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Biopellet characteristics of ironwood sawdust waste (*Eusiderxylon zwageri* Teijms. and Binned.) based on different amounts of adhesive

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Abstract

Biopellets from ironwood sawdust waste is one of the environmentally friendly renewable energy. The purpose of this study was to determine the biopellet characteristics of ironwood sawdust waste and the most efficient amount of adhesive from it. This study used Completely Randomized Design with 5 treatments and 3 replications. The result indicates the highest water content of ironwood sawdust biopellets waste was found in treatment A (0% adhesive) that was 9.72% and the lowest was in treatment E (20% adhesive) that was 1.62%. The highest density average value was in E (20% adhesive) that was 1.25 and the lowest was in treatment A (0% adhesive) with 1.08. The highest calorific value was found in treatment E (20% adhesive) that was 5,661.20 kcal/kg and the lowest treatment was in treatment A (0% adhesive) that was 4,665.12 kcal/kg. The highest volatile matter result of the research was found in treatment E (20% adhesive) with 32.05% and the lowest was in treatment A (0% adhesive) that was 19.05%. The highest ash content was found in treatment A (0% adhesive) which was 1.60% and the lowest 1.13% was found in treatment E (20% adhesive). The highest fixed carbon valuewas found in treatment B (5% adhesive) that was 70.13% and the lowest is in treatment E (20% adhesive) that was equal to 65.19%.Treatment A (0%, adhesive) is the most efficient treatment yielding a value of 4,665.12 kcal / kg. This treatment has been in accordance with ASTM quality standards (> 4,600 kcal/kg).

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Introduction

Energy demand in our country is increasing and inversely proportional to the availability and energy production of the country itself. The main problem lies in the lack of fossil fuels as the main energy source today. Some of the energy problems faced by Indonesia include a very high consumption and dependence on fuels; people wasteful behavior when using fuel; low public access (purchasing power) to obtain energy; energy industry is not optimal; rampant smuggling of subsidized fuels and fuels forgery; fuels supply and distribution often inadequate and uneven; slow energy conversion and diversification;low use of biofuels (bbn, biofuels) and biomass energy (Department of Energy and Mineral Resources, 2005).

According to Tampubolon (2008) the use of renewable energy in the context of energy diversification is very strategic because it is in line with sustainable development and environmentally friendly (relatively low greenhouse gas emissions). Itwas accommodated in Presidential Regulation No. 5/2006 on National Energy Policy (NEP).

Indonesia through the Ministry of Forestry and the Korea Forest Service has signed an agreement on the development of this wood pellet biomass industry on March 6, 2009. It is said that Indonesia's production capacity is only 40 thousand tons, while the opportunity to develop this fuel is very wide open considering our very large forest product waste, both from timber industrial waste and from plantations. Pellet as a renewable alternative, is potential to be developed considering the need for world energy resources continue to increase, while responding to the lack of utilization of environmentally friendly energy sources.

The high level of utilization of ironwood in addition to threatening the sustainability of it can also cause environmental pollution. Sawmills produce waste in the form of sawdust. So far, the waste is thrown away environmentally and pollute the environment, especially the river waters because the sawmill industries are generally on the edge of the river. Although there are already community members who use the waste, no activity can significantly prevent the accumulation of ironwood waste. Therefore, alternatives of waste utilization should be sought to compensate the rate of increase or accumulation from it.

Ironwood sawdust waste, which is commonly found in the furniture industry and sawmill industry, is still not maximally utilized and the amount of waste is quite much. Based on field surveys of every Ironwood furniture industry in Banjarbaru, each day they generate an average of ± 20 kg/day of sawdust waste from cutting and reinforcement works. Ironwood is a wood that has a high density and lignin content that it is suspected to be a material that has good quality to be processed into wood pellets.

One of the most influential factors in biopellet quality is the type of adhesive. The tapioca adhesive as an additive is an ingredient that is often used in making biopellet because it is easy to obtain, the price is relatively cheap, available in abundant quantities and can produce high adhesive strength. Tapioca adhesives contain 97% carbohydrate (starch) (Zamirza, 2009 in Zulfian *et al*, 2015). From the research of Utomo and Primastuti (2013) it is known that the smaller particle size of the material with the same amount of adhesive will increase the endurance of biopellet strength. Therefore, the purpose of this study is to determine the biopellet characteristics of ironwood sawdust waste and the most efficient amount of adhesive from it and this study entitled is Biopellet Characteristics of Ironwood Sawdust Waste (*Eusiderxylon zwageri* Teijms. and Binned.) Based on Different Amounts of Adhesive.

