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Enhancing Mechanical Properties of Particleboard using Waste Material (Fish Bones)

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

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DECLARATION

I declare that this thesis entitled “Enhancing Mechanical Properties of Particleboard using Waste Material (Fish Bones)” is the results of my own research except as cited in the references.

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Enhancing Mechanical Properties of Particleboard using Waste Material (Fish Bones)

ABSTRACT

This research aims to explore the feasibility and effectiveness of enhancing the mechanical properties of particleboard by incorporating waste material, specifically fish bones, at varying concentrations (5%, 10%, and 15%). The study focuses on evaluating the impact of fish bone fillers on bending strength, tensile strength, and dimensional stability of the particleboard. Employing a detailed methodology that includes preparation of materials from Kelempayan wood and fish bones, along with the use of urea-formaldehyde resin, the research provides valuable insights into the mechanical properties and dimensional stability of the produced particleboard. The findings indicate that the addition of fish bone content improves bending and tensile strengths at a concentration of 10%, but shows a decrease at 15%. The implications of this study are significant in the development of eco-friendly composite materials, utilizing waste as an effective and cost-efficient filler alternative in the construction and furniture industries, contributing to waste reduction and sustainable waste utilization. This study also opens avenues for further research in optimizing fish bone content in particleboard to achieve a balance between mechanical strength and environmental sustainability.

Keywords: Particleboard, Fish bones, Mechanical properties, Sustainability, Waste material.

ABSTRAK

Kajian ini bertujuan untuk mengkaji keberkesanan penggunaan bahan buangan, khususnya tulang ikan, dalam meningkatkan sifat mekanikal papan partikel. Penyelidikan ini memfokuskan pada penilaian impak penggunaan isi tulang ikan dengan konsentrasi yang berbeza (5%, 10%, dan 15%) terhadap kekuatan lentur, kekuatan tegangan, dan kestabilan dimensi papan partikel. Melalui metodologi yang terperinci, termasuk persiapan bahan dari kayu kelempayan dan tulang ikan, serta penggunaan resin urea-formaldehid, kajian ini menghasilkan data yang berharga mengenai sifat-sifat mekanikal dan stabiliti dimensi papan partikel yang dihasilkan. Hasil kajian menunjukkan bahawa penambahan isi tulang ikan meningkatkan kekuatan lentur dan tegangan pada konsentrasi 10%, namun menunjukkan penurunan pada konsentrasi 15%. Implikasi dari kajian ini penting dalam pembangunan bahan komposit mesra alam, dengan menggunakan bahan buangan sebagai alternatif bahan pengisi yang berkesan dan kos efektif dalam industri pembinaan dan perabot, menyumbang kepada pengurangan sisa dan pemanfaatan bahan buangan secara berkesinambungan. Kajian ini juga membuka peluang untuk penelitian lebih lanjut dalam mengoptimalkan kandungan tulang ikan dalam papan partikel untuk mencapai keseimbangan antara kekuatan mekanikal dan kelestarian lingkungan.

Kata kunci: Papan partikel, Tulang ikan, Sifat mekanikal, Kelestarian, Bahan buangan.

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

Wood composite materials have gained significant attention in various industries, including construction and furniture manufacturing, due to their exceptional mechanical properties, such as high strength-to-weight ratio, dimensional stability, and aesthetic appeal. These materials are typically manufactured by combining wood fibers or particles with adhesives to create a durable and versatile product. However, traditional manufacturing techniques used to produce wood composites often involve the use of non-renewable resources and chemicals that can harm the environment and human health.

Figure 1.1: Wood composite

In recent years, there has been a growing emphasis on sustainable manufacturing practices that aim to minimize the environmental impact of industrial processes. Sustainable manufacturing techniques for wood composites involve the use of recycled materials, non-toxic adhesives, and energy-efficient processes. These techniques have the potential to significantly reduce the carbon footprint associated with the production of wood composites while maintaining or even enhancing their mechanical properties.

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Despite the increasing interest in sustainable manufacturing, there is a lack of comprehensive research examining the mechanical properties of wood composites produced through sustainable techniques. Understanding the effects of sustainable manufacturing on the mechanical behavior of these materials is crucial for their successful integration into various applications.

The proposed study aims to investigate the mechanical properties of wood composite materials produced through sustainable manufacturing techniques. The research will explore the impact of different sustainable manufacturing parameters, such as the type and concentration of recycled materials, the formulation of non-toxic adhesives, and the optimization of manufacturing processes, on the mechanical performance of the resulting composites.

To achieve this objective, a systematic experimental approach will be employed. Initially, various sustainable manufacturing techniques will be identified and selected based on their potential for reducing environmental impact. The chosen techniques will be used to produce wood composites with different compositions and manufacturing parameters. The mechanical properties of these composites, including tensile strength, flexural strength, impact resistance, and hardness, will be evaluated using standardized testing methods.

Furthermore, the microstructural analysis of the composites will be conducted to investigate the bonding characteristics, fiber-matrix interaction, and uniformity of the material. This analysis will provide valuable insights into the structure-property relationships of the sustainable wood composites.

The findings of this study will contribute to the growing body of knowledge on sustainable manufacturing of wood composites and their mechanical properties. The results will help identify the most effective manufacturing techniques for producing wood composites with optimal mechanical performance while minimizing the environmental impact. Additionally, the study will provide valuable data for engineers, designers, and manufacturers to make informed decisions regarding the selection and implementation of sustainable manufacturing processes for wood composites.

Overall, investigating the mechanical properties of wood composite materials produced through sustainable manufacturing techniques is crucial for advancing the development and application of environmentally friendly wood composites in the construction and furniture industries. By combining the benefits of sustainable manufacturing with desirable mechanical properties, these materials have the potential to revolutionize the industry and contribute to a more sustainable and resource-efficient future.

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1.2 Problem statement

The purpose of this research proposal is to investigate the feasibility and effectiveness of enhancing the mechanical properties of particleboard through the incorporation of waste material, specifically fish bones. The study aims to assess the impact of varying concentrations of fish bone fillers on the bending strength, tensile strength, and dimensional stability of the particleboard. Additionally, the research seeks to explore the potential of fish bones as a sustainable and cost-effective alternative filler material for particleboard production. The findings of this study will contribute valuable insights into the development of eco-friendly composite materials and promote waste utilization in the construction and furniture industries.

1.3 Objectives of the study

1. To evaluate the bending strength of particleboard with varying concentrations of fish bone fillers to determine the optimal filler content that maximizes bending performance.
2. To determine the feasibility of using fish bones as a natural additive.

1.4 Scope of study

The scope of this research proposal is to investigate the feasibility and effectiveness of enhancing the mechanical properties of particleboard through the incorporation of waste material, specifically fish bones. The study will focus on assessing the impact of varying concentrations of fish bone fillers on the bending strength and a comparison with industry standards particleboard.

1.5 Significance of study

The significance of the proposed study on "Enhancing Mechanical Properties of Particleboard using Waste Material (Fish Bones)" lies in its potential to promote sustainability in the construction and furniture industries. By utilizing fish bones as filler material in particleboard production, the research addresses waste management challenges and reduces environmental impact. The study's findings can contribute to the development of eco-friendly composite materials, minimizing the demand for virgin wood resources and curbing deforestation. Moreover, understanding the effects of fish bone fillers on particleboard properties can lead to improved mechanical performance, enhancing the material's structural integrity and expanding its practical applications in load-bearing structures.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of kelempayan wood

Kelempayan wood, also known as Juvenile Neolamarckia cadamba, is a tropical hardwood that is native to Southeast Asia, particularly Malaysia and Indonesia. It belongs to the Verbenaceae family and is highly valued for its exceptional mechanical properties, making it a popular choice for various applications in the woodworking industry. This article provides an in-depth exploration of Kelempayan wood, including its characteristics, uses, and sustainable management practices.

