RECYCLED POLYSTYRENE WITH UF ADDITION AS THE BINDER FOR PARTICLEBOARD: EFFECT OF BINDER PERCENTAGE

MOHAMMAD DANIEAL FAHIMIN BIN MARLIZAN
J20A0480

A proposal submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Forest Resources Technology) with Honor's

FACULTY OF BIOENGINEERING AND TECHNOLOGY
UMK 2024

DECLARATION

I declare that this thesis entitled "Recycled Polystyrene with UF Addition As The Binder For Particleboard: Effect of Binder Percentage" is the results of my own research except as cited in the references.

Student's Name : Mohammad Danieal Fahimin Bin Marlizan

Date : ____________________________

Verified by:

Supervisor's Name: Prof. Madya Dr. Ts. Mohd Hazim Bin Mohamad Amini

Stamp : ____________________________

Date : ____________________________

ACKNOWLEDGEMENT

I would like to express my highest gratitude to Allah S.W.T for giving me time, opportunity and patience to complete my final year project and the final thesis writing. I would also like to gratitude my supervisor Dr. Mohd Hazim bin Mohamad Amini for his patience in helping and giving guidance for me to complete my final year project from the beginning until the end.

To all my course mate and friends especially Muhammad Zaqwan Bin Aziz, and Muhammad Amar Firdaus Bin Isa for helping me throughout this final project. Next, I would like to extend my gratitude to our lab assistant En. Mod Afifi bin Shuhaimin on his assist and guidance throughout my journey in finishing my lab work. I would like to thank you for those who exchanges ideas, techniques and help me in this journey directly or indirectly.

Finally, I would love to express my gratitude to both my beloved parents En. Marlizan Bin Abdul Ghafar and Pn. Darohaimi Binti Ahmad for always giving me continuous encouragement and full support for my study in University of Malaysia Kelantan. Without their support, it would be impossible for me to finish this thesis writing.

Study on the Recycled Polystyrene with UF Addition as The Binder For Particleboard: Effect of Binder Percentage

ABSTRACT

This study investigates the utilization of recycled polystyrene (RP) in combination with urea-formaldehyde (UF) resin as a binder for particleboard manufacturing. The primary focus is to evaluate the influence of varying binder percentages on the mechanical, physical, and thermal properties of the resulting particleboards. The motivation behind this research lies in the sustainable use of recycled materials in the composite panel industry, aiming to reduce environmental impact and enhance resource efficiency. In this study, will characterized the properties of wood dust impregnated with urea formaldehyde (UF) as a binder, and evaluated the physical and mechanical properties of wood composites made from rubber wood, by producing wood composites mixed with UF, for the use of wood dust for samples first 90% wood 10% UF, second sample 80% wood 20% UF and third sample 70% wood 30% UF with polystyrene for all three samples mixed with water to see the difference produced. Evaluations include rubber wood dust leakage tests, TGA, XRD, and FT-IR, as well as wood composite bending and water absorption tests. This study shows that the sample with lower UF is more compatible with the polystyrene mixture than other samples, where it has a high bending which is 6.918 while the other samples are only 5.410 for 20% UF and 4.285 for 30 % UF. However, the water absorption is opposite where the use more UF is much better which is 30% use of UF is only 26.72% after soaking for 24 hours while the other is 28.76% for 20% UF and 30.04% for the sample of 10% use of UF.

Keywords: Urea Formaldehyde, Rubber Wood Dust, Polystyrene, Rubber wood dust test and wood composite test.

Kajian tentang Polistirena Kitar Semula dengan Penambahan UF Sebagai Pengikat Papan Partikel: Kesan Peratusan Pengikat

ABSTRAK

Kajian ini menyiasat penggunaan polistirena (RP) kitar semula dalam kombinasi dengan resin urea-formaldehid (UF) sebagai pengikat untuk pembuatan papan partikel. Fokus utama adalah untuk menilai pengaruh peratusan pengikat yang berbeza-beza pada sifat mekanikal, fizikal dan haba papan partikel yang terhasil. Motivasi di sebalik penyelidikan ini terletak pada penggunaan mampan bahan kitar semula dalam industri panel komposit, bertujuan untuk mengurangkan kesan alam sekitar dan meningkatkan kecekapan sumber.

Dalam kajian ini, kami mencirikan sifat habuk kayu yang diresapi dengan urea formaldehid (UF) sebagai bahan pengikat, dan kami menilai sifat fizikal dan mekanikal komposit kayu yang diperbuat daripada kayu getah, dengan menghasilkan komposit kayu bercampur dengan UF, untuk penggunaan habuk kayu bagi sampel pertama 90% kayu 10% UF, sampel kedua 80% kayu 20% UF dan sampel ketiga 70% kayu 30% UF dan polisterina untuk ketiga-tiga sampel bercampur dengan air bagi melihat perbezaan yang dihasilkan. Penilaian termasuk ujian kebocoran habuk papan kayu getah, TGA, XRD, dan FT-IR, serta ujian lenturan komposit kayu, dan penyerapan air. Kajian ini menunjukkan sampel yang mempunyai UF yang lebih rendah adalah lebih sesuai dengan campuran polisterina daripada sampel lain, di mana ia mempunyai kekuatan yang tinggi semasa ujian lenturan iaitu 6.918 manakala sampel yang lain hanya 5.410 untuk 20% UF dan 4.285 untuk 30% UF. Namun, penyerapan air adalah berlawanan dimana penggunaan polisterina yang banyak lebih baik iaitu 30% penggunaan UF hanya 27.72% selepas direndam selama 24 jam manakala yang lain adalah 29.76% untuk 20% UF dan 31.04% untuk sampel 10% penggunaan UF.

Kata kunci: Urea Formaldehid, Habuk Kayu Getah, Polisterina, Ujian habuk kayu getah dan ujian komposit kayu.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Particleboard is a popular engineered wood product made by gluing together wood particles or fibres using a synthetic glue. Because of its strong bonding qualities and low cost, urea-formaldehyde (UF) resin has traditionally been the major adhesive used in particleboard manufacture. Urea–formaldehyde (UF) resins are the most important type of adhesive resins to produce wood-based panels. They convince by their high reactivity and good performance in the production and by their low price, however they lack in water resistance of the hardened resin owing to the reversibility of the amino methylene link and hence the susceptibility to hydrolysis. This need can be overcome by introducing other components like melamine to the UF resin molecules. The former problem of subsequent formaldehyde emission can be considered as solved owing to the decrease of the content of formaldehyde in the resins during the last two decades. Modern laboratory test methods enable a deep insight into the chemical structure and the gelling and hardening behaviour of the resins. (Mart, T. M.,2023). However, UF resins contain formaldehyde, a volatile organic compound (VOC) that is known to pose health and environmental hazards. There has been an increasing interest in identifying alternative binders that are more sustainable and ecologically friendly in recent years. One such option is to employ recycled polystyrene (RPS) as a particleboard binder. Polystyrene is a popular plastic that may be recycled and ground into a fine powder. RPS as a binder not only reduces waste but also acts as a replacement for UF resin in particleboard manufacture. The proportion of adhesive used in the particleboard manufacturing process is critical in influencing the overall performance and qualities of the board. It is feasible to investigate the impacts on the mechanical, physical, and dimensional properties of the resultant particleboard by modifying the adhesive proportion, especially by integrating RPS with UF resin at varied ratios.

Understanding the influence of adhesive 15% on particleboard qualities is critical for optimising the manufacturing process and producing particleboards with appropriate attributes. It enables researchers and manufacturers to achieve a compromise between the adhesive's binding powers, the production process's cost-effectiveness, and the environmental impact of employing recycled materials. The purpose of this research is to look at the impact of adhesive 10%, especially the inclusion of RPS with UF resin, on particleboard qualities. By assessing the particleboard's mechanical strength, physical properties, and dimensional stability at various adhesive percentages, significant insights may be gleaned to determine the appropriate adhesive ratio for particleboard manufacture. (Farrelly, T. A., & Shaw, I. C, 2017). The study's findings have the potential to contribute to the development of more ecologically friendly and sustainable particleboard manufacturing techniques. By lowering reliance on UF resins and using recycled polystyrene as a binder, the industry may move towards more environmentally responsible practises while preserving or even increasing particleboard quality and performance.

1.2 Problem Statement

The challenge at hand is the use of recycled polystyrene with urea-formaldehyde (UF) addition as a particleboard binder, as well as the evaluation of the influence of adhesive 15% on the qualities of the resultant particleboard. As worries about sustainability and the environment develop, there is a rising interest in discovering new ways to recycle and reuse materials. Polystyrene, which is frequently used in packaging and insulation, presents substantial disposal issues due to its contribution to landfill debris. It is feasible to lessen environmental effect while simultaneously utilising a potentially valuable resource by adding recycled polystyrene into particleboard manufacture. However, to successfully incorporate recycled polystyrene into particleboard, an adhesive binder must be used to connect the particles together. Because of its extensive use in the particleboard industry, urea-formaldehyde (UF) resin is used as the binder in this study. The primary goal is to investigate the influence of adhesive 15% on the qualities of particleboard made from recycled polystyrene with UF added as a binder. The adhesive percentage is the amount of UF resin applied as a proportion of the weight of the recycled polystyrene and rubberwood.

1.3 Expected Output

The study is anticipated to uncover the influence of adhesive 15% on particleboard mechanical qualities. Data on bending strength, modulus of elasticity, and internal bond strength at various adhesive percentages may be included in the output. Higher adhesive percentages are expected to increase mechanical strength, but extremely high percentages are expected to degrade performance.

For dimensional stability research will shed light on the effect of adhesive 15% on particleboard dimensional stability. At various adhesive percentages, outputs may include thickness swelling and water absorption readings. An ideal adhesive 15% is predicted to contribute to decreased swelling and absorption, improving the dimensional stability of the particleboard.

This research will look for any noticeable changes in the surface properties and visual appearance of particleboard when different adhesive percentages are used. Descriptions, pictures, or measurements of surface smoothness, colour, and texture may be included as outputs. The findings might shed light on the effect of adhesive 15% on particleboard attractiveness.

1.4 Objective

i. To study the effect of different adhesive percentages on the properties of particleboard produced using recycled polystyrene with urea-formaldehyde (UF) addition as the binder.

ii. To investigate the impact of different adhesive percentages on the of the particleboard.

1.5 Scope of Study

The study will involve the use of recycled polystyrene as one of the primary materials for particleboard production. When choosing recycled polystyrene, availability, quality, and compatibility for making particleboard will all be considered. Due to its broad use in the sector, UF resin will be selected as the adhesive binder. The research will the different adhesive percentages affect the particleboard's characteristics. There will be a variety of adhesive percentages considered, including various proportions of UF resin to the total weight of recycled polystyrene and rubberwood. Preliminary tests and industry standards will be used to identify the precise range of adhesive percentages.

1.6 Significance of Study

The utilization of recycled polystyrene in particleboard production offers a sustainable approach to managing waste materials. By investigating the effect of adhesive percentage, the study contributes to the development of eco-friendly solutions and promotes the circular economy by reducing the environmental impact associated with polystyrene disposal.

This research also explores the potential of incorporating recycled polystyrene, a commonly discarded material, into the production of particleboard. This not only reduces the demand for virgin materials but also helps conserve natural resources by reusing a valuable resource that would otherwise end up in landfills or incinerators.

This study investigation of how adhesive fraction affects particleboard characteristics enables production process improvement. The study's determination of the ideal adhesive proportion can assist increase the cost-effectiveness and commercial feasibility of producing particleboard from recycled polystyrene, making it a more affordable option for producers.

