The Effect of Traditional Fumigation on Physical, Mechanical and Anatomical Properties of Wooden Handicraft in West Kalimantan

Farah Diba and Lolyta Sisillia

Abstract

West Kalimantan wooden craft is internationally well known and its export is increasing. Currently, high durability and attractive color of wood material such as belian (*Eusideroxylon zwageri* Teysm & Binnend) is rarely available, then alternatively mangium (*Acacia mangium* Willd.) and laban wood (*Vitex pubescens* Vahl.) are used for handicraft. Fumigation is one possible way to improve wood service life and color shades. This paper determines the impact of traditional fumigation on wood raw material on physical, mechanical and anatomical properties. The timber fumigation technique was conducted for one week, with curing time from early morning until late afternoon. After treatment, the physical, mechanical and anatomical properties of wood were evaluated. The different of color before and after treatment was measured by image processing scanner Canon P 145. Physical and mechanical properties refer to the British standard method. Result shows that fumigation improves the quality of wood, especially on color of wood. The wood became dark and more shining. It's good for the handicraft materials. The quality of wood on moisture content value, both on mangium and laban wood was increased with average 30-50%. The average value of wood density of mangium wood after treatment with fumigation was 0.52, meanwhile laban wood was 0.55. The average value of radial shrinkage of mangium wood after fumigation treatment was 3.96% and tangential shrinkage was 6.34%. The average value of radial shrinkage of laban wood after fumigation was 6.43% and tangential shrinkage was 6.08%. The average value of hardness of mangium wood after fumigation treatment was 470.13 kg/cm^2 and laban wood was 625.46 kg/cm^2. The Fumigated wood color was darker and more attractive for decorative and craft products than non-fumigated wood. In general, this method could be used to preserve wood and to increase the physical performance of wood as raw material for handicraft.

Keywords: *Acacia mangium*, fumigation, *Vitex pubescens,* West Kalimantan, wood craft.

Introduction

Wood craft industry in West Kalimantan Province currently faces low raw material wood supply which has an attractive color and pattern as well as high in wood durability. Raw material is one of the elements that determine the quality of product so that the high quality wooden handicraft products indispensable quality raw material which is strong, durable, attractive in color and pattern (Khan *et al*. 2018). In addition, the price of high durability grade wood is now very expensive, then it is not economically in terms of raw material usage.

West Kalimantan craftsmen knows belian wood (*Eusideroxylon zwageri* Teysm & Binnend) as high-grade, durable, strong and decorative wood. However, the supply of belian wood is now diminishing. Alternatively, the craftsmen's using alternative species such as mangium (*Acacia mangium* Willd.) and laban wood (*Vitex pubescens* Vahl.) which are easily obtained, but lower durability grade than Belian wood (Abdurrohim *et al*. 2004).

Laban and mangium wood from land clearing forest are processed into wood carving handicraft items such as lawn chairs, statues, shields, and wall hangings. Mangium wood is classified as strong class II and class II-III durability, and laban wood is classified as strong class II and class I-II durable (Oey 1964; PIKA 1981). The average of mangium wood density of natural stand is about 0.6.. Arsad (2011) stated mangium heartwood was slightly brown colored, hard, strong, and durable in well-ventilated areas, though the wood is not resistant in contact with the ground Meanwhile laban wood also susceptible on fungi and termites attack (Oramahi *et al*. 2011). Fumigation is an alternative method for improving wood quality. Fumigation is one way to improve wood service life prior to further process (Duljapar 1996). Fogging treatment also aims to increase the value of the decorative wood. Suranto (2002) stated traditionally fumigation techniques by craftsmen is an alternative for wood preservation without chemical and attempt to preserve the natural wood, with curing time of treatment approximately a week.

Currently, timber fumigation is not widely conducted by timber industries to preserve wood. It is caused by the fact that there is limited study on the effects of fumigation into wood properties: physical, mechanical and anatomical. Though the process of curing could increase the service life of the wood product (Bower *et al*. 2009) and increase the durability of wood product against organisms and microbial destroyer (Abolagba and Igbinevbo 2010). The quality improvement of wooden handicraft products with traditional fumigation techniques should be supported by durability testing of wood against wood destroying organisms, especially termites.

