

Changes in Strength and Chemical Contents of Oil Heat Treated 15-year-old Cultivated *Acacia* Hybrid

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Abstract

Studies were conducted on the changes in strength and chemical contents of cultivated 15 year-old *Acacia* hybrid treated through oil heat treatment process. The timbers harvested and cut at the portions bottom, middle and top, were oil heat treated using palm oil for durations of 30, 60 and 90 min. at temperatures of 180, 200 and 220 °C. The untreated *A.* hybrid was used as control. The results of the studies showed that the oil heat treatment process causes some changes in the strength and chemical composition of the timbers. Strength reduction during the bending tests in both the MOR and MOE were noted throughout the treatment process. The chemical constituents of the treated timber also underwent changes in their contents. The holocellulose and cellulose degraded with the increasing of treatment temperature and duration in the oil heat treatment, while lignin showed

the increment in content through this treatment. The changes in values of both the strength and chemical contents were influenced by temperature and duration of the treatment.

Keywords: Oil heat treatment, Cultivated *Acacia* hybrid, Strength reduction, Chemical contents changes

1. Introduction

Forest plantation has become an important source in providing sustainable supply of raw materials to the Malaysian wood-based industry. This is due to the declining supply of timbers from the natural forests. This is further aggravated by the consumers demand in Europe and North America of getting supplies of timber with green products certification and their sensitivity about logging activities of naturally grown species from tropical rainforest. Plantation forestry provide attractive investments for the government and private sectors because of their short rotation compared to that of the natural stands.

Forest plantation project started in 1982 with *Acacia* species aimed at sustaining the supply of timber to the industries which was expected to face a shortfall from the natural forests (Shakri, 1995). *Acacia* species was chosen due to its rapid growth and easy adaptation to the Malaysian soil conditions (Pinyopusarerk et al., 1993). *Acacia* hybrid is classified under the slightly durable category, the wood requires preservative to prolong its use especially when used in exposed condition and in ground contact uses. However, wood preservative contains heavy metals which pollute the environment. Furthermore, most of the developed countries have banned the imported and usage of timber impregnated with copper chrome arsenic (CCA). The use of oil heat treatment which is considered environment friendly has become an alternative to enhance the durability of timber (Rafidah et al., 2009; Razak et al., 2005). This treatment uses hot oil as the medium of heat transfer and altered the main wood chemicals composition in treated wood.

The objectives of this study were to investigate the changes that occurred in the strength properties and main chemical contents as the results of the oil heat treatment process on the cultivated *A.* hybrid. The strength properties and the chemical contents are important parameters that influenced durability and stability of the wood. The results of this study will be of advantage and beneficial to the Malaysian wood-based industry.

2. Materials and Methods

2.1 Materials

Cultivated *A.* hybrid of age 15-year-old were harvested from the Sabah Forest Development Authority plantation in Kinarut, Sabah, Malaysia. The trees were randomly selected based on their age, physical characteristics, dbh diameter between 250-300 mm and having long straight boles. The trees were felled, cut and segregated into three height portions, namely, the bottom, middle and top, corresponding to 50 %, 30 % and 20 % of the merchantable height respectively. Blocks of 600 mm long were cut from the middle of each portion. The wood blocks were then transported to Universiti Malaysia Sabah for further processing and subsequent testing.

2.2 Sample Preparation

All wood blocks were initially air dried at room temperature for about a month to reduce the moisture to equivalent moisture content (15 %) and to remove stresses in them. After drying, the wood blocks were planed into sizes of 300 mm × 100 mm × 25 mm (length × width × thickness) for the oil heat treatment process. These samples were mixture of sapwood and heartwood.

2.3 Hot Oil Treatment Process

A. hybrid samples were oil heat treated in a stainless steel tank attached to the heat treatment machine. The temperatures of the oil and the wood samples were control through a control panel located out-side the tank. An electric generator was used to generate heat. Prior to treatment, the wood samples were stabilized to 12 % moisture content in a conditional chamber set at 65 % relative humidity and temperature 25 °C. Eighty (80) woods were prepared prior to the treatment. Weight of the woods was recorded before and after treatment to determine weight loss caused by the treatment. The tank was filled with the oil until it reached three quarters full. Treatment temperature was set at 180, 200 and 220 °C for 30, 60 and 90 min. The samples were initially placed into hot oil at 80 °C and real treatment time started when the oil bath reached target temperature. The temperatures were recorded every 10 min respectively. After each treatment period, the wood samples were removed from the tank and wiped with a clean cloth to avoid excessive oil seeping into wood tissues. The samples were then cooled and later conditioned in a conditioning chamber at 25 ± 2 °C and 65 ± 5 % relative humidity before reweighing. The wood samples were later cut into various sizes for respective testing for strength and chemical analysis tests. The procedure outlines by Razak et al. (2011), Izyan et al. (2010) and Rafidah et al. (2009) were followed for the wood treatment and testing.

