Comparison of Chemical Composition Small Diameter Wild *Leucaena leucocephala* and *Acacia mangium*

by

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DECLARATION

I declare that this thesis entitled "Comparison of Chemical Composition Small Diameter Wild *Leucaena leucocephala* and *Acacia mangium*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________________

Name : ______________________________

Date : ______________________________

ACKNOWLEDGEMENT

Foremost, I am grateful to the God for the good health and well being that were necessary to complete this book. After an intensive period of seven months, today is the day writing this note of thanks is the finishing touch on my thesis. It has been a period of intense learning for me, not only in the scientific arena, but also on a personal level. Writing this thesis has had a big impact on me. I would like to reflect on the people who have supported and helped me so much throughout this period.

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LIST OF ABBREVIATIONS

DBH	Diameter breast height
IPCC	Inter-governmental Climate Change
pH	Acidity level
TAPPI	Technical Association of Pulp and Paper Industry
ANOVA	Analysis standard of variance
ITIS	Integrated Taxonomic Information System

LIST OF SYMBOLS

%	Percent
CO_2	Carbon Dioxide
^{o}C	Degree Celsius
mm	Millimetre
ß	Beta
α	Alpha
cm	Centi Meter
ml	Millilitre
g	Gram
L	Litre
NaCl	Sodium Chloride
NaOH	Sodium Hydroxide
H_2SO_4	Sulphuric acid
×	Multiplication

Comparison of Chemical Composition Small Diameter Wild *Leucaena leucocephala* and *Acacia mangium*

ABSTRACT

Leucaena leucocephala and *Acacia mangium* are listed among of the fast growing species that are wide used in Malaysia as livestock forage and industrial production. Thus, study was conducted to identify the chemical composition of small diameter wild *Leucaena leucocephala* with *Acacia mangium* and to compare between of them. *Leucaena leucocephala* (diameter 5-8cm) was collected at area Grik to Lenggong, Perak meanwhile *Acacia mangium* at area Jeli. The stem has been processed to three portions (bottom, middle and top) into small particle form for the chemical composition analysis. The method of chemical composition, sampling and preparation of the sample for analyzed of extractive, holocellulose, cellulose and lignin were carried out according to the Technical Association of the Pulp and Paper Industry Standard (TAPPI) except hemicelluloses, because the data was collected by using equation. The data that was collected are analyzed by using analysis of variance (ANOVA). The result shows that, there are not significant different for the comparison between species but the result shows the different significant for dependent of extractive and lignin variable ($p<0.05$ and $P< 0.01$) in comparison between three different portion.

Perbandingan Komposisi Kimia Diameter kecil *Leucaena leucocephala* dan *Acacia mangium*

ABSTRAK

Leucaena leucocephala dan *Acacia mangium* merupakan salah satu spesies mudah membesar yang ditanam secara meluas di Malaysia sebagai makanan ternakan dan pengeluaran perindustrian. Objektif utama kajian ini adalah untuk mengenal pasti komposisi kimia diameter kecil *Leucaena leucocephala* dengan *Acacia mangium* dan untuk membandingkan komposisi kimia diameter kecil *Leucaena leucocephala* dengan *Acacia mangium* mengikut spesis yang berbeza dan bahagian (bawah, tengah dan atas). *Leucaena leucocephala* (diameter 5-8cm) telah ambil di kawasan Gerik ke Lenggong, Perak dan *Acacia mangium* di kawasan Jeli. Batang pokok ini telah diproses kepada tiga bahagian (bawah, tengah dan atas) ke dalam bentuk zarah kecil untuk analisis komposisi kimia. Kaedah komposisi kimia dan penyediaan sampel untuk dianalisis dalam ekstraktif, holocellulose, selulosa dan lignin telah dijalankan menurut *Technical Association of the Pulp and Paper Industry Standard* (TAPPI) kecuali hemicelluloses, kerana data itu dikumpul dengan menggunakan persamaan. Data yang dikumpul dianalisis dengan menggunakan analisis varians (ANOVA). Berdasarkan result, keputusan menunjukan bahawa tidak ada perbezaan yang ketara dalam perbandingan antara species manakala keputusan menunjukan ada perbezaan antara factor ektractive dan lignin bebas dalam perbandingan antara setiap tiga bahagian yang berbeza ($p< 0.05$).

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Leucaena leucocephala is one of the multipurpose plant species which from leguminous shrub of great importance in the tropic region (Vietmeyer *et al*., 1977). *Leucaena leucocephala* or locally known as "*Petai Belalang*" (Zayed *et al*., 2014) is a tropical tree that high growth in warm temperature and reduce growth when the temperature is cold especially in subtropical area. The best seasons for their growth is when sub-humid and humid climate with moderate dry seasons.

This tree is a fast growing tree species and very easy to be planted. Other than that, this tree is very good in charcoal producing and very high value in heating process and it very excellent in firewood (Orwa *et al*., 2009). Then, it can be multipurpose uses for example fuel wood, charcoal, pulp and for soil improvement. *Leucaena leucocephala* have been widely planted in agro forestry application because of its very useful in biomass energy production (Oggiano *et al*., 1997).

Other than that, *Leucaena leucocephala* is widely used as livestock forage, fuel-wood, reforestation material and green manure. Its uses have also been expanded to gum production, furniture and construction timber, pole wood, pulpwood, shade and support plants in agro forestry systems (Nazri *et al*., 2011).

Meanwhile, *Acacia mangium* is the most fast growing tree species and important multipurpose tree for the tropical lowlands. According to Eldoma and

Awang (1999), the species is typically found in the tropical lowland climatic zone characterised by a short dry period of 4 months. Other than that, it is one of the most widespread of the fast growing tree species which are used in plantation forestry programmes throughout Asia, the Pacific and the humid tropics (Sein & Mitlohner, 2011). According to National Research Council (1983), its desirable properties include rapid growth, good wood quality and tolerance of a wide range of soils and environments. Besides that, this species are widespread it genus which is about 1,200 species of tree and shrubs that occur naturally in all contents except Antarctica and Europe (Maslin, 2001). *Acacia mangium* is become naturalised in Brazil, Puerto Rico and many other area (Sein & Mitlohner, 2011).

Acacia mangium was listed as one of the exotic tree and it was planted widely in Peninsular Malaysia. Fast growing acacia plantations provide industrial wood for wood processing, pulp and paper industries and woodchip exports, as well as house old fuel wood supplies in rural areas. Acacia plantations are nitrogen fixing and the leaves provide an effective litter layer, making the species a favoured plantation genus (Sein & Mitlohner, 2011). Therefore, *Acacia mangium* are use to sustain the commercial supply of tree products in order to decrease pressure on natural forest ecosystems (Krisnawati *et al*., 2011).

This research will identify the chemical composition of small diameter of wild *Leucaena leucocephala* and *Acacia mangium*. Other than that, this study will compare the chemical composition of small diameter between them according to different portion (bottom, middle and top).

1.2 Problem Statement

.According to the report from Inter-governmental Panel on Climate Change (IPCC), there are more than 90% of global warming was occur (IPCC, 2001) that cause the climate are rapidly change and will effect to the tree growth. Nowadays, both species are used widely for production of pulp and this can cause the number of these species will decrease rapidly and need to be replacing with another exotic species. In order to meet increasing demand, government should find alternative way and develop more efficient technologies in order to ensure the sustainability of the natural species for the future generation.

The world was classified *Leucaena leucocephla* and *Acacia mangium* species as among of the important plantation program. Both are suitable for pulp, paper, creates and woodchips and board. Other than that, it also has high potential in moulding, sawn timber, veneers and furniture (Krisnawati *et al*., 2001). Besides that, there is no research data investigate in Malaysia that shows chemical composition analysis of small diameter wild *Leucaena Leucocephala* and *Acacia mangium* especially between portion and parts.

Thus, this research are carry out to evaluate the potential of small diameter *Leucaena leucocephala* and *Acacia mangium* wood according to difference portion. The entire portions (bottom, middle and top) were carrying out by extractive, holocellulose, cellulose, hemicelluloses and lignin. This is because, stem is one of the important parts that normally used in industry production. The diameters that are selected for this process are 5-8cm.

By using *Leucaena leucocephala* and *Acacia mangium* as the potential strand properties support the suitability and effective use of raw materials (Nazri *et al*., 2011). It is because leucaena and acacia have good wood quality and tolerance of a wide range of soils and environments (National Research Council, 1983). Other than that, chemical composition is important in order to determine the structure and the function of the plant. In addition, there are three basic functions which is transpiration of water from leave, mechanical support and biochemical support.

In this study chemical properties of small diameter wild *Leucaena leucocephala* and *Acacia mangium* was be conduct to provide more information about this species, which are biochemical mechanics and their potential function of this wood.

1.3 Objectives

a. To identify chemical composition of small diameter wild *Leucaena leucocephala* with *Acacia mangium*.
b. To compare the chemical composition of small diameter wild *Leucaena leucocephala* with *Acacia mangium* according to different species and portion.

CHAPTER 2

LITERATURE REVIEW

2.1 Wood

Wood comes from the trunk (main stem) of trees and it comes from living and growing trees. According to the Department of Primary Industry (2008), large areas of forest have been set aside and are managed primarily for the continued production of wood. It is because to ensure ensures a continual supply of wood to meet our present and future needs.

Two main purpose of wood stem is to support the branches, leaves and flowers of the tree, holding these firmly, even against the buffeting of wind and storms. Another important of wood stem is to transport water and nutrients from the roots to the leaves, and sugar and other food stuffs from the leaves to all the other areas of the living tree (Department Primary Industry, 2008).

2.1.1 Hardwood

Hardwood is an Angiosperm species that use flowers to pollinate for seed reproduction for example oaks, maples, birches and fruit trees. Other than that, structure of the hard wood is more complex compare with soft wood structure. The majority of hardwood volume is composed of fibre cells that offer structural support to the stem and it contain vessel element for water conduction (Brian, 2002). Fig. 2.1 shows the close-up section of hardwood.

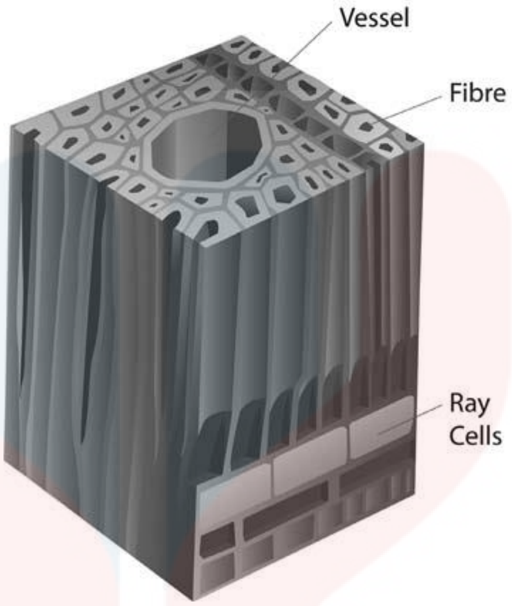


Figure 2.1: Close-up section of Hardwood (Department Primary Industry, 2008)

Hardwood come with variety of colour and shades such as reddish brown of black cherry, the deep chocolate brown of black walnut or the creamy white of hard maple. Besides that, many hard wood have distinctive natural odors for example, has an unmistakably fragrant aroma,while red oak is more bitter and acidic smelling. Other than that, the density of the hard wood is related to its hardness, strength and weight. Hardness is particularly useful when distinguishing between hard and soft maple. Soft maple can be easily dented with your fingernail or sliced with a razor blade, while hard maple is significantly more difficult to make an impression (Brian, 2002).

2.1.2 Softwood

Softwoods can be divided into two classifications based on the presence or absence of resin canals. Species that have resin canals for example pines, spruces, larches and Douglas-fir. The species that do not have resin canals include firs, hemlocks, cedars, redwood, baldcypress and yew (Brian, 2002). According to Department Primary Industry (2008) bulk of softwood made up of long narrow cells, or tracheids, that fit closely together. Furthermore, cell wall of tracheids are made of cellulose and the centres are hollow and Fig. 2.2 shows a close-up section of softwood.

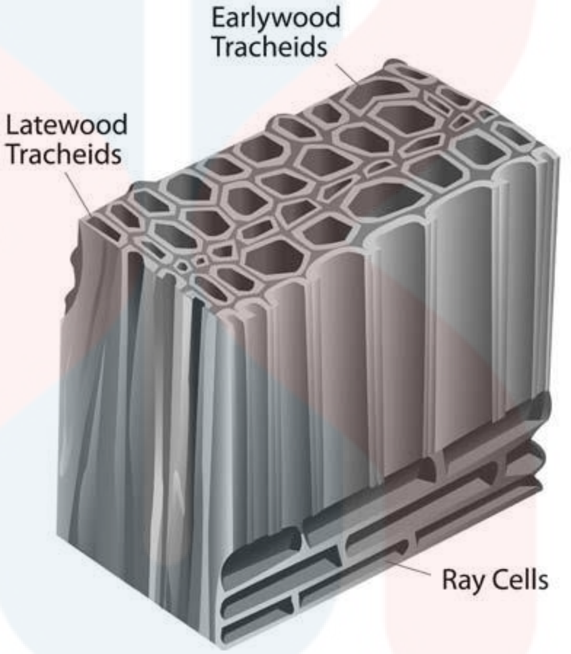


Figure 2.2: A close up section of softwood (Department Primary Industry, 2008)

Softwood is known for burning hotter initially, easy to light, having more pitch or sap, more sparks and it burns more quickly. Besides that,softwood have differences clours and density such as eastern redcedar has a distinctive deep purplish-red color, and redwood a deep reddish-brown and eastern white pine is consistently yellowish white, darkening to light brown with age (Brian, 2002).

2.1.3 Sapwood

Sapwood is located at the outer-wood that considered as inferior to heartwood and is often discarded during conversion and it gives structural support to the living tree, acts as a food storage reservoir and transports water (Sini, 2011). The sap wood are so well envolve in water transportation of water and mineral from root to the leave by vessels in hardwoods and tracheids in the softwoods (Bamber, 1987).

2.1.4 Heartwood

Heartwood is produced by the completion of death of the parenchyma cellsand. These changes occur gradually through a layer of cells of variable width known as the transition zone (Bamber, 1987). Furthemore, heartwood consists of dead cells, and the extractives in heartwood protect the tree against biological attack, lower the water content and act as fungicides (Wise & Jahn, 1952).

In chemical analysis, content and composition of the extractives in heartwood fluctuate and the heartwood is darker than the sapwood. Besides that, the dying cells produce heartwood extractives from the nutrients in them whilst the bordered pits are aspirated (Sini, 2011). According to Sustersic *et al* (2010) the age and growth rate of the tree affect the content and composition of extractives, and the amount of heartwood is higher in older trees than in younger ones, though it decreases from the butt to the top of the tree.

