

Trial production of fuel pellet from *Acacia mangium* bark waste biomass

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Abstract. Fuel pellet is one of the innovation products that can be produced from various sources of biomass such as agricultural residues, forestry and also wood industries including wood bark. Herein this paper, the potential fuel pellet production using *Acacia mangium* bark that abundant wasted from chip mill industry was studied. Fuel pellet was produced using a modified animal feed pellet press machine equipped with rotating roller-cylinders. The international standards quality of fuel pellet such as ONORM (Austria), SS (Sweden), DIN (Germany), EN (European) and ITEBE (Italy) were used to evaluate the optimum composition of feedstock and additive used. The results showed the quality of fuel pellet produced were good compared to commercial sawdust pellet. Mixed of Acacia bark (dust) with 10% of tapioca and 20% of glycerol (w/w) was increased the stable form of pellet and the highest heating value to reached 4,383 Kcal/kg (calorific value). Blending of Acacia bark with tapioca and glycerol was positively improved its physical, chemical and combustion properties to met the international standards requirement for export market. Based on this finding, production of fuel pellet from Acacia bark waste biomass was promising to be developed as an alternative substitution of fossil energy in the future.

1. Introduction

Indonesia and other tropical countries such as Brazil and Zaire have a great potential for creating energy from biomass as a substitute for petroleum. Taking into account the large size of Indonesia's forests and palm oil plantations, coupled with the possibility of using timber and agricultural residues, Indonesia has the ideal conditions for this change. Wood chips, oil palm and other plant biomass provide low cost residues that are renewable and underused, environmentally friendly and potentially capable of generating heat, steam and electric power [1,2,3]. Thus, they may constitute an alternative fuel for producing energy. In term of that, one of the potential sources of energy feedstock is *Acacia mangium* plantation and also its chip mill industry that produced the huge amounts of residues.

A. mangium is one of the major fast-growing species used in plantation forestry programs throughout Asia and the Pacific countries, including Indonesia. Due to its rapid growth and tolerance of very poor soils, *A. mangium* is playing an increasingly important role in efforts to sustain commercial supply of tree products while reducing pressure on natural forest ecosystems. As a Clean Development Mechanism (CDM) for climate change mitigation, *A. mangium* plantations are expected to provide efficient and profitable contributions to the sawlog and pulp markets [4]. The increase of



Acacia plantation in Indonesia is mainly driven by growing of global demand for pulp and paper. With the growth of pulp and paper production in Indonesia, the amounts of residues generated also shows a corresponding increase, mainly in formation of bark residues and sawdust.

Bark residue was produced from debarking process at harvesting areas and also chip mill industry in various types of material such as wood chunk, small log end and also sawdust (Figure 1a). The abundant of Acacia bark waste biomass was stimulated environmental problems such as contamination of groundwater sources through leaching of extractive materials with high tannin content, triggering and causing land fires around industrial sites and also requires a large buildup location and consumes land preparation around the industry (Figure 1b).

Due to those environmental problems and also opportunity to utilize and convert the waste material into the valuable renewable energy, herein this paper potential fuel pellet production using *A. mangium* bark that abundant wasted from chip mill industry was studied with the special emphasizes to point out the quality of fuel pellet produced, to find an optimum composition among wood bark waste, tapioca and glycerol used and to know the highest energy properties, including calorific value potentially generated. Comparison between the quality of fuel pellet produced with the global standard of wood pellet quality was also discussed. Fuel pellet has been chosen due to some advantageous factors that belongs of this product such as pelletization reduces moisture content, increases energy content (MJ/kg), enhances combustion efficiency, and produces greater homogeneity of composition as compared to raw biomass [5,6,7].

2. Materials and Methods

2.1. *Acacia wood bark waste biomass*

Waste of *A. mangium* wood bark biomass was collected from chip wood industry of PT. Sarana Bina Semesta Alam (SBSA), located at district Muara Kaman, Kutai Kertanegara, East Kalimantan, Indonesia. Before used, Acacia bark waste biomass was chipped, converted into the dust form and air-dried until approximately 12% of moisture content.

