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CHARACTERIZATION OF EXTRACTIVE COMPOSITION IN THE WOOD AND BARK OF CAJUPUTI (*MELALEUCA CAJUPUTI* SUBSP. *CAJUPUTI* POWELL.) GROWN IN GUNUNGKIDUL, INDONESIA

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ABSTRACT

The aim of this study was to analyze the extractive composition of the wood and bark of cajuput (*M. cajuputi* subsp. *cajuputi*) to consider the end use material according to the characteristics of the its extractives. Results showed that the extractives properties of *M. cajuputi,* i.e. the contents of *n*-hexane, methanol, hot water extractives and total phenolic content (TPC), flavonoid content (TFC) and total polysaccharides (TSP) were 0.84 to 1.05%, 1.00 to 1.03% and 1.43 to 1.46%, and 19.2 to 38.7 and 23.2 to 27.3 mg GAE/g dried extract, 11.8 to 16.0 and 7.55 to 14.0 mg QE/g dried extract and 79.3 to 102.8 and 148.8 to 165.9 mg Glu/g dried extract, respectively. Bark had higher extractive levels than wood. In addition, TPC and TSP in the bark were greater than in the wood parts, whereas the reverse trend was found in TFC. The relatively high contents of TPC and TFC in the wood and bark suggest that their potential antioxidant properties. Based on the GC-MS analysis, the high content of sterols-steroids (31.4%) and triterpenoids (21.9%) in the bark part will have potential in the field of pharmacology.

KEYWORDS: Extractives, wood, bark, total phenolics, *M. cajuputi* subsp. *cajuputi.*

INTRODUCTION

Cajuput (*Melaleuca cajuputi* subsp. *cajuputi*) known as the cajuput oil producing tree, is one of the most important commercially available essential oils in Indonesia (Pujiarti et al. 2011). This plant belongs to the Myrtaceae family and steam distillation of the leaves, twigs, and stems produces a fragrant essential oil with useful medicinal properties (Farag et al. 2004). The wood is generally hard, medium density, pest resistant, and has a high silica content (Rimbawanto et al. 2017). Cajuput occurs naturally in the Maluku Islands of Indonesia. Cajuput as natural resources in Maluku are managed to produce cajuput oil production. This species is commonly cultivated in Indonesia and is widely cultivated outside its natural range, including in Java, Sumatra, Sumbawa, Kalimantan, and Papua (Kartikawati et al. 2021).

The quality of cajuput essential oil is known to depend on the yield of 1,8-cineole, a pharmacologically active component of aromatic essential oils (Milthorpe et al. 1998). The requirements for high-quality essential oil of cajuput in Indonesia are expected to contain 1,8 cineole in the range of 50–65% according to the Indonesian National Standards (Badan Standarisasi Nasional, 2006). Certain key components of these plants exhibit specific biological activities as well as flavor and aroma. Cajuput is the source of cajuput oil, which is commonly used as ointments and inhalants to treat colds, stomach aches, insect bites, and other ailments (Kartikawati et al. 2021). The leaves are the part commonly used in the production of essential oil. However, other parts such as wood and bark, must be considered to ensure that they are not wasted without being optimally utilized. Therefore, not only essential oil products can be used, but also other derived products (product diversification), which can become better products than just waste.

The bark is typically removed in factories and burned to produce energy, but it has the potential to provide an important renewable raw material for high-value applications (Miranda et al. 2012). Bark is morphologically and chemically heterogeneous and varies widely between softwood and hardwoods as well as between species (Sen et al. 2015). Bark contains most of the same components as wood (cellulose, hemicellulose, pectin, lignin, and extracts), but the proportions are very different, for example, it has a higher content of extracts (Sjöström 1999). The bark is a source of many substances used in applications such as adhesives, medicines, and biocides (Sakai 2001).

Utilization routes for the production of bioactive and highly valuable compounds such as bark extracts are interesting. Some industrial processing wastes (bark, knots, pulp liquor) contain highly valuable extractables such as phytosterols, especially β-sitosterol (Fernandes et al. 2007), lignans (Pietarinen et al. 2006), and triterpenoids (Kolomitsyn et al. 2007). During pulp processing, a small amount of bark usually enters the pulp mill along with the wood chips.