2.2 *Leucaena leucocephala*

Leucaena leucocephala are commonly found with 3-15m tall and 10-35cm in bole diameter. It is a tropical species and it fast growing tree in size 20 ft tall and 10 cm of diameter stem (Orwa *et al*., 2009). Fig. 2.3 shows the mature tree of *Leucaena leucocephala*.

Figure 2.3: Mature *Leucaena leucocephala* (Hughes, 1998).

Leucaena is a tropical species that growth in warm temperature which is 25 to 30 ˚C for optimum growth. It has poor cold tolerance, and significantly reduced growth during cool winter months in subtropical areas (Walto, 2003). Other than that, it grows well only in sub humid or humid climates with moderate dry seasons of up to 6-7 months (Orwa *et al*., 2009).

2.2.1 Properties of *Leucaena leucocephala*

Leucaena leucocephala is tree that medium in size and variably shrubby and highly branched 5-10 m tall and with a trunk 5–50 cm in diameter (Orwa *et al*., 2009). Bark on young branches smooth, grey-brown, slash salmon pink, darker grey-brown and rougher with shallow. Leaf petioles are 10–25 cm long, with 4–9 pairs of pinnate per leaf (Walton, 2003). Other than that, the diameter of flowers head is 12-21mm (Orwa *et al*., 2009). The individual flowers are small and cream–white as shown in Fig. 2.4, with ten free stamens per flower and hairy anthers and it actively growing young shoots (Walton, 2003).

Figure 2.4: Open flower head and unopened flower buds (Hughes, 1998).

Leucaena leucocephala have several types of species and some of their species are very sensitive in acidic soil and the others species it can growth well in acidic soil (Palm & Alshareef, 2014). Leucaena have high quality in producing a large volume of a medium-light hardwood for fuel (specific gravity at 0.5-0.75) with low moisture and a high heating value and it also can produces excellent charcoal and producing little ash and smoke (Shelton & Brewbaker, 1994). Besides that, it also can be used for parquet flooring and small furniture as well as for paper pulp. According to Brewbakers *et al* (1985), *Leucaena leucocephala* are useful for posts, props and frames for various climbing crops.

Leucaena leucocephala have been used in several aspects such as medical uses. The seed of *Leucaena leucocephala* have high potential in medicine properties and it can be used to control stomach-ache, as contraception and absorption. Other than that, seed gum of *Leucaena leucocephala* can be used as binder in tablet (Verma & Balkishen, 2007). Another benefit of *Leucaena leucocephala* is it can be used in agriculture purposed. The leave of *Leucaena leucocephala* can be used in organic farming as green manner (Gangwar *et al*., 2004 and Mathuva *et al*., 1998). Besides that, the larger number of root and root nodules can be used and help to fix the atmospheric nitrogen in soil (Azeemoddin *et al*., 1988) and it prevent the soil erosion by wind and water when it planted at foot hill.

Leucaena leucocephala have high potential in biofuel production. *Leucaena leucocephala* have it own specific gravity and high calorific value that can make it as an excellent species in firewood compare with other species. It burn properly with little smokes, produces less than 1% ash and the species is very excellent in charcoal production. Other than that, it seed oil has no harmful agent and it can use as a biofuel in diesel agent. In the other hand, the fatty acid in seed oil of *Leucaena leucocephala* have great potential in bio-corrosion of mild steel and copper alloys uses (Meena *et al.*, 2013). Fig. 2.7 shows the morphological character of leucaena (Walton, 2003).

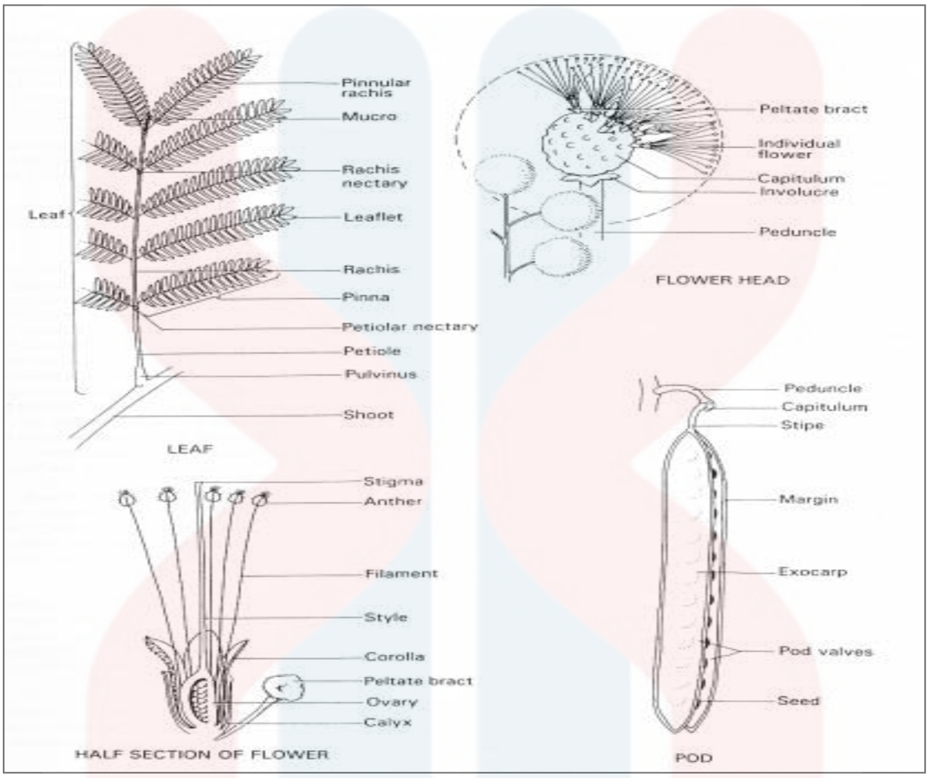


Figure 2.5: Morphological characters of leucaena (Walton, 2003).

2.2.2 Taxonomy of *Leucaena leucocephala*

Leucaena leucocephala was found in Mexico is fast growing and it is tropical and growth in warm temperature region. Besides that, this species contain high nutritive like carbohydrate, fat and protein (Meena *et al.*, 2013). *Leucaena leucocephala* are one of species that suitable for biomass and paper production (Lopez *et al.*, 2008). Table 2.1 shows the taxonomic name of *Leucaena leucocephala*.

Table 2.1: Taxonomic name of *Leucaena leucocephala* (Leeuw, 2014).

Categories	**Taxonomic name**
Domain	Eukaryota
Kingdom	Plantae Phylum
Subphylum	Angiosperm
Class	Dicotyledonae
Order	Fabales
Family	Fabaceae
Subfamily	Mimosoideae
Genus	Leucaena
Species	*leucocephala*

2.2.3 Distribution of *Leucaena leucocephala*

Leucaena leucochephala was found in Central America and the Yucatan Peninsula of Mexico over 400 years ago by the Spanish conquistadores. Besides that, he bring the seed of *Leucaena leucocephala* to the Philippines to make as a stock (Brewbaker *et al*., 1985). After that, this species was spread to another few countries and it was used as a plantation crop. Other than that, it was recognized around the world with two species of *Leucaena leucocephala* which is weedy and low yielding that come from scrubby free seedling (Jones, 1979).

In the other hand, *Leucaena leucocephala* species was spread into 25 countries except Antarctica and all of the countries have difference common name for *Leucaena leucocephala* species as shown in Table 2.2. In Australia, they were predicting that, *Leucaena leucocephala* species have high potential range in species of cultivation. The prediction focuses in difference factor which adaptive range, while others in potential economic range.

Table 2.2: Common name of *Leucaena leucocephala* (Brewbaker *et al*., 1985)

Common name	Countries
Leucaena	Australia, United States
Ipil ipil	Philippines
Lamtoro	Indonesia
Katin	Thailand
Yin ho	Huan China
Kubabul or Subabul	India
Koa haole	Hawai
Tangantangan	Some Pacific island
Cassis	Vanuatu
Guaje	Mexico
Huaxin	Central America (Maya)

2.3 *Acacia Mangium*

Acacia mangium is a fast growing tropical Mimosaceae tree species widely planted for reforestation and soil rehabilitation of degraded land in Southeast Asia, India and the southern provinces of China. *Acacia mangium* is used as raw material for the pulp industry due to its high yield and high-quality fibre (Tsai, 1988). According to the National Research Council (1983), other attributes of the species include rapid growth, optimum wood quality and tolerance of a wide range of soils, pH and environments. Fig. 2.6 shows *Acacia mangium* tree.

Figure 2.6: *Acacia mangium* tree (Krisnawati *et al*., 2011).

In Malaysia, fast growing tree species with short rotation period have been logged and successively reforested in virgin tropical forest. The species commonly use for planting are several imported species of Acacia and Eucalyptus (Ciencialaa *et al*., 2000). Besides that, *Acacia mangium* also represent as one of the most important species planted on the clear field area at Borneo Malaysia (Nykvist *et al*., 1996). In addition, these species are suitable for the plantation at marginal site (Arisman, 2003).

This species is able to grow even in acidic soils with pH as low as 4.2. The trees are useful for shade, ornamental purpose, demarcating boundaries, screening, and wind breaks as well as for use in agro-forestry and erosion control (Dhamodaran & Chacko, 1999). Furthemore, *Acacia mangium* tress are good plantation tress because it renowned for their robustness and adaptability and it also work on the diseases, soilgrowth, silviculture treatments, seeds and their establishment (Lim *et al*., 2011).

Acacia mangium is a species that evergreen fast growing tropical tree that growth in the humid tropical,lowland climatic zone and it has been characterize by a short winter, high total anual rain fall and dry seasons, which can grow up to

30 m tall and 50 cm thick, under favorable conditions (Hegde *et al*., 2013). The rainfall in Kudat Bengkoka/Sabah is up to the 2,500 mm and it consider adequate for *Acacia mangium* tree growth (Pinyopusarerk *et al*., 1993). Moreover, the trees will dieback during the dry season, when monthly rainfall is below 100 mm and the evaporation rate exceeds 130 mm per month because the tree are under moisture stress (Hegde *et al*., 2013).

Acacia mangium has good quality wood traits, such as a comparatively low proportion of parenchymatous cells and vessels, white and hard wood, and high calorific value. Therefore, it is useful for a variety of purposes, such as furniture, cabinets, turnery, floors, particleboard, plywood, veneer, fence posts, firewood, and charcoal (Hegde *et al*., 2013). According to National Research Council (1983), *Acacia mangium* trees can also be used as fire breaks as trees with diameters of 7 cm or more are commonly fire resistant

2.3.1 Properties of *Acacia mangium* Species

Acacia mangium is a large tree and it can growth up to height 30m with straight bole. The diameter of breast height (DBH) of trees are generally more that 60 cm and the diameter of steam up to 90 cm (National Research Council 1983**).** The stem are in longitudinal furrows. The colours of bark young trees which is develope 2-3 years is smooth and grenish colour. However bark in older trees are coloured brown to dark brown and the the bark is rough, hard and fissured near the base (Krisnawati *et al*., 2011). Fig. 2.7 and 2.8 show the bark of *Acacia mangium* of young and bark in old.

Figure 2.7: Bark of young *Acacia mangium* trees
(Krisnawati *et al*., 2011).

Figure 2.8: Bark of old *Acacia mangium* trees
(Krisnawati *et al*., 2011)

The phyllodes are simple and parallel veined, and the mature phyllodes of *Acacia mangium* trees very large and it can be up to 11-27 cm long and 3-10 cm broad (Hedges *et al*., 2013). Based on Maslin and McDonald (1996) phyllodes can be characterized by four main longitudinal nerves which is lower margin, minor nerves strongly anatomizing to form a prominent reticulum and figure 2.6 shows the Phyllode of *Acacia mangium* with four longitudinal veins.

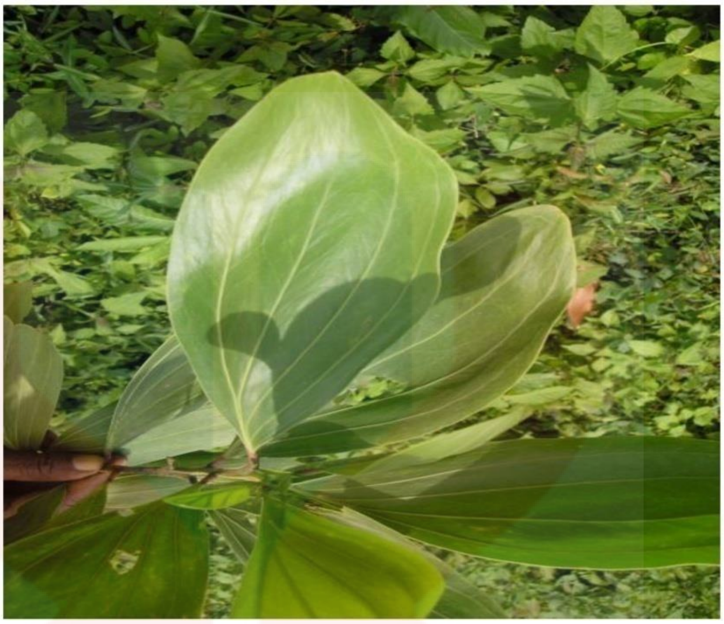


Figure 2.9: Phyllode of *Acacia mangium* with four longitudinal veins (Hedges *et al*., 2013).

The flower has a mild, sweet fragrance and whitish are in rather loose spikes 5-12 cm long on peduncles 0.6-1 cm long, singly or in pairs in the upper axils (Hedges *et al*., 2013). After that, the flowers change into a green pod that darkens to blackish-brown at maturity after the fertilization process (National Research Council 1983). The seed of *Acacia mangium* trees are form in black, shiny, longitudinal with a size of 3–5 mm by 2–3 mm and it attached to the linear seed pods (Krisnawati *et al*., 2011). Fig. 2.9 shows the *Acacia mangium* seeds.

Figure 2.10: *Acacia mangium* seed (Sein & Mitlohner, 2011).

2.3.2 Taxonomy of *Acacia mangium* Species

Specific name for *Acacia mangium* tress is an allusion to Rumphius' observation that this tree resembled 'mangge' or mangroves in Indonesia. Acacia contains 1,200-1,300 species and it *Phyllodinae* subgenus classed into seven sections, containing more than 900 species (Maslin and McDonald, 1996). Besides that, *Acacia mangium* can be classified into Juliflorae by having flowers in elongated spikes and numerous phyllodes, often anatomizing by longitudinal nerves (Hedges *et al*., 2013).

Acacia mangium are categorized into the sub-family Mimosodeae and the family is Leguminosae that native from Australia, Papua New Guinae and Indonesia (Lim *et al*., 2011). According to Integrated Taxonomic Information System ITIS (2010) Table 2.3 below shows the hierarchy of *Acacia mangium* species.

Table 2.3: Hierarchy of *Acacia mangium* species (ITIS, 2010).