2.2. *Lab-scale trial production of fuel pellet*

A. mangium bark waste fuel pellets of 8mm in diameter were prepared in a lab scale process with a modified animal feed pellet press machine equipped with rotating roller-cylinders (Figure 2). The production trials of Acacia bark waste fuel pellets were carried out by using 400g of Acacia bark and blending with 5-25% (w/w) tapioca in the presence and absence of various amounts of glycerol (5-20%, w/w). At the beginning, Acacia bark waste used as the main raw material in the absence of glycerol, however when the calorific value of the pellet was not good enough and satisfy, glycerol will be gradually added to mixture at the minimum percentage until quality of pellet increased. The temperature applied for the process was about 30-35°C, without any specific pressure used.

2.3. *Standard quality of fuel pellet (quality analysis)*

The international standards of pellet such as ONORM (Austria), SS (Sweden), DIN (Germany), EN (European) and ITEBE (Italy) were used to evaluate the quality of fuel pellet produced from *A. mangium* bark waste biomass.

3. Results and Discussion

3.1. *Physical properties of fuel pellet*

The production trials were carried out using mix of Acacia bark waste biomass (dust), and tapioca in the absence and presence of biodiesel by product, glycerol as additive. The aims of the trial productions are to know the optimum condition that can be applied to produce fuel pellet from waste of Acacia bark. The properties of raw materials used were determined as shown in Table 1.

Table 1. Chemical properties of *A. mangium* bark waste biomass and tapioca

Chemical Properties	Bark Waste Biomass	Tapioca
Moisture content (%)	12.71	12.65
Ash content (%)	5.58	0.10
Volatile matter (%)	84.58	87.33
Fixed carbon (%)	3.39	0.04
Lignin content (%)	35.91	-
Cellulose content (%)	35.73	-

**Figure1.**(a) Abundant Acacia wood bark and sawdust waste biomass produced daily in chip mill industry; (b) contamination of groundwater sources and vulnerable fire around industrial sites

Herein this study, we found the low technology developed from a modified common animal feed pellet press machine equipped with rotating roller-cylinders was effective to be used to made fuel pellet from Acacia bark waste biomass, even other additive materials such as tapioca and glycerol required to be blended to form the highest quality of fuel pellet (Figure 2.). Additives play a major role in wood pellet characteristics and are a subject of major interest as they act as binding agents for the biomass raw material[8]. We found in the less tapioca used, they were easily broken into the small pieces form during pelletizing or producing a low physical quality of fuel pellet. This fact was similar with the situation that reported on empty fruit bunches used as feedstock for the pellet production [9,10]. Tapioca was used to bind the small surface of bark dust material. This natural binder was applied to increase physical properties of feedstock such as low density and less surface area that hinder the smooth flow ability of biomass and also to substitute natural function of lignin as binder. Lignin as natural binder on briquette and pellet production was common used and reported previously [11].

Furthermore, we also observed that in the presence of suitable amounts of natural binder tapioca, the density of fuel pellets were good enough to reached 710-770 kg/cm³ to meet the Sweden (SS-187120) and Austria (ONORM) standards quality of pellet products (Table 2) (Figure 3).



Figure 2. Modified animal feed pellet press machine equipped with rotating roller-cylinders used on trial production of fuel pellet from *A. mangium* bark waste biomass



Figure 3. Long size and stable formation of Acacia bark waste fuel pellet in the presence of tapioca and glycerol as binder and additive; (a) 5% tapioca and (b) in the presence of 10% glycerol

Table 2. Physical properties of *A. mangium* bark waste biomass fuel pellet in various amounts of tapioca and glycerol

Compositions	Physical Properties of Acacia Bark Fuel Pellet			Global Standard Quality (kg/m ³)	
	Diameter (mm)	Length (mm)	Density (kg/m ³)	SS-187120	ONORM
Wood bark waste biomass (dust) + various amounts of tapioca in the absence of glycerol					
Tapioca 5%	7.47 ± 0.01	28.88 ± 0.10	770 ± 0.05	≥ 600	770 ± 0.05
Tapioca 10%	7.48 ± 0.03	29.39 ± 0.04	710 ± 0.00	≥ 600	710 ± 0.00
Tapioca 15%	7.40 ± 0.04	30.09 ± 0.07	740 ± 0.02	≥ 600	740 ± 0.02
Tapioca 20%	7.28 ± 0.00	30.31 ± 0.03	770 ± 0.03	≥ 600	770 ± 0.03
Tapioca 25%	7.21 ± 0.01	32.98 ± 0.19	760 ± 0.02	≥ 600	760 ± 0.02
Wood bark waste biomass (dust) + 10% tapioca in the presence of various amounts of glycerol					
Glycerol 5%	7.67 ± 0.02	2.93 ± 0.12	690 ± 30	≥ 600	690 ± 30
Glycerol 10%	7.66 ± 0.02	3.04 ± 0.01	660 ± 10	≥ 600	660 ± 10
Glycerol 15%	7.67 ± 0.06	3.12 ± 0.05	680 ± 10	≥ 600	680 ± 10
Glycerol 20%	7.70 ± 0.03	3.03 ± 0.26	730 ± 20	≥ 600	730 ± 20