Kelempayan wood is known for its excellent durability and strength, which are attributed to its high density and unique cell structure. The heartwood of Kelempayan is usually dark brown or reddish-brown, while the sapwood is lighter in color. The wood has a straight to interlocked grain, providing good dimensional stability and resistance to warping and cracking. It possesses a fine to medium texture, with a lustrous appearance when polished. Kelempayan wood also exhibits moderate to high natural resistance against decay and termites, making it suitable for outdoor applications. Kelempayan wood is renowned for its impressive mechanical properties, making it suitable for a wide range of applications that require strength and durability. The wood has a high bending strength, providing excellent load-bearing capabilities. It also displays good resistance to compression, making it suitable for structural purposes. Kelempayan wood exhibits moderate hardness, which allows it to resist wear and damage. Additionally, it has excellent shock resistance and performs well under impact loading.

Also, kelempayan wood is highly valued in the furniture industry due to its attractive appearance and durability. It is commonly used for crafting high-quality indoor and outdoor furniture, including tables, chairs, cabinets, and bed frames. The wood's natural beauty and resistance to decay make it ideal for both decorative and functional furniture pieces. Moreover, kelempayan wood's exceptional durability and resistance to moisture make it suitable for flooring and decking applications. It is often used to create elegant and long-lasting hardwood floors and decks in both residential and commercial settings. The wood's strength and stability allow it to withstand heavy foot traffic and environmental exposure. Furthermore, kelempayan wood finds applications in the construction industry for structural components such as beams, columns, and trusses. Its high strength and dimensional stability make it an excellent choice for supporting heavy loads and ensuring the structural integrity of buildings. It is also used in joinery applications for crafting doors, window frames, and moldings. And, kelempayan wood's natural resistance to decay, strength, and workability make it a favored choice for boatbuilding. It is often used for constructing boat hulls, decking, and interior components. The wood's durability and ability to withstand moisture make it suitable for marine environments.

As the demand for Kelempayan wood increases, it is crucial to adopt sustainable management practices to ensure the long-term availability and conservation of this valuable resource. Sustainable practices for Kelempayan wood include Promoting forest certification programs such as the Forest Stewardship Council (FSC) ensures that Kelempayan wood is sourced from responsibly managed forests. Certification helps protect biodiversity, maintain ecosystem health, and ensure the rights and welfare of forest communities. Furthermore, implementing regeneration and reforestation programs helps maintain the population of Kelempayan trees. By planting new trees and allowing for natural regeneration, the sustainability of the species can be ensured for future generations. After that, employing proper harvesting techniques, such as selective logging, reduces the impact on the forest ecosystem. Selective logging involves carefully choosing trees for harvesting while preserving the surrounding trees and minimizing disturbance to the forest floor. Lastly, conducting research and monitoring programs on Kelempayan wood and its habitats aids in understanding the species' ecology, growth patterns, and threats. This knowledge informs sustainable management strategies and facilitates informed decision-making.

In conclusion, kelempayan wood is a remarkable tropical hardwood that possesses excellent mechanical properties, making it highly sought after in the woodworking industry. Its strength, durability, and resistance to decay make it suitable for a wide range of applications, including furniture, flooring, construction, and boatbuilding. By adopting sustainable management practices, such as forest certification, regeneration programs, and proper harvesting techniques, the long-term availability and conservation of Kelempayan wood can be ensured. It is essential to balance the utilization of this valuable resource with responsible and sustainable practices to preserve its ecological and economic value for future generations (Siti Zalifah Mahmud, 2017).

2.2 Overview of particleboard

Particleboard is an engineered wood product that is widely used in various industries and applications due to its affordability, versatility, and ease of manufacturing. It is composed of small wood particles or fibers that are bonded together using a synthetic resin or binder. This results in a composite material with consistent density and strength throughout the board. Particleboard offers several advantages over traditional solid wood, including cost-effectiveness, dimensional stability, and the ability to utilize wood waste and by-products.

The manufacturing process of particleboard involves several key steps. First, wood particles or fibers, which can be sourced from various wood species and grades, are obtained through shredding or milling processes. These particles are then mixed with a resin binder, typically a urea-formaldehyde or melamine formaldehyde resin, which acts as an adhesive to hold the particles together. Additional additives, such as wax or fire retardants, may be incorporated to enhance specific properties of the particleboard. Once the wood particles and resin are thoroughly mixed, the resulting mixture is formed into a mat or panel using a continuous press or a hot-pressing method. Pressure and heat are applied to the mat, causing the resin to cure and bond the wood particles together. The panel is then trimmed, sanded, and cut into desired sizes and shapes.

Particleboard offers several advantages that contribute to its popularity in various applications. Firstly, it is cost-effective compared to solid wood, making it an affordable option for furniture, cabinetry, and other woodworking projects. It also exhibits good dimensional stability, meaning it is less susceptible to warping or shrinking when exposed to changes in temperature and humidity compared to solid wood. This characteristic makes particleboard suitable for applications where stability is crucial, such as in flooring or interior paneling. Furthermore, particleboard is highly versatile and can be manufactured in a variety of thicknesses, densities, and surface finishes to suit specific needs. It can be laminated with decorative veneers, melamine, or other finishes to enhance its appearance and mimic the look of more expensive wood products. The smooth and uniform surface of particleboard also makes it suitable for painting, staining, or applying other decorative treatments.

In addition to its versatility and cost-effectiveness, particleboard is an environmentally friendly choice. It utilizes wood waste and by-products, such as sawdust, wood chips, and even recycled wood, reducing the amount of wood material that would otherwise go to waste. By recycling and repurposing wood particles, particleboard helps to minimize deforestation and promotes sustainable use of forest resources. However, it is important to note that particleboard has some limitations as well. It is not as strong or durable as solid wood or other engineered wood products like plywood. It has lower resistance to moisture and may swell or deteriorate if exposed to prolonged wet conditions. Therefore, proper sealing or use of moisture-resistant coatings is necessary when using particleboard in applications that may come into contact with water or high humidity.

In summary, particleboard is an affordable, versatile, and sustainable engineered wood product that finds extensive use in the construction, furniture, and interior design industries. Its composition of wood particles bonded with resin provides consistent density, dimensional stability, and customization options. While it may have some limitations, particleboard remains a popular choice for cost-effective and eco-friendly wood-based applications (Abetie D, 2021).

2.3 Waste Material (Fish Bones) as a substitute for conventional binders.

Fish bones, an abundant waste material generated by the fish processing industry, have shown promise as a potential substitute for conventional binders in various applications. Conventional binders, such as synthetic resins, are commonly used to bond wood particles together in composite materials like particleboard. However, the use of these binders raises concerns regarding environmental sustainability and dependence on non-renewable resources. The exploration of waste material, such as fish bones, as an alternative binder offers a sustainable solution with potential benefits for both the environment and the industry.

One of the key advantages of using fish bones as a binder substitute is their natural adhesive properties. Fish bones contain collagen, a protein that exhibits adhesive characteristics when subjected to heat and pressure during the manufacturing process. Collagen-based adhesives have been studied for their potential as eco-friendly and biodegradable alternatives to conventional synthetic binders.

The utilization of fish bone-based adhesives can contribute to waste reduction and resource conservation. By transforming fish bones, which are typically discarded as waste, into a valuable resource for adhesion, the environmental burden associated with waste disposal is reduced. This supports the principles of the circular economy by creating a closed-loop system, where waste is repurposed as a valuable input in the manufacturing process.

In addition to their eco-friendly nature, fish bone-based adhesives may offer improved health and safety benefits compared to some conventional binders. Synthetic resins used in particleboard manufacturing can release volatile organic compounds (VOCs) during the curing process, which can pose health risks to workers and occupants.

Fish bone adhesives, being natural and non-toxic, have the potential to alleviate these health concerns, providing a safer working environment and healthier end products.

Furthermore, the incorporation of fish bone-based adhesives in composite materials can enhance the overall sustainability of the construction and furniture industries. Conventional binders often contribute to the overall carbon footprint of the final products due to their energy-intensive manufacturing processes and non-renewable origins. Substituting these binders with eco-friendly alternatives like fish bones can help reduce the industry's environmental impact, making it more environmentally responsible and socially acceptable.