Materials and methods

Materials

The collection of ironwood sawdust waste was done in sawmills and furniture industryy in Banjarbaru, the biopelletpelletizing process was carried out in the

Industry Standardization Body of Banjarbaru and its testing at the Faculty of Forestry Lambung Mangkurat University workshop.

The materials used in this research are ironwood sawdust waste and starch powder adhesive. The tools used in this research include saws, machetes, wood crusher tool, pelletizer machine, 40-60 mesh sieves, basins, glue, matches, oven, Bomb calorimeter, electric scale, spoons, calipers, porcelain cups, camera and stationeries.

The process of makingbiopellets

Materials preparation

Procurement of ironwood sawdust that wastaken from sawmills, Sawdust was dried until the water content reach 10% - 20%, Sawdust that slip through45 mesh sizewere sieved through60mesh size. Weighing of ironwood sawdust as much as 50 grams for 9-hole molds with the weight of each mold stuffing material 4.5 grams

Ironwood pelletizing process

Mixing of starch powder with ironwood sawdust according to the adhesive amount variations which are 0%, 5%, 10%, 15% and 20% from 50 grams weight of ironwood sawdust, Sawdust was put into the pelletizermachine, with the diameter of the machine is 1.2 cm and the height is 5 cm,Compressingwas conducted until the pellet wascompact enough with each temperatureof 130^{o}C for 25 minutes, the pellets were removed and cooled for ± 7 days (Nasir, 2015) Testing was conducted

Biopellet test parameters

Biopellets physical characteristics was measured with ASTM D5142-02.

Water content

Water content is the amount of water contained in the wood pellets until the water content balance is achieved in accordance with the air around it. The determination of water content was done by inserting one gram (g) of sample placed on aluminum foil that has been formed as cups. The sample was dried in an oven with a temperature of 103 ± 2^{o}C for 24 hours until the water content was constant. The sample after being dried, subsequently cooled in the desiccator for 15 minutes until the condition stabilized and then weighed (Nasir, 2015). The water content was calculatedusing the rule:

Water content $=\frac{BB-BKT}{BKT}x100\%$

Where:

BB= weight of materials before oven-dry

BKT= weight after oven-dry

Density

Density determination is expressed in comparison between the weight and volume of wood pellets. The sample density was calculated using the rule:

Density $= \frac{massa\ (g)}{volume\ (m3)}$

Ash content

Determination of ash content was done by placing one gram of sample placed in porcelain cups whose weight were already known. The sample then oven-dry in muffle furnace at 600-900^{o}C for 5 to 6 hours. The sample further cooled in the desiccator until the condition is stable and then weighed (Nasir, 2015). The sample ash content was calculated usingthe rule:

Ash content $=\frac{ash\ weight}{sample\ weight}x100\%$

Volatile matter

Determination of the volatile mattervalue was carried out with one gram of samples placed in a porcelain cups whose weight were already known. The sample was inserted into muffle furnace temperature 950 ± 20^{o}C for 7 minutes, then cooled in desiccator until the condition stabilized and then weighed (Nasir, 2015). The sample volatile mattervalue was calculated using the rule:

Volatile matter $=\frac{B-C}{W}x100\%$

Where:

B = sample weight after being dried from the water content test (g)

C = sample weight after oven-dry (g)

W= sample weight before water content test (g)

Fixed carbon

Determination of fixed carbonwas done after the results were obtained from water content, volatile matter and ash content test. The fixed carbon value was calculated by the rule:

Fixed carbon = 100- (Water content +volatile matter+ash content).

