) = \frac{3\ F_{max}\ l_1}{2\ b\ t^2}$$

Fmax is the maximum load, expressed in newtons.

Millimetres are used for l1, b, and t



1 = test piece
F = load
t = thickness
l_1 = 20t
l_2 = l_1 +

Figure 2: Arrangement of the bending apparatus (JIS A 5908, 2003)

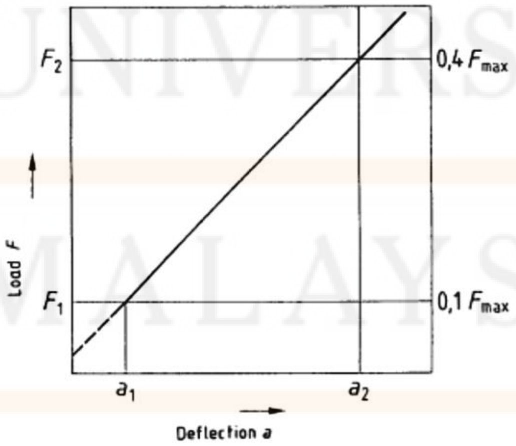


Figure 3 : Load-deflection curve inside of the elastic deformation range (JIS A 5908, 2003)

3.6 RESEARCH FLOW CHART

3.6.1 Flowchart

The research will be conducted in three stages: stage 1 will involve sample preparation, stage 2 will involve characterization, and stage 3 will involve a test on wood composites.

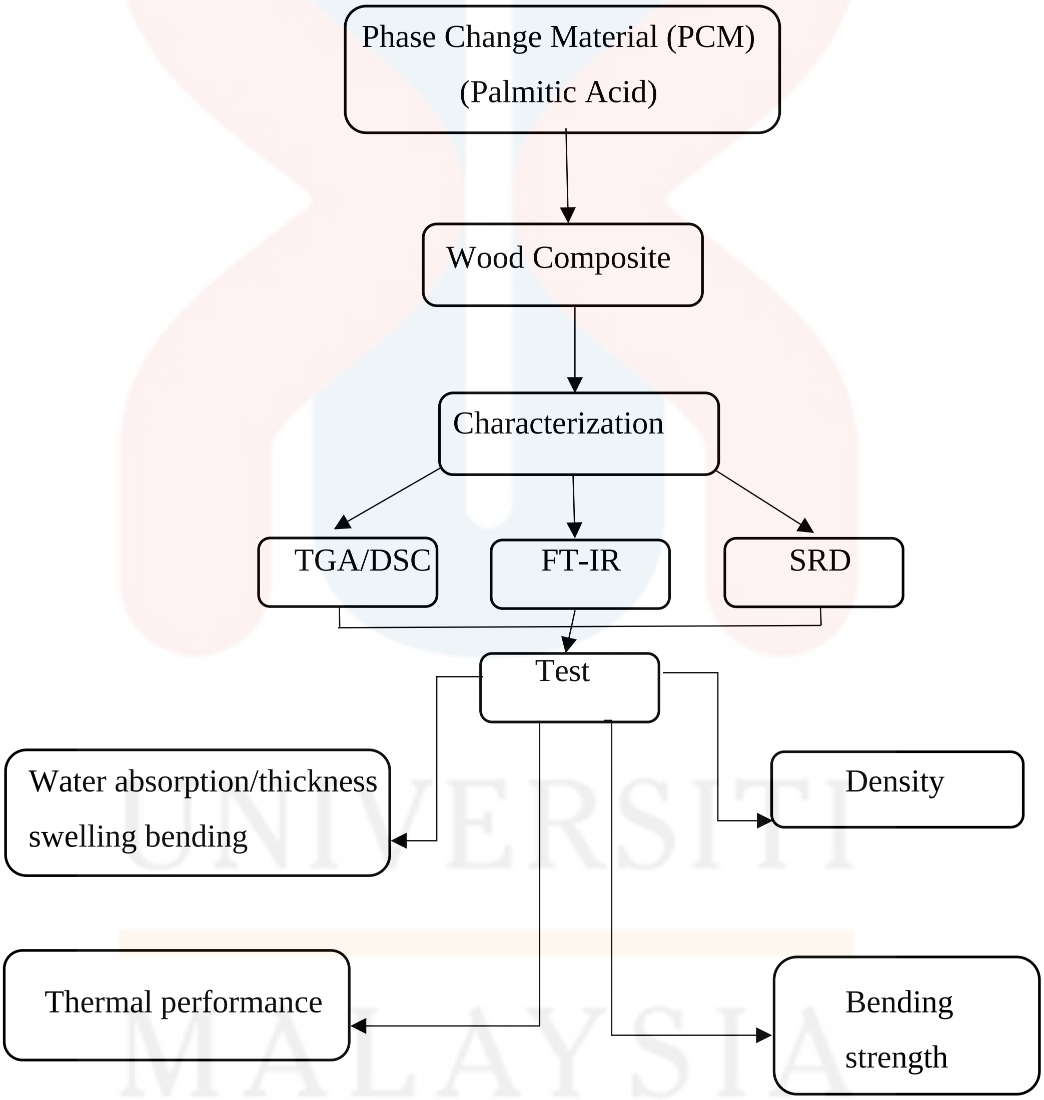


Figure 4: Research flowchart for recycle PS with UF addition as a binder for PCM-impregnated particleboard research project.

CHAPTER 4

4.0 RESULT AND DISCUSSION

4.1 Thermogravimetric analysis (TGA)

A thermogravimetric analysis (TGA) instrument measures the change in sample mass with temperature and time in a controlled atmosphere. TGA characterizes substances that experience mass loss or gain from loss, decomposition or oxidation of volatiles. This technique aids in the characterization of materials, providing insight into their thermal stability and decomposition behavior.

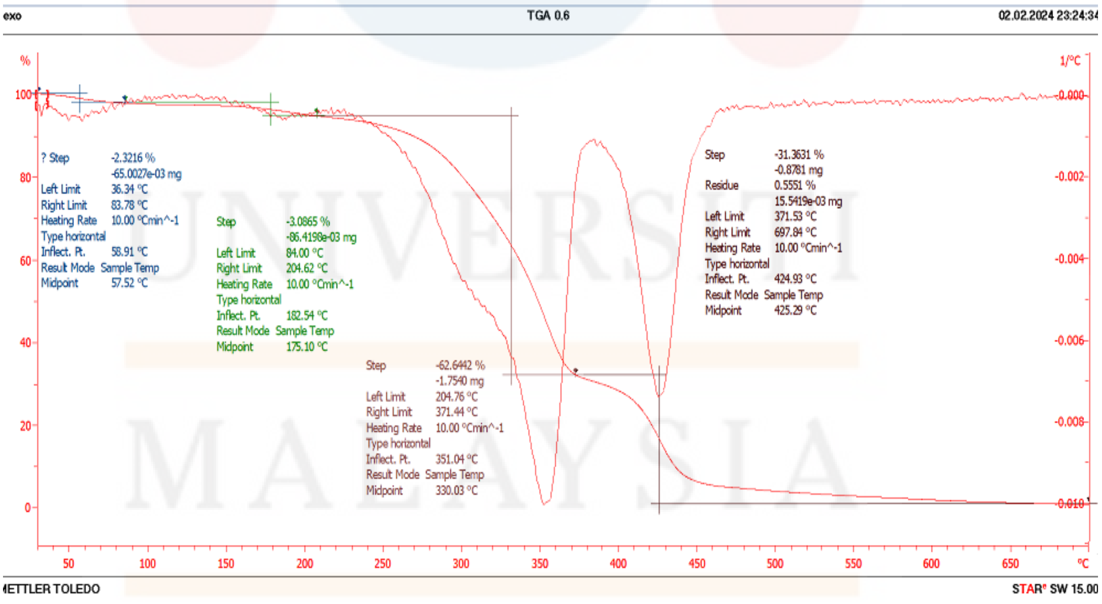


Figure 5: TGA analysis of rubberwood sawdust with density 0.6 *g/cm*^{3}

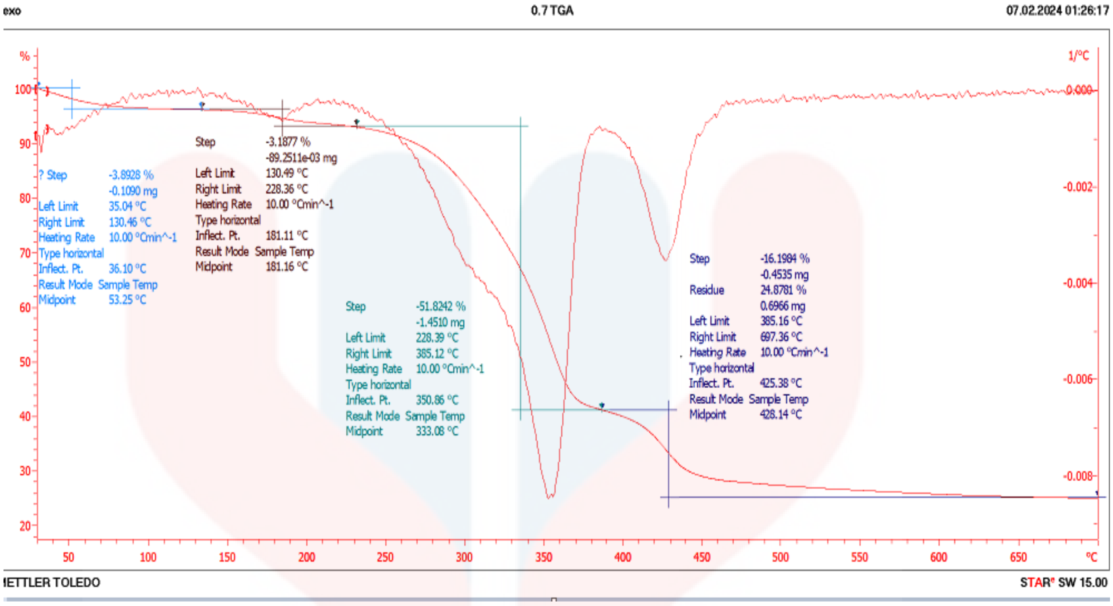


Figure 6: TGA analysis of rubberwood sawdust with density 0.7 *g/cm*^{3}

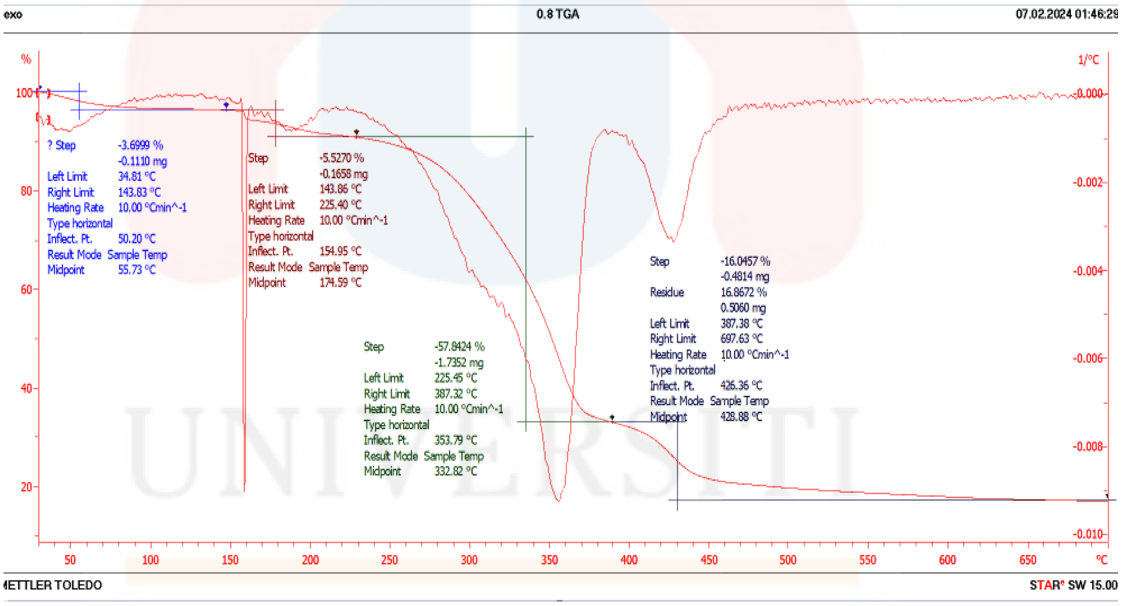


Figure 7: TGA analysis of rubberwood sawdust with density 0.8 *g/cm*^{3}

Discussion:

Thermogravimetric Analysis (TGA) is a valuable technique used to study the thermal decomposition behavior of materials by measuring their mass changes as a function of temperature. In the analysis of particleboard samples containing rubber wood, urea-formaldehyde (UF) resin, palmitic acid (PCM), and polystyrene, several distinct peaks were observed, each corresponding to a different decomposition process occurring in the sample. The results of the TGA analysis that has been performed on sawdust rubber for the DT0.6 g/cm^3 sample are displayed in Figure 5 above. TGA studies were carried out using a sample mass of about 2 mg and a temperature range of 30 to 800C.