In the study, the effects of adhesive % are assessed on the mechanical strength, dimensional stability, surface qualities, and formaldehyde emissions of particleboard. Knowing these connections makes it possible to verify that particleboard made from recycled polystyrene and UF resin satisfies or exceeds the necessary performance criteria, improving the quality and market viability of the final product.

CHAPTER 2

LITERATURE REVIEW

2.1 RUBBER WOOD (*Hevea brasilliensis*)

2.1.2 Taxonomy, Morphology and Ecology of Rubberwood

Hevea brasiliensis, commonly known as rubberwood, originates from South America, particularly in the regions of the Amazon and Orinoco River basins in Brazil and Bolivia. While originally native to South America, this rubber-producing tree has now spread to various tropical regions worldwide. Its natural and semi-natural habitats extend from Brazil to Venezuela, Colombia to Peru, and Bolivia in northern South America. Beyond its native range, Hevea brasiliensis is cultivated in eastern Africa, Asia, and some Caribbean islands with tropical climates. Countries cultivating this plant include Nigeria, Côte d'Ivoire, Cameroon, Liberia, and Gabon in Africa; Malaysia, Indonesia, Thailand, Vietnam, and Sri Lanka in Asia; as well as China, India, and Papua New Guinea. This information is based on data from (CABI, as of November 20, 2019. The latex produced by the rubber tree, also recognized as a rubber-yielding plant, is colorless and serves specific purposes. When the rubberwood tree is tapped on its trunk, it naturally produces latex, a raw material extensively used and marketed in various products. The polymer derived from this rubber tree is both natural and biocompatible. It has demonstrated its ability to stimulate tissue repair by enhancing vasculogenesis, guiding and recruiting cells involved in osteogenesis, and acting as a sturdy matrix. Furthermore, it is not only safe for the skin but also possesses antimicrobial properties, ensuring high quality in diverse product applications. As highlighted by (Nayrim Brizuela Guerraa, Giovana Sant'Ana Pegorin, Miguel Henrique Boratto, Natan Robertode Barrosd in 2021), this tall tree, owing to its numerous advantages, is easily accessible and widespread.

Figure 1 (Rubber Tree)

Figure 2 (Rubber Tree Latex)

Approximately 40% of the global rubber consumption is currently met by natural rubber (NR), extracted from the latex of the Hevea brasiliensis rubber tree, with the remaining 60% satisfied by synthetic rubber. The worldwide demand for natural rubber continues to rise due to its unique physicochemical properties, unmatched by synthetic materials. In 2004, the global production reached 97 million tonnes (FAO, 2006), primarily concentrated in Southeast Asia, particularly in Thailand, Indonesia, and Malaysia, but with growing production areas in China and Vietnam. Despite the Amazon basin in South America being the rubber tree's biological center of origin, only 97,000 tonnes of natural rubber are annually produced in Brazil, constituting just 1% of the global output and falling short of the country's own rubber requirements. This disparity is attributed to the fact that natural rubber production in Brazil relies predominantly on extractive production systems within the Amazon basin, where co-operatives collect latex from wild-growing rubber trees. In contrast, Asia, India, and Africa implement large-scale plantation cultivation of natural rubber. Plantations in Central and South America have not been able to reach their full potential, as trees are often eradicated before reaching physiological maturity. This stands in contrast to the plantation-scale cultivation seen in Asia, India, and Africa, as exemplified by (Dean in 1987).

2.2 Properties of Urea Formaldehyde

Urea-formaldehyde (UF) is a thermosetting resin known for its versatile properties and widespread applications in various industries. This synthetic polymer is formed through the reaction of urea and formaldehyde under controlled conditions, resulting in a resinous material with distinctive characteristics. UF resin exhibits excellent adhesive properties, making it a popular choice in the production of wood-based composite materials such as particleboard, medium-density fiberboard (MDF), and plywood. Its ability to form strong and durable bonds with wood fibers contributes to the structural integrity of composite products. UF resin also offers exceptional heat resistance, ensuring the stability and durability of the final cured products. Moreover, its affordability and ease of use in manufacturing processes have contributed to its widespread adoption in the woodworking and furniture industries. However, it's important to note that UF resins can emit formaldehyde gas, a potential concern for indoor air quality, and efforts have been made to develop low-emission or formaldehyde-free alternatives. The versatile and adhesive nature of urea-formaldehyde resin continues to make it a valuable material in various applications, while ongoing research seeks to address environmental considerations associated with its use.

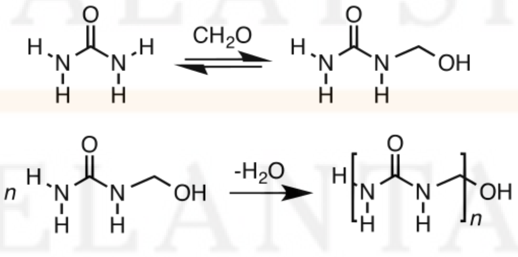


Figure 3: Structure of Urea Formaldehyde

Particleboard is a type of engineered wood that is commonly utilised in the building and furniture sectors. It is made from wood fibres or particles that are bound together with a binder to produce panels or boards. Particleboard has various advantages, including low cost, design adaptability, and less reliance on solid wood resources.

The binder or glue is essential in particleboard production because it offers cohesion and strength to the wood particles. Traditionally, the most often used particleboard binder has been urea-formaldehyde (UF) resin. UF resin is a synthetic glue made by combining urea and formaldehyde. It is commonly used because of its strong adhesive characteristics, quick drying, and low cost.

As a particleboard binder, UF resin has several benefits, including strong binding strength, superior water resistance, and great dimensional stability. It does, however, have certain restrictions. One of the biggest disadvantages is that it emits formaldehyde, which can be harmful to one's health and contribute to indoor air pollution. Formaldehyde is a volatile organic compound (VOC) that has been linked to respiratory troubles and other health concerns. Furthermore, the production of UF resin requires the use of non-renewable resources, which adds to environmental damage. (Gindl-Altmutter, 2018)

Given the environmental and health hazards linked with UF resin, researchers and producers have been aggressively investigating alternate binders for particleboard manufacturing. These alternative binders are intended to minimise formaldehyde emissions, increase sustainability, and enhance overall product performance. One such alternative binder that has gained popularity in recent years is recycled polystyrene with UF addition.

Post-consumer waste, such as packaging materials and throwaway items, is used to make recycled polystyrene (PS). It aids the environment by diverting plastic trash from landfills and minimising the use of virgin resources. The resultant binder solution attempts to improve the sustainability and performance of particleboard by blending recycled PS with UF resin.

(Riegler, M, 2018)

The utilization of recycled PS with UF addition as a binder for particleboard offers potential advantages such as reduced formaldehyde emissions, improved dimensional stability, and enhanced moisture resistance. Additionally, the incorporation of recycled PS can contribute to resource conservation and promote the circular economy.

Understanding the properties and performance of particleboard produced using recycled PS with UF addition as the binder, along with the effect of adhesive percentage, is crucial for optimizing the manufacturing process and achieving desired board properties. Extensive research has been conducted to evaluate the mechanical and physical properties, as well as the environmental impacts, of particleboards using this novel binder system.

2.3 Wood Composite

Wood composites have a rich history dating back to the early 1900s, and their evolution over the years reflects advancements in material science and a response to the changing needs of various industries. In the early stages, wood composites were introduced and marketed under the name Bakelite. These composites were primarily composed of wood flour, a fine wood powder, combined with phenol formaldehyde resin. Bakelite, renowned for its versatility and durability, marked the inception of wood-based composites. Over time, the applications of wood composites expanded, driven by innovations in manufacturing processes and a growing demand for materials that offered enhanced performance and sustainability. (Ahmed.J. Farhan, Harith.I. Jaffer, 2011).

The primary function of wood composites is rooted in their ability to combine the advantageous properties of different materials, resulting in a versatile and durable product. One of the key functions is as a replacement for traditional solid wood in various applications. By blending wood fibers with resins, such as phenol formaldehyde, the resulting composite material retains the natural appearance and feel of wood while offering improved resistance to factors like moisture, decay, and insect damage. This adaptability has led to the incorporation of wood composites in a wide range of products, including door components, windows, boards, and fences.

Wood composites serve various functions, each tailored to specific industrial needs. In the realm of construction and building materials, these composites find application in the production of structural elements such as particleboard, medium-density fiberboard (MDF), and plywood. The use of wood composites in these applications capitalizes on their ability to form strong and durable bonds with wood fibers, contributing to the structural integrity of the final products. The enhanced resistance to factors like moisture and decay makes wood composites an ideal choice for construction materials, ensuring longevity and stability in various environmental conditions.

In the flooring industry, wood composites have found applications, particularly in regions where their availability is abundant. Engineered wood flooring made from wood composites provides a cost-effective alternative to traditional hardwood flooring. The light color and ability to take finishes well contribute to the aesthetic appeal of interior spaces.

The properties of wood composites contribute significantly to their diverse applications. Their blend of wood fibers with thermoplastic materials imparts a range of advantageous characteristics. One of the key properties is their enhanced resistance to moisture and decay. (Surasit Rawangwong, Worapong Boonchouytan, Wiriya Thongruang, Thanate Ratanawilai, 2018) Unlike traditional solid wood, wood composites are less susceptible to environmental factors that can lead to deterioration, making them suitable for outdoor applications such as fences and decks.

The thermal properties of wood composites contribute to their suitability for certain applications. Their resistance to high temperatures ensures that they can withstand the rigors of manufacturing processes without compromising their structural integrity. This thermal stability makes wood composites well-suited for applications in which exposure to heat is a significant consideration.

However, the properties of wood composites also pose challenges and concerns. One such concern revolves around the potential emission of volatile organic compounds (VOCs), including formaldehyde, from certain types of wood composites. Formaldehyde is a common component of resins used in wood composite production, and its release can have implications for indoor air quality. To address this, there has been a push towards the development of low-emission or formaldehyde-free wood composites, aligning with a broader emphasis on environmentally friendly materials. (Donald L. Grebner PHD, Kevin Boston PHD, JD, 2022)

2.4 Properties Polystyrene

Polystyrene, a versatile and widely used polymer, has a history rooted in innovation and an array of properties that make it indispensable in various industries. Developed in the early 20th century, polystyrene was initially synthesized. (German pharmacist Edward Simon, 1839). However, its commercial production gained momentum in the 1930s when chemical company BASF introduced it under the trade name "Styrol." The polymer's popularity surged in the post-World War II era as industrial processes advanced, enabling mass production.

Polystyrene belongs to the family of synthetic aromatic hydrocarbons and is composed of long chains of styrene monomers. Its popularity is attributed to its lightweight nature, clarity, and insulating properties. Expanded polystyrene (EPS), commonly known as Styrofoam, is a well-known variation. Its insulation capabilities and versatility in packaging have contributed to its widespread use.

One of the key properties of polystyrene is its rigidity and durability, making it an ideal material for a range of applications. Its transparency allows for the creation of clear plastic products, used in items like disposable cups, food packaging, and optical lenses. The rigid form of polystyrene is often employed in the production of consumer goods, including appliances, toys, and various household items.

Expanded polystyrene, known for its lightweight and excellent insulation properties, has become synonymous with packaging and construction. Its low thermal conductivity makes it an efficient insulator, widely used in the construction industry for insulation panels, sheets, and as a component in concrete forms. Additionally, its buoyancy and resistance to moisture make it valuable in marine applications, such as flotation devices. (M. Davallo, H. Pasdar, M. Mohseni, 2010).

The versatile nature of polystyrene extends to its use in the food and beverage industry. Its non-reactive property makes it suitable for packaging materials that come in direct contact with consumables. Disposable containers, trays, and foam cups are commonly made from polystyrene due to its affordability and convenience.

