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The physical properties of densified Terentang wood (*Campnosperma auriculatum* (blume) hook. f) on various steaming and pressing time

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Abstract. The need for wood to meet the raw material of forestry industry is increasing, but the availability of high-quality wood tends to decrease. It is due to the prohibition to harvest wood from natural forests. To fulfill the wood needs, innovation needs to be done. One of the innovations in the field of wood construction is needed to overcome the scarcity in fulfilling the raw material of forestry industry by developing potential domestic of wood species, as well as fast-growing species. One type of fast-growing wood used is Terentang (*Campnosperma auriculatum).* Terentang wood has a low level of wood strength (strong class III-IV), so it is less desirable. One technology that has the potential to improve wood quality is compaction or wood compression, with a preliminary treatment of steaming or boiling wood at certain temperatures and pressures. The results of the study showed that the compaction technology applied to Terentang wood (*Campnosperma auriculatum)* was able to improve the physical properties of wood in moisture content, specific gravity, and dimension shrinkage, but not in the dimensions swelling. Where compressed Terentang wood has increased the strong class of Terentang wood into strong class II (0.632−0.851) seen from its specific gravity based on PKKI NI-5-1961.

1. Introduction

The need for wood to meet the raw material of forestry industry is increasing, but the availability of high-quality wood tends to decrease. This is due to the prohibition to harvest wood from natural forests. To fulfill the wood needs, innovation needs to be done. One of the innovations in the field of wood construction is needed to overcome the scarcity in fulfilling the raw material of the forestry industry by developing potential domestic wood species, as well as fast-growing species. One type of fast-growing wood used is Terentang (*Campnosperma auriculatum)* [1].

Terentang (*Campnosperma auriculatum)* is one type of domestic wood in secondary forests that have distribution in almost all regencies in Riau Province. This situation shows that the potential of Terentang wood is abundant in nature to be utilized. However, Terentang wood has a low level of wood strength (strong class III-IV) [1]. Therefore, it is less desirable by the carpentry industry considering that the wood is included in the wood class with a low strong class. One technology that has the potential to improve the quality of wood is compaction or wood compression, with a preliminary treatment of steaming wood at certain temperatures and pressures. Hence, it is necessary to conduct research on "Physical Properties of Terentang wood (*Campnosperma auriculatum)* Integrated Based on the Steaming and Compressing Time".

The research purpose is to determine the effect of the process of wood compression based on the steaming and compressing time on the physical properties of Terentang wood including moisture content, density, specific gravity, and dimensional changes.

2. Materials and method

This research was carried out at Biocomposite Laboratory, Wood Quality Improvement Technology Laboratory, Wood Building Design Draft Laboratory, and Wood Laboratory Workshop of Forest Products Department, Faculty of Forestry, Bogor Agricultural University. The research was conducted from June to August 2018.

The material used in this research was wood paint and tangential board of Terentang wood (*Campnosperma auriculatum*) obtained from Bengkalis, Riau Province.

The equipment used in this research was machines for heat presses, ovens, desicators, calipers, scales, clocks, autoclaves, Universal Testing Machine (UTM) chun yen brands, table saws and aluminum foil.

2.1. Research method

The research method used is factorial experiments in a Completely Randomized Design (CRD) with two treatment factors, namely steaming time (Factor A) (40 minutes, 50 minutes and 60 minutes) and compressing time (Factor B) (10 minutes, 20 minutes, and 30 minutes).

Steaming treatment factor consists of three levels, namely, 40 minutes (A.1), 50 minutes (A.2), and 60 minutes (A.3). Factor B, the compressing time consists of three levels, namely, 10 minutes (B.1), 20 minutes (B.2), and 30 minutes (B.3). Of the two treatment factors used above, this research used nine treatment combinations and one as a control. Each treatment combination was carried out three times.

2.2. Research implementation

2.2.1. Material collection preparation and test sample preparation. The material collection for research in the form of Terentang wood was carried out in the community forest of Bengkalis, Riau Province. Test samples were taken from wooden tangential boards measuring 32 cm (L) x 10 cm (W) x 2 cm (H) as many as 30 boards. Then, each piece was coded and painted on both ends to prevent excessive evaporation of water and fungal attacks. Furthermore, it was dried, aerated and measured to reach 12−18% moisture content for approximately six weeks. Then, the board was cut to the size of 32 cm (L) x 10 cm (W) x 2 cm (H). Furthermore, compression was carried out according to work procedures.