Calorific value

One gram of sample inserted in silica cups and then added to the Calorimeter Bomb tub (Nasir, 2015). Measurement of calorific value was done using a manual peroxidecalorimeter bomb. The calculation results based on the amount of heat released is equal to the amount of heat absorbed in units of cal/gram by the rule:

$$NK = \frac{\Delta t \ x \ W}{Mbb} - B$$

Where:

NK = calorific value (cal/g)

Δt= average temperature difference (°C)

Mbb = fuel mass

B = hot iron wire correction (cal g^{-1})

Data analysis

This study used Completely Randomized Design at 5 treatments with 3 replications so that the total test samples was 5 × 3 = 15 test samples. Data obtained from the research were analyzed using Microsoft Excel.

A= 0% adhesiveofironwood sawdust size 60 mesh

B= 5% adhesive of ironwood sawdust size 60 mesh

C= 10% adhesive of ironwood sawdust size 60 mesh

D= 15% adhesive of ironwood sawdust size 60 mesh

E= 20% adhesive of ironwood sawdust size 60 mesh

Result and discussion

Water content

The water content of the wood pellets affects the calorific value. The smaller the water content value the better the calorific value and vice versa if the water content value is high,then the calorific value will be low which will affect the quality of the pellets. Wood pellets have hygroscopic properties, which mean a property where wood can absorb and release water in accordance with environmental conditions, so that the calculation of water content aims to determine the hygroscopic nature of the research product wood pellets.

The average value of water content ranges from 1.62% - 9.72%. From the values of the water content, all treatments are in accordance with the standard set by Sweden, which is a maximum 12% and South Korean standard of 10% maximum, SNI set 10% standard, but for the ASTM standard which set the value of water content below 6%, treatment A with 0% adhesive is not yet suitable while the other treatments were appropriate.

The average graph of the adhesive amount effect on the wood pellets water content is shown in Fig. 1.

The analysis result of Figure 1 shows that there are differences of percentage of wood pellets water content in each treatment. The lowest percentage of water content was found in treatment E with the addition of 20% starch powder adhesive while the highest percentage of water content was seen in treatment A with the addition of 5% starch. The more the amount of adhesive given there is a decrease in the percentage of the water content of the wood pellets. This is because the starch particle size is smaller than the ironwood sawdustparticle size so that at the time of the compression process at 1200 psi pressure, the starchadhesive particles will fill the empty pores in the wood pellets which can reduce the water content in the wood pellet pores or otherwise known as “free” water.

Based on the analysis variance result, it is known that variations of adhesive addition have no significant effect on water content value. The result of the water content test is in accordance with Rahman's (2011) research cited in Adrian (2015) which states that high pressure at the time of pelletizing causes the wood pellets to become dense, high density, smooth and uniform so that the biomass particles with the addition of adhesive can co-fill the pores which is empty and lowers the water molecules that can occupy the pores.

High water content in pellet fuels will cause a slow burning process; generate a lot of smoke and low fire temperature at the time of combustion.

Density

Density shows the comparison between mass and volume of wood pellets.

The density valueis influenced by the size and homogeneity of the sawdust making up the wood pellet. Density also determines the quality of heat and also the duration of burning in wood pellets;high-density value of wood pellets will tend to provide high calorific value and more durable burning rate, but will be difficult in case of ignition.

