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Extractive contents of *Acacia aulacocarpa* wood grown in Indonesia

Abstract

Acacia aulacocarpa timber is distributed in several regions of Indonesia. Although the wood has been utilized for various end products, information on its wood properties remains limited. This study aims to provide information on inter-tree and intra-tree variations in extractive contents. The samples used in this study were three *A. aulacocarpa* individual trees (27 years) grown in Wanagama Educational Forest, Gunung Kidul, Yogyakarta. The variables were radial direction (inner heartwood, outer heartwood, and sapwood) and vertical direction (bottom, middle, and top parts). The sawdust samples were extracted successively using *n*-hexane, ethanol, and hot-water solvents. Then, the total phenolic content was (TPC) measured in ethanol soluble extracts. The *n*-hexane, ethanol (ESE), and hot-water (HSE) soluble extractives of the three individual trees ranged from 0.24-0.79%, 3.33-10.88%, and 0.80-1.52%, respectively. Total extractive contents (TEC) and total phenolic contents (TPC) ranged from 4.60-13.18% and 100-398 mg GAE/g, respectively. Analysis of variance showed that radial direction significantly affected ESE, HSE, TEC, and TPC levels. A significant difference between sapwood and heartwood was also observed. However, no significant differences were found between inner and outer heartwood. No significant effect of vertical direction was observed for any parameters. A moderate significant correlation (r=0.69**) was found between ESE and TPC values.

Keywords: wood chemistry, heartwood, within-tree, phenolics, axial direction

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Introduction

Acacia aulacocarpa A. Cunn. ex Benth is an Australian endemic plant naturally distributed from northern New South Wales to eastern and northern Queensland.[1] In Indonesia, it has not been found growing naturally. Although its distribution is quite extensive, its population is limited and classified as near threatened by the IUCN Red List.

A. aulacocarpa wood is often used as a raw material for pulp, furniture, shipbuilding, and handicrafts. Despite its widespread utilization, research on these wood properties remains limited, particularly regarding its extractives. One study described the general chemical properties of *A. aulacocarpa* wood grown in Thailand.[2] Extractives are related to wood durability and quality, which in turn impact its use and application. The effect of extractives on the properties of *A. aulacocarpa* wood pulp has been studied in previous reports.[3,4]

As secondary metabolites, extractives are affected by various factors, including within-tree variation.[5,6] The effect of position within the tree has previously been studied in *Acacia mangium*[7] and *Acacia* hybrid[8] which showed different patterns. Therefore, this study aims to determine the effect of radial and vertical directions on the extractive content of *A. aulacocarpa* trees grown in Indonesia.

Material and methods

Wood material

The material used in this study comprised three *A. aulacocarpa* individual trees collected from Wanagama Educational Forest, Gunungkidul, Yogyakarta Special Region, at 27 years of age. The trees' total height, merchantable height, and diameter at breast height were 22-26 m, 8-12 m, and 30-34 cm, respectively. The trunks of *A. aulacocarpa* trees (Figure 1) were felled 20 cm above the ground surface to the merchantable height. Each tree was then divided into three parts, namely the bottom, middle, and top parts. For each part, a disk (6 cm in thickness) was cut. Samples were taken by drilling the outer heartwood (2 cm from the sapwood boundary), inner heartwood (2 cm from the pit), and sapwood (2 cm from the bark). Each part was converted into wood sawdust (40-60 mesh size) to determine the extractive content.

Figure 1 *Acacia aulacocarpa* tree and its wood discs.

Determination of extractive contents

A total of 5 g (oven-dry equivalent) of sawdust was successively extracted using a soxhlet apparatus with *n*-hexane and ethanol solvents for 8 hours. The extracts were then evaporated to remove the solvents. Subsequently, hot water extraction was conducted by extracting the residue in a water bath at 100°C for 3 hours.[9] The extractive content for each solvent was determined based on the percentage between the dry weight of the extract and the initial sawdust weight. The total extractive contents were determined by summing all individual extractive values.