Kingdom	Plantae - Plantaes, Planta, Vegetal, Plants
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta -land plant
Superdivision	Embrayophyta
Division	Tracheophyta -vascular plant, tracheophytes
Subdivision	Spermatophytina -spermatophytes, seed plant, phanerogames
Class	Magnoliopsida
Superorder	Rosanae
Order	Fabales
Family	Fabaceae-peas, legumes
Genus	Acacia Mill
Species	*mangium*

2.3.3 Distribution of *Acacia mangium* species

According to National Research Council (1983) *Acacia mangium* species originates from the humid tropical forests of north-eastern Australia, Papua New Guinea and the Molucca Islands of eastern Indonesia. These species are widely distritribute which is over 1300 species throughout tropic and subtropics (Sein & Mitlohner, 2011). After that, *Acacia mangium* was introduce into Sabah, Malaysia, in the mid 1960s and it has been widely introduced into many countries, including Indonesia, Malaysia, Papua New Guinea Bangladesh, China, India, Philippines, Sri Lanka, Thailand and Vietnam In Indonesia (Pinyopusarerk *et al*., 1993).

The distribution is widely happened when strongly influenced by rainfall patterns and soil drainage. The latitudinal range is 1°-18 o 57'S and longitudinal range is 125 o 22'- 146 o 17'E. The mean altitudinal range is from just above sea level to about 100 m, with an upper limit of 780m (Dhamodaran & Chacko, 1999) .

2.4 Chemical Composition

Chemical compositions are including five analysis which is extractive, lignin, holocellulose, cellulose and hemicelluloses. Other than that, the entire sample will ground separately in wily mill and screened. Then, it will go through 40 mesh screen (0.40mm diameter) but retained on 60 mesh screen (0.25mm diameter). The standards that will be used are the Technical Association of Pulp and Paper Industry (TAPPI) standard (Mainoo *et al*., 1995).

2.4.1 Holocellulose

Holocellulose is one of the components that are important in chemical composition analysis. The hemicellulose are actually made of the carbohydrate polymers which consisting of simple sugars monomer (Browning, 1975). Holocellulose is the starting point in the carbohydrate biomass study and it also is made up of cellulose and all of the hemicelluloses and that is obtained by removing the extractives and the lignin from the original natural material (Rabemanolontsoa & Saka, 2012).

2.4.2 Cellulose

Major component of cell wall is cellulose it is because it provides strength and stability to plant. Cellulose is consisting of simple sugar monomer that made from carbohydrate polymer (Browning, 1975). All of the energy that absorb by plant through photosynthesis process will store in cellulose form (Raven & Event, 1992). Besides that, cellulose is usually known as polymer because it consists of two molecule of glucose. For isolation of cellulose from wood, a direct nitration of wood yields undergirded cellulose tri-nitrate, which is soluble in organic solvents (Guanyu & Pirjo, 2011). The chemical formula for cellulose is $C_6H_{10}O_5$. Cellulose is form when ß 1-4 linkages link between glucose rings and it insolubility in water and another solvent. Fig. 2.10 shows the structure of cellulose.

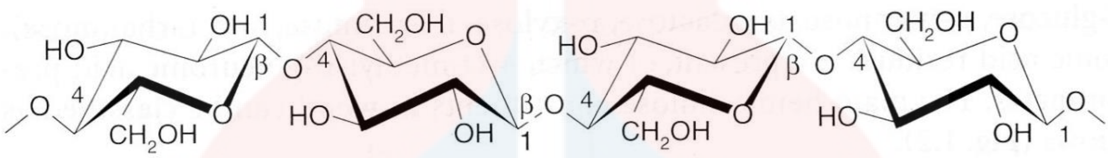


Figure 2.11: The Structure of Cellulose (Sjostrom, 1998).

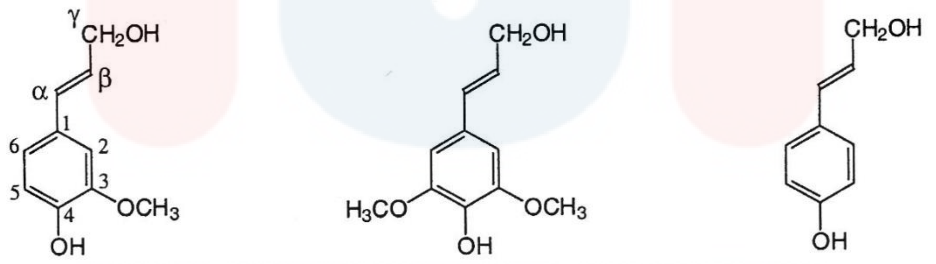
The tight fiber structure created by hydrogen bonds results in the typical material properties of cellulose, such as high tensile strength and insolubility in most solvents (Guanyu & Pirjo, 2011). Then, cellulose will convert to fuel and lower molecular weight chemicals is strongly influenced by physical factors such as the degree of polymerization, level of crystallinity and number of reducing ends associated with the substrate (Budarin *et al.*, 2010).

2.4.3 Hemicellulose

Hemicellulose is other major naturally occurring carbohydrate based polymer of sugar that enters into the plant cell wall which are clearly less well-defined than cellulose. The structures of hemicelluloses are hexoses, pentoses or deoxyhexoses (Guangyu & Pirjo). Besides that, it can be found in plant cell wall and it represent as a family of polysaccharides such as arabino-xylans, gluco-mamans and galactans. Other than that, hemicelluloses are produce from plant extracted with high degree of polydispercity, polydiversity and polymolecularity (Harmsen *et al*., 2010).

2.4.4 Lignin

Lignin is polymer from Phenyl-propane and it act as protective layer for the plant (Browning, 1975). Besides that, it can be define as polyphenolic material arising primarily from enzymic dehydrogenative polymerization of three phenylpropanoid units (p-hydroxycinnamyl alcohols), as shown in Fig. 2.11(Guangyu & Pirjo).



trans-Coniferyl alcohol *trans*-Sinapyl alcohol *trans-p*-Coumaryl alcohol

Figure 2.12: The Building Units of Lignin (Stenius, 2000).

Other than that, lignin acts as the bonding agent that binds the cells in the tress (Razak, 1998). It produce from biosynthetic process, for the higher plant, it divided into two categories which is hardwood (angiosperm) is made up from conifer and sinopyl alcohol and softwood (gymnosperm) that made up from more than 90% of conifer alcohol. Other than that, lignin are important in transport of water, nutrient and metabolism to plant cell for plant growth and their stability in food production process (Harmsen *et al*., 2010).

2.4.5 Extractive

Extractive is cell wall component that come from extraneous with low molecular weight component. The simple analogy of reinforced concrete can represent the role of each cell wall component (Brigid, 2010). Furthermore, extractive can be regards as non-structural wood constituents and usually represent a minor fraction in wood.There are distinct differences in the composition even there are similarities in the occurrence of wood extractives within families. Other than that, the extractives comprise both inorganic and organic components. Generally, content of extractives is higher in bark, leaves and roots, than that in stem wood. The inorganic components measured as ash seldom exceeding 1% of the dry wood weight (Guangyu & Pirjo, 2011).

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

The main material for this study is *Leucaena leucocephala* or the Malaysian people known as "*Petai Belalang*" and *Acacia mangium*. This species are randomly selected from the wild, with approximate same age, based on the diameter of plant stem (5-8 cm) at roughly same diameter. The *Leucaena leucocephala* are harvest at area Gerik to Lenggong, Perak and *Acacia mangium* at area Jeli.

3.1.1 Sample Collection and Preparation

Leucaena leucocephala and *Acacia mangium* in suitable growth stage and free from any disease were collected as a sampled. Then, the *Leucaena leucocephala* and *Acacia mangium* stem was cut and pull out their leave, then undergo into small pieces. Then, sample are randomly collected and were undergo process chipping, grinding and drying process in order to get their fix size of wood chip from raw material which is 1.5mm.

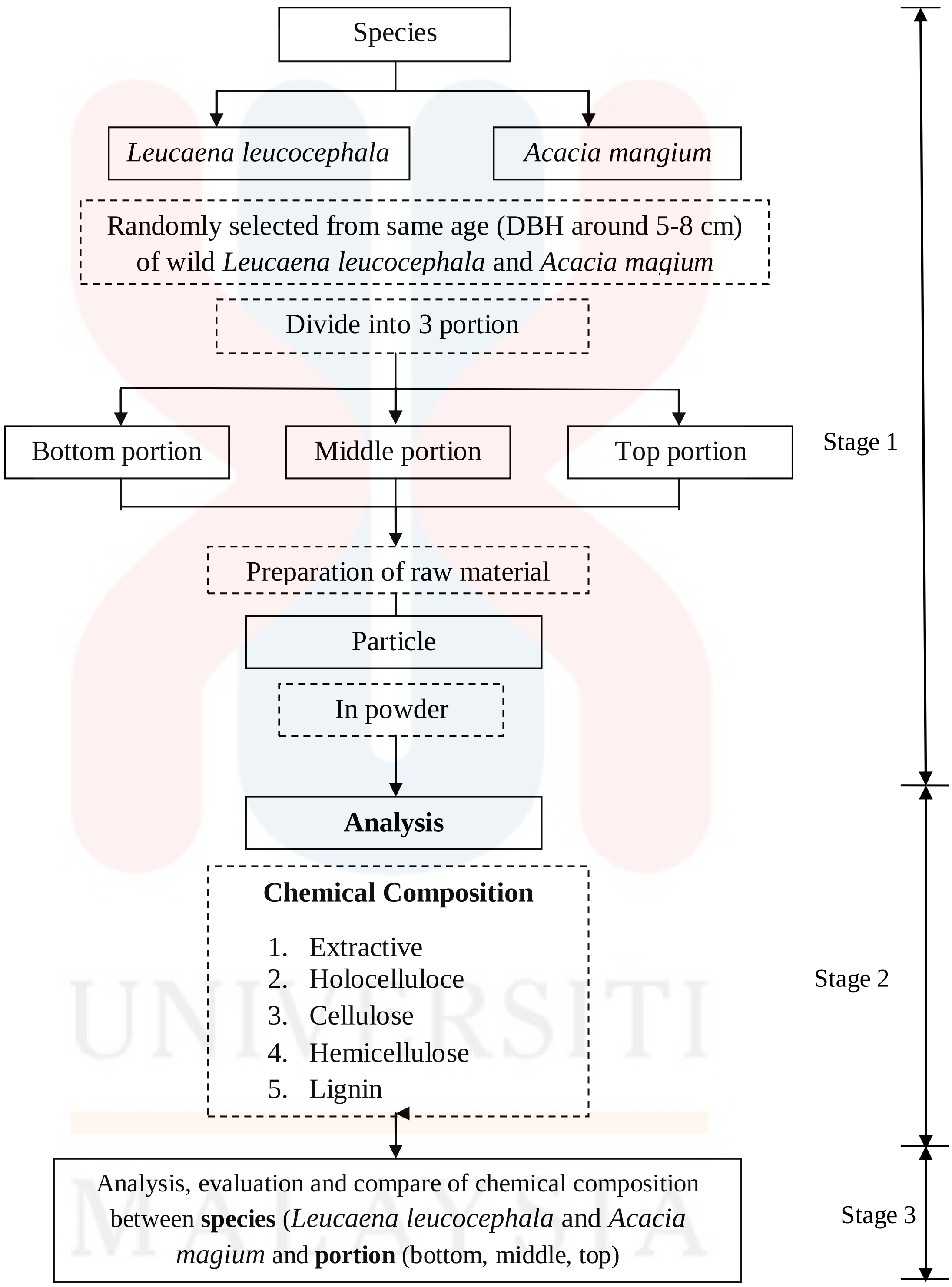
In chipping process, the sample are chip size by using drum chipper machine into smaller flicker that specially built to reduce wood chips and in order to ease easily used for both log and harvesting residues. The machine units are contain 12 knives installed in tangential position and it made up from steel. The size for the chip is more heterogeneous, with length up to 6.5 cm.

Grinding process is the process that dry and sawdust sample form were then grinded by disc mill machine and split them into another find sawdust form, particularly ranges between 0.5-2.0 mm. These processes were breaks down the lignin and increase the specific area of the material.

In drying process, the sample then was dry in oven under condition at 72°C for 12 hours. To avoid breaking up the lignin structure in the wood and to obtained moisture content range between 9-12% the drying temperature must be moderate properly.

3.2 Methods

Several procedures were carried out to prepare the *Leucaena leucocephala* and *Acacia mangium* for further analysis on its chemical composition analysis. Chemical composition analysis will include extractive, holocellulose, cellulose, hemicelluloses and lignin.



Note:

Stage 1: Material preparation (grouping based on **Species** and **Portion**)
Stage 2: Testing of *Leucaena leucocephala* and *Acacia magium* based on chemical analysis.
Stage 3: Analysis, evaluation and comparison of experimental data

Figure 3.1: Research flow chart

3.3 Chemical Composition Analysis

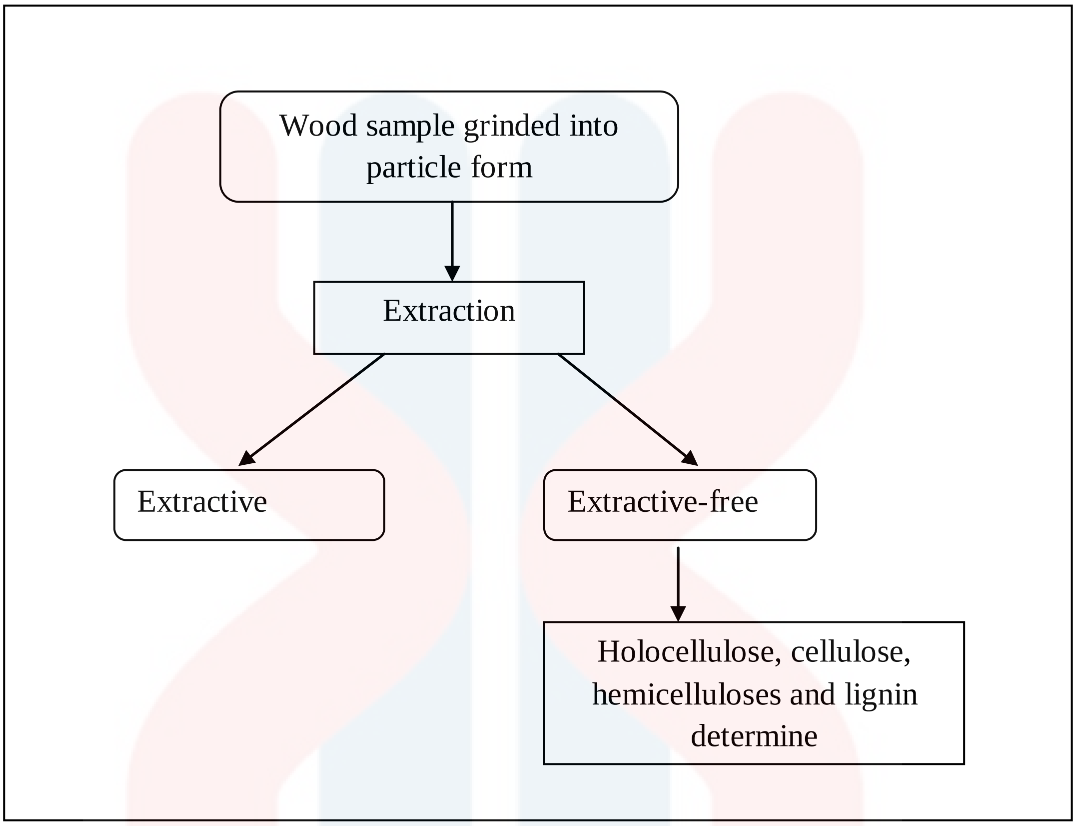


Figure 3.2: Simple schematic diagram of processes to determine wood chemical properties.