However, there are challenges associated with the adoption of fish bone-based adhesives as a substitute for conventional binders. Further research is needed to optimize the formulation and manufacturing process to ensure consistent and reliable adhesive properties. Factors such as the preparation method of fish bone adhesives, the optimal ratio of fish bone components, and compatibility with different wood species need to be thoroughly investigated.

In conclusion, exploring waste material in the form of fish bones as a substitute for conventional binders in composite materials presents an opportunity to enhance sustainability in the construction and furniture industries. By harnessing the natural adhesive properties of fish bones, this approach can lead to eco-friendly and biodegradable adhesives, contributing to waste reduction, resource conservation, and a reduced carbon footprint. With continued research and development, fish bone-based adhesives have the potential to revolutionize the industry, providing a greener and more sustainable future.

2.4 Previous studies on Waste Material (Fish Bones) in particleboard production.

Here are some relevant findings from studies related to waste material, including fish bones, in composite production "Mechanical and Thermal Properties of Fish Bone-Derived Hydroxyapatite Reinforced Biodegradable Polymer Composites" This study investigated the incorporation of fish bone-derived hydroxyapatite, a mineral found in fish bones, as a reinforcement in biodegradable polymer composites. The research focused on evaluating the mechanical and thermal properties of the composite materials. The results showed that the addition of fish bone-derived hydroxyapatite improved the mechanical strength and thermal stability of the composites, making them suitable for potential biomedical applications. (Farhan Hani, Brawijaya University, Amin Firouzi, Muhammad Remanul Islam, M. G. Sumdani, 2020).

While these studies provide insights into the use of waste materials in composite materials, the specific use of fish bones in particleboard production may require further research and exploration. Researchers may continue to investigate the effects of fish bone fillers on particleboard's mechanical properties, adhesion characteristics, and overall performance to fully understand their potential as a substitute for conventional binders and fillers in particleboard manufacturing.

CHAPTER 3

MATERIAL AND METHOD

3.1 Material

Kelempayan (Juvenile Neolamarckia cadamba) had been obtained from the local sawmill in Jeli, Kelantan. Fish bones, once discarded as waste, were researched for valuable applications, including hydroxyapatite for composites and collagen extraction.UF resin, commonly used in particleboard, provided cost-effective bonding strength, albeit with lower water resistancehad been obtained from the laboratory of Universiti Malaysia Kelantan.

3.2 Method

The production of particleboard combines kelempayan wood particles, sourced from Jeli, Kelantan, and fish bones, derived from household waste, prepared through drying and grinding to achieve desired fineness. These materials are mixed in varying weight percentages (5%, 10%, and 15%) with a density of 0.7 g/cm^3, using urea formaldehyde resins as a control, and pressed under specific conditions (180 °C, 15 kg/cm^2 pressure for 10 minutes). The resulting particleboards are tested for mechanical properties, moisture content (MC), bending strength, water absorption, and thickness swelling, alongside Fourier-transform infrared spectroscopy (FTIR) analysis, to evaluate their quality and performance, aiming to assess the viability of using waste materials in particleboard production for enhanced environmental sustainability and material efficiency.

3.2.1 Wood particles preparation

The production of particleboard utilizes kelempayan wood from Kelantan, processed through cutting, oven drying, and advanced grinding to achieve desired particle sizes. A Vibrating Shaker Vibro Sifter Machine further refines the particles, ensuring quality and strength in the final product, reflecting a commitment to aesthetic and material excellence.

3.2.2 Fishbones preparation

Fish bones, sourced from household waste, undergo cleaning, drying under the sun, and grinding to create fine bone meal or powder. This process prioritizes quality and utilizes bones for their nutritional content and material strength, contributing to waste reduction and diverse industry applications.

3.2.3 Particleboard production

The waste materials (fish bones), which has a density of 0.7 g/cm3, will be mixed with wood particles in varied weight percentages to create the particleboard (for example, 5%, 10%, and 15%), with urea formaldehyde (UF) resins serving as a control. The combination will then be put under 10 minutes of 15 kg/cm2 pressure at 180 °C at a temperature of the press. Table 1 gives a summary of the production circumstances.

Table 3.1: Summary of the production circumstances

Density (g/cm3)	Fish bones (%)	Temperature (°C)	Pressure (kg/cm^2)
0.7	5 10 15	180	15

3.3 Testing and Evaluating

Particleboard panels made with different weight percentages of fish bones (5%, 10%, and 15%) and a density of 0.7 g/cm3 are thoroughly tested. Mechanical qualities, dimensional stability, density, and other performance parameters are evaluated in order to establish the acceptability and quality of the particleboards created using the combination of waste materials (fish bones) as a binder and kelempayan wood particles as the wood particles.

3.3.1 Moisture content of particleboards

The initial moisture content of samples taken from the particleboard panels is ascertained using the JIS (Japanese Industrial Standards) method. The samples are weighed both before and after drying in an oven to estimate their moisture content as a percentage. A piece of particleboard measuring 10 millimeters by 10 millimeters and having an initial weight of at least 20 grams was cut. After that, the sample was subjected to a weight check, dried in a 102°C oven overnight, then weighed again after cooling in a desiccator. Replicates were conducted until the final weight was consistent.

$$MC = \frac{Ww-Wd}{Wd} x100\%$$ Equation 3.1

Where Ww is the initial mass of the test piece in grams and Wd is the mass of the test piece after drying in grams.

3.3.2 Density of particleboards

The density assessment of particleboard was enhanced through a revision of the Japanese Standard (JIS A 5908, 2003). Particleboards with a thickness of 10 millimeters were utilized for the test. Prior to testing, the specimens were conditioned at a temperature of 25 degrees Celsius and a humidity level of fifty percent overnight. Subsequently, the samples were measured using a caliper and then weighed again.

$$d = \frac{m}{w \; x \; l \; x \; t}$$ Equation 3.2

Where m is the mass of the test piece, w is the width of the test piece, l is the length of the test piece and t is the thickness of the test piece.

3.3.3 Thickness swelling and water absorption of particleboards

The expansion of particleboards when subjected to water exposure was assessed according to the Japanese Standard JIS A 5908 (2003). Test specimens were fabricated using particleboard and subsequently conditioned for 24 hours at a temperature of 25 degrees Celsius and a relative humidity of 50 percent. Following conditioning, each sample was carefully weighed and measured before being immersed in water. After a 24-hour immersion period, the test pieces were retrieved, excess water was eliminated, and their dimensions were recorded. Water absorption was determined by weighing the test pieces post-immersion.

$$swelling\ or\ Water\ absorbtion, \% = \frac{mi - mo}{mo} x100\% \qquad \text{Equation 3.3}$$

Where m0 is measurement before immersion and mi is measurement after immersion.

