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Energy Yield of the Carbonized Plant Leaf, Petiole and Branch Biomass Briquettes for Sustainable Production of Future Fuels

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Abstract. The effective use of waste biomass is an important factor for sustainability and global energy consciousness. Unsurprisingly, tree wastes such as leaves, petiole and branch are plentiful during trimming or autumn season which offer an economical source of biomass. The objective of this study was to probe the mechanical and thermal characteristics of briquettes created from tree waste of langsat, guava and rambutan tree. Collected tree wastes (leaves, petiole and branches) were chopped, mixed and then carbonized at 400-600 °C using a *Charcoal Retort* tube system. The briquettes were molded manually using a *Hydraulically Briquetting Machine* at pressures of 20 and 50 N/cm^2 for half an hour to 3 hours with regards on the type, density and fragments of the tree. Two system and machine were designed and fabricated by Biophysics Lab, Dept. of Physics, Faculty of Mathematics and Natural Sciences, Universitas Jember. Results indicated that briquettes made from tree waste of langsat, guava and rambutan have signs of mechanical and thermal properties which can be used as briquettes for various industrial uses.

Keywords: Sustainability, Alternate fuel, Tree waste, Biomass, Briquette

Introduction

Biomass briquette market share has grown 12% to 15% as more worldwide goverments and environment agencies focus towards replacing fossil fuel in concomitance to the rising demand to reduce fossil fuel usage [1,2]. The issue of global warming and renewable energy source has also alleviate biomass briquette role [3] especially carbonized briquette. In Indonesia, carbonized briquette has also found significant use as fossil fuel subsitutes in small home industries and even in domestic level. This shift is mainly caused by the ever increasing demand of fossil fuel, mainly LPG which in turn increases its price and restricts its use for small home industries. Carbonized briquette is one of the few types of alternative fuel that follows the main directions of biomass conversion which is having good thermal atributes while also being cheap with simple technolgy involved to produce in large quantites. However, this directions puts preasure towards tree harvesting, straining forestry and agriculture sectors.

An alternative way in is to utilize tree waste procured from natural tree death or as a result from tree maintenance such as prunning. Many studies have assesed that the volume of tree waste can fulfill the energy demands for small home industries and domestic level. From a raw material perspective, the use of biomass from tree waste is preferable than utilizing tree harvest, potentially being more environmental friendly and sustainable as tree waste is mostly under-utilized. Furthermore, tree waste is logistically more economical since it is more available in abundance. The most easy way of utilizing this form of fuel is as regular firewood which provides heat for

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cooking. However, due to their random form and high moisture content, regular firewood alone is not considered as a readily alternative fuel source.

Carbonized briquette is a solid biofuel that can provide heat for cooking. Basically, carbonized briquette is made by compacting loose biomass under high pressure in an effort to remove water and increase density. Prior to compaction, the biomass undergo carbonization in which volatile matter and excess moisture is removed [4] This process also enhances the caloric value of the end product. A binding agent is also added to increase compaction ease and product durability. As a result, carbonized briquette compared to regular firewood has better combustion attributes due to their higher carbon content. The end product is also more aesthetic pleasing, easy to transport and has a more homogen form which in turn ease its use for both small home industry and domestic purposes [5]. These aspects highlights the potential of carbonized briquette made from tree waste as a solution for sustainable alternative energy.

Sustainable energy depends on the supply of the material availability. Indonesia has the abundance of under-utilized tree waste as a result of its large scale of forestry and agricultural sectors. This paper serves as continuation to previous papers that emphasize production of carbonized briquette made from tree waste, mainly leaves, petiole and branches. In Indonesia, Langsat (*Lansium domesticum* L.), Guava (*Psidium guajava* L.) and Rambutan (*Nephellium lappaceum* Linn.). are commonly grown as a source of fruit. Previous studies have shown that rambutan and langsat (*Nephelium lappaceum*) has been used as biomass for briquetting [6,7]. however, the branch and leaves of the Langsat has not been reported. Guava leaves and wood showed a potency of solid densified biofuels in the form of pellet and briquette [8,9]. Considering Indonesia is the house of the Langsat and Langsat -Duku [10], utilizing of the petiole, leaves, branch those langsat could also give an addition of energy source of biomass. The thermal attributes of each tree waste carbonized briquette produced in this paper was investigated.

