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# *Extractive Content of White Jabon (Neolamarckia cadamba) and Red Jabon (Neolamarckia macrophyllus) Stemwood from Wonogiri, Central Java*

*(Kadar Ekstraktif Batang Pohon Jabon Putih (Neolamarckia cadamba) dan Jabon Merah (Neolamarckia macrophyllus) dari Wonogiri, Jawa Tengah)*

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## ABSTRACT

Jabon is a fast-growing tree species with two types, white and red. The families or the origin of the mother tree are sources of variation that influence the chemical composition, particularly the extractive properties. This research aimed to determine the chemical properties of the wood and bark of 10-year-old white Jabon (families 23, 11, and 6) and 5-year-old red Jabon (families 75, 85, and 2) planted in a progeny test plot in Wonogiri, Central Java. In the wood portion of white Jabon, family 23 had the highest n-hexane (HEC), methanol (MEC), and hot water (HWEC) soluble extractive contents, as well as total extractive content (TEC) and total flavonoid content (TFC), while family 6 had the highest total phenolic content (TPC). Meanwhile, in red Jabon, family 75 had the highest HEC, HWEC, and TFC, family 2 had the highest MEC and TEC, and family 85 had the highest TPC. In the bark portion, family 11 had the highest HEC, MEC, TEC, and TPC, while family 6 had the highest HWEC and TFC for white Jabon. In red Jabon, family 2 had the highest HEC, family 85 had the highest MEC, HWEC, and TEC, while family 75 had the highest TPC and TFC.

## *INTISARI*

*Jabon merupakan jenis pohon cepat tumbuh yang dibedakan menjadi jabon putih dan jabon merah. Famili (asal pohon induk) merupakan sumber variasi yang memengaruhi komposisi kimia terutama sifat ekstraktif. Penelitian ini bertujuan untuk mengetahui kadar ekstraktif, kadar fenolat total dan kadar flavonoid total pada bagian kayu dan kulit jabon putih berumur 10 tahun (famili 23, 11 dan 6) serta jabon merah berumur 5 tahun (famili 75, 85, dan 2) yang di tanam pada plot uji keturunan di Wonogiri, Jawa Tengah. Pada bagian kayu, nilai kadar ekstraktif larut n-heksana (KEH), metanol (KEM), air panas (KEAP), kadar ekstraktif total (KET) dan kadar flavonoid total (KVT) tertinggi pada famili 23, nilai kadar fenolat total (KFT) tertinggi pada famili 6 jabon putih. Sementara itu, pada jabon merah, nilai KEH, KEAP dan KVT tertinggi pada famili 75, nilai KEM dan KET tertinggi pada famili 2, nilai KFT tertinggi pada famili 85. Pada bagian kulit, nilai KEH, KEM, KET, KFT tertinggi pada famili 11, nilai KEAP dan KVT tertinggi pada famili 6 jabon putih. Sementara itu, pada jabon merah, nilai KEH tertinggi pada famili 2, nilai KEM, KEAP, KET tertinggi pada famili 85, nilai KFT dan KVT total tertinggi pada famili 75.*

## Introduction

Jabon (*Neolamarckia spp.*) has become a promising tree species for Industrial Plantation Forest development in Indonesia. It belongs to the *Rubiaceae* family, a wood-producing tree species. The Indonesian community has massively planted white Jabon (*N. cadamba*) and red Jabon (*N. macrophyllus*). The Forestry Instrument Standard Testing Center (BBPSIK) has established progeny test plots as improved seed sources in Wonogiri, Central Java, to increase the white and red Jabon plantation forests' productivity. The white Jabon progeny test plots used genetic material from populations in Banten, Lampung, and Kediri, with 76 families planted in February 2011. Meanwhile, the genetic material for the red Jabon progeny test plots comes from the Konawe provenance in Southeast Sulawesi, the natural distribution of red Jabon, with 55 families planted in February 2012 (Setyaji et al. 2013). The progeny test aims to obtain the best genetics from several families that can later serve as genetically improved seed sources.