Knowledge of the chemical composition of lipophilic extracts is important for a complete understanding of the phenomena associated with pitch deposition in kraft pulp mills. Lipophilic constituents responsible for the formation and deposition of pitch on pulp and equipment even in small amounts (Back and Allen 2000). However, information regarding the extractive characteristics of the cajuput wood and bark are still very limited, so that sometimes the wood and bark waste from this plant has low value and is not utilized optimally either for pulp and paper or other fields such as pharmacology. Therefore, this study aimed to analyze

the characterization of extractive compounds in the wood and bark of cajuput as a consideration in future application of the material.

MATERIAL AND METHODS

Materials and extraction

The lower part of the wood and bark of cajuput trees harvested from 15 years old trees in the Menggoran area (7.95^0'S, 110.49^0'E), Gunungkidul, Special Region of Yogyakarta. The trees produced from superior *M. cajuputi* seeds developed by the Center of Research and Development for Biotechnology and Tree Improvement, Yogyakarta. Subsequently, the wood and bark were air-dried and ground into a 40-60 mesh powder for chemical analysis. Then, powder of 240 g successively refluxed for 6 h using *n*-hexane, methanol, and hot water solvents. The solution was evaporated by a rotary evaporator. The extract was then dried in an oven (103±2°C) and the extractive content was quantified.

Phytochemical tests

Wood and bark extracts were subjected to phytochemical screening to identify major classes of secondary metabolites. Tests include Mollish for carbohydrates (Browning 1967), frothing for saponins (Kokate 1999), Mayer for alkaloids (Mir et al. 2016), ferric chloride for tannins (Trease and Evans 2002), and sodium hydroxide for flavonoids (Browning 1967).

Determination of total phenolic content

Total phenolic content (TPC) was determined using the Folin-Ciocalteu method (Singleton et al. 1999). Briefly, 2.5 mL of diluted Folin-Ciocalteu phenol reagent and distilled water (1: 9, v/v) were mixed with 0.5 mL of the samples (0.25 mg/mL) in a 9 mL glass bottle. After resting for 2 min, 7.5% aqueous Na_2CO_3 (2 mL) was added and the mixture was left at ambient temperature for 30 min. The absorbance was then measured using a visible spectrophotometer (model VIS-WPA S800+) and the standard solution was tested against a blank value at 765 nm. Additionally, TPC was performed as the mean ± standard deviation of two replication measurements and expressed in milligrams of gallic acid equivalents (mg GAE/g dried extract).

Determination of total flavonoid content

The $AlCl_3$ method was used to determine a total flavonoid content (TFC) (Brighente et al. 2007). Briefly, 2 ml of the samples (0.25 mg/ml) was added to a 2% $AlCl_3 \cdot 6H_2O$ solution, incubated for 1 h, and then left at 20 °C. The absorbance was then read against a blank value at 415 nm using a visible spectrophotometer (model VIS-WPA S800+). TFC was performed as the mean ± standard deviation of two replication measurements and expressed in milligrams of quercetin equivalents (mg QE/g dried extract).

Determination of total soluble polysaccharides

Total soluble polysaccharides (TSP) were determined according to DuBois et al. (1956). After mixing 1 mL of the sample solution (0.25 mg/mL) with 1 mL of 5% phenol reagent

solution (5 g in 100 mL of distilled water), 5 mL of sulfuric acid (98%) was added. Furthermore, the mixture was left at room temperature for 20 min and the absorbance of the standard solution was measured against the blank value at 490 nm using a visible spectrophotometer (model VIS-WPA S800+). TSP was determined as the mean ± standard deviation of two replication measurements and expressed in milligrams of glucose equivalents (mg Glu/g dried extract).

