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Impact of cold-immersion time to the preservation of galah bamboo (Gigantochloa atter (Hassk.) Kurz ex Munro) in extract of gadung (Dioscorea hispida Dennst.) tuber

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Abstract. Bamboo is one of the important non-timber products which are predominantly propagated in Nusa Tenggara. Besides its high potency to propagate, the ultimate considerations of propagating bamboos are because they are easy to cultivate, give high yield, have straight stem, and are relatively cheap. One of bamboo species found in West Nusa Tenggara is galah bamboo (Gigantochloa atter (Hassk.) Kurz ex Munro) which is suitable for light construction material, furniture, and craft. However, the bamboo is prone to insect and fungi attack. Thus, to increase its durability, treatments should be applied. The treatment was a cold immersion method. The objective of this study was to identify the absorption capacity of the G. atter, theoretical and actual retentions, and the impacts of immersion time to the bamboo durability. An experimental method was employed in this study. The experiment design was a complete random design with two treatments of immersion time, 3 days (A1) and 5 days (A2). The results showed that the immersion times did not significantly affect the absorption capacity of the bamboo and the theoretical and actual retention. The study found that the absorption capacity of G. atter was 0.49-1.25 g/cm^3, the theoretical retention was 0.05 – 0.08 g/cm^3, and the actual retention was -0.007 – 0.001 g/cm^3.

Keywords: Galah bamboo; cold immersion; extract of gadung tuber

1. Introduction

Bamboo is one of the non-timber forest products and is predominantly planted in Nusa Tenggara. Besides its high potency for propagation, bamboo also has several advantageous properties such as easy to propagate, has straight stems, and relatively inexpensive. A bamboo species, which is found in West Nusa Tenggara province, is galah bamboo (Gigantochloa atter (Hassk) Kurz ex Munro). This bamboo is suitable for light construction materials, furniture, and crafts. The density of G. atter is 0.49 [1], which was smaller than ampel bamboo (Bambusa vulgaris Schard), tali bamboo (G. apus), and petung bamboo (Dendrocalamus asper).

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The weakness of this bamboo was prone to insect and fungi attacks due to its high content of cellulose and starch which were preferred by them [2]. In order to improve the durability of the bamboo, preservation treatments were required which were simply conducted by the cold-immersion method. This method was known as inexpensive and simple although it would take more time compared to other preservation methods. The immersion might lower the content of starch in the bamboo and the immersion time was suggested to be no more than one month. Firmanto[3] states that the effectiveness of preservatives is not only determined by the level of toxicity but also by the method of preservation. Sumaryanto, Hadikusumo, & Lukmandaru[4] explain about the immersion time which the longer immersion time will result in more preservatives penetrate into the bamboo or materials through the wall cells. Factors that influence the success of preservation are the moisture content, the density, the time of immersion, and the anatomical structures of bamboo [5].

Besides the preservation method, the preservatives may also affect the success of preservation and is one of the important factors of preservation. Preservatives may be chemistry or biological compounds. One of the well-known biological compounds is extract of gadung (Dioscorea hispida Dennst.) tubers containing cyanide acid (HCN) substance which may potentially kill insects or other decomposers of bamboo. In average, the cyanide content in D. hispida tubers is 362 ppm [6]. This content is considered high because the maximum toxicity level of cyanide to humans is 50 ppm [7].

The objective of this study was to identify absorption values, theoretical retention, actual retention, and impacts of immersion time to the preservation of G. atter.

2. Methodology

This study employed experimental design and according to Sukmadinata[8] the experimental design was a research approach which was to examine the influence of one variable to another variable

2.1. Time and place

The study began in August 2020 and ended in November 2020. It was carried out in the laboratory of Forest Product Technology of Forestry Department, Faculty of Agriculture, University of Mataram.

2.2. Tools

Tools used in this study were : saw or blades to cut the samples, callipers to measure the diameter and length of the samples, digital balance to weigh the samples, knives to peel the skin of *D. hispida* tuber, pan and stove to boil the tuber to obtain the extract, sieve to filter the tuber extract, measuring glass to measure the preservative and water, bucket to be used for immersion, stationery, camera for documentations.

