ASSESSING THE INFLUENCE OF INITIAL MOISTURE CONTENT AND DENSITY ON RUBINATE UPTAKE BY MICROWAVE-DRIED SITKA SPRUCE WOOD

***(Uji Pengaruh Kadar Air Awal dan Kerapatan Kayu terhadap Penyerapan Rubinate oleh Sitka Spruce yang Dikeringkan dengan Energi Mikrowave*)**[1]

By/*Oleh*:

Karnita Yuniarti[2], Jeff Hann[3], and Ismail Budiman[4]

ABSTRAK

Penggunaan gelombang mikro direkomendasikan untuk meningkatkan permeabilitas kayu Sitka spruce. Akan tetapi, kayu yang diproses dengan gelombang mikro yang dipancarkan melalui aplikator terowong cenderung mengalami kerusakan struktur, terutama patahnya sel-sel jari-jari. Proses impregnasi kayu dengan resin, seperti rubinate, diharapkan dapat mengatasi masalah tersebut.

Beberapa faktor perlu diperhatikan dalam proses impregnasi kayu dengan bahan kimia. Beberapa faktor internal kayu yang berperan adalah tipe noktah antar sel, kadar air kayu awal dan kerapatan. Penelitian dilakukan untuk menguji pengaruh kadar air awal dan kerapatan kayu Sitka spruce yang dikeringkan dengan gelombang mikro- terhadap penyerapan rubinate. Hasil yang diperoleh menunjukkan bahwa penyerapan rubinate lebih dipengaruhi oleh kadar air awal kayu dan tidak dipengaruhi oleh kerapatan kayu.

Kata kunci : Kadar air, kerapatan, Sitka spruce, gelombang mikro, rubinate

---

[1] The data used in the paper were collected during the involvement of 1st author in Sitka Spruce project at University of Melbourne and funded by CRC for Wood Innovation
[2] Center for Forest Products Research and Development, Bogor
[3] University of Melbourne and Researcher of CRC for Wood Innovation
[4] Biomaterial Research Center-LIPI, Cibinong

ABSTRACT

The use of microwave energy is recommended to improve the permeability of Sitka spruce wood that is known as refractory or difficult-to-chemically treat species. However, wood processed with microwave energy emitted through waveguide applicator tends to get some wood structure rupture, particularly their ray cells. Impregnating the microwave-processed wood with resins, such as rubinate, is opted to solve this problem.

To successfully impregnate wood with chemical materials should consider factors that may influence the process. Some internal factors of the wood that may affect the treatment process are pit type, initial moisture content and density. The experiment was carried out to assess the influence of initial moisture content and density of microwave-processed Sitka spruce wood on its ability to absorb the rubinate resin. The result showed that rubinate uptake was affected significantly by initial moisture content and less affected by the wood density.

Keywords: Moisture content, density, Sitka spruce, microwave, rubinate

I. INTRODUCTION

Sitka spruce is recognized as a refractory softwood species. It means that the species is difficult to chemically treat (Kartal and Lebow, 2002, Messner, *et al.*, 2002). Dried samples of spruce were more difficult to treat than the green samples due to the aspiration of pits during the drying process (Messner, *et al.*, 2002). On the other way around, preservative treatment of this species is essential since spruce heartwood is still prone to decay (Alden, 1997).

The use of microwave energy, particularly those emitted through wave-guide applicator, is recommended for improving the permeability of Sitka spruce (Yuniarti, 2005). However, wood processed with microwave energy emitted through wave-guide applicator tends to get some structure ruptured, particularly their ray cells. To solve this problem, further treatment is required. Impregnating the microwave-processed wood with resins, such as rubinate, is opted as this kind of chemical is not only able to protect wood but also could seal back the ruptured structures during the pressing stage that follows after the impregnation process. Rubinate itself is an isocyanate-based resin and free from formaldehyde resin (Walker, *et al.*, 1993).

To successfully impregnate wood with chemical materials should consider both external and internal factors that may influence the process. External factors refer to conditions such as chemical types and impregnation method. Information and research so far only discussed the influence of common chemical types used to preserve wood (water-based and oil-based types), and rarely on resin-based types.

Internal factors refer to those within the wood that may affect the treatment process such as pit type, initial moisture content and density. According to Kollmann and Cote (1968), mostly articles describing influence of wood structure on preservative uptake discussed on pit types existed in the wood, and rarely on either moisture content or density of the wood itself.