Jabon has promising prospects due to its fast growth, relatively high resistance to pests and diseases, and ability to thrive in various soil types (Pratiwi 2003). The white and red Jabon woods can serve as raw materials for plywood, furniture industries, and lightweight construction (Halawane et al. 2011; Krisnawati et al. 2011; Arsad 2016). Previous research also identified Jabon as raw pulp and paper production material (Wistara et al. 2015; Misbahuddin et al. 2019). The white Jabon bark has medicinal properties (Gurjar et al. 2010; Kumar 2017), while the white and red Jabon barks contain several bioactive compounds (Dubey et al. 2011; Anisah et al. 2015, 2018; Prananta et al. 2020).

Knowledge of chemical properties is crucial as it determines the initial to the final stages of woodworking and processing (Lukmandaru et al. 2016). Extractive contents, such as hydrophilic and lipophilic compounds, are essential non-structural components in wood with high chemical diversity and determine the wood properties and processing. The extractive compounds determine the color, odor, and protection against wood-destroying organisms (Arisandi et al. 2019). Darker-colored extractives are associated with higher phenolic compounds content and color properties in wood (Pontis et al. 2014). The phenolic compounds become plants' defense mechanism against pathogens, parasites, and predators (Huang et al. 2009). Furthermore, flavonoid compounds exhibit biological activities that are antimicrobial or insecticidal (Panche et al. 2016). However, extractive content also has negative impacts. It can create significant problems, such as forming black spots on pulp machinery and bleached pulp, known as pitch resulting in reduced pulp yield and brightness (McLean et al. 2014). The extractive content also negatively affects wood processing, such as drying, bonding, finishing, and acoustic properties, and causes corrosion on metals that have contact with the wood.

The research on the chemical composition of white and red Jabon is limited to the overall chemical components of the cell walls. Research on the family of Jabon trees is limited to their physical and mechanical properties (Hidayati et al. 2020). Exploration of the chemical properties, especially extractive properties, by comparing wood and bark between white and red Jabon is still limited. Families or the origin of the mother trees become a crucial source of variation in certain tree species. This research used the Jabon family with the best phenotypic properties, such as height and diameter. These trees have been undergoing a progeny test in a tree breeding program. Previous research showed that the tree family could affect its chemical properties, including its extractive properties (Quang et al. 2010; Stackpole et al. 2011;

Lukmandaru et al. 2016; Wang et al. 2018). Therefore, this research aimed to evaluate the extractive characteristics of each investigated family and provide information for the tree breeding process.

## Materials and Methods

### Materials Preparation

This research used three 10-year-old white Jabon trees from families 23, 11, and 6 and three 5-year-old red Jabon trees from families 75, 85, and 2 harvested in 2021 and 2017, respectively. These trees were single samples without replication planted in progeny test plots established by the Forestry Instrument Standard Testing Center (BBPSIK) in Wonogiri, Central Java. These three families were selected because they showed the best phenotype (physical properties such as diameter and height) out of all families. Despite different ages, the two Jabon types had a relatively similar diameter of ±20 cm (Table 1), resulting from a faster growth rate of red Jabon compared to white Jabon. The genetic material for white Jabon came from the Sobang population, Pandeglang Regency, Banten Province, while red Jabon came from the Konawe provenance, Southeast Sulawesi. The samples were taken from the tree's base because it would biologically accumulate more extractive than other portions. The sample preparation started with cutting the felled trees into logs and selecting the trees' bases with a height of 15-30 cm above the ground to create 8 cm thick disks. Subsequently, for each disk, the wood and barks were separated. This research used an electric drill to obtain sawdust from the wood. Then, a grinder ground the sawdust and bark to obtain a 40-60 mesh size and a 5 g dry weight of each (Figure 1). The water content analysis used a modified oven-drying method (ASTM D 2016-74 1983) to determine the wet weight of the samples.