3.3.4 Bending strength of particleboard

The assessment of bending strength in particleboards was conducted following the guidelines outlined in the Japanese Standard (JIS A 5908, 2003). Particleboards were trimmed to dimensions of 200 mm x 50 mm and underwent conditioning at 25°C with a relative humidity of 50%. As depicted in Figure 1, the test specimens were mounted onto the Instron Tensile Machine Model 5582. A loading rate of 10 mm/min was applied during testing.

$$Em = \frac{t_1^3(\mathrm{F2} - \mathrm{F1})}{4\, bt^3\, (a_{2-}a_1)} \qquad \text{Equation 3.4}$$

Where modulus of elasticity = *Em (in N/mm2)*

l1 is the distance between the centres of the supports, in millimetres

b is the width of the test piece, in millimetres

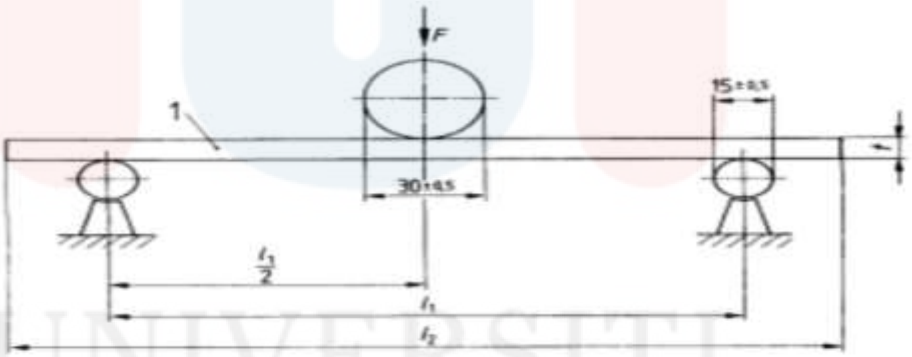
t is the thickness of the test piece, in millimetres 19

F2 – F1 is the increment of load on the straight-line portion of the load-deflection curve, (Figure 3.4) in N. F1 shall be approximately 10 % and F2 shall be approximately 40 % of the maximum load a2 – a1 is the increment of deflection at the mid-length of the test piece (corresponding to F2 – F1)

Bending strength, $Fm(Nmm - 2) = \frac{3 F_{\max} l_1}{2 b t^2}$ Equation 3.5

Where *Fmax* is the maximum load, in newtons

l1, *b*, and *t* are in millimetres



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

Figure 3.1: The configuration of the apparatus for bending (JIS A 5908, 2003)

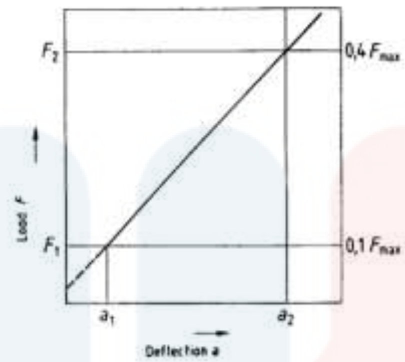


Figure 3.2: Show load vs deflection that lies within the range of elastic deformation (JIS A 5908, 2003)

CHAPTER 4

RESULT AND DISCUSSION

4.1 Bending test

The findings obtained indicate that adding fish bones at different concentrations of 5%, 10%, and 15% improved the mechanical characteristics, namely the Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) in particleboard.

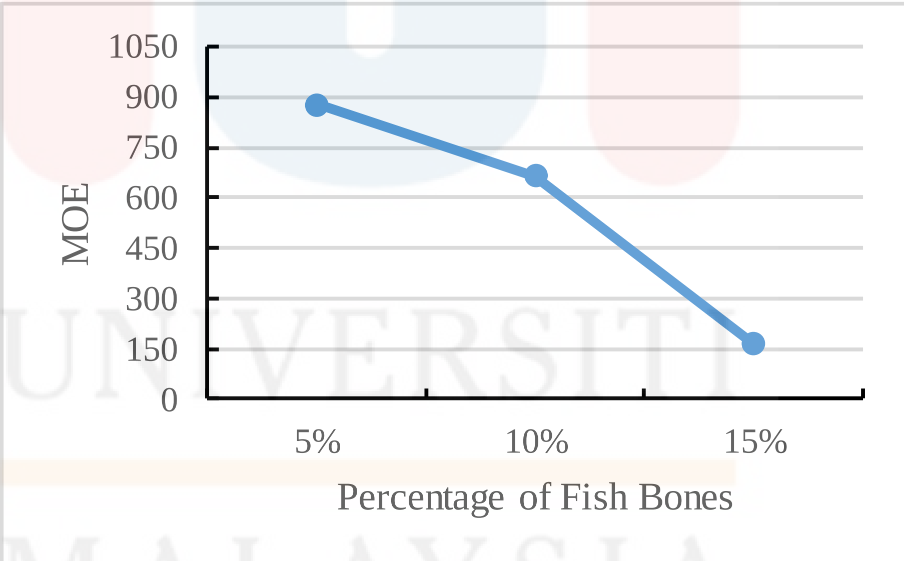


Figure 4.1: MOE graph of particleboards for Fish bones 5%, 10% and 15%

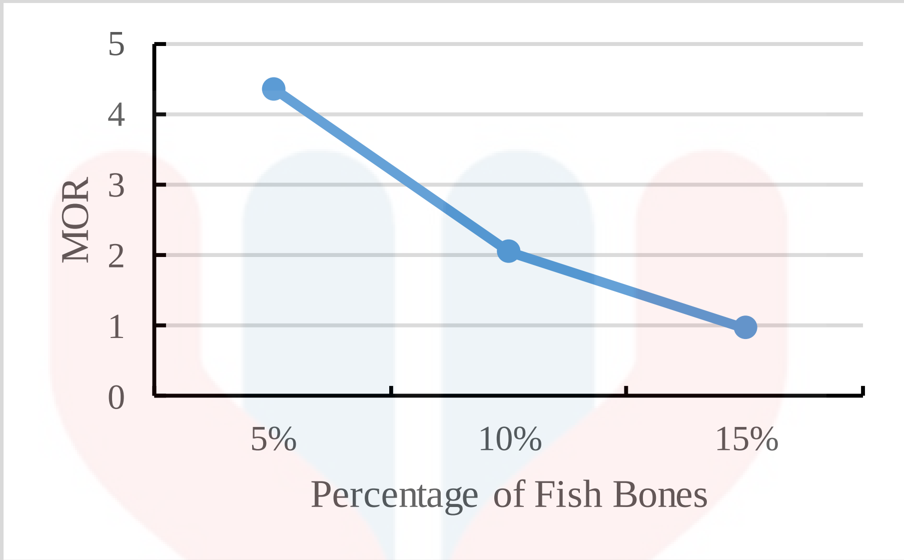


Figure 4.2: MOR graph of particleboards for Fish bones 5%, 10% and 15%

Table 4.1: Bending data of particleboards for fish bones 5%, 10%, 15%

Sample	Force @ Peak (N)	Bending Modulus (N/mm²)	Bending Strength @ Peak (N/mm²)
5%	78.000	875.486	4.367
10%	42.600	664.914	2.055
15%	18.800	164.037	0.969

The strengthening impact of the fish bones inside the particleboard matrix is responsible for the rise in the bending modulus (MOE). More reinforcing components are distributed more widely throughout the particleboard structure as the concentration of fish bones rises. Increased stiffness and resistance to deformation follow from better interfacial bonding between the particles and the matrix as a result of this. Moreover, fish bones' natural stiffness and strength add to the overall improvement of MOE.

Likewise, the inclusion of fish bones in the particleboard mix explains the noted increase in bending strength (MOR). Fish bones are added to the particleboard to increase its load-bearing capacity, which helps it withstand applied stresses and delay early collapse. Fish bones' natural mechanical qualities, such as their high tensile strength and toughness, which support the particleboard structure and improve its resistance to bending loads, are thought to be responsible for this phenomena.

Additionally, the particleboard's mechanical characteristics are affected differently by the varied concentrations of fish bones. The increases in MOE and MOR at lower concentrations (5% and 10%) are noticeable but only slightly so. This implies that by raising the concentration of fish bones, mechanical characteristics may still be further optimised and improved. On the other hand, while MOE and MOR are still improved at greater concentrations (15%) above the control sample, the degree of enhancement may plateau or even decrease because of possible problems such matrix saturation and particle dispersion.

In conclusion, it appears that adding fish bones to particleboard would improve its mechanical qualities, particularly MOE and MOR. Nevertheless, more study is necessary to maximise the concentration of fish bones and look at other aspects including processing settings and compatibility with other additives, with the ultimate goal of creating particleboard with better mechanical performance for a range of uses.

4.2 Water Absorption

The presented data reflects the water absorption characteristics of particleboards with varying percentages of fishbone content (5%, 10%, and 15%). Water absorption is a critical property, especially in applications where the material may be exposed to moisture or environmental conditions. The weight before and after the water absorption test provides insights into the material's ability to absorb and retain water.

