The Properties of Acacia Impregnated with Wood Vinegar Preservative and Silica Extracted Rice Husk Ash

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J20A0445

A reported submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Forest Resources Technology) With Honours

Faculty of Bioengineering and Technology

University of Malaysia Kelantan

2024

DECLARATION

I declare that this thesis entitled “The Properties of Acacia Impregnated with Wood Vinegar Preservative and Silica Extracted Rice Husk Ash” is the results of my own research except as cited in the references.

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Date : ____________________________

ACKNOWLEDGEMENT

It is a great pleasure to address people who helped me throughout this project to enhance my knowledge and practical skills especially in the research area. First and foremost, I express my deepest gratitude to CHM.TS. DR Nadiah bte Ameram my project supervisor, for their unwavering guidance, invaluable insights, and continuous support throughout the entirety of this research endeavor. Their mentorship has been a beacon, illuminating the path to academic and professional growth. Their commitment to excellence and dedication to fostering a conducive learning environment have been instrumental in shaping the trajectory of this project. Also, for their expert advice, constructive critiques, and the generosity with which they shared their wealth of knowledge. Their inputs have been instrumental in refining the conceptual framework and methodology, elevating the quality of this research.

My appreciation further extends to the Universiti Malaysia Kelantan for providing the necessary resources, research facilities, and a stimulating academic environment that has been crucial to the success of this project. The support from the Universiti Malaysia Kelantan has been a cornerstone in facilitating a conducive atmosphere for intellectual exploration and scholarly pursuits.

Heartfelt thanks are also due to my fellow undergraduate students who have been steadfast companions on this academic journey. Their camaraderie, shared insights, and collaborative spirit have added depth and richness to the collective learning experience. The exchange of ideas and the collective pursuit of knowledge have been a source of inspiration and motivation.

In closing, I extend my deepest appreciation to my beloved family and friends Vallery J.L, Heilen Ansayal, Jermaine Allen and Siti Sakinah for their unwavering support, encouragement, and understanding throughout this academic pursuit. Their patience, encouragement, and belief in my abilities have been a constant source of strength, propelling me forward even in the face of challenges.

Finally, as this project draws to a close, I reflect on the collective efforts and collaborative spirit that have made this endeavor a reality. This acknowledgment is a testament to the collaborative ethos that underlies the academic community, where shared knowledge and support foster an environment of growth and exploration.

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LIST OF ABBREVIATIONS

°C	Celcius
MOR	Modulus of Rupture
MOE	Modulus of Elasticity
TM	Thermal Modification
MC	Moisture Content
D	Density
M	Mass
V	Volume
WA	Water Absorption

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ABSTRACT

This thesis investigates the enhancement of Acacia wood properties through impregnation with wood preservative derived from wood vinegar and silica extracted from rice husk ash. Wood preservation is crucial to prolonging the lifespan of timber products and mitigating environmental impacts associated with deforestation. The utilization of natural extracts as wood preservatives presents a sustainable alternative to conventional chemical treatments. The study explores the impregnation process of Acacia wood with a wood vinegar preservative, aiming to enhance its wood pyhsical properties and mechanical properties Additionally, the incorporation of silica extracted from rice husk ash into the preservative formulation is investigated to further improve the wood's mechanical and physical properties. Experimental methodologies involve the preparation of wood vinegar preservative, extraction of silica from rice husk ash, impregnation of Acacia wood samples, and characterization of treated wood properties. Various analytical techniques such as mechanical testing are employed to evaluate the performance of the treated wood.

Keywords: Acacia wood, wood vinegar, silica extracted from rice husk ash.

Sifat-sifat Akasia yang Diimpregnasikan dengan Pengawet Cuka Kayu dan Silika yang Diekstrak dari Sekam Padi

ABSTRAK

Tesis ini menyiasat berkaitan peningkatan sifat kayu Akasia melalui impregnasi dengan pengawet kayu baru yang berasal daripada cuka kayu dan silika yang diekstrak daripada abu sekam padi. Pemeliharaan kayu adalah penting untuk memanjangkan jangka hayat produk kayu dan mengurangkan kesan alam sekitar yang berkaitan dengan penebangan hutan. Penggunaan ekstrak semula jadi sebagai pengawet kayu memberikan alternatif yang mampan kepada rawatan kimia konvensional. Kajian ini meneroka proses impregnasi kayu Akasia dengan pengawet cuka kayu, bertujuan untuk meningkatkan sifat fizikal dan sifat mekanikal kayu. Selain itu, penggabungan silika yang diekstrak daripada abu sekam padi ke dalam rumusan pengawet dijalankan untuk meningkatkan lagi sifat mekanikal dan fizikal kayu. Kaedah eksperimen melibatkan penyediaan pengawet cuka kayu, pengekstrakan silika daripada abu sekam padi, impregnasi sampel kayu Akasia, dan pencirian sifat kayu yang dirawat. Pelbagai teknik analisis seperti ujian mekanikal digunakan untuk menilai prestasi kayu yang dirawat.

Kata kunci: Kayu akasia, cuka kayu, silika yang diekstrak daripada abu sekam padi.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Wood maintains a distinctive place among materials for construction used by people due to an incredible number of appealing qualities, such as low thermal extension, low density, and suitable mechanical strength. To ensure long-term durability in these wood products further protection, typically in the form of chemical treatment, has become necessary due to an increase in global demand for timber and increase in preference towards quickly growing plantation species. The use of chemicals to enhance the physical, mechanical, and biological properties of woody materials has increased significantly in recent years. (Redzuan et al., 2019)

A tree called Acacia mangium grows quickly and can grow as tall as 30 metres (98 feet). This species is highly valued for its industry and sustainable uses. It is constantly grown for its timber, which is valued for being durable, and decay resistant. There are processes of impregnated wood to consistent the quality of the wood specifically on Acacia wood which is wood vinegar. Impregnated process refers to the treatment of wood with preservatives or protective compounds to increase its durability and resistance to decay, insect assault, and other types of deterioration. Other than that, silica is used as an impregnated preservative to test the durability of the wood from decay. One of the useful inorganic chemical substances with a variety of uses is silica. It can be found in amorphous, crystalline, and gel forms. It is the earth's crust's most adrift material. The production of pure silica needs a lot of energy. (Todkar et al., 2016)

Besides, silica is a substance that can be used to impregnate wood. To improve the mechanical qualities of the wood structure and add additional protection, silica is used during the impregnation process. While it's crucial to keep in mind that such a combination may not be a frequently studied or commercially available product, combining silica with wood vinegar may result in a combination that has special qualities. The specific qualities of both silica and wood vinegar would determine the characteristics of the mixture. Wood vinegar, which is often dark or reddish yellow in color, is produced when material combustion is condensed by the pyrolysis process. Typically, biomass containing cellulose, hemicellulose, and lignin components is used as the raw material for manufacturing wood vinegar. (Desvita et al., 2022)

Moreover, to improve the dimensional stability and durability properties of the wood thermal modification is a secure, effective, and cost-effective treatment procedure that increases the wood's biological resistance and dimensional stability without the use of harmful chemicals. Wood is heated to high temperatures in controlled conditions as part of a process termed thermal modification. (Chowdhury et al., 2005)

This study investigates the properties of acacia impregnated with wood vinegar and silica extracted rice husk. The resilience of acacia wood impregnated with wood vinegar and silica against decay is the focus, as opposed to thermal modification. To achieve this, the wood was subjected to several temperatures and durations of wood vinegar and silica treatment.

Problem Statement

Identifying the characteristics and potential uses of acacia wood impregnated with wood vinegar and silica derived from rice husk ash is an imminent task. With this mixture, the qualities and functionality of acacia wood are intended to be improved for a variety of uses. The specific issue is figuring out how this impregnation technique affects the properties of the acacia wood and comparing its potential benefits and drawbacks to untreated acacia wood or other substitute materials. Limited research has been conducted on the wood impregnated with wood vinegar and silica extracted rice husk ash. The result of this study will provide new insight into the potential uses of acacia wood impregnated with wood vinegar and silica extracted from rice husk ash. In addition, this experiment was also tested to see if wood vinegar and silica extracted from rice husk ash can dissolve into a preservative.

1.2 Objectives

The objective of this research:

1. To study wood vinegar and silica extracted rice husk are suitable as preservatives.
2. To study the optimal thermal temperature of treated acacia with wood vinegar and silica extracted rice husk ash.

1.3 Scope of Study

This study was conducted to investigate the properties of Acacia impregnated with wood vinegar and silica extracted from rice husk ash. The result of different temperatures and durations on the physical and mechanical properties of acacia wood impregnated with wood vinegar and silica extracted from rice husk ash were investigated. The durable, and decay resistant of acacia wood were measured and compared to the untreated.