While polystyrene possesses a multitude of advantageous properties, it has also faced criticism due to its environmental impact. The material's resistance to decomposition raises concerns about its persistence in the environment and contribution to plastic pollution. Efforts to address these concerns include recycling initiatives and the exploration of alternative materials.

In the realm of recycling, polystyrene presents both challenges and opportunities. Its lightweight and bulky nature can make transportation and recycling processes economically challenging. However, advancements in recycling technologies and increased awareness of environmental issues have led to the development of programs to collect and recycle polystyrene waste. Some regions have implemented specialized facilities equipped to process polystyrene, while others explore mechanical recycling methods or chemical depolymerization to break down the polymer into its constituent monomers for reuse.

Biodegradable alternatives to traditional polystyrene have emerged, offering a more sustainable option. These alternatives are designed to break down more easily in natural environments, reducing the long-term impact on ecosystems. Manufacturers are increasingly exploring bio-based materials and biodegradable polymers to mitigate the environmental concerns associated with traditional polystyrene. (Nava, 2015)

CHAPTER 3

3 MATERIAL AND METHOD

3.1 Material

Rubberwood (*Hevea Brasiliensis*) will be obtained from local planters in Jeli, Kelantan. Urea-Formaldehyde (UF), particleboards and recycled Polystyrene will be obtained from laboratory of University Malaysia Kelantan.

3.2 Method

3.2.1 Particleboard making

To distribute more equally through the particle board, polystyrene foam will be sliced or broken into little pieces. Polystyrene will be dissolved in acetone. Combine the rubber wood particles with the UF mixture after melting the polystyrene. The proposed board formulation is as follow:

Table 3.2.1: Particleboard making for Recycle Polystyrene as a Binder of UF-impregnated Particleboard.

	Ratio (%)	
Board	Wood	Urea-Formaldehyde
Sample 1	90	10
Sample 2	80	20
Sample 3	70	30

Urea-formaldehyde and polystyrene will usually be used in a ratio of 1:2, 1:1 and 2:1. Then, the ratio that will be use is 1:2 which is more polystyrene than urea-formaldehyde. It normally takes 5 to 10 minutes to completely combine the ingredients until a uniform dispersion is obtained. With a target density of 0.6 gcm-3 for each board to be manufactured, the mixture will be transferred into a mould or particle board press of 30 cm 30 cm x 10 cm. To ensure an even density and thickness throughout, repeatedly flatten the mixture in the mould. Now, apply heat and pressure to the mild using a heat press or oven. The mat will be pressed first at 500 kg/cm2 for 2 minutes before being hot pressed at a temperature of 180oC for 10 minutes. After the pressing cycle, let the particleboard cool and cure under pressure. This step ensures the strength and integrity of the final product. Once cool, remove the particle board from the mould or press. (Nemli et al., 2006, Hashim et al., 2001).

3.3 Characterization

The aim of this research is to examine the effects of impregnating rubber wood with Urea Formaldehyde (UF) on its properties. The impregnation process will be evaluated through various tests including leakage testing, TGA/DSC analysis, FT-IR analysis, and XRD analysis. These tests will help in characterizing the morphology and physio-chemical properties of the impregnated wood.

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

A Thermogravimetric Analyzer (TGA) is an essential laboratory instrument used to evaluate the characteristics of materials. It is employed to determine material properties relevant to various fields, including environmental science, food science, pharmaceuticals, and petrochemicals. TGA, in combination with Differential Scanning Calorimetry (DSC), offers weighing capabilities that encompass position-independent weighing. This advanced technology incorporates an automatic internal calibration weight, ensuring a wide measurement range, exceptional performance at low sample weights, and unparalleled weighing precision and accuracy. For this study, TGA and DSC analyses will be conducted using the SDT Q600-TA Instruments, employing a heating rate of 10°C/min, covering a temperature range from ambient to 700°F.

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

FTIR spectra may be used to determine the composition of solids, liquids, and gases. The principal uses of FTIR include detecting unknown compounds and confirming industrial materials, whether arriving or exiting. The information richness of FTIR spectra is very specific, allowing for exact separation of comparable constituents. The FT-IR equipment used in this work is the IRAffinity-1S, which can do scans ranging from 400 to 4000 cm (-1) in powder form. (Mathias, J, 2023).

III. X-ray diffraction (XRD)

X-ray diffraction (XRD) is a highly effective and non-destructive technique used to analyse the characteristics of crystalline materials. In the present study, the objective is to assess the crystalline index in a wood sample to determine its structure, phase composition, crystal orientation, and various structural parameters such as average grain size, crystallinity, strain, and crystal defects. The analysis will be performed using an XRD instrument (Rigaku model, Japan) operating with Cu Kα radiation at 35 kV and 30 mA. The analysis will be conducted within a diffraction angle range of 5 to 70 degrees (2θ) at a scan rate of 0.04 degrees per minute. (Pinkl.S, 2023)

3.4 Evaluation of properties of particleboards

The physical and mechanical properties of the particleboards produced were assessed, and the results are presented in the subsequent sections.

3.4.1 Moisture content of particleboard

The moisture content was determined in accordance with the Japanese Standard (JIS A 5908, 2003). A particleboard sample with dimensions of 10 mm × 10 mm was cut from the board to guarantee a minimum beginning weight of 20 g. The sample was originally weighed, then dried overnight in an oven at 102 °C, and then weighed again after cooling in a desiccator to acquire the final weight. This procedure was continued until a consistent final weight was obtained. The experiment was repeated three times, with the findings computed using a specified equation.

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

Where m_H is the initial mass of the test piece in grams and m_0 is the mass of the test piece after drying in grams.

3.4.2 Density of particleboard

With the sample dimension modified, the density of particleboards was determined using the Japanese Standard (JIS A 5908, 2003). Particleboards were cut to 10 mm 10 mm thickness. The test items were conditioned in a conditioning chamber overnight at 25°C and 50% humidity. The dimensions of the sample were measured again using a calliper and weighed with an analytical balance. The density was calculated using the equation.

$$\text{Density } (\text{kg.m}^{-3}), \rho = \frac{\text{m}}{\text{b}_1 \times \text{b}_2 \times \text{t}}$$

In this equation, m represents the mass of the test piece, b1 the width of the piece, b2 the length, and t the thickness.

3.4.3 Thickness swelling and water absorbtion of particleboard.

The swelling of particleboard thickness after immersion in water was measured using Japanese standards (JIS A 5908, 2003). 30 mm × 30 mm particleboard test pieces were cut and conditioned for 24 hours at 25 °C and 50% relative humidity. The width, length, and thickness of the sample were all measured, weighed, and then immersed in water. After 24 hours, the test pieces were removed, excess water was removed, and the dimensions after water immersion were measured. Weighing test pieces was used to evaluate the amount of water absorbed. The thickness swelling and water absorption capacity were calculated using the following equation.

$$\textit{Swelling or Water absorption},\% = \frac{m_{ii} - m_0}{m_0} \times 100$$

Where m_0 is measurement before immersion and m_i is measurement after immersion

3.4.4 Bending strength of particleboard

Particleboards were evaluated for bending strength using the technique described in the Japanese Standard (JIS A 5908, 2003). Particleboards were cut to 200 mm x 50 mm and conditioned at 25 °C and 50% relative humidity in a conditioning chamber. As illustrated in Figure 3.3, the test component was placed on the Instron Tensile Machine Model 5582. The loading rate was set to 10 mm/min for the tests. Results were expressed in modulus of elasticity and bending strength, using the equation.

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

Where

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

l_1 is the distance between the centres of the supports, in millimetres

b is the width of the test piece, in millimetres

t is the thickness of the test piece, in millimetres

$F_2 - F_1$ is the increment of load on the straight-line portion of the load-deflection curve, (Figure 3.4) in N. F_1 shall be approximately 10 % and F_2 shall be approximately 40 % of the maximum load

$a_2 - a_1$ is the increment of deflection at the mid-length of the test piece (corresponding to $F_2 - F_1$)

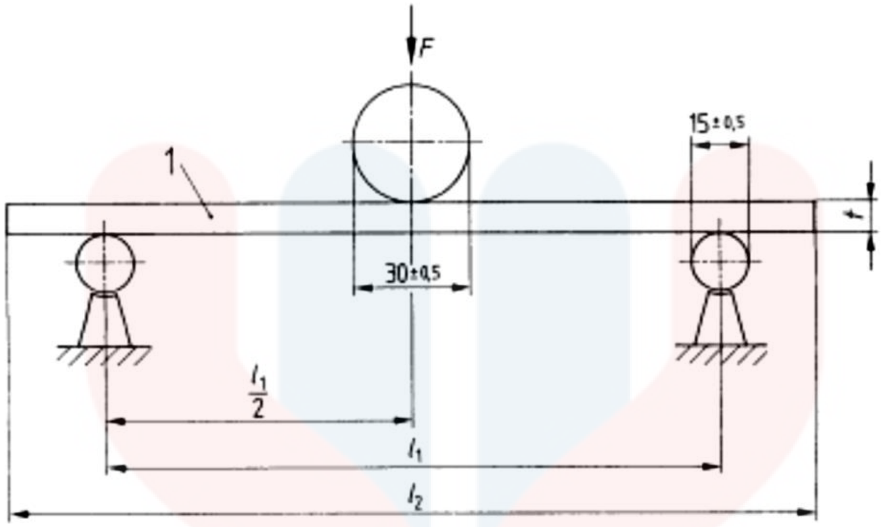
and bending strength (equation)

$$Bending\ strength, f_m\ (Nmm^{-2}) = \frac{3\,F_{max}\,l_1}{2\,b\,t^2} \quad (3.13)$$

Where

$F_{\max}$ is the maximum load, in newtons.

l_1, b, and t are in millimetres



1 = test piece
F = load
t = thickness
l_1 = 20t
l_2 = l_1 + 50mm

Figure 3.3: Arrangement of the bending apparatus (JIS A 5908, 2003)

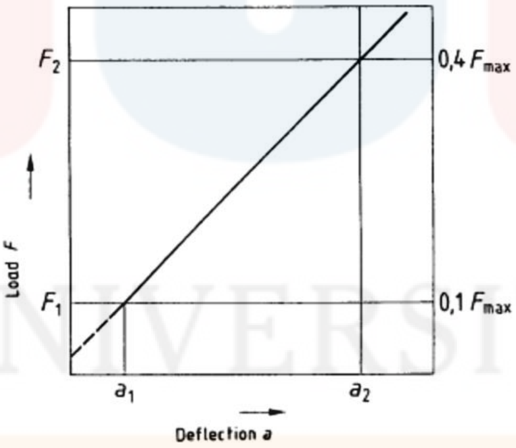


Figure 3.4.4: Load-deflection curve within the range of elastic deformation (JIS A 5908, 2003)

CHAPER 4

RESULT AND DISCUSSION

4.1 Rubberwood Sawdust Testing

4.1.1 Thermogravimeter analysis (TGA)

A thermogravimetric analysis (TGA) device determines the quantity and rate of change in a sample's mass as a function of temperature and time in a controlled environment. The method is applied to materials that show mass gain or loss because of oxidation, breakdown, and volatile loss.