2.4 Strength Properties (Modulus of Rupture and Modulus of Elasticity in Static Bending)

A Universal Testing Machine located in Forest Research Center, Sandakan, Sabah, was used for bending testing. The evaluation for the static bending of the wood was conducted with ASTM D4761 (1999) standard. The dimensions of wood samples for static bending test were 20 x 20 x 300 mm. The specimen was supported on a span of 280 mm and the force applied at mid-span using a loading head. The rate of loading was 6.6 mm/min. Wood were loaded on the radial surface. The tests were stopped once the wood started to break. The proportional limit and ultimate load and deflection were recorded, and the MOE and MOR were calculated automatically by the computer connected to the machine.

2.5 Chemical Properties

The chemical changes studied were holocellulose, cellulose, hemicellulose and lignin. All chemical analysis tests were conducted separately for heartwood and sapwood. The total amounts of chemical constituents were calculated based on the sapwood or heartwood ratios. Evaluation of chemical analysis was conducted using TAPPI T203 cm-99 (TAPPI 1999) and TAPPI T222 cm-02 (TAPPI 2002) standards.

3. Result and Discussion

3.1 Strength Properties (MOR and MOE in Bending Tests)

The result of strength properties of treated *A.* hybrid wood is presented in Table 1. It was clearly observed the values of both wood types (sapwood and heartwood) for modulus of rupture (MOR) and modulus of elasticity (MOE) decreased through oil thermally modified. The untreated wood still obtained the highest strength values compared to treated wood. The strength properties of wood usually decrease with increasing temperature and increase with decreasing temperature (Smith et al., 2003).

For the thermally modified wood, the highest values of MOR and MOE of every portion started to decreased when the treatment temperature reaching 180 °C. This strength values respectively decreased when treated at 200 °C and 220 °C. From the results obtained the values of MOR and MOE of untreated and treated wood showed a decrement with increasing sampling height. The variations in MOR and MOE along the tree height can be explained by the decrease in maturity of wood and fibre length from the base to the top of the tree (Rulliarthy & America, 1995). Wood treated at 180 to 200 °C in the presence of moisture resulted in a large reduction in the resistance to MOR, MOE and compression strength (Giebler, 1983). While other researcher reported that at temperature over 200 °C, MOE and MOR of wood can be reduced by up to 50 % (Bekhta & Niemz, 2003; Sailer et al., 2000; Kamden et al., 1999). The increased treatment duration which is 30 to 90 minutes also prolong the decreasing effect on strength. The higher the temperature the longer the treatment duration the lower is the strength value.

The strength properties of the oil heat treated wood are reduced by thermal modification but the dimensional stability and biological durability of wood is increased without having to add outside chemicals to the wood (Yildiz et al., 2006). The diminutions in the strength properties were related to the rate of thermal degradation and losses of substances after heat treatment (Rusche, 1973). The decrease in strength is mainly due to the depolymerization reactions of wood polymers (Kotilainen, 2000), where changes in or loss of hemicelluloses play key roles in the strength properties of wood heated at high temperatures (Hillis, 1984). Kocaefe et al. (2007) also noted that the change in mechanical properties of wood especially in strength at high temperature is mainly due to the hemicelluloses degradation. It has a lower molecule weight compared to the other wood polymers, therefore it degrades faster. Thus, the cellulose crystallization and lignin modification take place (Wikberg & Maunu, 2004).

The application of high temperatures has negative effect on degradation consequently on the strength properties (Kocaefe et al., 2007). The heat treatment affected lignin and hemicelluloses and resulted in water soluble polymer formation (Stamm, 1946). The moisture content, treatment temperature, presence and absence of oxygen and treatment time are the factors, which influence most the hydrolysis reactions, consequently the mechanical properties. However, the effects on strength decreases are different for each species, anatomical features and treatment methods (Mburu et al., 2008; Kocaefe et al., 2007).