1.4 Significant of Study

This research indicates that wood vinegar and silica extracted from rice husk ash is a preservative that is environmentally friendly and helps the acacia wood from decay and untreated. The impregnation method was chosen to test the wood's resistance to decay by using wood vinegar and silica extracted from rice husk ash. For treating wood that will be exposed to optimum temperatures or that needs to be durable over the long term, impregnation is an efficient technique. However, more research is needed to determine the optimum temperature that can enhance the characteristic of wood vinegar and silica.

CHAPTER 2

LITERATURE REVIEW

2.1 Acacia Wood (Acacia Mangium)

Figure 2.1: The physical appearance of acacia wood

(Source: Acacia Wood Database, 2022)

Acacia Mangium is one of the most popular fast-growing tree species implemented in plantation forestry strategies throughout Asia and the Pacific. Its beneficial characteristics include quick growth, high-quality wood, and tolerance to a variety of soils and conditions. The average *Acacia mangium* tree is huge and can reach a height of 30 metres. Its straight bole can reach a height of as much as fifty percent of the tree's overall height. Those with a diameter at breast height (DBH) more than 60 cm is uncommon. (Krisnawati et al., n.d.)

2.2 Wood Vinegar

(Termiticidal Activity of Wood Vinegar, Its Components and Their Homologues, n.d.) (Termiticidal Activity of Wood Vinegar, Its Components and Their Homologues, n.d.) A condensed liquid called raw wood vinegar is produced when wood is pyrolyzed or carbonised at temperatures between 400 and 500 °C without the presence of air. The principal chemical component of the wood vinegar, acetic acid, is among its many chemical components. All the time, wood vinegar is made and consumed, mostly for agricultural purposes. In this research, wood vinegar will be put to the test as a wood preservative. To build new applications beyond agriculture, it is crucial to figure out the properties of wood vinegar. (Termiticidal Activity of Wood Vinegar, Its Components and Their Homologues, n.d.). Besides, Pyrolysis is a process that produces three-phase products including solids, liquids, and gases from the thermal decomposition of biomass that takes place in the absence of oxygen and is a viable method for converting biomass to commercial goods including biogas, charcoal, and wood vinegar. However, due to variances in yield and complex constituents of wood vinegar produced by various raw materials or pyrolysis conditions, application research for pyrolysis liquid, particularly the wood vinegars, was uncommon. The primary elements of wood vinegar are organic acids, phenols, and ketones. These complex organic components and compounds are produced during the condensation of the volatiles in flue gas. (Hou et al., 2018)

2.3 Silica

One of the useful inorganic chemical substances with a variety of uses is silica. It can be found in amorphous, crystalline, and gel forms. It is the part of the earth's crust that is most unmodified. However, it requires a lot of energy to produce pure silica. Among all plant-based resources, rice husk has the highest silicon dioxide content, making it a promising plentiful bio-resource for the development of high value-added silica products. (Chun et al., 2020) The extraction of silica from rice husk ash by using a simple chemical procedure is suggested. Among the family of other agro-wastes, rice husk ash is one of the most silica-rich raw materials, containing between 90 and 98 percent silica after complete combustion. (Todkar et al., 2016)

2.4 Others Wood Preservative

Type of wood preservative	Based	Method of Applying	Preservatives Against
Borates	Liquid	Spray	Defends wood against termite attack
Copper Azole	Liquid	Spray	Prevents fungal decay and insect attack
Copper Napthenate	Liquid	Brush, Dip, Spray, and pressure treat wood	Against fungal rot, decay, termites and woodboring insects.

Table 2.1: Table Shows different types of preservatives.

(United State Environmental Protection Agency, 2023)

2.5 Impregnation Process

In the context of wood preservation, the impregnation process refers to the treatment of wood with preservatives or protective compounds to increase its durability and resistance to decay, insect assault, and other types of deterioration. Preservatives are deeply absorbed into the structure of the wood during the impregnation process so that they provide long-lasting protection. In this study, acacia wood impregnated in the wood vinegar with silica extracted rice husk ash to allow the wood to absorb the preservative fully. For treating wood that will be placed under optimal thermal temperature that needs long-term durability, impregnation is an efficient technique. It may improve a wood product's resistance to insects and decay while also extending its useful life and maintaining the structural integrity of the product over time. (Humar et al., 2019)

2.6 Thermal Modification

Wood is heated to high temperatures without any oxygen present as part of a process known as thermal modification, sometimes known as heat treatment or thermal modification. With this heat treatment, the wood's chemical and physical characteristics are changed, enhancing its stability, toughness, and resistance to decay. The structure of the wood is changed by thermal modification, which reduces its vulnerability to fungus and insects that cause degradation. The wood's durability and resistance to rot are improved by the enhanced stability and lower moisture content, which make it less conducive for these organisms to thrive. (Hill et al., 2021)

2.7 Moisture Content

A hygroscopic substance is wood. As a result, the current environmental circumstances determine the wood's moisture content. The quantity of water present in the structure of wood is referred to as the wood's moisture content, and it is stated as a percentage of the weight of the wood. It is a crucial aspect to consider in a variety of wood-using sectors and applications, including building, woodworking, and furniture production. Due to its impact on dimensional stability, strength, and durability, wood's moisture content is important. In reaction to changes in the environment, wood continuously gains and loses moisture. Wood usually has a high moisture content when it is first cut, which gradually goes down as it dries. (Wood Moisture - an Overview | ScienceDirect Topics, n.d.)

2.8 Density

The density of temperate woods ranges from around 0.3 to 0.9 grams per cubic centimeter, while it ranges from roughly 0.2 to 1.2 grams per cubic centimeter globally. The differences between species or samples of the same species are caused by different ratios of the wood substance, void volume, and extractive content. The density of wood is around 1.5 grams per cubic centimeter, and there are hardly any changes in this value between species. (Absorbed Water - an Overview | ScienceDirect Topics, n.d.)

2.9 Bending Test

Small transparent specimens were subjected to static bending tests at three treatment and five moisture levels. The thermal alteration decreased bending strength at typical (dry) climate conditions while generally increasing stiffness. Additionally, in both untreated and thermally processed wood, both characteristics declined as the moisture level rose. However, the moisture dependence of its bending capabilities was much reduced since thermally treated wood has a lower moisture sensitivity. Therefore, compared to untreated solid wood, thermally modified wood may be predicted to have stiffness and strength values that are similar to or even superior in wet conditions. (Bending Tests - an Overview | ScienceDirect Topics, n.d.)

CHAPTER 3

MATERIALS AND METHODS

3.1 Raw Materials

3.1.1 Acacia Wood

In this study, acacia wood (Acacia Mangium) was purchased from a local online seller. This wood is used to test the wood vinegar and silica extracted rice husk ash as preservatives and include the thermal modification treatment process. The wood was subsequently cut using a circular saw into the following dimensions: 300 mm in length, 200 mm in width, and 30 mm in thickness and air-dried for two weeks. The wood was then oven-dried at a temperature of 80℃ to a moisture content of 12%.

Figure 3.1: The physical appearance of acacia wood used.

3.1.2 Wood Vinegar

Wood vinegar was chosen as a preservative. The wood vinegar was purchased from a local shop located at Tanah Merah Jeli, Kelantan. The condensation of smoke created during the creation of biochar results in the formation of wood vinegar. Acetic acid, butyric acid, catechol, and phenol are its primary constituents. To immerse the samples, about 800ml of wood vinegar was used.

3.1.3 Silica extracted Rice Husk Ash

Rice husk ash frequently contains a substance called silica. By combusting at a high temperature and then solubilizing with a solvent to remove the non-silicon ingredient, rice husk ash can be converted to silica. About 90–95 percent of rice husk contains silica, sometimes referred to as RHA, or rice husk ash. To preserve wood, silica will be used.

3.2 Methodology

3.2.1 Impregnation Process

The impregnation technique, as used in the preservation of wood, is the process of treating wood with compounds that increase its durability and enhance the physical and mechanical properties. During the impregnation process, preservatives are thoroughly incorporated into the structure of the wood to offer long-lasting protection. Acacia wood was immersed in wood vinegar and silica extracted rice husk ash to enable the wood to thoroughly absorb the preservative. During the impregnation process, the wood will immerse in three different durations, which are 6 hours, 24 hours, and 48 hours. Before the impregnation process, the wood must be clean, and the condition of wood is completely dry.

3.2.2 Thermal Modification

The wood samples were labeled and divided into three parts. Wood samples were carried out with different temperatures during the thermal process. The temperature will be set at 120°C, 160 °C, and 180 °C for 120 minutes.

Label of wood	Soaked in Preservatives (hours)	Temperature of thermal modification	Time (minutes)
	Control		
A	6 hours	120 160 180	120
B	24 hours	120 160 180	120
C	48 hours	120 160 180	120

Table 3.1: Thermal Modification Timetable

3.2.3 Moisture Content Measurement

The wood was shaped into a sample with dimensions of 300 x 200 x 30 mm. Measurements were made of the sample's mass both before and after it was dried in an oven at a specific temperature. The equation below was used to determine the moisture content.

$$MC\ (\%) = \frac{W_1\ W_0}{} \times 100\%$$

$$W_0$$

Where MC is moisture content (%), $W_0$is after drying (g), and is $W1$ before drying (g).