Theoretical Background

Briquetting

Briquetting is the process of compressing biomass material [11]. It is well known that fixed carbon has a direct link with calorific value. Briquetting's caloric value is mostly determined by its quality, which is determined by the amount of water, volatiles, and ash content [12]. Its total heating value is predicted to be between 28 and 30 MJ/kg. Although freshly manufactured charcoal has no water, it can quickly absorb moisture from the air during storage. Charcoal, which is often used domestically, has a net caloric value of 28 MJ/kg. That implies it has nearly double the energy value of air-dried fuelwood. Because of this significant disparity, transporting charcoal over a greater distance is less expensive.

The criteria of the energy fuel are cellulose and lignin content. The main ingredient that must be contained in the charcoal briquette raw material is lignocellulose. Lignocellulose consists of cellulose, hemicellulose, and lignin. Briquetting process has focused on production of smokeless solid fuels from coal and agricultural wastes. However, briquetting of organic materials (agricultural wastes) requires higher pressure as additional forces is needed to overcome the materials springiness of these materials.

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Figure 1. Plant leaf, petiole, and branch biomass for sustainable production of future fuels (a) Guava (Jambu Biji), (b) Rambutan and (c) Langsat. Continuously pruning of plant should be conducted in order to prevent the tree plant of risk in electrical powerline. This can be sustainable source of biomass energy during their cycle of life

Materials and Methods

The charcoal briquette production comprises of various steps and is depicted on figure 2. Tree waste comprising of leaves, petiole and branch of langsat, guava and rambutan were collected from kalibaru region in Banyuwangi. Any foreign material was then removed by hand. The collected biomass was first prepared by chopping and sun dried to reduce moisture content. Each individual biomass was then carbonized seperately in a charcoal retort tube system (designed and fabricated by Biophysics Lab, Dept. of Physics, Faculty of Mathematics and Natural Sciences, Universitas Jember) at 400º- 600ºC for an hour and then left to cool for pulverazation. Following pulverazation, the powder was then mixed with corn starch (95%:5%) as binding agent, and mixed until it produce a slurry texture. The slurry was then fed into cylindrical tube molds and

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compressed at 20 N/cm^2 and 50 N/cm^2 using hydroulic briquette machine (fabricated by Biophysics Lab, Dept. of Physics, Faculty of Mathematics and Natural Sciences, Universitas Jember). Dwelling time was 30 minutes for each compression. The freshly molded briquettes were taken out from the cyclindrical mold and finaly oven dried for 24 hours at 60 ºC.

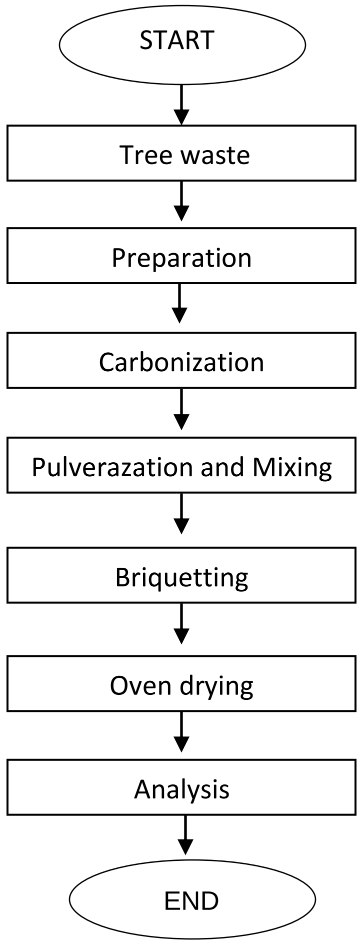

Figure 2. Research flowchat

Results and Discussion

Moisture Content of Briquette

Briquette moisture content is an important briquetting parameter. It can be observed that all of the briquettes had less than 8% moisture content, which is a favorable indicator of briquette quality (Figure 3). The heating value increases as the briquette's wet basis decreases, but the moisture content must be at an optimal level for the briquettes to perform well in combustion. Figure 3