This paper determines the impact of traditional fumigation on mangium wood and laban wood as materials for wood handicraft on physical, mechanical and anatomical properties of the woods.

Materials and Methods

Sample Preparation

Two wood species: mangium (*Accacia mangium* Willd.) and laban (*Vitex pubescens* Vahl.) were collected from wood craftsmen who lives in Budi Utomo street, Northern District of Pontianak City, West Kalimantann Indonesia. Wood raw material measuring length 100 cm, width 30 cm and .thickness 10 cm. Wood samples were grouped into two: fumigation and control (non-fumigation) with three replicates in a state of air dry. The average value of air dry density of mangium wood is 0.50 and laban wood is 0.51. The sample size for testing physical and mechanical properties refer to British Standard No. 373 (1957), consist of sample for moisture content and density with size 2 cm x 2 cm x 2 cm, dimension stability of 2 cm x 2 cm x 4 cm, mechanical properties (hardness) (of 2 cm x 2 cm x 6 cm and anatomical properties of 2 cm x 2 cm x 2 cm.

Sample Testing

Anatomical properties were evaluated based on macroscopic and microscopic structures. Sample for anatomical test was three replication. The macroscopic properties of wood anatomy were observed using loupe with 12-15 times magnification and wood color measurer. Touch impression was determined by touching the surface of wood which was conducted by three people (Arinana and Diba 2009).

Determination the Color of Wood

Wood color was measured using image processing scanner of Canon P 145 which connected to the MacBook Pro as a data storage and processed with Adobe Photoshop CS4 software that generates the value of L*, a* and b* which refers to Kjallstrand and Petersson (2001). Analysis of wood color based on color difference (ΔE), and data then compared to Table 1 to determine the effect of color differences. Color difference (ΔE) is calculated based on the CIELAB system (Christie 2007) with the formula:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Where :

ΔE = Color differences
ΔL^* = Lightness differences (L* before and after staining)
Δa^* = Red to green differences (a* before and after staining)
Δb^* = Yellow to blue differences (b* before and after staining)

Table 1. The effect of color differences

Different Color	Effect
< 0.2	Not visible
0.2 – 1.0	Very small
1.0 – 3.0	Small
3.0 – 6.0	Moderate
> 6.0	Large

Source: (Christie 2007)

Results and Discussion

Physical Properties of Wood

Moisture content. The average value of moisture content of untreated mangium wood was 15.29% and laban wood was 19.1%. Meanwhile the average value of moisture content of fumigated mangium wood was 9.85%, and laban wood was 5.88%. Moisture content of fumigated laban wood is less than mangium wood. Analysis of variance shows that fumigation treatment is significantly affect the value of mangium and laban wood moisture content, which means the moisture content of treated wood and untreated is significantly different. Analysis of variance of the interaction between fumigation treatment and wood species on moisture content resulted in very significant effect, which meansthe fumigation treatment has a different effect on moisture content value to mangium and laban wood. Fumigation treatment made the moisture content of mangium and laban wood decrease and it is good condition for wood as raw material of handicraft. The less moisture content made wood easy to crafting and more durable to wood destroying organims (Suranto 2002). The wood species

The fumigation treatment provides moisture content differences of treated and untreated wood. It is shown that moisture content of untreated mangium wood was about 15.29% and the treated of mangium wood was only 9.85%. Similarly, moisture content of untreated laban wood was about 19.1% and treated laban wood was about 5.88%. The moisture content values of treated and untreated mangium and laban wood are presented in Fig. 1.

