Effects of Tree Portion and Radial Position on Physical and Chemical Properties of Kelampayan (*Neolamarckia cadamba*) Wood

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This study aimed to determine the physical and chemical properties of Kelampayan wood. Three Kelampayan trees were sampled at the bottom, middle, and top and partitioned into sections described as near pith, intermediate, and near bark. The TAPPI standard T258 om-94 (1995) was followed to determine the physical properties including moisture content and specific gravity. Overall, the moisture content decreased from the bottom to the top portions and from near pith to near bark. The specific gravity increased with height and when moving from the inside to the outside of the stem. No significant variations were found among tree portions with cold water extractable content and ash content. The properties of Kelampayan in this study were comparable to rubberwood, which is the most common species used to make wood-based products in Malaysia.

Keywords: Kelampayan; Physical properties; Chemical properties

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INTRODUCTION

Kelampayan (*Neolamarckia cadamba*) is a fast-growing tropical tree species and belongs to the family of Rubiaceae. It is a light tropical hardwood with an air-dry density of 290 kg/m^3 to 465 kg/m^3 and can be cultivated in Malaysia. The large trees can reach up to 40 m tall and have a diameter of up to 100 cm (Lim *et al.* 2005). The self-pruning and straight bole, or trunk, characteristics of the tree have attracted attention to the tree as a potentially useful species for tree plantations (Nordahlia *et al.* 2014). The growth characteristics of this tree suggest that under natural regeneration a dense even-age stand can be formed, making it suitable for management in a plantation. The tree has been described as a 'wonder tree,' 'gem of a tree', and 'miracle tree' in the Philippines because of its multitude of uses and rapid growth (Sahri *et al.* 1995). The future of this tree as a source of raw materials is great due to its multiple uses. Research has shown that Kelampayan timber can be used for making a wide range of products such as plywood, packing case, wooden sandals, toys, disposable chopsticks, and possibly as a short-fibred pulp (Choo *et al.* 1999).

Wood is a hygroscopic substance, meaning it absorbs or loses water vapor depending on the temperature, humidity, and the amount of water in the surrounding atmosphere. Water is taken up by wood as bound water in the cell walls and as free water in liquid form in the cells' lumina. The physical and mechanical properties of wood are greatly affected by the fluctuations in the quantity of water present. The specific gravity of wood, exclusive of water, varies greatly both within and among species. The specific gravity of wood depends on the size of its cells and the thickness of the cell walls. If the fibers have thick walls and small lumina, then the total air space is relatively small and the specific gravity tends to be high. In contrast, if they have thin walls and large lumina, the specific gravity will be low (Panshin and de Zeeuw 1980).

Wood is primarily composed of cellulose, lignin, hemicellulose, and extractives. Cellulose is the major component and constitutes approximately 50% of wood by weight. Lignin constitutes 16% to 25% in hardwoods. It is often called the cementing agent that binds individual cells together. Hemicellulose is branched and associated with cellulose. It is composed of several different kinds of hexose and pentose sugar monomers. Extractives include resins, fats, oils, gum starch, waxes, tannin, and coloring matter. These components contribute to various wood properties including odor, color, taste, hygroscopicity, density, and decay resistance. Extractives make up 5% to 10% of the wood substance (Weimann 1999).

Tests of basic properties of Kelampayan have been conducted in this study to investigate the suitability and effective use of Kelampayan, especially for wood composites. Moreover, there is an apparent lack of information on Kelampayan, particularly on its physical and chemical properties that could have many potential applications. The data obtained is useful for wood composite manufacturers to consider Kelampayan as a substitute for rubberwood (*Hevea brasiliensis*) for coming years in Malaysia. Rubberwood is currently the major source of substrate for the panel, furniture, and solid wood industries. The objective of this study is to determine the physical and chemical properties of Kelampayan wood.

EXPERIMENTAL

Materials

Kelampayan trees with diameter at breast heights (DBH) of 35 cm to 45 cm were harvested from the Universiti Teknologi MARA's (UiTM) Pahang Forest Reserve (Jengka, Pahang, Malaysia). The trees used in this study were randomly selected, with a total of three trees harvested. The height from the bottom to the first branch of each tree was measured, and the value was divided by three. The trees were cut into three portions (bottom, middle, and top) using a chain saw. Two pieces of one-inch-thick disks were taken from each portion of fresh Kelampayan for physical and chemical properties determination.