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depicts the moisture content of three distinct briquette materials. It demonstrates that the greater the compaction, the lower the moisture content (50 N/cm^2 and 20 N/cm^2 were utilized). The Guava provided a lower moisture content. However, the moisture content of Langsat and Guava at of 50 N/cm^2 compaction is not significantly different. Because the water contents of the materials vary, it is proposed that water content analysis and material modification (e.g., rice husk) be performed prior to the briquetting process [13]. The greater the quality of the carbonized briquettes, the lower the moisture content of the briquettes. The lower moisture level was most likely caused by the drying process in the oven, allowing the water from the carbonized briquettes to evaporate more completely. The statistical analysis using SPSS revealed that there is a substantial difference in moisture content.

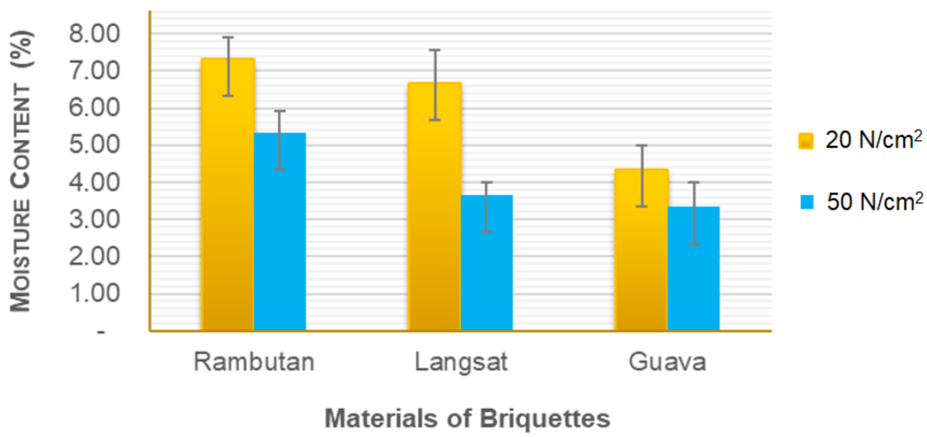

Figure 3. The Moisture Content (%) of briquette from Rambutan, Langsat and Guava (Jambu Biji) from the different of compaction of 20 N/cm^2 and 50 N/cm^2

Energy Output of the Briquette

A statistical test confirmed the findings, revealing that pressure had a significant influence on the energy output created. It demonstrates that carbonized briquettes generate a lot of energy. The biochar/carbonized briquette generated is a suitable alternative energy source to firewood and charcoal, and it may be used indoors since it is a cleaner energy form than un-carbonized briquette [14].

Figure 4 shows that the energy output of the three carbonized briquettes does not differ significantly across materials for the same compaction process of 20 N/cm^2. It also shows that with the same higher pressure of 50 N/cm^2, the briquettes have virtually the same energy output. However, the higher the pressure, the greater the energy output.

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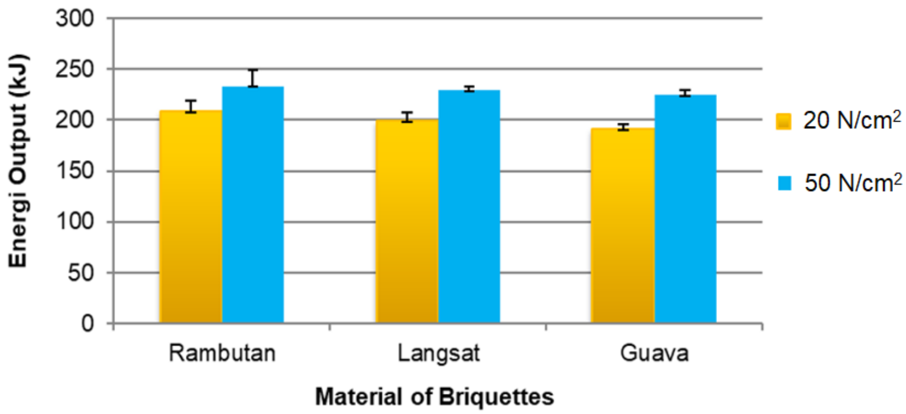