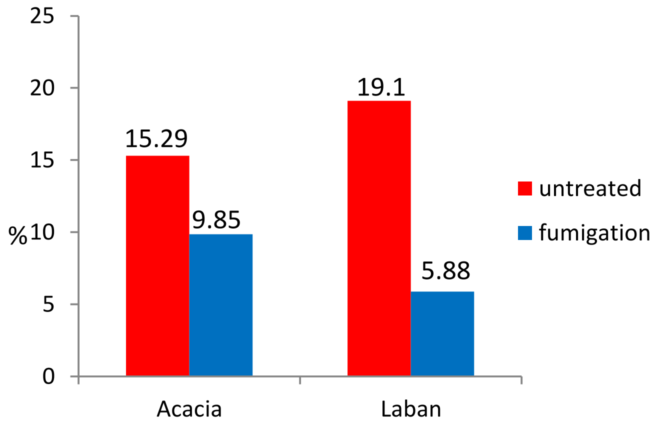


Figure 1. The moisture content of mangium and laban wood

Fig. 1 shows the average value of mangium and laban moisture content and Laban. Moisture content of fumigated wood are lower than untreated wood. Lower moisture content is mainly caused by lost of free water in cell cavities and less bound water in the cell wall. Fumigation process achieves its target in minimizing the moisture content of mangium and laban wood. Fumigation treatment greatly affects the value of the moisture content of mangium and laban wood. Rofii and Prayitno (2012) stated that the same phenomena is shown in jackfruit wood where moisture content was decreasing after steaming.

Pasaribu and Sisillia (2012) also reported that the change rate of teak moisture content increased inline with heat treatment. Moisture content reduction of fumigated wood was due to the water evaporation from the wood cells. Water evaporation influences the air temperature and humidity during curing process (Martinez *et al*. 2007). Amin and Dwianto (2006) also mentioned that the heat would urge the moisture out from the wood. High temperature damages the water molecules in the wood cells during high temperature treatment. In this condition, the heat causes damage to the H bonds between molecules within the matrix of hemicellulose-lignin.

Todd (2003) stated that moisture content of wood that had been fumigated reflects the percentage weight of water relative to the total weight of wood. Fumigation process generates heat that dries the wood and evaporate water from the wood cells. The amount of moisture in air dried mangium and laban is in the range of moisture content of air dry wood for Indonesian climate which is about 12-20% (Praptoyo 2010). Laban wood moisture content obtained from craftsmen is still above the SNI standard (SNI.01-0608-89) which states that the requirement of raw materials for furniture and wood crafts are 15% maximum (dry air). Hence, fumigated wood meets the standard in term of moisture content. Fumigation made the moisture content of wood decrease. When the process of wood fumigation, heat and smoke during the process made the wood dry and decrease the water inside the wood. Low moisture content levels will increase the resistance of wood against wood destroying organisms such as fungi and termites (Nandika et al 2015)

Wood density. The average of wood density of untreated mangium wood and treated wood was 0.62 and 0.52 respectively. Wood density of untreated and treated laban wood was 0.58 and 0.55 respectively. The treated mangium wood density were less than treated laban wood. Based on the analysis of variance, timber fumigation did not significantly affect the density of mangium and laban wood. The density value of untreated mangium wood and laban wood were relatively higher than the density of fumigation mangium and laban wood. The traditional fumigation methods was conducted in open area and the smoke during the process has widespread around the wood. The temperature inside the place of fumigation was unstable and made the effect to wood. Traditional fumigation treatment makes the density of wood low. According to Tsoumis (1991) wood density is influences by the cell size, thickness of the cell wall and the relationship between the number of cells varying to the size and thickness of the wall.

Palm *et al*. (2011) stated that fumigation is the penetration of volatile compounds (volatile matter) produced from burning wood and create products with specific odour derived from wood combustion. Fumigation generally used in food preservation processes such as fish, beef or other food processed products. The value of density mangium wood from fumigation treatment results are relatively similar with those reported by Hadjib *et al*. (2007). Density value of mangium wood before treatment was 0.62 and after fumigation was decreased into 0.52. Laban wood density before treatment was 0.58 and after fumigation was decreased into 0.55. Results show in general fumigation treatment decreased wood density. It is analogous to the relationship between the moisture content and density of the wood reported by Haygreen and Bowyer (1996), where wood density tends to decrease with increasing of moisture content.