Figure 4: TGA analysis of rubberwood sawdust for 30% Urea Formaldehyde

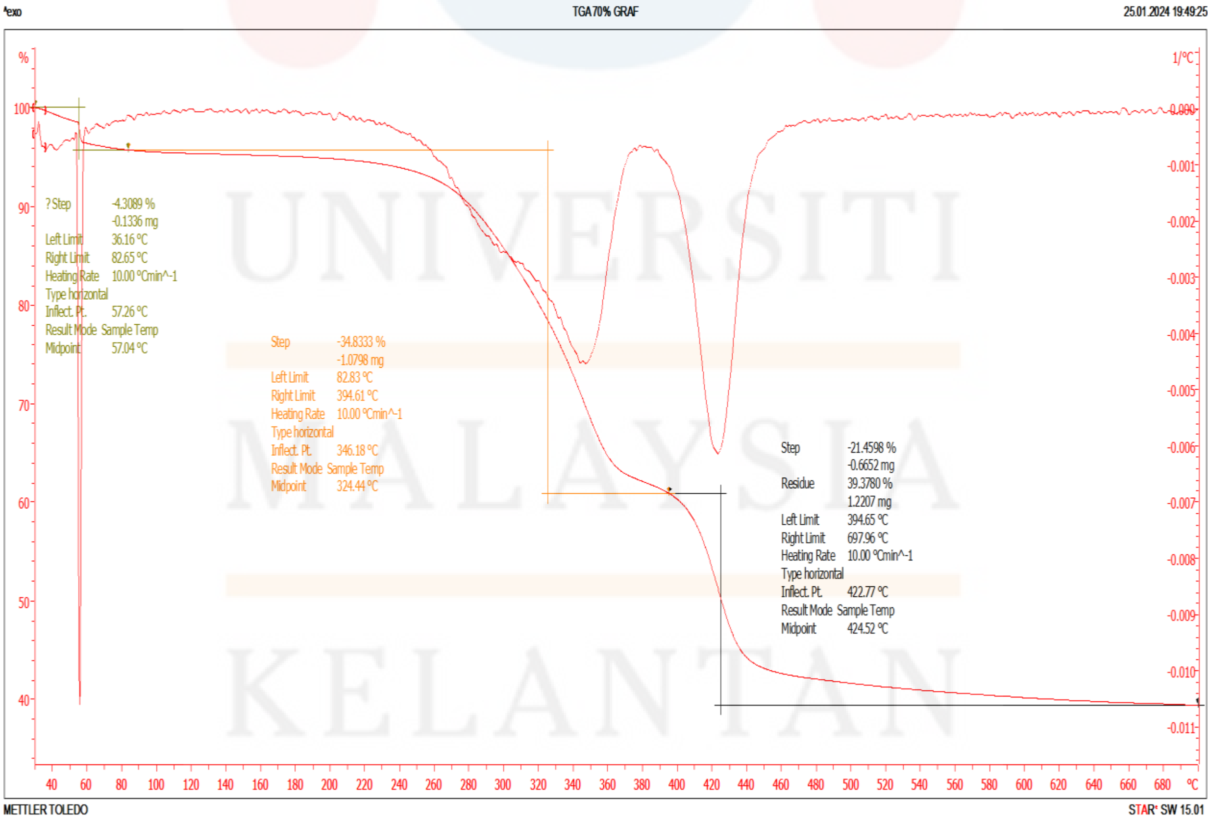


Figure 5: TGA analysis of rubberwood sawdust for 20% Urea Formaldehyde

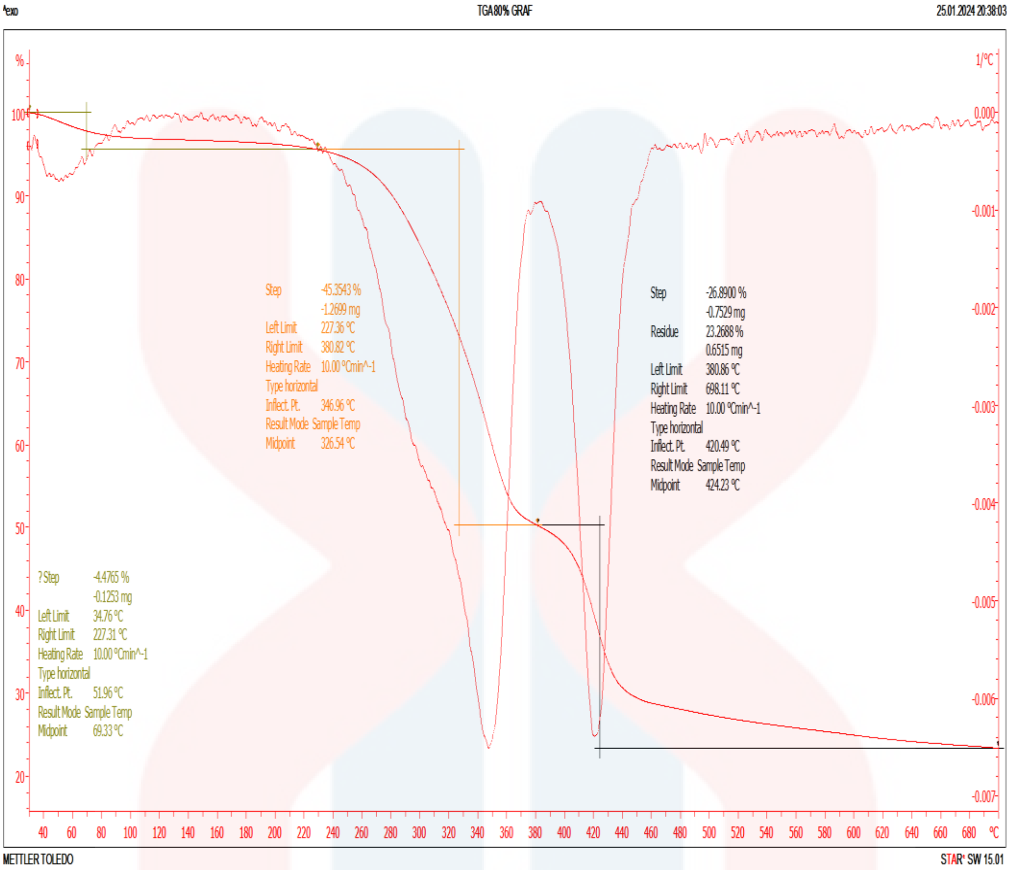
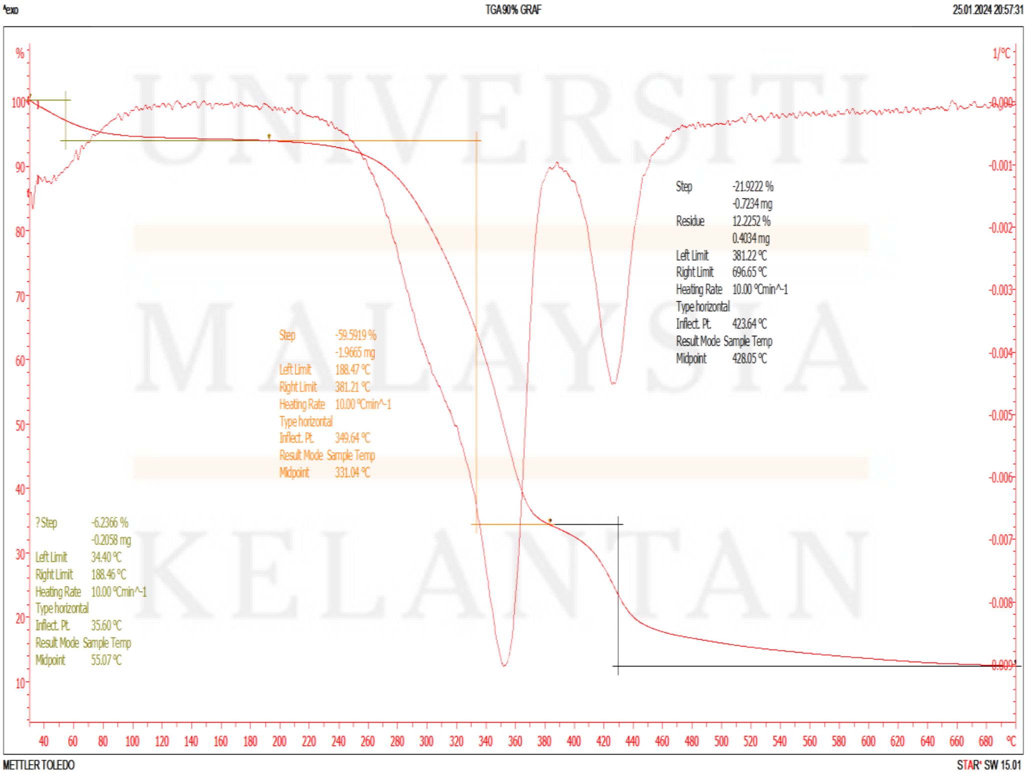


Figure 6: TGA analysis of rubberwood sawdust for 10% Urea Formaldehyde



Discussion:

Thermogravimetric analysis (TGA) was carried out on a 70% rubber wood sample mixed with 30% Urea Formaldehyde, with a total sample mass of 3.0999 mg. The sample was heated from 30°C to 800°C at 10°C/min under nitrogen atmosphere. The TGA curve shows three distinct mass loss steps occurring at different temperature regions. The first minor mass loss of 4.3089% (0.1336 mg) below 83°C can likely be attributed to the loss of adsorbed or bound water from the sample. The major mass loss event occurs between 83-395°C, accounting for 34.8333% (1.0798 mg) of initial mass. This large mass loss is likely due to decomposition or volatilization of the major sample component(s). The temperature range suggests the sample contains organic or polymeric material that is unstable at elevated temperatures. The third and final mass loss step occurs between 395-698°C with a loss of 21.4598% (0.6652 mg) of initial mass. This high temperature event can be assigned to further decomposition and char oxidation. After the three steps, 39.3780% (1.2207 mg) of non-volatile residue remains, possibly indicating inorganic fillers or additives in the original sample. Based on a clear weight loss measure, the total mass of water lost was 17.9182%.

The TGA results show that the sample 80% underwent thermal decomposition in three major steps when heated from 30°C to 800°C. The first step occurred between 34.76°C and 227.31°C. This step had a mass loss of 4.4765% (0.1253 mg) and a midpoint at 69.33°C. The low temperature onset and small mass loss suggest removal of residual solvents or moisture absorbed on the surface of the sample. The second step occurred between 227.36°C and 380.82°C with a much larger mass loss of 45.3543% (1.2699 mg). The midpoint was 326.54°C. This significant mass loss can be attributed to the burning off oxygen-containing functional groups from the graphene sheets, resulting in thermal reduction of the material. The oxygen groups start decomposing around 200°C and more rapidly above 300°C. The third step from 380.86°C to 698.11°C had a mass loss of 26.8900% (0.7529 mg) with a midpoint at 424.23°C.

This step is likely associated with the decomposition of the carbon structure, indicating the material begins degrading significantly above 400°C. After the three steps, 23.2688% (0.6515 mg) residue remained at 800°C, which can be attributed to the thermally stable graphitic structure of sample. The DTA curve shows endothermic peaks corresponding to the mass losses, with diminishing intensity at higher temperatures as less material remained. Based on clear weight loss measure, the total mass of water lost was 3.6212%.

The TGA analysis of the 90% sample showed a mass loss occurring in three distinct steps. The first step from 30-188.46°C showed a mass loss of 6.2366%, corresponding to 0.2058 mg. This likely represents evaporation of residual solvent or moisture. The second step from 188.47-381.21°C showed the largest mass loss of 59.5919%, corresponding to 1.9665 mg. This significant mass loss is likely due to decomposition of the main sample components. The third and final step from 381.22-696.65°C showed a smaller mass loss of 21.9222%, corresponding to 0.7234 mg. This final mass loss may be due to decomposition of more thermally stable components or charring. After the three steps, there was 12.2252% residue remaining, corresponding to 0.4034 mg. The sample was heated at a constant rate of 10°C/min under a N2 flow of 20 ml/min. Based on clear weight loss measure, the total mass of water lost was 9.697% The TGA results provide quantitative information about the thermal stability and decomposition behavior of the 90% sample. The distinct mass loss steps indicate that different components are decomposing at different temperatures. This analysis can help identify appropriate processing temperatures to avoid sample degradation.