Kollmann and Cote (1968) explained that higher permeability could be found in dry wood rather than in wet wood. However, Johnston and Maass (1929) in (Kollmann and Cote, 1968) previously stated that the penetration speed of impregnated chemical improved in green wood as well as in sapwood during pressure treatment. These contradictory opinions open the fact that the influence of initial moisture content on the uptake of preservatives by wood is still questioned. In addition, influence of density on preservative uptake by wood has also still received scarce attention. Thus, this paper aims to assess the influence of initial moisture content and density of microwave-processed Sitka spruce on its ability to absorb the rubinate resin. The rubinate resin was opted for this experiment due to its superiority as one of isocyanate-based resin that could produce very strong bond with hydroxyl groups of wood.

II. MATERIALS AND METHOD

A. Materials and Equipment

The materials used were 20 Sitka spruce boards taken from 10 logs with the width and thickness of each board 85 mm and 40 mm respectively; and rubinate resin as the chemical to be impregnated into the boards. The resin chemical (rubinate 1780) was provided by Huntsman Polyurethane Australia and is a typical di-isocyanate resin, which is a “benchmark” resin used for wood and wood-based products production. The logs were originally from a 1924s plantation in Beech Forest Plantation, Otway Ranges, about 150 km south-west of Melbourne. The kinds of equipment used were balance, timer, vacuum-pressure treatment vessel (small 25 L), and oven.

B. Method

The experiment was carried out in stages as follows:

1. Sampling and Microwave Conditioning Process

The boards were dried with microwave energy at 12 kW and 13.33 mm/s speed. The microwave-drying process was carried out using the wave-guide applicator developed by the University of Melbourne. Afterward, each dried Sitka spruce board was cut into five samples of around 410 mm in length, 85 mm in width and 40 mm in thickness. Biscuits at a length of 20 mm were taken between the samples and were used to determine the initial moisture content of the samples (Figure 1).

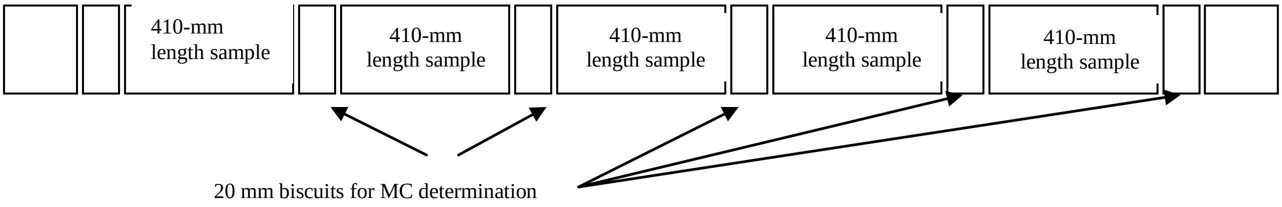

Figure 1. Sampling pattern for biscuits for initial moisture content determination
Gambar 1. Pola pengambilan contoh uji kadar air

2. Treatment Process

The samples were weighed before being stacked in the vessel. Afterwards, the vessel was closed and a vacuum (–85 kPa) was applied for five minutes. Subsequently, rubinate 1780 was introduced into the vessel, and pressure (200 kPa) applied for five minutes. Finally, the timber was removed from the vessel and drained before being reweighed.

3. Data Collection and Analysis

The data collected were green and oven dry mass of the biscuits, the dimension and weight of post-microwave treated samples; and post-treatment weight of the samples. The initial moisture content and density of the samples were determined with formula 1 and 2, while the uptake of rubinate resin was counted with formula 3.

$$\text{Moisture Content (\%)} = \frac{\text{green mass} - \text{oven dry mass}}{\text{oven dry mass}} \times 100\% \quad \ldots\ldots\ldots\ldots \quad \text{(formula 1)}$$

$$\text{Density (g/cm}^3\text{)} = \frac{\text{initial weight of samples (g)}}{\text{initial volume of samples (cm}^3\text{)}} \quad \ldots\ldots\ldots\ldots \quad \text{(formula 2)}$$

Rubinate uptake (g) = post-treatment weight (g) – post-microwave weight (g) (formula 3)

The data were then tabulated in table with moisture content and density as the independent variables and rubinate uptake parameter as the dependent variable. Mean and standard deviation values of each data were calculated. To assess the influence of moisture content and density on rubinate uptake, the data gathered were analyzed with linear regression analysis. Using SPSS 12 software, the analysis procedures were carried out subsequently as follow:

(i) Colinearity test to investigate the correlation between the independent variables observed. The test could be continued if there was no correlation between independent variables.

(ii) F- test to assess the accuracy of selected regression model; and

(iii) Partial test/t-test to assess the influence of moisture content and density on rubinate uptake.

III. RESULTS AND DISCUSSION

Table 1 showed the result of rubinate impregnation, the moisture content and density of each sample used in the experiment. As read, the initial moisture content of the samples used ranged from 5,4% to 17,55%, the density ranged from 0,33 g/cm^3 to 0,56 g/cm^3, and the rubinate uptake by the samples ranged from 54,5 g to 210,9 g.

