Fuelwood Characteristics of Five Species Grown in Merauke Forest

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Abstract

Papua has a large area of production forests, such as in Merauke. These forests provide great benefits for the pulp and wooden industries, which generate a large amount of biomass waste. Therefore, this study aimed to investigate the proximate analysis, specific gravity, calorific value, and Fuelwood Value Index (FVI) of wood and bark of five species, namely *Acacia mangium* Willd*, Acacia crassicarpa* A. Cunn*, Eucalyptus pellita* F. Muell*, Melaleuca viridiflora* Sol. Ex Gaertn*,* and *Lophostemon suaveolens* Sol. Ex Gaertn*.* The calorific value ranged from 4,066 to 5,435 cal/g, while the FVI values ranged from 4.04 to 76.41. The highest calorific value was observed in the bark of *Melaleuca viridiflora,* while the highest fuelwood value index was observed in *Eucalyptus pellita* wood. Furthermore, the calorific value of wood was higher compared to the bark in all species. There was no significant correlation between specific gravity, calorific or FVI value. It is noticed that a strong correlation (*r* = -0.92*) was observed between the calorific value and volatile matter in the bark. Based on the proximate analysis results, only the moisture content level was significantly correlated with the calorific value of wood or bark.

Keywords: green energy, proxymate analysis, waste biomass, fabaceae, specific gravity

Introduction

Wood is a commonly used source of energy due to its several advantages, both economically and environmentally. Firewood is very sustainable and is cheaper compared to fossil fuels, meanwhile, Indonesia has numerous tropical forests that provide great potential as a source of energy. One area with potential for biomass production is the Papua Province, with a forest area covers 25.1 million ha (Badan Pusat Statistik 2014).

Merauke is one of the forest areas in Papua with high biodiversity for the wooden and pulp industries. Several species grown in this forest include *Acacia mangium* Willd*, Acacia crassicarpa* A. Cunn*, Eucalyptus pellita* F. Muell*, Melaleuca viridiflora* Sol. Ex Gaertn*, and Lophostemon suaveolens* Sol. Ex Gaertn. The wood products commonly manufactured in Papua island include plywood, sawn wood, veneer, and molding/dowel. Furthermore, the wooden and pulp industries generate wastes from the processing or logging stages, meanwhile the presence of a large proportion of bark from trees produces unutilized wastes.

The calorific value and fuelwood value index (FVI) are important indicators to compare the effectiveness of woods in producing energy. Besides, the calorific value of *A. mangium, A. crassicarpa, E. pellita*, and *M. viridiflora* wood has been previously measured (Yantasath *et al.* 1993; Doran and Turnbull 1998; Dombro 2010), but data on proximate analysis and FVI are limited, while the energy properties of bark have also been less explored. Therefore, this study aimed to investigate wood and bark from Merauke forest as a source of energy. In addition, it also examined the relationship between energy and the related basic properties of wood.

Materials and Methods

Wood Preparation

The wood samples were obtained from one tree for each species in the forest area of PT Selaras Inti Semesta (Medco Groups), Papua, Merauke. For each tree, the discs were sawn at the bottom part while the wood and bark were separated. Furthermore, the samples were taken randomly in the form of wood powder and pieces to test the chemical and energy properties. Measurements of wood properties were performed in three replications.

Specific Gravity and Calorific Value Determination

The specific gravity was measured using the water displacement method with ASTM D 2395-02, while the calorific value was measured using an oxygen bomb calorimeter (Parr InstrumentInc., no. 1341 seri 3403) device referred to ASTM 5865-04.

Proximate Analysis

This test includes moisture content by oven method (ASTM D 4442-92), ash content by dry-ashing method (ASTM D1102-84), volatile matter content (ASTM D3175-02), and fixed carbon content (ASTM D3172).

Fuelwood Value Index

The fuelwood value index (FVI) was based on the properties of calorific value (kJ/g), wood density (g/cm^3), and ash (%) (Purohit and Nautiyal 1987) with the formula (FVI) = (Calorific Value ×Wood density)/Ash content.