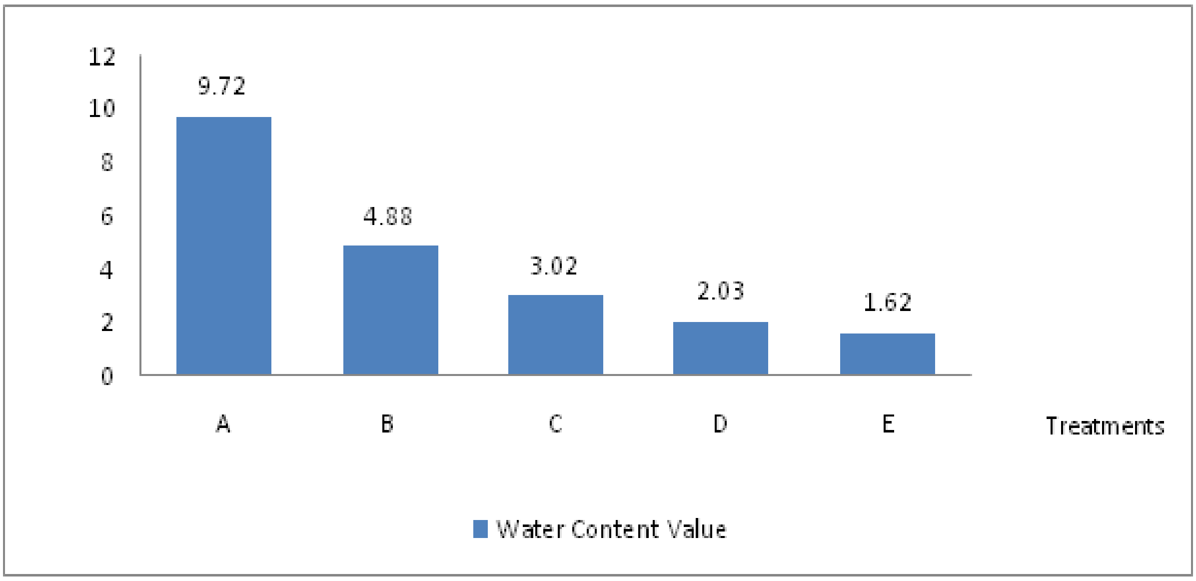

Fig. 1. Graphic ofironwood pellets water content on various adhesive variations.
A= 0% adhesive, B= 5% adhesive, C= 10% adhesive, D= 15% adhesive and E= 20% adhesive.

The result showed that the average values of ironwood pellet density in treatment A was 1.08 g/cm^3, B treatment of 1.15 g/cm^3, Ctreatment of 1.18 g/cm^3, D treatment of 1.20 g/cm^{3}and treatment E of 1.25 g/cm^3. The graph of ironwood pellet average density is shown in Figure 2.

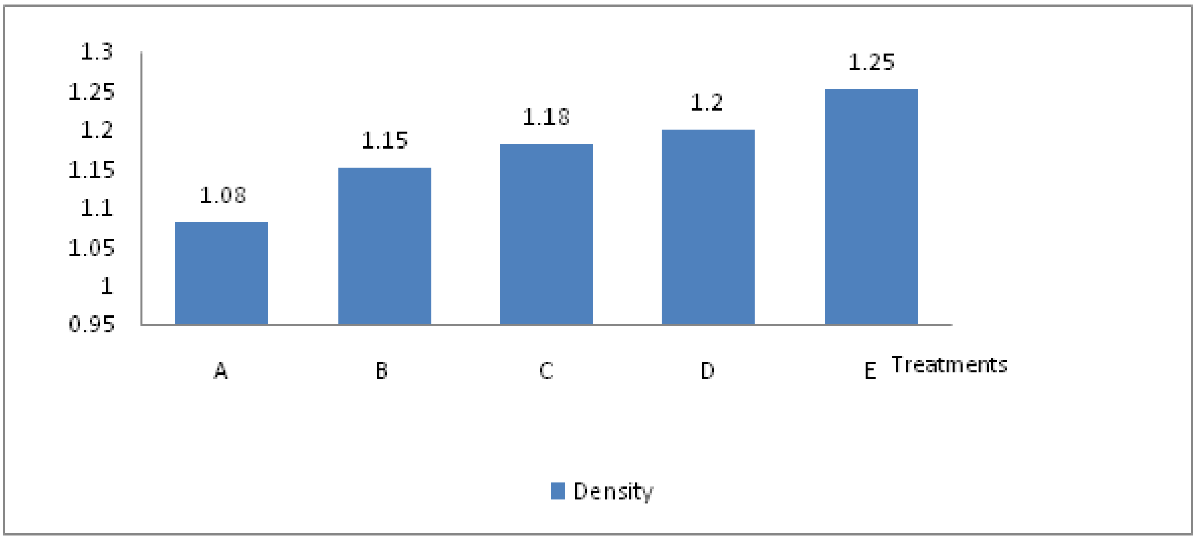

Fig. 2. The graph ofironwood pellet density in various adhesive variations.

The analysis result on Fig. 2 show the highest density value was found in treatment E of 0.25 g/cm³with the addition 20% starch adhesive and the lowest density value was found in the treatment with the addition of 5% starch adhesive of 1.08 g/cm³.

