Fossil Carbon Content in Wood-Based Materials Estimated by Elemental Analysis

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INTRODUCTION

Wood-based materials such as plywood and particleboard are mostly carbon-neutral products that contribute to a low-carbon society. However, most wood-based materials also contain synthetic adhesives, such as urea-, melamine-, and phenolic-formaldehyde resins. They emit fossil CO_2 when incinerated at the end of their life. Thus far, the IPCC inventory guidelines (IPCC 2006 and IPCC 2019) have not yet provided emission factors for this source. Focusing on the fact that urea and melamine resins contain nitrogen, and phenolic resin-based adhesives contain sodium as a pH adjuster, this study developed a method to estimate the adhesive content in wood-based materials by elemental analysis.

MATERIALS AND METHODS

The samples were veneer, solidified adhesives, plywood with known adhesive concentration (hereafter referred to as "reference plywood"), and commercial plywood. Three types of veneers, made from Japanese cedar, Japanese red pine, and imported lauan, were used. These veneers and adhesives (urea resin, melamine resin, and phenol resin) were used to make the reference plywood at three adhesive application levels: 55 g/m^2, 70 g/m^2, and 85 g/m^2. The samples were cut into 15 cm squares, crushed by Sanriki Seisakusho SF-1, and then pulverized with a mill (Osaka Chemicals D3V-10) to make the particle size around 0.2 mm to 0.5 mm. The pulverized samples were subjected to elemental analysis. C, H, and N were analyzed by JIS M 8819, and Na and Ca were analyzed by microwave acid-decomposition ICP emission spectrometry. In addition, Cl was analyzed for commercial plywood.

RESULTS AND DISCUSSION

Figures 1 and 2 show that fossil carbon concentrations in the reference plywood increased in proportion to the nitrogen and sodium concentrations. The outliers of lauan veneer in Figure 2 suggested an absorption of seawater during storage at sea level. These observations led to an equation that estimates fossil carbon concentrations in plywood (Eq. 1). The coefficients for N and Na, 0.8252 and 6.123, respectively, denote the slopes of the regression lines in Figures 1 and 2. The coefficient for Cl, 0.6485, is the ratio between the atomic masses of Na over Cl, which corrects for seawater absorption.

$$\boldsymbol{Fossil\_C = 0.8252 \times N + 6.123 \times max\{Na - 0.6485 \times Cl, 0\}} \qquad (\boldsymbol{Eq\ 1})$$

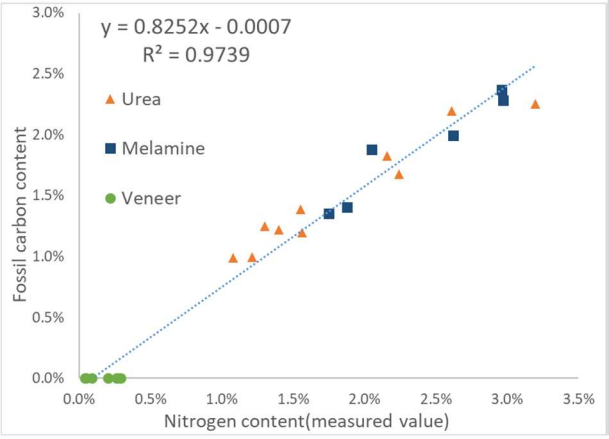

Figure 1 Correlation between nitrogen and fossil carbon concentration in the reference plywood.

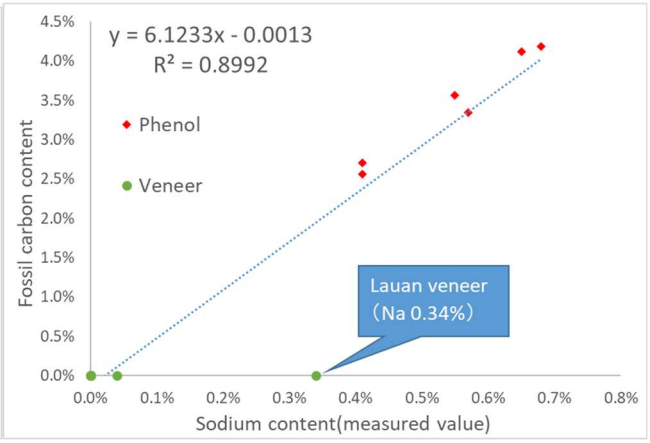

Figure 2 Correlation between sodium and fossil carbon concentration in the reference plywood.

The fossil carbon concentrations in the commercial plywood estimated by Eq. 1 (Table 1) generally fell within the range of those in the reference plywood with corresponding adhesives. One exception was sample No. 41, whose estimated fossil-C level was 4.11%, exceeding the range of fossil-C (1.0% to 2.3%) for the reference plywood with urea resins. This was probably caused by the smaller per-layer thickness of No. 41 (2.5 mm/3 ply) compared to the reference plywood (9 mm/3 ply).

Table 1 Estimated fossil carbon concentrations in the commercial plywood

No.	Name	N (%-dry)	Na (%-dry)	Cl (%-dry)	Fossil-C (%-dry)	Estimated resin type
35	Lauan plywood (non-water resistant)	3.41	0.12	0.25	2.81	Urea
36	Lauan plywood (type 1)	3.89	0.04	0.11	3.21	Melamine
37	Japanese cypress plywood 9 mm	0.45	0.51	<0.01	3.47	Phenol
38	Japanese cypress plywood 12 mm	0.37	0.44	<0.01	2.98	Phenol
39	Plywood for concrete form (no coating)	2.07	0.01	0.01	1.73	Melamine
40	Plywood for concrete form (urethane coating)	2.68	0.04	<0.01	2.44	Melamine + urethane
41	Curing plywood 2.5 mm (type 2)	4.98	0.01	0.02	4.11	Urea
42	Japanese linden plywood 9 mm (type 2 one side)	1.77	0.01	0.06	1.46	Urea
43	Lauan plywood (special type)	0.27	0.63	0.02	4.00	Phenol
44	Lauan plywood (special type)	0.21	0.43	<0.01	2.79	Phenol

Cl concentration below the detection limit were replaced by half the detection limit when used in Eq.1

CONCLUSION

An estimation method for fossil carbon content in plywood was developed based on the elemental analysis of the reference plywood. The method used a simple equation requiring only N, Na, and Cl concentrations in the samples and was successfully applied to commercial plywood samples.

ACKNOWLEDGEMENT

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