2.2.2. Compressing wood process. The compressing wood process refers to the research procedure carried out by Sulistyono, et al [2] as follows:

1. Wood samples were dried to air dry (moisture content 12−18%) and measured in dimensions and initial weight before pressing/compressing.
2. The wood samples were steamed in an autoclave with a time of 40 minutes, 50 minutes and 60 minutes with steaming temperature of 125°C.
3. After steaming, the sample was immediately wrapped in aluminum foil to keep the sample temperature hot and undamaged (burnt).
4. Compressing was carried out in the radial direction (figure 1) and pressurized at 7 MPa with a compression temperature of 125 °C in 10 minutes, 20 minutes and 30 minutes.
5. After the samples were compressed, the dimensions were measured and weighed; then the air was dried for seven days.
6. The compression results were then made a test sample for testing physical properties (moisture content, density, specific gravity, and dimensional changes) using the (British Standard) [3]

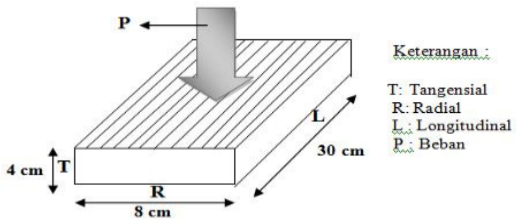

Figure 1. Compaction wood directions.

Table 1. Size test example for testing the physical and mechanical properties of wood [3].

Characteristic	Testing	Size on testing (cm)
Physical	moisture content, specific gravity, and dimensional changes	2 x 2 x 2 10 x 2 x 2

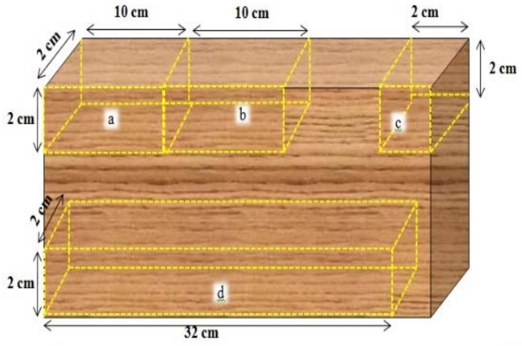

Figure 2. Taking test samples based on physical and mechanical properties of wood: a) dimension swelling of wood dimensions; b) wood shrinkage; c) moisture content, specific gravity.

2.3. Data analysis

The data obtained were processed by descriptive statistical methods. Furthermore, to analyze the effect of steaming time treatment and compressing time on physical properties, two factorial complete randomized experimental designs were carried out. Furthermore-, for analysis of variance with F count test. If there is a significant effect of the preliminary treatment factors and press time from the F count, the average difference test between treatments is done using the average test Duncan's New Multiple Range Test (DNMRT) at 5% level. Thus, the factorial complete randomized design formula is:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{k\,(ij)} \quad (1)$$

Y_{ijk} : Observation value on factor A treatment (boiling time) level i, and factor B treatment (compressing time) level j
μ : General average
α_i : Effect of boiling time factor (A) level i
β_j : Effect of compressing time factor (B) level j
$(\alpha\beta)_{ij}$: Interaction of factor A at level i and factor B at level j
$\varepsilon_{k\,(ij)}$: Effect of experimental error from the treatment factor A level i, and treatment factor B level j

3. Results and discussion

3.1. Moisture content

Statistically, the steaming time and compressing time have no significant effect on the moisture content of Terentang wood. However, when it was viewed from the number, there was a decrease, namely the value of Terentang wood moisture content which was compressed and ranged from 6.04%−7.75%. The value of Terentang wood moisture content can be seen in figure 3 below.