**Table 1**. Description of the tree samples

| Types | Families | Age (years old) | Diameter (cm) | Height (m) | Bark thickness (cm) |
|---|---|---|---|---|---|
| White Jabon | 23 | 10 | 24.2 | 18.0 | 0.4 |
| | 6 | 10 | 20.1 | 18.8 | 0.4 |
| | 11 | 10 | 19.3 | 18.8 | 0.3 |
| Red Jabon | 75 | 5 | 21.3 | 16.6 | 0.3 |
| | 85 | 5 | 20.0 | 16.0 | 0.2 |
| | 2 | 5 | 20.0 | 17.0 | 0.3 |

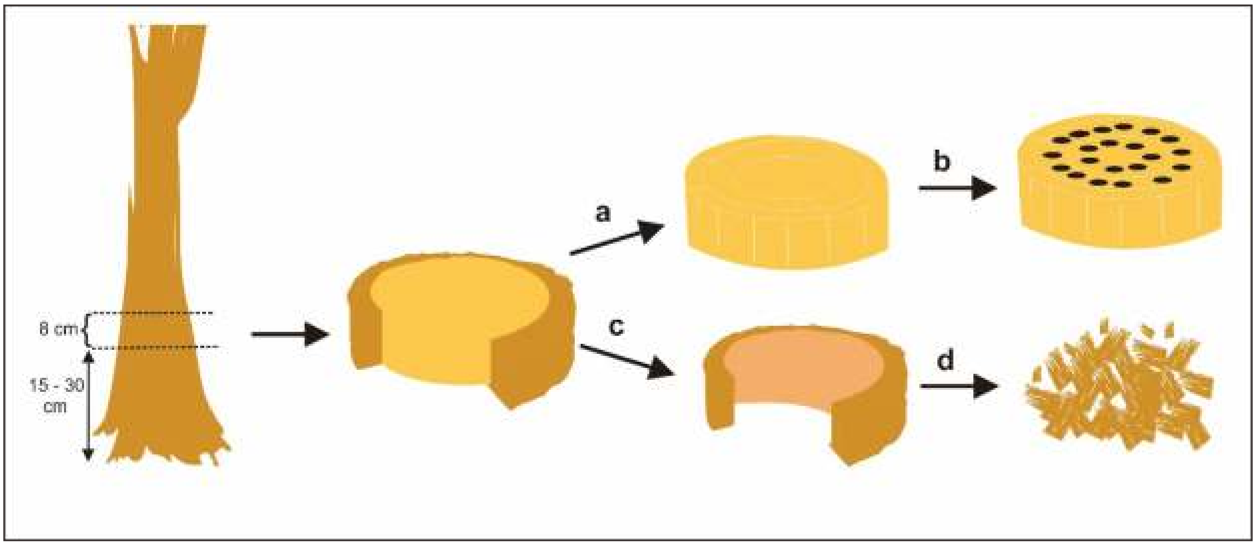


**Figure 1**. Sampling scheme: wood (a-b), bark (c-d)

### Determination of Extractive Content

This research used sequentially extraction using three different solvents, namely n-hexane, and methanol, in a Soxhlet apparatus for six hours (Lukmandaru 2009), hot water in a water bath for three hours (ASTM D 1110-84 2002) for the 5 grams of wood powder. Evaporation separated the solvent from the dissolved substances. The extractives were transferred into pre-weighed small bottles and left to dry. The extractive content of each solvent was gravimetrically determined based on the powder's initial oven dry weight in the extractive after filtration and removal of the solvent.