3.2.4 Density Measurement

The wood was shaped into a sample with dimensions of 300 x 200 x 30 mm. Using a digital caliper, the sample's width, length, and thickness were measured before calculating its volume. Following that, the sample's mass was measured, and the density was calculated using the equation given below:

$$\rho = \frac{W_0}{V}$$

Where ρ is wood density (g/cm^3) of the sample, $W_0$is mass of the sample (g), and V is volume of the wood sample (m^3)

3.2.5 Bending Properties Measurement

A Universal Testing Machine (UTM) was used to assess the bending properties of thermally treated and control wood samples. The wood samples were 20 mm x 30 mm x 300 mm in size. A three-point bending test was performed using a 260 mm effective span and a 5 mm/min loading speed. Using the following formulae, the samples' modulus of rupture (MOR) and modulus of elasticity (MOE) were determined.

$$\text{MOR}=\frac{3PL}{2bd^2}$$

Where MOR is a durable bending (kgf/cm²), P is maximum load weight (kgf), L is distance of buffer (cm), and b is width (cm), thick (cm) of the sample.

$$\text{MOR}=\frac{\Delta PL^3}{4\Delta Ybd^3}$$

Where MOE is modulus of elasticity (kgf/cm²), P is load (kgf), L is distance of buffer, b is width (cm), d is thickness (cm) and ΔY is flexibility in load (cm) of the sample.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Effect of Temperature on The Properties of Acacia Impregnated with Wood Vinegar Preservative and Silica Extracted Rice Husk Ash

Twelve Acacia wood were obtained using wood vinegar preservative and silica extracted rice husk ash. The wood samples were tested using several methods, for instance, Moisture Content Measurement, Density Measurement, Water Absorption Measurement and Bending Properties Measurement. This sample of wood is tested using different temperatures and durations. This experiment is conducted to examine the mechanical and physical properties of acacia wood against the preservatives used under certain conditions. The advantages of wood or furniture that has been treated will enhance the quality of wood in furniture making and construction aspects.

4.1.1 Moisture Content

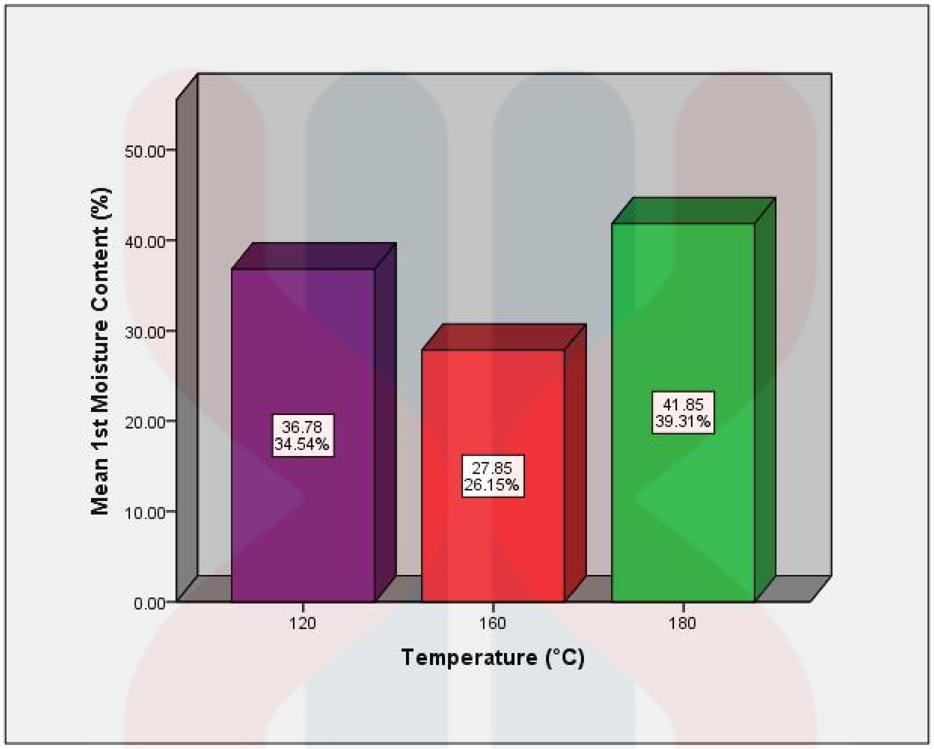

Figure 4.1: Effect of various temperature on moisture content

Figure 4.1 shows the different effects of temperature on wood moisture content. Wood samples were tested at several temperature levels, of 120, 160, and 180°C for the same duration of 120 minutes for each wood sample. As shown in figure, a wood sample that was treated at 160°C has the lowest percentage of moisture content compared to a wood sample that was treated at 180°C. This is also because of the selection of wood sections used in this experiment. The highest moisture content was the sample that treated at 180°C with 39.31% and the wood samples at temperatures of 120°C and 180°C also each have an average difference rate, at 36.78 for 120°C and 41.85 for 180°C. Based on figure 4.1, the graph depicts fluctuation in reading the result of moisture content. The moisture content of the wood during the heat modification process was demonstrated, illustrating its impact on enhancing dimensional stability. Generally, the moisture content decreased as the temperature increased. After the experiment was carried out, it became evident that the selection of wood sections for testing is crucial, as opting for non-specific wood sections can undermine the objectives of the study. Therefore, there was a huge difference between each sample treated at 120°C, 160°C, and 180°C with mean 36.78, 27.85 and 41.85.

4.1.2 Density

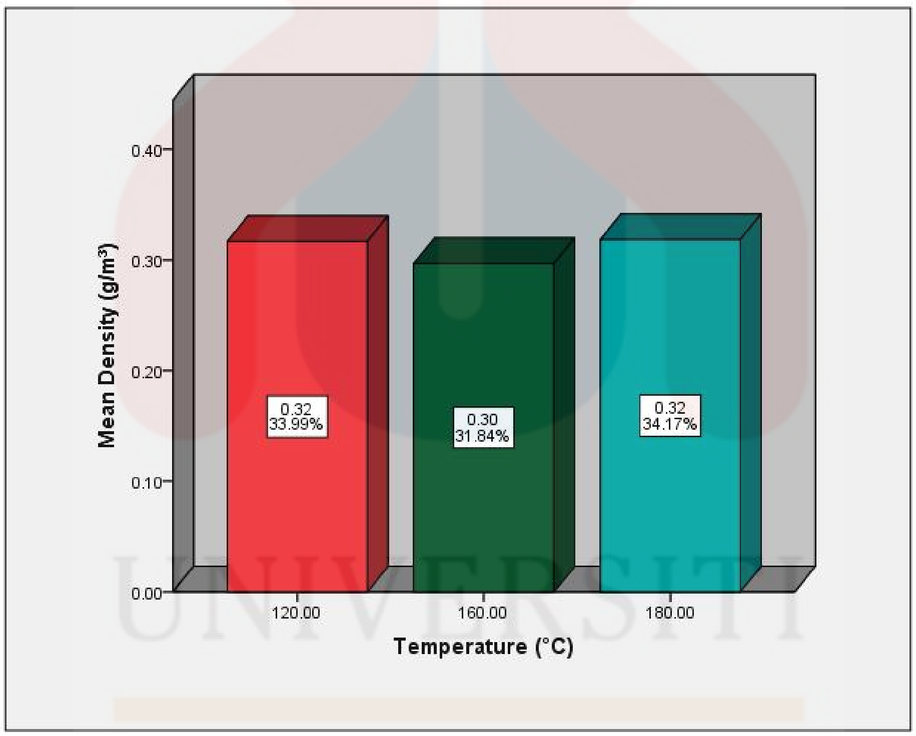

Figure 4.2: Effect of various temperature on density

Figure 4.2 shows the effect of different temperatures on density. The samples that were treated at 120°C and 180°C were approximately based on terms of density percentage results at 33.99% and 34.17% g/cm³ respectively. Meanwhile, the acacia wood that is treated at 160°C has the lowest impact density among the temperatures that have been tested. Due to the heat, degradation of cell wall components and mass loss during treatment, by adding preservatives somehow has affected and slowed down the cell wall degradation. Besides, Mass loss increases during the heat modification process, and it is caused by the emission of by-products. This is an outcome of the lignin's heat degradation, and the transfer of volatile chemicals will cause the density of the wood to drop. (Vasile, 2016). In general, higher density demonstrates the greatest strength of wood. However, temperatures at 120°C, 160°C and 180°C with mean of 0.30 and 0.32 g/cm³.This was ascribed to, the difference thickness of sample and selection part of wood that used and table shown displays each sample that was comparatively observed with slight changes to the level of sampling there was no striking effect between the sample that have carried out trials on even with different variability.