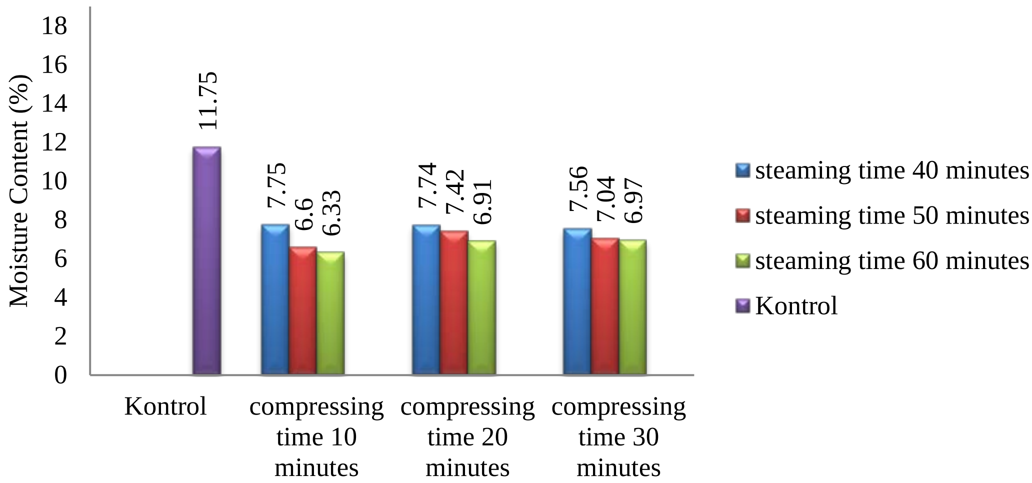

Figure 3. Terentang wood moisture content.

In general, the wood moisture content in the compression process tends to decrease with the increasing steaming duration. It is presumably because the steaming time in 60 minutes of the properties of wood hygroscopicity has decreased due to the longtime of heating. It is consistent with the statement of Amin et al. [4] that the magnitude of the decrease in wood hygroscopicity depends on the time and temperature of heating. Heating with a temperature above 100 ^{0}C which causes all water to be bound, including compressed water which is in the microcavity in the amorphous area of the cell wall which is smaller than the size of the outgoing water molecules which makes it difficult for the water in the wood to come out.

Otherwise it is also suspected because that the wood steamed for more than 50 minutes will change the amorphous part to crystalline, so that the ability of wood to bind water is getting reduced. This research is the same with the research of Nestri [5] that steaming will lower hygroscopicity of the wood because the amorphous part changed into crystalline. With the reduced of porosity and higroscopicity of the wood, the amount of water in the wood will decrease.

The result of this research showing that there are differences between moisture content of control and wood compression. The decrease of moisture content to under 10 % is thought to be due to the influence of heat at the time of pressing, it can reduce the moisture content in the cavity of wood cells. This is in line with Blomberg’s [6], that compaction treatment causes a reduction in the portion of cell cavities in wood (porisity) due to the multiplication of wood-making cells. Reduced wood porosity will result in wood getting denser.

Analysis of variance at 95% confidence interval held shows that there is no real interaction between the steaming time, compressing time, interaction and the two treatment factors (steaming time and compressing time) on the compressed Terentang wood moisture content. Duncan's further test results showed that the lowest value of Terentang wood moisture content sequentially was found in the steaming time of 60 minutes, 50 minutes, and 40 minutes, while in the compressing treatment there were 10 minutes, 30 minutes, and 20 minutes.

3.2. Specific gravity

From the test result, it was obtained that the value of Terentang wood specific gravity (SG) (*Campnosperma auriculatum)* the control was 0.472. Then, after compressing the value increased by 65.596%, which is in the range of 0.673─0.917. The data on the specific gravity of Terentang wood the control and the compressed can be seen in figure 4.

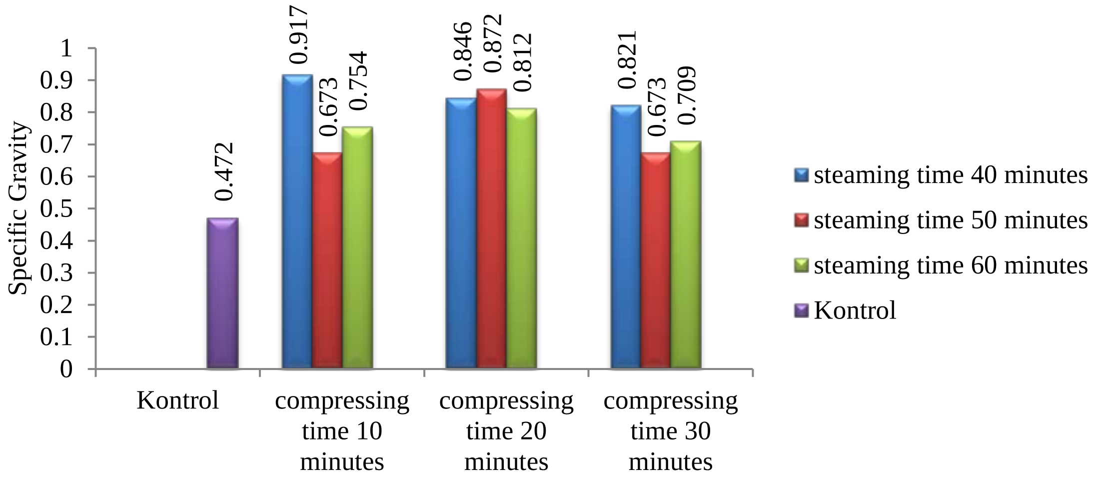

Figure 4. Specific gravity of Terentang wood.