Table 1. Rubinate uptake (g), initial moisture content (%) and density (g/cm^3) of each sample used in the experiment

Tabel 1. Penyerapan rubinate (g), kadar air awal (%) dan kerapatan (g/cm^3) dari masing-masing sampel yang digunakan dalam pengujian

Samples (*sampel*)	MC* (*KA*)	Density (*kerapatan*)	Rubinate uptake (*penyerapan rubinate*)	**Samples (*sampel*)**	MC* (*KA*)	Density (*kerapatan*)	Rubinate uptake (*penyerapan rubinate*)
	%	g/cm3	g		%	g/cm3	g
1	7.80	0.40	124.8	**51**	9.11	0.39	96.6
2	9.31	0.51	109.8	**52**	8.41	0.45	169.7
3	6.78	0.46	88.2	**53**	9.06	0.54	122.4
4	5.40	0.48	91.7	**54**	6.77	0.35	116.6
5	7.44	0.42	124.3	**55**	11.96	0.42	77.8
6	8.48	0.37	210.9	**56**	11.51	0.49	108.4
7	9.23	0.40	109.3	**57**	11.69	0.44	81.1
8	8.12	0.48	120.7	**58**	5.58	0.40	141.6
9	10.82	0.41	113.8	**59**	9.86	0.44	75.7
10	9.79	0.38	123.3	**60**	9.18	0.36	89.5
11	7.26	0.36	97.1	**61**	5.52	0.43	195.4
12	7.80	0.46	118.3	**62**	10.39	0.45	100.4
13	9.84	0.48	127.9	**63**	7.93	0.41	115.0
14	6.61	0.46	88.8	**64**	9.62	0.38	144.5
15	9.73	0.38	92.5	**65**	6.92	0.34	108.7
16	8.82	0.40	107.3	**66**	13.60	0.45	74.6
17	8.09	0.48	82.5	**67**	11.64	0.45	143.4
18	8.85	0.45	99.4	**68**	11.52	0.44	83.8
19	10.74	0.33	92.6	**69**	8.65	0.36	143.8
20	10.08	0.39	95.5	**70**	8.68	0.42	73.3
21	7.36	0.43	103.0	**71**	10.03	0.37	116.8
22	8.94	0.44	107.7	**72**	5.74	0.43	120.6
23	7.27	0.46	77.1	**73**	7.81	0.56	101.0
24	5.59	0.42	101.3	**74**	7.17	0.41	115.8
25	9.73	0.46	87.7	**75**	7.71	0.36	100.6
26	8.30	0.42	86.0	**76**	17.55	0.48	75.1
27	9.25	0.48	100.6	**77**	10.60	0.46	118.2

Samples (*sampel*)	MC* (*KA*)	Density (*kerapatan*)	Rubinate uptake (*penyerapan rubinate*)	**Samples (*sampel*)**	MC* (*KA*)	Density (*kerapatan*)	Rubinate uptake (*penyerapan rubinate*)
	%	g/cm3	g		%	g/cm3	g
28	9.57	0.41	103.2	**78**	10.39	0.42	79.9
29	10.66	0.34	99.3	**79**	7.94	0.41	99.6
30	10.05	0.39	72.3	**80**	9.82	0.42	78.3
31	8.67	0.42	95.2	**81**	10.62	0.37	80.4
32	9.12	0.49	127.4	**82**	6.35	0.42	113.9
33	7.02	0.40	97.0	**83**	9.52	0.46	81.4
34	5.54	0.43	93.6	**84**	7.63	0.39	110.3
35	8.71	0.37	127.9	**85**	7.87	0.40	80.0
36	8.44	0.45	100.1	**86**	16.90	0.48	69.9
37	9.29	0.47	88.6	**87**	12.08	0.45	54.5
38	10.90	0.40	84.0	**88**	8.58	0.56	78.6
39	11.09	0.35	87.6	**89**	5.96	0.41	128.8
40	8.18	0.41	98.2	**90**	9.12	0.42	95.4
41	7.80	0.41	92.5	**91**	10.36	0.34	87.3
42	9.13	0.49	99.5	**92**	7.53	0.43	108.2
43	6.66	0.39	95.3	**93**	7.85	0.50	65.6
44	7.00	0.44	77.3	**94**	8.53	0.40	120.4
45	9.28	0.37	92.8	**95**	6.83	0.35	76.2
46	9.30	0.47	86.3	**96**	15.30	0.42	66.3
47	9.23	0.48	86.0	**97**	10.64	0.44	92.2
48	10.52	0.41	103.3	**98**	9.10	0.45	69.2
49	9.25	0.37	108.4	**99**	7.06	0.37	127.2
50	10.65	0.38	96.0	**100**	10.10	0.41	76.4