Figure 4. The Energy output (KJ) of briquette from Rambutan, Langsat and Guava from the different of compaction of 20 N/cm^2 and 50 N/cm^2

Under the pressure of 20 N/cm^2 for the carbonized briquette, the energy output of Rambutan, Langsat, and Guava is 208.005 kJ, 199.151 kJ, and 191.025 kJ, respectively. Rambutan briquettes have the highest energy output, whereas Guava briquettes have the lowest energy output with a compaction of 20 N/cm^2. The energy production of rambutan, langsat, and guava under 50 N/cm^2 pressure is 233.475 kJ, 229.230 kJ, and 224.985 kJ, respectively.

Ash Content

Ash content vary among the material of the briquetting. National standard of Indonesia gives the value of the ash content ≤ 8%. It showed that Guava gives the lowest of the ash content compared to the Rambutan and Langsat carbonized briquettes.

The amount of ash in the briquetting material varies (Figure 5). Rambutan and Langsat carbonized briquets have similar values, with approximately 8% for Langsat and around 8.1 percent for rambutan, and less than 7% for Guava under briquetting with a compaction of 50 N/cm^2. The ash content of carbonized briquettes of Langsat is in the range of 5 to 7% when compacted at 20 N/cm^2, with the lowest ash content being for carbonized briquettes of Langsat. Except for the ash level of carbonized rambutan briquettes, which was slightly higher than the national standard of Indonesia (Standart Nasional Indonesia-SNI) of 8%, the findings revealed that all of the material briquettes met the national Indonesian standard.

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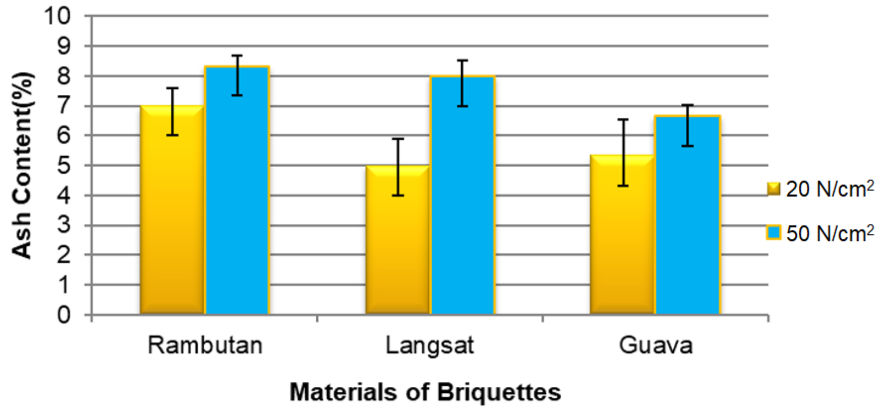

Figure 5. The Ash content (%) of briquette from Rambutan, Langsat and Guava from the different of compaction of 20 N/cm^2 and 50 N/cm^2

Rate of Combustion of the Briquettes

Figure 6 shows that the rate of combustion of the guava briquette is the greatest among the briquette materials, with the Rambutan and Langsat briquettes having comparably high rates of combustion under the compaction of 20 N/cm^2. It can also be observed in the figure that the compaction of 50 N/cm^2 resulted in a faster rate of combustion than the rate of 20 N/cm^2 from all of the materials utilized. Under a compaction of 50 N/cm^2, the rates of combustion of rambutan, langsat, and guava are 0.027 (g/s), 0.029 (g/s), and 0.042 (g/s), respectively. While the rate of combustion is about 0.021 (g/s), 0.021 (g/s), and 0.033(g/s) under the compaction of 20 N/cm^2 respectively.