### Total Phenolic Content Test

The total phenolic content analysis on methanol and hot water-soluble extracts used the Folin-Ciocalteu method (Gao et al. 2006). The extractives obtained from the extraction were dissolved in 0.5 ml of methanol and mixed with 2.5 ml of 10-fold diluted Folin-Ciocalteu reagent for two minutes at room temperature. Furthermore, 2 ml of 7.5% sodium bicarbonate solution was added and left for 30 minutes. The control used a blank with solvent without extractives. The absorbance was then measured at a wavelength of 765 nm using a UV-Vis Spectrophotometer (Optima Nano 3000SP model, Tokyo, Japan). The calibration curve used gallic acid solution, and the expression of the results was in milligrams of gallic acid equivalent per gram of dry extractive (mg GAE/g dried extract).

### Total Flavonoid Content Test

The total flavonoid content analysis used methanol and hot water-soluble extracts following the aluminum chloride ($AlCl_3$) method (Brighente 2007, as cited in Diouf 2009). As much as 2 mL of methanol extractive (1 mg/mL) was dissolved in methanol and then mixed with a 2% $AlCl_3.6H_2O$ solution (2 g in 100 mL methanol) and shaken. The control used a blank with the methanol extractive and without $AlCl_3.6H_2O$. The absorbance was measured at a wavelength of 415 nm using a UV-Vis Spectrophotometer (Optima Nano 3000SP model, Tokyo, Japan) after one hour of sample incubation at room temperature. The calibration curve used quercetin solution, and the expression of the results was in milligrams of quercetin equivalent per gram of dry extractive (mg QE/g dried extract).

### Data Analysis

The analysis of the n-hexane, methanol, and hot water-soluble extractive content, total extractive content, and the total phenolic and flavonoid content used descriptive statistics with the Microsoft Excel for Windows program.

## Results and Discussion

### Extractive Content

The n-hexane extractive content (HEC) in white Jabon was higher than in red Jabon, particularly in the bark, while the wood remained within the same range (Tables 2 and 3). The n-hexane had a low polarity index of 0.1 (Chandrasekaran 2021), which could dissolve lipophilic extractives, such as wax, fat, terpenoids, and alcohol (Lukmandaru et al. 2011). This result was still lower than that of Anisah et al. (2018), who used 6-year-old white Jabon wood and bark samples with maceration extraction. The difference in extractive values may be due to different extraction methods. However, the methanol extractive content (MEC) in white Jabon was lower than in red Jabon due to the darker color of the wood and bark in red Jabon (Tables 2 and 3). The methanol had a polarity index of 5.1 (Chandrasekaran 2021), which would dissolve hydrophilic extractives, such as condensed phenolic and tannin compounds (Lukmandaru et al., 2011). Previous research revealed that phenolic compounds in extractives were related to the wood color in some species (Burtin et al. 2000).

The difference in MEC contributed to the difference in natural durability. Gierlinger et al. (2004) stated that wood color and extractive content were inheritable properties. Plant breeding could lead to selecting a wood with specific colors that increase natural durability against destructive organisms. The natural durability of white and red Jabon was under classes V and IV, respectively (Martawidjaya et al. 1989; Halawane et al. 2011). Therefore, red Jabon had better natural durability than white Jabon. Setyaji et al. (2014) also stated that red Jabon had better wood strength and durability than white Jabon and sengon.

The hot water extractive content (HWEC) of white Jabon bark was lower than red Jabon, while HWEC in white Jabon wood was higher than in red Jabon (Tables 2 and 3). Water as a solvent has a high polarity index of 10.2 (Chandrasekaran 2021), which could dissolve carbohydrate compounds, such as sugars, and play a role in the tree's physiological processes (Lukmandaru et al. 2011). The HWEC in older wood was typically lower than in younger wood. This result contradicted the theory that older white Jabon wood yielded higher HWEC than younger red Jabon wood. The total extractive content (TEC) in the 10-year-old white Jabon was also lower than the 5-year-old red Jabon. This tendency differed from teak species, which showed an increasing extractive content as the tree aged (Lukmandaru 2009). This result was consistent research by Rencoret et al. (2011), which reported a decrease in the extractive content of *E. globulus* clone wood from Pontevedra, Spain, at one month, eighteen months, and nine years of tree ages. Moreover, Miranda and Pereira (2002) reported that TEC in *E. globulus* from Portugal decreased from three to six years.