The first samples that are prepared on site are wood sample preparation, with precautions and safety exercised. Safety is very important here because most of the process for these analyses are involves a lot of heavy machineries, if not follow the rules that have been recommended properly, the researcher may have high probability in grave injuries.

3.3.1 Determination of Extractive

Extractive content of *Leucaena leucocephala* and *Acacia magium* method are determined by using TAPPI T204 cm-97 (1997). Firstly, samples are weighted approximately in 5g for each sample. Then, the sample were put inside extraction thimble and extracted with ethanol-benzene solution at ration 2:1, 300ml, which span for 5-6 hours. In order to have only the extractives the extractive solution were evaporated in rotary evaporator. Then the sample was dried in a glass Petri dish after the extractives were obtained. After that, sample was dried at 105^{o}C for 24 hours to get a good dried extractive. Then, extractive content were calculate based on Equation (3.1).

$$\text{Extractive Content (\%)} = \frac{\text{weight of extractives (g)}}{\text{weight of oven dried sample (g)}} \times 100 \qquad (3.1)$$

3.3.2 Determination of Holocellulose

The sample that are used in holocellulose determination is air dried sample of extractive-free,3g of sample were put into 250ml conical flask and 100ml of distilled water, then 1.5 g of sodium chloride crystals and 5ml 10% acetic acid was added. Then, the flasks are put into water bath at temperature 70^{o}C (Ahmad, 2016).

Fume cupboard are used to conduct the experiment. After 30 minutes, 5 ml 10% of acetic acid was added and 30 more minutes, 1.5g sodium chloride (NaCl) were added. Then, every 30 minutes, 1.5g NaCl which sum 6g, for 4 hours duration. After that, the samples are heated for 30 minutes more. Then, sample are filtered by using filtered paper, washed 500 ml of cool distilled water, acetone (15 ml) and left in oven with temperature at 60^{o} C for 24 hours to dried the sample(Ahmad, 2016). Holocellulose content were calculate by using equation that shown in Equation (3.2).

$$\text{Holocellulose Content (\%)} = \frac{\text{Weight of Holocellulose (g)}}{\text{Weight of Oven dried (g)}} \times 100 \qquad (3.2)$$

3.3.3 Determination of Cellulose

Cellulose method had been carried out by using TAPPI T203 os-74 (1997). Cellulose does not dissolve in 17.5% sodium hydroxide (NaOH) . The samples that are used are come from dried holocellulose and these were made in ice water bath. Then, 1 g of holocellulose are mixed with 15ml 17.5% NaOH in 250 ml beaker. Stir slowly for 1 minute, 10 ml 17.5% and after 45 seconds, 10 ml more of 17.5% NaOH will be added. Left it for 30 minutes . After 2.5 minutes, add 20ml more of 17.5% and add same amount of 17.5% more at minutes 5 and 7.5 which sums to 65ml of 17.5% were used.

After that, 100 ml of distilled water was added, and stir quickly for 30 minutes. Then, filtered sample by using filter paper no 4. Washed the beaker by using 25 ml 8.3 % NaOH and left over . Then wash it again by using250 ml of distilled water and soak with 15 ml of 10% acetic acid for 5 minutes. After that, the sample were dried into oven at temperature 50^{o} C for 24 hours before weight and recorded. Cellulose content will be determined and compare by using equation that shown in Equation (3.3) .

$$\text{Cellulose Content (\%)} = \frac{\text{Weight of } \alpha\text{−cellulose (g)}}{\text{Weight of oven dried Holocellulose powder (g)}} \text{ x } 100 \quad (3.3)$$

3.3.4 Determination of Hemicelluloses

Based on the findings of holocellulose and Cellulose, hemicelluloses content determine be using equation (3.4) (Boonstra & Tjeerdsma, 2006).

$$\text{Hemicellulose (\%)} = \text{Holocellulose} - \text{Cellulose} \qquad (3.2)$$

3.3.5 Determination of Lignin

Lignin determination was carried out by using TAPPI T222 om-88 (2002) method. Usage of sulphuric acid to determine lignin was proposed by Klason & Carlson (1906). Air dried sample, extractive free of 1g are used. Then, 150 ml beaker are used to inserted sample and place in iced water bath 25 ml 72% sulphuric acid (H_2SO_4) were added and stirred with glass rod for every 10 minutes for 2 hours. After that, all the mixtures are transformed in 1L conical flask containing 400 ml distil water, and heated at 170°C with reflux for 4 hours. After that, the mixture sample was cooled overnight, sample then were filtered and washed with hot 500 ml distilled water until ph level neutralized. The sample then dried until the weight is constant .The lignin content had been determined by using Equation (3.5) as follows:

$$\text{Lignin content (\%)} = \frac{\text{Weight of lignin (g)}}{\text{Weight of Oven dried extractive – free (g)}} \times 100 \qquad (3.5)$$

3.4 Data Analysis

The obtained experimental data were analyzed, evaluated and compare between the species of *Leucaena leucocephala* and *Acacia magium* and three different portion (bottom, middle and top). All the experimental data are subjected to two-way ANOVA, to find any statistical significant of data collected with independent variables which species and portion. Collected data was compared between species of *Leucaena leucocephala* and *Acacia magium*. Tukey's post hoc test was conducted to find any more detail on statistical significance between three different portions.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Chemical Composition of *Leucaena leucocephala* and *Acacia mangium*

The chemical composition that has been discussed in this chapter is extractive, holocellulose, cellulose, hemicelluloses and lignin. Free extractive data were collected for extractive percentage calculation. In the other hand, extractive free were used for another chemical composition analysis which is holocellulose, α-cellulose, hemicellulose and lignin analysis.

Each test was conducted in order to get good data. It was necessary to conduct additional experimentation when analyzing for ethanol-benzene extractive content and holocellulose content. The ethanol-benzene test is the starting material for many of the other experiments. Both the lignin and holocellulose content test are performed with extractive-free of leucaena and acacia that is derived from the ethanol-benzene extractive test. Additionally, holocellulose is a necessary preparatory stage in order to determine the alpha-cellulose content.

All data value of chemical composition data in Table 4.1 was collected and calculated based on the formula stated on Chapter 3. The results were compared between two different species which is *Leucaena leucocephala* and *Acacia mangium* and three different portions (bottom, middle and top). The data was presented in percentage (%) and analysis of varience (ANOVA) two ways used to check whether all the result significant or not.

Table 4.1: Value of chemical composition of small diameter *Leucaena leucocephala* and *Acacia mangium.*

Species	Portion	Chemical composition (%)				
		Extractive	Holocellulose	Cellulose	Hemicellulose	Lignin
Leucaena leucocephala	Bottom	5.16	75.03	61.94	13.09	37.69
	Middle	2.99	78.35	47.14	31.21	22.94
	Top	2.39	86.82	37.81	49.01	19.67
Acacia mangium	Bottom	4.15	84.16	63.94	20.22	40.63
	Middle	1.18	84.63	59.46	25.17	15.27
	Top	1.525	91.18	45.03	20.09	12.01

Based on the Table 4.1, the highest value of chemical composition for both species is holocellulose. The second highest chemical composition for both *Leucaena leucocephala* and *Acacia mangium* is α-cellulose and followed by hemicelluloses, lignin, meanwhile the lowest chemical composition value is extractive.

The chemical composition analyses are most important factor to determine the suitability of wood as raw material for pulp and paper industry (Kayama, 1979). According to Spence *et al* (2010) cellulose contents were high for the chemical pulps for all wood pulps which are around (65–79%), while the respective lignin and extractive contents were low.

4.1.1 Extractive

In this study, based on Fig. 4.1 show the value extractive content of *Leucaena leucocephala* with 5.16% at the bottom portion, meanwhile the extractive content of *Acacia mangium* is 4.15% at the same portion. Apart from that, extractive content of leucaena and acacia are slightly increased at middle portion with value 2.99% and 1.18% respectively. Then, for the top portion, it contains high value of extractive content which is 2.39% for *Leucaena leucocephala* and 1.525% for *Acacia mangium*. Other than that, Fig. 4.1 shows the decreased trend for extractive value from bottom to top portion. The lowest value of extractive content is on middle portion of *Acacia mangium* species with 1.18% respectively.

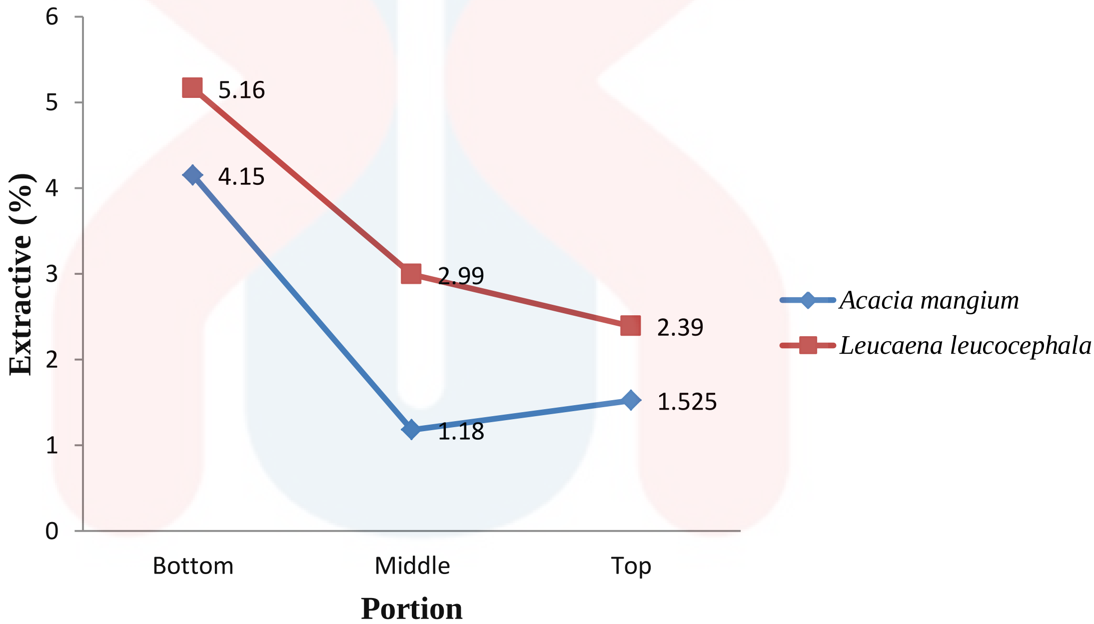


Figure 4.1: Trends on extractive content between wild *Leucaena leucocephala* and *Acacia magium* based on different portion.

According to Hilman (2002), *Acacia mangium* contain been recognized as an excellent sources for paper making , compare with other hardwood like *Betula pendula, Eucalyptus grandis, Eucalyptus urograndis and Eucalyptus Globules* because it contain high value of extractive contain. In contras, Li *et al* (2007) state that the decreased of extractive content in stem is correlate to that in tree where extractive deposition can also decreased with their age. In the other words, extractive content are increased as the portion increased. In addition, extractive content in bottom had significantly higher compare with the middle and bottom section. Thus, the extractive content can be modified depending on the wood species (Da silva *et al*., 2015).

The result of the extractive content may differ due to the extraction with 1/3 ethanol and 2/3 benzene solution, which typically give highest level of *extractive* because the additional dissolution of low molecular weight carbohydrates and polyphenols (Zhang *et al*., 2007). In this study, the value of extractive content is lower compare with previous study because young *Acacia mangium* and *leucaena leucocephala* was used in this study.

4.1.2 Holocellulose

Based on the holocellulose content in Fig. 4.2 the percentage of holocellulose content in small diameter of leucaena and acacia was observed with 75.03% and 84.16% respectively at bottom portion. Meanwhile, the value of holocellulose content for leucaena at the middle portion is 78.85% and 84.63% for acacia at the same portion. Apart from that, in the top portion the value of holocellulose content is 86.82% for *Leucaena leucocephala* and 91.18% for *Acacia mangium* respectively. Other than that, the graphs in Fig. 4.2 are decreased gradually due to their portion. The lowest holocellulose contain of wild *Leucaena leucocephala* and *Acacia mangium* is at the bottom portion and it slightly increased at the middle and highest value at top portion.

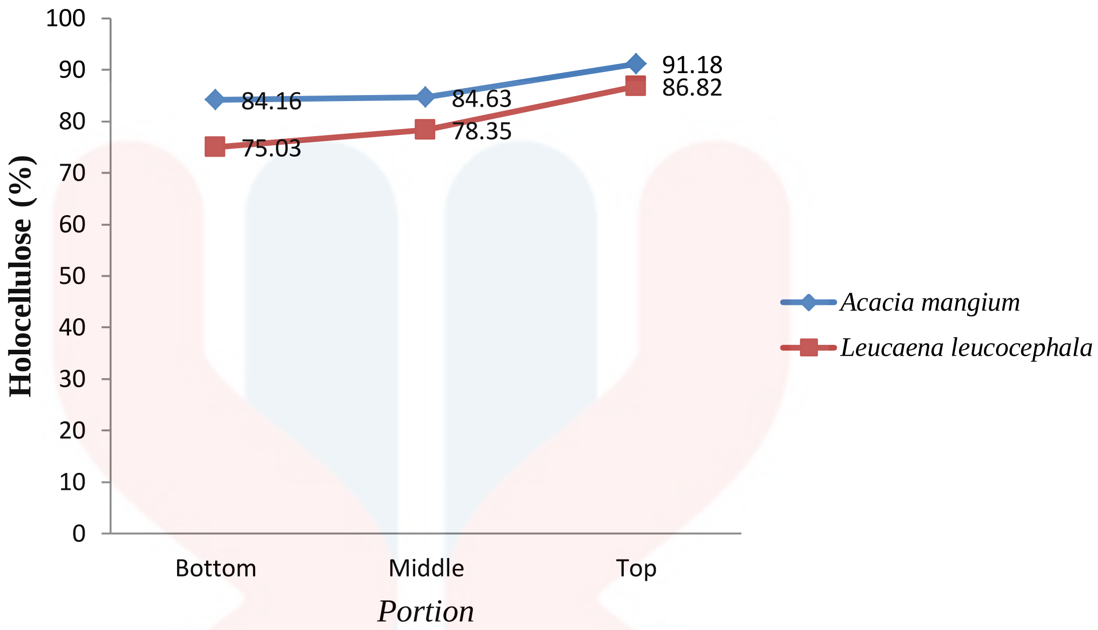


Figure 4.2: Trends on holocellulose content between wild *Leucaena leucocephala* and *Acacia magium* based on different portion.