2.3. Materials

Materials of this study were: D. hispida tuber which was boiled for the extract. The tuber was collected from Tamekan Village, Taliwang District, West Sumbawa Regency. The tuber for the study was about 1-year-old which was identified from the bud regrowth, the size of the tuber, and the old stem of the plants. *G. atter* was the bamboo that was studied and obtained from Penujak Village, West Praya District, Central Lombok Regency. Deionized water as the preservative solvent.

2.4. Research Design

In this study, the research study was non factorial completed research design (CRD) with one treatment. The treatment of the study was immersion times consisting 3 day-immersion and 5 day-immersion with 3 (three) replication, resulting 6 (six) samples.

Table 1. Matrix of Research Design and Its Replications

Immersion Time	Replication		
	B1	B2	B3
A1	A1B1	A1B2	A1B3
A2	A2B1	A2B2	A2B3

2.5. The Procedure

Several steps of the study are as follows:

2.5.1. Harvesting the Bamboo.G. atter

*B*amboo was harvested using blades or saw. Before being sawn down, G. atter bamboo was bark-chopped at about 25 cm above the ground. Three stems of bamboo were selected in line with the sample replications, where each stem represented one replication. Regarding Duryatmo[2], the selected bamboo should be mature, which were ready to be harvested, about 3-5 year-old, and the position was in the middle of the bamboo clump.

2.5.2. Samples Preparation.

The section of bamboo stem, which was prepared for samples, was the middle section. It was determined by dividing the total length of the stem into three sections and the middle section was selected as samples. This section was cut using blades into 15 cm in length and becoming 6 pieces of samples. The dimension of the samples was in accordance with SNI 8020-2014 standard regarding Bamboo Utilizations.

2.5.3. Preparation of D. hispida extract from the tubers.

Tubers of D. hispida could be used for raw materials for wood preservatives including bamboo because they contained cyanide which was toxic to insects. The toxic can be extracted from the tubers. The extraction was carried out by boiling the tubers in water, which was usually used to dissolve the cyanide in [9]. According to Arumsari[10] the simple process of D. hispida tubers extraction was:

a. The tubers are peeled and rinsed in running tap water to remove soils or dirt from the tubers.
b. Sliced the peeled tubers becoming thin tubers, maximum 2 mm, to make extractions easier.
c. The sliced tubers were boiled in 100°C deionized water for 30 minutes.
d. The ratio between the tubers and the water was 1:5 (w/w), and the ratio was maintained during the extraction process by adding deionized water.
e. After 30 minutes, the solution was cooled down for 10 minutes and filtered prior to further treatment.

When the extraction was completed, 10% of D. hispida extract was calculated in relation to the volume of the G. atter samples meaning that D. hispida solution containing 10% D. hispida extract was used to immerse the bamboo samples. The preparation of 10% D. hispida solution was adding sufficient deionised water into the extract.

2.5.4. Preservation by cold immersion method.

The process of the cold-immersion method was as follows:

a. The bamboo samples were put in buckets containing 10% D. hispida extract.

b. The first treatment buckets were 3 day-immersion and the second treatment buckets were 5 day-treatment.
c. After the immersion, the samples were dried with corresponding to the parameters measured.
d. Air-drying of the samples was done in the laboratory at room-temperature conditions for a week.

2.5.5. Measuring parameters of the samples.

a. Absorption

Absorption capacity is the volume of preservative solution that is absorbed by the bamboo (kg/m^3). It was calculated by subtracting the sample weights before and after being preserved and divided by the volume of the sample [11] as :

$$\text{Absorption} = \frac{Ba - Bbk}{VB} \quad (1)$$

Where,
Ba = weight after immersion (g)
Bbk = air-dried weight before immersion (g)
VB = volume of sample or bamboo (cm^3)

b. Retention

Retention is the concentration of preservative which was found in the samples after immersions and its unit is g/cm^3 or kg/m^3[12]. Retention was calculated by ways namely theoretical retention and actual retention.