4.1.2 Fourier-transform infrared (FT-IR)

FTIR is a technique for identifying organic, polymeric, and, in some cases, inorganic materials. The FTIR analysis method scans test samples with infrared light to observe chemical properties.

Figure 7: FT-IR peak of comparison rubberwood sawdust between 10%, 20% and 30% Urea-Formaldehyde

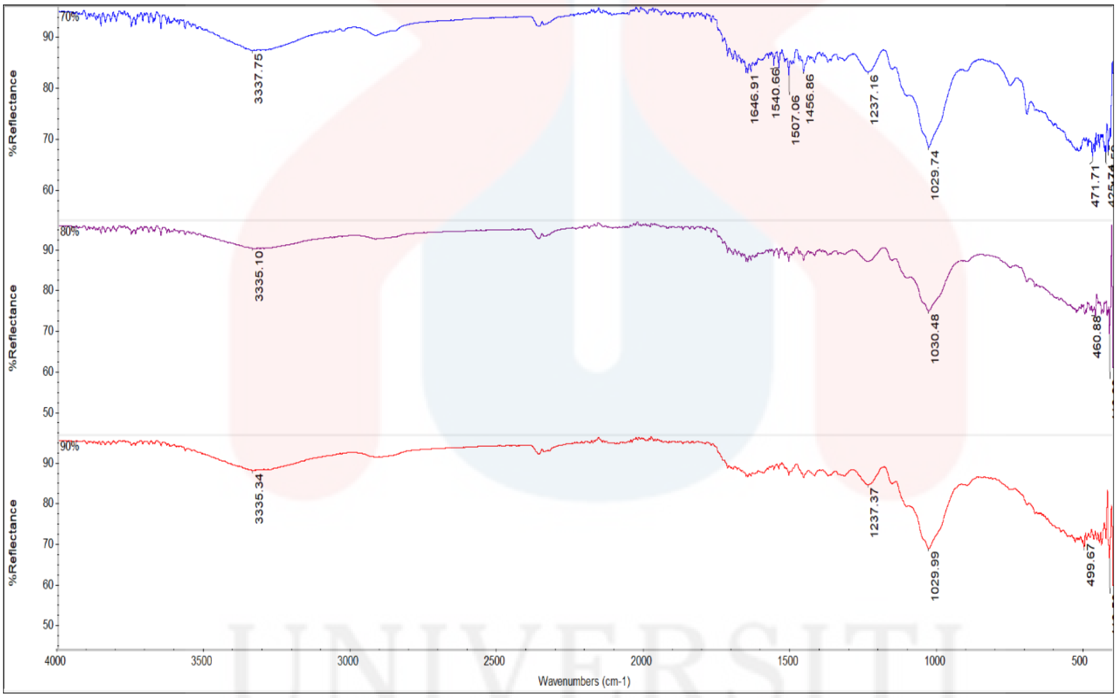


Figure 8 FT-IR main functional group of rubberwood sawdust for 30% Urea-Formaldehyde

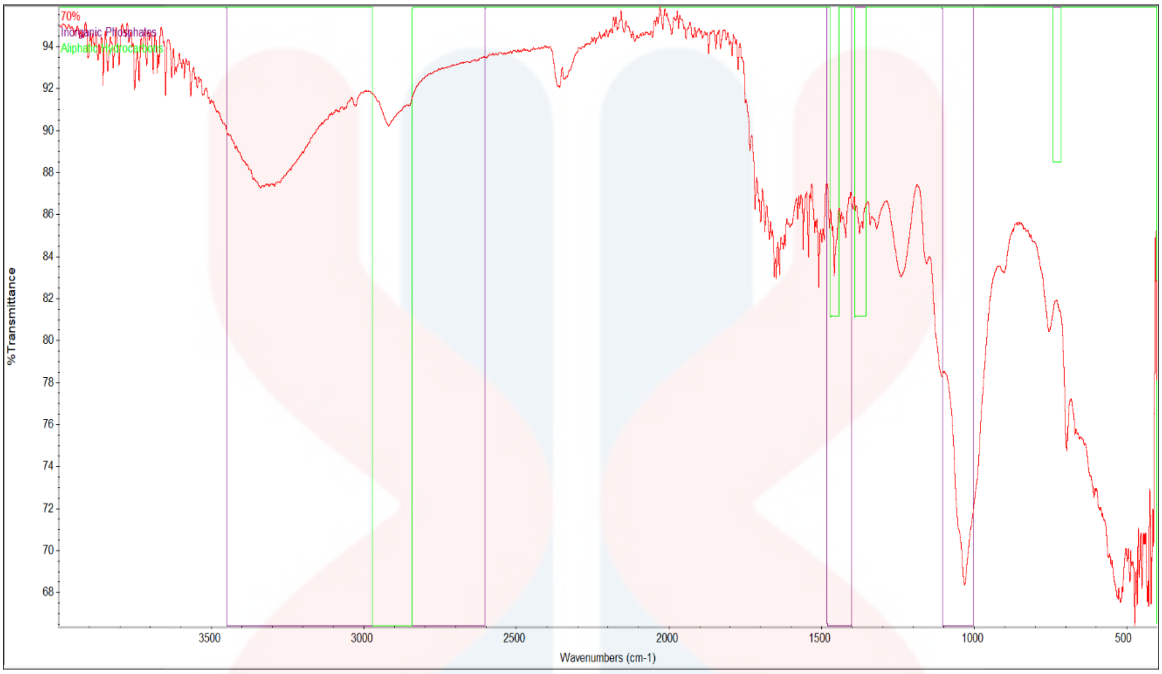


Table 1 FT-IR peaks main functional group of rubberwood sawdust for 30% Urea-Formaldehyde

Functional group	Peaks cm-1	Compound name	Bond
Inorganic Phosphate	1000 and 550	Potassium Phosphate	C-H stretch
	3400 and 1640	Silver phosphate	C-H stretch
Aliphatic hydrocarbon	around 3000	Hexane	C-H stretch
	around 1460 and 1380	2-methyl hexane, 2,2 dimethyl hexane	C-H deformation

Figure 9 FT-IR main functional group of rubberwood sawdust for 20% Urea-Formaldehyde

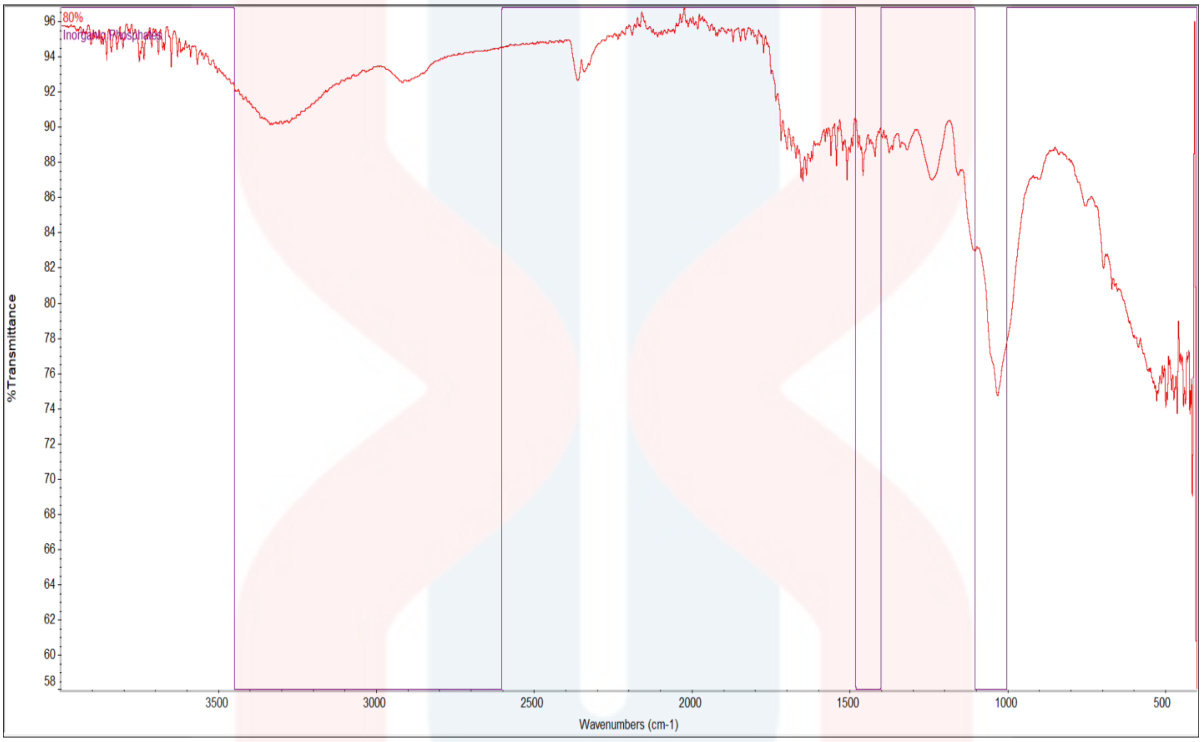


Table 2 FT-IR peaks main functional group of rubberwood sawdust for 20% Urea-Formaldehyde

Functional group	Peaks cm-1	Compound name	Bond
Inorganic Phosphate	1000 and 550	Potassium Phosphate	C-H stretch
	3400 and 1640	Silver phosphate	C-H stretch

Figure 10 FT-IR main functional group of rubberwood sawdust for 10% Urea-Formaldehyde

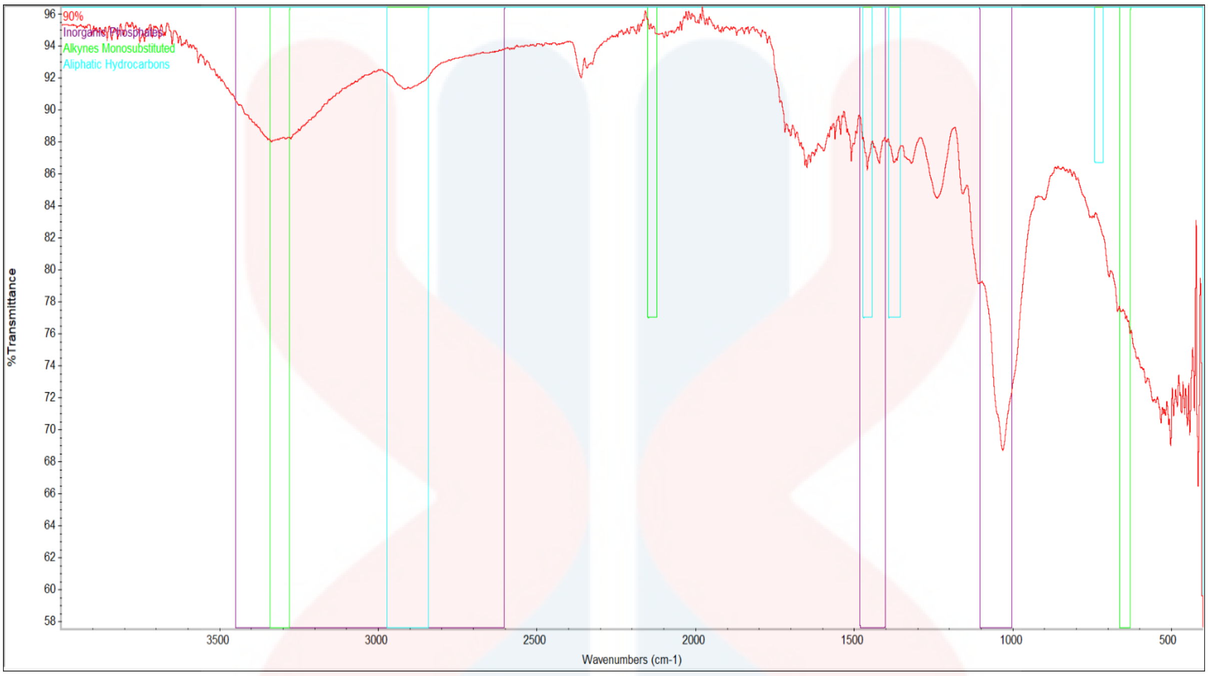


Table 3 FT-IR peaks main functional group of rubberwood sawdust for 10% Urea-Formaldehyde

Functional groups	Peaks cm-1	Compound name	Bond
Inorganic Phosphate	around 1000 and 550	Potassium Phosphate	C-H stretch
	around 3400 and 1640	Silver phosphate	C-H stretch
Alkynes Monosubstituted	Around 3300	4-Methyl-2-pentyne	C-H stretch
	Around 2100	1-octyne	-CH
Aliphatic hydrocarbon	Around 3000	Hexane	C-H stretch
	Around 1460 and 1380	2-methyl hexane, 2,2 dimethyl hexane	-CH

Discussion:

Figures 8, 9 and 10 show the main functional groups of rubberwood sawdust after treatment with 10%, 20% and 30% urea-formaldehyde. The functional groups were identified using FT-IR spectroscopy. The table 1, 2 and 3 list the functional group, the wavenumber at which it was detected, the compound name, and the type of bond.