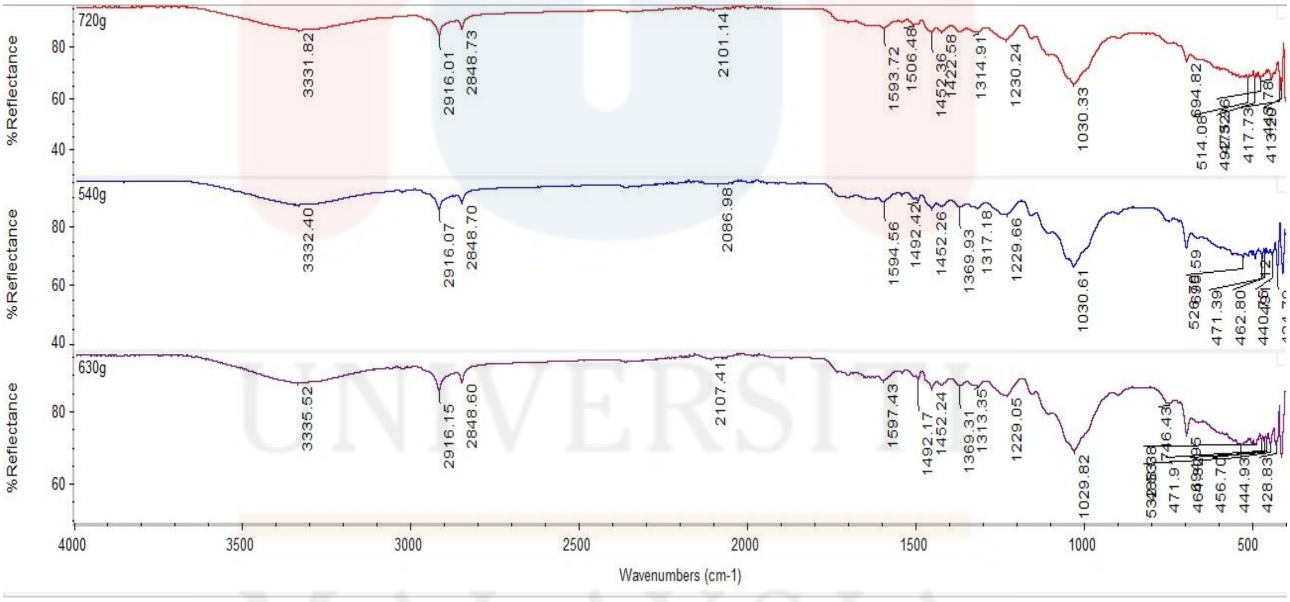
Initially, around 50°C was observed and attributed to moisture evaporation from samples DT0.6 g/cm^3, DT0.7 g/cm^3 and DT0.8 g/cm^3. Moisture is a common component found in many materials, including rubber wood, UF resin, palmitic acid and polystyrene. Removal of moisture at low temperature is a common initial step in TGA analysis. Subquently, it can be observed that occurs between 150°C to 200°C, is mainly due to the decomposition of urea-formaldehyde (UF) resin. UF resin, commonly used as a binder in composite materials, begins to decompose around 150°C and undergoes rapid decomposition up to 220°C. Although some decomposition of palmitic acid may also occur in this temperature range. Then extends from 200°C to 350°C, corresponding mainly to the degradation of palmitic acid. Palmitic acid, a component of phase change material (PCM), starts to decompose around 230°C and completes its decomposition around 350°C. Some residual UF resin decomposition may also occur in this temperature range. Following this, it occurs between 350°C and 370°C. Polystyrene, a common polymer used in a variety of applications, begins to decompose around 300°C and continues up to about 400°C. Decomposition of polystyrene contributes to overall weight loss. At high temperatures, it can be observed between 370°C and 450°C, indicating a final weight loss associated with the decomposition of any organic matter remaining in the sample. These may include components such as hemicellulose and lignin derived from rubber wood.

It is important to note that the exact temperature at which each substance decomposes may vary depending on factors such as heating rate, sample size and composition. Moreover, the TGA graph provides information about the weight loss but does not specify the exact compounds that are lost at each peak, requiring further analysis for a comprehensive understanding of the decomposition process occurring in the sample. The TGA curve for rubber sawdust occurs since at this point, the process involves the removal of hemicellulose which reflects the weight loss caused by the evaporation of organic matter such as carbon dioxide, methane, and carbon content. (Y Hafizal, 2017).

4.2 Fourier-transform infrared (FT-IR)

4.2.1 Fourier-transform infrared (FT-IR) DT0.6 *g/cm^3* and DT0.8 *g/cm^3*

FTIR is a technique used to identify organic, polymeric, and sometimes inorganic substances. It involves taking a test sample with infrared light to analyze its chemical properties and identify the functional groups present in the material. In this study, some physical and mechanical characteristics of particle board that has been manufactured using rubber wood dust waste, polystyrene, UF and PCM. Rubber wood dust was mixed with recycled PS with UF as a binder for PA at density of 0.6, 0.7, and 0.8.



(A): DT0.6 (540g) | **(B):** DT0.7 (630g) | **(C):** DT0.8 (720g)

Figure 8: FT-IR peaks of comparison rubber wood sawdust of PS, UF and PCM with different density.

Discussion:

Rubber wood dust, PS, UF and palmitic acid are all substances that can be analyzed using Fourier Transform Infrared Spectroscopy (FTIR). FTIR is a powerful analytical technique that provides information about the chemical composition and molecular structure of a sample based on the absorption of infrared radiation.

Rubber wood dust, which consists of a mixture of cellulose, lignin, and other organic compounds, also exhibits characteristic peaks in the infrared spectrum. The peak at 3340 cm^{-1} is likely due to stretching vibrations of O-H bonds in cellulose and/or lignin. The broad peak around 2900 cm^{-1} corresponds to the C-H bond stretching vibration in various organic components of wood. The peak at 1730 cm^{-1} may indicate the presence of ester groups in some wood constituents, while the peaks at 1230 cm^{-1} and 1030 cm^{-1} are likely due to stretching vibrations of C-O bonds in cellulose or lignin. PS, a commonly used plastic, also displays characteristic peaks in the infrared spectrum. The peak at 3030 cm^{-1} corresponds to the stretching vibration of the aromatic C-H bond in the polystyrene phenyl ring. The peak at 3020 cm^{-1} is likely due to the stretching vibration of the aliphatic C-H bonds in the polymer chain. The peak at 1940 cm^{-1} may indicate the presence of C=C bonds in the polystyrene backbone, while the peak at 1600 cm^{-1} indicates an aromatic C=C stretching vibration. The peak at 990 cm^{-1} can be attributed to the bending vibration of the aromatic C-H bond.

Starting with UF, these compounds exhibit several distinct peaks in the infrared spectrum. The peak at 3335.52 cm^{-1} corresponds to the stretching vibration of the N-H bond in urea. The peak at 1661 cm^{-1} indicates the presence of a carbonyl group (C=O) in the formaldehyde moiety. The peak at 1540 cm^{-1} corresponds to the C-N bond stretching vibration in urea, while the peak at 1249 cm^{-1} is associated with the C-N stretching vibration in formaldehyde. Finally, the peak at 750 cm^{-1} corresponds to the out-of-plane bending vibration of the C-H bond in the aromatic ring of urea formaldehyde. Finally, palmitic acid. Peaks at 2917 cm^{-1} and 2850 cm^{-1} indicate stretching vibrations of aliphatic C-H bonds in fatty acid chains. The peak at 1709 cm^{-1} corresponds to the stretching vibration of the carbonyl group (C=O). The peak at 1467 cm^{-1} is likely due to the C-H bond bending vibration, while the peak at 1295 cm^{-1} can be attributed to the O-H bond bending vibration.

FTIR is a valuable tool for the characterization and analysis of a wide variety of organic and inorganic materials. By identifying characteristic peaks in the FTIR spectra of rubber wood dust, PS, UF and palmitic acid, researchers can gain valuable insight into the chemical composition and structure of these materials. This information is important for various applications in fields such as materials science, chemistry and biochemistry.

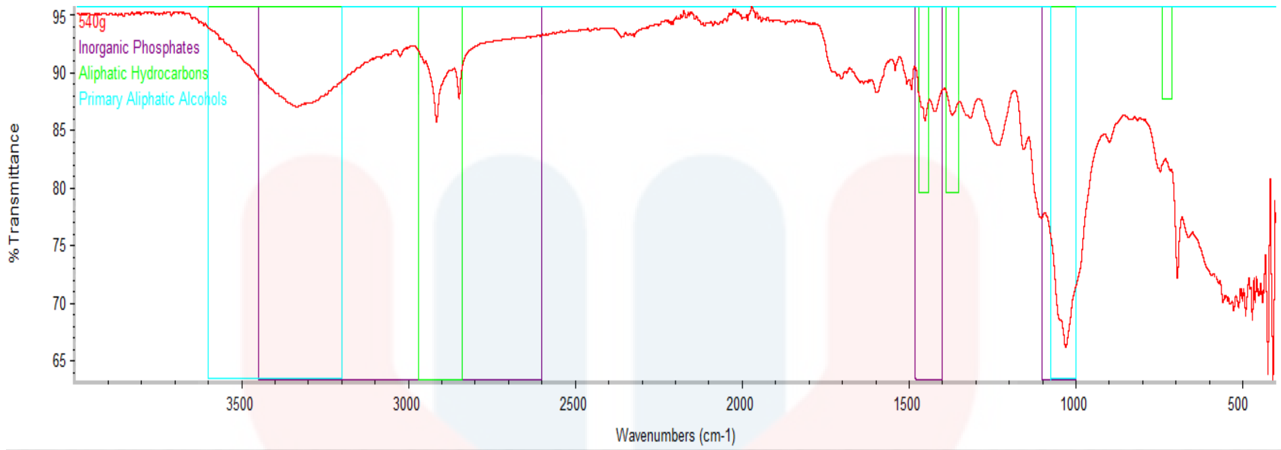


Figure 9: FT-IR main functional group of particleboards with UF and PCM for DT0.6 *g/cm*^{3}