4.1.3 Bending Properties (MOR)

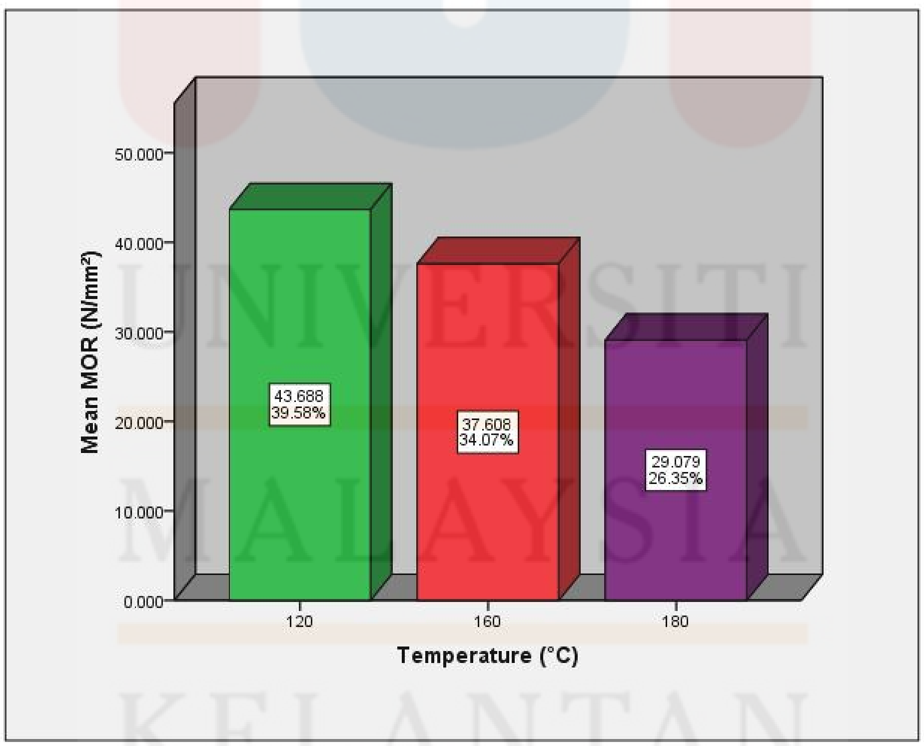

Figure 4.3: Effect of treatment temperature on MOR

Figure 4.3 shows correlations between three samples of acacia wood that were treated at different temperatures of 120°C, 160°C, and 180°C. The sample treated at 120 and 160 indicates the highest value compared to the 180 sample. As shown in the figure, the sample treated at 180 was the lowest with average at 29.079 N/mm². The graph showed that the MOR mean gradual dropped from 43.688 N/mm² at temperatures of 120°C to 37.608 N/mm² at 160°C and 29.079 N/mm² at 180°C. It was found that, wood samples that have been treated with preservatives like wood vinegar and silica extracted from rice husk ash helps increased the effectiveness of the treatment in enhancing the wood resistance to bending or flexural stresses. Based on the figure, a wood sample treated at 120°C was the highest mean among the other samples. Generally, the higher the temperature of the sample tested, the stronger the mechanical characteristics when treated with preservative. There was a significant difference between the sample from 120°C, 160°C and 180°C.

4.1.4 Bending Properties (MOE)

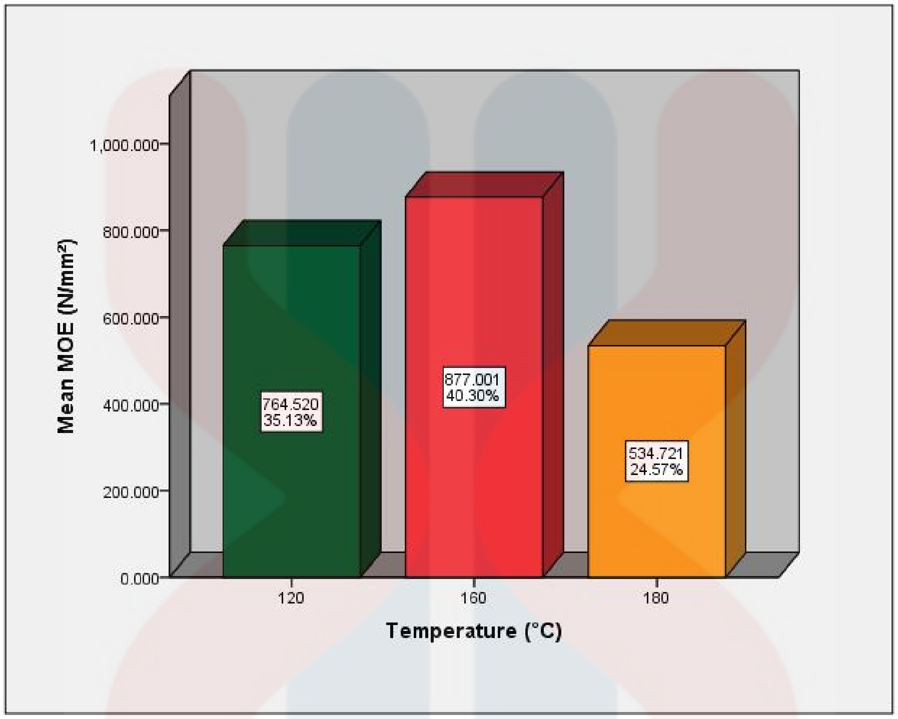

Figure 4.4: Effect of treatment temperature on MOE

Figure 4.4 shows the comparison on mean of MOE for samples that were treated at 120°C, 160°C and 180°C. The graph expressed that, the mean of MOE for sample that treated at 160°C was the highest with 40.30% of value mean MOE and the lowest was at 180°C with 24.57% of value mean. The trend of the graph shown above increased and then decreased drastically. Temperature has an impact on wood's moisture content as well, which influences MOE and other mechanical properties. High temperatures can accelerate the drying of wood, which could result in modifications to its stiffness. Besides, wood preservatives have the potential to reinforce wood fibres, increasing MOE.

4.2 Effect of duration on The Properties of Acacia Impregnated with Wood Vinegar Preservative and Silica Extracted Rice Husk Ash

4.2.1 Moisture Content

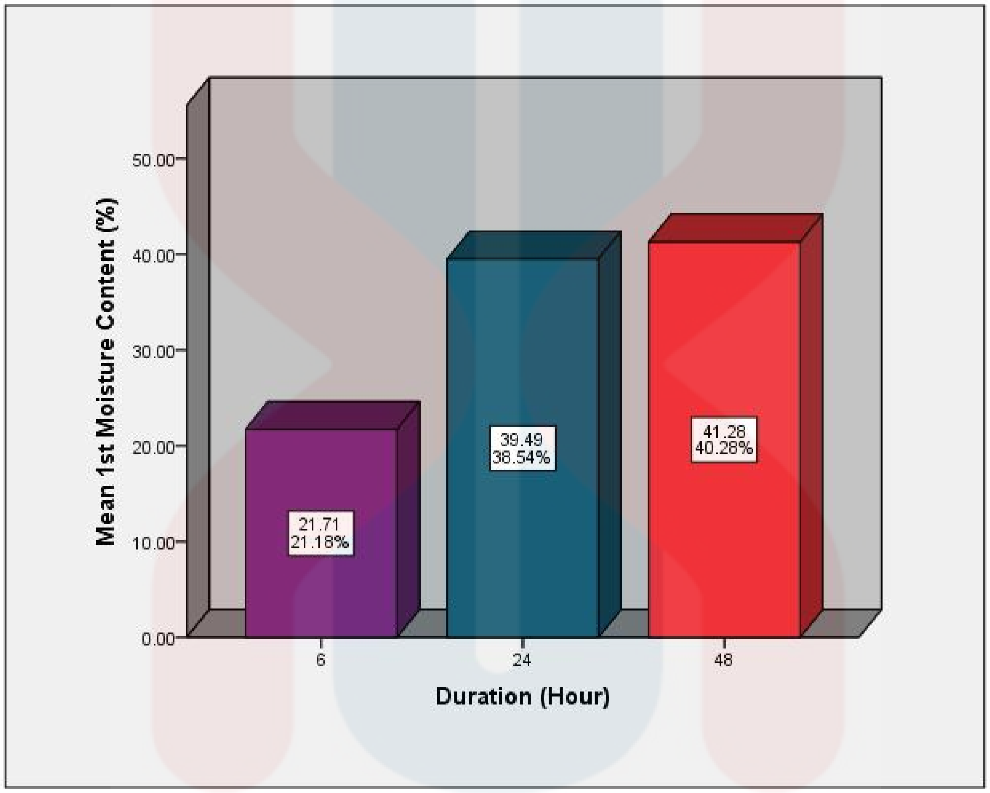

Figure 4.5: Effect of various duration on moisture content

Figure 4.6 shows the effect of duration on moisture content. Before the samples were treated on the same temperature at 120°C, the samples of acacia wood were immersed in wood vinegar and silica from rice husk ash preservative with different time duration at 6 hours, 24 hours, and 48 hours. The graph indicates that the mean of moisture content gradually increased. After 48 hours, the mean of moisture content reached the peak at 41.28 that equaled 40.28%. The difference in mean of moisture content at 24 hours and 48 hours were approximately, it increased only about mean at 1.77. The sample that was treated at 120°C had the lowest mean at 21.27 for 21.18%. From this observation, the moisture content of the wood may also be affected by the preservatives themselves. The abilities of the wood to absorb or release moisture may be impacted by some preservative's hygroscopic properties. The duration of the impregnation process could influence the moisture content of the wood by influencing how deeply the preservatives enter it. Based on previous research, it is advised that the moisture content of the wood be decreased before the preservation treatment since high moisture content wood is not suitable for being impregnated (Hermawan et al., 2020) However, there was a huge significant difference from the wood sample that was treated at 6 hours, 24 hours, and 48 hours with mean 21.71, 39.49 and 41.28.