In this study, the result shows the highest holocellulose contain are in *Leucaena leucocephala*, it is because leucaena wood is among the best hard wood for paper and rayong making. It produces pulp that is high in holocellulose which are important characteristic for pulp making (Mary, 2006). In addition, the value of holocellulose content is higher because young leucaena and acacia were used. Besides that, Hoong et al., (2009) stated in his previous study that Acacia mangium wood of Malaysian peninsular contains 79.99% to 89.00% of holocellulose . Other than that, holocellulose yield in this study also backup by Koh M.P (2011) where his study are recorded holocellulose content for Acacia mangium are 80.46% respectively.

The statement stated by Nazri *et al* (2008) young (8 years) tree had higher holocellulose content compared with the old tree (16 years). Other than that, wood is characterized by faster growth rate (Bendsten, 1978) which is lower wood density yields higher holocellulose and alpha cellulose contents in wood (Shupe *et* *al*., 1996). In addition, higher holocellulose content will reduce internal bonding performance between wood strands and resin (Jamaludin, 1999).

4.1.3 Cellulose

Cellulose is a carbohydrate macromolecule that represents 40-45 wt% of the wood, being slightly higher in hardwoods than in softwood (Katalin, 2014).Figure 4.3 shows the result cellulose content between *Leucaena leucocephala* and *Acacia mangium* in three portion which is bottom, middle and top. Other previous study are stated that, cellulose content from chemical composition view can be characterized as a good for pulp and paper manufacture through slendemess ratio and fibre length (Nieschlag et al., 1960).

Based on Fig. 4.3 the value cellulose content in *Leucaena leucocephala* is 61.94% at bottom portion and 63.94% in *Acacia mangium* at the same portion. The value of cellulose content for leucaena at the middle portion is 47.14% and 59.46% for *Acacia mangium* at the same portion. Other than that, in top portion, the percentage of cellulose in leucaena is 37.81% and 45.03% for *Acacia mangium* respectively. Besides that, the trends of the graph that show in Fig. 4.3 are slightly decreased due their different portion which is from bottom, middle and top.

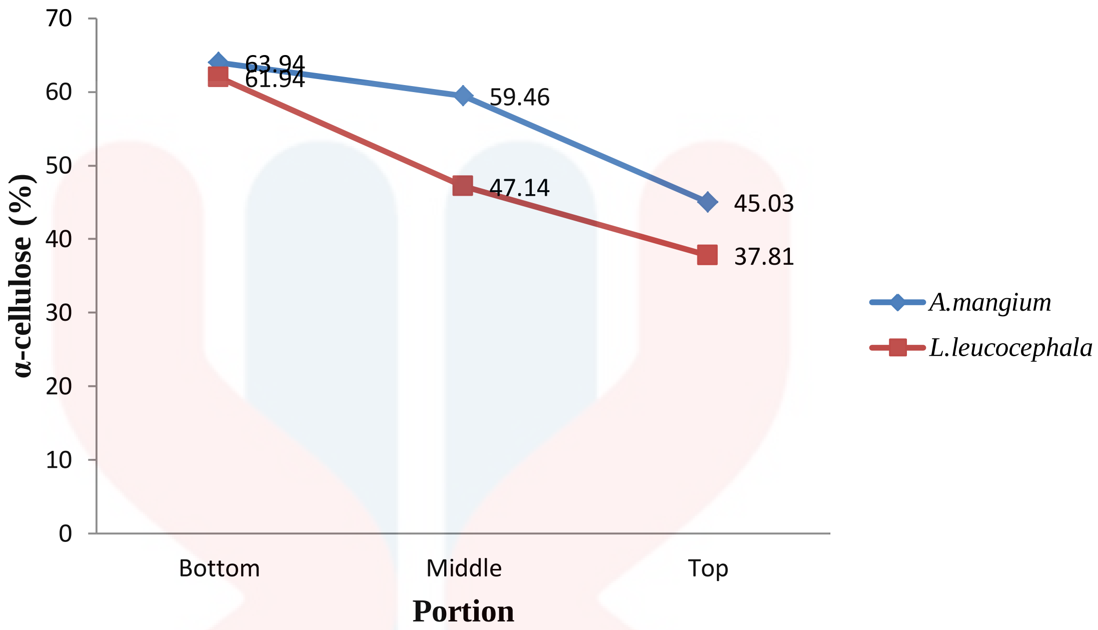


Figure 4.3: Trends on cellulose content between wild *Leucaena leucocephala* and *Acacia magium* based on different portion.

The reasons for high percentage of wood at bottom because cellulose is the main component of plant cell walls (Delmer & Haigler, 2002). In addition, previous study stated that bottom have higher cellulose content compare with top and middle portion (Abdel-el *et al.*, 2006). In the middle portion, cellulose content higher in acacia with 59.46% compare with leucaena which is 47.14%. Apart from that, in top portion cellulose content in *Leucaena leucocephala* and *Acacia mangium* shows many differences with 19.57% and 45.03% respectively.

4.1.4 Hemicellulose

In this study, Fig. 4.4 shows percentage of the hemicellulose content In *Leucaena leucocephala* with 13.09% at the bottom portion, meanwhile hemicelluloses contain is higher on *Acacia mangium* with 20.22% at the same portion. Furthemore, the value of hemicellulose content does not show many differences at middle portion for both acacia and leucaena which is 25.17% and 31.21% respectively. The lowest percentage of hemicelluloses content is acacia with 20.09% at the top and highest value in leucaena at top portion with 49.01% respectively.

In this study, the graph of hemicelluloses contain shown the decrease trend for *Acacia mangium* species while the graph shows increased trend in *Leucaena leucocephala* species. As described by esteves *et al* (2008) and windeisen et al (2008), hemicellulose degradation leads to loss of strength of the timber. This fact is clearly demonstrated when an increase in hemicellulose content happen at *Leucaena leucocephala* species. Increase in hemicellulose content is also increased in bending and tensile strength. The percentages of hemicelluloses are critically increased from bottom to top portion in leucaena species which is from 13.09% to 67.15% respectively. In addition, the percentages of hemicelluloses value in *Acacia mangium* are slightly decreased based on their portion which is decreased from bottom to top portion and increased in *Leucaena leucocephala*.

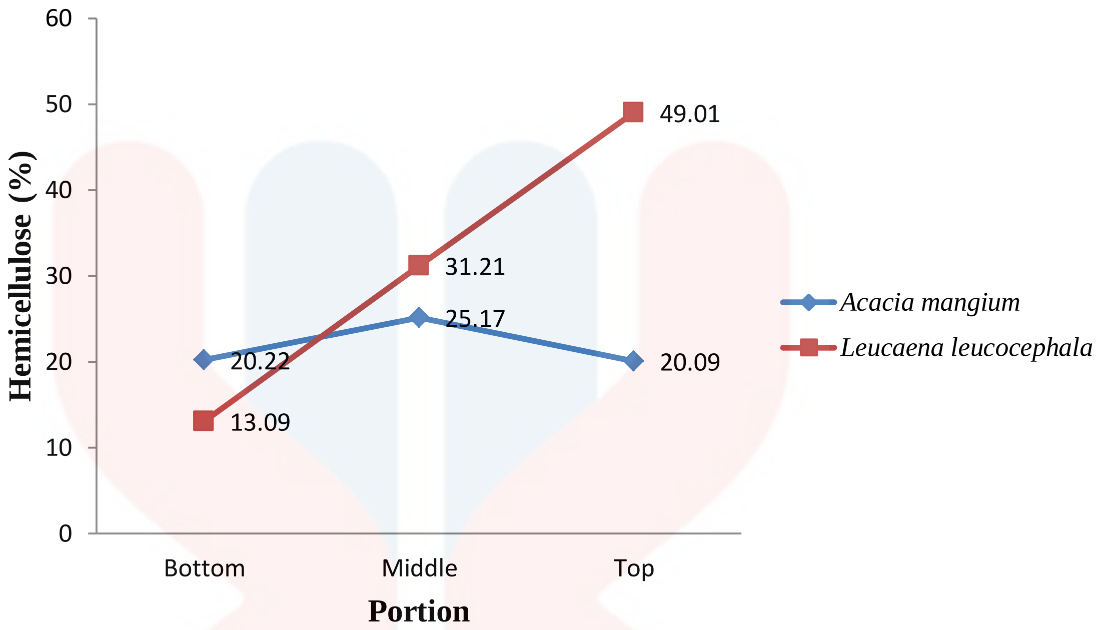


Figure 4.4: Trends on hemicellulose content between wild *Leucaena leucocephala* and *Acacia magium* based on different portion.

In comparison, top portion of *Leucaena leucocephala* contain more xylem and glucomannan in their stem compare with acacia. Besides that, the percentage of hemicelluloses was decrease with increased tree height between part which increased production of long polymer (cellulose) rather than short polymer (hemicellulose). In other words, the tree height will affected the value of hemicelluloses content in plant (Cordeiro *et al*., 2004).

4.1.5 Lignin

Botanically, lignin encloses the bundle cells, such as wood fibers and sclerenchyma cells. Therefore, Lignin can be categorized as an important component in the cell wall (Suzuki & Itoh, 2001). The lignin content is about 27–32 % in woody plants and about 14–25 % in herbaceous plants (Chen *et al.*, 1996).

Based on Fig. 4.5 *Leucaena leucocephala* species shows the higherst result at the bottom which is 37.69% and acacia with 40.63% from the same portion. Futhermore, in the middle portion leucaena shows 22.94% of their lignin content, meanwhile *Acacia mangium* show 15.27% of lignin content. Apart from that, the lowest percentage of lignin content is top portion of *Leucaena leucocephala* and *Acacia mangium* with result 19.67% and 12.01% respectively.

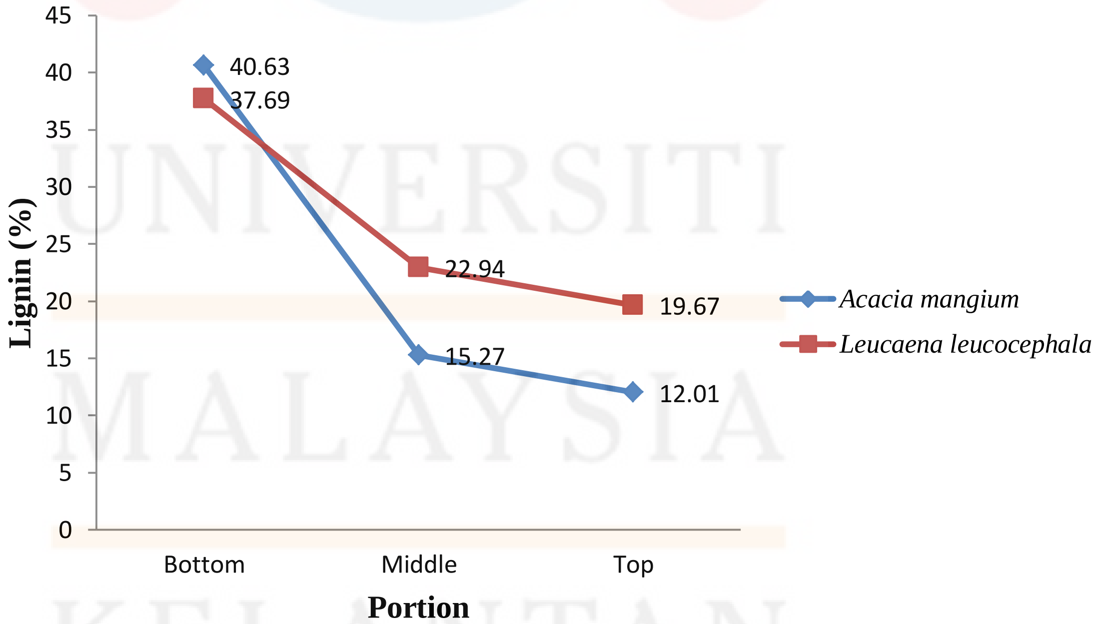


Figure 4.5: Trends on lignin content between wild *Leucaena leucocephala* and *Acacia magium* based on different portion.

Based on the previous study, the relative lower data for lignin content in leucaena has been found (Ververis *et al.*, 2004). The reason of height value of lignin content at the bottom because lignin content in bottom portion had the highest values followed by middle and top portion .In another words ,lignin content are decreased gradually with their height of the tree (Abdel-Aal *et al.*, 2006). In addition, lignin content was reported for bottom portion is higher compare with the top portion for both leucaena and acacia (Fukazawa and Imagawa 1981; Andrews 1986; Huang et al. 2012).

According to Robinson (1980) high in lignin content can cause the pulping process become more complicated and decreased in their production quality because high degree of lignin need more chemical substance and high in production cost. Based on the yield that produced in this study shows that the middle and top of both species are good in pulp and papering process because low in lignin are good in papering production.

4.2 Analysis of Variance (ANOVA) on Chemical Composition of Small Diameter Wild *Leucaena leucocepha* and *Acacia mangium.*

Based on the Table 4.2 below, the result showed on ANOVA test on chemical composition of small diameter wild *Leucaena leucocephala* and *Acacia mangium* on different portion. Two way ANOVA was conduct to compare effect of species and portion on the extractive, holocellulose, cellulose, hemicellulose and lignin. Other than that, ANOVA table decomposed the variability of extractive, holocellulose, α-cellulose, hemicelluloses and lignin into contribution due to various factors. The P-value tests the statistical significance of each of the factors.

Table 4.2: ANOVA test on chemical composition of small diameter wild *Leucaena leucocephala* and *Acacia mangium* on different portion.

Source	Dependent Variable	Sum of Square	df	Mean Square	F-ratio
Species	Extractive	2.263	1	2.263	0.951^{ns}
	Holocelluloce	65.142	1	65.142	2.488^{ns}
	Cellulose	77.329	1	77.329	0.629^{ns}
	Hemicellulose	129.085	1	129.085	0.780^{ns}
	Lignin	25.585	1	25.585	0.152^{ns}
Portion	Extractive	9.265	2	4.633	5.510^{**}
	Holocelluloce	98.963	2	49.482	2.094^{ns}
	Cellulose	464.783	2	232.391	3.674^{ns}
	Hemicellulose	329.158	2	164.579	0.954^{ns}
	Lignin	637.790	2	318.895	15.168^{**}

Note: *significant value, $P \leq 0.05$
** significant value, $P \leq 0.01$
^{ns} not significant

a) Effect of Species and Portion on Chemical Composition of *Leucaena leucocephala* and *Acacia mangium.*

Based on the ANOVA Table above, the data was concluded that there are no statistically significant differences between each species (*Leucaena leucocephala* and *Acacia mangium*) for all chemical properties of content.