(A)

Table 2: FT-IR peaks main functional group of particleboards with UF and PCM for DT0.6 *g/cm*^{3}

Functional group	**Peaks cm-1**	**Group**	**Bond**
Inorganic Phosphates	1492.42	Alkanes	C-H Stretch
Aliphatic Hydrocarbons	2848.70	Alkanes	C-H Stretch
	2916.07	Alkanes	C-H Stretch
Primary Aliphatic Alcohols	3335.52	Carboxylic acids	O-H Stretch
	1030.61	Amides	C-O Stretch

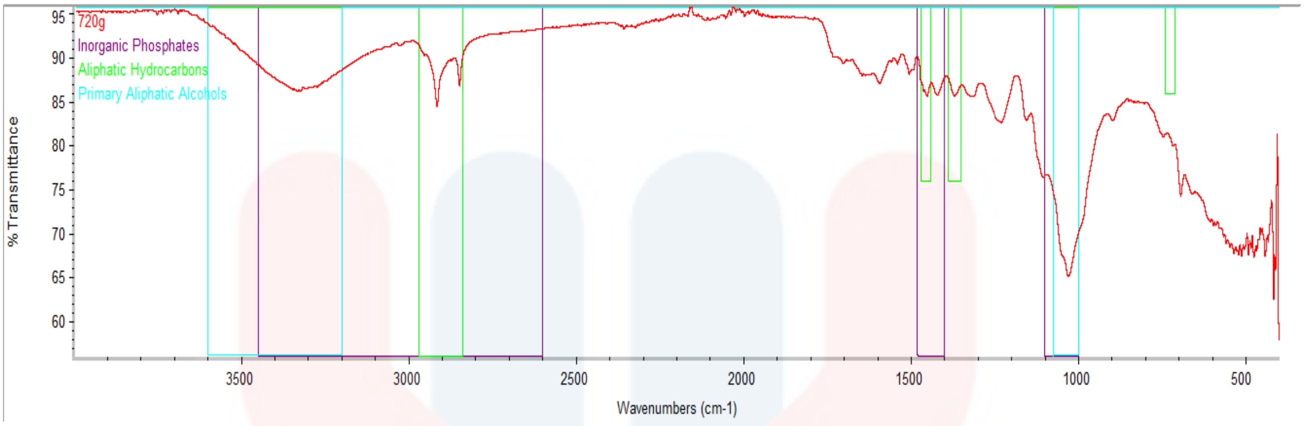


Figure 10: FT-IR main functional group of particleboards with PS, UF and PCM for DT0.8 *g/cm*^{3}

(B)

Table 3: FT-IR peaks main functional group of particleboards with UF and PCM for DT0.8 *g/cm*^{3}

Functional group	**Peaks cm-1**	**Groups**	**Bond**
Inorganic Phosphates	1452.36	Alkanes	C-H stretch
Aliphatic Hydrocarbons	2848.73	Alkanes	C-H Stretch
	2916.01	Alkanes	C-H Stretch
Primary Aliphatic Alcohols	1030.33	Amides	C-O Stretch
	3331.82	Carboxylic acids	O-H Stretch

Discussion:

As can be seen in figure 8, the Fourier transform infrared (FTIR) spectrometer identified the different functional groups present in rubber sawdust after it was combined with varying percentages of DT (0.6, 0.7 and 0.8). Table 2 and table is a list of functional groups found in DT0.6 g/cm^3 and DT0.8 g/cm^3 mixed rubber sawdust. This table refers to the graphs and peaks that can be found in figures 9 and 10 FT-IR analysis of the main functional groups of rubber sawdust revealed that there are three main functional groups present in the DT0.6 g/cm^3 sample of rubber sawdust. These results can be shown in figures 9 and 10 respectively. Some examples of functional groups include Inorganic Phosphates, Aliphatic Hydrocarbons and Primary Aliphatic Alcohols. In addition, the FT-IR peaks of the main functional groups of rubber sawdust can be shown in the table 2 This peak shows that there are groups in the inorganic phosphate that can be controlled in the main functional groups found. The inorganic photophate bond for both is in the alkanes group and for inorganic phophates DT0.6 g/cm^3, the peak is at 1492.42 cm-1 on the C-H stretch bond. For inorganic phophates DT0.8 g/cm^3, the peak is at 1452.36 cm-1 and at the C-H stretch bond. Then, in the aliphatic hydrocarbon category, there is also a group that is, alkanes for both (DT0.6 $g/cm^3$and DT0.8 g/cm^3). For DT0.6 g/cm^3, the peaks are 2848.70 and 2916.07cm-1, at the C-H stretching bond. As for DT0.8 g/cm^3, the peaks are 2848.73 and 2916.01, on the C-H stretch bond. In addition to the primary aliphatic hydrocarbon functional group, there are 2 groups present in DT0.6 $g/cm^3$and DT0.8 g/cm^3. The peak for the amides group is located at 1030.61 cm-1 and 1030.33 cm-1 on the C-O stretch bond, while the carboxylic acid group is located at 3335.52 cm-1 and 3331.82 cm-1 on the O-H stretch bond.

4.2.2 Fourier-tranform infrared (FT-IR) DT0.7 *g/cm*^{3}

Reffering to figure 4.2.4, the main FT-IR functional groups of rubber sawdust have been determined. The DT0.7 sample contains two different types of main functional groups: inorganic phosphates and aliphatic hydrocarbons.

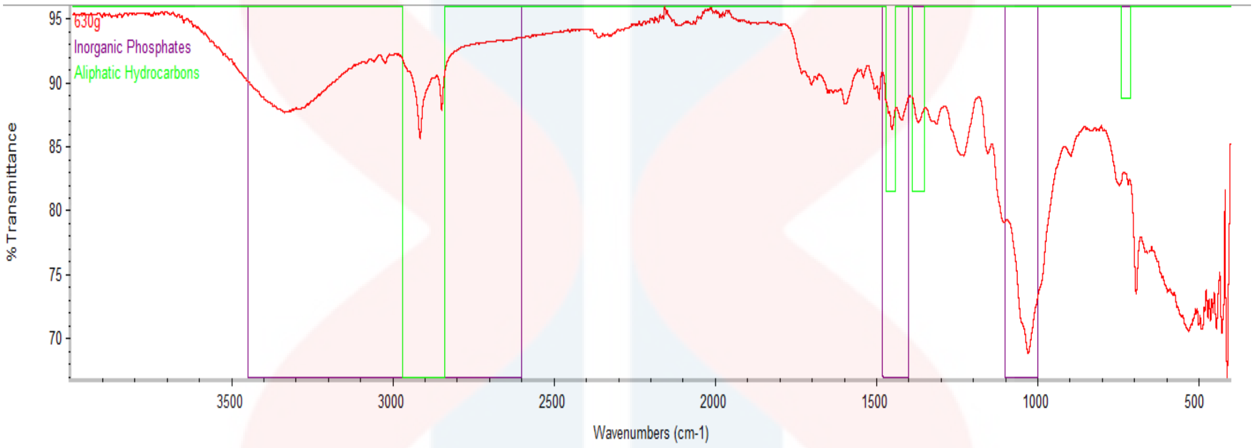


Figure 11: FT-IR main functional group of particleboards with UF and PCM for DT0.7 *g/cm*^{3}

(C)

Table 4: FT-IR peaks main functional group of particleboards with UF and PCM for DT0.7 *g/cm*^{3}

Functional group	**Peaks cm-1**	**Groups**	**Bond**
Inorganic Phosphates	3335.52	Carboxylic acids	O-H stretch
	1492.17	Aromatic rings	C=C stretch
Aliphatic Hydrocarbons	2848.60	Alkanes	C-H stretch
	2916.15	Alkanes	C-H stretch

Discussion:

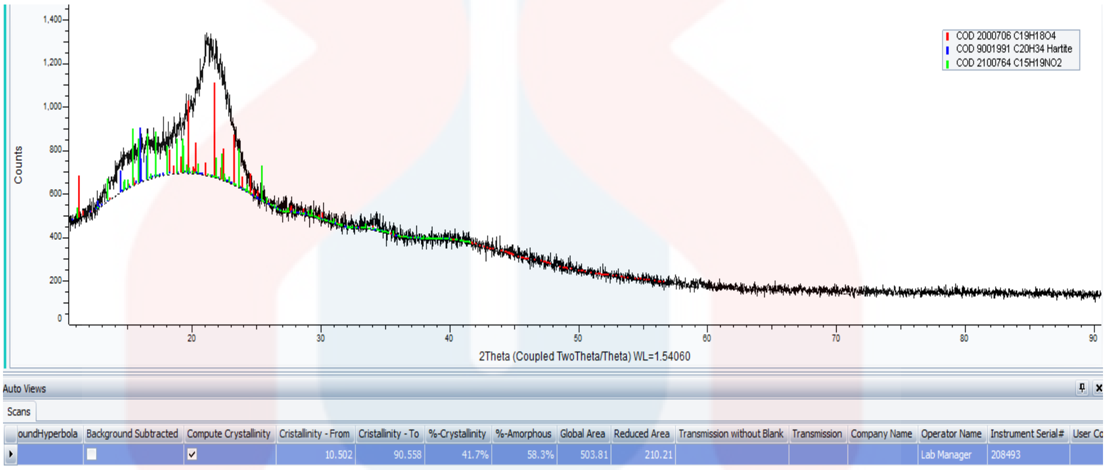
Fourier-transform infrared spectroscopy (FT-IR) is a powerful analytical technique used to characterize the chemical composition of materials based on the absorption of infrared radiation. In the analysis of rubber sawdust for DT0.7 g/cm^3, several functional groups were identified, each associated with specific peaks in the FT-IR spectrum.

The first functional group identified is inorganic phosphates. The available groups are carboxylic acids and aromatic rings. The peak found in the group of inogranic phosphates (aromatic rings) is at the peak of 1492.17 cm-1, indicating C=C stretching. The second peak (carboxylic acids) with a peak observed at 3335.52 cm-1, indicates O-H stretching. In addition, in the functional group Aliphatic Hydrocarbons have alkanes group. Alkanes are composed entirely of carbon and hydrogen atoms bonded together through single covalent bonds, leading to strong absorption of infrared radiation at characteristic frequencies (Western Oregon University, 2017). The peak found in the Aliphatic Hydrocarbon group (alkane) is at the peak of 1492.17 cm-1 and 3335.52 cm-1, indicating C-H stretching. Overall, FT-IR analysis revealed various functional groups present in rubber sawdust for DT0.7 g/cm^3, including inorganic phosphates and aliphatic hydrocarbons. These findings provide valuable information to understand the chemical composition and potential applications of rubber sawdust in various industries. The O-H stretching vibration frequency travels toward the low frequency direction, O-H forms hydrogen bonds with one another, and the higher the O-H content, the lower the wavenumber (Dai et al., 2023). This resulting in strong absorption in the FT-IR spectrum.

These functional groups are essential for characterizing the chemical composition of rubber sawdust and understanding its properties and potential applications. The identification of C-H, O-H, and other functional groups provides valuable information about the molecular structure and bonding arrangements within the material, enabling researchers to assess its suitability for various industrial and environmental applications, such as in composite materials, fuel production, or waste management. FT-IR analysis facilitates detailed insights into the chemical composition of complex materials like rubber sawdust, contributing to the development of sustainable and efficient utilization strategies.