Studies on the effect of high temperature on spruce wood found that MOE of spruce wood decrease when the treatment temperature rose over 100 °C (Bekhta & Niemz, 2003). At low temperatures up to approximately 100 °C, only minor changes occur in the mechanical properties of wood, however, strength properties of wood start to weaken and become brittle when treatment temperatures reach over 200 °C (Sundqvist, 2004). The compression failure usually occurs in wood with low density (Nurdahlia, 2008; Bodig & Jayne, 1982). The reduction of density in the treated material can caused reduction in some of the strength properties (Rafidah,

2008; Janssen, 1981). Strength loss increases with increased treatment temperature and time. Hence the use of heat-treated wood in load bearing constructions is restricted due to bending and tension strength decrease by 10 to 30 % (Korkut et al., 2007; Jamsa & Viitaniemi, 2001).

3.2 Chemical Properties

The chemical contents of the treated *Acacia* wood before and after undergoing the hot oil treatment process is shown in Table 2. Both the control sapwood and heartwood had the highest chemical contents of holocellulose and cellulose when compared with the oil heat treated wood at various treatment temperature and time. The results clearly showed that the changes of chemical contents occurred when the wood were treated at higher temperature and duration. At temperature above 180 °C, the treated wood experiences losses of polysaccharide material (Hill, 2006).

3.2.1 Holocellulose

Slight reduction on the holocellulose contents in the treated sapwood and heartwood occurred with the increasing of treatment temperature and time in comparison to both untreated sapwood and heartwood. The holocellulose contents ranged between 63.1 to 70.8 % for sapwood and 64.0 to 71.7 % for heartwood depending on the temperature and duration applied. Studies by Inari et al. (2007) and Boonstra and Tjeerdsma (2005) also reported similar observations. The holocellulose content of beech and pine decreases between 50 % and 60 % after heat treatment (Inari et al., 2007). While Boonstra and Tjeerdsma (2005) found that holocellulose content of heat treated Scots pine decreased between 79.7 % and 63.3 %. The decreases in the holocellulose content occurred when the wood were heated at a temperature above 100 °C (Hill, 2006). The content decrease is associated with the loss of cellulose and hemicellulose during the process.

3.2.2 Cellulose

Cellulose content determined for both wood types after heat treatment were between 98 % and 80 % for sapwood, while the values for heartwood were between 97 % and 78 %. The result showed that minor degradation of celluloses can be seen when wood treated at 180 °C in 30 min and it continually to decrease with the increase of temperature and time of treatment. Cellulose is more resistant to hydrolysis than hemicelluloses, pectins and starch, and it has generally a more regular and crystalline structure with considerably higher molecule weight (Sundqvist, 2004). From the analysis of molecule size of cellulose in heat treatment by using intrinsic viscosity measurement, it showed that heat treatment results in a considerable reduction in molecule size of cellulose. As stated by Yilidiz et al. (2006), crystalline structure of cellulose is not changed or even can improve up to a certain temperature, which may be as high as 200 °C depending on the conditions involved as in an agreement by Boonstra and Tjeerdsma (2005) which stated that different process conditions and treatment time applied during heat treatment can influence degradation rate of cellulose content. Fengel and Wegener (1989) found that the degree of polymerization of cellulose is already decreased in thermally treated spruce at temperatures above 120 °C due to cleavage of the glucosidic bonding that is accelerated by the presence of acids that are catalyzing the reaction. With extended heating, chain scission of the cellulose occurs, producing alkaline soluble oligosaccharides, with a concomitant decrease in the cellulose DP and degree of crystallinity (Hill, 2006). CO₂ and CO are produced when cellulose is heated at 170 °C (Shafizadeh, 1984) and heating for a longer periods results in an increase in carbonyl groups at the expense of carboxylic moieties (Fengel & Wegener, 1989).