b.1. Theoretical retention. According to Sadir[13], theoretical retention corresponded linearly to the concentration of the preservative. The higher concentration of preservative used in immersion will increase the theoretical retention of the samples. It was calculated using the formula:

$$\text{Theoretical Retention} = K \times A \quad (2)$$

Where:
K = Concentration of the preservative (%)
A = Absorption (g/cm^3)

b.2. Actual retention. Actual retention is the amount of dissolved preservative which is restrained in the samples [4] [14]. According to Darupraptomo[11], the actual retention of preservative is measured to understand if the material meets the requirement to be used for construction in accordance to the standard. The actual retention was calculated by subtracting the weight of samples after immersion with the weight of samples before immersion divided by the volume of the samples. The unit of the actual retention is g/cm^3, same as the theoretical retention.

$$\text{Actual retention} = \frac{Bak - Bbk}{VB} \quad (3)$$

Where,
Bak = air-dried weight after immersion (g)
Bbk = air-dried weight before immersion (g)
VB = volume of sample or bamboo (cm^3)

2.5.6. Data analysis.
The data were analysed using Anova at 95% confident. Further test would be conducted if there was a statistical significant difference in values using LSD test at 95% level of confident.

3. Results and Discussions

3.1. Absorption
The absorption of the preservatives is one important consideration to determine whether the materials, bamboo, are well protected from insect and or fungi attack. Hadikusumo[14] stated that the absorption of the preservatives was the amount of preservatives that was absorbed once the material was preserved per volume of the material (g/cm^3). The results of absorption for this study are presented in Table 3.1.

Table 2. Average values of Preservative Absorption of *G. atter*

Immersion Time	Replication			Average (g/cm^3)
	B1	B2	B3	
A1	0.49	0.79	0.52	0.60^a ($\delta\pm$ 0.17)
A2	1.25	0.61	0.76	0.87^a ($\delta\pm$ 0.33)

Note :A1 = 3-day immersion, A2 =5-day immersion, B1=replication 1, B2 = replication 2,B3 = replication 3

Table 2 shows that the absorption of the preservatives ranges between 0.49 g/cm^3 to 1.25 g/cm^3. The highest absorption value is found in 5-day immersion time, whereas the lowest is in 3-day immersion time. Comparing to a similar study conducted by Rosilina[15] the current study's results were higher than hers, which were 0.29 g/cm^3 and 0.30 g/cm^3 for 3-day immersion time and 5-day immersion time, respectively. These higher absorption values were caused by the concentration of the preservatives used in the study, 10%, which was lower than the other studies conducted by Santari [16] and Rosilina [15], 15%.

This condition was in line with the conclusion driven by Novriyanti and Nurrohman [17] which was the higher concentration of preservatives used for immersion, the less absorption occurred in materials tested. The higher concentration of preservatives in the solution increased the consistency of the solution which made the solution difficult to be absorbed into the materials [4].

Table 2 also shows that the average absorption values of 3-day immerstion time (A1) and 5-day immersion time (A2) are different, 0.60 ($\delta\pm$0.17) g/cm^3 and 0.87 ($\delta\pm$0.33) g/cm^3, respectively. The average of A2 is higher than A1 which means that the longer immersion time is, the more absorption value is found in the bamboo's pores [18] [19]. Low density of the bamboo, which is high in bamboo porosity, may have high absorption capacity.

Although the absorption values were different, the statistical tests confirmed that they had no significant difference between them (Table 3).

Table 3. The Anova Test of the Absorption Values of *G. atter*

Source of Variance	Sum Square	df	Mean Square	F	P-value	F_{crit}
Between Treatments	0.112	1	0.112	1.61	0.27	7.71

Within Treatment	0.278	4	0.070
Total	0.391	5	

The Anova test is presented in Table 3 and reveals that the F_{crit}> F and the P-value is also > 5% meaning that there is no significant difference between treatments, which are A1 and A2. In other words, the immersion times did not influence the absorption of the preservatives in bamboo samples.

