The Effect of Different Tree Section on The Physical and Chemical Properties of Rubberwood (*Hevea brasiliensis*)

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DECLARATION

I declare that this thesis entitled "The Effect of Different Tree Section on The Physical and Chemical Properties of Rubberwood (*Hevea brasiliensis)*" is the results of my own research except as cited in the references.

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The Effect of Different Tree Section on The Physical and Chemical Properties of Rubberwood (*Hevea brasiliensis*)

ABSTRACT

The use of wood-based products is determined by the inherent physical and chemical characteristics. This study has specifically investigated the species *Hevea brasiliensis*, where the tree trunk is divided into three parts of different heights (top, middle and bottom) and wood disc samples are collected from each part to investigate Near Pith (NB), Intermediate (I) and Near Bark (NB) is in the evaluation of physical and chemical properties. Samples were used for physical and chemical analysis according to the standards set by the Pulp and Paper Technical Association Industry USA (TAPPI) T 208 om-94 (1996). The statistical analysis of this study shows that both tree section and radial position have a significant influence on physical properties. The specific gravity of rubberwood is high at the bottom, followed by the middle and top. The moisture content of this tree species increases progressively from bottom to top. Likewise, the chemical composition is relatively consistent throughout its height in terms of moisture content, extractives, holocellulose, cellulose, hemicellulose, and lignin. However, the degree of variation between the top, middle and bottom can be specified. Finally, a survey was conducted to ascertain the exact physical and chemical properties of the various tree species and components. This information is then used to distinguish parts of the tree that can be used efficiently for various objective.

Keywords: Rubberwood, physical properties, chemical properties

Kesan Bahagian Pokok Berbeza terhadap Sifat Fizikal dan Kimia Kayu Getah *(Hevea brasiliensis)*

ABSTRAK

Penggunaan produk berasaskan kayu ditentukan oleh ciri fizikal dan kimia yang wujud. Kajian ini telah menyiasat secara khusus spesies *Hevea brasiliensis*, di mana batang pokok dibahagikan kepada tiga bahagian ketinggian yang berbeza (atas, tengah dan bawah) dan sampel cakera kayu dikumpul dari setiap bahagian untuk menyiasat Dekat Empulur (NB), Pertengahan (I) dan Dekat Kulit Kayu (NB) adalah dalam penilaian sifat fizikal dan kimia. Sampel digunakan untuk analisis fizikal dan kimia mengikut piawaian yang ditetapkan oleh Industri Persatuan Teknikal Pulp dan Kertas USA (TAPPI) T 208 om-94 (1996). Analisis statistik kajian ini menunjukkan bahawa kedua-dua bahagian pokok dan kedudukan jejari memberi pengaruh yang besar ke atas sifat fizikal. Graviti tentu kayu getah adalah tinggi di bahagian bawah, diikuti oleh bahagian tengah dan atas. Kandungan lembapan spesies pokok ini meningkat secara progresif dari bawah ke atas. Begitu juga, komposisi kimia yang agak konsisten sepanjang ketinggiannya dari segi kandungan lembapan, ekstraktif, holoselulosa, selulosa, hemiselulosa, dan lignin. Walau bagaimanapun, tahap variasi antara bahagian atas, tengah dan bawah boleh ditentukan. Akhirnya, tinjauan telah dijalankan untuk memastikan sifat fizikal dan kimia yang tepat bagi pelbagai spesies dan komponen pokok. Maklumat ini kemudiannya digunakan untuk membezakan bahagian pokok yang boleh digunakan dengan cekap untuk pelbagai objektif.

Kata kunci: Kayu getah, sifat fizikal, sifat kimia

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Rubberwood is scientifically known as *Hevea brasiliensis* (Euphorbiaceae) in Malaysia and rubberwood is prevalent in Peninsular Malaysia, Sabah, and Sarawak. *Hevea brasiliensis* originates from rainforests in the Amazon basin, namely in South America, including Ecuador, Colombia, Peru, and Bolivia. Rubberwood typically occurs in low-lying, humid woods, swamps, and regions that have been disrupted. However, when it initially emerges within the holes in the canopy, it may be partially covered by additional trees that occupy the openings. Nonetheless, it exhibits rapid growth of rubberwood which, derived from the *Hevea brasiliensis* tree, is a tropical hardwood characterized by its moderate density and vibrant color. Common rubberwood will be cultivated in rubber plantations to yield goods for many applications. Moreover, rubberwood is recognized for its compatibility with branding due to its effective utilization of plantation trees.

According to Jegatheswaran et al. (2015), rubberwood is one of the most important plantation crops in Malaysia, and it is widely used in almost all sectors of the wood manufacturing sector. *Hevea brasiliensi*s is cultivated in the tropical zone of latex production on over 10 million hectares. Asia accounts for 97% of the world's largest natural rubber producers, and the economic lifespan of rubberwood is 20 to 30 years for the rotation period, according to Nurmi et al. (2019). Although it varies depending on specific plantation management practices and the purpose of using the wood. However, there are also some plantations that may use shorter or longer rotation times depending on the specific management practices of rubberwood that are focused on producing high quality wood for furniture. There is not enough information available regarding the ideal rotation time of the harvest year in terms of wood quality.

1.2 Problem Statement

Rubberwood has established itself as a sustainable wood source with many advantages such as rapid growth, abundant availability, and overall performance. Rubberwood is marketed as a cheap and environmentally friendly material, however there are currently major concerns about how long the supply will last (Ratnasingam et al., 2011). However, this variation has created an important challenge for optimal processing in each different part of the tree, which is the physical and chemical properties of the extensive use of rubberwood. The main challenge for rubberwood, which has great potential to add value through product diversity and design innovation where it is necessary to comprehensively understand the influence of different parts of the tree (top, middle and bottom) on the physical and chemical properties of wood in order to optimize its use and encourage practice sustainable forest management.

In a previous study, 371 furniture makers evaluated the added value of wood in the furniture industry as well as the variables that affect the productivity of value-added products (Ratnasingam et al, 2011). In order to maximize the growth of rubberwood use for industry and economy, which ensures stability and durability used in many different applications, an effective way to overcome restrictions related to rubberwood must be developed.

1.3 Objective

The objectives of this study are:

1. To examine the effect of different trunk sections (top, middle, and bottom) on the physical properties of rubberwood.
2. To examine the effect of different trunk sections (top, middle, and bottom) on the chemical properties of rubberwood.

1.4 Scope of Study

Discovering and comprehending the impact of every tree section on the characteristics of rubberwood is the aim of this research. This research will be restricted to the use of laboratories in assessing investigations including the use of machines to detect physical features as well as the use of chemicals in wood, namely 1% NaOH, NaCIO, toluene, cold water, acetic acid, acetone and another chemical reagent. Furthermore, this study will involve the chemical composition of rubberwood in different section of the tree by focusing on extractives, holocellulose, cellulose, hemicellulose and lignin to understand the chemical composition in each part, namely from the bottom, middle, and top of the *Hevea brasiliensis* species, which is rapidly growing in the use of wood nowadays.

1.5 Significances of Study

Hevea brasiliensis is a rapidly growing tree that frequently emerges in areas where there is a widening gap in the tree canopy. This phenomenon can result in the formation of shade due to the increased presence of trees that occupy the gaps in the upper layer of vegetation, leading to the creation of a more compact and opaque covering. Furthermore, commercially produced latex is a very adaptable substance with diverse applications, particularly in the context of forestry development initiatives. This is a significant matter, as it entails the establishment of a powerful message of resilience to effectively compete in terms of excellence.

The taxonomic class *Hevea brasiliensis* from the family Euphorbiaceae includes a species of light-colored, medium density rubberwood. Rubberwood has a straight grain, generally a rough, open texture, or a low natural sheen. It is 75-100 feet (23-30 m) tall, 1-3 feet (3-1 m) in trunk diameter and 75-100 feet (23-30 m) long. When being worked with, rubberwood has a pungent odor, particularly when it is still green; however, this odor is eliminated after the wood dries out. *Hevea brasiliensis* is one of the woods that may be utilized to construct some of the most beautiful and high-quality furniture in the world of carpentry. Because of its strength and flexibility, it is an ideal material to use wherever it is required, such as in the construction of business cabinets, trays, and carvings. Naturally, additional materials, such as veneer, molding, fireboard, particle board, and other engineered woods, are frequently combined with this rubberwood during the manufacturing process. It also has the potential to be used as fuel, according to the wood part which is 17.194 MJ/kg for the branches, 17.225 MJ/kg for the upper part, 17.595 MJ/kg for the middle part, and 17.702 MJ. /kg for the lower part (Quartey, 2022). Rubberwood is a high-performance tree species that has a caloric value comparable to other fuel-producing tree species and the wood specific gravity of several radial variations of hardwood trees is widely documented.