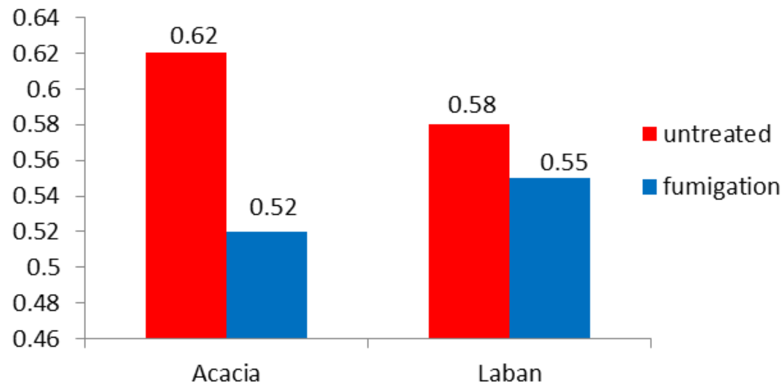


Figure 2. Density of mangium and laban wood.

The average value of the wood density of treated and untreated mangium and laban wood is presented in Fig. 2. Fig. 2 shows based on its density, mangium and laban wood are grouped into medium density wood. Measurement results of the mangium and laban wood density are classified as strong class II-III based on Regulation Timber Construction Indonesia (PKKI). Based on physical properties of moisture content and density, the treated mangium and laban wood could be used for craft materials and furniture.

Radial and tangential shrinkage. Wood shrinkage observed in this study was radial and tangential shrinkage. The average value of radial shrinkage of untreated and treated mangium wood was 3.58% and 3.96%, and 5.96% and 6.34% in tangential shrinkage. The average value of radial shrinkage of untreated and treated laban wood was 4.98 and 6.43% respectively, while in the tangential direction was 4.74% and 6.08% respectively (Fig. 3). Based on the analysis of variance for the average value of radial direction shrinkage of wood, timber fumigation did not significantly affect shrinkage in radial direction, whereas the wood species and their interaction was not significantly different. High significant difference test results is recorded in radial shrinkage of fumigated wood. Results of analysis of variance shows tangential shrinkage, fumigation treatments and wood species had no significant effect.

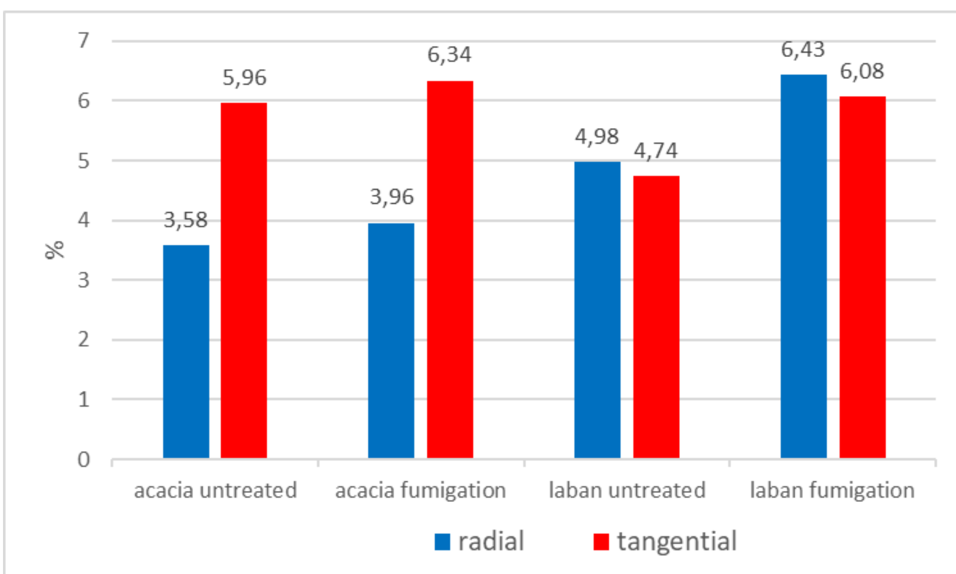


Figure 3. Radial and tangential shrinkage of mangium wood and laban wood.