Methods

Sampling for physical properties

The disks from the bottoms, middles, and tops were marked as 2 cm × 2 cm × thickness ranging from 5 cm to 8 cm. The samples for specific gravity and moisture content measurements were taken from the marked samples, which represented the near pith (NP), intermediate (I), and near bark (NB) sections (Fig. 1). Ten replicates for each sample were used for the determination of the physical properties. All of the other samples not utilized were used for the chemical properties determination. The sampling, preparation, and testing of wood analysis were performed in accordance to the TAPPI standard T258 om-94 (1995).

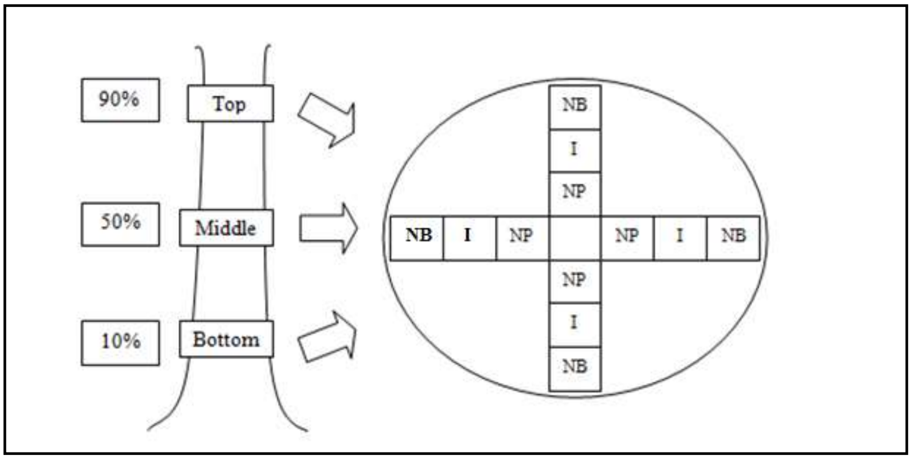

Fig. 1. Procurement of wood disks

Sampling for chemical analysis

Chemical analysis was conducted using air-dried Kelampayan sawdust. The sampling and preparation of the sawdust for this analysis were performed according to the TAPPI standard T257 cm-02 (2002). The Kelampayan samples used in this analysis were taken from the samples that were not utilized in the determination of physical properties. The samples were divided into bottom, middle, and top portions. The samples were fed into a wood chipper and then flaked into small particles using a knife ring flaker. The samples were then ground to a fine size using a wood grinder before being sieved to a 60-mesh size sawdust. Then, the sawdust was air-dried for at least one day prior to chemical analysis so that the reaction of the wood with the reagents used in the chemical analysis was complete. Three replicates were run for each tree portion. The analyses were carried out according to the following standard methods: cold and hot water extractable content (TAPPI standard T207 cm-99 (1999)), alcohol toluene extractable content (TAPPI standard T204 cm-97 (1997)), ash content (TAPPI standard T211 om-02 (2002)), alkali (1% sodium hydroxide) extractable content (TAPPI standard T212 om-02 (2002)), lignin content (TAPPI standard T222 om-02 (2002)), and holocellulose content (TAPPI standard T222 om-02 (2002)). The statistical analysis was performed using IBM SPSS Statistical 20 Software (Armonk, NY, USA).

RESULTS AND DISCUSSION

Physical Properties

The variations of moisture content and specific gravity, according to portion and radial position of Kelampayan wood, are given in Table 1. The moisture content of the bottom, middle, and top portions ranged between 94.6% and 1189.0%. The bottom portion had the highest average moisture content (112.8%) and the top portion had the lowest (101.3%). Moisture content at the radial position was observed to show a decreasing trend from near pith to near bark for all portions except for the middle portion. For the middle portion, the intermediate location exhibited the highest moisture content (106.9%) while the portion closer to the bark was the lowest (104.1%). The specific gravity values ranged from 0.35 to 0.41. From the results, the highest average specific gravity determined was 0.39 for the top portion while the lowest was 0.36 in the bottom portion. For the radial positions, the highest specific gravity was nearer to the bark, and all portions also indicated the same trend.