In general figure 4 showing that SG of wood compression is increased compared to control wood. This is presumably because the length of the wood steaming process makes the wood soft and easier when pressed, so that the cell cavity and cell walls become dense and tend to flatten, and also will reduce the volume of the wood, in other hand the weight is constant. This is in line with the statement Megawat et al. [7] that the changes in the shape of denser building blocks of wood can increase the value of SG. Besides, it is also related to changes in the shape of the constituent cells. According to Suroto and Setiawati [8], wood will be increasingly dense if the volume of wood decreases so that the specific gravity increases. The results of this study also showed that the faster the steaming time and compressing time the higher the wood SG value. It was suspected that with 10 minutes steaming time and 10 minutes compressing time, the wood was not damaged. It was due to compression so that the wood structure would not be damaged which caused the wood strength low. It is consistent with Sulistyono et al. [2] which revealed that the way to compress wood without damaging the wood structure is excessive by releasing tense and elastic strain stored in the microfibrils and matrix under conditions that cause elastic and plastic lignin flow, a combination of wood moisture content, temperature and heating time. In addition, the rate and magnitude of pressure will affect the results of wood compression.

The high amount of SG of wood that steaming over 40 minutes, it is assumed that the large number of tylosis sediment and extractive substance in the cavity of wood cells steamed for 40 minutes, so that it can increase the value of SG wood compression that getting steamed for 50 minutes and 60 minutes. This is in line with Panshin and De Zauw in Manuhuwa [9] that high density and gravity of wood are due to the large number of cell wall substance and extractive substances in wood.

The results of variance analysis showed that the single factor of duration treatment of steaming has a significant effect on Terentang wood. However, there is no significant effect on the interaction of steaming time and compressing time. Likewise, the single factor duration of the press does not have a real effect. Duncan's further test results showed the best specific gravity values for steaming treatment were 40 minutes, 60 minutes and 50 minutes, whereas the best specific gravity values in the pressing treatment were 20 minutes, 10 minutes and 30 minutes.

3.3. Dimension swelling

The mean value of changes in dimensions of Terentang wood (Campnosperma *auriculatum*) includes dimension swelling and shrinkage. The changes in the dimensions of Terentang wood value for the average dimension swelling of the dimensions of compressed wood rangs from 22.37%−32.52%, and for control wood is by 5.89%. The average value of compressed wood shrinkage ranges from 3.89%−8.68%, and for the average value of control wood is 6.65%. The expand of compacted stretched timber is still quite high and has increased dramatically from its control. It is assumed that during steaming, the wood is getting plastisity and pressed below the proportional point, thus allowing the cell to spring back when soak. This is in line with the research of Ekajuni [10] that the wood which hasn't reach the drying set condition, causing the bond formed not getting permanent and leaves considerable internal stress. Wood as an object has internal stress so it wil react if there is an external force that influences it. This also occurs i ncompacted wood, where the wood will try to return to its original form as resistance to pressure at pressing time. In extreme enviromental conditions, especially the influence of water, wood will release all the stress so it can expand. The following data are the changes in dimensions of Terentang wood and the compressed which can be seen in figure 5 and figure 6.

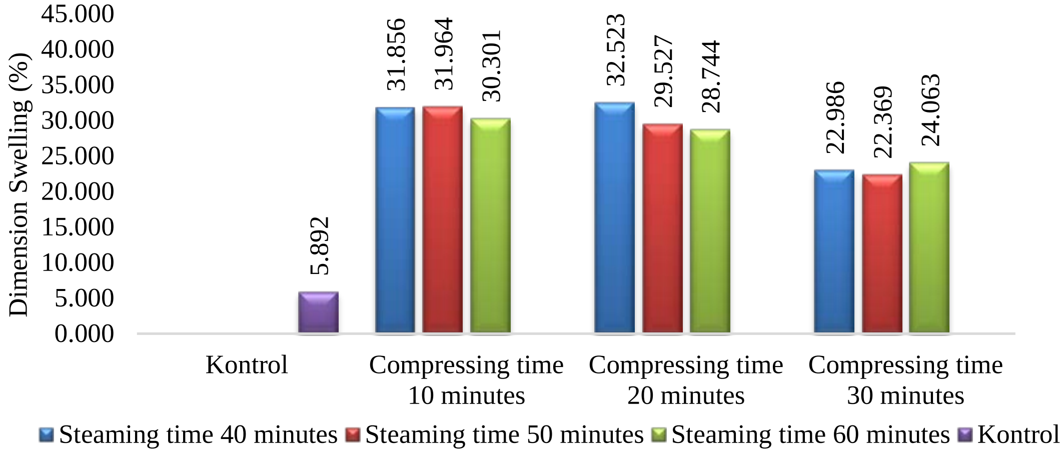

Figure 5. Value of dimension swelling of Terentang wood dimension.