4.2.2 Density

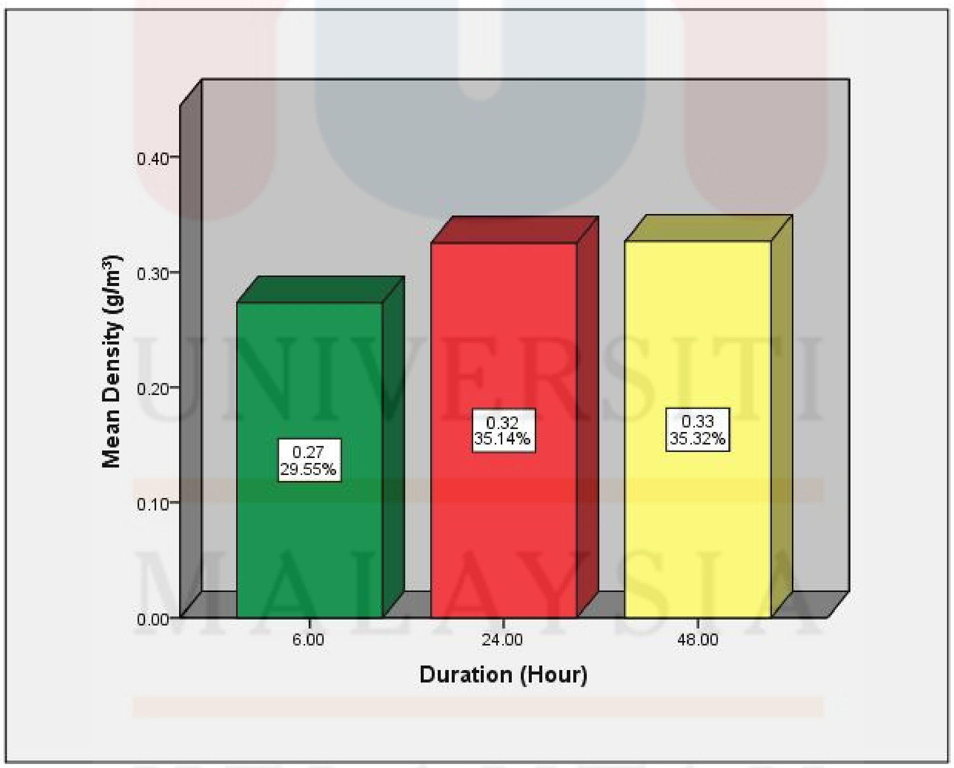

Figure 4.6: Effect of various duration on density

Figure 4.7 indicates the effect of different duration on density, based on the sample that was treated at 160°C. There were three different time durations used to measure the density of the sample of acacia wood: 6 hour, 24 hours, and 48 hours. These samples before were immersed in wood vinegar and silica extracted with rice husk ash preservatives. The figure expressed that the mean of density on 6 hours of the duration was the lowest among the samples. Meanwhile, the sample at 24 hours and 48 hours have a close mean of density. The mean of density has gradually increased from 6 hours at mean for 29.55% to 48 hours for 35.32%. Density is an effective measure to evaluate the durability and structural strength of wood. Denser wood usually has higher mechanical qualities, such as stiffness and load-bearing capacity, because it usually includes more material per unit volume. As a result, denser wood is often stronger and more durable. However, there was no significant difference between the sample treated at 24 hours and 48 hours compared to the sample treated at duration of 6 hours.