Table 1. Average Values for Moisture Content and Specific Gravity of Kelampayan Wood According to Tree Portion and Radial Position

Portion	Radial Position	MC (%)	SD	SG	SD
	Near pith	118.95	10.99	0.35	0.02
	Intermediate	111.88	8.27	0.35	0.01
	Near bark	107.55	6.39	0.37	0.02
Bottom	**Average**	**112.79**		**0.36**	
	Near pith	105.22	5.59	0.38	0.03
	Intermediate	106.89	5.72	0.37	0.04
	Near bark	104.13	5.84	0.40	0.03
Middle	**Average**	**105.41**		**0.38**	
	Near pith	107.86	7.54	0.39	0.02
	Intermediate	101.59	5.07	0.38	0.03
	Near bark	94.58	4.20	0.41	0.02
Top	**Average**	**101.34**		**0.39**	

Values are an average of 10 samples; MC = moisture content, SG = specific gravity, and SD = standard deviation

Statistical Significance

The analysis of variance (ANOVA) on the effects of the tree portion and radial position and their interactions on moisture content and specific gravity is shown in Table 2. All of the main factors of tree portion and radial position showed a significant effect on the moisture content and specific gravity values at a 95% confidence level. Interaction between the tree portion and radial position showed no significant interaction on the moisture content but had a significant effect on the specific gravity.

Table 2. Summary of ANOVA on the Moisture Content and Specific Gravity of Kelampayan Influenced by Tree Portion and Radial Position

Source of Variance	Df	MC (%)	SG
Tree Portion	2	21.25*	8.80*
Radial Position	2	11.67*	18.36*
Tree Portion × Radial Position	4	2.49ns	3.92*

Df = degree of freedom, MC = moisture content, SG = specific gravity, ns = not significant at $p > 0.05$, and * = significant at $p < 0.05$

Effects of Tree Portion

Figure 2 presents the summary of a Duncan Multiple Range Test (DMRT) on the effects of tree portion on moisture content and specific gravity. With respect to tree height, which is from bottom to top portions, it was observed that the moisture content showed a decreasing trend. The moisture content decreased significantly with the tree portion at $p < 0.05$. The correlation analysis further revealed that the moisture content showed a significant negative correlation with tree portion ($r = -0.51$*) (Table 3). With increasing tree height, there was a general increase of specific gravity from the bottom to the top portion.

The specific gravity of the bottom portion was significantly lower than the specific gravity of the middle and top portions. However, the specific gravity values of the middle and top portions were insignificantly different from each other. Table 3 shows a significant positive correlation coefficient between the specific gravity and increasing tree height (r = 0.28*), which indicated that the specific gravity increased from the bottom to top portion. In general, it was comparable with the specific gravity of other local popular hardwood timbers such as *Acacia mangium* (Lim *et al.* 2003), *Octomeles sumatrana* (Binuang), and *Paraserianthes falcataria* (Batai) (Nordahlia *et al.* 2014). The specific gravity reflects the moisture content of wood. Wood with a high specific gravity has a high concentration of cells that have thick cell walls and small lumina (Josue 2004) and thus less spaces in the cell walls and lumina. This translates to less space to be filled with water, which results in a low moisture content. Kelampayan is a fast-growing species and can be harvested in short age rotations. The timber would contain higher proportions of juvenile wood compared with traditionally harvested wood. Juvenile wood consists of thinner cell walls, spiral grains, and larger amounts of reaction wood whose anatomical characteristics and physical properties are different from mature wood of the same tree (Gorisek *et al.* 2004).

Fast-growing trees generally show an increase in specific gravity from the bottom to top portion of the tree because of the growth factors affecting the tree (Panshin and de Zeeuw 1980). Usually, the specific gravity of wood increases with tree height due to a higher proportion of heartwood formation at the bottom and a higher proportion of juvenile wood at the top (Zobel and Buijtenen 1989). However, the values of specific gravity according to the tree portion in this study differed from those reported by other researchers. The differences may have been due to the varying growth influences and the difference in the proportion of cell types in different parts of the tree. A previous study mentioned that the specific gravity of wood mainly depends on the location and not so much on the genetic basis (Gryc *et al.* 2011). A study by Sahri and Ismail (1992) reported a similar pattern for the effect of specific gravity with tree portion on the same species. Based on the findings obtained, it was concluded that the specific gravity increased significantly from the base upward in the same tree.