In order to detect in detail in any significant differences between each portions of *Leucaena leucocephala* and *Acacia mangium* species, further statistical test was made. Test made are based on Tukey's post hoc test to find significant differences between different portions (bottom, middle, top).

Therefore, the tables 4.3 below show the result on Turkey-test of *Leucaena leucocephala* and *Acacia mangium* with different portion (bottom, middle and top) on extractive, holocellulose, cellulose, hemicelluloses and lignin. From the output, the was significant effect on lignin with significant value are respect to 95% level meanwhile there no significant effect on extractive, holocellulose, Cellulose, hemicelluloses.

Table 4.3: Turkey test on chemical composition of small diameter on different portion.

Source (Portion)	Dependent Variable				
	Extractive	Holocellulose	Cellulose	Hemicellulose	Lignin
	F= 5.510^{ns}	F= 2.094^{ns}	F= 3.674^{ns}	F= 0.954^{ns}	F= 15.168*
Bottom	4.65 ^{a}	79.59 ^{a}	62.94 ^{a}	16.65 ^{a}	39.16 ^{a}
Middle	2.08 ^{a}	81.49 ^{a}	53.30 ^{a}	28.19 ^{a}	19.10 ^{b}
Top	1.95 ^{a}	89.00 ^{a}	41.42 ^{a}	34.55 ^{a}	15.84 ^{b}

Note: *significant value, $P \leq 0.05$
** significant value, $P \leq 0.01$
^{ns} not significant

The data shows the significant different on lignin. Statistical significant difference are found between bottom portion and middle portion with p=0.044 respectively meanwhile the results yielded between bottom and top is p=0.030. Both portions are significant at level 95%. Therefore, there no significant effect on portion for extractive, holocellulose, α-cellulose and hemicelluloses with p= 0.099, p= 0.270, p= 0.156 and p= 0.478 respectively.

Due to the previous study from Muslyza *et al* (2014) stated that, lignin content have significant effect on bottom portion to top potion meanwhile holocellulose content is not statistically significant from bottom to top portion . Futhermore, cellulose hemicelluloses and extractive are not significant at the level of sample position.

Based on the statement above, all of the content can be used in differentiate the entire wood component for another species. Besides that, the content of extractive, holocellulose and lignin can be used to determine the same portion within each species have significant value for the same portion. Thus, cellulose and hemicellulose contents could not be used to identify sample position because both does not shows the significant value for all portions.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The chemical composition analysis of small diameter wild *Leucaena leucocephala* and *Acacia mangium* between different portion which is bottom, middle and top was analyzed for content of extractive, holocellulose, cellulose, hemicelluloses and lignin. The chemical composition analysis data was collected from this study and it was considered are not in normal range for tropical species.

According to the analysis, *Acacia mangium* species shows the highest result at the bottom portion for content of holocellulose, cellulose as well as lignin. Meanwhile, the extractive and hemicelluloses content shows the highest result at the same portion in *Acacia mangium* of small diameter tree. In this study, comparison between species have no significant effect and portion are significant at lignin content and not significant at extractive, holocellulose, cellulose and hemicellulose. The result are calculated by using turkey table.

The main material that was used in this study is *Leucaena leucocephala* and *Acacia magium* because it is wild and fast growing species and the wood trees are suitable for wide range product for example paper production. Through this research, the data of chemical composition analysis was determined and collected. Thus, the data between different species and portion that provide are useful for process and application in wood industry.

5.2 Recommendation

Based on the previous research, chemical composition are important and useful for future purpose because *Leucaena leucocephala* and *Acacia mangium* is suitable to be used as alternative source of cellulose pulp. The following recommendations are offered as possible ways to improve this study. Study other *Leucaena leucocephala* and *Acacia mangium* species are recommended, since species offers a broad range of relative density of chemical and physical dimensions and each of them has their own properties exceptional.

In the other hand, used right chemical solution for the laboratory works in order to get a good and specific result for all the analysis in chemical composition. Another recommendation for future study is different types of extractor can be used for extraction of wood which is by using another extraction system called accelerated solvent extraction (ASE). ASE combines elevated temperatures and pressures with the standard solvents used for Soxhlet extraction. ASE is much faster and requires considerably less solvent than traditional techniques. ASE system is expensive, but it is the promising efficient extraction method. ASE technology is a flow-through solvent extraction system that helps increase productivity and sample throughput while reducing preparation cost and providing a platform for automation.

REFFERENCE

Ahmad.S & Majid.K. (2011) . Chemical Composition Properties of Stem and Branch in Alianthus altissima Wood, Middle-East Journal of Scientific Research 8 (5), 967-970.

Arisman, H., & Hardiyanto, E. B. (2006). Acacia mangium-a historical perspective on its cultivation. In *Aciar Proceedings* (Vol. 124, p. 11). ACIAR; 1998.

Azeemoddin G, Jagan Mohan Rao S, Thirumala Rao SD. (1988) . J Food SciTechnol , 25,158.

Abdel-Aal, M.A, A.S Mohareb & N.D Shetta. (2006) . evaluation of sewage sludge application on chemical composition of CCasuarina Cunninghamiana wood, J. Agric, Sci, Monsura Univ, 33(7), 5197-5208.

Andrews, E. K. (1986). Impact of fiber morphology and chemical composition on the kraft process and subsequent handsheet properties. TAPPI Reasearch and Development Conference. Rayleight, USA, TAPPI: 111-119.

Ahmad Nurruddin Abdul Ghani. (2016). Chemical Properties of Small Diameter Wild *Acacia mangium* species, Dissertation of Final Year Project.

Bendsten BA. (1978) . Properties of wood from improved and intensively managed trees, Forest Products Journal, 28, 61–72.

Bamber.R.K. (1987) . Sap Wood and Heart Wood, Wood Technology and Forest Research Division Australia, 4, 2-7.

Bergman, P.C.A., Boersma, A.R., Zwart, R.W.H., Kiel, J.H.A. (2005a). Development of torrefaction for biomass co-firing in existing coal-fired power stations, ECN report, ECN-C, 05-013.

Bhatia, M., & Banerjee, S. G. (2011). *Unleashing the potential of renewable energy in India*. World Bank Publications, 13-43.

Boonstra, M. J., & Tjeerdsma, B. (2006). Chemical analysis of heat treated softwoods. *Holz als Roh-und Werkstoff*, *64*(3), 204-211.

Bond, B. (2002). Wood identification for hardwood and softwood species native to Tennessee. Agricultural Extension Service, University of Tennessee.

Brewbaker, J.L ,Hegde, N., Hutton , E.M , Jones , R.J , Lowry, J.B , Moog, F. and van denBeldt, R . (1985) .Leucaena - Forage Production and Use, NFTA, Hawaii, 39 pp.

Browning, B.L., (1975) . The Chemistry of Wood. Robert E. Krieger Publishing Co.

Budarin, V. L , Clark, J. H , Lanigan, B. A ,Shuttleworth, P., Macquarrie, D. J . (2010) . Microwave assisted decomposition of cellulose , A new thermochemical route for biomass exploitation. BioresourceTechnology , 101 (10), 3776-3779.

Chen H.Q, Gong Y, Fang Z. (1996) . The situation and aspect of application for macromolecule (I)-cellulose, lignin and starch. Yunnan Chem Technol, 11(1), 41–6.

Delmer D.P, Haigler C.H. (2002) . The regulation of metabolicflux to cellulose, a major sink for carbon in plants. Metab.Eng, 4, 22-28.

Da Silva, M. R., Brito, J. O., Govone, J. S., de Oliveira Machado, G., Junior, C. C., Christoforo, A. L., & Lahr, F. A. R. (2015). Chemical and Mechanical Properties Changes in Corymbia Citriodora Wood Submitted to Heat Treatment. *International Journal of Materials Engineering*, *5*(4), 98-104.

Dhamodaran T.K, Chacko K.C. (1999). Growth And Wood Characteristics Of *Acacia Mangium* Grown In Kerala, Kerala Forest Research Institute Peechi, Thrissur, Research Report 174, 3-60.

Dixon R K, Brown S, Houghton, R A, Solomon A M, Trexler M C and Wisniewski J. (1994).Carbon Pools and Flix of Global Ecosystems. Science, 263, 185-190.

Dobele, G., Urbanovich, I., Volpert, A., Kampars, V., & Samulis, E. (2007). Fast pyrolysis– Effect of wood drying on the yield and properties of bio-oil.*BioResources*, *2*(4), 698-706.

Esteves, B., Graca, J., & Pereira, H. (2008). Extractive composition and summative chemical analysis of thermally treated eucalypt wood. *Holzforschung*, *62*(3), 344-351.

Fukazawa, K. and H. Imagawa (1981). "Quantitative analysis of lignin using an UV microscopic image analyzer - Variation within one growth increment." Wood Science and Technology 15(1): 45-55.

Gangwar, K.S, Sharma, S.K, Tomar, O.K . (2004) . Indian Journal of Agronomy, 49(2) , 84-88.

Guanyu.Y & Pirjo. J. (2011) . Wood chemistry and isolation of extractives from wood, Literature study for BIOTULI project, Saimaa University of Applied Sciences, 6-47.

Grierlinger.N. (1984) . Radial Distribution of Heartwood Extractive and Lignin in Mature European larch, Wood Fibre Science, 36, 387-394.

Haruthaithanasan, M., Haruthaithanasan, K., Thanawat, A., Phromlert, S., & Baysangchan, A. (2010). The potential of Leucaena leucocephala, Eucalyptus camaldulensis, Acacia mangium and Acacia spp.(mangium× auriculaeformis) as plantation crops for energy. In *Proceedings of the 48th Kasetsart University Annual Conference, Kasetsart, 3-5 March, 2010. Subject: Plants.*. Kasetsart University.

Harmsen P.F.H , W.J.J. Huijgen ,L.M. Bermúdez López ,R.R.C. Bakker . (2010) Literature Review of Physical and Chemical Pretreatment Processes for Lignocellulosic Biomass,Wageningen University & Research centre - Food & Biobased Research (WUR-FBR, NL) Energy Research Centre of the Netherlands (ECN, NL) Abengoa Bioenergía Nuevas Tecnologías (ABNT, ES), 8-3.

Hegde, M., Palanisamy, K., & Yi, J. S. (2013). Acacia mangium Willd.-A Fast Growing Tree for Tropical Plantation. *Journal of Forest and Environmental Science*, *29*(1), 1-14.

Hilman.D.C. (2002) . Single Species Pulping, the world preferred market, 27-30.

Hughes .C.E. (1998) . Leucaena; a genetic resources handbook. Tropical forestry Papers,. Oxford Forestry Institute,Department of Plant Sciences, University of Oxford and Department for International Development, 37, 1-8.

Huang, F., R. Lanouette and K. N. Law (2012). "Influence of Jack pine earlywood and latewood fibers on paper properties." Nordic Pulp & Paper Research Journal 27(5): 923-929.

Hoong Y.B , M.T. Paridah, C.A. Luqman, M.P. Koh, Y.F. Loh (2009), Fortification of sulfited tannin from the bark of Acacia mangium with phenol–formaldehyde for use as plywood adhesive. Industrial Crops and Products Volume 30, Issue 3, November 2009, Pages 416–421.

Ismail, B. (2010) . Energy Resources and Their Effects on Environment, Vocational School of Technical Studies Electrical Programme Marmara University GöztepeKampüsü, Kadıköy 34722 Istanbul TURKEY, 6 , 327-334.

IPCC (Intergovernmental Panel on Climate Change) . (2001) . Climate Change Impacts,Adaptation and Vulnerability, Summary for Policy Makers and Technical Summary of the Working Group II Report , World Meteorological Organisation (WMO), Geneva, Switzerland and UN Environmental Programme (UNEP), Nairobi, Kenya, 89 .

Jones, R.J. (1979) . The value of *Leucaena leucocephala* as a feed for ruminants in the tropics,World Animal Review ,31, 13-23.

Klason, P., & Carlson, T. (1906). Zur Kenntniss der organischen Nitrate.*Berichte der deutschen chemischen Gesellschaft*, *39*(3), 2752-2754.

Krisnawati.H, Kallio.M & Kanninen.M . (2011). Acacia mangium wild, Ecology silviculture and productivity, CIFOR,Bogor,Indonesia. 1-14.

Kayama.T . (1979) . Pulp and Paper Making Properties and Wood Properties of Tropical Hardwood, Forpride Dig, 8, 42-45 & 48-49.

Katalin. K. (2014) . Effect of natural aging on wood, thesis for the degree of Doctor of Sciences, 9-19.

Koh M.P (2011). “Chemical Composition” Properties of Acacia mangium planted in peninsular Malaysia. Forest Research Institute Malaysia, Perpustakaan Negara Malaysia, ISBN 978-967-5221-52-1.

Jamaludin .K. (1999) . Properties of particleboard and particle-filled thermoplastic composite from bamboo (Gigantochloa scortechinii). PhD dissertation, Universiti Putra Malaysia, Serdang.

Leeuw, S. De. (2014) . Leucaena leucocephala suppression in Sint Eustatius, (August).

Lim, S. C., Gan, K. S., & Tan, Y. E. (2011). Properties of Acacia mangium planted in Peninsular Malaysia. *ITTO Project on Improving Utilization and Value Adding of Plantation Timbers from Sustainable Sources in Malaysia*.

Li, X. B., Shupe, T. F., Peter, G. F., Hse, C. Y., & Eberhardt, T. L. (2007). Chemical changes with maturation of the bamboo species Phyllostachys pubescens. *Journal of Tropical Forest Science*, 6-12.

Lopez, F, M.M. Garcı a, R. Ya nez, R. Tapias, M. Ferna ndez, M.J. D az, Leucaena species valoration for biomass and paper production in 1 and 2 year harvest, Biosource technology, 4846-4853.

Mathuva, M. N., Rao, M. R., Smithson, P. C., & Coe, R. (1998). Improving maize (Zea mays) yields in semiarid highlands of Kenya: agroforestry or inorganic fertilizers?. *Field Crops Research*, *55*(1), 57-72.

Meena Devi, V. N., Ariharan, V. N., & Prasad, N. (2013). Nutritive value and potential uses of Leucaena Leucocephala as biofuel–A mini review.*Research Journal of Pharmaceutical, Biological and Chemical Sciences*,*4*(1), 515-521.

Mašek, O., Budarin, V., Gronnow, M., Crombie, K., Brownsort, P., Fitzpatrick, E., & Hurst, P. (2013). Microwave and slow pyrolysis biochar—Comparison of physical and functional properties. *Journal of Analytical and Applied Pyrolysis*, *100*, 41-48.

Mainoo, A. A. (1995). *Growth, wood yield and energy characteristics of Leucaena Leucocephala, Gliricidia Sepium and Senna Siamea at age four* (Doctoral dissertation).

M. R. Islam, R. Saidur, N. A. Rahim and K. H. Solangi . (2010) . Usage of Solar Energy and its Status in Malaysia, Engineering e-Transaction (ISSN 1823-6379), 5, 6-10.