Note: average and standard deviation from triplicate samples; fuel pellet was prepared from 500g mixture of bark waste feedstock and additives

3.2. Chemical properties and calorific value of fuel pellet

Chemical properties of fuel pellet from Acacia bark biomass was evaluated. Evaluation was done by assesment of moisture content (MC), ash content, volatile matter and fixed carbon of pellet in the presence and absence of tapioca and biodiesel side product, glycerol into the mixtures.

From this trial production we found the distribution of moisture content (MC) of the samples were 6.39% to 8.29% and its was good to meet with the global standard quality of pellet products. Li and Liu [12] reported that a good quality pellet has MC ranging between 6% and 12%. Further, other studies also found that wood pellets having MC ranging between 9% and 14% are most durable and resistant to abrasion [13,14]. Water has a crucial role in the pelletizing process and, along with lignin content, the MC of the feed is one of the most important parameters determining pellet durability and its also strong influence on heating value, combustion efficiency, and bulk density [15,16].

Table 3. Chemical properties of *A. mangium* bark waste biomass fuel pellet in various amounts of tapioca and glycerol

Compositions	Chemical Properties of Acacia Bark Fuel Pellet			
	Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)
Wood bark waste biomass (dust) + various amounts of tapioca in the absence of glycerol				
Tapioca 5%	7.52 ± 1.50	5.91 ± 0.27	88.51 ± 1.70	5.59 ± 1.96
Tapioca 10%	7.07 ± 1.75	5.06 ± 0.94	89.66 ± 1.48	5.29 ± 2.43
Tapioca 15%	7.13 ± 1.78	5.10 ± 0.37	89.46 ± 2.53	5.44 ± 2.90
Tapioca 20%	6.43 ± 1.59	4.63 ± 0.20	90.37 ± 1.77	5.01 ± 1.96
Tapioca 25%	6.39 ± 2.65	4.81 ± 0.15	89.23 ± 2.41	5.95 ± 2.26
Wood bark waste biomass (dust) + 10% tapioca in the presence of various amounts of glycerol				
Glycerol 5%	8.29 ± 2.53	5.63 ± 0.17	88.43 ± 2.47	5.94 ± 2.64
Glycerol 10%	7.79 ± 2.21	5.04 ± 0.27	88.84 ± 1.98	6.12 ± 2.25
Glycerol 15%	7.56 ± 3.31	4.45 ± 0.53	89.37 ± 3.19	6.18 ± 3.72
Glycerol 20%	7.42 ± 3.37	4.30 ± 0.81	89.50 ± 3.03	6.20 ± 3.84

Note: average and standard deviation from triplicate samples; fuel pellet was prepared from 500g mixture of bark waste feedstock and additives

The ash content, volatile matter dan fixed carbon of fuel pellet produced from Acacia bark were evaluated and the results were compared to the global pellet standard. The results showed that the ash content of Acacia bark pellets is still quite high at 4.30% - 5.91% (>1%). The higher ash content of pellet was believed due to silica, the minor element commonly found in tropical climatic plant [16]. Silica is one of the ash compounds other than potassium, calcium and magnesium. Concerning the effect of bark on the quality of biofuel, Filbakk et al [17] reported that the presence of bark in solid biofuels is related to increased tendency towards sintering during combustion and is therefore related to combustion problems. Concerning ash, [18] reported that increasing ash content results to lower heating value of the biofuel, implies the risk of sintering and negatively affects processing equipment.

The bark pellets produced has also lower carbon content ranging from 5.01% to 6.20%. The lower fixed carbon of pellets were believed due to high ash and volatile matter of bark material used. The results also showed that the fixed carbon values was positively increased when the number of glycerol added into the mixture increased.