Explanation (*keterangan)* : * MC = Moisture Content (KA = kadar air)

As previously mentioned, the data in Table 1 was further analyzed with linear regression method. The result of linear regression analysis was summed in Table 2. As read in Table 2, the variance index factor (**VIF**) values of independent variables were below 5, thus it was concluded that there was no multi co-linearity between variables and all independent variables that could be used in the model tested. Therefore, the linear regression model that could be developed for the data was as follow:

$$\mathbf{Y = 160.834 - 3.892\, X_1 - 57.173\, X_2}$$

with Y representing rubinate uptake, X_1 representing initial moisture content (%) and X_2 representing the density of the samples. The model had unadjusted R^2

around 13.0% and adjusted R^2 around 11.2%. This showed that the developed model could explain around 13% of the variety of the Y-value obtained. Though the R^2 values were low, Table 2 also showed that the F-value of the developed model was significant at confidence level of 95%. This showed that simultaneously the independent variables (X_1, X_2) affected the value of dependent variable (Y).

Table 2. Linear regression analysis result
Tabel 2. Hasil analisa regresi linear

Model (*Model*)	**VIF**	**R^2**		**F-test**	**T-test**
		Unadjusted	**Adjusted**		
$Y = 160.834 - 3.892 X_1 - 57.173 X_2$		0.130	0.112	0.001	
Y= Rubinate uptake					
X_1=Moisture content	1.009				0.001
X_2 = Density	1.009				0.253

Further assessment on influence of each independent variable on rubinate uptake was carried out with T-test at confidence level used was 95%. As read in Table 2, the significant value for moisture content variable was 0.001, indicating that moisture content had a significant influence on rubinate uptake.

The significant influence of moisture content on rubinate uptake showed that the dryness level of the wood plays an important role in successfully impregnating wood with rubinate. According to Usta (2004) the existence of moisture content does affect the available void volume inside the wood that can be filled with preservative materials. In general, it is known that if the moisture content is above fiber saturation point, the preservative retention will usually decrease and vice versa (Usta 2004). Furthermore, dependency of rubinate impregnation on initial moisture content of the wood might also be affected by the rubinate character as a resin-based material. Unlike water-based materials, resin-based material is usually more viscous and thus more difficult to flow into the wood (Yuniarti, 2005).

The same t-test procedure as well showed that the significant value for density variable was 0.253. This indicated that the rubinate uptake by microwave-dried samples was not affected significantly by the density variation. Since the samples were collected from trees with similar age, it was preliminary assumed that the density variation was less varied and the microwave phase did not resulted in significant variation change, thus might contribute to the result obtained from this analysis. Further experiment with different ages of trees used for sampling process and wider range of microwave power used for drying process is suggested to be carried out to complete the information already obtained in this experiment.

IV. CONCLUSION AND RECOMMENDATION

The experiment showed that rubinate uptake by Sitka spruce previously microwave-dried at 12 kW and 13.33 mm/s speed was significantly affected by variation in initial moisture content resulting from the radiation phase. Influence of post-microwave density observed was insignificant.

REFERENCES

Alden, H. A. 1997. Softwoods of North America. Forest Products Laboratory. Madison, Wisconsin.

Kartal, S. N. and S. T. Lebow. 2002. Effects of incising on treatability and leachability of CCA-C-treated Eastern Hemlock. Forest Product Journal 52 (2):44-48.

Kollmann, F. F. P. and J. W.A. Cote. 1968. Principles of Wood Science and Technology. Springer-Verlag. Berlin, Germany.

Messner, K., A. Bruce and E. Tucker. 2002. *Making refractory wood species treatable by fungal pre-treatment*. Enhancing the Durability of Lumber and Engineered Wood Products. Forest Products Society. Kissimme (Orlando), Finland.

Usta, I. 2004. The effect of moisture content and wood density on the preservative uptake of Caucasian Fir (*Abies nordmanniana* (Link) Spach.) treated with CCA. Turkish Journal of Agriculture and Forestry 28 1-7. Tubitac.

Walker, J.C.F, B.G. Butterfield, T.A.G. Langrish, J.M.Harris,. & J.M. Uprichard, 1993. *Primary Wood Processing:Principles and Practices*.Edisi 1. Chapman & Hall, London.

Yuniarti, K. 2005. The use of microwave technology for processing Sitka spruce (*Picea sitchensis* (Bong.) Carr.). Tesis. Faculty of Land and Food Resources. University of Melbourne. Melbourne. Tidak dipublikasikan.