4.2.3 Water Absorption

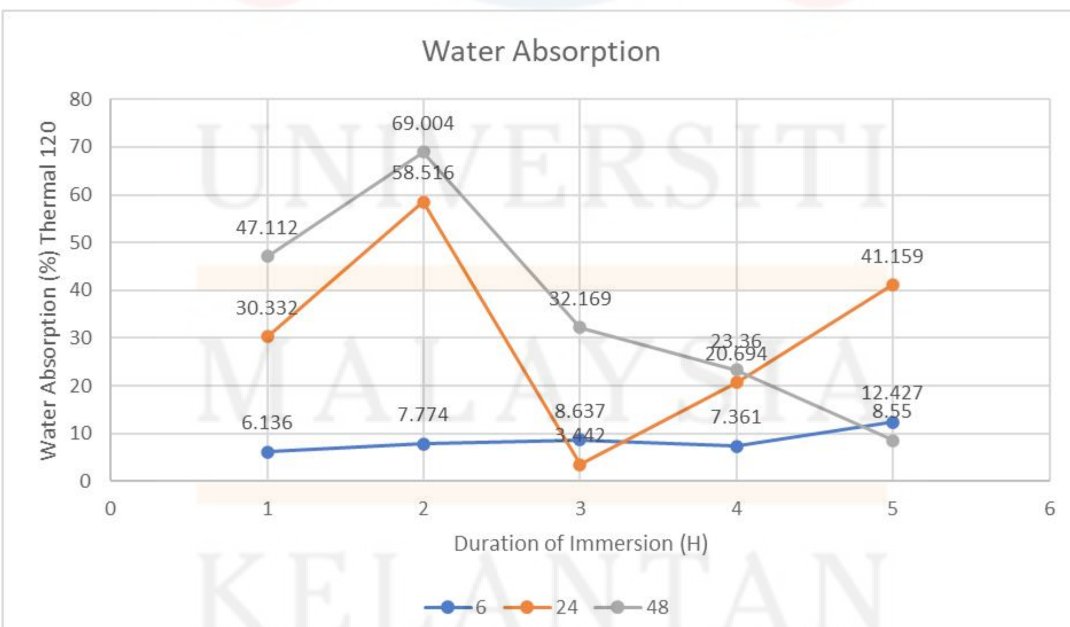

Figure 4.7: Effect of various duration on water absorption

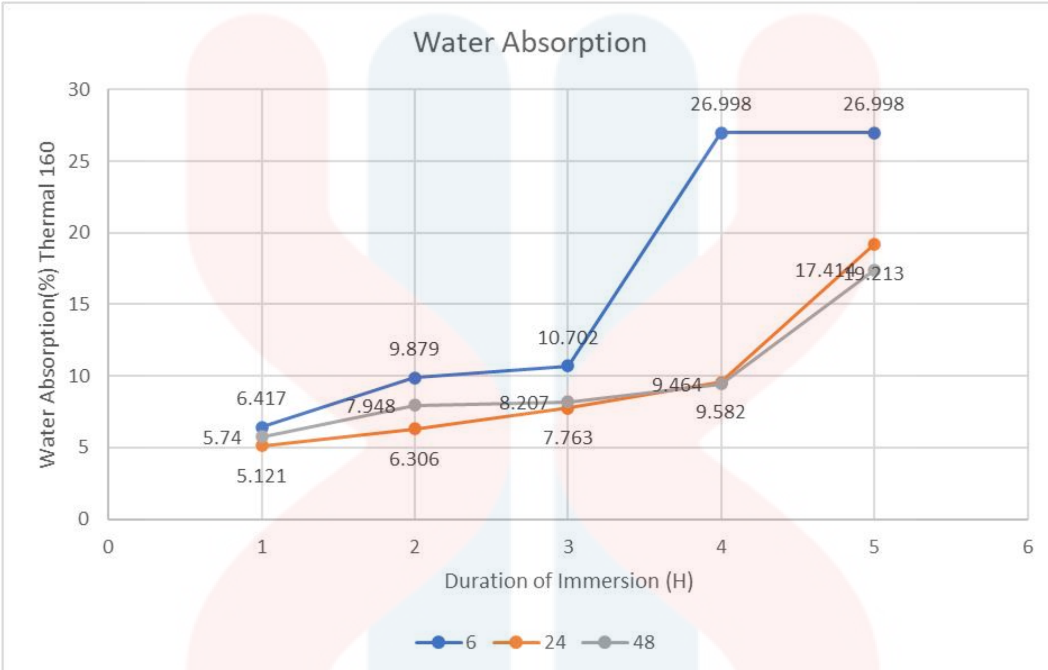

Figure 4.8: Effect of various duration on water absorption

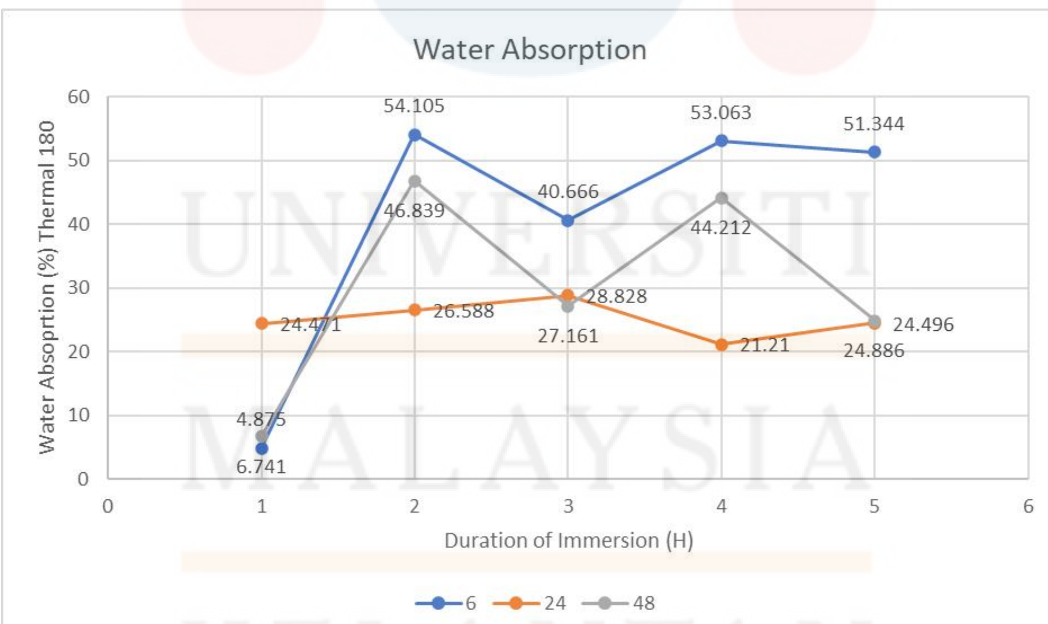

Figure 4.9: Effect of various duration on water absorption

Figure 4.8, Figure 4.9, and Figure 4.10 shows three different temperatures of samples. There were three temperature and duration that used to treat the samples at 120°C, 160°C, and 180°C. Before the samples were tested, the samples of wood acacia were impregnated with wood vinegar and silica extracted with rice husk ash thermal with three different temperatures and duration that were stated. Then the samples were soaked in water for 1hour, 2 hours, 3 hours, 5hours, and 24 hours. Based on the graph shown above, there were increased levels of water absorption from 1 hour until 24 hours of the duration compared to the wood sample that was thermal at 120°C before, the reading of the wood sample that was thermal for 6 hours and soak in the water remained constant. There was not much change in percentage of water absorption for five-time duration that was 6.136% for 1 hour,7.774% for 2 hours, 8.637% for 3 hours, 7.361% for 5 hours, and 8.55% for 24 hours with. As for the acacia wood samples that were treated on 24 hour and 48 hours, the reading for data was uneven from the first soaked time until 24 hours. However, preliminary studies showed that it is crucial to reduce the amount of water that wood absorbs since less permeability to water indicates improved resistance against organisms that degrade wood and is mechanically stable. (Ház A et al., n.d.) Therefore, there were huge differences between duration and the temperature treated on the samples of acacia wood.

4.2.4 Bending Properties (MOR)

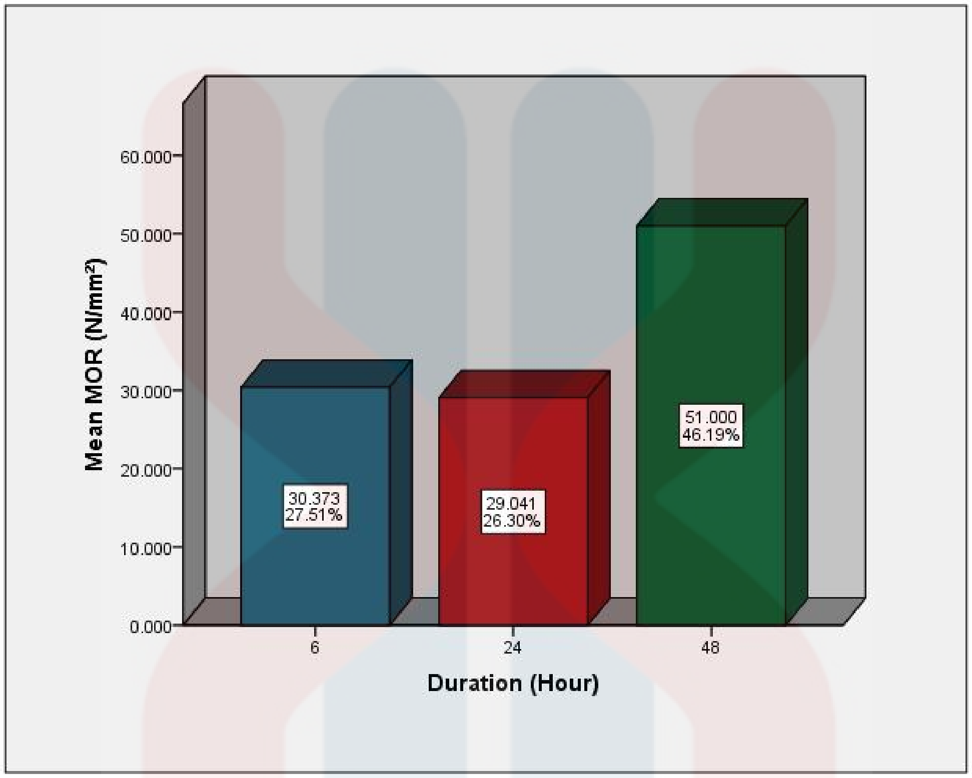

Figure 4.10: Effect of treatment duration on MOR

Figure 4.11 shows the collation of three different samples that were treated under a different duration. The highest value of MOR mean was the sample that tested for 48 hours with a mean of 51.000 equal to 46.19%. The samples tested for 6 hours, and 24 hours have a close mean of MOR which means MOR 30.373N/mm³ for 6 hours and 29.041N/mm³ for 24 hours. However, wood preservatives played a role in this study. The mechanical qualities of wood can be directly impacted by the compounds found in wood preservatives. Preservatives have the potential to strengthen wood fibres, which would raise MOR. Compared to untreated wood that could deteriorate, wood that has been maintained and shielded from decay has a lower chance of deteriorating and hence has a higher MOR value.