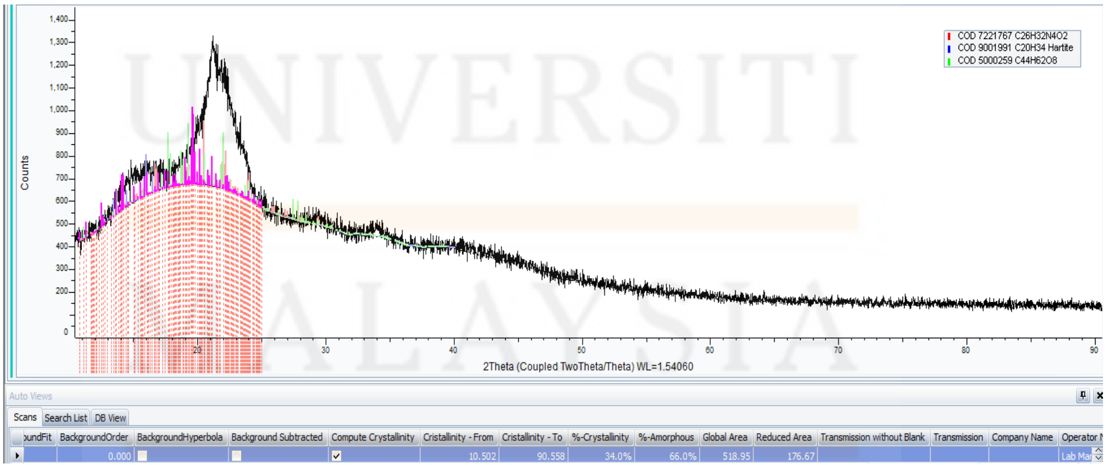
4.3 X-ray diffraction (XRD)

X-ray powder diffraction (XRD) is a rapid analytical method mainly used to identify phases in crystalline materials and provide insight into unit cell dimensions. After homogenization of the material, the sample is coarsely ground, and subsequently, the average bulk composition is established. This technique facilitates the examination of a variety of materials, offering valuable information about their crystal structure and composition with a relatively fast recovery time.



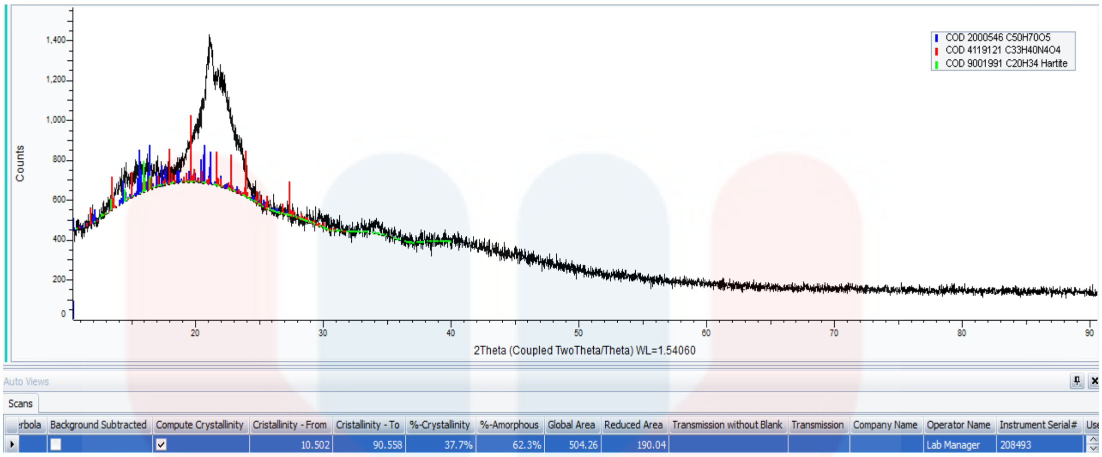
oundHyperbola	Background Subtracted	Compute Crystallinity	Cristallinity - From	Cristallinity - To	%-Crystallinity	%-Amorphous	Global Area	Reduced Area	Transmission without Blank	Transmission	Company Name	Operator Name	Instrument Serial#	User Co
	☐	☑	10.502	90.558	41.7%	58.3%	503.81	210.21				Lab Manager	208493	

Figure 12: XRD analysis for sample DT0.6 *g/cm*^{3}



oundFit	BackgroundOrder	BackgroundHyperbola	Background Subtracted	Compute Crystallinity	Cristallinity - From	Cristallinity - To	%-Crystallinity	%-Amorphous	Global Area	Reduced Area	Transmission without Blank	Transmission	Company Name	Operator N
	0.000	☐	☐	☑	10.502	90.558	34.0%	66.0%	518.95	176.67				Lab Ma

Figure 13: XRD analysis for sample DT0.7 *g/cm*^{3}



rbola	Background Subtracted	Compute Crystallinity	Cristallinity - From	Cristallinity - To	%-Crystallinity	%-Amorphous	Global Area	Reduced Area	Transmission without Blank	Transmission	Company Name	Operator Name	Instrument Serial#	Use
	☐	☑	10.502	90.558	37.7%	62.3%	504.26	190.04				Lab Manager	208493	

Figure 14: XRD analysis for sample DT0.8 *g/cm*^{3}

Table 5: percentage of crystallinity and amorphous of Urea-Formaldehyde and Palmitic Acid for DT 0.6, DT 0.7 and DT 0.8.

Sample	Crystallinity	Amorphous
DT 0.6	41.7%	58.3%
DT 0.7	34.0%	66.0%
DT 0.8	37.7%	62.3%

Discussion:

A study using diffraction was carried out to study the amorphous structure and crystallinity in treated sawdust derived from rubber wood. Referring to the figure 12 and the table 5 shows the degree of crystallinity is 41.7% in the DT0.6 *g/cm*^{3} sample where the rubber wood dust that has gone through the impregnation process. This is because, normally, a liquid or liquid solution needs to be cooled below its melting point to crystallize. The latter can result in the formation of single crystals. Crystallization in polymers can also be caused by stretching of the material. In this particular illustration, the crystallization process in the 5% sample is driven by the orientation of the molecules in the direction of the stretch. There is an increase in the crystallinity of wood composite materials that can be attributed to the fact that the wood is treated in several different ways. Both the measured increase in average crystallite size and the decrease in deuteration accessibility of the crystallite region are equal to each other. In addition, the samples for this test include 2000706 $C_{19}H_{18}O_4$ PCM, 9001991 $C_{20}H_{34}$ Polystyrene, 2100784 $C_{15}H_{19}NO_2$ Urea-Formaldehyde, 58.3% of the mixture of polystyrene, UF and PCM on the particle board has an amorphous structure, which is an important value to consider when thinking about the physical properties and different chemicals present in different dosage formulations of drugs when they are in the solid state. The need to increase the bioavailability of materials with low solubility in water is a major factor behind the recent surge of interest in amorphous materials.

Figure 413 illustrates the composition of particleboard samples containing various components, including urea-formaldehyde, palmitic acid and polystyrene in sample DT0.7 g/cm^3. This analysis allows the identification and quantification of each constituent, contributing to the crystallinity value of the entire sample, which amounts to 34.0%. The presence of crystalline material significantly affects the physical properties of the sample, such as density, ductility, and yield strength. In particular, the amorphous content for the sample with DT0.7 g/cm^3 is 66.0%, due to the promotion of amorphous crystallization refer to the table 3 Wood composite materials, although often costing more, offer a promising lifespan and reduced maintenance requirements compared to traditional ones. wood. However, while wood remains the decking material of choice due to its natural aesthetic, it is not resistant to damage. Composite materials, although more resilient, may not provide the desired natural appearance and color. The crystallinity of a sample indicates the proportion of crystalline material present, affecting its mechanical and structural properties. Higher crystallinity usually corresponds to greater stiffness and strength, while increased amorphous content can increase flexibility and durability. Therefore, the composition and crystallinity of particle board powder play an important role in determining its suitability for various applications, especially in construction and furniture manufacturing.

Diffraction investigations were carried out to investigate the amorphous structure and crystallinity of particleboard containing polystyrene, urea-formaldehyde and palmitic acid derived from rubber wood. The degree of crystallinity is 37.7% in DT0.8 *g/cm*^{3} of the sample in wood that has gone through the impregnation process can be seen in the table 3 and figure 14. This is because, usually, liquid solutions, liquids or powder mixtures need to be cooled below their melting point to crystallize. However, in this case, the powder does not need to be cooled below its melting point. The latter can result in the formation of single crystals. Crystallization in polymers can also be caused by stretching of the material. In this particular illustration, the crystallization process in the DT0.8 *g/cm*^{3} sample is driven by the orientation of the molecules in the direction of stretching. In this procedure, it is possible to say that the crystallinity of the wood composite material may be related to the fact that the wood is treated and heated in many different ways. In particular, this increase in crystallinity can be attributed to this method. The decrease in deuteration accessibility of the crystalline region and the measured increase in the average size of the crystals correspond very closely to each other. An increase in the average crystal size was measured. In addition, the sample used in this test consists of 2000546 $C_{50}H_{70}O_5$ PCM, 4119121 $C_{33}H_{40}N_4O_4$ Urea-formaldehyde, 9001991 $C_{20}H_{34}$ Hartie. The percentage of amorphous structure in the DT0.8 mixture on particle board is 62.3%, and this figure is important when considering various physical properties.

In Table 5, the sample containing DT0.6 *g/cm*^{3} shows the highest crystallinity percentage at 41.7%, surpassing the other samples. This phenomenon may be due to the residual moisture content during the drying process. The presence of chemical residues in the powder may also contribute to this observation. While for Amorphous, in table 5, the sample containing DT0.7 *g/cm*^{3} shows the highest Amorphous percentage at 66%, surpassing other samples. The findings underscore the complex interplay between composition, processing methods, and the properties of the resulting material. Understanding the crystallinity and amorphous structure is important for optimizing the performance and properties of materials. The ability to induce crystallization without extensive cooling offers opportunities for controlled material design and fabrication.

4.4 WOOD COMPOSITE (PHYSICAL TESTING)

4.4.1 Moisture Content (MC)

Particle board's density as well as its level of moisture content. The moisture level of the particle board ranged from 2.39 percent to 5.25 percent. According to JIS A 5908:2003, the permitted range for the amount of moisture in the product was between 5% and 13%.