Following that, the purpose of this research is to investigate the physical and chemical properties of *Hevea brasiliensis* wood. However, rubberwood can be processed into pulp, which is then used as the main ingredient in papermaking. This technique allows rubberwood to be used in the creation of pulp. The rubberwood fibers extracted from the tree are subjected to chemical treatment resulting in the production of pulp. This pulp can then be used in the production of various paper goods (Jahan et al, 2011). The physical strength properties of pulp produced from rubberwood are superior to pulp produced from branches and mixed hardwoods. After dissecting the rubberwood into its component pieces which mostly consist of the bottom, middle and top, the next step is to identify the rubberwood. In addition, rubberwood is an appropriate replacement for a raw material that is expanding quickly and can be use in a variety of contexts. Rubberwood necessitates having access to an adequate supply of raw materials, being compatible with the processing methods that are in use today and having a physical and chemical structure that is comparable to that of wood.

CHAPTER 2

LITERATURE REVIEW

2.1 Physical Properties of Rubberwood

Rubberwood is a versatile wood that is used for various purposes, a term in the field of wood manufacturing such as furniture, flooring, and doors. It is a good choice for indoor applications as it is relatively cheap and easy to use. Therefore, it is important to note that rubberwood is not a durable wood and should not be used for outdoor applications.

According to Hossain et al. (2018), rubberwood has a reported density of 0.557 and a moisture content of 12%. Under these conditions, the specific gravity of the untreated wood panel is 0.684, which is quite like that of the treated wood panel. In contrast, Majumdar et al. (2015) contends that rubberwood has a moisture content of 63% and a volume shrinkage of 7.43%. Rubberwood with an age of 30 years has a density of 570 and 590 m3 whereas significant differences were found in moisture content, shrinkage and density between different age and height classes.

As shown in Figure 1, rubberwood has the same compressive, tensile, and bending strength as other hardwoods, such as maple, and the same hardness (6000 N). It has a good bending strength of 50MPa, which makes it suitable for applications involving bending. Therefore, when choosing rubberwood for an application, it is important to consider the factors that affect its strength (Prakash,2012).

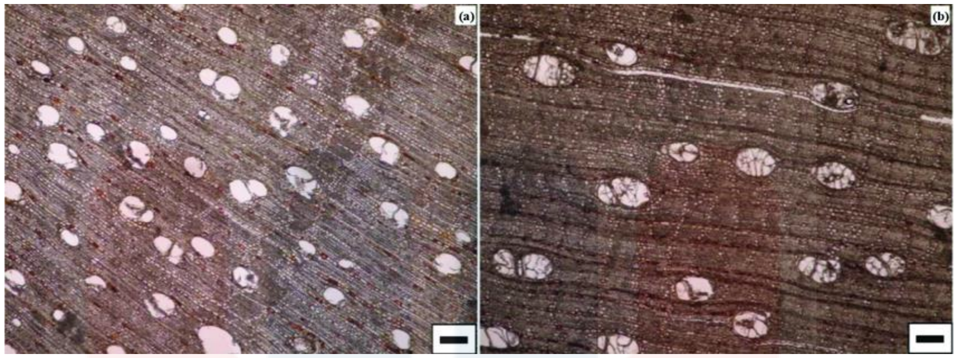

Figure 2.1: Physical Properties of Rubberwood

(Source: Longui et al, 2023**)**

2.2 Chemical Properties of Rubberwood

Gaining a comprehensive understanding of the chemical characteristics of rubberwood is crucial for maximizing its utilization. This knowledge can assist in assessing compatibility during various processing techniques. Rubberwood exhibits many chemical features such as extractive content, holocellulose, cellulose, hemicellulose, and lignin (Zhang et al., 2015).

Holocellulose is a carbohydrate fraction of biomass (lignocellulose) that includes the whole proportion of polysaccharides that remain after extractives and lignin are removed from natural sources. Cellulose is the main structural component of wood and comprises most of the chemical composition of rubberwood and cellulose provides rigidity to the wood structure which will contribute to its overall mechanical properties. The hemicellulose also acts as a matrix material, binds the cellulose fibers together, and provides flexibility, while the lignin provides rigidity, strength, and decay resistance. The low lignin content of rubberwood makes it more susceptible to degradation than other hardwoods (Zhang et al, 2015).

The of chemical and techniques that are utilized can change in accordance with the scale of the extraction as well as the result that is wanted. When treated at high temperatures with a concentrated alkaline solution, sodium hydroxide, or NaOH, is the chemical compound of choice. The hemicellulose and lignin components of the cell wall will be stripped away during this process, but the cellulose component will be preserved.

2.2.1 Decay Resistant Susceptibility to Fungal

Fungal decay occurs when there is a biological attack of wood by certain species of fungi. This happens when the wood has oxygen, moisture and nutrients with moisture being a critical component. If there is no moisture against the wood, the fungus cannot survive even if it has nutrients and oxygen. Anatomical characteristics natural chemical composition, and the presence of certain defense mechanisms are only a few of the variables that have an impact on the rubberwood decay barrier. In addition, several species of rubberwood have inherent qualities that make them more resistant to microbial deterioration. Thus, increased natural extractive concentrations such phenolic chemicals, which might inhibit fungal development and colonization, may be included in this. According to the analysis, degradation cannot occur when the moisture content is below 25%, both anti-swelling efficiency (ASE) and moisture exclusion efficiency (MEE) are regarded as metrics for evaluating the efficacy of improvements (Thybring, 2013).

2.3 Processing Effects on Chemical and Physical Properties

Based on the study of Hik et al. (2009), the influence of drying temperature on the physical and mechanical properties of rubberwood, that is commercial drying of rubberwood at high temperatures is still unknown. This is relevant when the rubberwood content has a high moisture content that needs to be reduced to increase stability and cracks when freshly cut.

Next, chemical treatment and heat treatment known as heat modification also play a role in physical and chemical processes and through chemicals that preserve can be used on wood with pressure methods or non-pressure methods (Gerardin, 2016). For example, preservative treatment can be used to protect and prevent wood from decay and insect attack, while heat treatment is more suitable when the use of rubberwood at high temperatures in more controlled environmental conditions is involved so that this process can change the chemical structure wood in a more effective way.

Research on rubberwood is proposed to be done using rubberwood that has been sawn, dried, and machined to improve its physical and chemical qualities and ensure its suitability for various purposes. For example, allows the modification of rubberwood for easy installation. Sawing techniques will affect production recovery, and various stitch patterns will affect how the wood dries (Ratnasingam et al, 2010).

Depending on the processing method, the conditions under which the process is carried out, and the type of rubberwood being processed, the effects of processing on the physical and chemical properties of rubberwood can vary processing of rubberwood can have a great impact on its physical and chemical properties.

2.4 Variability of Physical and Chemical Properties

While considering the physical and chemical properties of rubberwood and ensuring that it is acceptable for future industrial applications, it is crucial to maximize the natural variability of the material (Riyaphan et al, 2015) indicates that both the age and height of a tree influence its physical characteristics.

Furthermore, the mechanical properties of wood, as well as its longitudinal shrinkage, are influenced by its composition. Specifically, the cellulose microfibrils, which are present in wood, are believed to be responsible for its tensile strength (Hyotenan et al, 2011). Furthermore, the composition of the extract is intricately linked to the chemical characteristics that give rise to color, odor, and resistance to chemical degradation. To guarantee that rubberwood products satisfy the appropriate quality, durability, and performance standards in different industries, it is essential to make well-informed decisions throughout the processing, manufacturing, and application selection stages. This is achievable with a comprehensive comprehension of the diverse characteristics and attributes of rubberwood in terms of its physical and chemical qualities.

2.5 Applications and Utilization of Rubberwood Based on Properties

Hevea brasiliensis has long been introduced in the Malay Peninsular more than a century ago and the economic lifespan of rubberwood is about 25 years. Only in recent decades has rubberwood become an important wood in the furniture manufacturing economy. This is said because it has interesting characteristics in terms of cream color and good working properties. Conventional physical and chemical control has been a successful method to prevent the growth of dye fungi, however, the effects of chemicals are of concern because they can cause problems for the environment and humans (Teoh et al, 2011).

The application of rubberwood used as an important resource in the industry is of course the ever-expanding processing of furniture manufacturing that has an attractive appearance and moderate durability. The nature of medium density and strength of wood allows the construction of furniture pieces to be stronger. In addition, various products that can be produced from rubberwood which are flooring, constructing woodworking, packaging materials, decorative crafts and rubberwood can be processed into plywood or veneer. Not only that, the best thing that application and utilization of rubberwood is can be renewable energy. Rubberwood waste such as branches and sawdust can be utilized as a biomass fuel for energy generation. The exploitation of rubberwood biomass to generate is limited if compared with other existing biomass (Ratnasingam et al, 2015).It is necessary to ensure that rubberwood can provide acceptable performance for various reasons, and rubberwood may react differently based on its own factors. Rubberwood is considered a sustainable and environmentally friendly resource due to its renewable nature and that sets it apart from other types of wood.