The varianceanalysis result showed that the variation in the amount of adhesives had a significant effect; therefore honest significant difference test was conducted.The HSD test result shows the density value at each treatment. Ttreatment E (20% adhesive) significantly different from treatment A (0% adhesive), treatment D (15% adhesive) was not significantly different from treatment C (10% adhesive) as well as treatment D was not significantly different from treatment B. From the HSD, the E treatment is the best treatment because its effect is significantly different with the effect of the lower value treatmentswhich was treatment (D, C, B and A).

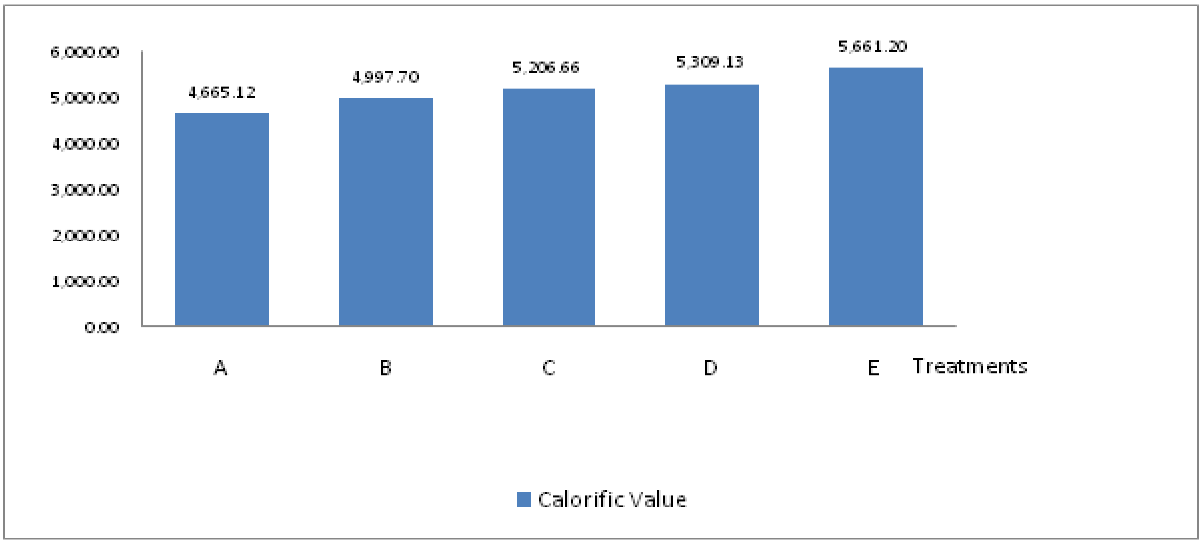

Fig. 3. Graph of wood pellets calorific value on various adhesive variations.

Wood pellet density values will increase with the increasing of adhesive amount; this is because the starch that act as an adhesive will bind the ironwood sawdustparticles during the compression process. Adrian (2015) states that the size of the starch adhesive particles is smaller than the sawdust particlesso that in the compression process the starchadhesive can fill the empty poresof the wood pellets. Masturin (2002) also suggests that smaller particle sizes can expand the bonding field between powders, thereby increasing the density of wood pellets. It is also in line with the opinion of Yakin (2014) that the addition of adhesives will increase the bonding between particles to minimize the wood pellets pores.

The value of wood pellet density is important to know, it is directly related to the wood pellets produced because it will facilitate in terms of handling, storage and transportation. A higher density will make pellets difficult to burn, but the calorific value and compression will increase Hendra (2012).The density values of all treatments are in accordance with the Swedish standard that set the value greater than 0.8 g/cm³, the South Korean standard setting is greater than 0.64 g/cm³, the SNI standard is 0.45 - 0.65 g/cm³and ASTM standards that set above 0.46 g/cm³.

Calorific value

Heat value greatly determines the quality of wood pellet and is an important parameter in the selection of solid fuels such as wood pellet. The higher the calorific value of wood pellets, the better the quality of the wood pellets produced, but otherwise if the calorific value is low then the quality of the wood pellets is also low. Woods of high density tend to have high calorific values.

The results showed that the calorific value of ironwood pellet at treatment A was 4,665.12 cal/g, treatment B 4,997.70 cal/g, treatment C 5,206.66 cal/g, treatment D 5,309.13 cal/g and treatment E 5,661.20 cal/g. With a high wood density, the calorific value of ironwood pellets also shows good quality. The graph of the adhesive amounteffect on the wood pellets calorific value is shown in Fig. 3.