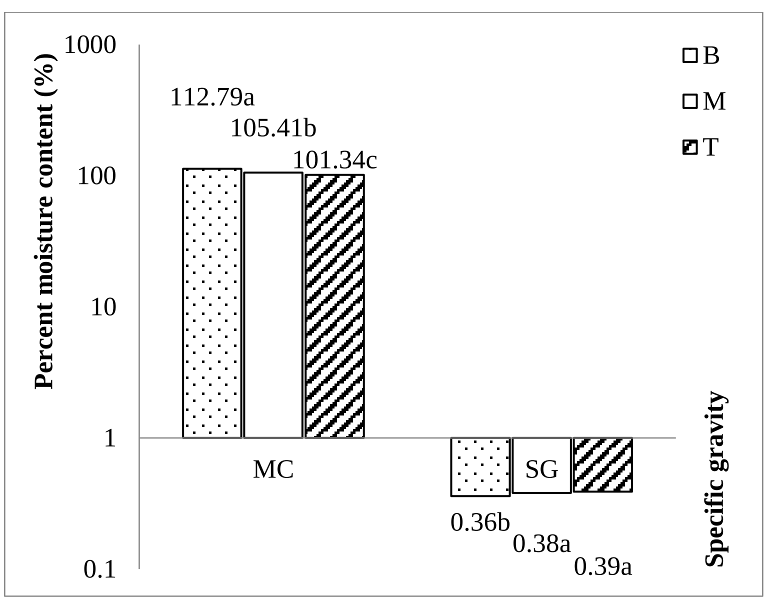

Fig. 2. Effects of tree portion on MC and SG; B = bottom, M = middle, and T = top

Effects of Radial Position

Figure 3 shows the effect of radial position on the moisture content and specific gravity. Moving across the radial position, a decrease in moisture content from the inner to outer wood was noted. The results indicated that the moisture content decreased significantly from the near pith to near bark of radial position. The correlation analysis further revealed that the moisture content had a significant inverse correlation with the radial position (r = -0.39*) (Table 3). At the radial position, there was a general increase in specific gravity from the near pith to near bark (Fig. 3). Significant variation was observed from the near pith to near bark, but variation between the near pith and intermediate portions was not significant. The correlation analysis revealed that the specific gravity showed a significant positive correlation with radial position (r = 0.48*) (Table 3).

This result correlated with Lokmal and Mohd Nor (2010). They reported that the increase of specific gravity from near pith to near bark was related to the transition of juvenile wood to mature wood. Mature wood had higher specific gravity values because it contains higher amounts of heartwood cells that have thick cell walls (Guler *et al.* 2007). The increasing specific gravity resulted from increasing wall thicknesses from inner to outer wood portions. The outer wood regions have thicker cell walls and small lumina, while the wood at the inner parts consist of thinner cell walls and larger lumina (Josue 2004). This decrease in space may have created a lower storage capacity of water in the outer part of wood region and thus lowered the moisture content of the wood. A similar pattern of specific gravity at the radial position was found by previous research (Ajala and Ogunsawa 2011). The pattern of variation of this study was in agreement with the “Type 3” variation of specific gravity in radial positions proposed by Panshin and de Zeeuw (1980). The variation of specific gravity among species and within individual trees is related to their age and genetic differences (Zziwa *et al.* 2006). The tendency of specific gravity to increase with increasing age has been established for many tree species.