CHAPTER 3

MATERIALS AND METHOD

3.1 Raw Material Procurement

Hevea brasiliensis which is a type of rubberwood that was used at the breast height diameter of 40 to 50 cm in this study. The trunk of this tree was taken from a sawmill in the Jeli area, which is an area close to the study site. The trunk of the rubberwood was divided into three section, which are the top, middle and bottom of each part of the trunk. To ensure that the wood reacts completely with the reagents used in the analysis, perform moisture content analysis first or air-dry the sample for at least a day before performing the chemical analysis. In addition, two one-inch size discs were cut from the near bark of each piece of rubberwood to examine its physical and chemical properties. This study was several methods to obtain moisture content TAPPI 258 OM-94 Standard (1995), extractive content, holocellulose TAPPI T 259 om-88, cellulose TAPPI T 204 cm-97 (2007) , hemicellulose (HPLC) and lignin TAPPI Standard T 222 om-02 (2006).

Figure 3.1: Rubberwood from sawmill in the Jeli

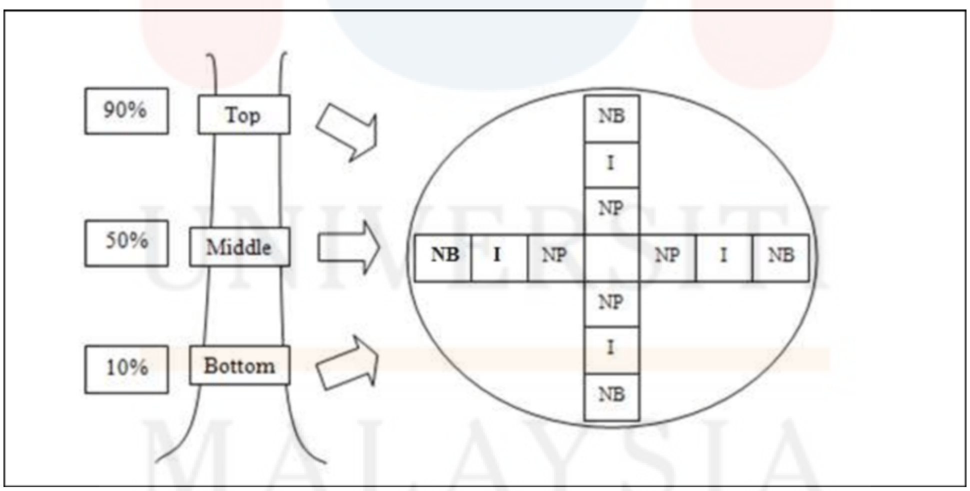

Figure 3.2: Merchantable bole and Procurement of Wood Disk of Rubberwood

3.2 Sampling Method for Physical Properties Evaluation

The physical properties of rubberwood are affected by the removal of two discs from each section. While the thickness of the disc from the bottom, middle and top is marked as 2 cm x 2 cm. Specific gravity (SG) and moisture content (MC) measurements were performed on samples representing near pith (NP), intermediate (I) and near bark (NB) to identify any differences. These physical properties were determined using three parts of each sample.

3.2.1 Determination of Physical Properties

In determining the physical properties, the wood was tested using the TAPPI (Technical Association of the Pulp and Paper Industry) standard procedure to determine the specific gravity and moisture content of the wood. As part of the laboratory course, this has been developed to learn more about the structure and composition of wood, a very useful skill for research.

3.2.2 Determination of Specific Gravity

To measure the determination of gravity has used the TAPPI standard (T 258 om -94) (1995) where this method used water displacement in the research of rubberwood samples. This method has outlined a standard procedure for sampling and preparing wood samples to investigate weight changes, moisture distribution and the presence of knots after soaking according to different portions, one from the bottom, one from the middle, and one from the top. In addition, by comparing the specific gravity of samples from different portion, the impact value on the characteristics of rubberwood, namely strength and weight. So, this method will help to get an accurate gravity percentage calculation (3.1).

$$\text{Specific gravity (\%)} = \frac{Wo}{Wdv} x100 \qquad (3.1)$$

where,

Wo = oven dry weight (g)

Wdv = weight of displaced volume of water (g)

3.2.3 Determination of Moisture Content

TAPPI 258 OM-94 Standard (1995) was used to determine the moisture content. This investigation has used the same wood sample to calculate the specific gravity by weighing it first and dried in an oven at a temperature of 103°C. The proportion of dry weight lost compared to the final weight was used to calculate the moisture content of the test specimen. Next, use the calculation procedure that has been prepared to obtain the final oven dry weight loss percentage by calculating the moisture content of the test specimen (3.2).

$$\text{Moisture content (\%)} = \left(\frac{Wg - Wo}{Wo}\right) x100 \qquad (3.2)$$

where,

Wg = weight of green sample (g)

Wo = weight of oven dried sample (g)

3.3 Chemical Properties Sampling

Rubberwood samples were prepared for further research by following TAPPI method 204 cm-07 (2007). The method was analyzed to describe and measured the extractive solvent content where the solution obtained from the extraction uses chromatographic techniques to measure the extractive component of the sample (Michael Buchanan, 2017). Using the method, three interactions were carried out for each part, which are the top, middle and bottom.

3.3.1 Determination of Moisture Content

Rubberwood experimental samples can generally be maintained in air humidity balance, although the air humidity is low or high, it must be considered when calculating the percentage of various chemical components. According to (Hartley et al, 1988), when the mass of water exceeds the oven dry mass of wood, as is common in green wood from species with low density, the moisture content will exceed 100%. The determination of this moisture content is important in the chemical composition even if the moisture is only minimal, it must be certified when calculating the percentage of chemical components. Wherein, excess research analysis has been used to clean and dry aluminium scales with an oven. Next, approximately 2 grams of air-dried sawdust was put into aluminium container and was weighed. After drying at 103°C for 24 hours, the samples were dried for 10 to 15 minutes before weighing. The percentage were calculated using the dry weight of air.

$$\text{Moisture Content (\%)} = \left(\frac{Wa - Wo}{Wo}\right) x\ 100 \qquad (3.3)$$

where,

Wa = weight of air-dried sawdust (g)

Wo = weight of oven dried sawdust (g)

3.3.2 Determination of Extractive Content

The process of separating natural products from raw materials begins with extraction. Therefore, this method was used to characterize the chemical composition of rubberwood, and the sample was first filtered to allow the extraction to be carried out. A moisture content analyzer was used to measure the moisture content of the sample, and 7 grams of it was extracted using ethanol and toluene before being subjected to Soxhlet extraction for 6 hours. The extract was then put into a small flask and evaporated at a temperature of 58°C. Beakers without extractives were then covered with parafilm after being weighed using a digital analytical balance. After being dried on a hot plate, the next rubberwood extract was preserved in plastic to be used as a sample for subsequent experiments. The extractive percentage was taken into the experiment (3.4).

$$\textit{Extractive Content (\%)} = \frac{W1}{Wo} \; x \; 100 \qquad (3.4)$$

where,

W1 = weight of extraction (g)

Wo = weight of oven dried samples (g)

3.3.3 Determination of Holocellulose

It will be carried out according to the TAPPI T 259 om-88 method. It requires a 500 ml beaker to be filled with 2 grams of air-dried sawdust in each portion, top, middle, and bottom, which has been accurately weighed using an analytical balance. Then, a total of 200 ml of water was poured into a 1000 ml beaker until it boils on a hot plate with a temperature that has reached 70°C. The sample of each portion was put into a conical flask and then was put into a 1000 ml beaker to boil twice at a temperature of 70 °C. In each conical flask that has contained the sample, 100 ml distilled water, 5ml (10m%) acetic acid and 1.5g sodium chlorite ($NACIO_2$). After 30 minutes, the sample was treated with 5ml 10% acetic acid and 1.5g sodium chlorite for 2 hours, sodium chlorite ($NACIO_2$) and acetic acid were added alternately every 15 minutes (with 6g natrium chlorite and 20 ml acetic acid). The sample was heated for 15 minutes after the last addition of sodium chlorite. The sample was cooled before filtering with filter paper. The sample was rinsed with cold distilled water during the filtration process until it was no longer slippery. After filtration, the sample was rinsed with acetone and dried in open air at room temperature. Then, the percentage calculation of holocellulose was recorded.

$$\textit{Holocellulose Content (\%)} = \left(\frac{Who}{Wo}\right) x\ 100 \qquad (3.5)$$

where,

Who = weight of oven dried holocellulose (g)

Wo = weight of oven dried sawdust (g)