Analysis of gas chromatography-mass spectrometry (GC-MS) analysis

Dried *n*-hexane extracts of the samples were analyzed by gas chromatography-mass spectrometry (GC-MS)-QP 2010 (Shimadzu, Japan). GC-MS was performed under the following conditions: RTX-5MS capillary column (30 m × 0.25 mm I.D. and 0.25 μm; GL Sciences, Tokyo, Japan); column temperature from 70°C (2 min) to 290°C at 5°C/min. Injection temperature was 200□. The detection temperature was 285□. The collection mass ranges from 50 to 666 amu using helium as the carrier gas. The method used derivatization with trimethylchlorosilane (TMCS), and the samples were derivatized before injection according to a modification of the method described by Moldeveanu and David (2018). Subsequently, 100 μL in a mixture of N,O-bis-(trimethylsilyl)-trifluoroacetamide (BSTFA) and 1% trimethylchlorosilane (TMCS) was added to 2 mg of each dry *n*-hexane extract diluted with 100 μL pyridine. Then, the resultant mixtures were ultrasonicated at room temperature and the mixtures were heated for 30 min at 103□. Before injecting 1 μL (1 mg/mL) into the GC-MS, 1 mL of *n*-hexane solution was added to the mixture and sonicated at room temperature. Compounds were identified by comparing experimental GC-MS data with the NIST-MS library (NIST 2011) and study literatures. For the quantification, the relative area percentage of the lipophilic constituents were expressed as percentages obtained by a computerized integrator based on the peak area from total ion chromatography (TIC), all relative response factors being taken as one.

RESULTS AND DISCUSSION

Extractive content

Theoretically, a non-polar solution (*n*-hexane) removes fats, waxes, resins, and sterols (Lukmandaru 2011). On the other hand, cold and hot water-soluble extracts dissolve inorganic salts, sugars, tannins, phenolic compounds, pigments, pectins, free acids, etc. (Fengel and Wegener 1989; Han and Rowell 1997). Furthermore, methanol, methanol-water (70/30, v/v), and ethanol-water (80/20, v/v) extracts to identify sugar components. Average of *n*-hexane, methanol, and hot water extractives content were ranged from 0.84 to 1.05%, 1.00 to 1.03%, and 1.43 to 1.46% based on oven-dried wood, respectively (Fig. 1).

This result was lower compared to previous study in ***M. cajuputi*** wood (Yuningsih et al. 2022). The authors reported that the extractive content of benzene and hot water were 4.01% and 8.73%, respectively. Subsequently, in the same family (Myrtaceae), the levels of ethanol and hot water extracts were also lower in comparison to young ***E. pellita*** wood from progeny trials in Wonogiri (Fatimah et al. 2013) and from South Borneo (Lukmandaru et al. 2016) with

the values ranged from 3 to 6.4% (ethanol-toluene extract) and from 0.8 to 3.5% (hot water extract). Arisandi et al. (2019a) also reported that ethanol and hot water extractive levels ranged from 1.58 to 4.95%, and 0.64 to 1.89% in *E. pellita* wood and bark. Meanwhile, the non-polar solution (*n*-hexane) in this study was slightly higher than that reported by Arisandi et al. (2019a) for the same species in dichloromethane extract (0.19 to 0.38%).

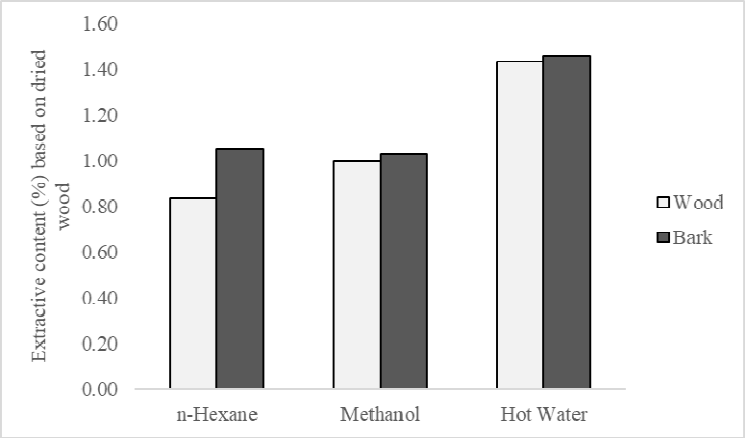

Fig. 1: The extractive content of n-hexane, methanol, and hot water (% based on oven-dried sample) in the wood and bark of M. cajuputi.

In radial variation, the extractive content in the bark was greater than in the wood. These results were consistent with those reported in a previous study in *E. globulus* of the same family (Myrtaceae), where methanol-water extract was much more abundant in the bark than in the wood parts (Luís et al. 2014). In general, extractive content in the bark was larger compared to the wood parts (Fengel and Wegener 1989). Bark is morphologically and chemically heterogeneous and varies widely between hardwoods and softwoods as well as between species. Bark contains most of the same components as wood (cellulose, hemicellulose, pectin, lignin, and extracts), but the proportions are very different. For example, it has a higher content of extracts (Sjöström and Westermark 1999).