From the data, it can be observed that the guava briquette has the greatest rate of combustion, with a compaction of 50 N/cm^2. This is because the rate of combustion is related to the density and ash content of the briquettes. The longer the rate of combustion, the higher the density and ash content. The length of the combustion process is another aspect that influences the rate of combustion. The pressure and substance of the briquette, as well as the rate of burning, had statistically significant effects in the two-way ANOVA.

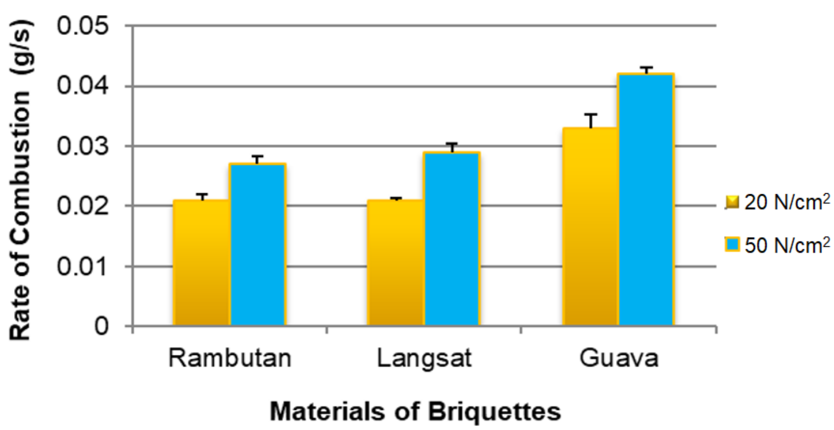

Figure 6. Rate of combustion of carbonized briquette of Rambutan, Langsat and Guava under the Compaction of 20 N/cm^{2}and 50 N/cm^2

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Briquetting Performance

In the Table 1, it can be seen that the performance of the carbonized briquette are varies among the material briquettes and under the different compaction. There is another requirement of the briquette that should be not easy to break, not brittle and have smooth surface. It should also not leave black to the hand [15]. It can be seen that there are different results of the briquette under pressure 20 N/cm^2 and 50 N/cm^2 for the same material of the briquette such as that under the pressure of 20 $\mathrm{N/cm^2}$ showed of more sturdy of the briquette, not easy to brake, compact but might have different appearance of surface, either rough (i.e., Rambutan and Guava) or soft (Langsat). While under pressure of 50 N/cm^2, the appearance of the briquette seems brittle, easy to brake, not compact, with the rough surface for both Rambutan and Guava, and soft for Langsat. However, all the carbonized briquette qualified for small industry and household demand.

Table 1 The performance of the carbonized briquette of Rambutan, Langsat and Guava under pressure of 20 N/cm^2 and 50 N/cm^2

Pressure (N/cm^2	Rambutan		Langsat		Guava	
20		Sturdy, not brittle, not easy to brake compact and rough surface		Sturdy. Not brittle, not easy to brake and soft/good surface		Sturdy, not brittle, not easy to brake, compact, and rough surface
50		Not so sturdy, brittle, easy to brake, not compact and rough surface		Not so sturdy, brittle, easy to brake, not compact, soft surface		Not so sturdy, easy to brake, not compact, rough surface

Conclusions

The chemical structure of the sample and its density suggest that briquettes formed from tree debris of langsat, guava, and rambutan have mechanical and thermal capabilities that may be employed as briquettes for diverse industrial purposes. With this potential of alternative and sustainable energy, the prospect of diversity as a home for the tree plant was recommended. Because the fruit is a good source of vitamins and bioactive compounds, it has a lot of advantages. Briquetting technology might be employed as a solution for home trash and the demand for sustainable energy for the area in the future, given the briquette's characteristics and the continual generation of biomass waste.

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