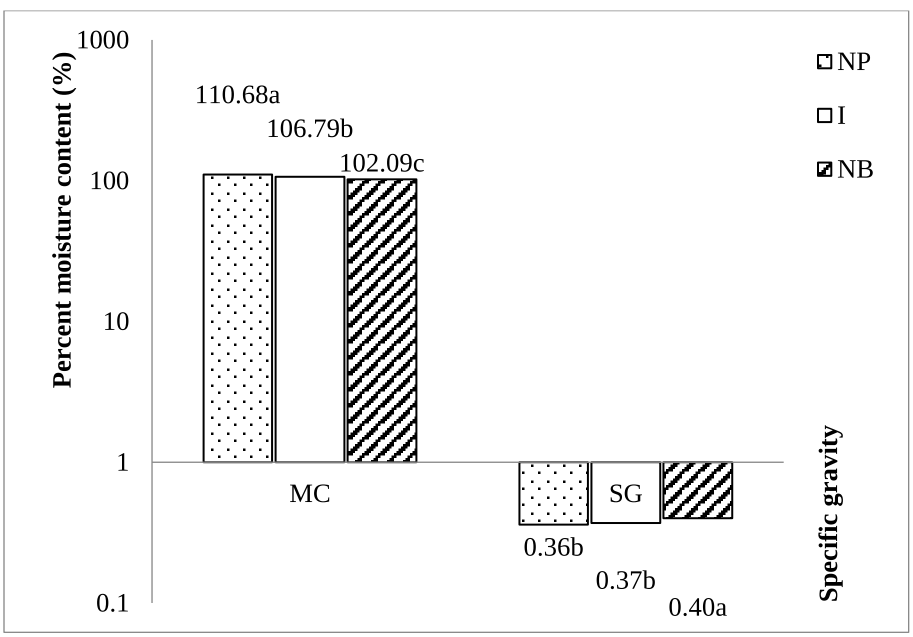

Fig. 3. Effects of radial position on MC and SG; NP = near pith, I = intermediate, and NB = near bark

Table 3. Correlation Coefficients of Moisture Content and Specific Gravity with Tree Portion and Radial Position

Variable	Tree Portion	Radial position
Moisture content	-0.51*	-0.39*
Specific gravity	0.28*	0.48*

Note: *Significant at $p < 0.05$

Chemical Properties

The experimental results for the chemical composition of Kelampayan for different tree portions are summarized in Table 4. The chemical composition of Kelampayan varied widely based on the tree position. They were widely variable due to heterogeneity of the wood itself. The highest value for cold water extractable content was observed in the middle portion (5.75%) and the lowest was in the top portion (5.54%). The percentage of hot water extract was higher for the top portion (6.94%), and the smallest was in the middle portion. The alkali extractable content of Kelampayan wood ranged from 17.5% to 18.8%. The contents were higher in the bottom portion of the tree compared to the middle and top portions. The top portion exhibited the highest percentage of alcohol toluene extractable content (2.58%), whereas the lowest was in the middle portion (2.24%). The ash contents of Kelampayan wood averaged from 0.55% to 0.74%. The ash content of the bottom portions was relatively higher and the values decreased from the bottom to top portions of the tree. The lignin contents of the bottom and middle portions (bottom 30.20%, and middle 24.58%) were lower than those of the top portions (30.9%). The highest average value of the holocellulose content was also obtained from the top portion (70.9%) of the Kelampayan trees.

Statistical Significance

The ANOVA on the effects of tree portion on chemical properties is shown in Table 5. The tree portion was found to affect the hot water extractable content, 1% NaOH extractable content, and alcohol toluene extractable content significantly at the 95% confidence level. The tree portion also affected the lignin and holocellulose content significantly. An exception of insignificance was seen for the cold water extract content and ash content.

Cold and Hot Water Extractable Contents

Cold and hot water extractable contents are important for the determination of water soluble extracts, such as tannin, starch, sugar, pectin, and phenolic compounds, within any lignocellulosic material (Jamaludin 2006). Figure 4 illustrates the effects of tree portion on the cold and hot water extract contents. The portion was found to not affect the cold and hot water extractable content significantly. Table 6 further reveals that cold water extractable content had an insignificant and positive correlation with tree portion ($r = 1.00$, ns). However, the hot water extractable content had an insignificant negative correlation with the tree portion ($r = -0.10$, ns). The portion with higher values of cold and hot water extractable contents contained more active cells (Wan Mohd Nazri *et al.* 2009). During hot water extraction, partial hydrolysis of hemicellulose occurred, which involved the development of organic acids passing to water solutions (Doczekalska and Zborowska 2010). This also could explain why the amount of hot water extract was higher than that of the cold water.

