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Production and Characterization of Coffee Husk and Sawdust Briquettes with Potato Peel, Waste Paper and Molasses as a Binding Material

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Abstract— Ethiopia produces considerable amount of biomass each year which has been utilized for domestic energy purpose, mainly by direct combustion. Ethiopia still relies heavily on traditional sources of energy for cooking and heating. The main aim of this research paper was to produce and characterize coffee husk and sawdust briquette with different type and ratio of binding material for modern utilization of biomass wastes. The problem of briquette utilization was its varying properties with different raw material and binding material type and ratio. In this study coffee husk and sawdust fuel briquettes, comprising varying ratios of potato peel, waste paper and molasses as a binder, were molded and characterized. Physical property, volatile matter, ash content, moisture content, fixed carbon and heating value, among other properties, were determined for the produced briquettes. The results of the physical properties investigated were; height of briquette ranges (2.4-5.2cm), diameter of briquette (12.6cm), mass of briquette ranges (83.5-414.5gm), and bulk density ranges (0.21-0.71gm/cm^3) for all briquette produced from the selected biomass waste with different binder material ratio. The proximate analysis gave the following results; % volatile matter ranges (60.87-71.05), % ash content ranges (5.65-10.73), % moisture content ranges (6.42-11.32), % fixed carbon (20.87-28.73) and the heating value was found to be in range of (30075.39-31796.94 kJ/Kg) for the above selected biomass with different type and ratio of binders.

Index Terms—Biomass, Binder Material, Briquettes Characterization, Carbonization, Fuel Briquette

1. INTRODUCTION

Ethiopia produces considerable amount of biomass each year which has been utilized for domestic energy purpose, mainly by direct combustion. Many of the developing countries produce huge quantities of agro residues but they are used inefficiently causing extensive pollution to the environment. Ethiopia still relies heavily on traditional sources of energy for cooking, and heating. The use of wood is also increasing on daily basis especially in the less technologically developed countries of the world [1]. Agricultural waste accounts for 35% of primary energy consumption in developing countries, which constituting about 14% of the world's total primary energy consumption [2]. Woody biomass constitutes 95% of total potential supply. About 77% of annual biomass consumption in Ethiopia is met from fuel wood followed by animal dung 13% and crop residue 9% respectively [3].

Ethiopia has enormous amount of coffee husk, industrial and agricultural waste potential. Annually, from only limu and tepi farms, 3,676,088 and 3,535,224 kg of coffee husk and dry coffee pulp were generated respectively, which has been consumed by households in place of firewood with inefficient open fire stoves [4]. Briquetting is the process of compaction of residues into a product of higher density than the original raw materials. It can be done with or without a binder, doing without binder is more convenient but it requires sophisticated and costly presses and drying equipment [5]. This makes such processes unsuitable in a develop-ing country like Ethiopia because of high machine and briquette production cost. Biomass briquettes can pro-vide an alternative household solid fuel, especially in rural areas. These can be burnt clean and, therefore, are eco-friendly.

In selecting biomass for briquette, emphasis is given to the local availability of biomass with lower lignin and ash con-tent [6]. Moisture content should be as low as possible, generally in the range of (10-15%). Biomass residues normally have much lower ash content (except for rice husk with 20% ash) but their ashes content should be as low as possible [7]. When biomass wastes are con-verted to fuel briquette, they can substantially replace fossil fuel, reduce the emission of greenhouse gases (GHG) and providing renewable energy to people in developing countries, like Ethiopia. Therefore, the ob-jectives of this study were to produce fuel briquettes from coffee husk and sawdust with different type and ratio of binders to evaluate their energy potential and characterize their fuel property.

2. Materials and Methods

The convensional methods of briquette production was used in this study.

1. Waste paper was used both as raw material and binding agent in briquette production. Molasses was used for carbonized coffee husk briquette production. Potato peels was used as a binder agent for uncarbonized coffee husk and sawdust by boiling with water until the sticky gel is formed.
2. The briquettes were produced from coffee husk and sawdust as raw material. The selected raw materials were mixed with different ratio of waste paper, potato peels and molasses as a binding agent.
3. Composite samples were take from produced briquettes for characterization through physical and proximat analyses. Proximate analysis, which is a standardized procedure that gives an idea of the bulk components that make up a fuel, was done to determine the average of the percentage volatile matter content, percentage ash content, moisture content and percentage content of fixed carbon of the briquettes obtained from different samples. The procedures of the ASTM standard was adopted to obtain the above parameters.

(a) Produced Priquette from Carbonized and Uncarbonized biomass.

(b) Sample Of Briquette Taken For Test

Fig. 1. Fuel Briquettes production and Test.

2.1. Proximate analysis

1. Percentage Volatile Matter

The percentage of volatile matter (PVM) was determined by pulverizing 2gm of the briquette sample in a crucible and placing it in an oven until a constant weight was obtained. The dried sample left in the crucible was covered with a lid and placed in muffle furnace, maintained at 950 ± 20 °C for 7 minutes (ASTM D-3175). The PVM was then calculated using the Equation below:

$$PMV = \frac{A - B}{A} X100 \quad (1)$$

Where A is the weight of the oven dried sample and B is the weight of the sample after 7 minute in the furnace at 950°C.