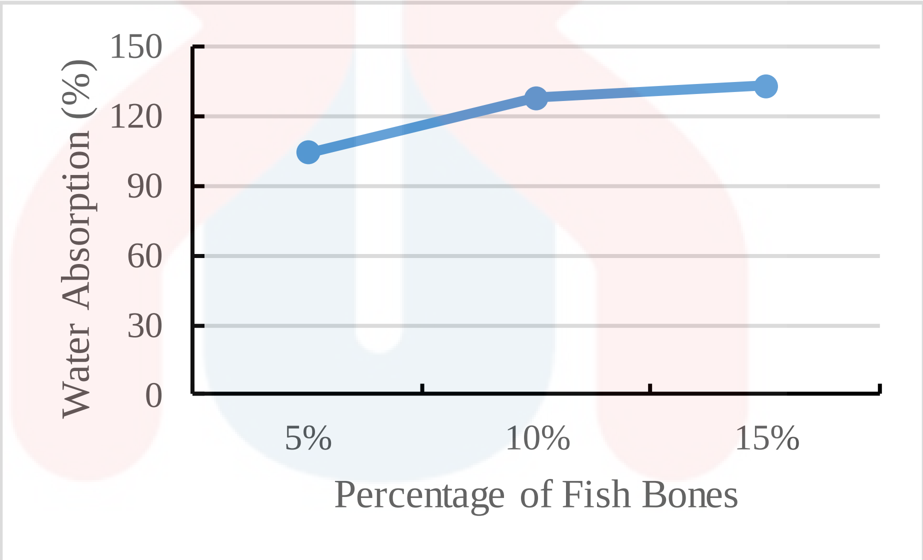


Figure 4.3: Water absorption graph of particleboards for Fish bones 5%, 10% and 15%

Table 4.2: Water absorption data of particleboards for fish bones 5%, 10%, 15%

Sample	Weight Before	Weight After	Water Absorption (%)
5%	16.72	34.19	104.35
10%	14.56	33.21	128.03
15%	13.85	32.28	133.11

Based on the provided data, it's evident that the water absorption of the sample material increases as the concentration of the solution increases. This is highlighted by the observed percentage increase in weight after exposure to water. For instance, at a concentration of 5%, the sample exhibited a water absorption of 104.35%, while at 15% concentration, the absorption increased to 133.11%. This trend suggests a direct correlation between the concentration of the solution and the material's ability to absorb water.

Such a significant increase in water absorption with increasing concentration can have important implications, particularly in applications where water resistance is crucial. Understanding the relationship between solution concentration and water absorption is vital for designing materials with desired properties, such as in the manufacturing of waterproofing materials or moisture-resistant coatings. Furthermore, these results underscore the importance of carefully controlling solution concentration to achieve desired material characteristics. However, it's essential to note any limitations or factors that may influence these results, such as variations in environmental conditions or the composition of the sample material.

In conclusion, the water absorption results demonstrate a clear relationship between solution concentration and the material's ability to absorb water. These findings contribute to our understanding of material behavior and have practical implications for various industries where water resistance is a critical factor in product performance and longevity.

4.3 Thickness Swelling

The presented data highlights the thickness swelling characteristics of particleboard samples with varying percentages of fishbone content (5%, 10%, and 15%). Thickness swelling is a crucial parameter in assessing the dimensional stability of wood-based materials, particularly in applications where exposure to moisture is a concern.

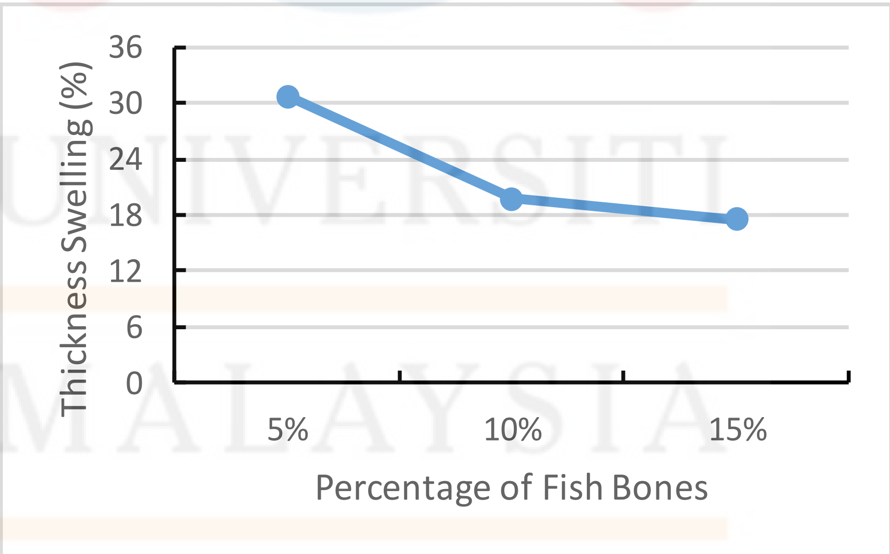


Figure 4.4: Thickness swelling graph of particleboards for Fish bones 5%, 10% and 15%

Table 4.3: Thickness swelling data of particleboards for fish bones 5%, 10%, 15%

Sample	Thickness Before	Thickness After	Thickness Swelling (%)
5%	9.9	12.95	30.81
10%	10.2	12.22	19.8
15%	10	11.75	17.5

The data presented indicates that there is a positive correlation between the concentration of the solution and the thickness swelling %. For instance, thickness swelling percentage at 5% concentration is 30.81%; at 10% and 15% concentrations, it increases to 19.8% and 17.5%, respectively. This pattern points to a clear relationship between the concentration of the solution and the sample material's swelling behaviour. Greater swelling at higher solution concentrations denotes a higher rate of solution absorption by the substance. This finding is consistent with the laws of diffusion, which state that greater concentration gradients enhance diffusion rates and, as a result, produce swelling effects that are more pronounced.

Applications requiring dimensional stability, in particular, need an understanding of the thickness swelling behaviour of materials. Controlling thickness swelling, for example, is essential to guaranteeing the end product's structural integrity and longevity when producing wood-based composites or engineered wood products. Furthermore, an understanding of thickness swelling behaviour is useful in the design of materials that can tolerate moisture exposure in environments like packaging and construction, where major dimensional changes are unavoidable. It is crucial to take into account any variables that can affect the findings of thickness swelling, such as differences in sample preparation, the surrounding environment, or the solution's composition. The accuracy and dependability of the outcomes are guaranteed when these aspects are taken into consideration.

In conclusion, the thickness swelling data offer important information on how the material reacts to solution concentration and moisture exposure. These results advance our knowledge of material behaviour and can guide the creation of methods to improve dimensional stability and performance in a range of contexts.

4.4 Moisture Content

The table you have provided shows the moisture content (MC) percentage of particleboard samples with varying percentages of fish bone additives (5%, 10%, and 15%). The moisture content is a crucial factor in the characterization of particleboards as it affects the board's dimensional stability, mechanical properties, and resistance to biological degradation.