The HEC, MEC, and HWEC in the bark were higher than in the wood (Tables 2 and 3), which were consistent with the general trend that extractive content is higher in the bark than in the wood (Rowell 2005; Fengel and Wegener 1995; Sjostrom 1993). The MEC (30-63%) was generally dominant, followed by HWEC (25-48%) and HEC (5-23%) of the total soluble extractive (Figure 2). The polar extractive content tended to be higher than the non-polar extractive content (Anisah et al. 2018). The previous observation indicated that the bark of white Jabon contained a higher polar extractive than non-polar extractive. The white Jabon from family 23 and the red Jabon from

**Table 2**. Chemical composition from wood and bark of white Jabon (10 years) in three different families

| Parameter | White Jabon | | | | | |
|---|---|---|---|---|---|---|
| | Wood | | | Bark | | |
| | 23 | 11 | 6 | 23 | 11 | 6 |
| *Extractive Content (%)* | | | | | | |
| HEC | 0.65 | 0.49 | 0.51 | 1.88 | 2.50 | 2.29 |
| MEC | 2.14 | 2.05 | 2.02 | 3.53 | 3.77 | 3.13 |
| HWEC | 1.72 | 1.52 | 1.27 | 4.48 | 4.83 | 4.96 |
| TEC | 4.51 | 4.06 | 3.80 | 9.89 | 11.10 | 10.38 |
| *Total Phenolic Content (mg GAE/g sample)* | | | | | | |
| TPC-M | 61.87 | 48.24 | 57.05 | 93.90 | 95.89 | 89.97 |
| TPC-HW | 75.85 | 75.32 | 89.76 | 171.31 | 178.39 | 133.79 |
| *Total Flavonoid Content (mg QE/g sample)* | | | | | | |
| TFC-M | 25.25 | 25.52 | 26.74 | 54.45 | 51.64 | 56.27 |
| TFC-HW | 47.92 | 42.81 | 41.49 | 56.68 | 59.11 | 60.94 |

Remarks : HEC= n-hexane extractive content; MEC= methanol extractive content; HWEC= hot water extractive content; TEC= total extractive content; TPC-M= total phenolic content of methanol extractive; TPC-HW= total phenolic content of hot water extractive; TFC-M= total flavonoid content of methanol extractive; TFC-HW= total flavonoid content of hot water extractive. 23, 6, 11= families of white jabon.