4.2.5 Bending Properties (MOE)

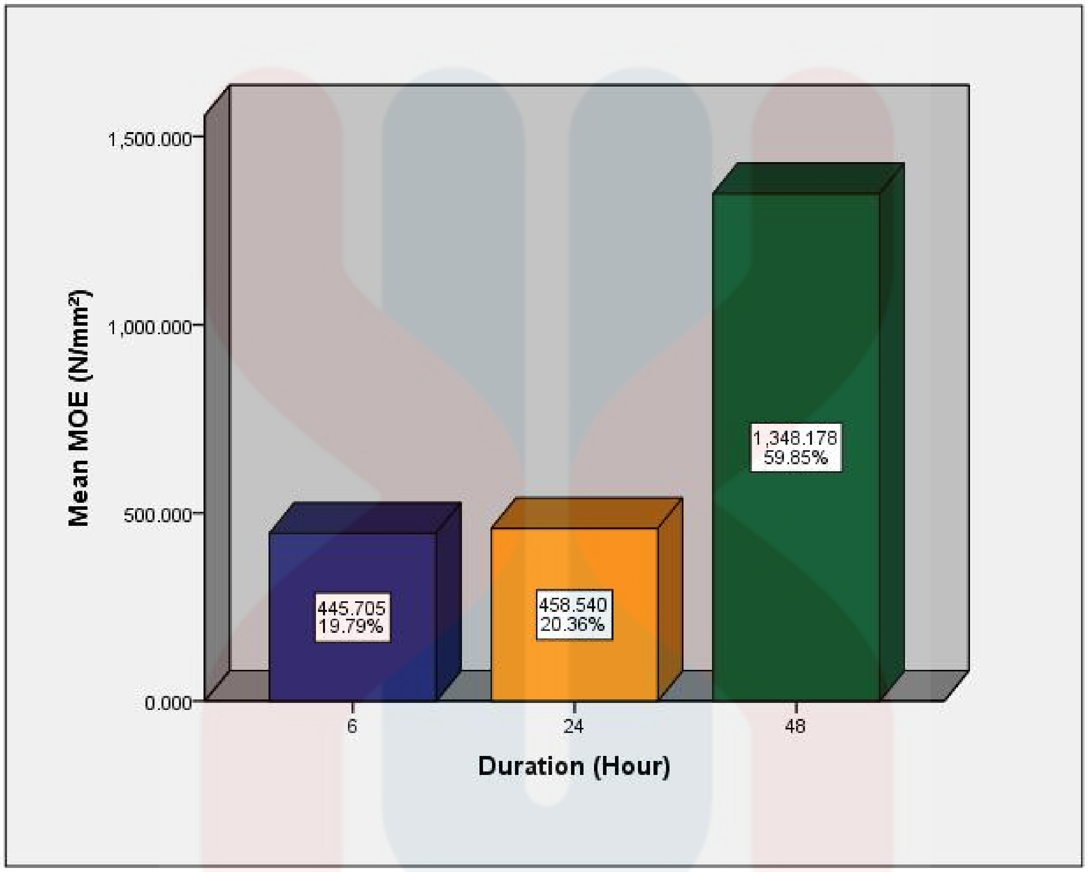

Figure 4.11: Effect of treatment duration on MOE

Figure 4.12 shows the value of MOE with three samples that have been tested under different duration. In the figure above, the sample that is treated 48 hours has the highest value of mean MOE 59.85% compared to the other two samples. As for the sample that was treated for 6 hours, and 24 hours the value of mean were close which was at 19.79% for 6 hours and 20.36% for 24 hours. The value of mean MOE increased drastically. Based on the graph, extended testing times could provide a more comprehensive moisture treatment of the wood samples. The mechanical characteristics of wood, especially MOE, can be significantly changed by variations in moisture content. Besides, wood vinegar and silica extracted with rice husk ash may strengthen the wood fibers, leading to an increase in MOE.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The objective of this study is to evaluate the properties of acacia wood. The effect of the properties of acacia impregnated with wood vinegar and silica extracted rice husk ash were observed on the mechanical and physical properties. To summarize, the effect executed from the analysis data of moisture content, density, water absorption and bending properties on the acacia wood was significant after studying the wood vinegar and silica extracted rice husk ash preservatives. The acacia wood treated with the thermal modification and impregnated with the wood vinegar and silica extracted rice husk ash had changed the dimensional stability. When compared to untreated wood, the moisture content and water absorption of Acacia wood have decreased because of impregnating it with wood vinegar and silica. This decrease indicates improved resistance to moisture-related problems such swelling, and warping as well as increased dimensional stability. It is possible that the preservatives work to seal the wood fibres and stop them from absorbing too much moisture. Besides, the impregnation process has resulted in slight increase in wood density. Higher density contributes to enhanced mechanical properties such as strength and stiffness. Greater values of the Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) indicate that the bending properties of impregnated Acacia wood are better. The impregnated wood is now appropriate for structural applications that call for a high load-bearing capacity and bending stress resistance because of this improvement. Hence, thermal treatment and preservative can be used in acacia wood to improve the physical and mechanical properties which add value to this wood species for end-use products. However, the selection of wood sections also influences the data outcomes.

5.2 Recommendations

In further research, it is recommended to maximize the effectiveness of the impregnation process, study the optimal concentrations, times, and temperatures. In addition, to determine if impregnation is appropriate, consider how it affects mechanical attributes including bending strength, stiffness, impact resistance, and stress behaviors for the wood is also suggested. Therefore, in further study, recommended to investigate the microstructure of impregnated wood samples and uncover changes in cellular content or structure, as well as the distribution and depth of preservative penetration, employ sophisticated imaging and microscopy techniques. Lastly, Evaluate the environmental sustainability of impregnating Acacia wood with wood vinegar and silica as an alternative to conventional preservatives, taking into consideration things like energy and resource consumption, emissions, waste production, and emissions throughout the treatment process.

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APPENDIX A

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.

MC1st	Between Groups	402.366	2	201.183	.339	.721
	Within Groups	5345.305	9	593.923		
	Total	5747.671	11			
MC2nd	Between Groups	297.620	2	148.810	.213	.812
	Within Groups	6274.953	9	697.217		
	Total	6572.573	11			
Duration	Between Groups	.000	2	.000	.000	1.000
	Within Groups	2673.000	9	297.000		
	Total	2673.000	11			

Table A.1: One-way ANOVA determine if it has relation between temperature and duration effect on moisture content of Acacia wood.

MC1st

	Temperature	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	160	4	27.8450
	120	4	36.7800
	180	4	41.8525
	Sig.		.705
Tukey B[a]	160	4	27.8450
	120	4	36.7800
	180	4	41.8525
Duncan[a]	160	4	27.8450
	120	4	36.7800
	180	4	41.8525
	Sig.		.457

Table A.2: Homogeneous Subset determine the significance of temperature on moisture content.

MC2nd

	Temperature	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	160	4	45.3050
	120	4	49.0875

	180	4	57.2400
	Sig.		.803
Tukey B[a]	160	4	45.3050
	120	4	49.0875
	180	4	57.2400
Duncan[a]	160	4	45.3050
	120	4	49.0875
	180	4	57.2400
	Sig.		.556

Table A.3: Homogeneous Subset determine the significance of temperature on moisture content.

Duration

	Temperature	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	120	4	25.50
	160	4	25.50
	180	4	25.50
	Sig.		1.000
Tukey B[a]	120	4	25.50
	160	4	25.50
	180	4	25.50
Duncan[a]	120	4	25.50
	160	4	25.50
	180	4	25.50
	Sig.		1.000

Table A.4: Homogeneous Subset determine the significance of duration moisture content.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
MC1st	Between Groups	766.557	2	383.279	.693	.525
	Within Groups	4981.114	9	553.457		
	Total	5747.671	11			
MC2nd	Between Groups	762.645	2	381.323	.591	.574

	Within Groups	5809.927	9	645.547		
	Total	6572.573	11			
	Between Groups	.000	2	.000	.000	1.000
Temperature	Within Groups	7466.667	9	829.630		
	Total	7466.667	11			

Table A.5: One-way ANOVA determine if it has relation between temperature and duration effect on moisture content of Acacia wood.

MC1st

	Duration	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	6	3	21.7067
	24	6	39.4933
	48	3	41.2767
	Sig.		.529
Tukey B[a,b]	6	3	21.7067
	24	6	39.4933
	48	3	41.2767
Duncan[a,b]	6	3	21.7067
	24	6	39.4933
	48	3	41.2767
	Sig.		.313

Table A.6: Homogeneous Subset determine the significance of duration moisture content

MC2nd

	Duration	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	6	3	37.1033

	24	6	53.5333
	48	3	58.0067
	Sig.		.536
Tukey B[a,b]	6	3	37.1033
	24	6	53.5333
	48	3	58.0067
Duncan[a,b]	6	3	37.1033
	24	6	53.5333
	48	3	58.0067
	Sig.		.318

Table A.7: Homogeneous Subset determine the significance of duration moisture content.

Temperature

	Duration	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	6	3	153.33
	24	6	153.33
	48	3	153.33
	Sig.		1.000
Tukey B[a,b]	6	3	153.33
	24	6	153.33

	48	3	153.33
	6	3	153.33
Duncan[a,b]	24	6	153.33
	48	3	153.33
	Sig.		1.000

Table A.8: Homogeneous Subset determine the significance of temperature moisture content.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
MOE	Between Groups	264433.637	2	132216.819	.339	.722
	Within Groups	3515284.378	9	390587.153		
	Total	3779718.015	11			
MOR	Between Groups	456.957	2	228.479	.333	.725
	Within Groups	6168.896	9	685.433		
	Total	6625.854	11			
Duration	Between Groups	3.000	2	1.500	.005	.995
	Within Groups	2670.000	9	296.667		
	Total	2673.000	11			

Table A.9: One-way ANOVA determine if it has relation between temperature and duration effect on MOE of Acacia wood.

MOE

	Temperature	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	180	6	534.72083
	120	3	764.52000
	160	3	877.00067
	Sig.		.750
Tukey B[a,b]	180	6	534.72083
	120	3	764.52000
	160	3	877.00067

Duncan[a,b]	180	6	534.72083
	120	3	764.52000
	160	3	877.00067
	Sig.		.500

Table A.10: Homogeneous Subset determine the significance of temperature on Modulus of Elasticity (MOE)

MOR

	Temperature	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	180	6	29.07933
	160	3	37.60833
	120	3	43.68800
	Sig.		.742
Tukey B[a,b]	180	6	29.07933
	160	3	37.60833
	120	3	43.68800
Duncan[a,b]	180	6	29.07933
	160	3	37.60833
	120	3	43.68800
	Sig.		.492

Table A.11: Homogeneous Subset determine the significance of temperature on Modulus of Rupture (MOR)

Duration

	Temperature	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	180	6	25.00
	120	3	26.00
	160	3	26.00
	Sig.		.997
Tukey B[a,b]	180	6	25.00
	120	3	26.00

	160	3	26.00
	180	6	25.00
Duncan[a,b]	120	3	26.00
	160	3	26.00
	Sig.		.942

Table A.12: Homogeneous Subset determine the significance of temperature MOE and MOR

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
MOE	Between Groups	1798272.997	2	899136.498	4.084	.055
	Within Groups	1981445.018	9	220160.558		
	Total	3779718.015	11			
MOR	Between Groups	1045.104	2	522.552	.843	.462
	Within Groups	5580.750	9	620.083		
	Total	6625.854	11			
Temperature	Between Groups	533.333	2	266.667	.360	.707
	Within Groups	6666.667	9	740.741		
	Total	7200.000	11			

Table A.13: One-way ANOVA determine if it has relation between temperature and duration effect on MOR of Acacia wood.