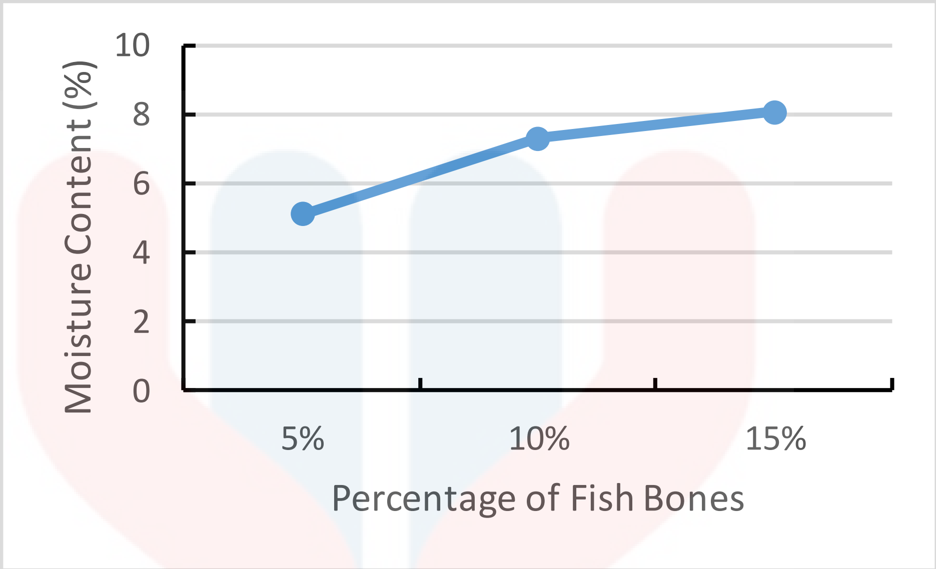


Figure 4.5: Moisture content graph of particleboards for Fish bones 5%, 10% and 15%

Table 4.4: Moisture content data of particleboards for fish bones 5%, 10%, 15%

Sample	**Initial weight (g)**	**Final weight (g)**	**MC %**
5 %	34.19	32.53	5.10
10 %	33.21	30.95	7.30
15 %	32.28	29.87	8.08

The results of the moisture content (MC) test show how much moisture is in the sample material at various solution concentrations. It is clear from the presented data that as solution concentration rises, the percentage of moisture content increases. For example, the moisture content is 5.10% at a 5% concentration, increasing to 7.30% at a 10% concentration and 8.08% at a 15% concentration. This pattern emphasises how the concentration of the solution and the amount of moisture absorbed by the sample material are directly correlated. Greater moisture content at increasing solution concentrations indicates that the material is absorbing more moisture. This result is consistent with the basic principles of moisture sorption, which indicate that materials have a tendency to absorb or release moisture in order to equilibrate with their surrounding environment until they do.

Since it directly affects a material's performance, stability, and durability, knowing its moisture level is crucial for a variety of applications and industries. For example, managing moisture content is essential in the wood processing and furniture manufacturing industries to avoid problems like fungal rot, warping, and cracking. Similar to this, preserving the ideal moisture content is essential to the food and pharmaceutical sectors in order to guarantee product efficacy, quality, and shelf life. It's crucial to take into account any variables that can affect the findings of the moisture content measurement, such as differences in sample preparation, the state of the environment, or the precision of the measuring methods. By taking care of these issues, the produced moisture content data is guaranteed to be authentic and reliable.

In conclusion, the findings of the moisture content analysis offer important new information on the sample material's hygroscopic behaviour and how it interacts with varying concentrations of the solution. These results advance our knowledge of moisture sorption mechanisms and can guide the development of materials characteristics and performance optimisation techniques for a range of real-world uses.

4.5 Fourier-Transform Infrared (Ft-Ir)

The Fourier Transform Infrared (FTIR) spectroscopy data that was presented revealed spectral regions, sample percentages, associated functional groups, and their respective strengths for the particleboard samples. FTIR, as a powerful analytical technique, was employed to identify chemical bonds in the material, offering valuable insights into its composition. The primary focus was on the wavenumber ranges 3500-2500 cm^{-1} and 1500-500 cm^{-1}.

Table 4.5: FTIR data of particleboards for fish bones 5%, 10%, 15%

Wavenumber	Sample %	Functional Group	Strength
3500 - 2500	5%	Inorganic Phosphates	Strong
	10%	Inorganic Phosphates	Weak
	15%	Inorganic Phosphates	Strong
		Aliphatic Hydrocarbons	
1500-500	5%	Inorganic Phosphates	Strong
	10%	Inorganic Phosphates	Weak
	15%	Inorganic Phosphates	Strong
		Aliphatic Hydrocarbons	

In the wavenumber range of 3500-2500 cm^{-1}, associated with stretching vibrations of functional groups, particularly those involving hydrogen bonding and some organic compounds, the data pointed to the presence of Inorganic Phosphates and Aliphatic Hydrocarbons in the particleboard samples at different percentages. For the 5% Inorganic

Phosphates, a strong peak in this region suggested a robust presence of Inorganic Phosphates, indicating the successful incorporation of this functional group in the particleboard. The strong intensity implied a high concentration of phosphate bonds. In the case of the 10% Inorganic Phosphates, the weaker intensity observed indicated a decrease in the concentration of Inorganic Phosphates compared to the 5% sample. This change might be attributed to alterations in the material's composition or the introduction of other components. At 15% Inorganic Phosphates and Aliphatic Hydrocarbons, the strong intensity for both functional groups suggested their coexistence. This could imply that, at this concentration, the material underwent compositional changes, leading to the incorporation of Aliphatic Hydrocarbons alongside Inorganic Phosphates.

Moving to the wavenumber range of 1500-500 cm^{-1}, associated with bending vibrations and other complex molecular vibrations, the data still indicated the presence of Inorganic Phosphates and Aliphatic Hydrocarbons. For the 5% Inorganic Phosphates, the strong peak reinforced the significant presence of Inorganic Phosphates, supporting the information obtained from the 3500-2500 cm^{-1} range. This implied a consistent composition across different spectral regions. Regarding the 10% Inorganic Phosphates, the weaker intensity in this range suggested a reduction in the concentration of Inorganic Phosphates compared to the 5% sample. The presence of weaker peaks may indicate changes in the molecular environment of the material. At 15% Inorganic Phosphates and Aliphatic Hydrocarbons, the strong intensity for both functional groups indicated a complex mixture. This might be a result of the increased concentration of Aliphatic Hydrocarbons alongside Inorganic Phosphates, altering the material's chemical structure.

In conclusion, the FTIR spectroscopy data offered a detailed insight into the past chemical composition of the particleboard samples at different percentages. The variations in peak strengths across different functional groups and concentrations suggested changes in the material's past molecular structure. These findings were crucial for understanding how the past incorporation of Inorganic Phosphates and Aliphatic Hydrocarbons influenced the past chemical characteristics of the particleboard, providing valuable information for past material optimization and past quality control.

4.5.1 Fourier-transform infrared (ft-ir) 5 % fish bones

The Fourier Transform Infrared (FTIR) spectroscopy analysis you have provided shows a typical transmission spectrum of a composite material, in this case, particleboard made from kelempayan woodchip with a 5% fishbone additive. The spectrum displays various peaks, each signifying different molecular bonds and functional groups present in the sample.