3.3.4 Determination of Cellulose

It has obtained the extraction of cellulose from rubberwood boards using the TAPPI T 204 cm-97 (2007) standard. An analytical balance was used to weigh 2 grams of sawdust without extract in a conical flask. A glass rod and a beaker of 250 ml of cold water, the sample was then added to 15 ml of NaOH 17.5% and rotated slowly. It was mixed with 10 ml of 17.5% NaOH. Another 10 ml of 17.5% NaOH was added after 45 seconds, and another 35 ml was added after another 2 minutes. The sample was then left for an additional 3 minutes and for 5 minutes. After 2.5, 5 and 7.5 minutes, 10 ml of 17.5% NaOH has been added, 75 ml of NaOH will be added to the mixture. The addition of 100 ml of distilled water was stirred rapidly for 30 minutes at 20°C. A knife (aperture 3) was used to filter the sample, and its weight was recorded. With 25 ml of 8.3 ml NaOH at 20 °C, the beaker was cleaned, and the residue was removed. After that, 650 ml of cold distilled water (20°C) was used to wash the sample again. After 10 minutes, the vacuum tube was removed, and 15 ml of 10% acetic acid was in the beaker. Connect a vacuum tube to drain the 10% acetic acid. To ensure that the sample was stable, it was then dried and weighed.

$$\textit{Cellulose content (\%)} = \frac{Wa}{Wo} \times 100 \qquad (3.6)$$

where,

Wa = Weight of cellulose

Wo = Weight of oven dry holocellulose

3.3.5 Determination of Hemicellulose

High performance liquid chromatography (HPLC) is one of the techniques that was used in the hemicellulose method. Approximately 2 grams sample of the remaining oven-dried alcohol-toluene mixture was placed in a 250-ml flask, along with 100 ml of distilled water, 1.5 grams of sodium hydroxide (NaOH), and 5 ml of 10% acetic acid. After 30 minutes in a water bath at a temperature of 70 °C, the extract was given an additional 5 ml of acetic acid and 1.5 grams of NaOH. Acetic acid and NaOH were added alternately until 6 g of NaOH had been completely added, repeating this process every 30 minutes. For an additional 30 minutes, the mixture was changed until it turns creamy white. The mixture was then filtered, washed with ice-distilled water, followed using acetone, and the residue was dried to constant weight. Based on a 0.5-gram sample, the extracted moisture content was calculated. The sample was then dried in an oven for a final time at 103 °C until there was no change in weight. The percentage used during the experiment was recorded.

$$Hemicellulose = Holocellulose - Cellulose \qquad (3.7)$$

3.3.6 Determination of Lignin

The TAPPI T 222 om-02 (2006) standard was used in carrying out this procedure. This method has outlined the steps that can be taken to determine the amount of acid-insoluble lignin in wood and to achieve all grades of non-bleaching lignin. Using an extractive free air-dried sample of 1 gram to determine the moisture content. The sample was placed in a 150 ml beaker and placed in steam water at a temperature of 20°C. Then, a pipette containing 25 ml of sulfuric acid (72%) was inserted into a 50 ml beaker filled with 4 grams of oven dried sawdust without extract and stirred for two hours using a glass rod. After two hours, the sample was quantitatively transferred from the combined washing vessel into a 500 ml conical flask and 300 ml of distilled water was added. Reflux for 4 hours in a water bath that has been filled with boiling water and the sample has been cooled and filtered using a paper filter. After that, the filter residue has been washed with 250 ml of hot distilled water until the pH level is neutralized and the crucible is dry. Then, it will be placed in a drying oven set to 103°C. The proportion of lignin will be determined for extractive free sawdust (Figure 3.2).

$$\textit{Lignin extract content (\%)} = \frac{Wle}{Wes}\ x\ 100 \qquad (3.8)$$

Where,

Wle = weight of oven dried lignin extract (g)

Wes = weight of oven dried sawdust (g)

CHAPTER 4

RESULT AND DISCUSSION

4.1 Physical Properties

Variations in moisture content and specific gravity are shown in Table 4.1 according to the section and radial position of rubberwood. It includes three portions, the bottom, middle and top, each of which has a different moisture content from 13.80% to 26.42%. Table 4.1 also shows the average moisture content in each part which is 14.36%, 14.70% and 20.10% respectively. This is said because rubberwood parts may have different water absorption capabilities in each part and different wood structures can affect the wood's ability to absorb and retain moisture. Not only that, the bottom section can be averaged high compared to the top and middle section because it has many void structures that can still store a large amount of water molecules, so this is one of the reasons why the humidity is high (Yang et al, 2023).

In addition, the data also shows the specific gravity of rubberwood varies depending on the distance from the pith and the part of the tree, each of which has 0.76, 0.51, and 0.61 in the range of specific gravity. Table 4.1 shows the overall average specific gravity in each portion, among which is 0.64 in the bottom section, 0.47 in the middle section, and 0.57 in the top section. This has shown that the average specific gravity is higher in the bottom section of the tree than the upper section which is likely due to the lower section of the tree being stronger to support the weight of the tree and on the other hand the upper section is less dense and not so heavy. Moisture content and specific gravity are two important elements that affect raw materials according to suitability where each product weight is significantly affected by moisture and each part of strong strength has a value to be used.

Table 4.1: Average Values for Moisture Content and Specific Gravity of Rubberwood According to Tree Portion and Radial Portion

DISTANCE	PORTION	SPECIFIC GRAVITY	MOISTURE CONTENT (%)
Near Pith	Bottom	0.69	13.80
Intermediate		0.46	14.64
Near Bark		0.76	14.65
Average		**0.64**	**14.36**
Near Pith	Middle	0.48	14.92
Intermediate		0.41	14.72
Near Bark		0.51	14.46
Average		**0.47**	**14.70**
Near Pith	Top	0.60	18.87
Intermediate		0.51	26.42
Near Bark		0.61	15.02
Average		**0.57**	**20.10**

Note: Values are average of 2 samples, MC = Moisture Content, SG = Specific Gravity

4.1.1 Effects of Tree Portion

Figure 4.1 depicts the correlation between the vertical position of the breast tree and the corresponding moisture content, demonstrating a clear upward tendency. In summary, the tree exhibits an upward gradient in size, with the specific gravity being greater in the middle and bottom sections compared to the top section.

The bottom and middle sections specific gravities exhibit a substantial increase compared to the top specific gravity values. However, the difference in specific gravity between the top section and middle sections is significance. This phenomenon occurs because wood had the ability to expand or contract in response to fluctuations in atmospheric humidity and variations in moisture content. According to Figure 4.1, a lower part specific gravity (11.46a) indicates a higher density, making it denser and heavier compared to the middle portion specific gravity (9.76a). The middle portion of the structure is denser than the upper part. The study reveals that the bottom section (9.6b) of the rubberwood experiences greater levels of pressure and tension compared to the middle portion. This is due to the production of wood fibers in the bottom portion, which serve to reinforce it. The presence of tylose in the wood increases its weight, resulting in higher density and gravity.

Next, the moisture content graph on the tree section is shown in Figure 4.2. This graph represents the equilibrium moisture content (EMC) of wood, which is a state where it does not gain or lose moisture but is in balance with the relative humidity and temperature of its surrounding environment (Loffer, 2024). From Figure 4.2, the moisture content of the lowest section value of 21.19%, which is greater than the moisture content value of the top and middle section, which are 14.65% and 15.04%, respectively. The elevated moisture content value in the lower section of the tree indicates a significant accumulation of water in the wood at the base. Excessive moisture in wood can lead to changes in its dimensions, such as swelling and shrinking. The lower portion of the wood, which has a higher moisture content, is more susceptible to deterioration. Nevertheless, a higher moisture content can enhance flexibility and facilitate the processes of carving, shaping, and grafting (Lawler, 2023).In short, the fluctuation in moisture content within a tree is crucial in assessing the appropriateness of the wood for a specific use.

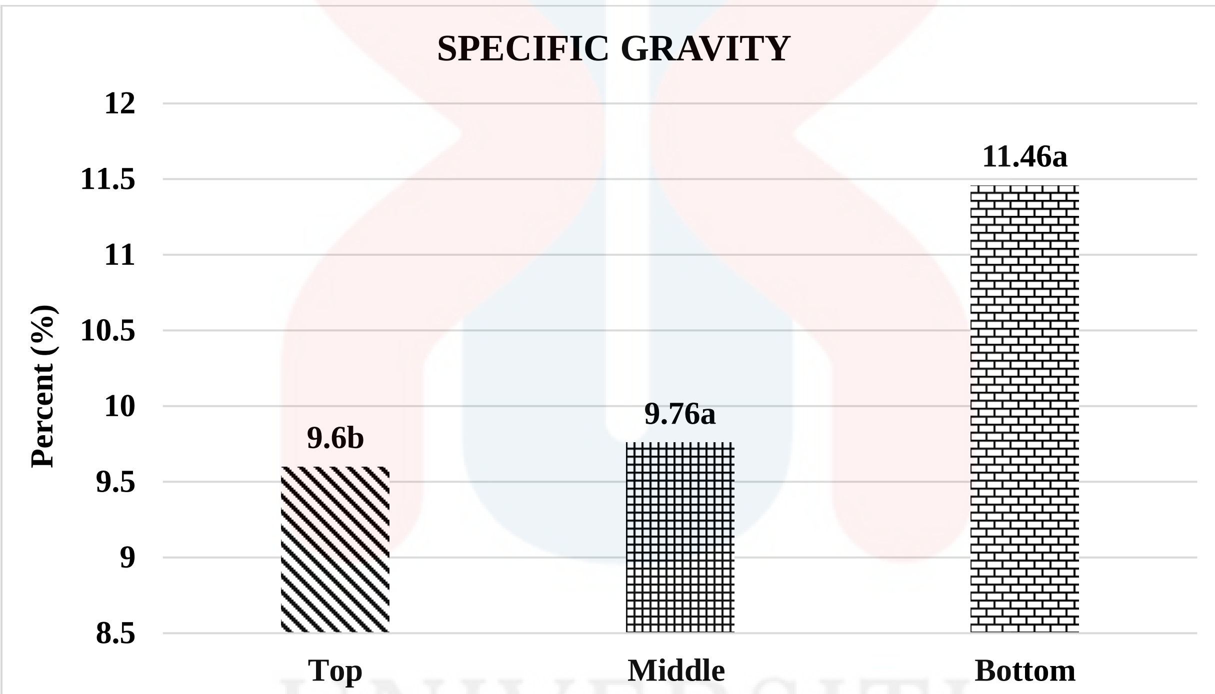

Figure 4.1: Effects of Tree Portion on Specific Gravity (SG)