2. Percentage Ash Content

The percentage ash content (PAC) was also determined by heating 2gm of the briquette sample in the furnace at a temperature of 550°C for 4hr and weighed after cooling in a desiccator to obtain the weight of ash (C). The procedures of the ASTM standard D5373-02 (2003) was adopted to obtain the parameters. The PAC was determined using the Equation below.

$$PAC = \frac{C}{A} X100 \quad (2)$$

Where A is the weight of the oven dried sample.

3. Percentage Moisture Content

The percentage moisture content (PMC) was found by weighing 2gm of the briquette sample (E) and oven drying it at 105°C until the mass of the sample was constant. The change in weight (D) after 60 min was then used to determine the sample's PMC using the Equation below:

$$PMC = \frac{D}{E} X100 \quad (3)$$

4. Percentage of Fixed Carbon

The fixed carbon content was calculated by applying the mass balance for the biomass sample. The percentage fixed carbon (PFC) was computed by subtracting the sum of PMC, PVM and PAC from 100 as shown in the Equation below:

$$PFC = 100\% - (PVM + PAC + PFC) \quad (4)$$

5. Heating Value

The gross or high heating value is the amount of heat produced by the complete combustion of a unit quantity of fuel. This was calculated using the formula:

$$Heatingvalue = 2.326(147.6FC + 144VM) \quad (5)$$

Where FC is the percentage fixed carbon and VM is the percentage volatile matter [8]

3. Result and Discussion

3.1. Physical Property

The result from physical properties of the produced briquettes revealed that the produced briquettes has good indication for efficient burning. Bulk density of the raw biomass briquette increased in line with binder agent ratio increase. This showed that substantial space could be saved in transportation and storage of briquettes prepared. The results of the physical properties investigated were; diameter of briquette (12.6cm), height of briquette ranges (2.4-5.2cm), mass of briquette ranges (83.5-414.5gm).

Table 1. Set of Observations

1. coffee husk:Waste Paper Ratio					
S.No	Item	70:30	60:40	50:50	0:100
1	Density (g/cm^3)	0.27	0.29	0.34	0.51
2	Moisture Content (MC%)	9.72	8.63	7.40	6.42
3	Volatile Matters (VM%)	68.40	68.99	69.89	71.05
4	Ash Content (AC%)	10.73	8.39	7.02	5.65
5	Fixed Carbon (FC%)	20.87	22.62	23.09	23.30
2. Sawdust:waste papers ratio					
S.No	Item	70:30	60:40	50:50	0:100
1	Density (g/cm^3)	0.21	0.24	0.26	0.51
2	Moisture Content (MC%)	8.06	7.34	6.66	6.42
3	Volatile Matters (VM%)	67.84	68.62	69.02	71.05
4	Ash Content (AC%)	9.57	7.30	6.08	5.65
5	Fixed Carbon (FC%)	22.58	24.08	24.90	23.30

3.1.1. Density

The briquette produced in this study had the bulk density greater than bulk density of sawdust with binding agent ratio increased from (10-50) % and resulted bulk density ranges (103.87-159.48) kg/m^3 for phytoplankton, (117.61-178.32)kg/m^3 for banana peels, (126.04-185.62)kg/m^3 for yam and (130.43-198.51) kg/m^3 for cassava peels. The density of briquette produced from sawdust and coffee husk with binder of potato peels was greater than the sawdust briquette with banana peels and cassava peels binder [9]. The carbonize coffee husk briquette had bulk density greater than briquettes produced from elephant grass and spear grass by moderate pressure, which had a corresponding value of densities of 0.319gm/cm^3 and 0.367gm/cm^3 respectively [10]. The density of briquette produced from sawdust and coffee husk with binder of potato peels was greater than the sawdust briquette with banana peels and cassava peels. From the result carbonized coffee husk with 25% molasses binder ratio had the greatest bulk density. The variation of the bulk density depending on the composition of the briquette and binder material ratio.