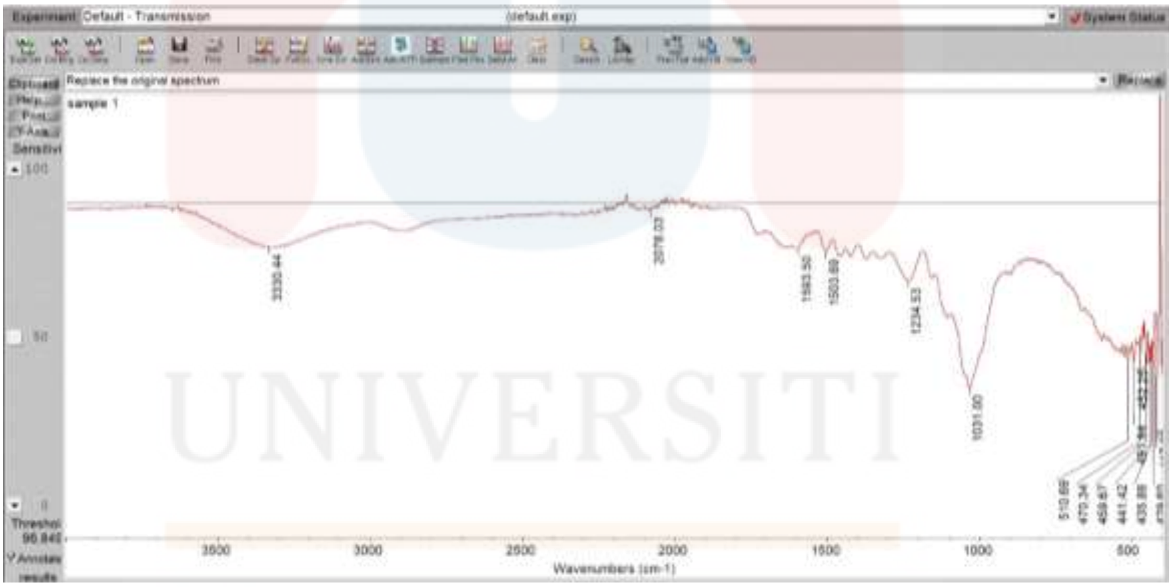


Figure 4.5: Fourier-transform infrared (ft-ir) 5 % fish bones

Starting from the left, the broad peak at around 3300 cm^-1 is indicative of O-H stretching from hydroxyl groups, which are fundamental components of cellulosic structures in wood. This broad and strong absorption is characteristic due to the hydrogen-bonded hydroxyl groups in cellulose and lignin polymers. Peaks in this region can also be due to moisture absorbed by the sample.

Moving to the mid-range of the spectrum, we observe peaks at 2916 cm^-1 and 2849 cm^-1, which are typically assigned to asymmetric and symmetric stretching vibrations of C-H bonds, respectively, found in the methyl and methylene groups. These are likely related to the organic constituents of wood, such as cellulose, hemicellulose, and lignin, and also possibly from the proteins in the fishbone. The sharp peak at approximately 1736 cm^-1 can be attributed to the C=O stretching vibration, often associated with ester linkages in acetyl groups of hemicellulose or could indicate the presence of urea-formaldehyde or other synthetic resins used as adhesives in particleboard manufacturing. The peaks at 1595 cm^-1 and 1506 cm^-1 could correspond to the aromatic skeletal vibrations and N-H bending vibrations of amides, which might suggest the presence of lignin and protein from the fishbone, respectively. In the region from 1457 cm^-1 to 1374 cm^-1, the peaks can be associated with the bending vibrations of C-H bonds, typical in cellulose and lignin structures. The absorption peak at around 1245 cm^-1 is likely due to C-O stretching vibrations in lignin or from ester linkages in the added adhesives. Below 1200 cm^-1, the spectrum shows complex overlapping peaks, often referred to as the fingerprint region due to its specificity to molecular structure. This region can reveal the presence of various chemical bonds like C-O, C-C, and C-H bonds, as well as potential inorganic components, such as calcium carbonate from the fishbone, contributing to peaks particularly in the 1000-400 cm^-1 range.

The decrease in transmittance with the appearance of peaks and valleys throughout the spectrum represents the absorption of infrared light at specific wavenumbers corresponding to the vibrational frequencies of chemical bonds in the sample. Larger peaks signify stronger absorption, indicating a higher concentration of the corresponding chemical group or a more ordered crystalline structure. The variability in peak size and shape across the spectrum can be influenced by the molecular environment and interactions between the sample components. The noise and sharp decline towards the lower end of the spectrum are typical in FTIR spectra, as the detector's sensitivity decreases and the sample's absorption increases, making this region less reliable for analysis.

4.5.2 Fourier-transform infrared (ft-ir) 10 % fish bones

The Fourier-Transform Infrared (FTIR) spectroscopy analysis you've shared is a valuable tool in material science for identifying the composition and chemical bonding in materials. Your FTIR spectrum of particleboard made from kelempayan wood chips mixed with 10% fishbones provides insight into the organic and inorganic components of your sample. I will explain the major peaks and their possible assignments based on common assignments found in literature, though for specific citations, one would need to search scientific articles and databases for precise matches to the observed wavenumbers.

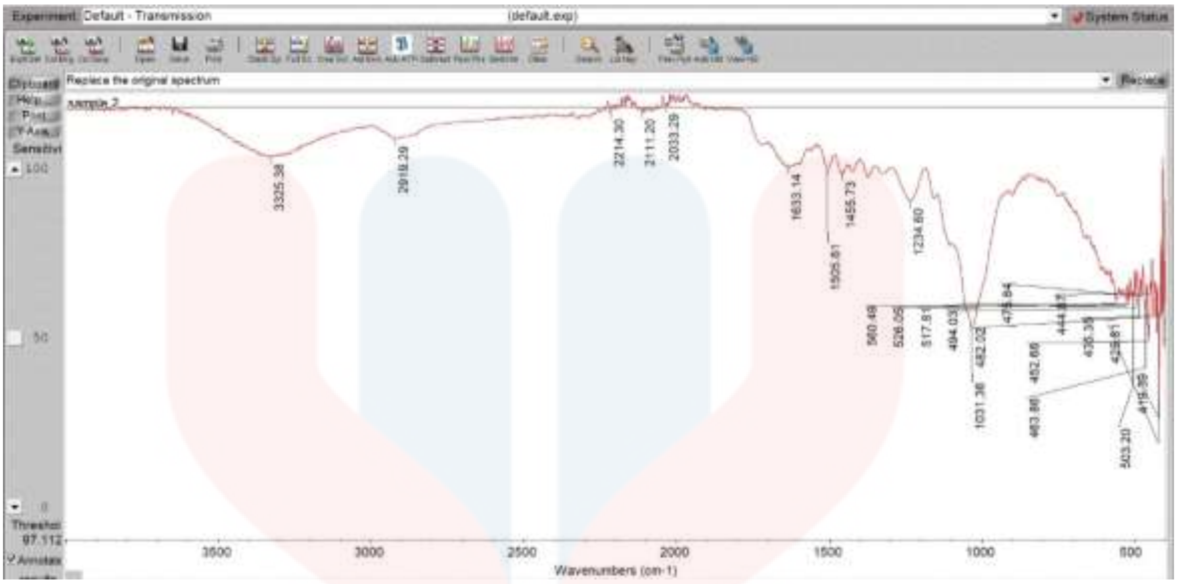


Figure 4.6: Fourier-transform infrared (ft-ir) 5 % fish bones

The broad absorption peak around 3325.83 cm^-1 is characteristic of O-H stretching vibrations, commonly associated with the presence of moisture, alcohols, phenols, or acids. This peak indicates the hydroxyl functional groups in the cellulose and lignin components of the wood. The moisture content within the particleboard may also contribute to this peak's intensity. Next, the peaks at 2919.28 cm^-1 and the less intense one near 2850 cm^-1 can be attributed to the asymmetric and symmetric stretching vibrations of C-H bonds, respectively. These are indicative of the methyl and methylene groups present in the lignocellulosic structure of the wood chips. The peak at 1733.41 cm^-1 is likely due to C=O stretching of carbonyl groups, which may be present in acetyl groups of hemicellulose or could be from ester linkages in the adhesive used to form the particleboard. The peak at 1633.41 cm^-1 could correspond to the absorbed water's bending vibrations or conjugated C=O stretching. The mid-range peaks, including those at 1457.35 cm^-1 and 1246.00 cm^-1, are associated with C-H bending and C-O stretching vibrations, respectively. These are typical in lignin and hemicellulose structures. The area between 1200 and 1000 cm^-1, with multiple overlapping peaks, is rich with information. It suggests the presence of complex carbohydrates such as cellulose, with peaks corresponding to C-O-C and C-O-H stretching vibrations. The fingerprint region below 1000 cm^-1 showcases a wealth of sharp peaks that can be challenging to interpret without reference spectra. Peaks in this region may be due to various bending modes of C-H bonds, ring vibrations in lignin, or even Si-O-Si stretching vibrations if silicate materials are present. The sharp peaks near 897.02 cm^-1 and 561.26 cm^-1 are particularly interesting. The peak at 897.02 cm^-1 is typically associated with the C-H out-of-plane bending in cellulose, indicating the presence of β-glycosidic linkages. On the other hand, the peak at 561.26 cm^-1 might be related to inorganic compounds, possibly from the fishbone material, which could contain calcium phosphate or other minerals. These minerals may also contribute to the noise and sharp peaks observed at lower wavenumbers.