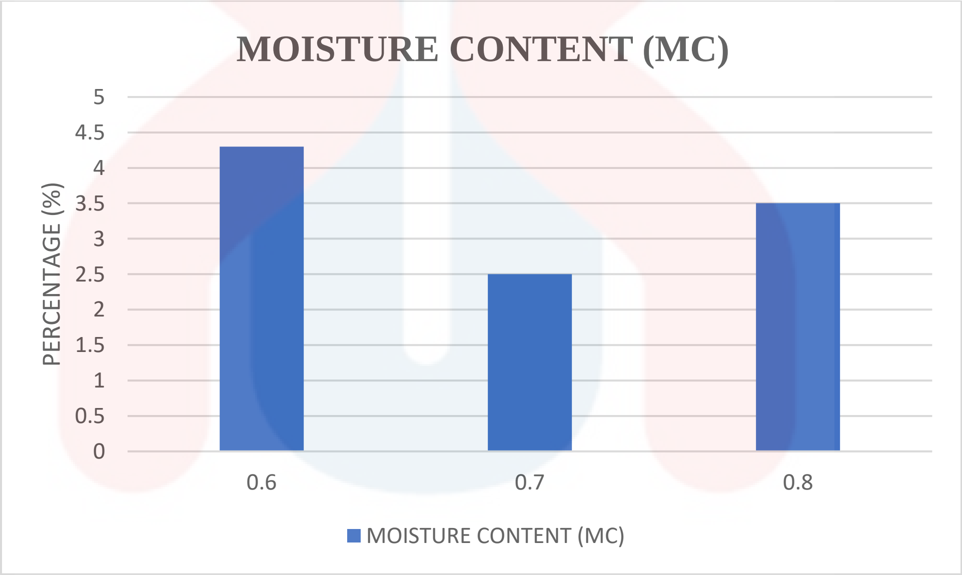


Figure 15: Moisture Content for particleboards sample of sample density 0.6 *g/cm³,* 0.7 *g/cm³* dan 0.8 *g/cm³*

Sample (*g/cm³*)	**Initial weight (g)**	**Final weight (g)**	**Density**	**MC (%)**
DT 0.6	23.25	22.09	0.6	5.25
DT 0.7	26.04	25.05	0.7	2.50
DT 0.8	24.88	22.74	0.8	2.39

Table 6: Moisture Content (%) of three sample

Discussion:

The outcomes of the moisture content (MC) examination on three sawdust samples which is mixed with recycled polystyrene with urea-formaldehyde (UF) addition as the binder for Palmitic Acid are detailed in Table 6 and depicted in Figure 15. By burning the particleboard containing recycled polystyrene with urea-formaldehyde (UF) addition as the binder for Palmitic Acid for 24-hours and then weighing it, this test can detect how much water content the particleboard has lost. After spending 24-hours in an oven set to 120-degree Celsius, a sample of particleboard was weighed in order to determine how much the moisture content had changed using the me formula. The results from Figure 15 and Table 6 reveal that the particleboard's moisture content was highest at the DT0.6 g/cm^3 registering at 5.25%, while the DT0.8 g/cm^3 exhibited the lowest moisture content at 2.39%. The DT0.7 g/cm^3 recorded a moisture content percentage of 2.50%, as indicated in Table 6. This table effectively demonstrates an inverse relationship between density and moisture content.

The examination of sawdust moisture for particle board was one of the most important but also one of the most challenging ways to obtain trustworthy results. Prior to the drying process in the oven, the initial weight of the particleboard was determined with the assistance of added water. It was imperative to conduct the oven-dried test on the particleboard's weight before introducing any water to avoid compromising accuracy or consumer distrust. Moisture meter provided the most accurate and timely information. The meters make an estimate of the moisture content after oven drying.

$$\text{Moisture content}, \% = \frac{\mathrm{m_H} - \mathrm{m_0}}{\mathrm{m_0}} \times 100$$

A formula for calculating the MC value that will be entered into a calculator or spreadsheet.

To perform the oven-dry test, an oven and a scale are essential tools. The total cost of acquiring these apparatuses is subject to fluctuations, and the selection of their size and quality should align with the anticipated duration of usage, particularly for the 24-hour testing period.

Considering that examinations form an integral part of the ongoing quality control process, investing in high-quality equipment proves beneficial, delivering value through enhanced accuracy, speed, and operational ease during tests. The oven utilized for these tests is typically a tabletop model, powered by an electric element. Its external dimensions range from 5 cm in width by 0.5 cm in height. In our university's largest oven, we fine-tune parameters to expedite the drying of complete boards while ensuring accuracy. The temperature in the oven must be able to reach and be maintained at 266 degrees Fahrenheit (103^oC). This is quite important in determining the accuracy of the exam.

Upon cutting, samples must be promptly weighed, and each specimen should be placed inside an oven. Once the initial weight is established, there is no requirement to maintain specific storage measurements. During the weighing process, it is advisable to use either a data sheet containing the sample number or, in certain instances, directly note the weight on the sample itself. Given that there is no rebound after recording the first sample weight and the drying process has commenced, maintaining precise records becomes crucial. Following a 24-hour period, the sample is extracted from the oven, and its final weight is determined using a scale. The moisture content can then be calculated using the appropriate formula. Subsequently, the data should be organized in tabular form, resembling Table ...., to obtain the percentage of moisture content readings. This shows that DT0.6 g/cm^3 has the highest MC value of 5.25% compared to DT0.7 g/cm^3 and DT0.8 g/cm^3.

4.4.2 Thickness Swelling

Table 7: Show the initial weight of particleboard

Sample/ Weight of particleboard	**1 hours**	**2 hours**	**24 hours**
Initial (g)	**10.32**	**12.84**	**13.65**
0.6	12.06	15.84	14.16
0.7	13.33	17.51	16.60
0.8	15.78	17.55	17.31

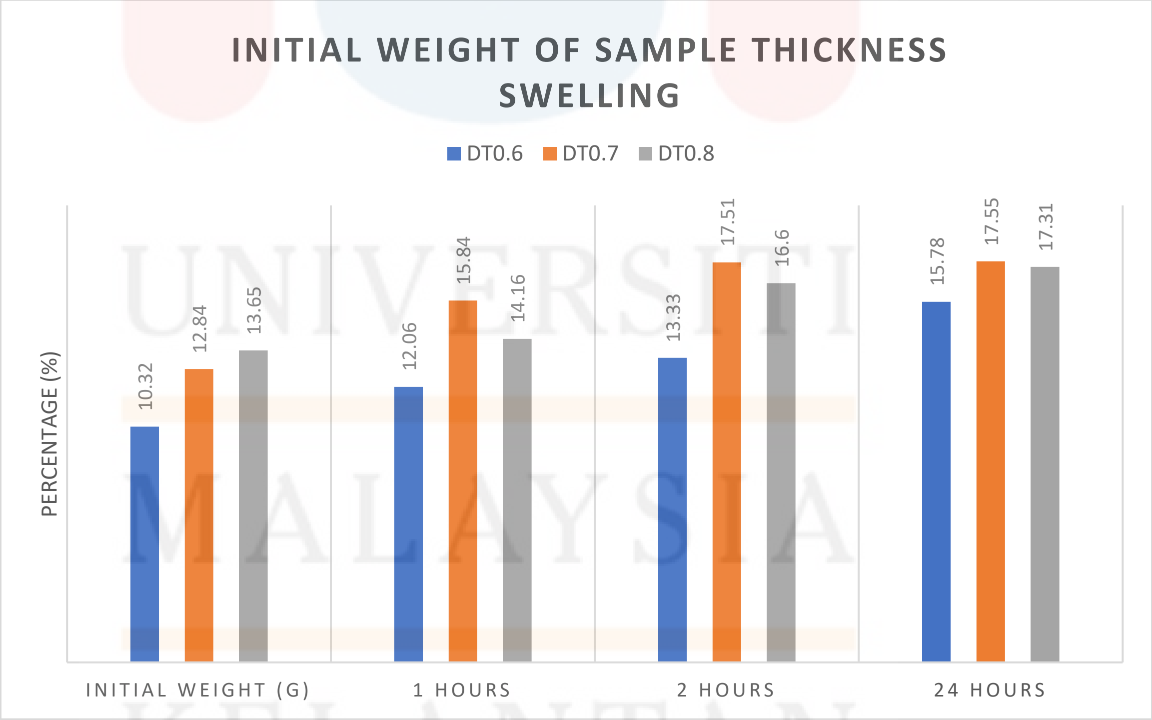


Figure 16: The chart of thickness swelling for sample DT0.6 *g/cm*^{3}, DT0.7 *g/cm*^{3} and DT0.8 *g/cm*^{3}.

Table 8: Thickness Swelling for particleboards sample for sample

Sample/ Weight of	**1 hours**	**2 hours**	**24 hours**
0.6	16.86	29.17	52.91
0.7	23.36	36.37	36.68
0.8	3.74	21.61	26.81

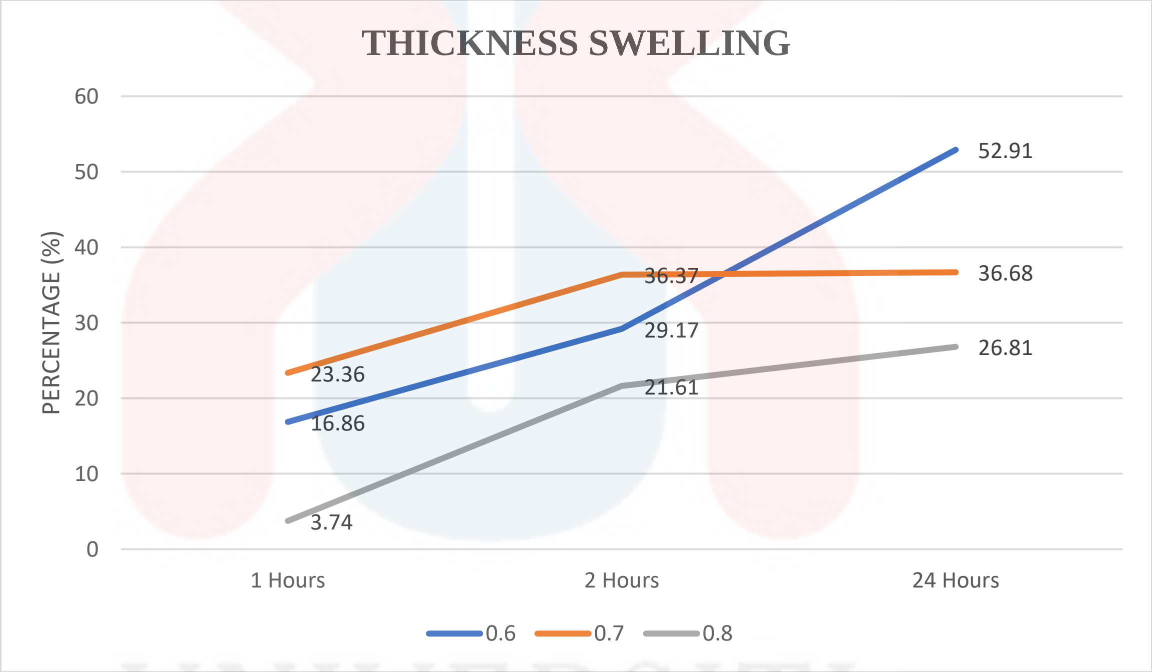


Figure 17: Thickness Swelling for particleboards sample of Urea-formaldehyde and Palmitic Acid for DT0.6 g/cm^3, DT0.7 g/cm^3 and DT0.8 g/cm^3.

Discussion:

Particleboard samples containing varying amounts of urea-formaldehyde and palmitic acid were evaluated for thickness swelling when immersed in water for different periods of time. Tests are conducted according to ASTM D1037 standards. Sawdust from rubber wood mixed with urea formaldehyde (UF) resin together with palmitic acid was used to produce particle board samples. Samples will be named DT0.6 g/cm^3, DT0.7 g/cm^3 and DT0.8 g/cm^3.

Thickness swelling tests were conducted at 1-hour, 2-hour, and 24-hour intervals. This procedure involves soaking the sample in water for a set period of time and then measuring its thickness using a digital caliper. In addition, water absorption tests were carried out by soaking sawdust specimens mixed with polystyrene, urea-formaldehyde, and palmitic acid. At each 1-hour, 2-hour, and 24-hour intervals, specimens were removed from the water, weighed, and the difference in weight was calculated to determine water absorption. These tests aim to evaluate the performance and durability of particleboard samples under different immersion conditions, providing valuable insight into their suitability for various applications.