Mary.M.M. (2006) . The Evaluation of Leucaena leucocephala (Lam) De Wit: A Rewnewable protein supplement for low-quality forages, 4-42.

Muslyza Che Hussin , Jamaludin Kasim , Nur Farahin Yusoff , Nor Farhana Jasmi & Siti Nadzirah Misfar (2014), " Effect Of Tree Portion And Distance From Pith On The Basic Density, Fiber Properties And Chemical Composition Of Albizia Falcataria Wood" ,International Journal of Latest Research in Science and Technology, Volume 3, Issue 6: Page No.187-191, November-December 2014.

National Research Council. (1983). Mangium and other fast-growing Acacias for the humid tropics, National Academy Press, Washington, DC.

Nazri.W.M, Jamaludin.K, Rahim.S, N. Yuziah, M.Y & Hazandy.A. H. (2011). Strand properties of Leucaena leucocephala, African Journal of Agricultural Research Vol. 6(22), pp. 5181-5191.

Nazri, W. M., Jamaludin, K., Rudaini, M. N., Rahim, S., & Yuziah, M. N. (2009). Effects Of Chemical Components On Properties Of Oriented Strand Board From" Leucaena Leucocephala" Wood. *Journal of tropical forest science*, 353-360.

Neto.C.P, Silvestre, A.J.D, Evtuguin.D.V, Freire.C.S.R, Pinto.P.C.R, Santiago.A.S, Fardin.P, Holmbom.B. (2004) . Bulk and surface composition of ECF Bleached hardwood kraft pulp fibre, Nordie Pulp and Paper Reaserch Journal, 19(4), 513-520.

Nykvist, N. (1996). Regrowth of secondary vegetation after the 'Borneo fire'of 1982–1983. *Journal of Tropical Ecology*, *12*(02), 307-312.

Oggiano, N. Angelini, L.G, Cappelletto, P . (1997) . Pulping and paper properties of some fibre crops. Industrial Crops and Products 7 (1): 59–67.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Simons, A. (2009). Agroforestree database: a tree reference and selection guide version 4.0. 2009. *Url: http://www. worldagroforestry. org/af/treedb/(Accessed on 15 February, 2011)*.

Palm, O & Alshareef, . (2014). Key Facts about the Feasibility of Leucaena as a Complementary Biomass Crop to, 32–34.

Pipatmanomai, S. (2011) . Overview and Experiences of Biomass Fluidized Bed Gassification in Thailand, Journal of Sustainable Energy &Enviromental Special Issues, 29-33.

Pinyopusarerk, K., Liang, S. B., Gunn, B. V., Awang, K., & Taylor, D. A. (1993) Taxonomy, distribution, biology, and use as an exotic, MPTS Monograph Series Winrock International and FAO, Bangkok, Thailand, 3, pp 56-62.

Raven, P.H., R.F, Evert . (1992). Biology of plants (6th edition). W.H. Freeman and company/Worth Publishers.

Rabemanolontsoa, H., & Saka, S. (2012). Holocellulose determination in biomass. In *Zero-Carbon Energy Kyoto 2011* (pp. 135-140). Springer Japan.

Razak, W. (1998) . Effect OD selected preservatives on the durability of Gigantochloa scortechinii. Ph. D.Thesis, University of London, London.

Robinson, J.V. (1980). Fiber bonding (Vol.2. 3 rd Edition pp. 915- 956). Pulp and paper chemistry and chemical technology. New York: Wiley-Interscience Publication.

Sein.C.C & Mitlohner.R. (2011). Acacia mangium wild, ecology and silviculture. CIFOR, Bogor, Indonesia, 1-14.

Shelton, H.M., & Brewbaker, J.L. (1994) . *Leucaena leucocephala*-the most widely used forage tree legume, *Forage Tree Legumes in Tropical Agriculture*, 15-29.

Sini.M.K. (2011) . Differences between sapwood and heartwood of thermally modified Norway spruce (Picea abies) and Scots pine (Pinus sylvestris) under water and decay exposure, 771, 54-68.

Sjostrom, E., (1998). Analytical method in wood chemistry,pulping and paper making, springer-verlag berlin.

Suriyea, T., Pornyungyuen, T., & Kanokjaruvijit, K. (2013) . Study of Incineration of Acacia Wood Chips for Biomass Power Plant of the Royal Thai Navy in Sattahip, Chonburi Province, Thailand, 7, 610-612.

Sustersic, Z., Mohareb, A., Chaouch, M., Petrissans, M., Petric ,M. & Gerardin, P. (2010). Prediction of the decay resistance of heat treated wood on the basis of its elemental composition. Polymer Degradation and Stability, 95, 94?97.

Svoboda K, Pohorely M, Hartman M, Martinec J. (2009) . Pretreatment and feeding of biomass for pressurized entrained flow gasification. Fuel Process Technol, 90, 629–35.

Suzuki K, Itoh T. (2001) . The changes in cell wall architecture during lignification of bamboo, Phyllostachys aurea Carr, Trees-Struct Function, 15(3), 137–47.

Spence, K. L., Venditti, R. A., Habibi, Y., Rojas, O. J., & Pawlak, J. J. (2010). The effect of chemical composition on microfibrillar cellulose films from wood pulps: mechanical processing and physical properties. *Bioresource technology*, *101*(15), 5961-5968.

Shupe T.F, Choon.G. et & Yang C.H. (1996). The effects of silviculture treatments on the chemical composition of plantation-grown loblolly pine wood, Wood and Fiber Science 28, 286−294.

Tsai, L. M. (1988). Studies on Acacia mangium in Kemasul forest, Malaysia. I. Biomass and productivity. *Journal of Tropical Ecology*, *4*(03), 293-302.

Technical Association of Pulp and Paper Industry (TAPPI). (1997) . T 204 cm-97: Solvent ectractives of wood and pulp, TAPPI test method.

Technical Association of Pulp and Paper Industry (TAPPI). (2002) . T 203 cm-99: Alpha-, beta and gamma-cellulose in pulp, TAPPI test method.

Technical Association of Pulp and Paper Industry (TAPPI). (2002) . 222 om-02: Acid-insoluble lignin in wood and pulp. 2002-2003 TAPPI *Test Method.*

Thahirah, S.J . (2009) .National Energy Policies and the Electricity Sector in Malaysia,Proceedings of ICEE 2009 3rd International Conference on Energy and Environment, Malacca, Malaysia , 441-448.

Verma, P. R. P., & Razdan, B. (2007). Studies on disintegrant action of Leucaena leucocephala seed gum in ibuprofen tablet and its mechanism.*Journal of Scientific and Industrial Research*, *66*(7), 550.

Vietmeyer, N., Cottom, B., & Ruskin, F. R. (1977). Leucaena, promising forage and tree crop for the tropics. *Leucaena, promising forage and tree crop for the tropics.*

Ververis, C., Georghiou, K., Christodoulakis, N., Santas, P., R.,. (2004). Fibre dimension,lignin and cellulose content of various plant material and their suitability for paper production, Industrial Crops and Products , 19(83), 245-254.

Watson, R.T., Noble, I.R., Bolin, B., Ravindranath, N.H., Verardo, D.J. and Dokken, D.J. (eds) . (2000) . Land Use, Land-Use Change and Forestry, IPCC Special Report , Cambridge University Press,Cambridge . 377.

Walton, C. S. (2003). *Leucaena (Leucaena leucocephala) in Queensland*. Land Protection, Department of Natural Resources, Mines, and Energy.

Willenbacher, N., & Hanciogullari, H. (1997). TAPPI 1997 Advanced Coating Fundamentals Symposium Notes.

Wise, L. E., Murphy, Murphy, M, D'Addieco, A.A. (1946) . Chloride holocellulose, its fractionation and bearing on summative wood analysis and on studies on the hemicelluloses, Paper Trade J, 122(2), 35-43.

Wise, L.E. & Jahn, E.C. (1952). Wood Chemistry. Reinhold publishing company, United States of America.

Windeisen, E., Bächle, H., Zimmer, B., & Wegener, G. (2009). Relations between chemical changes and mechanical properties of thermally treated wood 10th EWLP, Stockholm, Sweden, August 25–28, 2008. *Holzforschung*, *63*(6), 773-778.

Zhang X, Nguyen D, Paice M ,Tsang A , Renaud S. (2007) . Degradation of wood extractive in themochemical pulp by soybean lipoxygenase, Enzyme and Microbial Technology 40, 866-873.

Zayed, M. Z., Ahmad, F. B., Zaki, M. A., Ho, W. S., & Pang, S. L. (2014). The reduction of mimosine content in Leucaena leucocephala (petai belalang) leaves using ethyl methanesulphonate (EMS). *Archives of Applied Science Research*, *6*(4), 124-128.

APPENDIX A - FIGURE

Soxhlet ectraction set

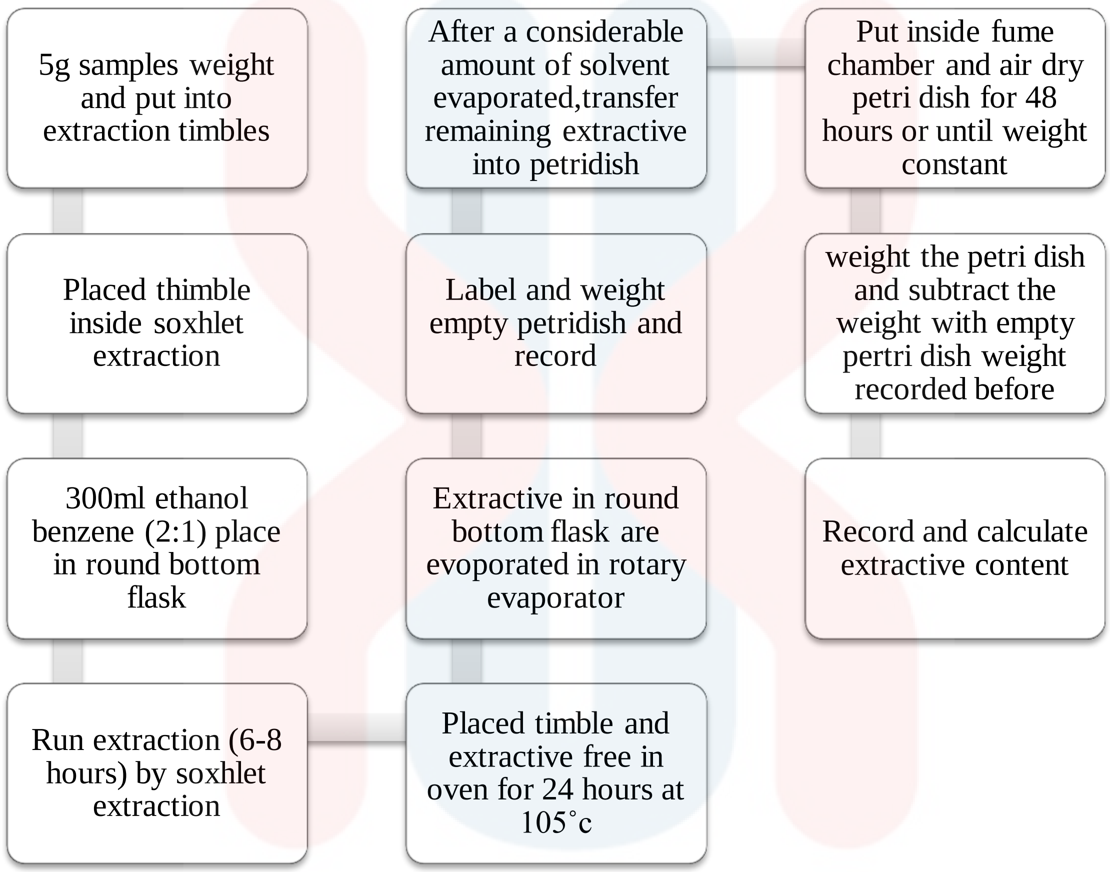
Extraction solution of leucaena and acacia

