Effects of Age and Tree Portion on Chemical Properties of *Leucaena Leucocephala* Wood

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ABSTRACT

The chemical components of wood strongly influence the characteristics, properties and opportunities for use of wood as composite material. The data on the chemical composition of wood material is generally preferred and required for various processes and applications in the wood industry. The main objective of the study is to determine the basic chemical properties of Leucaena leucocephala *from eight year-old and sixteen year-old trees. This study revealed that age shows no significant effect while tree portion significantly affect the cold water and hot water solubles. Alkali solubility also shows similar trend. Alcohol toluene soluble was significantly affected by age and tree portion. Effect of tree portion in ash content shows a significant difference between bottom and both middle and top portions. However, effect of age shows no significant difference with percentage of ash content. The lignin content shows a positive correlation with increasing age but correlated insignificantly with tree portion. The holocellulose content decreases significantly with age and positive increases with tree portion. Generally, eight year-old wood was found to be a suitable raw material to manufacture wood composite.*

Keywords: *alcohol toluene, ash, lignin, holocellulose, tree portion*

Introduction

In the wood industry, the use of fast-growing woody species may be an alternative way to not only extend the wood supply, but also to preserve natural resources from over-exploitation. *Leucaena leucocephala*, a fast-growing leguminous shrub from Central America, is a multi-purpose species. It is widely used as livestock forage, fuelwood, reforestation material, green consumption, and green manure. Its uses have also been expended to gum production, furniture and construction timber, pole wood, pulpwood, shade and support plants in agroforestry systems. In Southeast Asia, large growing trees are used to shade coffee and cacao plantations (NAS, 1979; Brewbaker, 1987; Diaz et al., 2007).

Leucaena leucocephala has been the focus of a great deal of research in the past few decades (National Research Council, 1977; International Development Research Centre, IDRC, 1983). Research on mechanical properties, including static bending, compression strength and toughness indicates that *Leucaena leucocephala* has fair qualities, which would not limit its uses as solid products (Tang, 1981). Van den Beldt and Brewbaker (1985) reported that *Leucaena leucocephala* produces wood of medium density with moderate strength properties. Its specific gravity ranges from 0.45 to 0.55 at the age of two years, a value that is fairly comparable to other commonly grown fuelwood species such as *Gliricida sepium* (McDicken & Brewbaker, 1982). The wood of *Leucaena leucocephala* has excellent pulping qualities and makes excellent pulping and writing paper (Brewbaker, 1987). It has higher cellulose and lower lignin contents than other native hardwood of Taiwan (Tang and Ma, 1982). The chemical characteristics of *Leucaena* varieties, indicate its possible use as alternative source of cellulose pulp. Fibre lengths and other raw materials characteristics have been more appropriate for the second year than that for the first year of *Leucaena leucocephala* (Diaz et al., 2007).

Approximate chemical analysis is often used to determine the general chemical composition available in wood species. The chemical components of wood strongly influence the characteristic, properties and opportunities for use of this complex natural composite. The data on the chemical composition of wood material is generally preferred and required for the many processes and applications in wood industry. According to Miller (1999), wood is primarily composed of cellulose, lignin, hemicelluloses, and minor amounts (5% to 10%) of extraneous materials. Cellulose, the major component, constitutes approximately 50% of the weight of the wood substance. Unlike the major constituents of wood, extraneous materials are not structural components. Both organic and inorganic extraneous materials are found in wood. The organic component takes the form of extraneous or extractives, which contribute to wood properties such as color, odor, taste, decay resistance, density, hygroscopicity and flammability. Extractives include tannins and other polyphenolics, coloring matter, essential oils, fats, resins, waxes, gum starch and simple metabolic intermediates. These components are termed extractives because they can be removed from wood by extraction with solvents, such as water, alcohol, acetone, benzene, or ether (Maldas & Kamdem, 1999).

Studies on *Leucaena leucocephala* leaves, seeds and roots have been carried out by Ram et al. (1994) and Gupta and Atreja (1999) but only few studies were done on the basic properties of *Leucaena leucocephala* wood. Basic wood properties will help to support suitability and effective use of raw material in wood composite. The main objective of the study is to determine the basic chemical properties of *Leucaena leucocephala* from eight-year-old and sixteen-year-old trees.

Materials and Methods

The samples were harvested and received from the Malaysian Agricultural Research Development Institute (MARDI) station at Jeram Pasu, Pasir Putih, Kelantan, Malaysia. Wood samples for chemical analysis was ground to a fine particle size (saw dust) to permit complete reaction of the wood with the reagents used in the analysis. The sawdust used in this study was taken from several wood disks of eight year-old and sixteen year-old from the top, middle and bottom portions of the tree (Figure 1). The sampling and preparation of saw dust for this analysis were carried out according to the standard Technical Association of the Pulp and Paper Industry USA (TAPPI) T257 cm-85 (1996). T 257 specifies that the sawdust should be ground to pass a 0.4 mm (40 mesh) screen. Sawdust samples were air-dried, homogenized in a single lot to avoid differences in composition among aliquots, and stored.