Table 4. Chemical Composition of Kelampayan

Chemical Composition	Tree Portion	Kelampayan	SD	Rubberwood (Harmaen *et al.* 2005)
Cold water extract content (%)	Top	5.54	0.27	
	Middle	5.75	0.36	
	Bottom	5.65	0.13	
	Average	**5.65**		
Hot water extract content (%)	Top	6.94	0.55	6.55
	Middle	6.03	0.25	
	Bottom	6.70	0.00	
	Average	**6.56**		
1% NaOH extract content (%)	Top	18.33	0.09	
	Middle	17.50	0.33	
	Bottom	18.83	0.10	
	Average	**18.22**		
Alcohol toluene extract content (%)	Top	2.58	0.08	3.34
	Middle	2.24	0.10	
	Bottom	2.54	0.07	
	Average	**2.45**		
Ash content (%)	Top	0.55	0.01	0.60
	Middle	0.57	0.02	
	Bottom	0.74	0.32	
	Average	**0.62**		
Lignin content (%)	Top	30.92	0.91	23.00
	Middle	24.58	0.84	
	Bottom	30.20	0.95	
	Average	**28.57**		
Holocellulose content (%)	Top	70.93	1.00	66.86
	Middle	68.44	1.01	
	Bottom	70.14	0.21	
	Average	**69.84**		

Values are averages of 3 determinations, SD = standard deviation

Table 5. Summary of the ANOVA on Chemical Properties Influenced by Tree Portion

SOV	CW	HW	NaOH	AT	Ash	Lignin	Holo
Tree Portion	0.45 ns	5.40*	32.05*	14.60*	1.04 ns	44.60*	192.45*

SOV = source of variance, CW = cold water, HW = hot water, NaOH = 1% sodium hydroxide, AT = alcohol toluene, and Holo = holocellulose

Generally, the hot water extractable content of Malaysian hardwoods is in the range of 0.1% to 14.4% (Khoo and Peh 1982). The average values of hot water extractable content of Kelampayan in this study were almost similar to rubberwood (6.55%), as reported by Harmaen *et al.* (2005) (Table 4). Rubberwood is the most common species used to make composite products in Malaysia.

Alkali (1% NaOH) Extractable Content

The alkali extracts were low molecular weight carbohydrates that consisted of degraded cellulose and hemicellulose in wood. The content indicates the intensity of deterioration caused by fungi, heat, light, and oxidation (Júnior and Moreschi 2003). It is closely related to the degree of wood degradation. A higher wood degradation value resulted in a higher 1% NaOH extractable content. Figure 4 shows the effect of tree portion on alkali extractable content of Kelampayan. The alkali extractable content showed a significant effect between the portions of the tree. The bottom portion had significantly higher alkali extractable contents compared with the other portions. The high alkali extractable content of the bottom portions can be attributed to the higher concentration of organic acid, polyphenol, polysaccharides, and tannin compared to the middle and top parts (Zaki *et al.* 2012). The correlation analysis revealed that the alkali extractable content showed an insignificant inverse correlation with tree portion (r = -0.26, ns) (Table 6). Previous research reported that 1% alkali extractable content in Malaysian hardwoods ranges from 2.6% to 24.5% (Khoo and Peh 1982).

Alcohol Toluene Extractable Content

The alcohol toluene extractable content measures the extractives or nonstructural components of wood including fats, resins, waxes, and certain other ether-insoluble components such as wood gums (Harmaen *et al.* 2014). Figure 4 shows the DMRT on the effect of alcohol toluene extractable with tree portion. The correlation analysis revealed that the alcohol toluene content showed an insignificant inverse correlation with tree portion (r = -0.02, ns) (Table 6). The percentages of alcohol toluene extractable contents for top and bottom portions were insignificantly different from each other; however, the value of the top portion was slightly higher than that of the bottom portion. The middle portion of the tree was significantly lower in the alcohol toluene extractable content. A previous study found that the percentage of alcohol toluene extractives in the top portion was higher than that of the bottom portion (Yeh *et al.* 2006). The authors mentioned that the higher proportion of cambium, or living cells, on top of the tree may have caused the extractives component to also be higher.