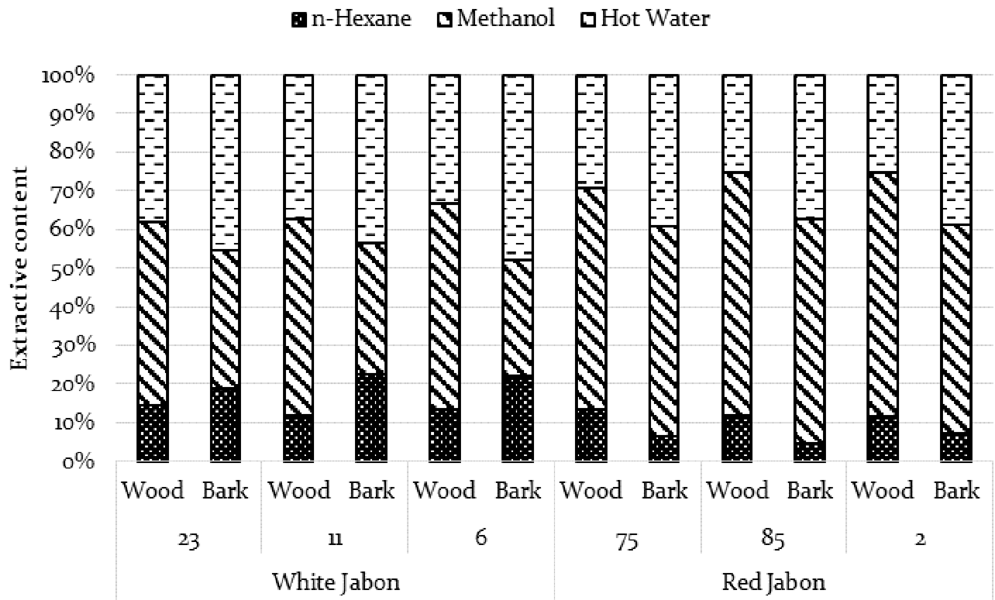


**Figure 2**. Composition of total extractive content (% of extractive weight) from wood and bark of white (10 years) and red (5 years) Jabon in three different families

family 2 had the highest TEC, suggesting that the two families had better natural wood durability than the others. However, wood with high extractive content, specifically lipophilic extractive, was less preferred as pulp and paper raw material because it could lead to pitch deposits and yield reduction (McLean et al. 2014; Gutiérrez et al. 2004).

**Total Phenolic Content**

The methanol extractive's total phenolic content (TPC-M) was lower than the hot water extractive (TPC-HW) (Tables 2 and 3), indicating that phenolic compounds are more soluble in hot water than in methanol. The TPC of red Jabon was higher than white, but the TPC of white and red Jabon in this research was relatively lower than other fast-growing species. Arisandi et al. (2019) reported that the TPC of methanol and hot water extractives in age-unknown eucalyptus species (*E. pellita*) ranged from 368.4 – 632.5 and 199.9 – 429.6 mg gallic acid/g sample, respectively. According to Purba et al. (2021), the 6-year-old hybrid acacia (*A. mangium* x *A. auriculiformis*) had TPC of methanol and hot water extractives ranging from 117.11 – 448.35 and 43.28 – 198.92 mg gallic acid/g sample, respectively.

Family 6 of white Jabon and family 85 of red Jabon had the highest TPC in the wood of methanol and hot water extractives (Tables 2 and 3), suggesting that the white and Jabon from these families had better strength and durability than the others. Phenolic compounds generally play a role in wood's color, strength, and durability. Plant phenolic compounds contribute to defense mechanisms against pathogens, parasites, and predators. These compounds also play a role in plant portion coloring. These compounds also determine the plant's color (Huang et al. 2009).

Family 11 of white Jabon and family 75 of red Jabon had the highest TPC in the bark (Tables 2 and 3), although there were no physical differences (height, diameter, and color) between these families and the others. This result allowed future research to discover compounds with antioxidant activity. Technically, phenolic compounds are good antioxidant agents and act as primary antioxidants or free radical scavengers (Diouf 2009; Pereira et al. 2009). Previous research demonstrated that red and white Jabon contain bioactive compounds. For example, red Jabon bark contains antioxidant activity (Prananta et al. 2020),

**Table 3**. Chemical composition from wood and bark of red Jabon (5 years) in three different families

| Parameter | Red Jabon | | | | | |
|---|---|---|---|---|---|---|
| | Wood | | | Bark | | |
| | 23 | 11 | 6 | 23 | 11 | 6 |
| | *Extractive Content (%)* | | | | | |
| HEC | 0.65 | 0.52 | 0.61 | 1.41 | 1.15 | 1.57 |
| MEC | 2.81 | 2.78 | 3.36 | 12.29 | 14.38 | 12.02 |
| HWEC | 1.43 | 1.11 | 1.35 | 8.78 | 9.20 | 8.61 |
| TEC | 4.90 | 4.41 | 5.32 | 22.47 | 24.73 | 22.21 |
| | *Total Phenolic Content (mg GAE/g sample)* | | | | | |
| TPC-M | 91.53 | 94.97 | 77.05 | 269.42 | 244.64 | 227.50 |
| TPC-HW | 101.50 | 146.39 | 115.66 | 310.76 | 222.40 | 272.53 |
| | *Total Flavonoid Content (mg QE/g sample)* | | | | | |
| TFC-M | 39.93 | 41.32 | 43.65 | 81.72 | 82.60 | 75.15 |
| TFC-HW | 78.13 | 75.86 | 74.17 | 85.13 | 81.01 | 83.44 |