The lowest calorific value of 4,665.12 cal/g was in treatment A (0% adhesive), while the highest heat value of 5,661.20 cal/gwas found in treatment E (20% adhesive). The analysis results show that the calorific value will increase with the increase amount of starch, because wood pellets with high amount adhesive will produce low water content, while low water content will produce high calorific value. This is in accordance with the opinion of Nurhayati (1974) in Wijayanti (2009) that the heat is influenced by the amount of water content and ash content of wood pellets.

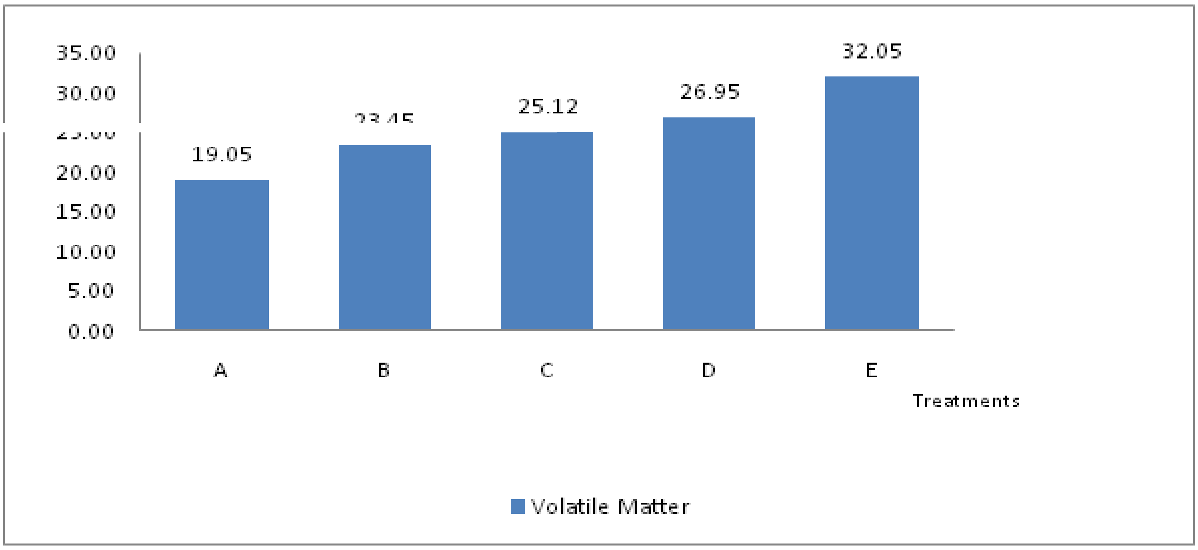

Fig. 4. Graph of ironwood pellets volatile matter in various adhesiveamount.

The high calorific value indicates abetter quality of a fuel; the value is inversely proportional to the water content value. The higher the water content of a fuel will result inlower calorific value. Yanti (2013) also states that the calorific value is closely related to the water content and the density of the wood pelletsproduced. Lower water content will increase the density of the wood pellet and the more dense the product is produced in line with the increasing % of calorific value. The calorific value of all treatments is in accordance with the standard set by Sweden, which is 4,500 cal/g, South Korean standard is 4,300 cal/g, and the SNI standard specifies at least 4,000 cal/g and ASTM standard which specify at least 4,600 cal/g.

The result of the analysis of variance showed that the varied treatments of adhesiveamount had no significant effect so that no further test was conducted. This is in accordance with Faizal's (2014) research that showedthe calorific value of rubber wood biobricket with adhesive variations of 5%, 10% and 15% was not statistically significant.

Volatile mattervalue

The research result showed that the average value of the ironwood pellet volatile matter in treatment A was 19.05%, treatment B was 23.45%, treatment C was 25.12%, treatment D 26.95% and treatment E 32.05%. The graph of the effect of the adhesiveamount on the values of the volatile matter is shown in Figure 4.

The lowest volatile matter value of 19.05% was found in treatment A (0% adhesive) while the highest value of 32.05% was found in treatment E (20% adhesive). The results of the analysis showed that the value of volatile matter increases with the addition of starch adhesive in the wood pellets. At the time of the wood pellet heating, the starch evaporates, whichresulting in the increase of the volatile mattervalues by the increasing of the adhesiveamount. This in accordance with the opinion of Meliza (2009) which states that the value of volatile matter in briquettes produced is influenced by the composition of adhesive and raw materials.