Determination of total phenolic content

The total phenolic content was measured in the ethanol extract of *A. aulacocarpa* wood mentioned above. The absorbance value using a visible spectrophotometer was obtained by dissolving 5 mg of ethanol extract in 5 ml of ethanol to obtain a concentration of 1000 ppm. From this solution, 0.5 ml was taken, and 2.5 ml of 10% Folin-Ciocalteu reagent was added. After shaking and allowing it to stand for 2 minutes, 2 ml of 7.5% Na_2CO_3 was added, and the mixture was left for 1 hour at room temperature. The solutions were then read at a wavelength of 765 nm. Calibration was performed using gallic acid. Gallic acid standards were prepared at six concentrations: 1000 ppm, 500 ppm, 250 ppm, 125 ppm, 62.5 ppm and 31.25 ppm. The results were expressed as gallic acid equivalents.[10]

Statistical analysis

The variation in extractive contents was analyzed using two-way analysis of variance (ANOVA) followed by Tukey's post-hoc test ($p = 0.05$). Pearson's correlation coefficients were used to determine the relationship between ethanol soluble extractive content and total phenolic content. The data were analyzed using SPSS-Win 16.0.

Results and discussion

Extractive contents

Successive extraction of soluble compounds from *A. aulacocarpa* in this study used several solvents based on polarity levels. The amounts of *n*-hexane soluble extractives (HSE), ethanol soluble extractives (ESE), and hot-water soluble extractive (WSE) ranged from 0.1-1.19%, 2.74-12.96%, and 0.66-1.88%, respectively. The total extractive content (TEC) ranged from 4-7.3% in the sapwood, 10.11–14.45% in the outer heartwood, and 7.14–14.57% in the inner heartwood. The average values based on radial and vertical positions are presented in Table 1. These ranges were lower than those of *A. aulacocarpa* wood grown in Thailand.[2] The reported ethanol-benzene, ethanol, hot water solubility, and TEC values were 6.80-10.17%, 0.61-0.96%, 9.25-10.92, and 16.66-22.05%, respectively. Compared to *A. mangium* wood (25 years),[7] *A. aulacocarpa* showed lower HSE and TEC values but fell within the range of methanol soluble extractive content. On the other hand, A. *aulacocarpa* had higher extractive contents compared to *A.* hybrid.[8] ANOVA indicated no significant interaction between radial and vertical direction.

Table 1 Extractive contents of *Acacia aulacocarpa* wood (27 years) in vertical and radial directions

	n-hexane extractive content (%)			
Position	**Sapwood**	**Outer heartwood**	**Inner heartwood**	**Average**
Bottom	0.56	0.6	0.79	0.65
Middle	0.46	0.65	0.73	0.61
Top	0.24	0.52	0.56	0.44
Average	0.42	0.69	0.59	
	Ethanol extractive content (%)			
	Sapwood	Outer heartwood	Inner heartwood	Average
Bottom	4.34	9.79	10.88	8.34
Middle	3.33	7.72	10.66	7.24
Top	3.42	8.96	10.01	7.46
Average	3.70 a	10.52 b	8.82 b	
	Hot-water extractive content (%)			
	Sapwood	Outer heartwood	Inner heartwood	Average
Bottom	0.98	1.16	1.52	1.22
Middle	0.8	1.14	1.09	1.01
Top	0.96	1.37	1.27	1.2
Average	0.91 c	1.29 d	1.22 d	
	Total extractive content (%)			
	Sapwood	Outer heartwood	Inner heartwood	Average
Bottom	5.88	11.56	13.18	10.2
Middle	4.6	9.51	12.49	8.86
Top	4.62	10.64	12.5	9.25
Average	5.03 e	12.72 f	10.57 f	

Remarks: Average of three individual trees. The same letters on the same row are not statistically different at $P < 0.05$ by Tukey's test.

Total phenolic content (TPC) in this study was measured from ethanol extracts, and the values ranged from 57.82 to 312.73 SAG/g in the sapwood, 350.76 to 413.61 SAG/g in the outer heartwood, and 342.61 to 450.47 SAG/g in the inner heartwood. All three trees had relatively similar TPC levels, except for tree no. 3, in which the sapwood at the bottom and top parts differed significantly compared to trees no. 1 and no. 2. The average values by radial and vertical position are summarized in Table 2. The TPC values were within the range reported for juvenile teak wood (6 and 8 years).[11]

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Table 2 Total phenolic content of *Acacia aulacocarpa* wood (27 years) in vertical and radial directions

	Total phenolic content (mg GAE/g)			
	Sapwood	**Outer heartwood**	**Inner heartwood**	**Average**
Bottom	222	382	398	334
Middle	189	383	394	322
Top	100	381	366	282
Average	170 a	382 b	386 b	