Ice water-bath of α-cellulose

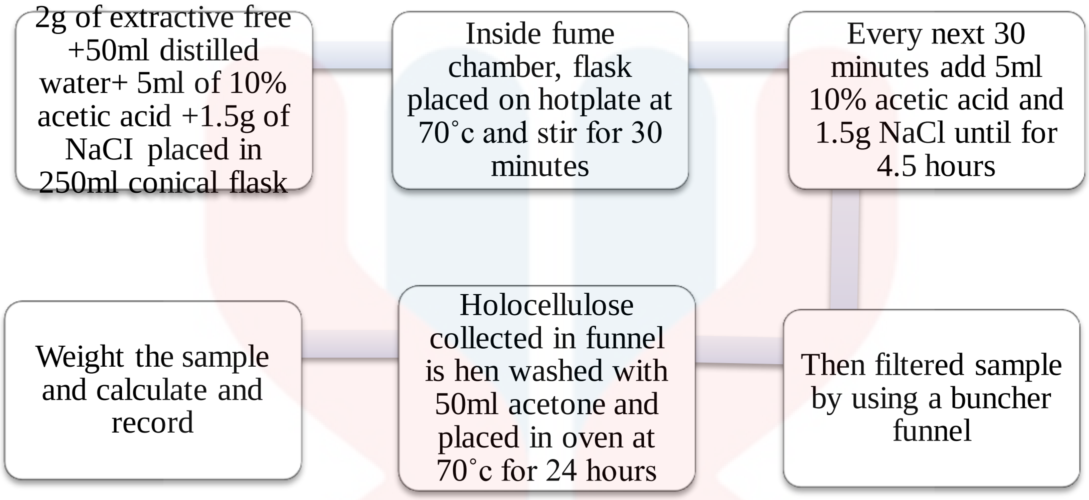
Lignin of leucaena and acacia

APPENDIX B – STANDARD OF PROCEDUR

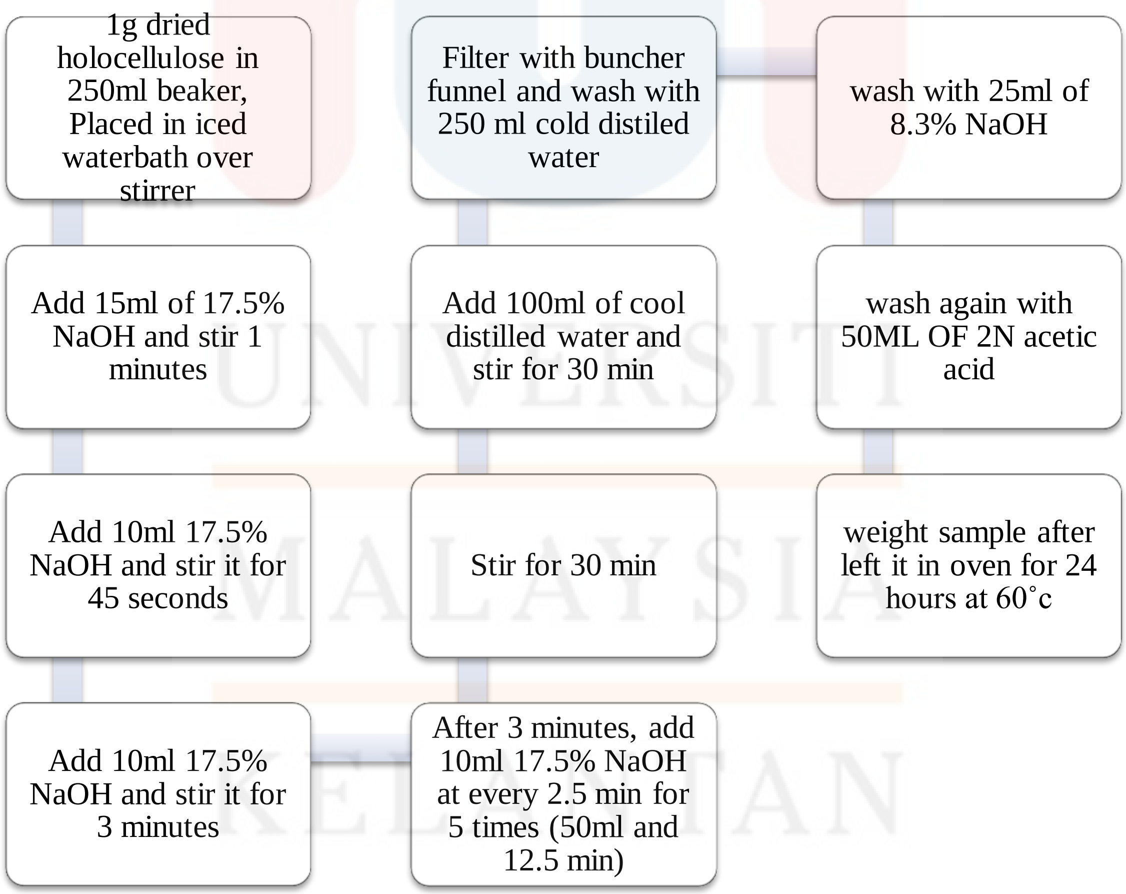
Extractive content



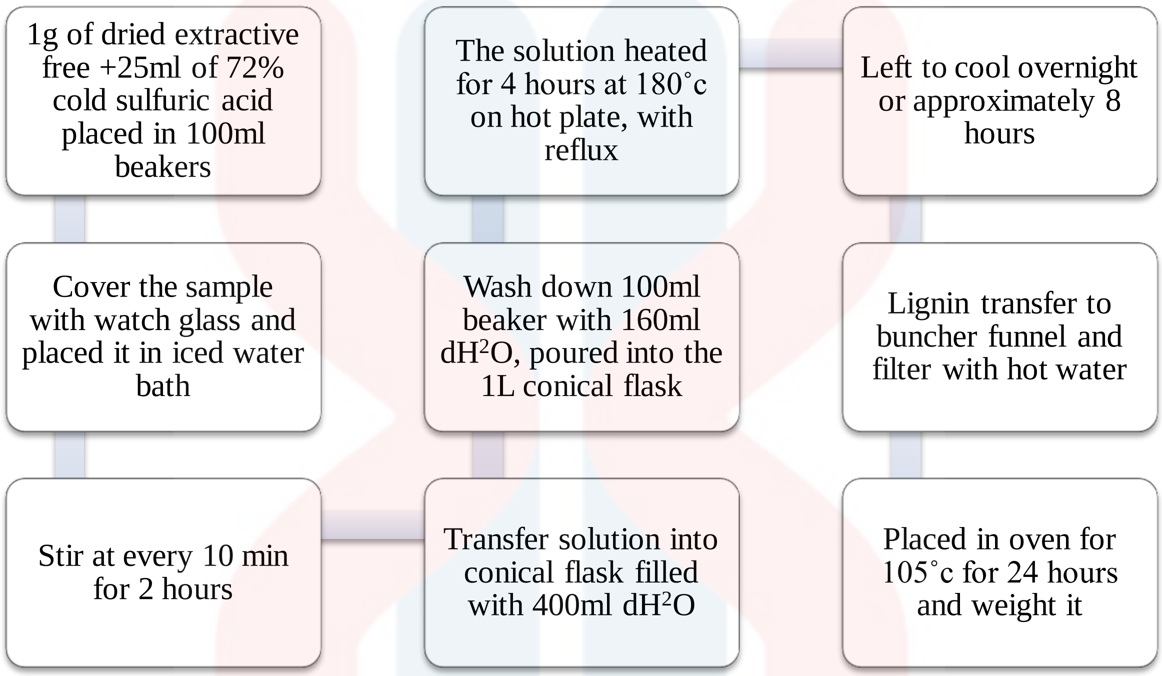
Holocellulose



Cellulose



Lignin


1g of dried extractive free +25ml of 72% cold sulfuric acid placed in 100ml beakers
Cover the sample with watch glass and placed it in iced water bath
Stir at every 10 min for 2 hours
Transfer solution into conical flask filled with 400ml dH^2O
Wash down 100ml beaker with 160ml dH^2O, poured into the 1L conical flask
The solution heated for 4 hours at 180˚c on hot plate, with reflux
Left to cool overnight or approximately 8 hours
Lignin transfer to buncher funnel and filter with hot water
Placed in oven for 105˚c for 24 hours and weight it

APPENDIX - B

RESULT:

EXTRACTIVE

Portion	Species	Sample weight (g)	Dried Extractive weight (g)	Extractive content (%)
Bottom	*Leucaena leucocephala*	5.036	0.26	5.16
	Acaccia mangium	5.054	0.21	4.15
Middle	*Leucaena leucocephala*	5.001	0.15	2.99
	Acacia mangium	5.008	0.059	1.18
Top	*Leucaena leucocephala*	5.011	0.12	2.39
	Acacia mangium	5.006	0.076	1.525

HOLOCELLULOSE

Portion	Species	Free extractive weight (g)	Dried Holocellulose weight (g)	Holocellulose content (%)
Bottom	*Leucaena leucocephala*	3.012	2.26	75.03
	Acacia mangium	3.030	2.55	84.16
Middle	*Leucaena leucocephala*	3.012	2.36	78.35
	Acacia mangium	3.001	2.54	84.63
Top	*Leucaena leucocephala*	3.02	2.622	86.82
	Acacia mangium	3.019	2.753	91.18

CELLULOSE

Portion	Species	Sample weight (g)	Dried α-cellulose weight (g)	Cellulose content (%)
Bottom	*Leucaena leucocephala*	1.001	0.62	61.94
	Acacia mangium	1.001	0.64	63.94
Middle	*Leucaena leucocephala*	1.014	0.478	47.14
	Acacia mangium	1.009	0.60	59.46
Top	*Leucaena leucocephala*	1.005	0.380	37.81
	Acacia mangium	1.006	0.453	45.03

HEMICELLULOSE

Portion	Species	Holocellulose (%)	Cellulose (%)	Hemicellulose content (%)
Bottom	*Leucaena leucocephala*	75.03	61.94	13.09
	Acacia mangium	84.16	63.94	20.22
Middle	*Leucaena leucocephala*	78.35	47.14	31.21
	Acacia mangium	84.63	59.46	25.17
Top	*Leucaena leucocephala*	86.82	37.81	49.01
	Acacia mangium	91.18	45.03	20.09

LIGNIN

Portion	Species	Free extractive weight (g)	Dried Lignin weight (g)	Lignin content (%)
Bottom	*Leucaena leucocephala*	1.008	0.38	37.69
	Acacia mangium	1.041	0.423	40.63
Middle	*Leucaena leucocephala*	1.011	0.232	22.94
	Acacia mangium	1.008	0.154	15.27
Top	*Leucaena leucocephala*	1.098	0.216	19.67
	Acacia mangium	1.032	0.124	12.01

APPENDIX - C

Analysis of Varience (ANOVA)

a) Extractive

Tests of Between-Subjects Effects

Dependent Variable: Extractive

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.263[a]	1	2.263	.951	.385
Intercept	50.431	1	50.431	21.180	.010
Species	2.263	1	2.263	.951	.385
Error	9.524	4	2.381		
Total	62.218	6			
Corrected Total	11.787	5			

a. R Squared = .192 (Adjusted R Squared = -.010)

Tests of Between-Subjects Effects

Dependent Variable: Extractive

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9.265[a]	2	4.633	5.510	.099
Intercept	50.431	1	50.431	59.984	.004
Portion	9.265	2	4.633	5.510	.099
Error	2.522	3	.841		
Total	62.218	6			
Corrected Total	11.787	5			

a. R Squared = .786 (Adjusted R Squared = .643)

Multiple Comparisons

Dependent Variable: Extractive

Tukey HSD

(I) Portion	(J) Portion	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bottom	Middle	2.5700	.91692	.131	-1.2615	6.4015
	Top	2.6975	.91692	.118	-1.1340	6.5290
Middle	Bottom	-2.5700	.91692	.131	-6.4015	1.2615
	Top	.1275	.91692	.989	-3.7040	3.9590
Top	Bottom	-2.6975	.91692	.118	-6.5290	1.1340
	Middle	-.1275	.91692	.989	-3.9590	3.7040

Based on observed means.

The error term is Mean Square(Error) = .841.

b) Holocellulose

Tests of Between-Subjects Effects

Dependent Variable: Holocelluloce

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	65.142[a]	1	65.142	2.488	.190
Intercept	41695.005	1	41695.005	1592.571	.000
Species	65.142	1	65.142	2.488	.190
Error	104.724	4	26.181		
Total	41864.871	6			
Corrected Total	169.866	5			

a. R Squared = .383 (Adjusted R Squared = .229)

Tests of Between-Subjects Effects

Dependent Variable: Holocelluloce

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	98.963[a]	2	49.482	2.094	.270
Intercept	41695.005	1	41695.005	1764.185	.000
Portion	98.963	2	49.482	2.094	.270
Error	70.902	3	23.634		
Total	41864.871	6			
Corrected Total	169.866	5			

a. R Squared = .583 (Adjusted R Squared = .304)

Multiple Comparisons

Dependent Variable: Holocelluloce

Tukey HSD

(I) Portion	(J) Portion	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bottom	Middle	-1.8950	4.86150	.922	-22.2098	18.4198
	Top	-9.4050	4.86150	.274	-29.7198	10.9098
Middle	Bottom	1.8950	4.86150	.922	-18.4198	22.2098
	Top	-7.5100	4.86150	.390	-27.8248	12.8048
Top	Bottom	9.4050	4.86150	.274	-10.9098	29.7198
	Middle	7.5100	4.86150	.390	-12.8048	27.8248

Based on observed means.

The error term is Mean Square(Error) = 23.634.

c) Cellulose

Tests of Between-Subjects Effects

Dependent Variable: Alpha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	262.417[a]	1	262.417	.941	.387
Intercept	14719.325	1	14719.325	52.785	.002
Species	262.417	1	262.417	.941	.387
Error	1115.426	4	278.856		
Total	16097.168	6			
Corrected Total	1377.843	5			

a. R Squared = .190 (Adjusted R Squared = -.012)

Tests of Between-Subjects Effects

Dependent Variable: Alpha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	978.387[a]	2	489.193	3.674	.156
Intercept	14719.325	1	14719.325	110.545	.002
Portion	978.387	2	489.193	3.674	.156
Error	399.456	3	133.152		
Total	16097.168	6			
Corrected Total	1377.843	5			

a. R Squared = .710 (Adjusted R Squared = .517)

Multiple Comparisons

Dependent Variable: Alpha

Tukey HSD

(I) Portion	(J) Portion	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bottom	Middle	9.6400	11.53915	.710	-38.5789	57.8589
	Top	30.5900	11.53915	.148	-17.6289	78.8089
Middle	Bottom	-9.6400	11.53915	.710	-57.8589	38.5789
	Top	20.9500	11.53915	.305	-27.2689	69.1689
Top	Bottom	-30.5900	11.53915	.148	-78.8089	17.6289
	Middle	-20.9500	11.53915	.305	-69.1689	27.2689

Based on observed means.

The error term is Mean Square(Error) = 133.152.

d) Hemicellulose

Tests of Between-Subjects Effects

Dependent Variable: Hemicellulose

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	352.207[a]	1	352.207	.920	.392
Intercept	5217.371	1	5217.371	13.632	.021
Species	352.207	1	352.207	.920	.392
Error	1530.942	4	382.736		
Total	7100.520	6			
Corrected Total	1883.149	5			

a. R Squared = .187 (Adjusted R Squared = -.016)

Tests of Between-Subjects Effects

Dependent Variable: Hemicellulose

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	732.168[a]	2	366.084	.954	.478
Intercept	5217.371	1	5217.371	13.599	.035
Portion	732.168	2	366.084	.954	.478
Error	1150.981	3	383.660		
Total	7100.520	6			
Corrected Total	1883.149	5			

a. R Squared = .389 (Adjusted R Squared = -.019)

Multiple Comparisons

Dependent Variable: Hemicellulose

Tukey HSD

(I) Portion	(J) Portion	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bottom	Middle	-11.5350	19.58725	.835	-93.3846	70.3146
	Top	-26.9650	19.58725	.454	-108.8146	54.8846
Middle	Bottom	11.5350	19.58725	.835	-70.3146	93.3846
	Top	-15.4300	19.58725	.735	-97.2796	66.4196
Top	Bottom	26.9650	19.58725	.454	-54.8846	108.8146
	Middle	15.4300	19.58725	.735	-66.4196	97.2796

Based on observed means.

The error term is Mean Square(Error) = 383.660.

e) Lignin

Tests of Between-Subjects Effects

Dependent Variable: Lignin

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	25.585[a]	1	25.585	.152	.717
Intercept	3661.034	1	3661.034	21.686	.010
Species	25.585	1	25.585	.152	.717
Error	675.279	4	168.820		
Total	4361.899	6			
Corrected Total	700.864	5			

a. R Squared = .037 (Adjusted R Squared = -.204)

Tests of Between-Subjects Effects

Dependent Variable: Lignin

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	637.790[a]	2	318.895	15.168	.027
Intercept	3661.034	1	3661.034	174.130	.001
Portion	637.790	2	318.895	15.168	.027
Error	63.074	3	21.025		
Total	4361.899	6			
Corrected Total	700.864	5			

a. R Squared = .910 (Adjusted R Squared = .850)

Multiple Comparisons

Dependent Variable: Lignin

Tukey HSD

(I) Portion	(J) Portion	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bottom	Middle	20.0550*	4.58527	.044	.8945	39.2155
	Top	23.3200*	4.58527	.030	4.1595	42.4805
Middle	Bottom	-20.0550*	4.58527	.044	-39.2155	-.8945
	Top	3.2650	4.58527	.774	-15.8955	22.4255
Top	Bottom	-23.3200*	4.58527	.030	-42.4805	-4.1595
	Middle	-3.2650	4.58527	.774	-22.4255	15.8955

Based on observed means.

The error term is Mean Square(Error) = 21.025.

*. The mean difference is significant at the .05 level.