Based on these findings it was suspected that the immersion times of this study could have been changed with more time gap between them, for example, 1-day immersion time and 5-day immersion time or 3 day-immersion time and 7-day immersion time, instead. Xu, Harries, Li, Liu, and Gottron [20] found 1-day immersion time had improved the strength the bamboo. In this study, the immersion times were 1-day and 7 day.

3.2. Retention

Bamboo preservation does not solely depend on the types or the characteristics of the preservative but also on the amount of preservative which is absorbed in the bamboo [21]. Retention is one of the parameters to determine the durability of bamboo. It is different from absorption because the retention counts the preservative contained in bamboo, whereas the absorption is not only the preservative to be counted but also the solvent of the preservative [22]. The retention was calculated after the immersion in two conditions, namely wet condition and air-dried condition. The wet condition was used to calculate the theoretical retention by measuring the absorption, and the air-dried condition was used to calculate the actual retention.

3.2.1. Theoretical Retention.

Theoretical retention is calculated using the absorption value and the concentration of the preservative (see Equation (2)). High retention was expected to improve the bamboo durability and prolong the use of bamboo. The theoretical retention of the bamboo from this study is presented in Table 4.

Table 4. Average Values of Theoretical Retention of G. atter

Immersion Time	Replication			Average (gr/cm^3)
	B1	B2	B3	
A1	0.05	0.08	0.05	0.06^a ($\delta\pm0.02$)
A2	0.13	0.06	0.08	0.09^a ($\delta\pm0.03$)

Note : A1 = 3-day immersion, A2 = 5-day immersion, B1 = replication 1, B2 = replication 2, B3 = replication 3

The theoretical retention of G. atter ranged between 0.05 g/cm^3 to 0.08 g/cm^3. The highest retention was found in 5-day immersion time (B1) and the lowest was in 3-day immersion time (B1 and B3). The average of theoretical retention for A1 was 0.06 ($\delta\pm0.02$) g/cm^3 and for A2 was 0.09 ($\delta\pm0.03$) g/cm^3.

The 5-day immersion time had higher theoretical retention of preservative than the 3-day immersion time. The longer immersion time would result in higher values of theoretical retention [23]. The review of theoretical retention might be the same as the review of absorption because theoretical retention has a direct correlation with absorption. The differences between them were determined by the concentration level of the solution as the Equation (2).

A similar study conducted by Novitasari[24], using an extract of Lantana camara leaves as the natural preservative, on G. atter preservation showed that the theoretical retention ranged from 0.03

g/cm^3 to 0.09 g/cm^3. These two studies applied different immersion times, which the study conducted by Novitasari[24] had a longer immersion time. This proved a conclusion made by [10] which stated that the immersion times could increase the theoretical retention.

One important application of bamboo in communities is for light construction materials, such as woven bamboo or gedheg for house walls or other utilisations such as crafts and furniture. For external usage, SNI 01-5010.1-1999, which is the Indonesia standard of wood preservation for housing and buildings, has set up the minimum retention of preservatives to be met, 0.08 g/cm^3. Therefore, 5-day immersion time with 10% concentration of preservatives was considered sufficient to treat bamboo for external usage in housing and buildings. In order to understand the influence of immersion times to the theoretical retention of G. atter, an Anova test was carried out and the results are presented in Table 5.

Table 5. The Anova of the Theoretical Retention of G. atter

Source of Variance	Sum Square	df	Mean Square	F	P-value	F_{crit}
Between Treatments	0.001	1	0.001	1.61	0.27	7.71
Within Treatment	0.002	4	0.001			
Total	0.003	5				

The Anova test is presented in Table 3.4. and reveals that the F_{crit}> F and the P-value is also > 5% meaning that there is no significant difference between treatments, which are A1 and A2. In other words, the immersion times did not influence the theoretical retention of the preservatives in bamboo samples.

3.2.2. Actual Retention.

An actual retention is the amount of "dry" preservative which is restrained in the material after the immersion [4] [25]. The preservative solution was absorbed in bamboo and was air-dried for a week at room-temperature conditions prior to weighting. The result of the actual retention of preservative in the G. atter is presented in Table 6.