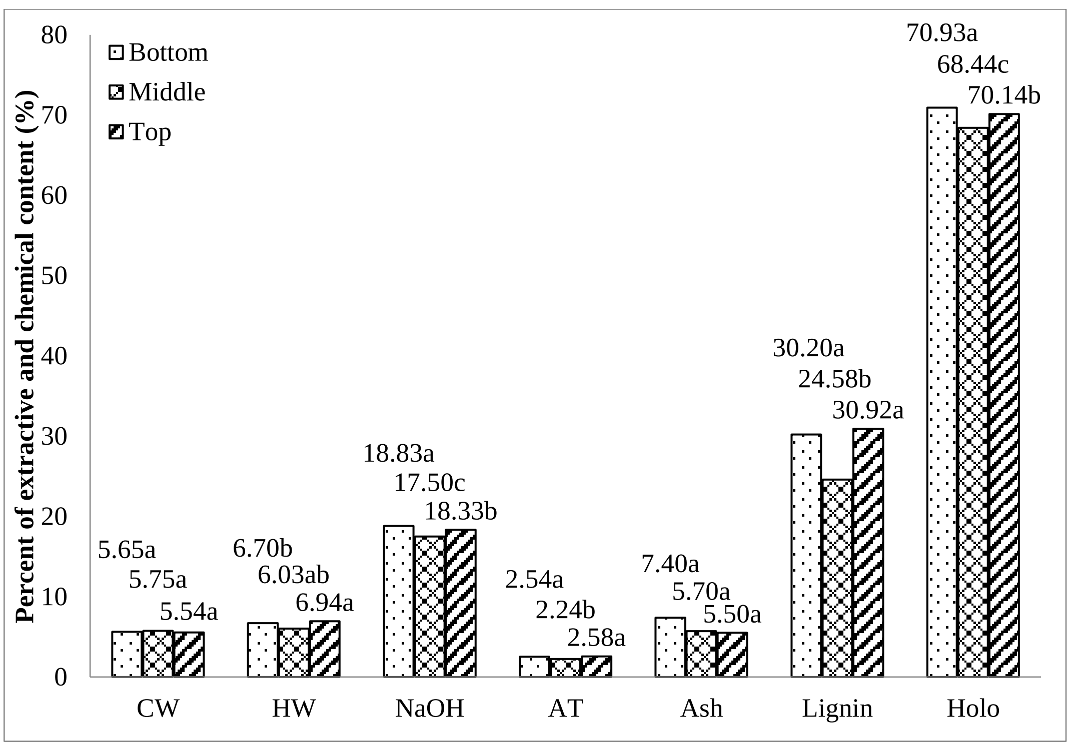

Fig. 4. Effects of tree portion on chemical properties; CW = cold water, HW = hot water, NaOH = 1% sodium hydroxide, AT = alcohol toluene, and Holo = holocellulose

The amount of extractives in *Hevea brasiliensis* was 6% to 10% (Hong and Sim 1994). However, in this study Kelampayan tended to possess a lower extractive content than the most popular tropical hardwood species, *Hevea brasiliensis*. A previous study estimated that the amount of alcohol toluene extractable content of rubberwood was 3.34% (Table 4) (Harmaen *et al.* 2005). Extractive components constituted as much as 20% of the dry weight of tropical hardwoods. These components play important roles in fungal resistance, insect resistance, increasing the paint curing time, and resin spots creation (on pulp sheets) (Harmaen *et al.* 2014). Lower extractives in Kelampayan, especially lack of latex gave an advantage to this specie when compared to *Hevea brasiliensis*.

Ash Content

Ash is an inorganic element and does not burn, even when heated to 575 °C. Ash content is normally 0.1% to 0.5% of the oven-dry weight of wood (Panshin and de Zeeuw 1980). Figure 4 depicts the effect of tree portion on the ash content. The ash content tended to have a higher percentage value in the bottom portion of the tree. Ash is related to the amount of minerals present, such as silica. Silica in wood cells is caused by a high proportion of heartwood (Zaki *et al.* 2012). The trend of ash content decreasing from the bottom to the top portion was associated with the higher proportion of heartwood formation at the bottom part due to the development of mature wood. The DMRT analysis showed that the percentage of ash content varied insignificantly with tree portion. The correlation analysis further revealed that the ash content had an insignificant negative correlation with tree portion (r = -0.09, ns) (Table 6), implying that the ash content decreased from the bottom to top portions. The decrease in ash content from the bottom to top portions of the trees has also been reported by Harmaen *et al.* (2014). Excessive amounts of silica in wood will dull machine tools. Because ash content is commonly related to the amount of silica, the selection of the specific portions of Kelampayan with low ash content for specific products is essential towards optimum utilization. In this study, the Kelampayan had an average ash content of 0.62%, which was similar to that of rubberwood (0.60%) (Harmaen *et al.* 2005), which will allow it to have similar effect on cutting tools.