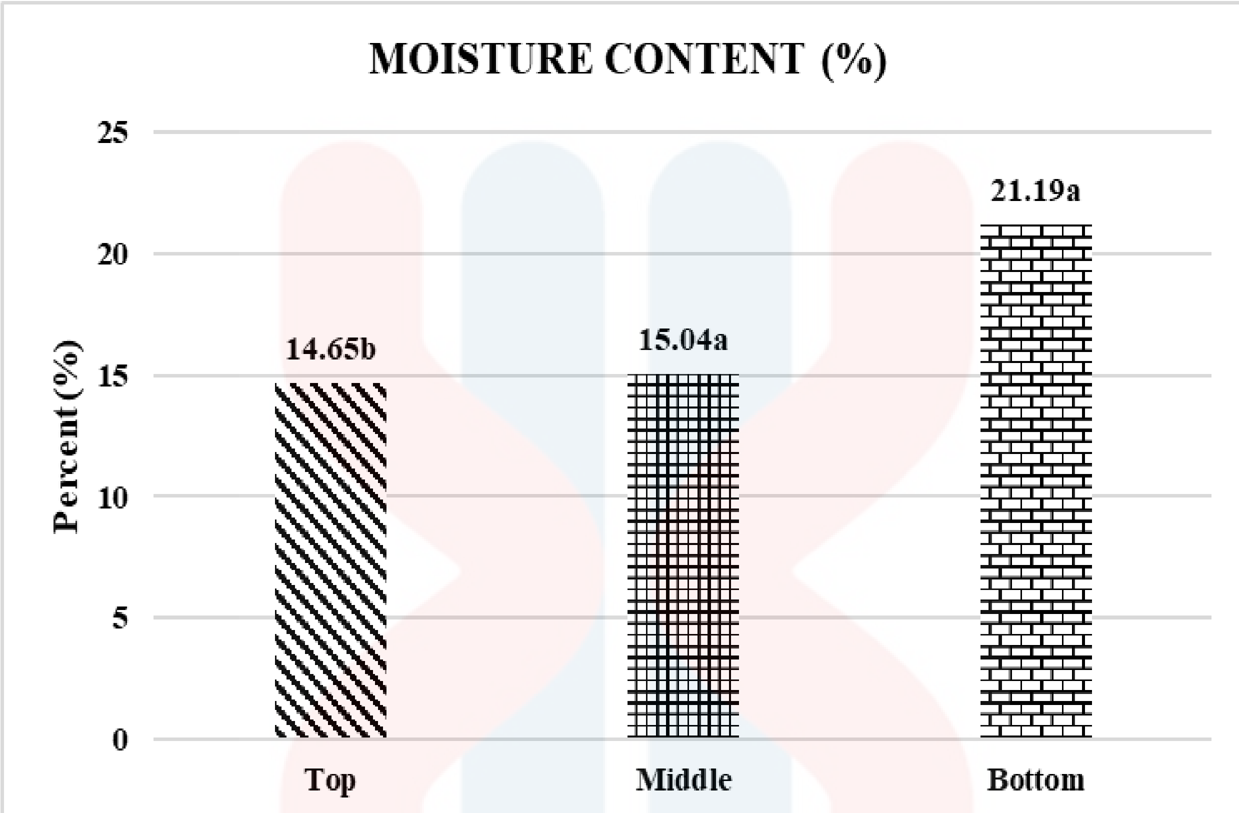

Figure 4.2: Effects of Tree Portion on Moisture Content (MC)

In addition, this gravity flow exhibits a higher wood density per unit and a reduced cell wall thickness, which varies depending on the level of maturity and the species. Nevertheless, wood with a higher weight may necessitate an extended period of drying to achieve the optimal moisture content equilibrium (EMC) for the intended environment, while minimizing the potential for degradation (Ratnasingam, 2009). This demonstrates the correlation between the specific gravity of wood and its moisture content, which is influenced by several factors such as climate, location, species, genetics, silvicultural techniques, reproduction, and other relevant elements (Hermawan, 2018). In contrast to the lower portion, the low-density juvenile wood found in the upper trunk and branches has advantages such as simpler machinability despite higher finishing needs, and its stability is excellent for goods such as molds (Hossain et al, 2021).Consequently, there is a reduced amount of internal space available for residential cells. The wall and lumen are to be filled with water. The wood possesses a substantial specific gravity. This statement is accurate as the specific gravity of a substance is influenced by the proportion of cell wall material to the empty spaces within the cells. Moreover, the evaluation of wood quality often relies on the utilization of specific gravity (Shier et al, 2002).

4.1.2 Effects of Radial Position

The variation in wood density along the radial axis is illustrated in Figure 4.3, which presents the specific gravity values allocated to distinct radial positions in the tree which are near pith, intermediate, and near bark. The wood located closer to the center of the tree, near the pith, has a lower value of 9.6b. This is due to its relatively lower maturity and higher proportion of early wood, which often has a lower density. Wood located at the mid-radial position exhibited a higher specific gravity in comparison to wood near the pith, as compared to the intermediate (10.42a) and near bark (10.82a). The observed rise in density could be attributed to a more even distribution of earlywood and latewood, with latewood playing a significant role. Furthermore, the wood located near the bark, which is the outermost layer of the tree, demonstrates the highest specific gravity compared to the other two positions. This is attributed to its larger concentration of late wood, which is characterized by greater density and structural maturity.

The specific gravity of the near bark at the radial section exhibits a general increase. In contrast to the irregular peak pattern observed in certain species, current data on rubberwood indicate a gradual increase in specific gravity from the innermost part of the tree to the outside bark, with the highest values found in fully developed wood (Loh et al., 2022). The radial specific gravity trend is influenced by several anatomical parameters. One of these elements is the proportion of latewood, which increases as rubberwood mature. Each growing season, there is a higher percentage of thick-walled latewood compared to earlywood (Bakar et al., 2006). Consequently, the proportion of late wood grows in a radial manner, leading to the highest possible specific gravity toward the outer layer.

Next, according to Figure 4.4, the moisture content at various distances from the center of the tree has been determined near bark had the greatest moisture content value of 19.02%. This is likely due to its greater exposure to the outside temperature, which can lead to higher moisture content. When comparing the moisture content of wood at the mid-radial location, it is seen that it is somewhat higher than the surrounding near pith in both the close pith (15.7%) and intermediate (16.19%) samples. This rise may be attributed to the transition from early wood to late wood, wherein late wood exhibits higher density and lower moisture retention. Hence, the center of the tree (proximate to the pith) and the outermost region (proximate to the bark) are prone to having a greater moisture content, although the middle portion exhibits moderate amounts of moisture.

On contrast to the specific gravity of rubberwood, the moisture content (MC) exhibits the opposite radial trend, whereby the highest moisture content values are generally observed in the mature outer wood in proximity to the epidermis. The existence of growth stress can be ascribed to the accumulation of tension in the outer layer of mature wood during trunk development. Consequently, the stress-induced fractures and fissures facilitate the ingress of moisture into the wood situated near the surface (Fue et al., 2023).