3.2.3 Hemicellulose

Hemicelluloses content for both heat treated sapwood and heartwood showed fluctuation in values, but showing no specific trend. The hemicelluloses for sapwood experiences changes in content from 24.4 % in control to 26.1 % in heat treated samples. While in the heartwood the content changes from 24.5 % to 26.2 %. Both wood experiences an increases in the hemicelluloses contents. Mburu et al. (2008) found that the increment in lignin content of *Grevillea robusta* wood with treatment time confirming higher susceptibility of hemicelluloses to thermal treatment. Rowell et al. (2005), stated that hemicelluloses change is predominate at temperatures below 200 °C. The lower thermal stability of hemicellulose compared to cellulose is usually explained by the lack of crystallinity (Kotilainen, 2000). When wood is heated, the most thermally labile of the hemicelluloses begin to degrade, resulting in the production of methanol, acetic acid and various volatile heterocyclic compounds (Hill, 2006). The acetic acid is generated when the acetylated hydroxyl groups of the hemicellulose chains are split off (Johansson, 2008). It is suggested that volatile organic acids formed due to heating of wood are trapped in the process and promote the degradation rate (Viitaniemi, 2001).

3.2.4 Lignin

The lignin content of sapwood and heartwood in the *A.* hybrid increased with an increase in treatment temperature and duration. An increment in lignin content of the sapwood from 20.8 % in the untreated wood to 24.7 % in the heat treated wood, while the lignin content of the heartwood from 22.4 % in the untreated heartwood to 25.0 % in the heat treated wood. Similar observations were also made by Brito et al. (2008), Mburu et al. (2008), Inari et al. (2007), Yildiz et al. (2006) and Sarni et al. (1990). The changed in lignin composition showed that there was a changed in the lignin structure of wood. The loss of polysaccharides material during the heat treatment leads to an increase in the lignin content of the wood (Sandermann & Augustin, 1964).

3.2.5 Analysis of Variance and Correlation Coefficient between the Strength and Chemical Properties

The analysis of variance for the strength properties are shown in Tables 3. The analysis was conducted to determine whether there was significance difference between physical properties with treatment temperatures, duration, wood types and sampling height. There were significant difference between moisture content with treatment temperatures, duration and wood types. However there was no significant difference between moisture content and sampling height (bottoms towards the top) of the tree. For basic density, there were significant difference was observed with treatment temperatures, duration, wood types and sampling height.

The analysis of variance indicated that for MOR there are significant differences in treatment temperature, duration of treatment and sampling height. However, there is no significant difference in the wood type. For MOE, only two significant differences were observed, which are treatment temperature and wood types. There is no significant difference in duration of treatment and sampling height.

The ANOVA (see Table 4) showed that there was a significant difference between the temperatures and duration of the treatment relating to content of lignin. Almost all of the chemical components were significantly affected by temperature, treatment duration and wood types. There were a significant difference between the treatment temperature, duration and wood type of the treatment relating to the content of holocellulose, cellulose and lignin. Therefore, it can be concluded that the effects of temperature, treatment duration and wood types were a caused of the change in chemical composition of those chemical component. For the hemicellulose, the ANOVA showed that there was no significant difference with wood type of the treatment relating to the content of hemicellulose. The wood types did not affect the changed in hemicellulose content in oil thermally modified process. The effects of temperature and treatment duration were a cause of decrement of hemicellulose composition. Changes in the chemical contents of the wood occurred with the increases in temperature. The chemical composition in *A.* hybrid wood is highly affected by treatment temperature, duration and wood types in oil thermally modified process.

The correlation between the strength and chemical properties are presented in Table 5. There was a correlation between the strength properties (MOR and MOE) and chemical composition of *Acacia* wood. There were a correlation between MOR and MOE and chemical composition of treated wood. Positive correlation was obtained between MOR and MOE, holocellulose and cellulose, while hemicellulose and lignin were negatively correlated with MOR. For MOE there was also a correlation between chemical contents of treated wood. Positive correlation was obtained between MOE, holocellulose and celluloses, while the hemicellulose and lignin were negatively correlated with MOE.

4. Conclusions

- 1) The strength properties of the oil heat treated *A.* hybrid wood were reduced during the treatment process. Both the MOR and MOE in the bending tests decreases throughout the treatment process and were influenced by the increases in the treatment temperature and duration.
- 2) The main chemical composition of the treated *A.* hybrid wood experienced changes in their contents. Holocellulose, cellulose and hemicellulose contents degraded with the increasing of treatment temperature and time of heating exposure, while lignin showed the increment in content through this treatment.
- 3) The increase in the holocellulose and cellulose contents causes an increase in the strength (MOR and MOE) of the *A.* hybrid wood. On the other hand, the reduction of the hemicellulose and lignin contents causes the drop in strength of the hot oil treated *A.* hybrid.

