Conversion and Recycle of Wood Residues in Rubber Wood Process

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1. Introduction

In Southeast Asia Countries, rubber wood is processed to manufacture the parts of household furniture. A typical timber process in these countries at present is shown in **Figure1** (enveloped by thin line). In this process, a portion of wood residues are being thrown away to isolated country site or dumping site and it is burned at open area, both legally and illegally. These methods of disposal do cause accidental forest burning and release of hazardous gases into the environment[1]. Besides, many of the chemical preservatives being used in preventing the wood products against fungus, molds, and termites are highly toxic and can easily diffuse into the environment[2]. These problems are quite serious in these countries. By the way, wood vinegar, which is obtained by pyrolysis or carbonization of wood, have the potential of preserving wood[3,4].

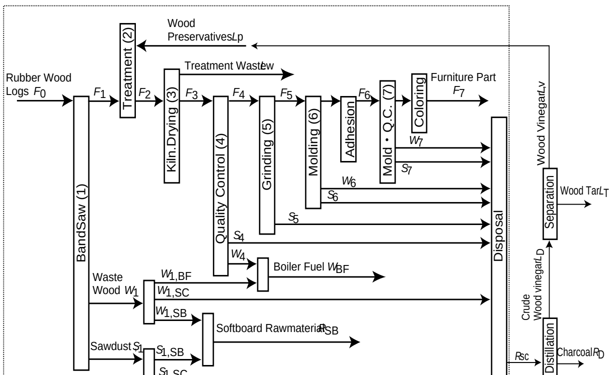

Fig.1 Schematic diagram of rubber wood process

The aim of this study is to improve the rubber wood process by conversion of the wood residues to wood vinegar preservative and the recycle of this. In the first stage, the wood vinegar from rubber wood was characterized, especially to examine the preservative properties. In the second, the rubber wood process was improved and was simulated to study its viability.

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2. Characterization of Wood Vinegar from Rubber Wood

2.1 Experimental

Crude wood vinegar (CWV) used in this study was obtained from Malaysia charcoal factory. The vinegar was collected under natural condensation of the smoke while carbonization of rubber logs and sawn waste wood. The sample is reddish brown in color.

Simple distillation of CWV was carried out to remove the tar fraction and to obtain the wood vinegar (WV). Density and pH value of the WV samples were determined using standard hydrometer and glass conductor pH meter, respectively. The WVs and tar were analyzed by a gas chromatograph (FID) with a capillary column to determine mass fractions of the components shown in **Table 1**, which are preservatives and a Karl Fishcer titrator to determine water content.

2.2 Results and discussion

The density, pH, water content, and tar content of the CWV are summarized in **Table 2**. The experimental values of density, pH, and water content fell within the ranges prescribed[5,6]. The CWV used in this study had similar physical properties as typical CWV. From simple distillation of CWV, result shows that CWV from rubber wood contain 2% wood tar. This result also fell within the acceptable range.

Table 1 Components contained in wood vinegar from rubber wood

Component	Mass fraction in CWV [–]	Fractional recovery by distillation [–]	
		in WV	in Tar
Acetone	0.0008	0.53	0.47
Methanol	0.0016	1.00	0.00
Acetic Acid	0.0422	0.96	0.04
Guaiacol	0.0005	0.98	0.02
Phenol	0.0005	0.99	0.01
O-cresol	0.0004	0.44	0.56
M-cresol	0.0001	0.52	0.48
P-cresol	0.0004	0.24	0.76
Syringol	0.0019	0.25	0.75

Table 2 Physical properties of CWV

	This work	Previous work[3,6]
Density [$g \cdot cm^{-3}$]	1.014	1~1.050
pH	2.98	1.97~3.49
Water content [–]	0.87	0.8~0.9
Tar content [–]	0.02	0.02~0.11