The analysis was carried out based on the standard method used to determine the general chemical composition present in the wood. The approximate chemical analysis was carried out according to the following standard procedures. The *Leucaena leucocephala* wood were analysed for cold water and hot water, 1% natrium hydroxide soluble, ethanol toluene extractable, ash, lignin and holocellulose, respectively (T 207 om-93, 1996; T 212 om-93, 1996; T 204 om-88, 1996; T 211 om-93, 1996; T 222 om-88, 1996; Wise et. al., 1946).

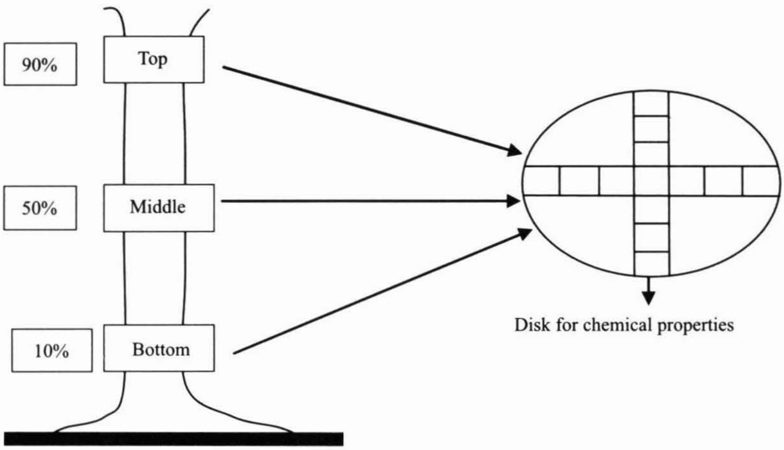

Figure 1: Procurement of Wood Disk

The statistical analysis was employed to determine the significance of data collected by using SPSS (2003) software. The results of the chemical properties were evaluated by analysis of variance (ANOVA) where significant interactions between the main factors of age and tree portion were obtained. Analysis of variance (ANOVA) from general liner model (GLM) procedure was used to evaluate the significant effects of age and tree portion. Correlation analysis was also carried out in order to study the relationship of chemical properties with age and tree portion.

Results and Discussion

Chemical Properties

All samples were measured in triplicate and Table 1 shows the chemical properties of *Leucaena leucocephala* according to age and tree portion.

Cold and Hot Water Solubles

The extractives in wood can be removed by extracting with a single solvent or combinations of solvents. Water solubles are important in the evaluation of extractives such as tannin, starch, sugar, pectin and phenolic compounds from any lignocellulosic materials (Maldas and Kamdem, 1999). The cold water (CW) and hot water (HW) solubles of *Leucaena*

Table 1: Chemical Properties of *Leucaena leucocephala* According to Age and Tree Portion

Age	Portion	CW (%)	HW (%)	NaOH (%)	AT (%)	Ash (%)	Lignin (%)	Holo (%)
8yr	Top	5.97	7.91	17.73	2.11	0.63	21.03	76.25
	Middle	5.01	6.68	15.59	1.76	0.70	23.33	75.16
	Bottom	4.44	5.48	15.54	1.73	0.87	24.67	73.38
	Average	**5.14**	**6.69**	**16.29**	**1.87**	**0.73**	**23.01**	**74.93**
16yr	Top	5.44	6.84	17.29	2.61	0.73	25.19	72.36
	Middle	4.52	5.28	16.06	2.06	0.76	26.28	71.77
	Bottom	4.25	5.56	16.33	1.99	1.12	27.07	69.56
	Average	**4.74**	**5.89**	**16.56**	**2.22**	**0.87**	**26.18**	**71.23**

Note: Values are averages of three determinations
CW = Cold Water Solubles, HW = Hot Water Solubles, NaOH = Alkali Solubles, AT = Alcohol Toluene Solubles, Holo = Holocellulose

leucocephala are given in Table 1 and they were observed to increase from the bottom to the top portion of the tree. The highest CW soluble was observed in the top portion (5.97%) of the eight-year-old tree and the lowest in bottom portion (4.25%) of sixteen-year-old. The highest HW was observed in the top portion (7.91%) of eight year-old and the lowest value was found in middle portion (5.28%) of sixteen year-old tree. Generally, the value of HW solubles is higher than CW solubles. The difference in solubility is due to hydrolysis and corresponding increase in solubility of some part of the wood substance during the boiling with water (Hawley et al., 1924).