Table 8 illustrates the thickness swelling (TS) of particleboard under water immersion, showing a consistent increase in swelling with prolonged immersion, stabilizing after 24 hours. TS trends were mainly influenced by weight fraction, indicating that higher fiber weight fractions correlated with increased swelling thickness. This highlights the influence of urea-formaldehyde and palmitic acid on sawdust and polystyrene mixtures, significantly influencing the observed data. These findings emphasize the importance of considering material composition in understanding and managing thickness swelling behavior in particleboard production.

In the first hour, DT0.6 g/cm^3 showed a thickness swelling rate of 16.86%, especially lower than DT0.7 g/cm^3 (23.36%). While for DT0.8 g/cm^3 it shows a swelling rate of only 3.74%. This difference shows that DT0.8 g/cm^3 experiences minimal swelling due to the resistance of palmitic acid, a component of PCM material, and its robust integration with urea-formaldehyde (Can et al., 2023). In the second hour, all variants experienced increased swelling, with DT0.6 g/cm^3 at 29.17%, DT0.7 g/cm^3 at 36.37% and DT0.8 g/cm^3 at 21.61%. However, DT0.8 g/cm^3 shows a relatively high improvement compared to the others. After 24 hours, DT0.6 g/cm^3 experienced a significant increase in swelling to 52.91%, almost three times that of DT0.7 g/cm^3 which is 36.68% and it is also higher than DT0.8 g/cm^3 which is 26.81%. This difference emphasizes the stability of DT0.7 g/cm^3 against swelling, attributed to the protective properties of palmitic acid and its effective association with UF.

The rate of water absorption resulting in the high initial swelling process can be explained by the phenomenon of the diffusion process, such as the movement of the liquid in which water spreads itself through the channels and cellular walls of the sawdust particles. The water absorption rate also depends on the difference in water content which is called the driving force and as a result the water will be absorbed into the pores of the particle board. When the sample is soaked in water, there will be a transfer process in which dimensional stability is less. This process is a common behavior in wood composites during TS testing.

Saw dust particles of rubber wood will swell when the composite is exposed to moisture. It results in swelling of the particle board and will also cause cracks in the sample. Therefore, the cellulose content in this sawdust contributes to more water than it penetrates the sample, through these cracks due to the swelling of the fibers and creating swelling pressure. The spring back panel, which is a common tendency of any wood composite, is displaced in reduced dimensional stability when it is immersed in water.

4.4.3 Water Absorption (WA)

Table 9: Show the initial weight of particleboard

Sample/ Weight of	**1 hours**	**2 hours**	**24 hours**
Initial (g)	22.09	25.95	22.74
0.6	24.51	36.56	27.59
0.7	27.14	41.85	32.21
0.8	42.56	46.38	41.64

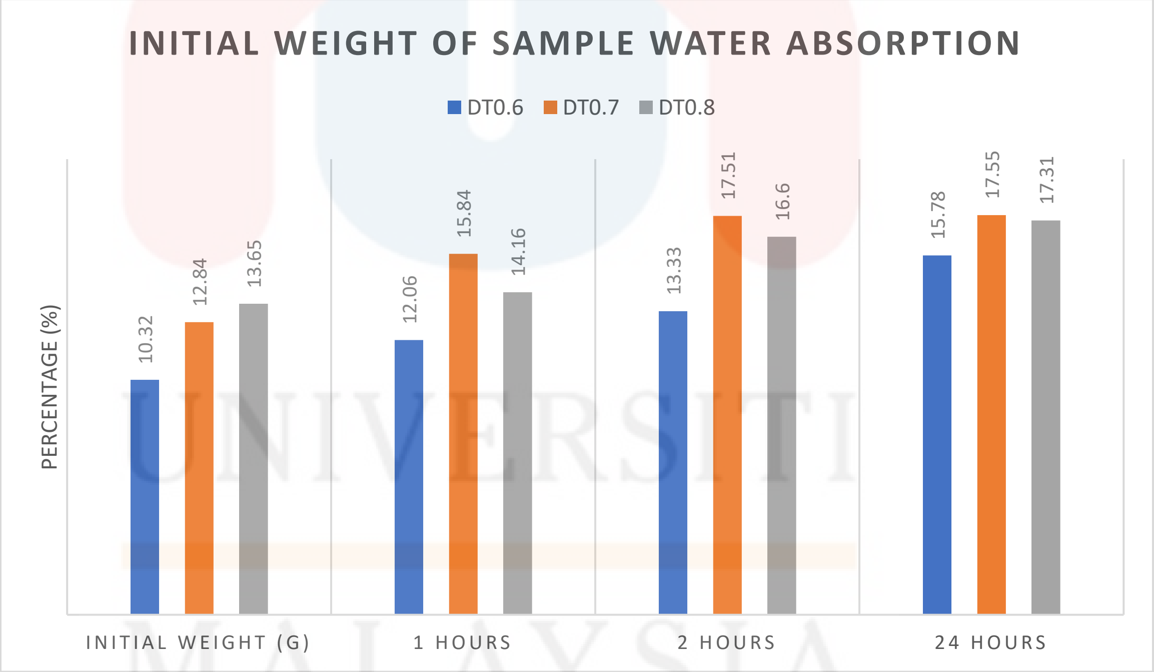


Figure 18: Show the chart for initial weight of particleboard

Table 10: Water absorption for particleboards sample of Urea-formaldehyde and Palmitic Acid for DT0.6 *g/cm*^{3}, DT0.7 *g/cm*^{3}, and DT0.8 *g/cm*^{3}

Sample/ Weight of	**1 hours**	**2 hours**	**24 hours**
0.6	10.96	22.86	92.67
0.7	40.89	61.27	78.73
0.8	21.33	41.64	83.11

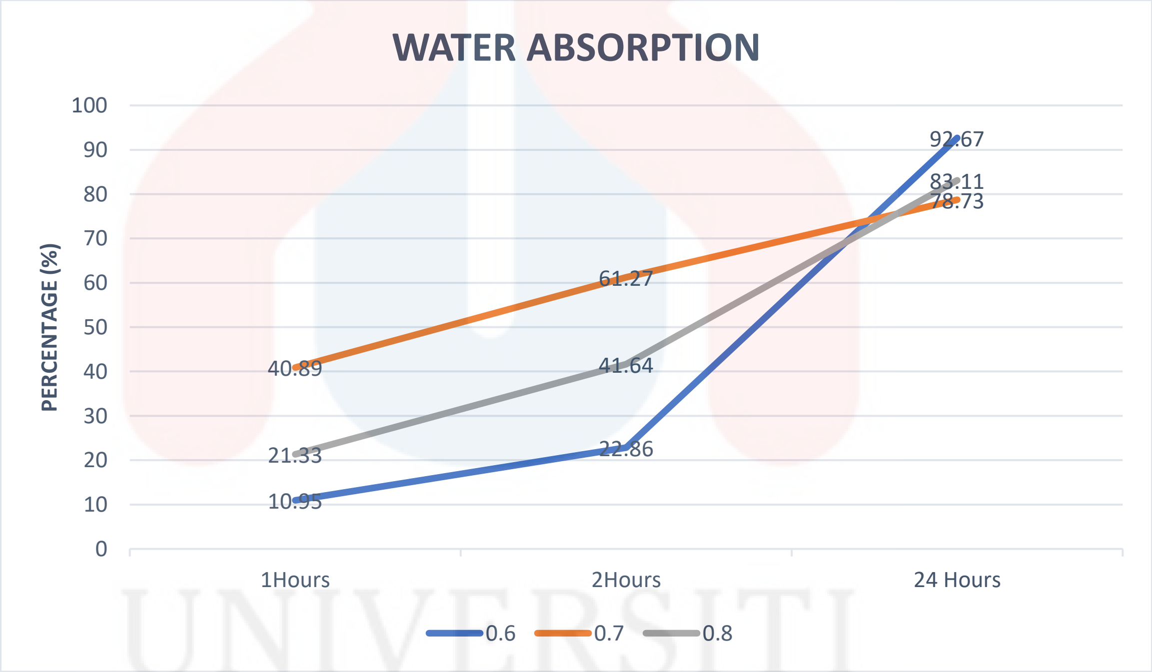


Figure 19: Water absorption for particleboards sample of Urea-formaldehyde and Palmitic Acid for density DT0.6 *g/cm*^{3}, DT0.7 *g/cm*^{3} and DT0.8 *g/cm*^{3}.

Discussion:

Particleboard samples with varying densities, denoted as DT0.6 g/cm3, DT0.7 g/cm3, and DT0.8 g/cm3, were subjected to moisture uptake evaluation by immersing 5cm x 5cm specimens in water for a period of 1 which is different, 2, and 24 hours. The sample composition includes wood particles, polystyrene, UF resin, and palmitic acid.

In the first hour of immersion, DT0.6 g/cm^3 exhibited the lowest absorption rate of 10.96%, while DT0.7 g/cm^3 recorded the highest absorption of 40.89%. DT0.8 g/cm^3 shows an average weight gain of 21.33%. After 2 hours, DT0.6 g/cm^3 maintained the same absorption value of 22.86.73% while DT0.8 g/cm^3 showed an increase of 41.64%. However, DT0.7 g/cm^3 showed an increase to 61.27%%. After 24 hours of wetting, DT0.6 g/cm^3 showed a significant increase in absorption to 92.67%, indicating significant moisture entry over time. DT0.8 g/cm^3 experienced an increase to 83.11%, while DT0.7 g/cm^3 only slightly increased compared to the others at 78.73%. The limited absorption observed in the first 1-2 hours across densities can be attributed to the presence of hydrophobic polystyrene and palmitic acid, which slow down the initial water penetration. However, DT0.6 g/cm^3 showed a fivefold increase in absorption at 24 hours due to its higher porosity. The hygroscopic nature of wood fibers allows them to absorb moisture when wet for a long time, overcoming the initial barrier effect. This phenomenon is particularly noticeable in the porous structure of DT0.6 g/cm^3. In contrast, DT0.8 g/cm^3, with its denser particle distribution, restricts moisture movement to a greater extent. DT0.7 g/cm^3 achieves an optimal balance between compaction and void content, offering the best overall water resistance.

Swelling or Water Absorption, %= (m_i- m_0)/m_0 ×100

A formula to calculate the WA value that will be entered into a calculator or spreadsheet.

The transition of particleboard samples from initially hydrophobic to increasingly hygroscopic over time is clear. The 24 hours readings exceed the expected 1-2 hours for DT0.6 g/cm^3 and DT0.8 g/cm^3, mainly due to wood's natural affinity for moisture. DT0.7 g/cm^3 increased higher than DT0.6 g/cm^3 and DT0.8 g/cm^3 at 1-2 hours but at 24 hours later, it showed low absorption compared to others, indicating robust moisture barrier properties. Optimization of particle density and arrangement in DT0.7 g/cm^3 effectively prevents excessive porosity without affecting density. The trends observed emphasize the importance of understanding the interplay between particle density, composition and moisture absorption in particleboard manufacturing. Although higher density can offer better mechanical properties, it can also lead to increased susceptibility to moisture ingress over time. Conversely, lower density boards may show initial resistance to moisture but are prone to greater absorption with prolonged exposure. DT0.7 g/cm^3 appears as a promising option, offering a balance between mechanical strength and moisture resistance.

Further research could explore the effect of various resin formulations and additives on moisture absorption properties. Additionally, investigating alternative materials or processing techniques that reduce moisture absorption while maintaining mechanical integrity may improve the performance of particleboard in humid environments. Evaluation of moisture uptake in particleboard samples highlights the complex relationship between density, composition and moisture resistance. DT0.7 g/cm^3 exhibits superior moisture barrier properties, making it an ideal choice for applications requiring resistance to environmental moisture. By understanding and optimizing these factors, manufacturers can develop particleboard products that meet the demands of diverse end users while ensuring durability and longevity.