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Table 1. Average values of chemical changes of 15-year-old oil heat-treated *Acacia* hybrid wood

Wood type	Temp. (°C)	Treatment duration (min)	Chemical Composition (%)			
			Holocellulose	Cellulose	Hemicellulose	Lignin
Sapwood	Control	Control	71.5	47.1	24.4	20.8
		30	70.8 (-1.0)	46.2 (-1.9)	24.6 (0.8)	20.7 (-0.5)
	180	60	69.7 (-2.5)	45.1 (-4.2)	24.6 (0.8)	22.0 (5.8)
		90	66.6 (-6.9)	43.6 (-7.4)	23.0 (-5.7)	22.1 (6.3)
	200	30	68.6 (-4.1)	42.5 (-9.8)	26.1 (7.0)	23.9 (14.9)
		60	65.3 (-8.7)	39.2 (-16.8)	26.0 (6.6)	23.8 (14.4)
		90	64.5 (-9.8)	38.5 (-18.3)	26.0 (6.6)	24.7 (18.8)
	220	30	66.4 (-7.1)	41.6 (-11.7)	24.8 (1.6)	23.7 (13.9)
		60	64.9 (-9.2)	38.9 (-17.4)	26.0 (6.6)	24.3 (16.8)
	Heartwood	Control	Control	73.4	48.9	24.5
30			71.7 (-2.3)	47.8 (-2.3)	23.9 (-2.5)	21.7 (-3.1)
180		60	70.6 (-3.8)	46.3 (-5.3)	24.3 (-0.8)	22.9 (2.2)
		90	67.9 (7.5)	44.7 (-8.6)	23.2 (-5.3)	23.0 (2.7)
200		30	68.8 (-6.3)	42.6 (-12.9)	25.9 (5.7)	24.5 (9.4)
		60	68.3 (-6.9)	42.1 (-14.0)	26.2 (6.9)	24.9 (11.2)
		90	66.5 (-9.4)	40.9 (-16.4)	25.6 (4.5)	25.0 (11.6)
220		30	67.1 (-8.6)	42.0 (-14.1)	25.7 (4.9)	24.7 (10.3)
		60	65.1 (-11.3)	39.7 (-18.8)	25.4 (3.7)	24.8 (10.7)
			90	64.0 (-12.8)	38.1 (-22.1)	25.9 (5.7)

() = % change from control

Note: Holocellulose is the total polysaccharide fraction of wood that is composed of cellulose and all of the hemicelluloses and what is obtained when the extractives and lignin are removed from the natural material.

Table 2. Average values of bending strength (MOR and MOE) of sapwood and heartwood *Acacia* hybrid through oil-heat treatment process