The average value of mangium wood shrinkage in the radial direction is smaller than laban wood, both on treated and untreated wood. Vice versa the average value, of mangium wood shrinkage in tangential direction was higher than laban wood. Basri *et al*. (2015) stated that mangium wood after grirdling treatment has a radial shrinkage from green to oven-dry condition (%) was 2.78% and tangential shrinkage from green to oven-dry condition was 7.87%. Compare to our research the radial shrinkage of treated mangium wood was 3.96% and tangential shrinkage was 6.34% Fig. 3 shows that in general tangential shrinkage value is higher than those of radial direction. According to Dumanauw (1990), more wood shrink in the direction of a growing circle (tangential), and reduced in the transverse direction circle grew and very little shrink in the direction along the fiber (longitudinal). The differences are due to tangential and radial directions perpendicular to the fiber orientation. Fiber elongated shape in the direction of the fingers and thought that all cells are the longitudinal direction has a shrinkage which is very small in the direction of its length, therefore, the fingers will resist shrinkage radial elements longitudinally.

Mechanical Properties

Hardness of wood. Wood hardness is one of important mechanical properties on determination ability of wood to withstand the style up a notch or indentation or scraping (abrasion). The average value of hardness of treated mangium wood with fumigation was lower than untreated mangium wood, which respectively value 470.13 kg/cm^2 and 687.1 kg/cm^2. Similarly, the hardness of untreated laban wood was higher than treated wood with value of 712.2 kg/cm^2 and 625.46 kg/cm^2. Hardness value of mangium wood and laban wood is presented in Fig. 4.

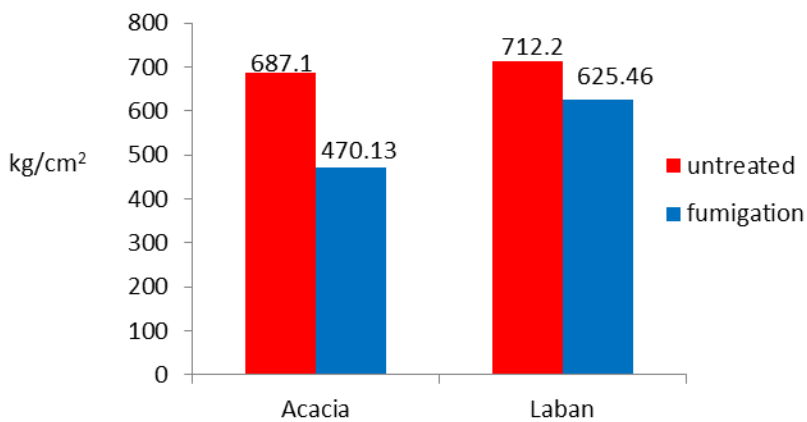


Figure 4. Hardness value of mangium and laban wood.

Based on the analysis of variance, timber fumigation treatment did not significantly affect the hardness value of mangium and laban wood. This is evidenced by the average value of the hardness smoked wood lower than untreated, either on mangium and laban wood. Mangium wood hardness value in this study is higher than the results of the study of Hadjib *et al*. (2007) which hardness value of 384.5-443.0 kg/cm^2. Laban wood hardness value is much lower compared to the results of research of Widiati and Susanto (2005) with an average value of 102,8 kg/cm^2.

Wood density affect the properties of hygroscopicity, shrinkage, strength, acoustic and electrical properties as well as other properties associated with subsequent woodworking (Tsoumis 1991). From the results of tests performed showed hardness values of treated mangium and laban wood was lower than untreated wood. d. This is in line with the statement that the wood heat treatment to improve the durability, lower hygroscopicity and improve dimensional stability of the wood, in addition, it can decrease the strength and hardness of wood (Boonstra *et al*. 2007).