Phytochemical screening

Initial screening using qualitative methods revealed that cajuput wood and bark contains alkaloids, flavonoids, saponins, tannins and carbohydrates. However, alkaloids were detected only in the wood and bark of *n*-hexane extracts (Tab. 1). Flavonoid and tannin contents were detected higher in the bark than in the wood parts. Sládková et al. (2015) reported that tree bark contains significantly higher levels of extractives than wood, such as lignans and neolignans (phenylpropanoids), norlignans (diphenylpentanes), flavonoids (diphenylpropanes), stilbenes (bibenzyls, phenantrenes), isoprenoids (tropolones, sesquiterpenes), tannins (condensed catechins, hydrostilbenes, hydrolysable gallotannins, ellagotannins), and other compounds such as saccharides, triglycerides, waxes, phenols and alkaloids. Meanwhile, saponin and carbohydrate contents were detected relatively equally in both methanol and hot water extracts in the wood and bark parts.

Tab. 1: Qualitative analysis of alkaloid, flavonoid, saponin, and carbohydrate test of M. cajuputi wood and bark.

Solvents	Alkaloid		Flavonoid		Saponin		Tannin		Carbohydrates	
	Wood	Bark	Wood	Bark	Wood	Bark	Wood	Bark	Wood	Bark
n-Hexane	(+)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Methanol	(-)	(-)	(+)	(++)	(+)	(+)	(+)	(++)	(++)	(+++)
Hot water	(-)	(-)	(+)	(++)	(+)	(+)	(+)	(++)	(+++)	(+++)

Note: (-): not detected, (+): low detected, (++): moderately detected, (+++): highly detected.

Total phenolics, flavonoids, and polysaccharides

Total contents of phenolics, flavonoids, and polysaccharides in methanol and hot water extracts ranged from 19.2 to 38.7 and 23.2 to 27.3 mg GAE/g dried extract, 11.8 to 16.0 and 7.55 to 14.0 mg QE/g dried extract, 79.3 to 102.8 and 148.8 to 165.9 mg Glu/g dried extract, respectively (Fig. 2).

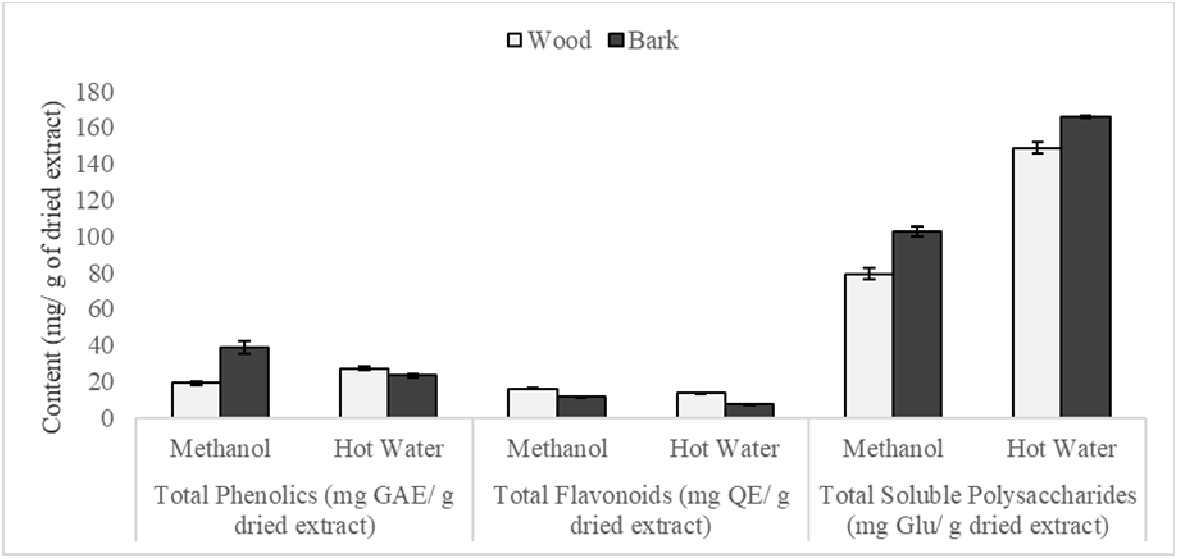

Fig. 2: Total phenolics, total flavonoids, and total polysaccharides (means of two replications) in the wood and bark of M. cajuputi.