Statistical Analysis

The relationships between the independent variables were analyzed using Pearson's correlation analysis. All statistical calculations were performed with SPSS-Win 12.0.

Results and Discussion

The specific gravity results are presented in Figure 1. The highest values were observed in *Lophostemon suaveolens* wood (0.87), while the value in acacia woods was relatively low compared to the other three species (>0.75). Furthermore, there was a significant difference between the specific gravity values of the wood and bark for each species, meanwhile, the specific gravity levels for the two acacia species (family Fabaceae) were greater in the bark compared to the other three species (family Myrtaceae). The high specific gravity value in the bark is presumably caused by the compression of dead bark cells and the formation of thick-walled phellem cells.

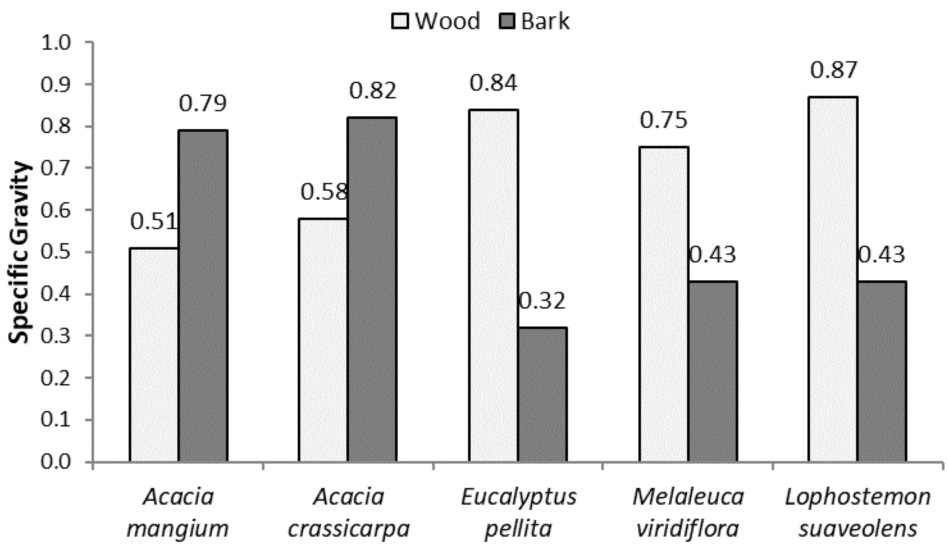

Figure 1. Specific gravity of five tree species growing in Merauke forest (mean of three replications)

Table 1. Proximate analysis of five tree species growing in Merauke forest (mean of three replications)

Species/Part	Moisture content (%)	Ash content (%)	Volatile matters (%)	Fixed carbon (%)
Acacia mangium				
Wood	16.6	0.23	85.64	14.12
Bark	17.3	2.57	79.38	18.04
Acacia crassicarpa				
Wood	13.2	0.24	82.75	17.00
Bark	16.7	1.04	81.81	17.15
Eucalyptus pellita				
Wood	15.5	0.20	83.88	15.92
Bark	16.5	0.28	79.48	20.23
Melaleuca viridiflora				
Wood	16.2	0.46	84.09	15.45
Bark	14.5	1.44	75.57	22.98
Lophostemon suaveolens				
Wood	15.5	0.58	83.97	15.44
Bark	17.0	1.77	79.70	18.52

In general, an ideal raw material for energy needs to have low moisture, ash, volatile matter, and high fixed carbon content. The proximate analysis results are presented in Table 1. The moisture content obtained ranged between the air-dry content (13-18%), while the ash content was higher in the bark (Fengel and Wegener 1984) except for *Eucalyptus pellita*. Furthermore, the volatile matter content was higher in the wood compared to fixed carbon. The lowest ash content value was found in *Eucalyptus pellita wood* (0.20%), meanwhile, there was no significant difference in the volatile matter and fixed carbon contents of wood and bark in *Acacia crassicarpa*. The highest fixed carbon level was observed in the bark of *Melaleuca viridiflora* (22.98%), while the lowest volatile matter concentration was also obtained in the same species (75.57%).