Remarks: HEC= n-hexane extractive content; MEC= methanol extractive content; HWEC= hot water extractive content; TEC= total extractive content; TPC-M= total phenolic content of methanol extractive; TPC-HW=total phenolic content of hot water extractive; TFC-M= total flavonoid content of methanol extractive; TFC-HW= total flavonoid content of hot water extractive. 75, 85, 2= families of red jabon.

while the leaves, wood, and bark of red Jabon, especially the bark, contain a fraction of phenolic compounds with antidiabetic activity (Anisah et al. 2018). Dubey et al. (2011) also reported that white Jabon bark had antidiabetic and antioxidant activities.

### Total Flavonoid Content

The methanol extractives' total flavonoid content (TFC-M) was lower than the hot water extractives (TFC-HW) (Tables 2 and 3) due to the lower molecular weight of the flavonoid compounds in the extractive and more soluble in polar solvents with higher polarity, such as water. The red Jabon had a higher TFC than the white Jabon, and the bark had a higher TFC than the wood. Flavonoid compounds could play a role in biological activities, such as nitrogen fixation and protection against excessive ultraviolet radiation. Some flavonoid syntheses responded to UV radiation, microbiological disturbances, and physical attacks (Panche et al. 2016). Aminah et al. (2017) revealed that several medicinal plants containing flavonoids had beneficial biological activities, such as antioxidant, antibacterial, antiviral, anti-inflammatory, anti-allergic, and anti-cancer. Gurjar et al. (2010) evaluated a phytochemical in methanol extractive on white Jabon and found the presence of flavonoid, alkaloid, carbohydrate, protein, and glycoside. Kumar (2017) indicated that the main constituents of white Jabon were triterpenes, triterpenoid glycosides, flavonoids, saponins, and indole alkaloids. Anisah et al. (2015) also stated that the compounds detected in various parts of the red Jabon tree were flavonoids, alkaloids, triterpenoids, saponins, and hydroquinones.

The highest TFC in white and red Jabon wood was found in families 23 and 75, respectively (Table 2). Furthermore, the highest TFC in white and red Jabon bark was found in families 11 and 75, respectively (Table 3). The TPC in red and white Jabon was higher than the TFC. This result was consistent with previous research that revealed flavonoid and flavanol content was significantly lower than phenolic content (Diouf 2009).

The result of this research suggested that families affected the extractive properties. Different families produced varied values of extractive properties. Previous research also indicated that the family of a tree affected the chemical composition, including extractive properties (Quang et al. 2010; Stackpole et al. 2011; Lukmandaru et al. 2016; Wang et al. 2018), suggesting that each family could produce different values, causing some families to be better than others in each parameter. However, further research was needed with more samples to include replication for each family and variance analysis to explore in-depth the effect of family differences on the extractive properties.

## Conclusion

The sequential extractives indicated that wood and bark samples of red and white Jabon contain highly soluble polar extractives, particularly in the methanol extractive. The HEC in white Jabon was higher than in red Jabon, particularly in its bark. However, the MEC in red Jabon was higher than in white Jabon. The bark of white Jabon had a lower HWEC than red Jabon, while the wood of white Jabon was higher than red Jabon. Family 23 of white Jabon and family 2 of red Jabon had the highest TEC in the wood. The TPC and TFC in red Jabon were higher than in white Jabon. Family 11 of white Jabon and 75 of red Jabon had the highest TPC in the bark. Family 23 of white Jabon and 75 of red Jabon exhibited the highest TFC in the wood.

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