As shown in table 1, 2 and 3 show the main functional groups in rubber sawdust for 10%, 20% and 30% urea formaldehyde have inorganic phosphate, potassium phosphate, silver phosphate, and C-H stretch. Inorganic phosphate is the main functional group, with peaks at 1000 and 550 cm-1. Absorption bands at 1000 cm^{-1} and 550 cm^{-1} are characteristic of inorganic phosphate groups where these bands are usually associated with the vibration of phosphate ions (PO_4^{3-}) in inorganic compounds. Potassium phosphate has a peak around 1030 cm-1. Silver phosphate has peaks around 3400 and 1640 cm-1, and the C-H stretch has peaks around 2922 cm-1.

Based on the tests that have been identified on the three samples using FT-IR spectroscopy, the sample that uses 20% urea-formaldehyde only shows the inorganic phosphate as shown in table 2. This may be due to several factors such as chemical treatment, urea formaldehyde reaction, sample composition and detection sensitivity. For example, chemical treatment may have altered or removed aliphatic hydrocarbons. Chemical processes, such as polymerization or reaction with urea formaldehyde, can modify the chemical composition of the material.

In Fourier Transform Infrared (FTIR) spectroscopic analysis, samples with 10% Urea-Formaldehyde only have Alkynes Monosubstituted as shown in table 3, where two different alkynes, monosubstituted, have been identified 4-Methyl-2-pentyne and 1-octyne. The presence of this alkyne is explained by the characteristic peak in the FTIR spectrum. For 4-Methyl-2-pentyne, a prominent peak is observed around 3300 cm^{-1}, corresponding to the C-H stretch of the alkyne. Additionally, for 1-octyne, another distinctive peak appears around 2100 cm^{-1}, indicating stretching of the -CH bond in the alkyne. This compound is an alkyne, a type of hydrocarbon characterized by carbon-carbon triple bonds. The peak position at about 3300 cm^{-1} aligns with the C-H stretching vibration specific to alkynes. In 4-Methyl-2-pentyne, the methyl group (CH_3) is substituted on the carbon adjacent to the triple bond. This substitution can influence the local environment of the triple bond, affecting the vibrational modes and, consequently, the peaks observed in the FTIR spectrum. The identification of 4-Methyl-2-pentyne underscores the specificity of FTIR in distinguishing fine structural variations in alkynes. Moving to the second compound, 1-octyne, a distinctive peak around 2100 cm^{-1} corresponds to the stretching of the -CH bond in the alkyne. 1-octyne is an alkyne with its triple bond located at the first carbon position of the eight-carbon chain. The position of the triple bond in the carbon chain contributes to the peak observed in the FTIR spectrum. Alkynes, with their unique triple bonds, exhibit distinct infrared absorption patterns. The C-H stretching vibration around 3300 cm^{-1} and the -CH bond stretching around 2100 cm^{-1} are robust markers for alkynes in FTIR spectroscopy.

The peaks around 3000 cm^{-1} correspond to C-H (carbon-hydrogen) stretching vibrations in aliphatic (non-aromatic) hydrocarbons. This region is known as the CH stretching region. Then, there are two compounds in Aliphatic Hydrocarbons: Hexane with a peak around 3000 cm-1 on C-H stretch bonds and 2-methyl hexane, 2,2 dimethyl hexane with peaks around 1460 cm-1 and 1380 cm-1 on the -CH stretch bond. As shown in tables 1 and 3, only the samples with 10% and 30% Urea-Formaldehyde only have Aliphatic Hydrocarbons.

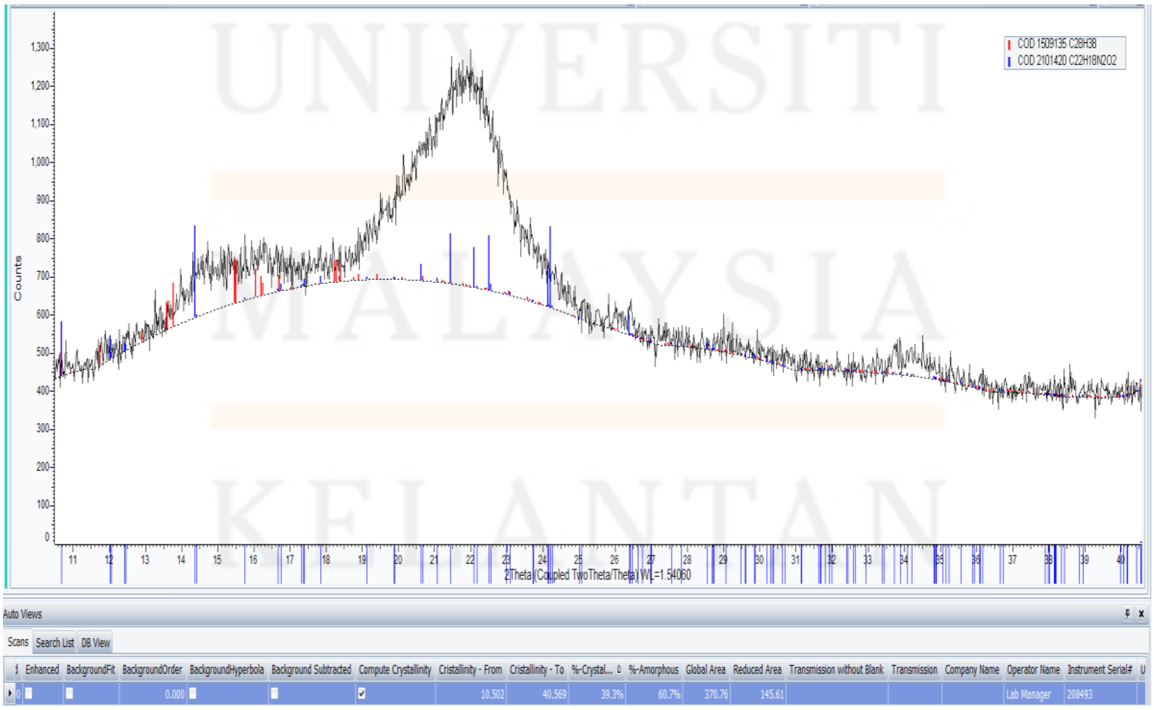
4.1.3 X-ray diffraction (XRD)

X-ray diffraction (XRD) is a technique used in materials science to determine a material's crystallographic structure. XRD works by bombarding a material with incident X-rays and then measuring the intensities and scattering angles of the X-rays that escape.

Figure 11: XRD analysis for rubberwood sawdust for 30% Urea-Formaldehyde

	rvature	Threshold	Enhanced	BackgroundFit	BackgroundOrder	BackgroundHyperbola	Background Subtracted	Compute Crystallinity	Cristallinity - From	Cristallinity - To	%-Crystal...	%-Amorphous	Global Area	Reduced Area	Transmission without Blank	Transmission	Company Name	Operator Name	Ins
▸	1.000	1.000	☐	☐	0.000	☐	☐	☑	10.502	40.569	43.8%	56.2%	390.76	171.32				Lab Manager	208

Figure 12: XRD analysis for rubberwood sawdust for 20% Urea-Formaldehyde



		Enhanced	BackgroundFit	BackgroundOrder	BackgroundHyperbola	Background Subtracted	Compute Crystallinity	Cristallinity - From	Cristallinity - To	%-Crystal...	%-Amorphous	Global Area	Reduced Area	Transmission without Blank	Transmission	Company Name	Operator Name	Instrument Serial#	U
▸	0	☐	☐	0.000	☐	☐	☑	10.502	40.569	39.3%	60.7%	370.76	145.61				Lab Manager	208493	

Figure 13: XRD analysis for rubberwood sawdust for 10% Urea-Formaldehyde

eshold	Enhanced	BackgroundFit	BackgroundOrder	BackgroundHyperbola	Background Subtracted	Compute Crystallinity	Cristallinity - From	Cristallinity - To	%-Crystal...	%-Amorphous	Global Area	Reduced Area	Transmission without Blank	Transmission	Company Name	Operator Name	Instrument Serial
1.000	☐	☐	0.000	☐	☐	☑	10.502	40.569	42.2%	57.8%	374.80	158.21				Lab Manager	208493

Table 4: XRD analysis data

Sample	Amorphousness %	Crystallinity %
10%	57.8%	42.2%
20%	60.7%	39.3%
30%	56.2%	43.8%

Discussion:

The relationship between crystallinity and amorphous characteristics is complex. Generally, higher crystallinity indicates a more ordered and structured material, while higher amorphous content suggests a more disordered and random structure. Table 4 and figures 11,12 and 13 show where the sample with 30% Urea-Formaldehyde has the highest crystallinity which is 43.8% compared to 10% and 20% Urea-Formaldehyde which are respectively 42.2% and 39.3%. Meanwhile, for the value of amorphous sample 20% Urea-Formaldehyde has the highest value which is 60.7% followed by sample 10% Urea-Formaldehyde which is 57.8%, and 30% Urea-Formaldehyde has an amorphous value of 56.2%. There is an effect of concentration of Urea-Formaldehyde. The concentration of Urea-Formaldehyde seems to have an impact on both crystallinity and amorphous characteristics. The sample with 30% Urea-Formaldehyde has the highest crystallinity but the lowest amorphous content, suggesting a more ordered structure. On the other hand, the 20% Urea-Formaldehyde sample, despite having the lowest crystallinity, has the highest amorphous content, indicating a more disordered structure. In addition, the reaction kinetics during the synthesis of Urea-Formaldehyde polymers can influence the degree of crystallinity and amorphousness. The concentration of reactants, reaction temperature, and reaction time can impact the final structure of the polymer. It's possible that the conditions favoring the formation of amorphous regions are more prevalent or efficient in the case of the 20% Urea-Formaldehyde sample.

4.2 Wood Composite Testing

This water absorption test is carried out for the purpose of identifying the percentage of water that enters the sample after being soaked in water for a certain period.