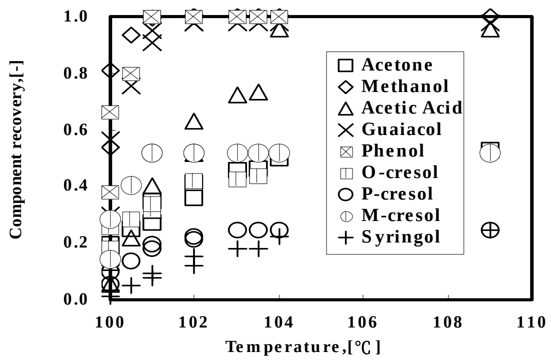

Fig.2 Fractional recovery by distillation

The WV compositions and fraction recovery are shown in Tab. 1.The composition recovered at different temperatures are shown in **Figure 2**.The most abundant component in wood vinegar is acetic acid. This is likely to be responsible for the high level of acidity of the CWV as indicated by it's pH value. In preservative, aldehydes or ketones react with phenols to form a layer of membrane on wood surface. This membrane prevents water from getting in contact with the wood, which is necessary condition for bacillus to survive. Guaiacol and Syringol are also a kind of natural preservative to wood. Both compositions are originally contained in tree itself[7]. Cresols also have been reported as an ingredient in preservatives.

Regarding to the preservative compositions recovery result, the first and last fractions were collected at 100 °C and 109 °C respectively. Fig.2 shows that complete separation of the WV was accomplished at 109 °C. This indicated that simple distillation can be used successfully in separating the preservative compositions from wood tar.

These experimental results showed that WV from rubber wood has potential of wood preservatives.

3. Improvement of Rubber Wood Process

3.1 Outline of the process

The improved process is shown also in Fig.1. The rubber wood residues are carbonized to produce CWV and charcoal (dry distillation). This CWV is separated into the WV and tar fraction by distillation. Thus obtained WV is recycled to the treatment step in the process as a preservative. By this conversion and recycle, the amounts of dumping and burning wood residues and harmful preservative effluents can be reduced.

3.2 Equations for the process and calculation

The basic equations are the simple material balances (omitted here) and is defined in **Table 3**.

The principal assumptions, specifications and conditions are shown in Table 3. The ω_2 and X_V were estimated from the above experimental result of the density and fraction of WV in CWV, respectively. The flow rate of the feed rubber wood, F_0, was fixed at $1.6{\times}10^6$ t·year^{-1}[8].

Under these specifications and conditions, the mass flow rate of wood vinegar that can be produced, L_V, that of wood preservatives, L_P, and so forth were calculated and were compared with each other.

Table 3 Principal parameters used for calculation

Parameter (definition)		
α_1 (=F_1/F_0)	[–]	0.15~0.20
α_4 (=F_4/F_3)	[–]	0.97
α_5 (=F_5/F_4)	[–]	0.95
α_6 (=F_6/F_5)	[–]	0.85
α_7 (=F_7/F_6)	[–]	0.97
β_1 (=W_1/F_0)	[–]	0.77
β_6 (=W_6/F_5)	[–]	0.13
β_7 (=W_7/F_6)	[–]	0.02
γ_4 (=S_4/F_3)	[–]	$1.1{\times}10^{-3}$~$6.6{\times}10^{-3}$
ω_2 (=L_P/F_1)	[–]	0.10
$\varphi_{1,BF}$ (=$W_{1,BF}/W_1$)	[–]	0.40~0.80
$\varphi_{1,SB}$ (=$W_{1,SB}/W_1$)	[–]	0.20
X_D (=L_D/R_{SC})	[–]	0.15
X_V (=L_V/L_D)	[–]	0.98

Table 4 Principal results of calculation

α_1	[–]	0.20
γ_4	[–]	$1.1{\times}10^{-3}$
$\varphi_{1,BF}$	[–]	0.60
F_0	[t·yr^{-1}]	$1.60{\times}10^6$
R_{SC}	[t·yr^{-1}]	$3.56{\times}10^5$
L_V	[t·yr^{-1}]	$5.20{\times}10^4$
L_P	[t·yr^{-1}]	$3.29{\times}10^4$

3.3 Results and discussion

An example set of calculated results are summarized in **Table 4**. The mass flow rate of wood vinegar from wood residues, L_V, were comparable with or larger than that of wood preservatives required for the treatment step, L_P. Further, the energy balance etc. should be estimated as well.

4. Conclusion

The experimental results showed that the wood vinegar prepared from rubber wood had the potential to preserve woods. In the process calculation based upon the experimental results, the rubber wood process could be improved by conversion of the wood residues into the wood vinegar and recycle of this. Consequently, this was proposed as a way to solve environmental problem in Southeast Asia countries.

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