The phenol content was lower compared to the previous studies in cajuput (160 mg GAE/g dried extract) and gelam wood (93.6 mg GAE/g dried extract) (Batubara et al. 2012; Ramadhan and Forestryana 2021). The phenol levels were also lower in this study compared to previous studies of the same family (Myrtaceae), such as wood and bark of *E. pellita* and *E. globulus* (Vázquez et al. 2008; Santos et al. 2011; Arisandi et al. 2019a). The TPC values in methanol/ethanol and hot water extract of these species were 368.4 to 632.5 and 410 mg GAE/g dried extract and 199.9 to 429.6 and 155 mg GAE/g dried extract, respectively. However, the results of this study were almost the same as the TPC values found in *E. globulus* wood (9.4 mg GAE/g dried extract) and bark parts (32.4 mg GAE/g dried extract) and were greater when compared to 3 *Eucalyptus* species of the bark (*E. camaldulensis*, *E. globulus*, and *E. rudis*) ranged from 5.89 to 7.51 mg GAE/g dried extract (Cadahía et al. 1997).

With regard to TFC, the TFC levels in this study were higher than in the studied by Batubara et al. (2012) who reported a TFC of 5.2 mg QE/g of methanol dried extract in

M. cajuputi wood. However, these results were almost the same compared to studies in wood and bark of *E. globulus* (8.50 to 12.9 mg QE/g of dried methanol extract) (Luís et al. 2014), but lower than 10 wood clones of *Eucalyptus* spp (73.6 to 256 .8 mg QE/g of dried methanol extract) (Vieira et al. 2021). Subsequently, the TSP content in the wood and bark of cajuputi (*M. cajuputi*) in this study was found to be slightly higher than that reported by Masendra et al. (2020). The authors found that the TSP in the inner and outer bark were 97.3 and 148.2 mg Glu/g of methanol dried extract and 91.5 and 78.7 mg Glu/g of hot water dried extract, respectively. However, the TSP in this study was smaller than that of 1- to 5-year-old *S. mahogani* wood, with TSP ranged from 160 to 688 mg Glu /g of hot water dried extract (Arisandi et al. 2021).

In the radial variation, the TPC and TSP in the bark was generally larger than in the wood parts. This pattern was similar to previous studies on *E. globulus,* where TPC values were higher in the bark than in the wood (Luís et al. 2014). This may be related to the tree`s defense mechanism. Gao et al (2007) reported that sapwood is rich in nutrients like sucrose and glycosides, whereas heartwood and outer bark are poor in these nutrients. Thus, to protect living tissues from biological attack, outer bark and heartwood are rich in secondary metabolites such as flavanols and other phenolic compounds. The reverse trend was observed in TFC, where wood had a larger TFC than bark parts. The similar trend was observed in *E. globulus*, where the wood part showed higher TFC in methanol and ethanol dried extract compared to the stump bark (Luís et al. 2014). Extractive levels are usually higher in the bark than in the wood part, and TPC has likewise been shown to be higher in the bark parts (Sjöström 1993; Chow et al. 2008). However, some studies have reported higher polyphenol levels in the wood than in the bark parts (Chang et al. 2001; Wang et al. 2004). The higher TFC in the wood compared to the bark of cajuput (*M. cajuputi*) may help explain the high resistance of this wood to wood-destroying organisms. Furthermore, more polyphenol compounds were detected in the methanol extract than in the hot water extract (Fig. 2). This may be because the methanol solvent dissolves many of the active compounds (Batubara et al. 2009).

GC-MS Analysis

General composition

The GC-MS analysis detected lipophilic constituents, including hydrocarbons, fatty acids, resin acids, fatty alcohols, sterols and steroids, triterpenoids, and others (Tab. 2).

Tab. 2: Lipophilic constituents of n-hexane extract from M. cajuputi wood and bark.