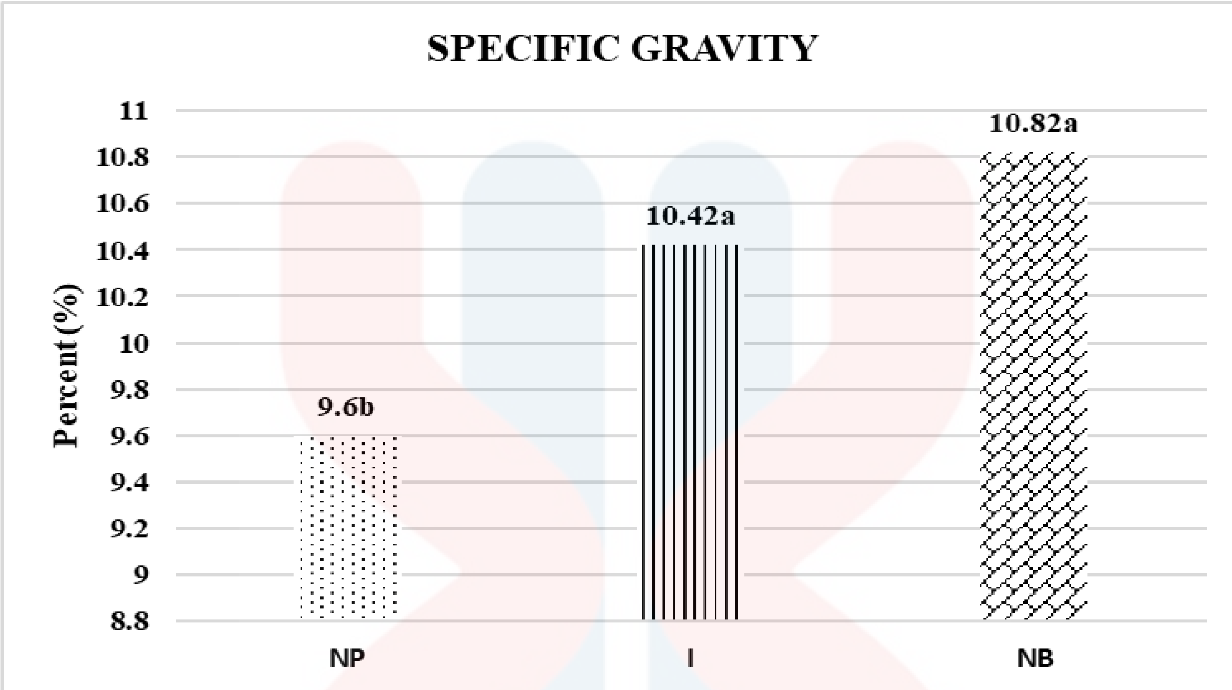

Figure 4.3: Effects of Radial Position on Specific Gravity (SG)

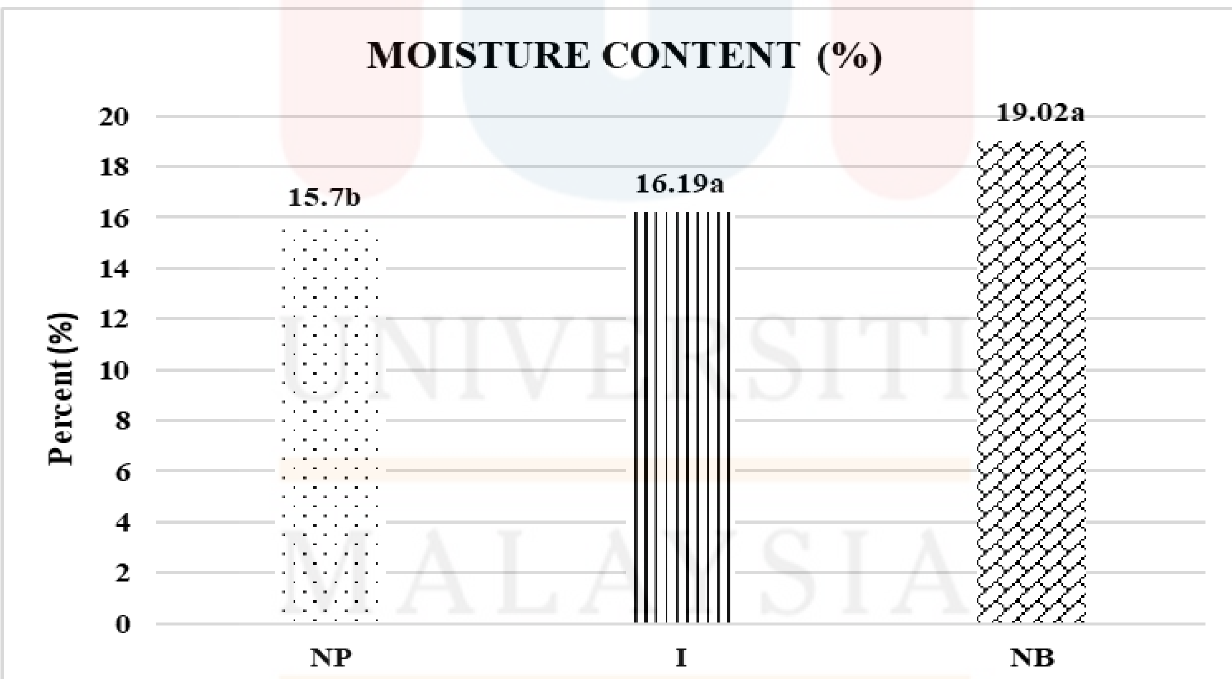

Figure 4.4: Effects of Radial Position on Moisture Content (MC)

4.2 Chemical Properties

Rubberwood, scientifically known *as Hevea brasiliensis*, is a variety of durable timber composed of holocellulose, cellulose, hemicellulose, and lignin. These components contribute to the wood's enhanced stability and resistance. By going through wood chemical analysis experiments that have been carried out to find out in advance the chemical structure of its chemical composition and important factors will determine the suitability of the product's users. Among the characteristics found in chemical properties are the result of extractives, holocellulose, cellulose, hemicellulose and lignin will determine the properties of wood products according to portion. Moreover, the characteristic features are essentially permanent products that have been synthesized by the developing wood cells after making several divisions in the cambium.

The fiber wall is composed of cellulose, hemicellulose, and lignin, which are the primary constituents. Cellulose, being the most robust polymer constituent in wood, is mainly responsible for the strength of wood fibers with an important polymerization level (Winandy & Rowel). The term "extractive" pertains to the final classification of wood constituents. These components are typically specific to a species or genus, typically soluble, and vary in terms of their abundance, structure, and amount (Seddiqi et al,2021). Table 4.2 summarizes the experimental findings for the chemical composition of rubberwood for three separate portions of the tree, demonstrating a substantial effect on all three.

According to Table 4.2, the extractive content of the bottom of the wood that received the largest value was 21.80% and the lowest value on the top of the wood is 13.96%. This causes the bottom section of the wood to have the highest value. Holocellulose content had a greater value percentage of 90.0% at the upper section of the wood, while the lower value was 83.06% at the bottom section of the wood. The percentage of cellulose content was highest in the upper section of the wood, which was 58.0%, it is slightly lower on the wood surface, at 54.30%, and much lower in the middle portion, at 50.0%. This shows the difference. The concentration of hemicellulose is 37.1% in the middle sections of the wood, but it is 25.0% under the board. Finally, the upper sections of the stick recorded a value of 19.53%, while the middle sections of the stick exhibited a larger value of 23.51%. On the other hand, under wood produces a percentage of lignin content of 21.82. Furthermore, the top of rubberwood exhibited the highest mean holocellulose content, measuring 86.72%. This indicates that the chemical composition of rubberwood varies at different sections and heights of the wood.

Table 4.2: Chemical Properties of Rubberwood

	Tree Portion	Rubberwood	Kelampayan (Rahman et,al 2018)
Moisture Content (%)	Top	7.2	22
	Middle	7.45	
	Bottom	5.95	
	Average	**6.87**	
Extractive Content (%)	Top	13.96	
	Middle	19.94	
	Bottom	21.80	
	Average	**18.56**	
Holocellulose Content (%)	Top	90.0	69.84
	Middle	87.10	
	Bottom	83.06	
	Average	**86.72**	
Cellulose Content (%)	Top	54.30	
	Middle	50.0	
	Bottom	58.0	
	Average	**54.1**	
Hemicellulose Content (%)	Top	35.7	
	Middle	37.1	
	Bottom	25.0	
	Average	**32.6**	
Lignin Content (%)	Top	19.53	23.00
	Middle	23.51	
	Bottom	21.82	
	Average	**21.62**	

4.2.1 Extractive Content

Extractives are mostly related with the production of heartwood and occur both outside and inside the cell wall. These additives are known as extractives because they may be extracted from wood using appropriate solvents while causing little alteration to the underlying wood structure. Tannins, terpenes, polyphenols, lignin, acid resins, lipids, waxes, and carbohydrates are low-molecular-weight chemicals found in wood species (Bouhtoury et al,2020). Extractives can contribute to other wood qualities, such as strong decay resistance in some species, in addition to impacting the appearance of the wood, particularly in color.