Wood Anatomy Properties

Macroscopic wood properties. The macroscopic properties of mangium and laban wood data was recorded from macro observation with magnifying glass of 10-15X. This data includes color, direction of fibers, surface gloss, smell, texture and touch impression. The rough nature of such wood fiber direction, color, odor, texture, impression felt, and gloss is obtained from observations of various surfaces (Sarajar 1982 as cited by Wahyudi 2013). Wood color is caused by the presence of certain pigments. Wood texture refers to the feel of a piece of wood. It can be smooth or rough,. Results of the study are presented in Table 2.

Table 2. Macroscopic of mangium and laban wood.

Wood	Treatment	Fiber direction	Color	Surface texture	Odor	Touch impression
Mangium	untreatment	straight	cream/beige	shiny	odorless	smooth, slippery
	fumigation	straight	black brown	shiny	smoke smell	sheen slick
Laban	untreatment	straight and blend	White brownies	not shiny	odorless	sheen
	fumigation	straight and blend	black brown	shiny	smoke smell	sheen slick

Laban wood untreated | Fumigated Laban wood | Mangium wood untreated | Fumigated Mangium wood

Figure 5. Color of Mangium and Laban wood before and after fumigation.

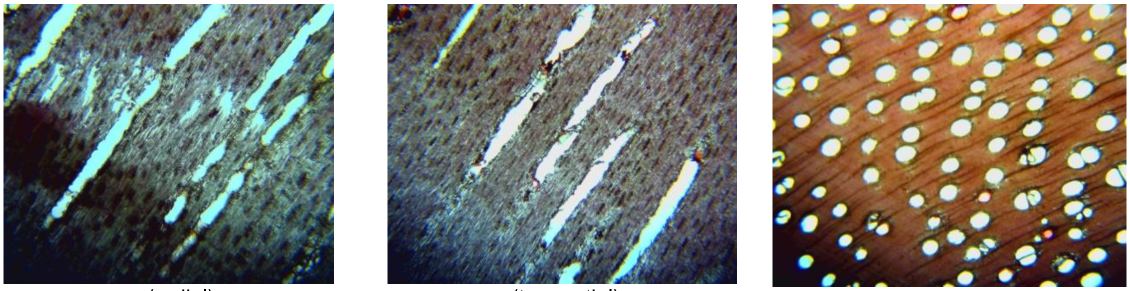
Fumigation of wood produced different colors from the original color, and the wood is darker. Untreated mangium wood color was light brown while treated fumigation wood color was black brown. This is due to the high temperature during fumigation. The untreated mangium and laban wood color was brighter than the color of fumigation wood. Visual color and surfaces of mangium and laban wood for both treatment are presented in Fig. 5.

The effect of different colors (ΔE) at untreated mangium and laban wood and treated mangium and laban wood a row by 14.46 and 32.29. Under the influence of differences in the color table (Hunter Lab 2008), the color difference >6.0 indicates that the temperature during the fumigation was a considerable influence on the staining wood. The value of color difference (ΔE) of laban wood is greater than mangium wood. This is evident from the test sample of laban in Fig. 5, where the wood is not pure white after fumigation and turned into a dark brown slightly black. Darker colors provide more decorative timber and preferably by craftsmen. Mostly the craftsman made a pattern of wood crafting, then fumigated the wood. This material will increase the value of wood handicraft. According to Inoue *et al*. (1992) as cited by Sulistyono and Surjokusumo (2001) fumigated wood provides an attractive color appearance, in which the color changed to a darker after high temperature during the process.

Fumigated mangium and laban wood has the impression of more delicate touch and slippery than untreated wood. This is due to the narrowing of pores or voids wood cells so that the surface becomes smooth compared with those of larger pores or voids (Bowyer *et al*. 2003). The impression of a smooth touch will facilitate the further process for crafting of the wood carving. Mangium and laban wood curing process results causes mangium wood surfaces become more shiny than untreated wood. The fumigation wood when touched feels more slippery, smooth and textured surfaces as the waxy layer provide wood is lighter in color than untreated wood. This impression is influenced by the presence of extractive substances. This character is very interesting, because of the color, pattern and surface gloss and smoothness smoked wood decorative value and will provide added value to be used as interior components.