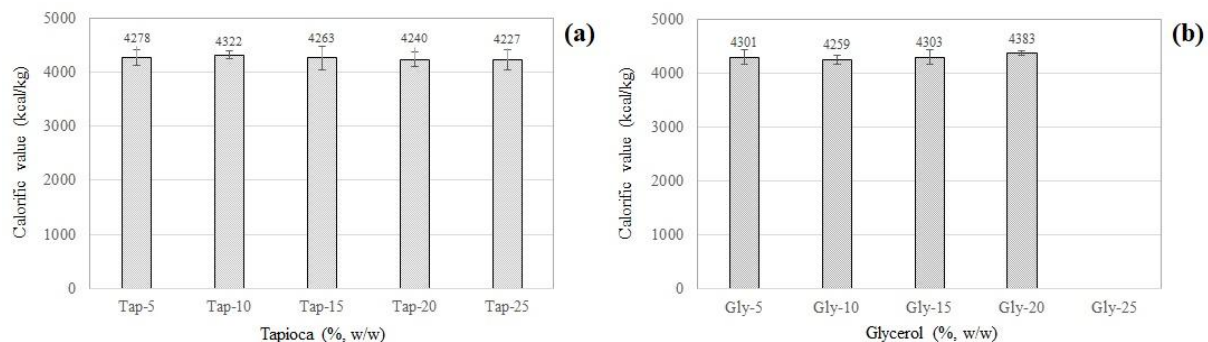


Figure 4. Calorific values of Acacia bark fuel pellet (a) in the presence various amounts of tapioca (Tap), and (b) 10% of tapioca and various amounts of glycerol (Gly) as binder and additive

The calorific value of bark pellets were also evaluated to find out the highest energy potency from pelleting process. Among the data collected, we found the highest calorific value was obtained from the mixture of bark dust material and 10% tapioca in the presence of 20% of glycerol to reached 4,383 kcal/kg of heating value. On the other hand, in the absence of glycerol the heating values of bark fuel pellet were only 4,227 to 4,322 kcal/kg. The heating value of pellet was increased trends linearly to correspond the increase number of glycerol added into the feedstock. In term of this, again we found that glycerol was clearly affect on the heating value of the pellet. This phenomenon was related with the properties of glycerol that known as a good source of energy and when it was used as an additive in fuel will be able to maintain the burning stability of the fuel, and increasing the heat of the fuel [10,19,20].

Table 4. General quality of fuel pellet produced from *A. mangium* waste bark biomass in the presence of tapioca and biodiesel side product, glycerol

Parameters	Status of quality	Global Standard Quality
Physical properties		
Fuel pellet density	Qualified	(SS 18 71 20)
Calorific Value	Qualified	(SS 18 71 20), (DIN 51731)
Chemical Properties		
Moisture content	Qualified	(ONORM M7135), (SS 18 71 20), (DIN 51731)
Ash content	Qualified	(ONORM M7135) (ITEBE)
Volatile matter	-	
Fixed carbon	-	
Total Sulphure	Qualified	(ONORM M7135), (SS 18 71 20), (DIN 51731)

Potential sulphur emission released on firing of fuel pellet from *A. mangium* bark waste biomass was also measured, especially those obtained in the presence of 10% tapioca and 20% of glycerol into the mixture. The results showed that the sulphur emission level was 0.07%, which still meets the global standard of pellet products ($0.07 \leq 0.08\%$). The low sulphur level of bark fuel pellets will positively reduce the emission rate in the air. Due to the low sulphur emission obtained, we also strongly believed that bark fuel pellet will be more environmentally friendly compared to coal and other fossil fuel energy.

4. Conclusion

Finally, we concluded that *A. mangium* waste bark biomass was potentially used as alternative feedstock for the fuel pellet production. Successful manufacture of fuel pellets from Acacia bark waste biomass was achieved for all combinations studied. The optimum mixture compositions among bark waste biomass, tapioca and glycerol was found at 10% of tapioca used in the presence of 20% glycerol to reached the highest calorific value 4,383 kcal/kg. Generally, the quality of fuel pellet produced from mix of bark waste biomass, tapioca and glycerol was satisfy to met the international standard quality of fuel pellet such as ONORM standard (Austria), SS (Sweden), DIN (Germany), EN (European) and ITEBE (Italy). Moreover, the modified common animal feed pellet press machine equipped with rotating roller-cylinders was effective used to produced fuel pellet in the small scall production.

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