Lignin Content

Lignin is a complex and highly amorphous polymer that is present within the cell walls and between the individual cells. Lignin is very intimately associated with cellulose and hemicellulose within the cell walls and it provides rigidity to the cells. Between the cells, lignin serves as a binding agent to hold the individual cells together (Ray *et al.* 2009). Figure 4 indicates that the lignin content was insignificantly affected by tree portion. The correlation analysis also revealed that lignin content showed an insignificant negative correlation with tree portion (r = -0.46, ns) (Table 6). A previous study described that lignin content varies only slightly along the stem (Panshin and de Zeeuw 1980). The percentage of lignin content at the top was slightly higher than that of the bottom portion. The middle portion recorded a significantly lower lignin content as compared with the bottom and top portions of the tree. This trend is likely due to the fact that thinner cell walls tend to have a higher lignin content (Zaki *et al.* 2012). The top portion contains larger proportions of juvenile wood. In juvenile wood, there is inherently a higher amount of sapwood with thin walls and large lumina. Therefore, it can be assumed that the lignin content should also be higher at the top portion of the tree. Indeed, another study has found that juvenile wood has higher lignin compared to mature wood (Yeh *et al.* 2006). Usually, the lignin content in Malaysian hardwoods ranges from 12.7% to 34.2% (Khoo and Peh 1982). While 20% to

28% is typical in normal hardwoods, it can exceed 30% in tropical hardwoods (Sjóstrom 1981). Previous research found that rubberwood contains 23% lignin by mass and that the lignin content of Kelampayan is higher than that of rubberwood, as shown in Table 4 (Harmaen *et al.* 2005). The 5% higher lignin content in Kelempayan will have tend to have more influence if target product need to undergo refining stage.

Table 6. Correlation Coefficients of Chemical Properties with Tree Portion

Properties	Portions
Cold water extract content	1.00 ns
Hot water extract content	-0.10 ns
Alkali extract content	-0.26 ns
Alcohol toluene extract content	-0.02 ns
Ash content	-0.09 ns
Lignin content	-0.46 ns
Holocellulose content	-0.35 ns

Note: ns = not significant at $p > 0.05$

Holocellulose Content

Holocellulose is the proportion of extractive-free wood. It includes cellulose and hemicellulose. Wood with high levels of cellulose or hemicellulose (or both) tends to possess a higher holocellulose content. The DMRT showed that holocellulose content differed significantly with tree portion (Fig. 4). The correlation analysis revealed that holocellulose content had an insignificant negative correlation with tree portion ($r = -0.35$, ns) (Table 6). The results observed in Fig. 4 indicated an inconsistent pattern in the effect of holocellulose content on tree portion. The holocellulose level of the bottom portions was significantly higher than that of the top and middle portions, while the middle portion showed significantly lower holocellulose levels than the top and bottom portions. This may have been related to the higher proportion of juvenile wood in fast growing species. Juvenile wood is characterized by higher cellulose content and undergoes rapid growth. The higher cellulose content of juvenile wood at the bottom of the tree could contribute to greater holocellulose content. The holocellulose content of rubberwood is 66.9% (Harmaen *et al.* 2005). In this study, the Kelampayan had a holocellulose content of 69.8%, which was higher than rubberwood, as shown in Table 4. Previous research reported that the holocellulose content of Malaysian tropical hardwoods is within the range of 59.4% to 85.4% (Khoo and Peh 1982). In this study, the holocellulose content of Kelampayan fell within this range.

CONCLUSIONS

This study provided data on the suitability of Kelampayan, a fast-growing species, as a possible alternative for rubberwood.

1. Variations in the tree portion and radial position of Kelampayan were not significant for most of the extract properties studied, indicating wood uniformity along and across the stem.

2. The averages of the extractive contents were: cold water extracts (5.6%), hot water extracts (6.6%), alkali extracts (18.2%), alcohol toluene extracts (2.4%), and ash (0.62%). The lignin and holocellulose average content were measured at 28.6% and 69.8%, respectively. Kelempayan wood properties show suitability for wood composite feed stock in Malaysia.

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