Compounds	**Formula**	**Wood (%)**	**Bark (%)**
Hydrocarbons**		**3.11**	**13.0**
Pentadecane	$C_{15}H_{32}$	-	2.71±0.32
Cetene	$C_{16}H_{32}$	1.21±0.25	1.47±0.08
Hexadecane	$C_{16}H_{34}$	-	3.47±0.20
Heptadecane	$C_{17}H_{36}$	1.06±0.20	3.81±0.20
Octadecene	$C_{18}H_{36}$	0.84±0.08	
Cycloeicosane	$C_{20}H_{40}$	-	1.50±0.11
Fatty acids		**71.4**	**21.3**
Octanoic acid**	$C_8H_{16}O_2$	0.82±0.07	-
Nonanoic acid**	$C_9H_{18}O_2$	0.78±0.04	-
Dodecanoic acid*	$C_{12}H_{24}O_2$	1.13±0.11	-

Tridecanoic acid**	$C_{13}H_{26}O$	0.89±0.10	-
Palmitic acid*	C□□H□□O	49.1±8.19	9.62±0.54
Heptadecanoic acid**	$C_{17}H_{34}O_2$	0.96±0.10	-
Linoleic acid*	$C_{18}H_{32}O_2$	1.50±0.95	-
Oleic acid*	$C_{18}H_{34}O_2$	5.10±0.28	4.26±0.24
Stearic acid*	$C_{18}H_{36}O_2$	7.12±0.51	3.89±0.13
Arachidic acid*	$C_{20}H_{40}O_2$	0.96±0.24	-
Heneicosanoic acid**	$C_{21}H_{42}O_2$	1.28±0.41	-
Docosanoic acid*	$C_{22}H_{44}O_2$	0.82±0.27	-
Tetracosanoic acid*	$C_{24}H_{48}O_2$	0.95±0.35	1.65±0.02
Hexacosanoic acid**	$C_{26}H_{52}O_2$	-	1.90±0.20
Fatty alcohols**		**1.43**	**9.63**
Hexacosanol	$C_{26}H_{54}O$	-	2.30±0.09
Octacosanol	$C_{28}H_{58}O$	1.43±0.75	7.33±0.03
Sterols and Steroids		**17.1**	**31.4**
Stigmast-4-en-3-one**	$C_{29}H_{48}O$	5.18±1.17	
Stigmasterol**	$C_{29}H_{48}O$	1.94±0.51	2.09±0.83
β-Sitosterol*	$C_{29}H_{50}O$	10.0±2.76	29.3±2.65
Triterpenoids**		**6.10**	**21.9**
β-Amyrin	$C_{30}H_{50}$	-	2.01±0.15
Lupeol	$C_{30}H_{50}O$	-	2.47±0.33
Cycloeucalenol	$C_{30}H_{50}O$	-	4.22±0.97
Cycloeucalenol acetate	$C_{32}H_{52}O_2$	2.90±1.09	-
Cyclolaudenol	$C_{31}H_{52}O$	2.13±0.25	-
Cycloartenol	$C_{30}H_{50}O$	1.08±0.58	13.1±0.86
Aldehydes		**0.88**	**1.70**
E-15-Heptadecenal**	$C_{17}H_{32}O$	0.88±0.16	1.70±0.07
Total		**100**	**100**

Note: (-) not detected; means of two replications; * compared with standard compound; ** compared with similarity index > 80% (NIST Library 2011) and/or with data from the literatures.

The results of TMCS derivatization in the wood and bark parts showed that sterols and steroids constituted the largest fraction, followed by triterpenoids, fatty acids, hydrocarbons, fatty alcohols and aldehydes in the bark part, while the fatty acid fraction in wood was the highest, followed by sterols and steroids, triterpenoids, hydrocarbons, fatty alcohols and aldehydes (Fig. 3). Furthermore, the bark contains much higher levels of each lipophilic fraction than the wood part except for fatty acids. Meanwhile, the wood part had a much higher fatty acid content compared to the bark part.

Fig. 3: Lipophilic extractive composition (%) based on dried n-hexane extract in the wood and bark of M. cajuputi.

Composition of hydrocarbons

The bark contained a much higher hydrocarbon fraction than in the wood parts. Arisandi et al. (2019b) also found that the hydrocarbon was the second largest fraction in the bark of *Swietenia macrophylla.* In addition, hydrocarbon groups were also observed in the wood of *E. globulus* (Gutiérrez et al. 1999; Swan and Åkerblom 1967). In the bark part, the compounds of pentadecane, hexadecane and heptadecane were the major compounds in the hydrocarbon fraction, whereas cetene was the minor compound in this fraction. Neutral compounds such as hydrocarbons do not form soluble soaps and are prone to scaling and causing pitch problems in kraft pulp (Allen 1988). On the other hand, previous studies have shown that four hydrocarbon compounds, including cyclohexene, hexadecane, tricosene, and heptacosane have antibacterial and antimicrobial activity (Shoaib et al. 2019; Tiji et al. 2021).