The research found that the dimension swelling of compressed Terentang wood dimension was still quite high and increased dramatically from the control. It is because the wood has not yet reached the drying set condition, so that the formed bonds are not permanent and leave considerable internal stress. Wood as an object has internal stress so it will react when there is an outside force that influences it.

The results of the variance analysis showed that the single factor duration of pressing had a very significant effect on the dimension swelling, on the duration of compressing 10 minutes, 20 minutes or 30 minutes. On the other hand, the time of steaming does not have a significant effect on the dimension swelling. Duncan's follow-up test results showed that the highest value of Terentang wood dimension swelling was found in the treatment of steaming time 40 minutes, 60 minutes and 50 minutes. Whereas in the compressing treatment, there were 10 minutes, 20 minutes, and 30 minutes press time.

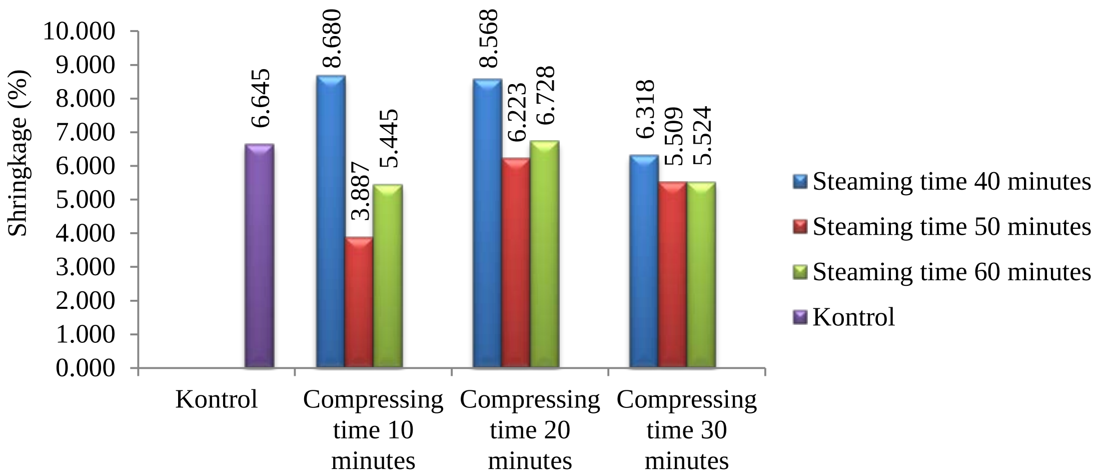

Figure 6. The shrinkage value of Terentang wood.

The test results obtained that the treatment of compressing time, the better the shrinkage value of wood. It is assumed that the wood is a solid because the wood has a smaller level of dimensional change than other compressing treatment. The increase in density causes compressed wood cells tend to flatten. Thereby, reducing the volume of cavities will simultaneously reduce the wood volume while the weight remains so that the dimensions change more stable [2].

The results of variance analysis showed that the single factor of steaming time has a significant effect on shrinkage, while the compressing time and interaction between these two factors has no significant effect. Duncan's further test results showed that the lowest value of Terentang wood is sequentially found in the treatment steaming time 50 minutes, 60 minutes, and 40 minutes. Whereas in the compressing treatment there are 30 minutes, 10 minutes and 20 minutes in the press.

4. Conclusions

1. Compression technology applied to Terentang wood (Campnosperma *auriculatum*) can improve the physical properties of wood in moisture content, specific gravity, and dimension shrinkage, but not in the dimension swelling
2. In this research, the compressed Terentang wood has increased the strong class, from strong class III to strong class II (0.632−0.851), which is seen from its specific gravity based on PKKI NI-5-1961.

5. Recommendations

1. Terentang wood (*Campnosperma auriculatum)* with compression innovation can increase the strong class of wood into strong class II, so that it can be used as a construction of raw material.
2. Further research related to the testing of compressed wood based on the position of the wood (Edge, middle, and base)needs to be done in order to find out the best physical properties of compressed Terentang wood which have not been reached in this research.

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