Wood Type	Temp. (°C)	Treatment duration (min)	MOR (N/mm ²)			MOE (N/mm ²)			
			B	M	T	B	M	T	
Sapwood	Control	Control	69.78	67.22	65.08	3864.54	3803.57	3776.72	
		30	64.05 (8.21)	61.98 (7.80)	63.37 (2.63)	3535.7 (8.51)	3455.43 (9.15)	3492.52 (7.53)	
		60	63.43 (9.10)	59.66 (11.25)	52.23 (19.74)	3475.95 (10.06)	3416.45 (10.18)	3265.79 (13.53)	
	180	90	62.31 (10.71)	55.82 (16.96)	47.99 (26.26)	3470.29 (10.20)	3412.22 (10.29)	3207.16 (15.08)	
		30	55.06 (11.64)	54.85 (18.40)	45.31 (30.28)	3407.97 (11.81)	3328.01 (12.50)	3094.19 (18.07)	
		60	60.11 (13.86)	54.70 (18.63)	44.86 (31.07)	3333.09 (13.75)	3228.98 (15.11)	3035.35 (19.63)	
	200	90	55.38 (20.64)	50.41 (25.01)	42.85 (34.16)	3244.75 (16.04)	3172.19 (16.60)	2972.25 (21.30)	
		30	53.9 (22.76)	49.72 (26.03)	40.57 (37.66)	3216.75 (16.76)	3101.06 (18.47)	2938.18 (22.20)	
		60	51.42 (26.31)	46.89 (30.14)	38.15 (41.38)	3133.38 (18.92)	3046.50 (19.90)	2716.33 (28.08)	
	220	90	41.21 (40.94)	40.33 (40.00)	37.03 (43.10)	3001.51 (22.33)	2787.39 (26.72)	2599.31 (31.18)	
		Control	Control	68.51	70.76	90.43	3975.49	4004.07	4067.94
			30	67.42 (1.59)	65.24 (7.80)	66.70 (26.24)	3676.91 (7.51)	3637.29 (9.16)	3721.56 (8.51)
60	66.77 (2.54)		63.47 (10.30)	54.98 (39.20)	3658.9 (7.96)	3634.52 (9.23)	3437.94 (15.49)		
180	90	65.59 (4.26)	58.81 (16.89)	51.06 (43.54)	3587.34 (9.76)	3599.88 (10.09)	3376.74 (16.08)		
	30	63.27 (7.65)	58.75 (16.97)	47.74 (47.21)	3577.19 (10.02)	3547.83 (11.39)	3291.87 (19.08)		
	60	58.8 (14.17)	57.74 (18.40)	47.7 (47.25)	3545.84 (10.81)	3503.17 (12.51)	3229.33 (20.62)		
200	90	58.57 (14.51)	53.63 (24.21)	45.67 (49.50)	3488.98 (12.24)	3435.31 (14.20)	3162.30 (22.26)		
	30	57.96 (15.40)	52.89 (25.25)	43.62 (51.76)	3422.08 (13.92)	3299.28 (17.60)	3159.49 (22.33)		
	60	55.30 (19.28)	50.42 (28.75)	41.02 (54.60)	3369.22 (15.25)	3275.80 (18.19)	2920.83 (28.20)		
220	90	44.31 (35.32)	44.7 (36.83)	39.81 (55.98)	2997.64 (24.60)	3227.43 (19.40)	2794.95 (31.29)		

Note: { } = % change from control samples, B = Bottom, M = Middle, T = Top.

Table 3. ANOVA on the strength properties of oil heat treated *Acacia* hybrid

Source of Variance	Dependent Variable	Sum of Squares	Df	Mean Square	F-Ratio
Temperature	MOR	12076.80	3	4025.59	15.99**
	MOE	1.81	3	6.02	12.66**
Duration	MOR	3425.40	2	1712.70	6.80**
	MOE	2.72	2	1.36	2.86 ^{ns}
Wood Types (Sap and Heartwood)	MOR	565.80	1	565.80	2.25 ^{ns}
	MOE	2.16	1	2.16	4.55*
Sampling Height	MOR	3098.58	2	1549.29	6.15**
	MOE	2.06	2	1.03	2.17 ^{ns}

Table 4. ANOVA on chemical compositions of oil heat treated 15 year-old *Acacia* hybrid

Source of Variance	Dependent Variable	Sum of Squares	Df	Mean Square	F-Ratio
Temperature	Holocellulose	1618.96	3	539.65	564.15**
	Hemicellulose	139.12	3	46.37	85.82**
	Cellulose	2460.23	3	820.08	1018.75**
	Lignin	368.90	3	122.97	461.45**
Duration	Holocellulose	250.82	2	125.41	131.10**
	Hemicellulose	7.43	2	3.72	6.88**
	Cellulose	210.26	2	105.13	130.60**
	Lignin	12.69	2	6.35	23.81**
Wood types (Sap and Heartwood)	Holocellulose	96.80	1	96.80	101.20**
	Hemicellulose	0.01	1	0.01	0.01 ^{ns}
	Cellulose	95.20	1	95.20	118.27**
	Lignin	52.22	1	52.22	195.94**

Table 5. Correlations analysis between chemical and strength properties of oil heat treated 15 year-old cultivated *Acacia* hybrid

Wood Properties	MOR	MOE	Holocellulose	Hemicellulose	Cellulose	Lignin
MOR	1	0.60**	0.42**	-0.19*	0.42**	-0.36**
MOE		1	0.35**	-0.24**	0.37**	-0.31**
Holocellulose			1	-0.34**	0.96**	-0.69**
Hemicellulose				1	-0.59**	0.61**
Cellulose					1	-0.77**
Lignin						1

Note: Total number of wood = 216, ** = significant at $p \leq 0.01$, * = significant at $p \leq 0.05$, ns = not significant, MC = Moisture Content, BD = Basic Density, MOR = Modulus of Rupture, MOE = Modulus of Elasticity.