Composition of fatty acids

Fatty acids in the wood were much more abundant than in the bark and it was the highest fraction in the wood (71.4%). Fatty acids such as palmitic, oleic, and stearic acids were the dominant compounds in the fatty acid fraction, while heneicosanoic, docosanoic, tetracosanoic and hexacosanoic acids were the minor compounds both in wood and bark. Similar components have been also reported in other species such as *E. urograndis* clones, *E. pellita*, *E. dunnii*, and *E. grandis* × *E. urophylla* clone wood, where compounds of palmitic, oleic, and linoleic acids were the main lipophilic fractions in both of wood and bark parts (Silverio et al. 2007; Kilulya et al. 2014; Arisandi et al. 2020). Arisandi et al. (2020) reported that palmitic, linoleic, arachidic, docosanoic, tetracosanoic, and hexacosanoic acids in *E. pellita* was greater in the heartwood than in the bark part. The wood parts containing high levels of fatty acids can be used for biological activities. For example, palmitic acid is used as an antioxidant, hypocholesterolemic, antibacterial agent, and anti-inflammatory (Sermakkani and Thangapandian 2012), oleic acid is an antibacterial agent and anti-tumor (Carrillo et al. 2012), and linoleic acid is an anti-inflammatory, antibacterial, hepatoprotective, hypocholesterolemic, anticoronary, antihistamine, and antiarthritic (Sermakkani et al. 2012). However, it should be noted that detection of even small amounts of long-chain fatty acids (heneicosanoic, docosanoic, tetracosanoic and hexacosanoic acids) can cause pitch problems in the pulp industry. Because long-chain fatty acids have higher melting points than short-chain fatty acids, they tend to form precipitates during paper pulp production (Pietarinen et al. 2004). In addition, short chain fatty acids such as nonanoic and dodecanoic acids were also detected in other species such as both in wood and bark of *E. pellita* and *E. globulus* (Arisandi et al. 2020; Gominho et al. 2020).

Composition of fatty alcohols

The level of fatty alcohols in the bark (9.63%) was greater than in the wood part. Hexacosanol and ocatacosanol compounds were detected in the bark part, while in the wood was found only octacosanol. These two compounds were also found in large quantities in other species such as *E. globulus* in the inner and outer bark parts (Friere et al. 2002) and in *E. sideroxylon* bark (Ferreira et al. 2018). Fatty alcohols are classified as unsaponifiable compounds, meaning they do not form soaps and can be deposited and cause pitch problems

in pulp and paper production (Douek and Allen 1982). However, compound such as octacosanol exerts various biological effects such as anti-hypoxic, anti-fatigue, anti-inflammatory, antioxidant, and anti-tumor (Zhou et al. 2022).

Composition of sterols-steroids, triterpenoids, and aldehydes

Sterol and steroid was the largest fraction found in this bark sample (31.4%) and the second most abundant fraction in the wood part (17.1%). In previous other species, sterols mainly constituted the second largest fraction, as reported in same family (Myrtaceae) such as *E. grandis* × *E. urophylla*, *E. dunnii, E. pellita,* and *E. grandis* (Kilulya et al. 2014; Arisandi et al. 2020). The levels of sterols in the bark part were more abundant compared to wood part. The similar findings have been reported in previous studies in other species such as *E. pellita* (Arisandi et al. 2020). The sterol and steroid compounds detected in the wood and bark were stigmast-4-en-3-one (only in wood), stigmasterol, and β-sitosterol. β-sitosterol was the largest compound that has been detected. In other species such as the lipids of *E. pellita*, β-sitosterol was the main sterol compound in the bark part (Arisandi et al. 2020). According to previous studies, it was found in both free and esterified forms as the main component of all sterol groups in eucalyptus trees (Hafizoğlu et al. 2002). It has also been reported to be the most abundant compound in the outer bark of *E. globulus* and other *Eucalyptus* trees such as *E. botryoides, E. camaldulensis, E. maculata, E. grandis, E. urograndis, E. rudis, E. viminalis, and E. sideroxylon* (Freire et al. 2002; Domingues et al. 2010; Ferreira et al. 2018). In addition, stigmasterol compounds have also been detected in the inner and outer bark, wood, and wood pulp of the *E. globulus* species (Freire et al. 2002; Gutiérrez et al. 2006). Subsequently, stigmast-4-en-3-one detected in wood and bark of *E. pellita* (Arisandi et al. 2020), *E. globulus* wood (Gutiérrez et al. 1998), and in *E. camaldulensis* and *E. maculata* bark (Ferreira et al. 2018).