Table 2 shows the effect of age and tree portion on the cold water and hot water solubles. Age showed no significant effect while tree portion significantly affected the cold water and hot water solubles. The higher percentage of solubility recorded in hot water solubility is due to the increase in hydrolysis process during boiling with water. Concentrations of HW extractives were 1.2 to 1.3 times higher than those of CW extractives. This is because hot-water extraction eliminates a greater quantity of materials, removes a portion of the cell structure, and extracts some inorganic extractives (Shebani et al., 2008). According to Maldas and Kamdem (1999) the removal of water-soluble extractives contributes to the increase of the hydrophilic nature of the wood surface. Table 3 further reveals that cold water and hot solubles had insignificant negative correlation with age (r = -0.28ns and r = -0.40ns) and positive

Table 2: Effects of Age and Tree Portion on Chemical Properties

Age	CW	HW	NaOH	AT	Ash	Lignin	Holo
8	5.14a	6.69a	16.29a	1.86b	0.73a	22.34b	74.93a
16	4.74a	5.89a	16.56a	2.22a	0.87a	26.01a	71.23b
Tree portion	CW	HW	NAOH	AT	Ash	Lignin	Holo
Bottom	4.35b	5.52c	15.82b	1.85b	0.99a	25.37a	71.47b
Middle	4.77b	5.98b	15.93b	1.91b	0.73b	24.05b	73.47a
Top	5.70a	7.37a	17.51a	2.36a	0.68b	23.11c	74.31a

Note: Different letters down the column indicate significant at $p < 0.05$
CW = Cold Water Solubles, HW = Hot Water Solubles, NaOH = Alkali Solubles, AT = Alcohol Toluene Solubles, Holo = Holocellulose

Table 3: Correlation Coefficients of Chemical Properties with Age and Tree Portion

Properties	Age	Tree Portion
Cold water solubles	-0.28ns	0.78**
Hot water solubles	-0.40ns	0.77**
Alkali solubles	0.16ns	0.75**
Alcohol-toluene solubles	0.58*	-0.68**
Ash content	0.41ns	-0.78**
Lignin content	0.87**	-0.44ns
Holocellulose content	-0.80**	0.50*

Note: ns = not significant at $p > 0.05$, * significant at $p < 0.05$,
**highly significant at $p < 0.01$

correlation with tree portion (0.78** and 0.77**). Generally, the portion with higher CW and HW solubles contained higher active cell and those portions with lower CW and HW solubles contained higher lignin content. According to Panshin and De Zeuuw (1980) upper reaches of crown contained higher early-wood type of juvenile wood and getting less to the base of the tree.

Alkali Solubles

The alkali solubles can be related to the processes of wood decay, and to the damage caused by animal and plant pest (Hill, 2006). The alkali solubles of *Leucaena leucocephala* (Table 1) ranged from 15.54% to

17.73%. The highest and lowest alkali solubles were observed at the top portion (17.73%) and bottom portion (15.45%) of the eight year-old tree. The results further indicate that the alkali solubles tended to have higher values in the top portion of tree height.

Table 2 shows the effects of age and tree portion on alkali solubles of *Leucaena leucocephala* wood. Age was found not to affect alkali solubility but tree portion showed a significant effect. The correlation analysis (Table 3) further reveals that the alkali solubility showed insignificant correlation with increasing age ($r = 0.16$) but was positively correlated with tree portion ($r = 0.75^{**}$). This could explain the reason that most of the extractives that can be dissolved by alkali solubles are located in the active cell at top portion of the tree. A common explanation of this difference is that the sapwood in top portion of the tree contains more starch, sugar, protoplasm, gums, etc., but these elements are not found in the heartwood. Moreover, these elements normally furnish food for fungi and encourage its growth (Hawley et al., 1924). Ucar and Yillgor (1995) reported that alkali solubles were high in juvenile wood and that the alkali solubility was correlated with the degree of bacterial attack.

Alcohol Toluene Slolubles

Table 1 indicates that the alcohol toluene solubles tended to have a higher percentage value in older tree and near to the top portion of the tree. As expected, ethanol-toluene extraction of sixteen-year-old wood afforded a much higher average extractive content than that of the eight-year-old wood and the trend for tree portion increase from bottom to top. The ethanol-toluene extraction of *Leucaena leucocephala* wood sample afforded an average extractive content of 1.87 to 2.22%, which was about 3% for a fast-growing pioneer native tree species, was obtained by ethanol-benzene extraction (Pettersen, 1984). The Duncan's Multiple Range Test (DMRT) (Table 2) indicated that alcohol toluene solubles was significantly affected by age and tree portion. The correlation analysis (Table 3) further revealed that the alcohol toluene solubility showed a positive correlation with increase of age ($r = 0.58^{*}$) and negatively correlated with tree portion ($r = -0.68^{**}$). Higher percentage of extractive in sixteen-year-old wood makes it more resistant and stiffer. According to Luxford (1931) extractives helped to reinforce wood structure. Extractive compounds in heartwood are recognised as the most important factor in fungal resistance (Taylor et al., 2002). According to Jackson