4.2.1 Water Absorption

Figure 14: Water absorption of particlesboard for 10%, 20% and 30% Urea-Formaldehyde

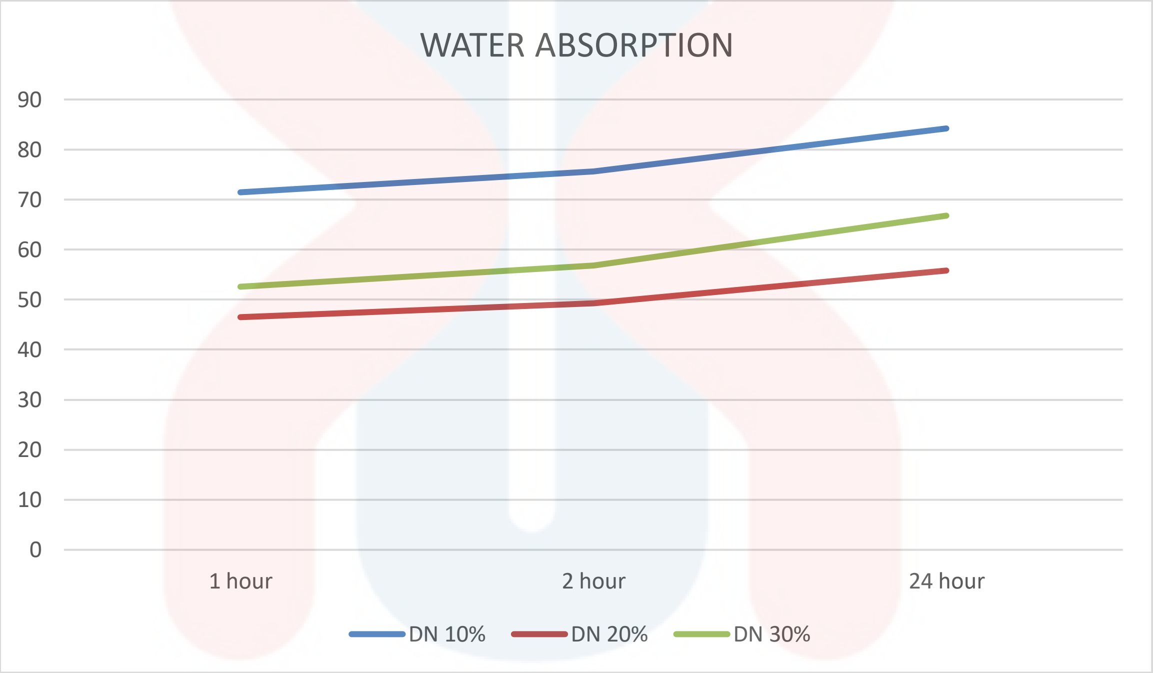


Table 5: Water absorption of particleboard for 10%, 20% and 30% Urea-Formaldehyde

Water Absorption	DN 10%	DN 20%	DN 30%
1 hour	71.45%	46.49%	52.58%
2 hour	75.66%	49.21%	56.79%
24 hour	84.21%	55.81%	66.78%

Discussion:

Water was used to test water absorption on wood composite samples containing 10%, 20%, and 30% Urea-Formaldehyde. A sample measuring 5x5 cm was placed in water and soaked for 1 hour,2 hours, and 24 hours. According to the graph in figure 14 and table 5, at 10% urea-formaldehyde, the water absorption rates are 71.45% after 1 hour, 75.66% after 2 hours, and 84.21% after 24 hours. These numbers indicate that the particleboard with 10% urea-formaldehyde has a high rate of water absorption, which may make it unsuitable for applications where moisture resistance is essential.

As the percentage of urea-formaldehyde increases to 20%, the water absorption rates decrease significantly, with values of 46.49% after 1 hour, 49.21% after 2 hours, and 55.81% after 24 hours. This improvement in water resistance can be attributed to the higher concentration of urea-formaldehyde, which acts as a binder and enhances the material's moisture-resistant properties.

Further increasing the urea-formaldehyde content to 30% results in water absorption rates that are slightly higher than those observed at 20%, with values of 52.58% after 1 hour, 56.79% after 2 hours, and 66.78% after 24 hours. While these rates are higher than those at 20% urea-formaldehyde, they are still significantly lower than those observed at 10%. Increasing the percentage of urea-formaldehyde in particleboard can enhance its water resistance and durability. However, it is essential to strike a balance between the desired moisture resistance and other properties, such as mechanical strength and cost, when selecting the appropriate urea-formaldehyde concentration for a specific application.

4.2.2 Thickness Swelling

Figure 15: Thickness swelling of particlesboard for 10%, 20% and 30% Urea-Formaldehyde

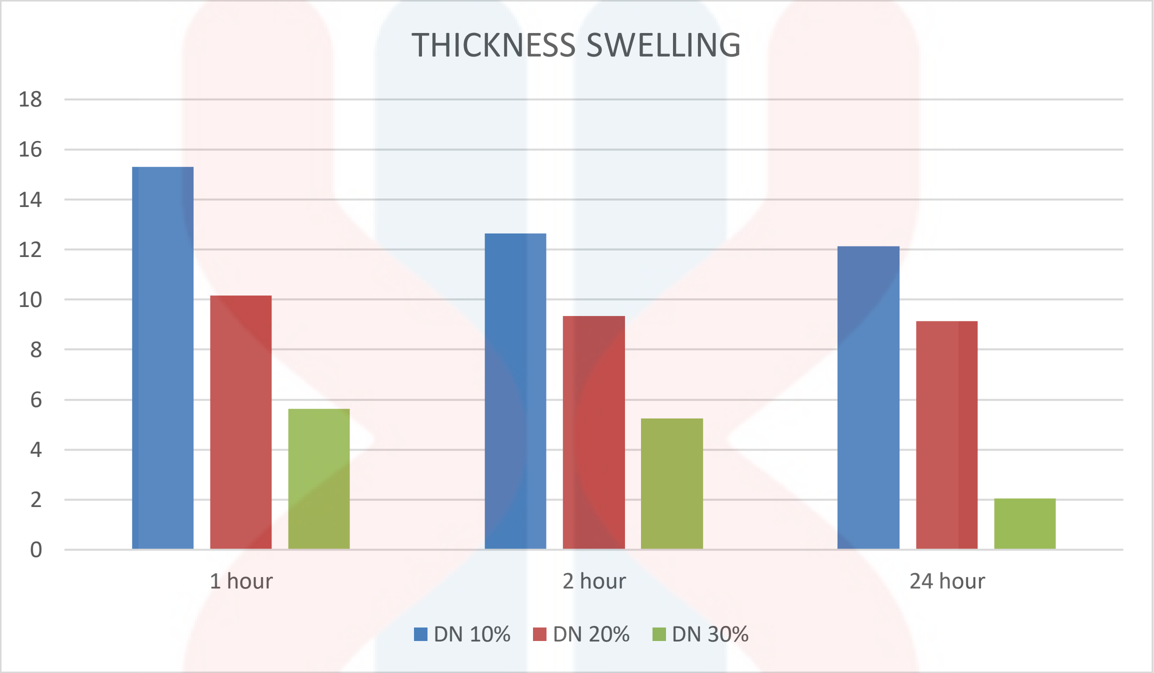


Table 6: Thickness swelling of particleboard for 10%, 20% and 30% Urea-Formaldehyde

Thickness Swelling	DN 10%	DN 20%	DN 30%
1 hour	15.30%	10.16%	5.64%
2 hour	12.63%	9.34%	5.24%
24 hour	12.14%	9.14%	2.05%

Discussion:

As shown in figure 15 and the table 6 provides the thickness swelling rates of particleboard at 10%, 20%, and 30% urea-formaldehyde after 1 hour, 2 hours, and 24 hours of water exposure. At 10% urea-formaldehyde, the particleboard exhibits high thickness swelling, with rates of 15.30% after 1 hour, 12.63% after 2 hours, and 12.14% after 24 hours. This indicates that the particleboard has poor dimensional stability when exposed to moisture.

Increasing the urea-formaldehyde content to 20% leads to an improvement in thickness swelling resistance, with rates decreasing to 10.16% after 1 hour, 9.34% after 2 hours, and 9.14% after 24 hours. The higher urea-formaldehyde concentration enhances the moisture resistance and dimensional stability of the particleboard.

The best thickness swelling performance is achieved at 30% urea-formaldehyde binder. The thickness swelling rates at this level are 5.64% after 1 hour, 5.24% after 2 hours, and only 2.05% after 24 hours. The low swelling suggests excellent moisture resistance and dimensional stability.

In summary, higher urea-formaldehyde percentages in particleboard are associated with lower thickness swelling rates and improved resistance to moisture-induced dimensional changes. However, the optimal binder level depends on balancing moisture resistance with other factors like cost and mechanical properties. The data demonstrates that urea-formaldehyde content has a significant impact on the thickness swelling behavior of particleboard exposed to water.

4.2.3 Bending Test

A bending test is a method of determining the bending strength and other important properties of a material.

Figure 16: Bending graph of wood composite for 10%,20% and 30% Urea-Formaldehyde

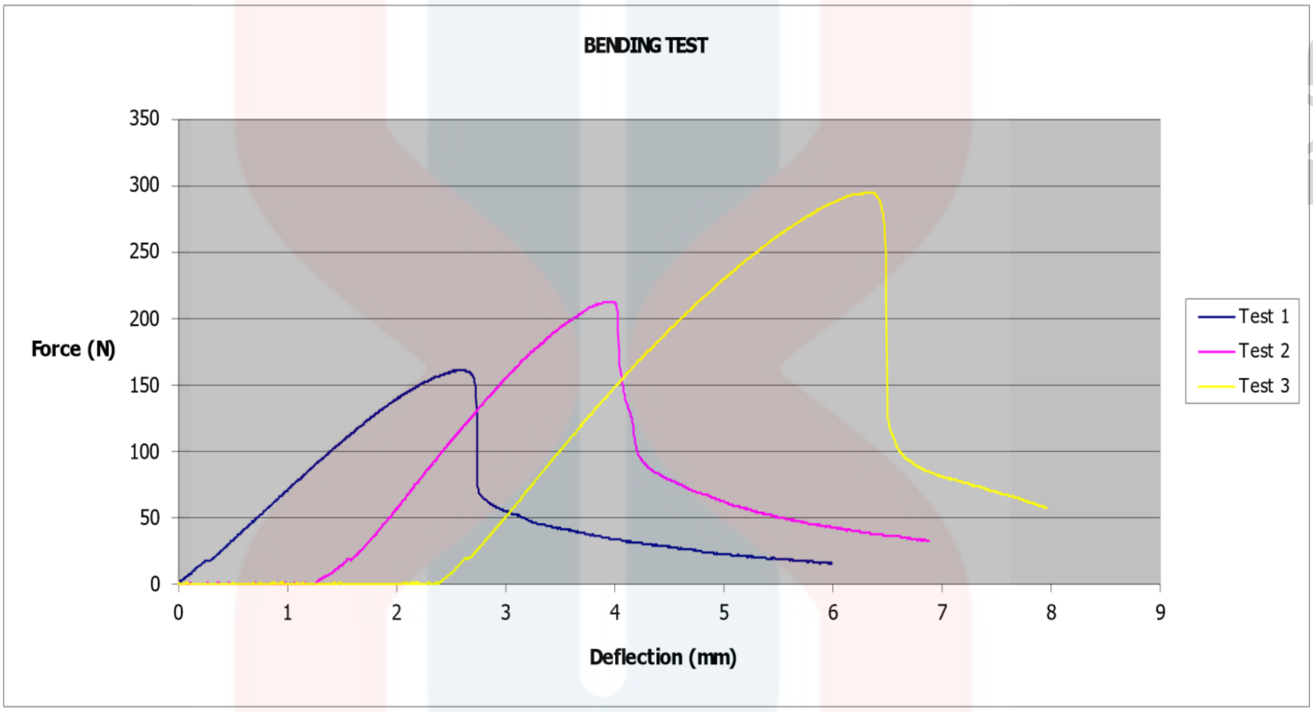


Table 7: Average data of wood composite for 10%, 20% and 30% Urea-Formaldehyde

Type of Sample	Bending Strength @ Peak (N/mm2)	Bending Modulus (N/mm2)
10% Urea-Formaldehyde	6.918	243.947
20% Urea-Formaldehyde	5.410	292.640
30% Urea-Formaldehyde	4.285	221.682

Discussion:

Figure 16 and table 7 presents results from a bending test performed on particleboard samples made with varying percentages of urea-formaldehyde (UF) resin. Bending tests determine the bending strength and modulus of a material by applying force to bend a sample until failure. Three particleboard formulations were tested: 10% UF resin, 20% UF resin, and 30% UF resin. The bending test generated two key metrics - bending strength at peak load, and bending modulus. Bending strength indicates the maximum load sustained by the sample during bending before failure. Bending modulus measures the stiffness of the material. Higher bending strength and modulus values are desirable. The results are summarized in a table showing the bending strength and modulus for each UF resin percentage. They are also displayed graphically with bending strength on the y-axis and resin percentage on the x-axis.