Figure 20: Sample before soaked in the water for sample DT0.6 *g/cm*^{3}, DT0.7 *g/cm*^{3}, and DT0.8 *g/cm*^{3}.

Figure 21: Sample 1 hour soaked in the water for sample DT0.6 *g/cm*^{3}, DT0.7 *g/cm*^{3}, and DT0.8 *g/cm*^{3}.

Figure 22: Sample 2 hour soaked in the water for sample DT0.6 *g/cm*^{3}, DT0.7 *g/cm*^{3}, and DT0.8 *g/cm*^{3}.

Figure 23: Sample 24 hour soaked in the water for sample DT0.6 *g/cm*^{3}, DT0.7 *g/cm*^{3}, and DT0.8 *g/cm*^{3}.

4.4.4 Bending Test

The bending test for particle board mixed with polystyrene mixed with urea-formaldehyde (UF) resin and palmitic acid involves the evaluation of the bending strength and stiffness of the board. UF resin acts as the primary adhesive, binding wood particles together, while palmitic acid can act as a modifier, affecting properties such as moisture resistance. During testing, a particleboard sample is subjected to a controlled force, usually at its midpoint, to assess its ability to withstand bending without breaking or deforming excessively. The values for the boards produced from rubber wood dust are shown in the table, and they have a total content of Urea-formaldehyde and Palmitic Acid of DT0.6 *g/cm*^{3}, DT0.7 *g/cm*^{3}, and DT0.8 *g/cm*^{3}, as can be observed from the moisture content numbers. Particleboard at 0.6 *g/cm*^{3} has the lowest overall moisture content.

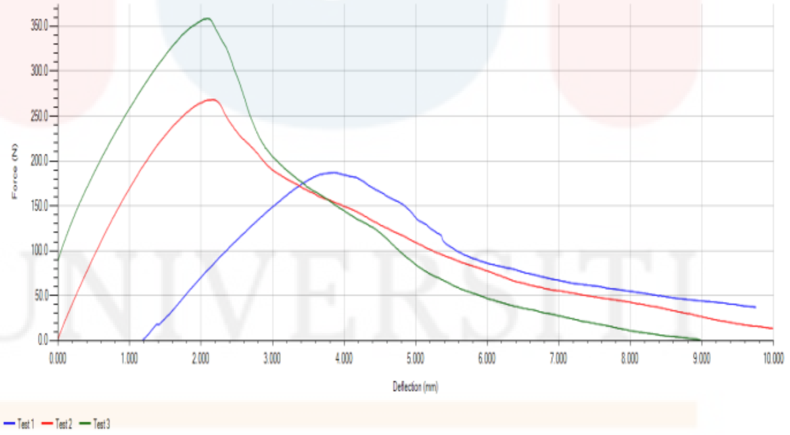


Figure 24: Bending graph of particleboard for DT0.6 *g/cm*^{3}, DT0.7 *g/cm*^{3}, and DT0.8 *g/cm*^{3}

Table 11: Bending data of particleboard for DT0.6 *g/cm³*, DT0.7 *g/cm³*, and DT0.8 *g/cm³*

Test No UF & PA (g/m3)	Bending Modulus (N/mm²)	Bending Strength @ Peak (N/mm²)
0.6	196.819	3.980
0.7	216.143	4.027
0.8	310.848	5.046

Figure 25: Bending machine process bending particleboard for DT0.6 *g/cm³*, DT0.7 *g/cm³*, and DT0.8 *g/cm³*

Figure 26: Wood composite for sample DT DT0.6 *g/cm³*, DT0.7 *g/cm³*, and DT0.8 *g/cm³* after testing

Discussion:

Particle board can also be called as wood composite, subject to bending test. The bending test conducted in the study is a 3-point bending test on particle board samples with different densities, specifically DT0.6 g/cm^3, DT0.7 g/cm^3, and DT0.8 g/cm^3. Each density is represented by three samples. UF is the resin used in this sample and it is mixed with palmitic acid that has been used in the manufacturing process. The wood composite bending graph is displayed in Figure 27.

As can be seen, the sample DT0.6 g/cm^3, has the lowest value of elasticity modulus among other samples which is 196.819 N/mm2. DT0.7 g/cm^3 achieved a higher modulus of 216.143 N/mm2. The maximum modulus of 310.848 N/mm2 was achieved by DT0.8 g/cm^3. This shows a 57.9% increase in modulus from sample 1 to sample 3. Flexural strength follows the same increasing trend as density. DT0.6 g/cm^3 has a minimum bending strength of 3.980 N/mm2. DT0.7 g/cm^3obtained a slightly higher bending strength of 4.027 N/mm2. DT0.8 g/cm^3 achieved a maximum bending strength of 5.046 N/mm2, which is 26.7% more than DT0.6 g/cm^3. Then, the Results show that the modulus of elasticity is between 196.819 N/mm2 for DT 0.6 to 310.848 N/mm2 for DT0.8 g/cm^3. The flexural strength also increased from 3.980 N/mm2 for DT0.6 g/cm^3 to 5.046 N/mm2 for DT0.8 g/cm^3. These findings suggest that the mechanical properties of particleboard improve as the density increases, which is in line with expectations. A higher density will usually result in better bonding between the particles, leading to improved stiffness and strength.

As for the sample, it showed cracks but did not break completely into two parts probably due to the presence of UF resin and palmitic acid in the composition. UF resin provides adhesion between wood particles, increasing the internal bond strength of the composite. This allows the board to resist crack propagation and delay complete fracture failure. In addition, palmitic acid is often used as a hydrophobic additive to increase the moisture resistance of particleboard. It creates a barrier against water absorption, which makes the board more dimensionally stable and less prone to swelling cracks. The hydrophobicity provided by palmitic acid increases the durability and crack resistance of particle board. Thus, UF resin binds the wood particles together, while palmitic acid protects against moisture ingress. Together, these components provide toughness to the composite matrix and increase its damage tolerance.

The observed increase in mechanical properties with density can be attributed to factors such as lower porosity and higher compressive strength. of the material. A denser distribution of particles reduces voids in particleboard, allowing for better stress transfer between particles. As a result, this provides a higher resistance to bending loads. The bending test results confirm the expectation that particle board density is the main factor controlling the bending properties. Higher density boards are likely to perform better in load bearing applications. The test method, including specified spans, speeds and loading conditions, effectively evaluates the bending performance of particleboard samples. The data showed good reproducibility between the 3 specimens tested.

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This work aims to study particleboard mixed with rubberwood dust, recycled polytyrene with urea-formaldehyde addition as the binder for palmitic acid. This study is focused on tests such as Bending Test, Water Absorption, Moisture Content, FT-IR, TGA/ DSC, and XRD performed on samples of rubber sawdust mixed with Urea-Formaldehyde as a palmitic acid binder with different values of 0.6 g/ m3, 0.7 g/m3, 0.8 g/m3 mixed into recycled polystyrene to see the difference produced from all the results. In general, the results show a significant difference between the concentrations of 0.6 g/m3, 0.7 g/m3 and 0.8 g/m3. In all tests performed from Bending Test analysis, Water Absorption, Moisture Content, FT-IR, TGA/ DSC, and XRD test data. In terms of tests for wood composite samples also show significant differences. Based on the study of sawdust wood composites on the moisture content, this shows a weakness in the DT0.8 sample. This is said because, in the table ... it shows the moisture content percentage reading DT0.6 has the highest MC value which is 5.25% compared to DT0.7 MC percentage is 2.50% while DT0.8 has the lowest MC percentage which is 2.39%

5.2 RECOMMENDATION

To produce quality particleboard, it is recommended to use wood composites that have been impregnated with an adhesive that contains a high level of urea-formaldehyde. This is a result of its strong reactivity, its adaptability from a chemical point of view, and its resistance to water and moisture. The use of urea-formaldehyde based adhesives, which have stronger potential but may be limited in the near future, can be used in particle board production. In addition, phase change materials (PCMs) such as palmitic acid are beneficial because they can be used to control temperature in various applications because they are liquid and solid at certain predetermined temperatures. Compared to materials that perceive heat energy, materials that melt when heated are much more effective at absorbing heat energy. A large amount of energy can be stored and released using PCM. Materials undergo a relatively stable temperature transition from solid to liquid and back again during this process. During this transition, the internal structure of the material changes. Compared to sawdust that is not mixed with palmitic acid, sawdust that has pores in its body has more space to store materials such as palmitic acid to make a stronger composite.

In this study it was found that density 0.8 is better for making furniture. However, it can be seen in the water absorption section, it is a wood that absorbs water more than density 0.7 in the thickness swelling section, it only slightly increases in thickness compared to density 0.6 and density 0.7. So, when making furniture such as a table, it needs to be waterproofed so that it does not absorb water and damage the table. Density 0.8 has more binder than density 0.6 and density 0.7, due to which the strength for wood dust to stick to each other is stronger than the other two.

REFERENCES

Al-Yasiri, Q., & Szabó, M. (2021). Incorporation of phase change materials into building envelope for thermal comfort and energy saving: A comprehensive analysis. *Journal of Building Engineering*, *36*, 102122. https://doi.org/10.1016/j.jobe.2020.102122 .

Can, A., Lee, S. H., Antov, P., & Abd Ghani, M. A. (2023). Phase-Change-Material-Impregnated Wood for Potential Energy-Saving Building Materials. *Forests*, *14*(3), 514. https://doi.org/10.3390/f14030514

Children's Environmental Health Network. (2021, May 6). *FAQs: STYROFOAM - Children's Environmental Health Network*. Children's Environmental Health Network - a Healthy Environment for All Children. https://cehn.org/our-work/eco-healthy-child-care/ehcc-faqs/faqs-styrofoam/#:~:text=Polystyrene%20is%20slow%20to%20degrade,greatly%20contributes%20to%20global%20warming.

Dai, F., Zhuang, Q., Huang, G., Deng, H., & Zhang, X. (2023). Infrared Spectrum Characteristics and Quantification of OH Groups in Coal. *ACS Omega*, *8*(19), 17064–17076. https://doi.org/10.1021/acsomega.3c01336

Dancahill. (2022, October 13). *What is X-Ray Diffraction (XRD) | SciMed*. SciMed. https://www.scimed.co.uk/education/what-is-x-ray-diffraction-xrd/#:~:text=X%2Dray%20diffraction%2C%20or%20XRD,wholly%2C%20or%20part%2C%20crystalline.

Farrelly, T., & Shaw, I. (2017). Polystyrene as Hazardous Household Waste. In *InTech eBooks*. https://doi.org/10.5772/65865 .

Hailu, G. (2021). Energy systems in buildings. In *Elsevier eBooks* (pp. 181–209). https://doi.org/10.1016/b978-0-12-820592-1.00008-7

Jelle, B. P., & Kalnæs, S. E. (2017). Phase Change Materials for Application in Energy-Efficient Buildings. In *Elsevier eBooks* (pp. 57–118). https://doi.org/10.1016/b978-0-08-101128-7.00003-4

JIS A 5908: Particleboard : Japan Standards Association (JSA) : Free Download, Borrow, and Streaming : Internet Archive. (2003). Internet Archive. https://archive.org/details/jis.a.5908.e.2003/page/n9/mode/2up .