The energy properties of the five species were measured in the form of calorific value (Figure 2) and FVI (Figure 3). To use wood as fuels, both parameters are required in high amounts. The highest calorific value was found in the bark of *Melaleuca viridiflora* (5,435 cal/g), while the highest FVI value was observed in *Eucalyptus pellita* (76.41). Furthermore, the bark's calorific value was greater than the wood in *Acacia mangium, Eucalyptus pellita*, and *Melaleuca viridiflora*. There was no huge difference in calorific value between bark and wood in *Eucalyptus pellita* and *Lophostemon suaveolens*. Meanwhile, the calorific value of wood varies with the value of the bark due to the different properties of both parts (Shmulsky and Jones 2011). Regarding the chemical properties, the bark has a higher lignin and ash content compared to wood (White 1987; Fuwape 1991). Variations between the species indicate the presence of other factors aside from these parameters. Therefore, a chemical analysis of the wood and bark is necessary for a detailed explanation.

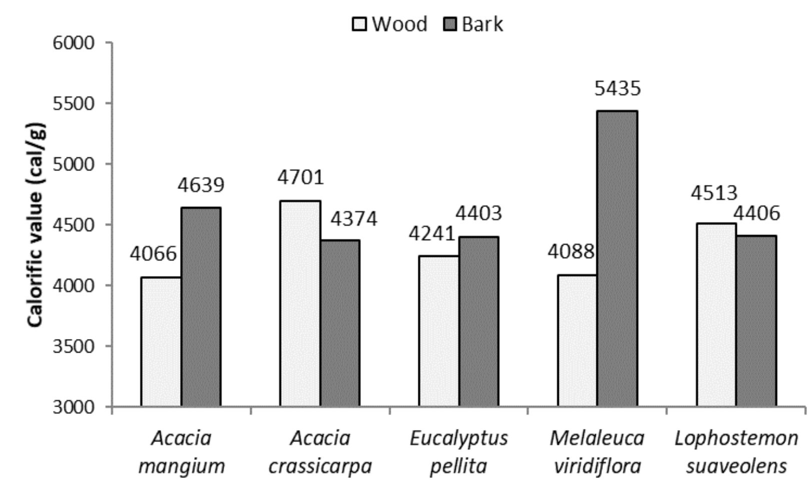

Figure 2. Calorific value of five tree species growing in Merauke forest (mean of three replications)

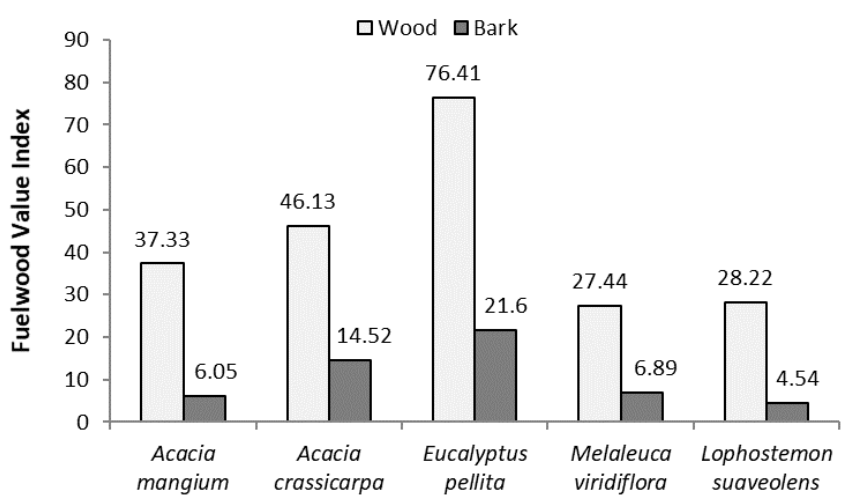

Figure 3. Fuelwood value index of five tree species growing in Merauke forest (mean of three replications)