Remarks: Average of three individual trees. The same letters on the same row are not statistically different at $P < 0.05$ by Tukey's test. GAE = gallic acid equivalent

Effects of radial direction

The radial directions used in this study were sapwood, inner heartwood, and outer heartwood. ANOVA results showed a significant effect of radial direction on ESE, WSE, and TEC. Based on Tukey's test, the values in the sapwood were significantly lower than those of heartwood. However, no significant difference was found between the inner and outer heartwood. Previously, toluene-soluble and total extractive contents were greater in heartwood than in sapwood of teak (11 years), while the reverse was observed for hot-water extractive content.[6] In addition, toluene- and total extractive contents were higher in outer heartwood than in inner heartwood. Higher TPC levels in heartwood than in sapwood were observed in juvenile teak wood.[11] Several other studies also showed that ethanol and hot-water extracts of heartwood were higher than sapwood for *A. mangium*.[7,12] Furthermore, the *n*-hexane extract of heartwood was higher than sapwood in *Acacia mangium*.[5]

In general, non-polar solvents will dissolve compounds such as fats, fatty acids, waxes, and resins.[12,13] This finding suggest that the lipophilic components in *A. aulacocarpa* may not be highly influenced by heartwood formation or the transition from juvenile to mature wood. Ethanol solvent dissolves phenolic compounds, condensed tannins, and flavonoid polymers. Hot water dissolves sugars, starches, gums, and colored substances in wood.[9] Heartwood contains higher phenolic levels than sapwood.[14,15] This indicates that darker heartwood contains more dissolved sugars and colored substances.

The Pearson's correlation analysis confirmed a moderately significant positive correlation between ethanol extractive content and total phenolic content (r=0.69**). This indicates that wood contains more phenolic content when the ethanol extractive content is greater (Figure 2). In an earlier study for *A. mangium* wood, TPC was moderately correlated with extractives in hot water (r=0.39**) and in ethanol-toluene (r=0.79**).[5] Therefore, it is also assumed that there are no considerable differences in phenolic compounds between inner and outer heartwoods of *A. aulacocarpa*.

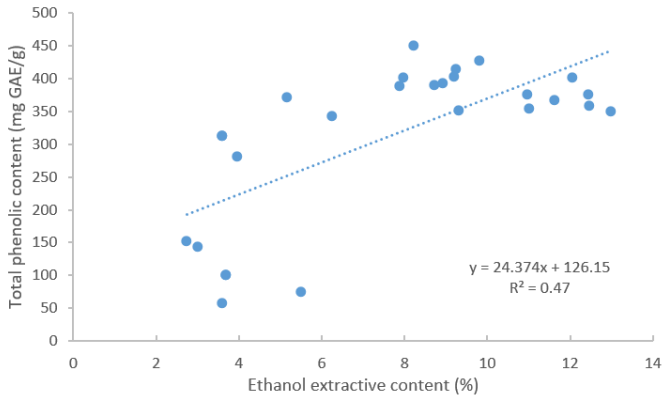

Figure 2 Scatterplots between ethanol extractive content and total phenolic content of *Acacia aulacocarpa* wood (27 years).

Effects of vertical direction

Vertical (axial) direction was divided into bottom, center (middle), and top parts of the trees. ANOVA showed no significant effect on vertical position of the trees. This pattern is similar to *A.* hybrid[8] or a study of acetone-soluble extracts of 36-year-old *Picea sitchensis* wood.[16] Previously, vertical stem analysis of samples obtained from the bottom, center, and top showed the toluene extractive content and total extractive content in the center part of the teak wood (11 years) were lower than other parts.[6] Theoretically, the proportion of juvenile wood is highest at the top of the tree and close to the heartwood. This indicates a small difference in extractive content between juvenile and mature wood in *A. aulacocarpa*.

Conclusion

The amounts of n-hexane, ethanol (ESE), and hot-water (HSE) soluble extractives of the three individual trees ranged from 0.24-0.79%; 3.33-10.88%; and 0.80-1.52%, respectively. Total phenolic contents (TPC) values ranged from 100-398 mg GAE/g. Sapwood exhibited significantly lower values than heartwood in ESE, HSE, total extractive content, and TPC. No significant differences were observed between the outer and inner heartwood for all parameters. The vertical direction did not significantly affect any of the observed parameters.

Acknowledgments

None.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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