Figure 4.5 indicates that three section of rubberwood have been studied. The extractive content of the lower half had the highest value, reaching 21.80%, compared to the middle section which had a value of 19.94%. However, the upper section has the lowest value, measuring only 13.96%. This is because the extractive content was largest near the bottom, indicating a need for additional investigation into heartwood formation. The bottom section of the tree often consists of aged wood that has experienced notable alterations in its composition, including a rise in extractives. Environmental factors or specialized conditions for growth around the tree's base can also lead to an increased amount of extractive substances. Nevertheless, the diminished proportion of extractive content in the top section can be attributed to various variables. This region is typically characterized by a youthful state, which tends to exhibit a lower extractive content. Additionally, the extractive output can be influenced by environmental conditions and the physiological characteristics of the tree (Rouhier, 2021).

In addition, the average extractive content provides an overview of the wood sample and is influenced by the value contribution of each part, which is 18.56%. A uniform or typical mean indicates that rubberwood samples from different portion (top, middle, bottom) or different trees of the same species exhibit comparable extract content. Consistent material quality is essential for a company that relies on determination. Not only that, more extensive extractive sampling and analysis on the entire rubberwood revealed whether the increase in coral extract towards the base is true which can be referred to in Figure 4.5. Also, to determine whether the overall range of 18.56% is typical across many woods or unique to rubberwood may have practical implications for commercial applications targeting specific extractive properties (Junior et al,2015).

4.2.2 Holocellulose Content

Holocellulose content of wood is the total amount of cellulose and hemicellulose found in wood (Segato et al, 2014). Cellulose and hemicellulose are complex carbohydrates that form the main components of plant cell walls, serve as an important support system, and contribute significantly to the total composition of wood. Figure 4.5 shows significant variation in holocellulose content across different parts of the tree. The investigation showed that the holocellulose content had an inconsistent pattern of effects in the middle section (87.1%) and bottom section of the head (83.6%), and it was not significant with respect to the holocellulose content. This phenomenon is associated with more juvenile wood seen in species that exhibit rapid development rates and are also characterized by higher levels of cellulose content. In a previous study (Rahman et al., 2018), the average value of Kelampayan wood was 69.84%, which was lower than the average value of rubberwood which is 86.72%.

According to Segato et al. (2014), the range of tropical hardwoods includes rubberwood, which has a percentage that was between 70% and 85%. However, this percentage is slightly greater than the typical range for rubberwood itself. Based on the results of this investigation, it can be concluded that the biomass of this plant contains cellulose and hemicellulose at levels appropriate for industrial processing into products such as biofuel, bioplastics, chemical raw materials, and others. The comparatively high average of 86.72% total holocellulose suggests this. Not only that, this assertion is made based on the growth conditions that were established and the soil that is rich in nutrients, adequately aerated, and exposed to ample sunlight tends to have increased cellulose formation, resulting in a higher holocellulose content in the upper portion characteristics of wood that add to its rigidity and strength. Nevertheless, other characteristics like density and evaporation might also be impacted by an extremely high holocellulose concentration.

4.2.3 Cellulose Content

Cellulose is a well-organized polysaccharide polymer that imparts strength and stiffness to the cell walls of plants. The structure is composed of D-glucose units interconnected in elongated chains (Eriksan et al,2017).Establishing the cellulose composition of plant biomass yields valuable insights for endeavors that necessitate the decomposition or manipulation of this substance, such as in the production of textiles and paper.

The source of analysis, which is shown in Figure 4.5, has a greater value in the bottom section (58.0%), followed by the top section (54.3%) and the middle section (50.0%). The percentage of cellulose from the upper, middle, and bottom section regions is shown in the figure. The data illustrates the variation in cellulose content across the structure, with a somewhat larger concentration in the bottom section compared to the middle section. This phenomenon can be related to the increase in the height of the bottom section compared to other portions which can be explained by the occurrence of lignification in the aging plant tissue. Lignification refers to the accumulation of lignin and cellulose in cell walls. Furthermore, the bottom section may show a higher cellulose content, while the top section is characterized by enhanced lignification. The bottom portion may also obtain a greater concentration of nutrients or resources that aid in cellulose production. This can be attributed to factors such as nutrient transfer, soil chemistry or root spread.

On average, the structure contains 54.1% cellulose. Prior research has provided quantitative data indicating that the percentage of cellulose falls between the range of 40% until 50%. However, each distinct tree species, while resembling the rubberwood category may possess varying levels of cellulose content. This assertion is since, on average, 54.1% of the plant exhibits a promising capacity for being transformed into textile fibers or undergoing enzymatic conversion into glucose and subsequent fermentation into ethanol biofuel. In summary, the significant cellulose content, along with the previously obtained holocellulose data, indicates the potential utilization of lignocellulosic biomass for industrial applications.

4.2.4 Hemicellulose Content

Hemicellulose is a primary constituent of plant cell walls, ranking second in importance after cellulose, and followed by lignin. It is a type of complex carbohydrate that enhances the structural integrity of the cell wall and contributes to the process of morphological development. It is crucial to comprehend the hemicellulose concentration to assess wood as a raw material or biomass material (Fang et al., 2008).

The provided values represent the hemicellulose content percentages measured in three distinct sections of the wood samples which are top, middle, and bottom. The top section had a value of 35.7%, the middle section had a value of 37.1%, and the bottom section had a value of 25.0%. The greater proportion of hemicellulose in the upper and middle sections, as opposed to the lower proportion in the lower section, indicates variations in the structure and composition of the cell wall along the vertical axis of the wood. These findings demonstrate that plant growth triggers physiological changes that lead to differences in wood production across different sections of the stem.

According to Table 4.2, the average percentage of biomass fractionation using sodium hydroxide solution (NaOH) to remove hemicellulose by breaking acetyl groups and glycosidic linkages between monomers is 32.6% (Peng et al, 2012). The higher hemicellulose content seen in the upper and middle sections of the wood suggests that these areas are more likely to yield a greater amount of dissolved hemicellulose after the initial mild alkaline extraction with NaOH, in comparison to the bottom section. In addition, acetic acid acts as a complement by effectively dissolving hemicellulose. Furthermore, it is predicted that the top and middle high hemicelluloses will exhibit a more active response to exposure to acetic acid due to the higher concentration of hemicellulose biomass at 35.7% and 37.1%, respectively (Lio et al., 2019).

In turn, assessing the distribution of hemicellulose offers valuable understanding of the diversity in cell wall composition and the expected effectiveness of extracting biomass for future application. Maximizing the hemicellulose output from this wood source is likely to prioritize the top and middle section.

4.2.5 Lignin Content

Lignin is a constituent of wood that forms the secondary cell wall structure. It plays a crucial role in determining the physical properties, chemistry, and energy content of wood. Typically, lignin makes up around 25% of wood composition (Novaes et al, 2010). Based on Figure 4.5, the middle part has the highest lignin content which is 23.51%, while the bottom part has a relatively low value which is 21.82%. The upper p has the lowest value which is 19.53%. This phenomenon is associated with the development of heartwood, which usually has a greater concentration of lignin than sapwood. The variation in lignin content observed, increasing from top to bottom, is likely to indicate a transition from sapwood to heartwood in the middle (Rouhier et al, 2021).

Furthermore, the middle portion of the wood contains a higher amount of lignin than the bottom portion this can be influenced by a few factors pertaining to the tree's growth and development. In general, lignin content tends to increase when wood transitions from sapwood to heartwood, and older sections of the tree often have higher lignin concentrations. According to Table 4.2, the average content of the wood sample was 21.62%. This phenomenon is attributed to the intricate organic polymer present in the cell walls of plants, including wood and cellulose offers structural reinforcement to cell walls and enhances the overall robustness and longevity of wood. According to earlier research, Kelampayan wood had a mass percentage of 23% lignin, that had a higher lignin concentration than rubberwood (Rahman et al, 2018). The Kelampayan wood variety, with its 2% higher lignin content, will exert a more significant impact when the target product undergoes the refining process.

Furthermore, using sulfuric acid to quantify the lignin concentration of the sample resulted in a black hue at the end of the study, indicating that the use of sulfuric acid had broken down the complicated structure of lignin into its constituent monomer units, making it easier to measure. Thus, "Lignin" is a general name for a family of biopolymers that includes a wide variety of aromatic compounds; these biopolymers are very prevalent on earth. As the world's primary supplier, it gives wood its stiffness and antibacterial qualities and makes up around 30% of wood's weight (Tribot et al, 2019).