It should be noted that sterols have a much higher viscosity than fatty acids (Domingues et al. 2010) and may play an important role in pitch deposition during kraft process. In addition, sterols also belong to the unsaponifiable class and tend to be easily deposited and cause pitch problems (Allen 1988). However, in pharmaceuticals, β-sitosterol is one of the most common forms of phytosterols and has anti-bacterial, anti-cancer, antioxidant, anti-inflammatory, and antinociceptive properties (Sayeed et al. 2016). Furthermore, triterpenoid fraction was greater in the bark than in the wood. Triterpenoids were the second largest fraction detected in the bark (21.9%). The compounds cycloeucalenol acetate and cyclolaudenol were only detected in the wood, while the compounds of β-amyrin, lupeol, cycloeucalenol, and cycloartenol were recorded in the bark part. The largest triterpenoid compound found was cycloartenol (13.1%) in the bark. Cycloartenol compound had been found in other species such as *Swietenia mahagoni* (Rastogi and Mehrota 1993). In addition, β-amyrin and lupeol were also found in the inner bark, outer bark and wood of the *E. globulus* species (Freire et al. 2002; Gominho et al. 2020).

Certain terpenoids are unsaponifiable, poorly soluble in water, and difficult to remove. In other species, such as *E. globulus*, terpenoids were responsible for pitch problems in the wood and bark regions (Fengel and Wegener 1989; Silverio et al. 2007; Gominho et al. 2015). However, in pharmaceuticals, the lupeol compound has many pharmacological effects, including anticancer, antioxidant, anti-inflammatory, and antibacterial effects (Liu et al. 2020).

On the other hand, cycloartenol has various pharmacological effects, including anti-tumor, anti-inflammatory, antioxidant, anti-Alzheimer's and antibiotic (Zhang et al. 2017). Other compound that was detected in small amount was E-15-heptadecenal. E-15heptadecenaal in the bark was higher compared to wood part. The compound of E-15-heptadecenal is known to have antibacterial effects (Ghalloo et al. 2022).

Information regarding the lipophilic compounds detected in the wood and bark provides considerations for the end-use of the wood and bark of *M. cajuputi*. Fatty acids were the most abundant in the wood part. Meanwhile, the bark of this species contains high levels of sterols-steroids, triterpenoids, and hydrocarbons, which may cause pitch problems in the pulp and paper industry. However, the high concentrations of these fractions in the bark could potentially be exploited to increase their value, especially in the field of pharmacology. On the other hand, it should be noted that lipophilic extractive parameters are not sufficient to be taken into consideration when the species has the potential or not to be utilized as raw material for pulp and paper, but it is also necessary to consider other parameters such as delignification rate, pulp yield, and fiber quality (Pérez et al. 2023). Therefore, further research is needed to evaluate these properties. Moreover, wood debarking process prior to pulping, the potential for pitch problem by wood extractives can be assist minimized (Lehr et al. 2021).

CONCLUSIONS

The extractive contents of *n*-hexane, methanol and hot water ranged from 0.84 to 1.05%, 1.00 to 1.03% and 1.43 to 1.46%, respectively. The extractive content was higher in the bark than in the wood parts. The TPC, TFC and TSP in the methanol and hot water extracts were 19.2 to 38.7 and 23.2 to 27.3 mg GAE/g dried extract, 11.8 to 16.0 and 7.55 to 14.0 mg QE/g dried extract and 79.3 to 102.8 and 148.8 to 165.9 mg Glu/g dried extract, respectively. TPC and TSP were greater in the bark and an opposite trend was found for TFC. In addition, methanol generally solubilized more polyphenols, whereas the opposite pattern was observed for TSP values. The high levels of TPC and TFC in the wood and bark of *M. cajuputi* have potential antioxidant properties that should be investigated in the future. GC-MS detected six fractions including hydrocarbons, fatty acids, fatty alcohols, sterols-steroids, triterpenoids and aldehydes. The bark was high in sterols-steroids and triterpenoids which are advantages if this species is to be used in pharmacology.

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