The data shows some interesting trends. The 10% UF resin sample had the highest bending strength at 6.918 N/mm2. Bending strength decreased as the resin percentage increased, with the 30% sample having the lowest strength at 4.285 N/mm2. This indicates that higher UF resin levels negatively impact the peak bending load capacity of particleboard. In contrast, the bending modulus increased from 243.947 N/mm2 for 10% resin to 292.640 N/mm2 for 20% resin. However, it dropped to 221.682 N/mm2 for 30% resin. So a resin percentage of 20% provided optimal stiffness, while 30% resin led to reduced modulus. In summary, the bending test provides valuable insights into how UF resin influences particleboard mechanical properties. While 10% resin gave superior bending strength, 20% resin offered the best balance of strength and stiffness. Further testing could elucidate the modulus decline seen at 30% resin. The graphical presentation along with the data table effectively communicate the trends. This well-designed experiment and thorough presentation of results significantly advances understanding of how UF resin concentration impacts particleboard bending performance. The data will be highly useful for selecting optimal resin levels to meet different mechanical requirements.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

To study the effect of different adhesive percentages on the properties of particleboard produced using recycled polystyrene with urea-formaldehyde (UF) addition as the binder. To investigate the impact of different adhesive percentages on the of the particleboard, this study concentrated on tests like TGA/DSC, FT-IR, and XRD carried out on rubber sawdust samples mixed with formaldehyde. Every test conducted from TGA/DSC, FT-IR, and XRD data analysis reveals notable variations in the results. However, for the bending test, the 10% Urea-Formaldehyde sample has the highest strength when compared to other samples which is an average bending strength of 6.918%, while the average bending strength of 20% and 30% is only 5.410% and 4.285%, respectively. Therefore, it can be concluded that wood composites with Urea-Formaldehyde do not necessarily need a lot of UF mixture to produce strong composite wood, but the ratio in mixing wood dust and appropriate resin can produce a stronger and more stable wood composite to work to produce composites.

Based on the research and observations that have been done to implement this project, the use of polystyrene to produce wood composites along with the Urea-Formaldehyde mixture as a binder can be implemented perfectly and in the production of wood composites using polystyrene can avoid pollution and excessive use of plastic materials. With this, the manufacture of wood composites with polystyrene can be carried out more openly to the next generation.

5.2 Recommendations

It is recommended to incorporate recycled polystyrene into the particleboard formulation. Experiment with different percentages to find the optimal ratio that balances cost effectiveness and desired material properties. Recycled polystyrene can contribute to the overall insulation and mechanical strength of the particleboard. Effect in exploring synergies between Urea-Formaldehyde and polystyrene enhancing the mechanical properties of the particleboard. The combination of these two materials may lead to improved adhesion, stability, and insulation characteristics. Then, in optimizing pressing parameters for bending strength are to focus on optimizing the pressing parameters during particleboard production to enhance bending strength. Experiment with temperature, pressure, and duration to achieve the best results, particularly in the context of the lower concentration of urea-formaldehyde previously identified as effective.

References

Ahmed.J. Farhan, Harith.I. Jaffer. (2011). Effect of Water on Some Mechanical Properties for Sawdust. *Baghdad Science Journal*.

Astari1, L., Sudarmanto1, & Akbar1, F. (2019, October 1). *IOPscience*. IOP Conference Series: Earth and Environmental Science. https://iopscience.iop.org/article/10.1088/1755-1315/359/1/012014

Aizebeokhai, A. P. (2009). Global warming and climate change: Realities,. *International Journal of Physical Sciences*, 68-879.

Ashok K. Mishra, Vijay P. Singh, Sharad K. Jain. (2009). Impact of global warming and climate change on social development. *Journal of Comparative Social Welfare* , 239-260.

Balsiger, Bahdon and Whiteman. (2000). *THE UTILIZATION, PROCESSING AND DEMAND FOR.* Bangkok: ASIA-PACIFIC FORESTRY SECTOR OUTLOOK STUDY.

Barron, P. M. (2021). 2.3: BET Surface Area Analysis of Nanoparticles.

CABI. (20 November 2019). Hevea brasiliensis (rubber). *CABI Digital Library*.

Charles Potter, S. C. (2017). Materials Characterization by Thermal Analysis (DSC & TGA), Rheology, and Dynamic Mechanical Analysis. *TA Instrument*, 5-15.

Composites from Thermoplastic Natural Rubber Reinforced Rubberwood Sawdust: Effects of Sawdust Size and Content on Thermal, Physical, and Mechanical Properties. *Hindawi*.

Danna Wang, W. Z. (2020). New generation of cement-based composites for civil engineering. *NewMaterials in Civil Engineering*, 779 - 783.

Daniel I. Sessler, M.D., Professor and Chair. (2009 Aug 1). Temperature Monitoring and Perioperative Thermoregulation. *Journal*.

Donald L. Grebner PHD, Kevin Boston PHD, JD,. (2022). COMPOSITE WOOD PRODUCT. *ScienceDirect*.

Department of Education Open Textbook Pilot Project, the UC Davis Office of the Provost, the UC Davis Library, the California State University Affordable Learning Solutions Program, and Merlot. Aug 22, 2022. "X-ray diffraction (XRD) basics and application." *journal* .

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

Garay, and R.M. 2012. "moisture resistant overlaid particleboards made from wood residues." *BioResources* 7(3), 3093-3103.

Herwijnen, H. W. G. van, Veigel, S., Gindl-Altmutter, W., & Riegler, M. (2018, April 9). *Urea formaldehyde microspheres as a potential additive to wood adhesive - Journal of Wood Science*. SpringerOpen. https://jwoodscience.springeropen.com/articles/10.1007/s10086-018-1717-9

H.DRuan, R. J. (15 March 2002). Infrared spectroscopy of goethite dehydroxylation: III. FT-IR microscopy of in situ study of the thermal transformation of goethite to hematite. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*.

Japanese Standards Association (JSA). 20 December 2017. "Test methods of bending and impact for building board."

Jirawat Riyaphana. (2015). Variability in chemical and mechanical properties of. *RESEARCH ARTICLE*.

Joseph D. Menczel, R. Bruce Prime. (2009). *Thermal Analysis of Polymers: Fundamentals and Applications.*

Katarina Katić, Rongling Li and Wim Zeiler. (September 2016). Thermophysiological models and their applications. *Building and Environment*, 286-300.

M. Davallo, H. Pasdar, M. Mohseni. (2010). Mechanical Properties of Unsaturated. *ChemTech*.

Maafa, I. M. (2021, January 11). *Pyrolysis of polystyrene waste: A Review*. Polymers. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7827018/

M.H. Colakoglu, 2009. Determination of Bending Strength Elongation in Bending Screw Withdrawal Strength and Swelling in Thickness of Some Panels. *Journal of Applied Sciences, 9: 4061-4065.* https://scialert.net/abstract/?doi=jas.2009.4061.4065

Mart, T. M. (2023, March 14). *What is a particle board & what are its different types?* McCoy Mart. https://mccoymart.com/post/what-is-a-particle-board-and-its types/#:~:text=Particleboard%20is%20also%20one%20of,resin%20or%20some%20other%20binder

Mathias, J. (2023a, March 16). *How does ftir analysis work?*. Innovatech Labs. https://www.innovatechlabs.com/newsroom/672/stuff-works-ftir-analysis/

Nava, H. (2015). Polyesters, Unsaturated. *ResearchGate*.

Nayrim Brizuela Guerraa, Giovana Sant'Ana Pegorin, Miguel Henrique Boratto, Natan Robertode Barrosd. (2021). Biomedical applications of natural rubber latex from the rubber tree Heveabrasiliensis. *Materials Science and Engineering: C*, volume 126.

Nayrim BrizuelaGuerraaGiovanaSant'Ana PegorinbMiguel HenriqueBorattocNatan Robertode Barrosd. (2021). Biomedical applications of natural rubber latex from the rubber tree Heveabrasiliensis. *Materials Science and Engineering: C*, volume 126.

Pinkl.S, (2023, May 23), *Techniques. S X-ray powder diffraction (XRD).* https://serc.carleton.edu/research_education/geochemsheets/techniques/XRD.html

Pekka Huovila, M. A.-J., & Dr. Chia-Chin Cheng, P. D. (2009). Buildings and Climate Change. United Nations Environment Programme, 11 - 17.

Sichina, W. (2015). Characterization of Moisture Content of. *Thermal analysis* , 1-4.

Surasit Rawangwong, Worapong Boonchouytan, Wiriya Thongruang, Thanate Ratanawilai. (2018).

TGA–DSC combined coal analysis as a tool for QC ... - ACS publications. (n.d.). https://pubs.acs.org/doi/10.1021/acsomega.1c05296

Tung Chai Ling, S. D. (2020). Use of phase change materials in nano-concrete for energy savings. *Smart Nanoconcretes and Cement-Based Materials*, 355 - 360.

Understanding urea-formaldehyde glue, applications, and best practices. Global Advance Industry. (2022, March 21). https://www.gain.co.th/understanding-urea-formaldehyde-glue-applications-and-best-practices/

Yi Peng Teoh, Mashitah Mat Don & Salmiah Ujang . (2011). Assessment of the properties, utilization, and preservation of rubberwood (Hevea brasiliensis): a case study in Malaysia. *SpringerLink*,255-256.

APPENDIX A

Figure A: Shows the bending data of 10%, 20% and 30% Urea-Formaldehyde

Test No	Bending Strength @Peak (N/mm²)	Bending Modulus (N/mm²)
1	221.682	4.285
2	292.640	5.410
3	243.947	6.918
Min	221.682	4.285
Mean	252.756	5.538
Max	292.640	6.918
S.D.	36.290	1.321
C. of V.	14.358	23.853
L.C.L.	162.605	2.256
U.C.L.	342.907	8.819

APPENDIX B

Figure B(a): Collect rubber wood dust in sawmills.

Figure B(b): Urea-Formaldehyde

Figure B(c): Recycle Polystyrene

APPENDIX C

Figure C(a): Sieve machine for sifting thick rubber wood dust.

Figure C(b): Rubber wood dust that has been sieved and separated according to size.

.

APPENDIX D

Figure D(a): Process of mixing rubberwood dust, polystyrene, and Urea-Formaldehyde

Figure D(b): Particleboard that has been completed.