The FVI value is linearly related to the density and calorific value but inversely to the ash content. The value was relatively higher in wood compared to the bark for all species, while the highest difference in FVI values between wood (76.41) and bark (21.6) was observed in *Eucalyptus pellita*. Furthermore, the relatively low calorific value (4,241 cal/g), low ash content (0.20%), and high specific gravity (0.84) altogether caused the high FVI values obtained in *Eucalyptus pellita* wood. A previous study showed that woods with an FVI value of at least 10 is suitable as firewood (Kataki and Konwer 2002). This implies that wood is better used as fuel compared to bark.

The degree of relationship between the parameters was evaluated by Pearson's correlation (Table 2?). The results of the correlation between proximate values and energy properties when the two parts were combined together showed that the calorific value is strongly correlated with volatile matter (*r* = -0.80**) and fixed carbon (*r* = 0.80), while FVI was negatively correlated with ash content (*r* = -0.73) and volatile matter (*r* = 0.65*). In contrast, when the two parts were separated, there was no significant correlation between the proximate values and the FVI. Furthermore, the calorific value was strongly negatively correlated with the moisture contents in both parts, while a strong correlation (*r* = -0.92*) was also observed between the calorific value and volatile matter in the bark.

Table 2. Pearson's correlation coefficients between energy properties and basic wood properties of five tree species growing in Merauke forest

Parts	Calorific value	Fuelwood Value Index
Wood - Bark		
Specific gravity	-0.27	0.32
Moisture content	-0.50	-0.41
Ash content	0.42	-0.73*
Volatile matters	-0.80**	0.65*
Fixed carbon	0.80**	-0.53
Wood		
Specific gravity	0.07	0.16
Moisture content	-0.90*	-0.22
Ash content	0.10	-0.72
Volatile matters	-0.79	-0.21
Fixed carbon	0.77	0.33
Bark		
Specific gravity	-0.20	-0.21
Moisture content	-0.88*	0.05
Ash content	0.19	-0.87
Volatile matters	-0.92*	0.35
Fixed carbon	0.83	-0.02

The calorific value value was linearly proportional to fixed carbon and specific gravity but inversely related to the ash content and volatile matter. This relationship was also observed in previous studies (Jenkins *et al.* 1998; Patabang 2011). However, this trend was not observed, especially when the two parts were separated. The small number and the limited variations in values between the species are thought to have influenced this result. Furthermore, the moisture content levels were consistently negatively correlated with the calorific value, therefore, the dryer the wood, the higher the calorific value (Munalula and Meincken 2009). A similar trend was also observed in FVI. There was no significant correlation between specific gravity and calorific value or FVI, indicating that differences in moisture content and chemical properties such as lignin, extractives, and inorganic materials (White 1987; Fuwape 1991) among species or between bark and wood had a greater impact. In addition, the correlation between specific gravity and calorific value was not strong as expected due to the varying specific gravity and calorific value values between trees which potentially leads to a negative correlation (Montes 2011).

Conclusions

Wood and bark showed considerable differences and varied by species as indicated by the specific gravity values. Based on the proximate analysis, the lowest value of ash content was found in *Eucalyptus pellita* wood while the highest value for fixed carbon and the lowest value in the volatile matter was found in the bark of *Melaleuca viridiflora*. Furthermore, the highest calorific value was observed in the bark of *Melaleuca viridiflora,* while the highest fuelwood value index was observed in *Eucalyptus pellita* wood. In general, the fuelwood value index in wood were greater compared to the bark for all species. The moisture content was found to be significantly negatively correlated with the calorific value of the bark or wood. Based on the results, there was no significant correlation between specific gravity, calorific value, or fuelwood value index of the five tree species studied. In summary, *Eucalyptus pellita* wood should be considered to be the most appropriate biomaterial for energy purpose.

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