Kara Rogers. (2023, May 5). *Polystyrene | chemical compound*. Encyclopedia Britannica. https://www.britannica.com/science/polystyrene

Khan, K. S., Li, G., Du, D., Ali, B., Zhang, S., Zhong, M., Stoffella, & Guo, Y. (2023). Impact of polystyrene microplastics with combined contamination of norfloxacin and sulfadiazine on Chrysanthemum coronarium L. *Environmental Pollution*, *316*, 120522. https://doi.org/10.1016/j.envpol.2022.120522 .

Kundra, Y. (2021, October 1). *ASTM D1037 Evaluating Properties of Wood-Base fiber and Particle panel Materials*. Infinita Lab. https://infinitalab.com/astm/evaluating-properties-of-wood-base-fiber-and-particle-panel-materials-astm-1037/

Libretexts. (2020, July 14). *11.5: Infrared Spectra of Some Common Functional Groups*. Chemistry LibreTexts. https://chem.libretexts.org/Bookshelves/Organic_Chemistry/Map%3A_Organic_Chemistry_(Wade)_Complete_and_Semesters_I_and_II/Map%3A_Organic_Chemistry_(Wade)/11%3A_Infrared_Spectroscopy_and_Mass_Spectrometry/11.05%3A_Infrared_Spectra_of_Some_Common_Functional_Groups

Lee, S. H., Chen, L., Geng, B. J., Kryšťák, Ľ., Antov, P., Pędzik, M., Rogoziński, T., Taghiyari, H. R., Lubis, M. Z., Fatriasari, W., Yadav, S., Chotikhun, A., & Pizzi, A. (2022). Particleboard from agricultural biomass and recycled wood waste: a review. *Material Research and Technology*, *20*, 4630–4658. https://doi.org/10.1016/j.jmrt.2022.08.166

Li, J., & Zhang, Y. (2021). Morphology and Crystallinity of Urea-Formaldehyde Resin Adhesives with Different Molar Ratios. *Polymers*, *13*(5), 673. https://doi.org/10.3390/polym13050673

MTC Wood Wizard. (2024). Mtc.com.my. https://mtc.com.my/wizards/mtc_tud/items/report(105).php

Pike, R. A. (2022, April 25). *Adhesive | Definition, Types, Uses, Materials, & Facts*. Encyclopedia Britannica. https://www.britannica.com/technology/adhesive

Polystyrene (PS). (n.d.). Polygrade.eu. (2020) https://www.polygrade.eu/polystyrene-ps/ . Accessed May 10, 2023.Sulaiman, N. S., & Amini, M. H. M. (2022). Review on the Phase Change Materials in Wood for Thermal Regulative Wood-Based Products. *Forests*, *13*(10), 1622. https://doi.org/10.3390/f13101622 .

Rubio, M. R., & Rubio, M. R. (2021). Recycling of Polystyrene Wastes | EcoMENA. *EcoMENA*. https://www.ecomena.org/polystyrene-wastes/

Temiz, A., Hekimoğlu, G., Demirel, G. K., Sarı, A., & Amini, M. H. M. (2020). Phase change material impregnated wood for passive thermal management of timber buildings. *International Journal of Energy Research*, *44*(13), 10495–10505. https://doi.org/10.1002/er.5679 .

Uppala, R., & Muthukumaran, A. (2022). Management of biodegradable waste through the production of single-cell protein. In *Elsevier eBooks* (pp. 39–49). https://doi.org/10.1016/b978-0-12-822933-0.00016-4

Western Oregon University. (2017, April 17). *CH105: Chapter 7 - Alkanes and Halogenated Hydrocarbons - Chemistry*. Chemistry. https://wou.edu/chemistry/courses/online-chemistry-textbooks/ch105-consumer-chemistry/ch105-chapter-7/#:~:text=Alkanes%20are%20organic%20compounds%20that,alkanes%2C%20and%20cycloalkanes%20(Fig.

World Health Organization finds increased cancer risk for chemical found in plastics. (2022, August 6). U.S. PIRG Education Fund. https://pirg.org/edfund/media-center/world-health-organization-finds-increased-cancer-risk-for-chemical-found-in-plastics/ .

Y Hafizzal. (2017). Experimental validation on the effect of material geometries and methodology of Polyox ymethylene (POM). processing https://iopscience.iop.org/article/10.1088/1757-899X/226/1/012158/pdf

APPENDIX A

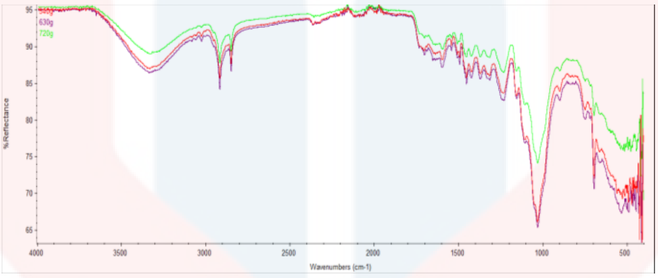
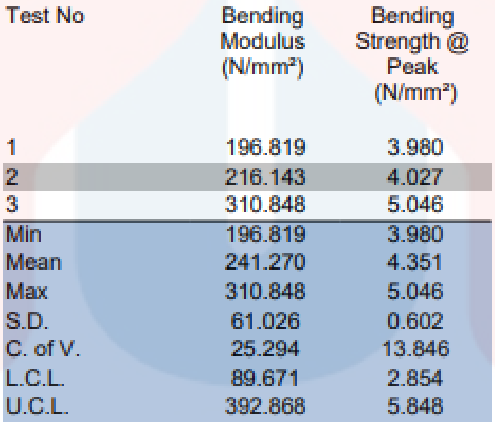


Figure 27: 3 sample for FT-IR



Test No	Bending Modulus (N/mm²)	Bending Strength @ Peak (N/mm²)
1	196.819	3.980
2	216.143	4.027
3	310.848	5.046
Min	196.819	3.980
Mean	241.270	4.351
Max	310.848	5.046
S.D.	61.026	0.602
C. of V.	25.294	13.846
L.C.L.	89.671	2.854
U.C.L.	392.868	5.848

Figure 28: Bending test modulus and peak for 0.6 g/ m3, 0.7 g/m3, 0.8 g/m

Figure 29: Went to the rubber wood factory to collect rubber wood dust to make particleboard.

APPENDIX B

Figure 30: Dried the wood dust for 24 hours in oven.

Figure 31: Separating the rubber wood dust which is divided into four, i.e. Free, 100mm, 150mm, 750mm into a sieved machine

Figure 32: Materials were mixed with polystyrene and wood dust along with UF and palmitic acid. Acetone was used to dissolve the polystyrene.

APPENDIX C

Figure 33: The polystyrene was melted using acetone.

Figure 34: Rubber wood dust that had been separated according to the specified density.

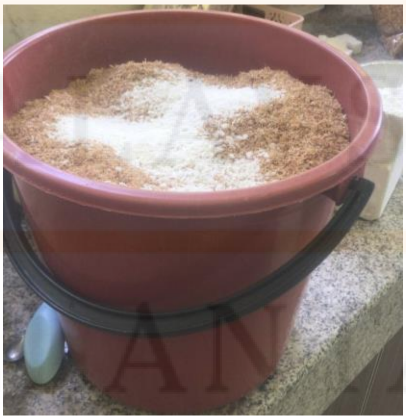


Figure 35: The UF and PA were mixed into rubber wood dust that had been mixed with PS.

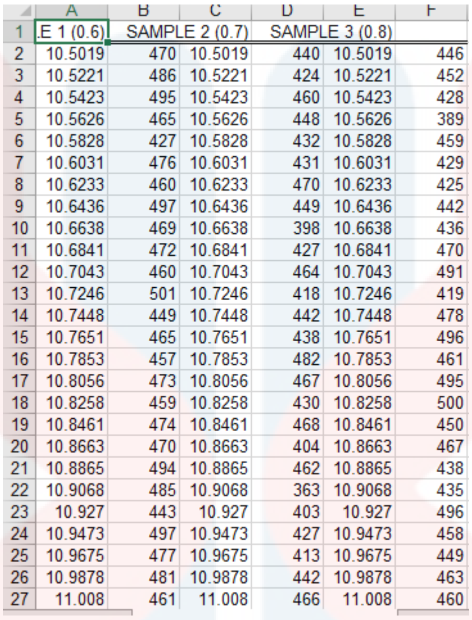
APPENDIX D

Figure 36: The hot press machine was used to press wood dust mixed with PS, UF, and PCM to make particleboard.

Figure 37: The shape of the particleboard was released from the hot press.

Figure 38: Using a cutting machine, we obtained the shape of the wood to carry out bending, MC, TS, WA, density, TGA, FT-IR, and XRD testing.

APPENDIX E



	A	B	C	D	E	F
1	.E 1 (0.6)	SAMPLE 2 (0.7)		SAMPLE 3 (0.8)		
2	10.5019	470	10.5019	440	10.5019	446
3	10.5221	486	10.5221	424	10.5221	452
4	10.5423	495	10.5423	460	10.5423	428
5	10.5626	465	10.5626	448	10.5626	389
6	10.5828	427	10.5828	432	10.5828	459
7	10.6031	476	10.6031	431	10.6031	429
8	10.6233	460	10.6233	470	10.6233	425
9	10.6436	497	10.6436	449	10.6436	442
10	10.6638	469	10.6638	398	10.6638	436
11	10.6841	472	10.6841	427	10.6841	470
12	10.7043	460	10.7043	464	10.7043	491
13	10.7246	501	10.7246	418	10.7246	419
14	10.7448	449	10.7448	442	10.7448	478
15	10.7651	465	10.7651	438	10.7651	496
16	10.7853	457	10.7853	482	10.7853	461
17	10.8056	473	10.8056	467	10.8056	495
18	10.8258	459	10.8258	430	10.8258	500
19	10.8461	474	10.8461	468	10.8461	450
20	10.8663	470	10.8663	404	10.8663	467
21	10.8865	494	10.8865	462	10.8865	438
22	10.9068	485	10.9068	363	10.9068	435
23	10.927	443	10.927	403	10.927	496
24	10.9473	497	10.9473	427	10.9473	458
25	10.9675	477	10.9675	413	10.9675	449
26	10.9878	481	10.9878	442	10.9878	463
27	11.008	461	11.008	466	11.008	460

Figure 39: Raw data of XRD for sample 0.6 g/cm3, 0.7 g/cm3, and 0.8 g/cm3

RUBBERWOOD DUST:

$\frac{0.6}{\text{CM3}}\ \text{X}\ \frac{\text{Mass}}{900} = 540\text{g}$ $\quad \frac{0.7}{\text{CM3}}\ \text{X}\ \frac{\text{Mass}}{900} = 630\text{g}$ $\quad \frac{0.8}{\text{CM3}}\ \text{X}\ \frac{\text{Mass}}{900} = 720\text{g}$

POLYSTYRENE:

$\frac{15}{100}\ \text{X}\ 540g = 81$ $\quad \frac{15}{100}\ \text{X}\ 630g = 94.5$ $\quad \frac{15}{100}\ \text{X}\ 720g = 108$

UREA-FORMALDEHYDE:

$\frac{5}{100}\ \text{X}\ 540g = 27$ $\quad \frac{15}{100}\ \text{X}\ 630g = 31.5$ $\quad \frac{15}{100}\ \text{X}\ 720g = 36$

PCM (PALMITIC ACID):

$\frac{5}{100}\ \text{X}\ 540g = 27$ $\quad \frac{15}{100}\ \text{X}\ 630g = 31.5$ $\quad \frac{15}{100}\ \text{X}\ 720g = 36$

Figure 40: Calculation for density 0.6 g/cm3, 0.7 g/cm3, and 0.8 g/cm3