(1957) natural durability of timber depends not on the amount of extractable substances present but rather on the exact nature of the components in the extractives. However, too high extractive compounds can interfere bonding between wood and adhesive. According to Plomley et al., (1976) and Tohmura (1998) extractives have been shown to interfere with the cure of phenolic resin systems used in wood composite manufacture.

Ash Content

Table 1 shows that the ash content of *Leucaena leucocephala* ranges from 0.63 to 1.12%. The highest ash content was found in the bottom portion (1.12%) of the sixteen-year-old while the lowest was recorded from the middle portion (0.63%) of the eight-year-old tree. The ash content decreases from the bottom to the top portion of the tree. Effect of tree portion shows a significant difference between bottom and both middle and top portion. However, effect of age shows no significant difference with percentage of ash content. The correlation analysis (Table 3) further revealed that the ash content showed insignificant correlation with increase in age (r = 0.41) and was negatively correlated with tree portion (r = -0.78**). The result shows that wood with higher density contributed to the increase in percentage of ash content. The sixteen year-old wood with higher wood density showed higher percentage. This could be due to the presence of more heartwood in older tree. Jenkins et al. (1995) reported that ash content, primarily silica could be one of the reasons for the presence of more heartwood content.

Lignin Content

Lignin occurs in wood throughout the cell wall. It is concentrated towards the outside of the cells and between cells. Lignin is often called the cementing agent that binds individual cells together (Miller, 1999). Table 1 shows that lignin content exhibit definite trend with age and tree portion. It was seen that the lignin content increased from the eight year-old tree to sixteen year-old tree and decreased from bottom portion to top of the tree. The highest and lowest lignin contents were observed at the bottom portion (27.07%) of the sixteen-year-old and top portion (21.03%) of eight year-old, respectively. The lignin content shown in the Duncan's Multiple Range Test (DMRT) (Table 2) was significantly affected by both age and tree portion. The correlation analysis (Table 3) further revealed that the lignin content showed a positive correlation with increase in age (r = 0.87**) and insignificantly correlated with tree portion (r = -0.44). According to Panshin and De Zeuuw (1980) lignin content shows a general decrease of 1.5 to 3 percent from pith to the bark and a few increases from top to bottom of the tree. Boudet (2000) stated that the functional significance of lignin has long been associated with the mechanical support for plant organs that enables increased growth in height.

Holocelullose Content

The holocellulose content of *Leucaena leucocephala* irrespective of age and tree portion (Table 1) varied from 69.56 to 76.25%. The highest value was observed at the top portion (76.25%) of the eight-year-old tree while the lowest value in the bottom portion (69.56%) of the sixteen-year-old tree. Generally, sixteen-year-old tree is 3 to 4% lower in holocellulose compared to the eight-year-old tree. Diaz et al., (2007) reported that the holocellulose content of the *Leucaena* varieties under their investigation was higher than 68%.

The results observed in Table 2 indicates a clear decreasing trend on the effect of age and an increasing trend in tree portion for holocellulose content. This was further strengthened by the correlation analysis (Table 3) which revealed that the holocellulose content decreased significantly with age (r = -0.80**) and positive increased with tree portion (r = 0.50*). According to Bendtsen (1978) juvenile wood is characterised by faster growth rate, lower density and higher cellulose content. Shupe et al., (1995; 1996) found that lower wood strand densities yielded higher holocellulose and alpha cellulose content in wood.

Conclusion

The chemical nature of *Leucaena leucocephala* wood was analysed for cold and hot water solubles, alkali solubles, alcohol toluene solubles, ash content, lignin content and holocellulose content. The approximate chemical analysis indicated that, the cold water and hot water solubles were insignificantly correlated with tree age but found to correlate positively with tree portion. Age was found not to affect alkali solubility but tree portion showed a significant effect. The alcohol toluene solubility showed a significant correlation with increasing age and correlated negatively with tree portion; decreasing amount downwards. The ash content decreases from bottom to top portion of the tree. However, there was no effect of age on the percentage of ash content. The lignin content showed a positive correlation with increasing age but correlated insignificantly with tree portion. The holocellulose content decreased with age and increased with tree portion. Generally, age and tree portion were found to affect the chemical properties significantly. The eight year-old wood was found to be a suitable raw material to manufacture wood composite.

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