Table 6. Average Value of The Actual Retention of G. atter

Immersion Time	Replication			Average (g/cm^3)
	B1	B2	B3	
A1	-0.024	-0.011	0.001	-0.011^a ($\delta\pm$0.013)
A2	-0.020	-0.007	-0.010	-0.012^a ($\delta\pm$0.007)

Note : A1 = 3-day immersion, A2 = 5-day immersion, B1 = replication 1, B2 = replication 2,B3 = replication 3

The actual retention ranged between -0.024 g/cm^3 to 0.001 g/cm^3 which both values were found in 3-day immersion time (A1). On the other hand, the average values of the actual retention A1 and A2 were similar, -0.011 ($\delta\pm$0.013) g/cm^{3}and -0.012 ($\delta\pm$0.007) g/cm^3, respectively.

These values were also confirmed to be no significant different statistically (Table 7). Table 7. shows that the F_{crit}> F and the P-value is also > 5% meaning that there is no significant difference between treatments, which are A1 and A2. In other words, the immersion times did not influence the actual retention of the preservatives in bamboo samples.

Table 7. The Anova of the Actual Retention of *G. atter*

Source of Variance	Sum Square	df	Mean Square	F	P-value	F_{crit}

Between Treatments	0.0000	1	0.0000	0.015	0.909	7.709
Within Treatment	0.0004	4	0.0001			
Total	0.0004	5				

Comparing to a study conducted by Hamzah et al. [26] using extract of clove (Syzygium aromaticum) as the preservative, the results of this current study was similar because the actual retention was very little, ≤ 0.001 g/cm^3. In their study, the actual retention was 0.0002 g/cm^3 – 0.0005 g/cm^3.

Kusmaningsih[27] describes more about factors influencing the actual retention, namely chemical, physical properties of wood or bamboo, and anatomical structure of bamboo. Besides those factors, the concentration and composition of active preservative may also influence the actual retention. A study conducted by Sumaryanto et al. [4], for example, on actual retention of teak (Tectona grandis) using borax (5%) and boric acid (5%) as preservatives in cold immersion method for 2-day immersion time, ranged from 6.72 g/cm^3 to 7.06 g/cm^3. Although the concentration of the preservative and the immersion time were lower than the current study, the actual retentions of the preservative were higher, because of other factors mentioned by Kusumaningsih[27]. It was suspected due to the porous structure of the materials that made teak had higher the actual retention of the preservative than bamboo.

Porous structure of bamboo and wood was studied by He et al. [28] using moso bamboo (Phyllostachys heteyocycla cv. Pubescens) and pine (Pinus sylvestris L.) and concluded that the median pore size of P. heteyocycla was smaller than P. sylvestris, 33.8 nm and 445.0 nm, respectively. With this pore diameter size, bamboo tends to have higher density than wood [29]. Therefore the actual retention of bamboo is likely to be lower than of wood.

In this study, several values of actual retention were negative meaning that the air-dried weight of samples after the treatment was lighter than the samples before the treatment. It was no firmed explanation about this but it was suspected that the preservative solution had dissolved a small portion of the samples. Although the immersion time did not influence the actual retention, the average value of 5-day immersion time (A2) actual retention < 3-day immersion time (A1) actual retention (Table 3.5.). Moreover, a research carried out by Abdurachman and Ismanto [30] mentioned that starch and lignin in ampel bamboo (B. vulgaris) were removed 16.7% and 36.5%, respectively, after 7-day immersion time in stagnant water. This might be explaining factors that made the weight of G. atter after the immersion was lighter than the weight of G. atter before the treatment. The longer immersion time might dissolve more materials or substrates of G. atter.

4. Conclusion

The immersion times did not influence significantly the absorption, the theoretical retention, and the actual retention of the extract of D. hispida in G. atter. Based on the theoretical retention, the treatment to the G. atter met the requirement stipulated up in SNI 01-5010.1-1999 for G. atter to be used as external construction materials. Some actual retention values of this study were negative. It occurred because a little amount of materials, such as starch and or lignin in the G. atter were dissolved during the immersion.

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