MOE

	Duration	N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a,b]	6	3	445.70500	
	24	6	458.53983	
	48	3	1348.17767	
	Sig.		.069	
Tukey B[a,b]	6	3	445.70500	
	24	6	458.53983	
	48	3	1348.17767	
Duncan[a,b]	6	3	445.70500	

	24	6	458.53983	
	48	3		1348.17767
	Sig.		.972	1.000

Table A.14: Homogeneous Subset determine the significance of duration on Modulus of Elasticity (MOE)

MOR

	Duration	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	24	6	29.04100
	6	3	30.37267
	48	3	51.00033
	Sig.		.492
Tukey B[a,b]	24	6	29.04100
	6	3	30.37267
	48	3	51.00033
Duncan[a,b]	24	6	29.04100
	6	3	30.37267
	48	3	51.00033
	Sig.		.287

Table A.15: Homogeneous Subset determine the significance of duration on Modulus of Rupture (MOR)

Temperature

	Duration	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	6	3	153.33
	48	3	153.33
	24	6	166.67
	Sig.		.793
Tukey B[a,b]	6	3	153.33

	48	3	153.33
	24	6	166.67
	6	3	153.33
Duncan[a,b]	48	3	153.33
	24	6	166.67
	Sig.		.545

Table A.16: Homogeneous Subset determine the significance of temperature on MOE and MOR

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Duration	Between Groups	3.000	2	1.500	.005	.995
	Within Groups	2670.000	9	296.667		
	Total	2673.000	11			
Density	Between Groups	.001	2	.001	.038	.963
	Within Groups	.120	9	.013		
	Total	.121	11			

Table A.17: One-way ANOVA determine if it has relation between temperature and duration effect on Density of Acacia wood.

Duration

	Temperature	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	180.00	6	25.0000
	120.00	3	26.0000
	160.00	3	26.0000
	Sig.		.997
Tukey B[a,b]	180.00	6	25.0000
	120.00	3	26.0000

	160.00	3	26.0000
	180.00	6	25.0000
Duncan[a,b]	120.00	3	26.0000
	160.00	3	26.0000
	Sig.		.942

Table A.18: Homogeneous Subset determine the significance mean of duration and temperature on Density.

Density

	Temperature	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	160.00	3	.2967
	120.00	3	.3167
	180.00	6	.3183
	Sig.		.966
Tukey B[a,b]	160.00	3	.2967
	120.00	3	.3167
	180.00	6	.3183
Duncan[a,b]	160.00	3	.2967
	120.00	3	.3167
	180.00	6	.3183
	Sig.		.815

Table A.19: Homogeneous Subset determine the significance mean of temperature on Density.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Density	Between Groups	.006	2	.003	.241	.791
	Within Groups	.115	9	.013		
	Total	.121	11			
Temperature	Between Groups	533.333	2	266.667	.360	.707
	Within Groups	6666.667	9	740.741		
	Total	7200.000	11			

Table A.20: One-way ANOVA determine if it has relation between temperature and duration effect on Density of Acacia wood.

Density

	Duration	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	6.00	3	.2733
	24.00	6	.3250
	48.00	3	.3267
	Sig.		.806
Tukey B[a,b]	6.00	3	.2733
	24.00	6	.3250
	48.00	3	.3267
Duncan[a,b]	6.00	3	.2733
	24.00	6	.3250
	48.00	3	.3267
	Sig.		.559

Table A.21: Homogeneous Subset determine the significance of duration on Density.

Temperature

	Duration	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	6.00	3	153.3333
	48.00	3	153.3333
	24.00	6	166.6667
	Sig.		.793
Tukey B[a,b]	6.00	3	153.3333
	48.00	3	153.3333

	24.00	6	166.6667
	6.00	3	153.3333
Duncan[a,b]	48.00	3	153.3333
	24.00	6	166.6667
	Sig.		.545

Table A.22: Homogeneous Subset determine the significance mean of temperature and duration on Density.

Temperature	Duration	W dry (g)	W wet (g)		Water Absorption (%)	
			1st	2nd	1st	2nd
Thermal 120	(1 hour)					
	6	15.7063	16.67	17.87	6.136	12.11
	24	6.97	10.0046	12.63	30.332	44.81
	48	5.6802	10.74	11.56	47.112	50.9
	(2hours)					
	6	11.6758	12.66	13.48	7.774	13.4
	24	6.78	16.343	17.96	58.516	62.24
	48	5.604	18.08	19.78	69.004	71.7
	(3hour)					

	6	14.6094	15.99	16.54	8.637	11.7
	24	8.76	9.0723	11.23	3.442	22
	48	6.9866	10.3	12.47	32.169	44
	(5hours)					
	6	24.1974	26.12	28.32	7.361	14.56
	24	18.1926	22.94	25.13	20.694	27.61
	48	18.7384	24.45	26.78	23.36	30.03
	(24hours)					
	6	21.2977	24.32	26.83	12.427	20.62
	24	13.8334	23.51	27.43	41.159	49.57
	48	19.3691	21.18	24.52	8.55	21

Table A.23: Water absorption of wood vinegar and silica on the properties modified Acacia wood for 1, 2, 3, 5, and 24 hours.

Temperature	Duration	W dry (g)	W wet (g)		Water Absorption(%)	
			1st	2nd	1st	2nd
Thermal 160	(1hour)					
	6	8.8249	9.43	10.74	6.417	17.83
	24	17.9795	18.95	19.83	5.121	9.33
	48	10.7366	11.39	12.72	5.74	15.6
	(2hours)					
	6	7.9667	8.84	9.73	9.879	18.12
	24	15.4595	16.5	17.81	6.306	13.2
	48	10.9726	11.92	12.63	7.948	13.12
	(3hours)					

	6	8.9744	10.05	11.43	10.702	21.5
	24	18.6872	20.26	22.32	7.763	16.27
	48	8.7203	9.5	10.81	8.207	19.33
	(5hours)					
	6	16.3487	19.58	23.14	16.503	29.34
	24	20.778	22.98	30.43	9.582	31.72
	48	17.9251	20.1	23.72	9.464	24.43
	(24hours)					
	6	15.1332	20.73	25.42	26.998	40.5
	24	22.5314	27.89	29.37	19.213	23.3
	48	17.9251	21.82	24.28	17.414	25.8

Table A.24: Water absorption of wood vinegar and silica on the properties modified Acacia wood for 1, 2, 3, 5, and 24 hours.

Temperature	Duration	W dry (g)	W wet (g)		Water Absorption (%)	
			1st	2nd	1st	2nd
Thermal 180	(1hour)					
	6	13.8312	14.54	15.72	4.875	12.02
	24	5.6872	7.53	8.27	24.471	31.23
	48	13.5972	14.58	15.53	6.741	12.5
	24	18.753	20.47	22.32	8.388	16
	(2hours)					
	6	9.4314	20.55	21.67	54.105	56.5
	24	8.8828	12.1	14.13	26.588	37.14
	48	10.15	19.0931	20.92	46.839	51.5

24	16.9094	18.93	20.14	10.7	16.04
(3hours)					
6	9.1079	15.34	16.72	40.666	45.53
24	7.0394	9.89	11.54	28.828	39
48	9.92	13.6191	15.71	27.161	37
24	16.6442	18.55	20.21	10.273	17.64
(5hours)					
6	15.7142	33.48	36.27	53.063	56.7
24	25.2915	32.1	35.71	21.21	29.2
48	17.08	30.6157	33.52	44.212	49.1
24	20.5203	23.11	26.84	11.206	23.54
(24hours)					
6	12.276	25.23	29.82	51.344	58.83
24	15.7802	20.9	26.37	24.496	40.2
48	15.43	20.542	25.42	24.886	39.3
24	17.8707	21.42	24.71	16.57	27.7

Table A.25: Water absorption of wood vinegar and silica on the properties modified Acacia wood for 1, 2, 3, 5, and 24 hours.

APPENDIX B

Figure B.1: Acacia wood soaked into wood vinegar and silica extracted rice husk ash.

Figure B.2: Acacia wood dried room temperature before oven dry.

Figure B.3: Acacia wood has been thermal after soaked in preservatives.

Figure B.4: Acacia wood after thermally heated.