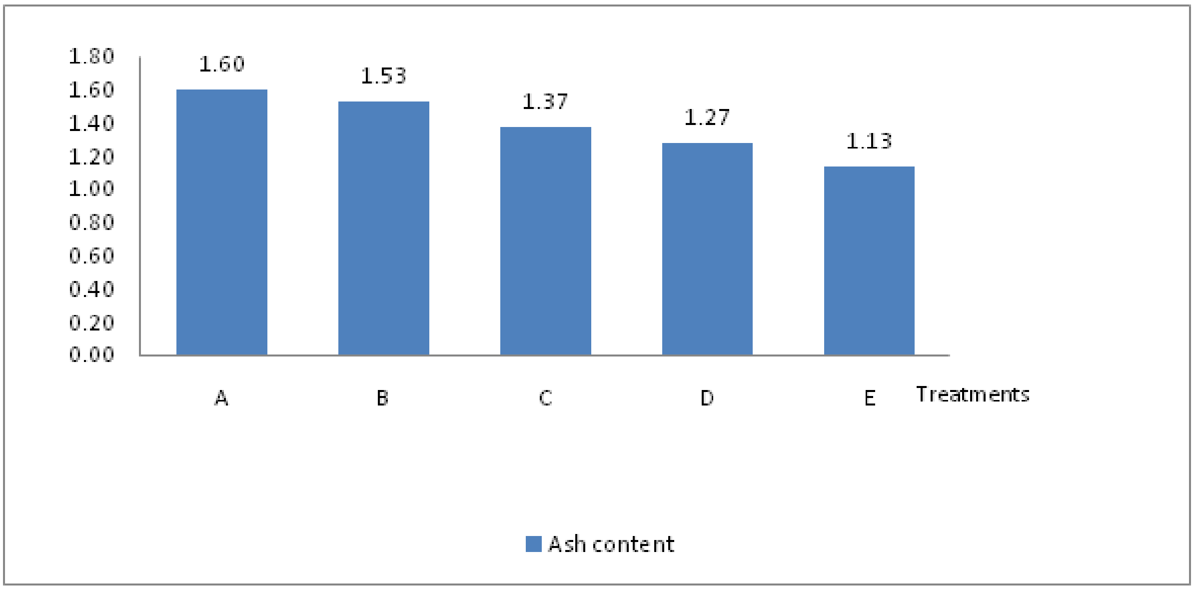

Fig. 5. Graph of ironwood pellet ash content on various adhesive variations.

The analysis of variance result showed that the various amountsof adhesive had a very significant effect on the volatile mattervaluestherefore the Duncan test was continued.

Based on Duncan test results, each treatment to the volatile matter value showed that E (20% adhesive) treatment was significantly different with D treatment (15% adhesive), C treatment (10% adhesive) and B treatment (5% adhesive). From Duncan test, the treatment of E, D and C is the best treatment because it has a more significant differentce frequency compared with other treatment.

Ash content

The results showed the average value of ironwood pellet content in treatment A was 1.60%, B treatment was 1.53%, C treatment was 1.37%, treatment D 1, 27% and treatment E 1, 13%. The graph of the effect of the adhesiveamount of the ash content is shown in Fig. 5.

Based on the analysis results on figure 5, it can be seen that the ash content resulting from this study ranged from 1.13% - 1.60%. The highest ash content was obtained in wood pellet with treatment A (0% adhesive) which was 1.60%, while the lowest ash content of the treatment E (20% adhesive) was 1.13%. It is assumed thatstarch adhesive ash content which has an ash content value of 0.14% will decrease the ash content value of wood pellets.

Analysis of variance results showed that the adhesive amount differencestreatment had a very significant effect on the ash content value so that it was necessary to carry out further test of honest significantdifference test (HSD). The results of the HSD follow-up showed that the best treatment was seen in treatment E, D and C.

The value of ash content is seen to be higher along with the least adhesiveamount added to the mixture. This is in agreement with Ismayana (2011) which states that the higher the ash content of raw materials and the more adhesive composition the resulting ash content will decrease.