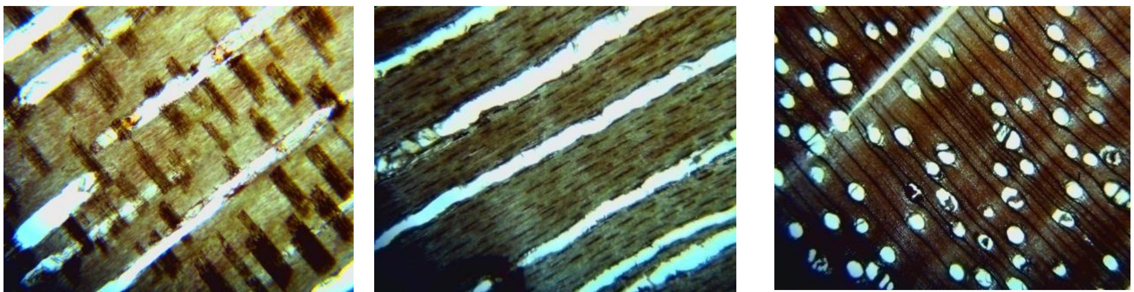
Fumigation treatment does not affect the direction of the wood fibers. In general, Mangium wood which treated and untreated showed a straight grain direction. Fiber direction associated with longitudinal orientation of the cells making up the dominant timber to the axis of the rod. Fiber direction is said to be straight because of the orientation of the mangium wood cell is parallel to the axis of the rod.

Microscopis wood properties. Observations wood fiber radial direction, radial, tangential using a microscope with a magnification of 30X. There is a relationship change in the anatomical structure of the wood with fumigation treatment. Fumigation treatment of mangium and laban wood indicate the occurrence of narrowing of the arteries (pores) and the timber cavity although the difference is not very large compared to untreated wood. (Fig. 6-8). Narrowed this timber vessels causes both mangium and laban wood structure becomes denser and solid.



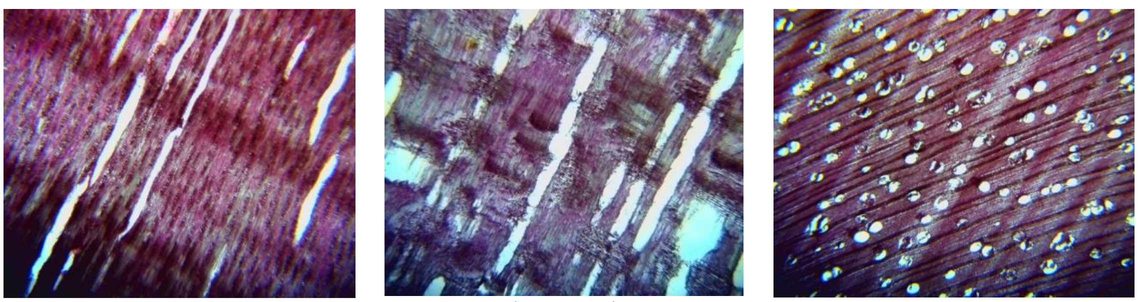
(radial) (tangential) (transversal)

Figure 6. Anatomical structure of untreated mangium wood (magnification 30x).



(radial) (tangential) (transversal)

Figure 7. Anatomical structure of fumigated mangium wood (magnification 30x).



(radial) (tangential) (longitudinal)

Figure 8 Anatomical structure of untreated laban wood (magnification 30x).

Conclusions

Fumigation treatment of mangium and laban wood is able to reduce moisture content and increase wood density. Traditional timber fumigation by craftsman provides darker color wood and could be used for decorative timber. Timber fumigation techniques could be implemented to preserve wood for wooden crafts.

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