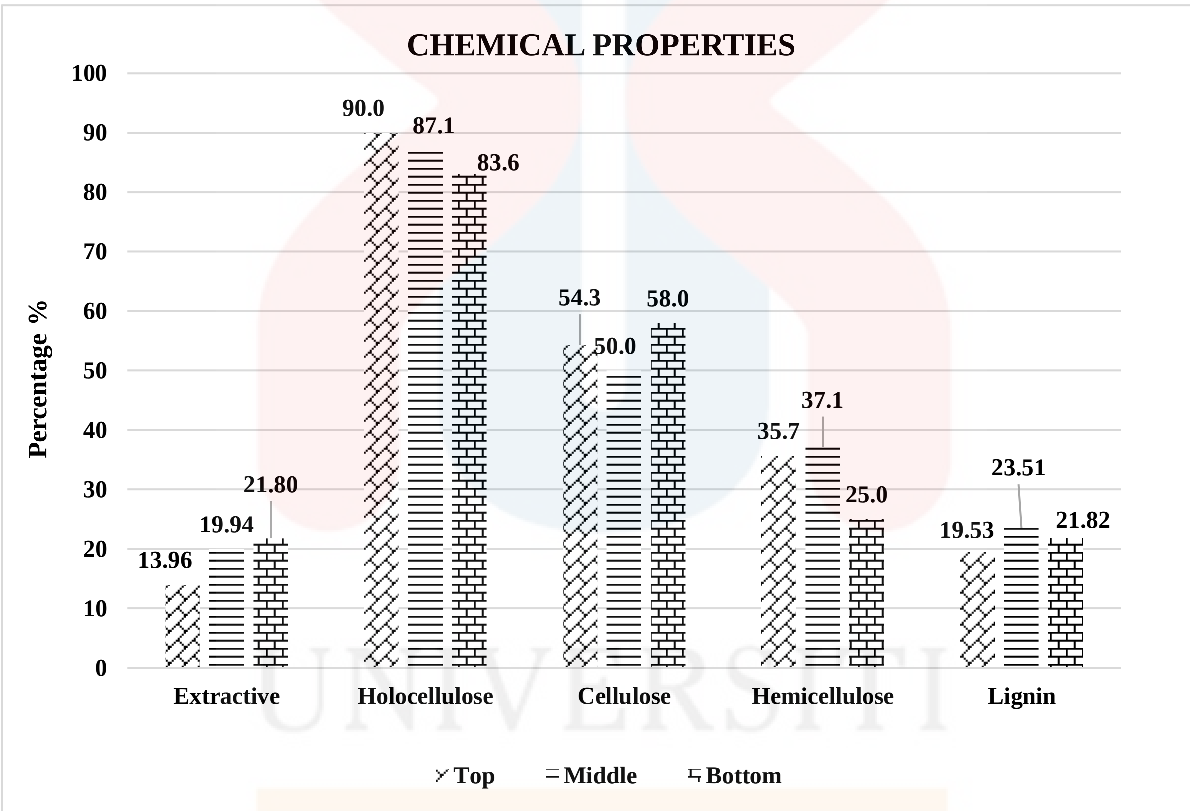

Figure 4.5: Effect of Tree Portion on Chemical Analysis

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The findings of a comparative analysis of rubberwood obtained from the main trunk against side branches provide convincing evidence that tree anatomy and physiology cause significant changes in wood quality in the same tree, one of the most popular tree species is rubberwood or *Hevea. brasiliensis* for industrial forest plantations because of its adaptation to soil requirements and its widespread importance in the timber industry. This study clearly shows that the ratio of rubberwood obtained from wood has a significant effect on the results of its physical and chemical characteristics. By conducting this study, this study found that the radial position and tree spacing had little effect on the physical characteristics of rubberwood. There was clear evidence of great variability in physical properties (Table 4.1), such as specific gravity (0.64) and moisture content (21.19%) in the tree effect portion position. The lower section has physical properties that keep increasing. Besides, the trunk part surpasses the branch in the important stage it achieves superior density, hardness, compressive strength along the grain, and flexural strength. Chemical examination reveals that each part contains a large amount of holocellulose, cellulose, hemicellulose, and lignin obtained from each different portion. These components have different proportions and can be explored for potential industrial applications. According to the findings of the chemical analysis of this study on rubberwood section (Table 4.2) chemical properties differ between parts in terms of extractive content, holocellulose, cellulose, and lignin. It has a higher extractive (21.80%) despite reducing more holocellulose and cellulose at the top, which are 90.0% and 54.30% respectively. This clearly displays the up and down patterns in rubberwood, an important feature for its use in furniture, building and other types of industries.

This performance can be attributed to the inherent differences in cellular structure and composition between the strong main load-bearing trunk and the more delicate branches. As the rubber tree grows, it devotes more resources to strengthening the lower half of its structure, which is essential to support the height and growth of its upper organs. Furthermore, with the increasing recognition of rubberwood as a sustainable hardwood choice for furniture and construction, it is important to understand the variability found within tree trunks for the purpose of optimizing product design and tree harvesting practices. Determinants give priority to choosing wood from trunk sections with the aim of increasing durability, stability, and biomechanical performance, especially in areas where structural integrity is of utmost importance. Furthermore, the progressive changes in the structure of the cell wall as it moves from the stem core towards the outer layer results in higher concentrations of components in the inner wood compared to the less developed cells at the edge of the branch.

This statement is made because by accurately identifying quality differences in rubberwood allows for more efficient allocation of resources, improved processing efficiency, and consistent product quality produced in the manufacture of rubberwood products. The specifier has the capacity to select wood from the part of the tree trunk that requires the best structural effectiveness, while providing less important branch material for cosmetic purposes that does not provide any load bearing support. This action increases the overall efficiency in maximizing the benefits obtained from each harvested tree. By taking a different point of view on the variability in rubberwood quality, we can efficiently use this abundant, rapidly growing and environmentally friendly resource.

5.2 Recommendation

The use of rapid-growth tree species in planting systems is a topic of frequent discussion in both scientific and practical contexts. Rubberwood exhibits significant heterogeneity, offering both prospects and perils to land users and the surrounding ecosystem. Various tree species and kinds can be planted on-site for forestry purposes, including in Short Rotation Plantations (SRC) on agricultural land. The selection of tree species, planting techniques, rotation times, and management practices are mostly determined by the goals of the land user.

On top of that, one can enhance the quality of rubberwood (*Hevea brasiliensis*) by utilizing the understanding of the variations between different portions of the wood. This can be achieved by selecting wood from the main part of the tree rather than from the branches, particularly when prioritizing structural integrity for the final use. This is attributed to its increased density, hardness, strength, and chemical qualities, which result in exceptional load-bearing capability. As a result, it is well-suited for applications in furniture, building materials, and other biomechanically demanding jobs. Furthermore, stratified harvesting and processing involves the separation of wood based on its source within the tree. This means that logs and milled wood from the butt, mid, and top trunk are kept separate from peripheral branch sections. The high-quality butt and trunk grades are then used for structural products, while the branches are diverted for use in load-free finish bearings and furniture components.

Moreover, it is necessary to adapt industrial activities with the goal to meet the fluctuations in the wood composition of stems and branches. To efficiently address variations in moisture content, holocellulose, lignin, and cellulose between sections, one can enhance the cutting pattern, curing conditions, adhesives, and coating chemistry. This can enhance the efficiency, efficacy, and uniformity of performance. In addition, create suitable rubberwood solutions that are precisely tailored to correspond with the distinct chemical and mechanical characteristics of trunks and branches. The utilization of biodegradable composites and mulches will enhance the effectiveness of all types of wood, while also mitigating any inherent limitations through careful design.

Finally, establish a selective breeding initiative for high-quality rubberwood cultivars, using the amount of diversity in wood traits within individual trees as the main criterion for selection, and acquiring genotypes for this purpose. Furthermore, expand the evaluation of wood characteristics to encompass the diversity of trees found in a wider range of tropical wood species. Trunk versus branch differences may arise in the context of fast-growing plantation trees, such as rubberwood, which are both applicable and environmentally friendly.

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APPENDIX A

Figure A.1: The trunk was taken from a sawmill.

Figure A.2: Wood disk of rubberwood.

Figure A.3: Wood disk had been crashing before graining.

Figure A.4: Physical of properties.

Figure A.5: Extract content process.

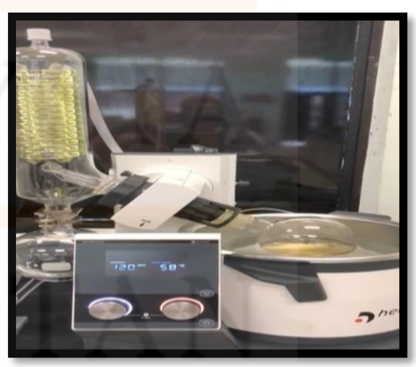

Figure A.6: Rotary evaporate

APPENDIX B

Figure B.1: Filter of Holocellulose process.

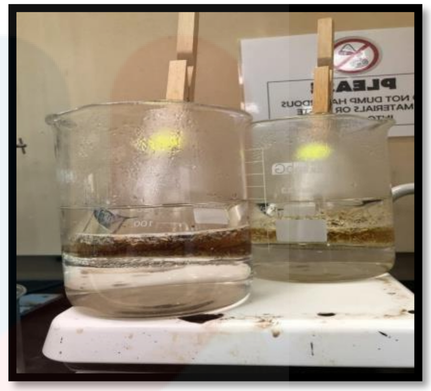

Figure B.2: Cellulose content process.

Figure B.3: Lignin content process.

Figure B.4: Filter of Lignin process.

Figure B.5: Sawdust of each portion.

Figure B.6: Sawdust of lignin.