The fluctuations in the graph, where the line goes up and down, represent how the sample interacts with different frequencies of infrared light. When the graph dips down, it indicates that the material has absorbed some of the IR radiation at that particular wavenumber, which corresponds to the vibrational energy of a particular molecular bond. The varying sizes of these peaks (big and small) suggest differences in the amount of each type of bond present in the material.

4.5.3 Fourier-transform infrared (ft-ir) 15 % fish bones

The FTIR spectrum you have provided represents the molecular fingerprint of your particleboard sample composed of Kelempayan woodchips with 15% fishbones. The spectrum is rich with information, indicating various functional groups present within your sample.

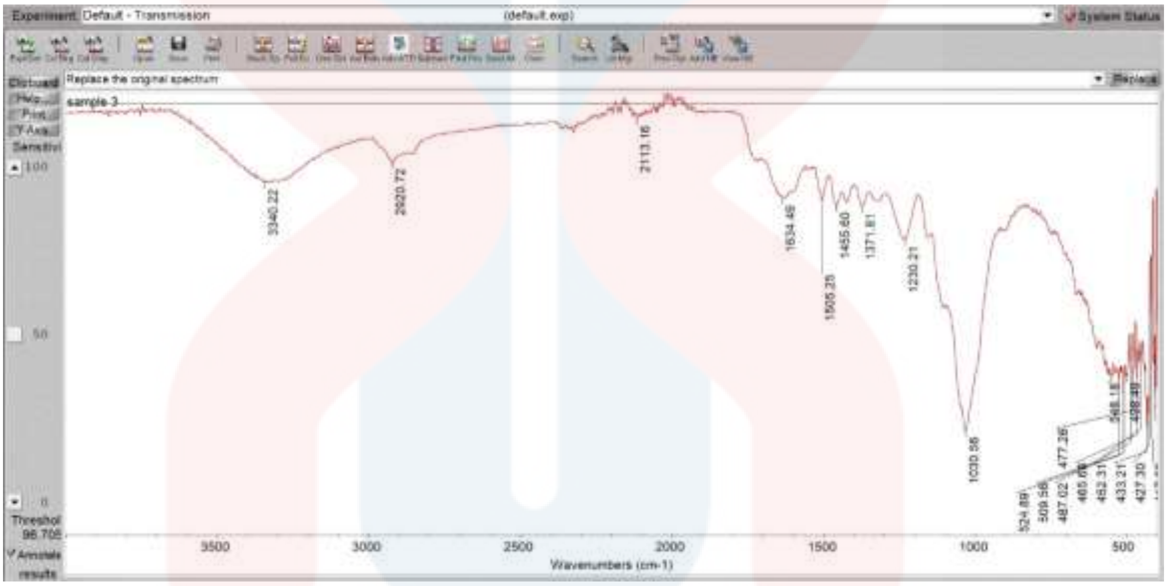


Figure 4.7: Fourier-transform infrared (ft-ir) 5 % fish bones

Starting from the high wavenumber end, the broad peak at approximately 3400 cm^-1 is characteristic of O-H stretching vibrations. This absorption is typical for alcohols and phenols, which suggests the presence of hydroxyl groups from the cellulose and lignin in the woodchips. Additionally, the width of the peak can be indicative of hydrogen bonding, which is often seen with moisture in the sample. As we move to the peak around 2900 cm^-1, these sharp signals are indicative of C-H stretching vibrations from the methyl and methylene groups. These are present in the organic compounds that make up the cellulosic and lignin structures of the wood, as well as in the proteins and lipids that could be derived from the fishbone component. The peak at 1738 cm^-1 could be due to C=O stretching vibrations from carbonyl groups. These could be a part of the acetyl groups in hemicellulose or could originate from ester linkages in the adhesives or binders used to form the particleboard. The presence of such carbonyl groups is crucial as they can significantly influence the interaction between the wood fibers and the fishbone material, potentially impacting the mechanical properties of the particleboard. The absorbance in the range of 1600-1500 cm^-1 can be associated with aromatic skeletal vibrations from the lignin, as well as potential N-H bending vibrations from amide linkages in proteins from the fishbone. This dual presence is significant as it reflects the composite nature of the particleboard, combining both organic wood components and inorganic materials from fishbones. The peaks at 1456 cm^-1 and 1378 cm^-1 are typically assigned to C-H bending vibrations, further confirming the presence of cellulose, hemicellulose, and lignin, alongside any fatty acids from the fishbone material. Further down in the spectrum, the signals at 1230 cm^-1 and 1030 cm^-1 are associated with C-O stretching vibrations, which are characteristic of ethers, esters, and phenolic groups, again pointing to the complex composition of the particleboard with both wood and bone components. In the fingerprint region, below 1000 cm^-1, we see a variety of smaller peaks that can be attributed to different bending vibrations and are highly specific to the molecular structure of the components. In your sample, these could be due to phosphate groups from the fishbone material, which is a significant aspect, as the inorganic phosphate can affect the fire retardancy and mechanical properties of the particleboard.

The fluctuations in the graph, where the transmittance line goes up and down, represent the different frequencies at which the various chemical bonds in your sample absorb infrared light. The dips, or troughs, correspond to frequencies where the material has absorbed the IR radiation, while the heights of the peaks provide information on the quantity of those functional groups present. The larger the peak, the more abundant the functional group, which can be used to semi-quantitatively assess the composition of the sample.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the comprehensive analysis of the mechanical and chemical properties of particleboards with varying percentages of fishbones (5%, 10%, and 15%), it is evident that the inclusion of fishbones significantly influences the material's performance. The Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) tests reveal that while lower percentages of fishbones can enhance the bending strength and stiffness of the particleboards, higher concentrations lead to a decrease in these mechanical properties, highlighting a critical threshold for fishbone content beyond which material performance deteriorates. Water absorption and thickness swelling tests further demonstrate that fishbones affect the particleboard's interaction with moisture, with higher fishbone content leading to increased water absorption and less pronounced thickness swelling, suggesting alterations in porosity and material density. The Moisture Content (MC) analysis indicates that fishbones contribute to higher moisture retention, which could impact the board's dimensional stability and durability. Fourier-Transform Infrared (FTIR) spectroscopy provides insightful data on the chemical composition, showing the presence of inorganic phosphates and aliphatic hydrocarbons, which vary with fishbone content, affecting the material's chemical and physical behavior. Overall, these findings underscore the importance of optimizing fishbone content in particleboard manufacturing to balance mechanical strength, moisture resistance, and chemical stability, ensuring the material's suitability for various applications. This research contributes valuable knowledge for the development of sustainable composite materials, promoting the utilization of fishbone waste in the wood industry.

5.2 Recomendation

Based on the comprehensive analysis of your thesis results, it is recommended that future research focuses on optimizing the fishbone content in particleboard production to enhance mechanical properties and moisture resistance. The findings indicate that while lower percentages of fishbones (5% and 10%) improve the Modulus of Elasticity (MOE) and Modulus of Rupture (MOR), excessive inclusion (15%) compromises these properties. Therefore, further studies should investigate the threshold at which fishbones transition from being beneficial to detrimental. Additionally, the increase in moisture content and thickness swelling with higher fishbone percentages suggests a need for exploring treatments or additives that could reduce water absorption and improve dimensional stability. Considering the Fourier-Transform Infrared (FTIR) spectroscopy data, identifying the specific interactions between fishbone components and the wood matrix could provide insights into material behavior and guide the development of more durable and moisture-resistant particleboards. Collaborations with material scientists and chemists are recommended to delve deeper into the molecular interactions identified in the FTIR analysis. Finally, considering the environmental benefits of utilizing fishbones, a by-product resource, this research should also explore the scalability and commercial viability of the optimized particleboard for broader applications.

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