Of the ash content, all treatments are not in accordance with the Swedish standards which set ash values below 0.8% and South Korean standards that set ash values below 0.7%, alsonot in accordance with the ASTM standard which sets the value of ash content below 1 % But ofthe SNI standards that set a maximum ash value of 1.5%, treatment of C, D and E have been in accordance it.

Fixedcarbon

The average fixed carbon values range from 65.19 to 70.13%. The graph of fixed carbon values can be seen in Fig. 6.

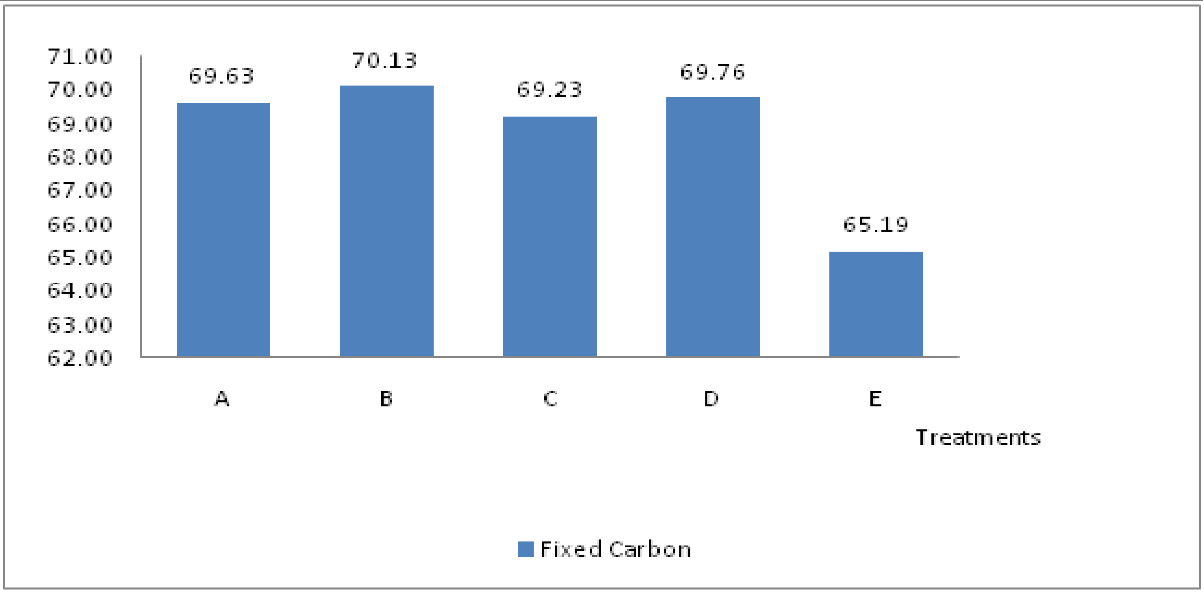

Fig. 6. Graph of fixed carbon values on wide varieties of adhesiveamount.
A= 0% adhesive, B= 5% adhesive, C= 10% adhesive, D= 15% adhesive and E= 20% adhesive

Based on the analysis result infigure 6, the lowest fixedcarbon value was obtained in wood pellets with E (20% adhesive) treatment of 65.19%, while the highest fixed carbon value was obtained from treatment B (5% adhesive) of 70.13%.

The value of the carbon depends on the amount of water content, ash content and volatile matter value. The lower the water content, the ash content and the volatile matter the greater the value of the fixed carbon content.

The result of the variance analysis showed that the adhesive amount differenceshad a very significant effect on the fixed carbon values so that it continued withHSD test. From the result of HSD further test, the best treatment is found in the treatment of E, D, B and C.

Conclusion

The characteristics of the best wood pellets compared to treatments A, B, C and D were shown by the E treatment (20% adhesive addition) with a density value of 1.25 g/cm^3, 1.62% water content, 5,661.20 cal/g, ash content of 1.13%, the value of volatile matter 32.05% and the fixed carbon value of 65.19%, Treatment A (0%, adhesive) is the most efficient treatment yielding a value of 4,665.12 kcal / kg. This treatment has been in accordance with ASTM quality standards (> 4,600 kcal / kg).

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