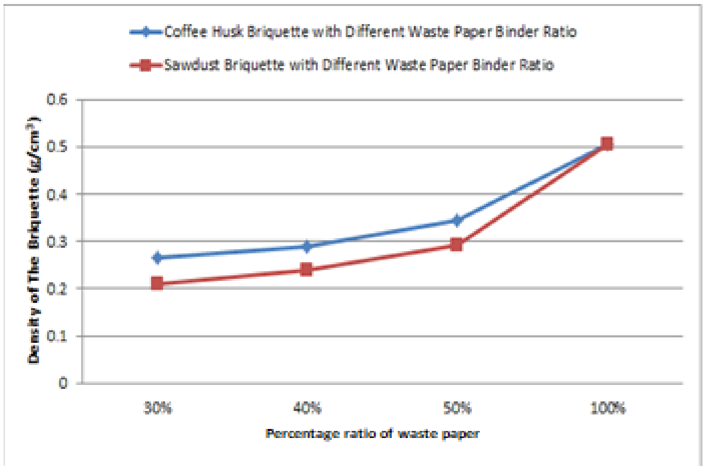

Fig. 2. The Density of the Briquette for Different Waste Paper Binder Ratio

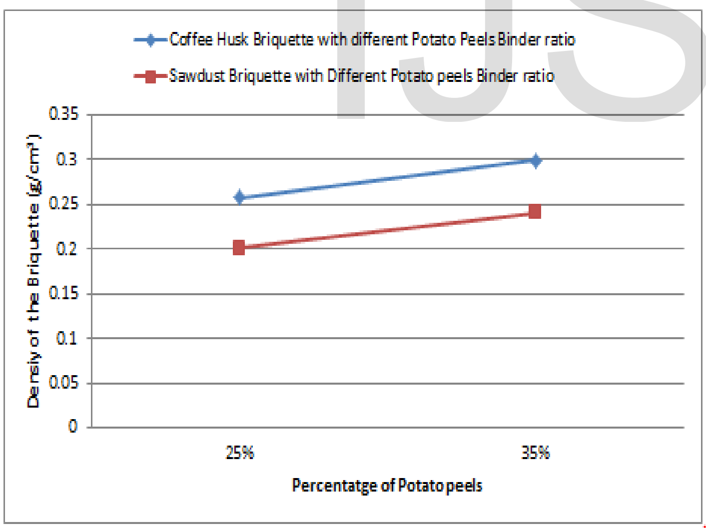

Fig. 3. The density of the briquette with potato peels as a binder.

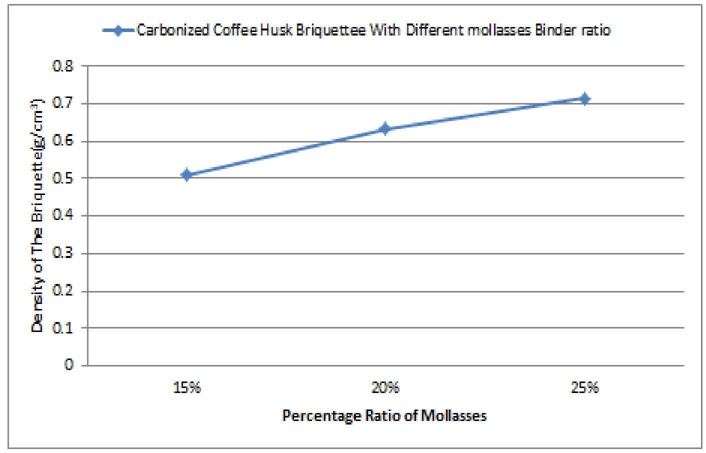

Fig. 4. The Density of the Briquette Produced With Molasses as a Binder

3.2. Proximate Analysis

The briquette prepared from sawdust, coffee husk and waste paper were an acceptable source of fuel due low ash content. The result of proximate analysis of the formed briquette: moisture content, ash content, heating value and fixed carbon were computed. The proximate analysis gave the following results; % volatile matter ranges (60.87-71.05), % ash content ranges (5.65-10.73), % moisture content ranges (6.42-11.32), % fixed carbon (20.87-28.73) and heating value in range of (30075.39-31796.94) kJ/Kg for the above selected biomass with different ratio of waste paper, molasses and potato peels binder. Moisture content of uncarbonized coffee husk briquette was highest compared to other briquettes. The volatile matter increase with the concentration of the binder. The density of the briquette varies with the binder ratio.

3.2.1. Moisture content

The moisture content of the briquettes produced in this study had smaller moisture content than the briquettes produced from rice husk which was 12.67% [11]. The quality specification of charcoal usually limits the moisture content between 5 to 15%. Therefore, the moisture content of briquettes obtained in this study was inline with this specification. However, to facilitate heat transfer, moisture content should be as low as possible [3]. The charcoal briquette from carbonized coffee husk with 25% molasses binder ratio had the lowest moisture content. The variation of the Moisture content depending on the composition and binder material ratio.

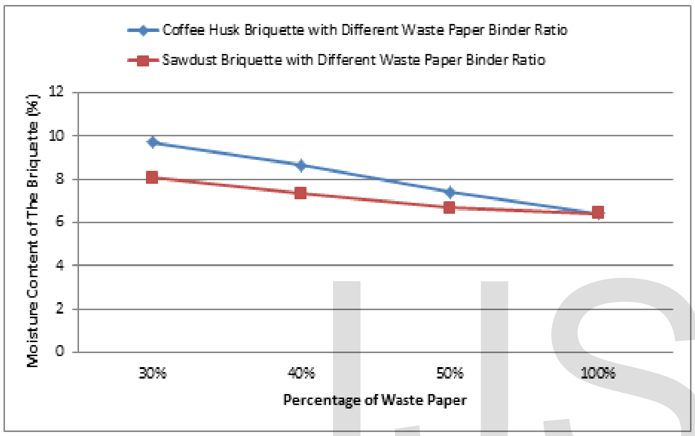

Fig. 5. The Moisture Content of the Briquette for Different Paper Binder Ratio

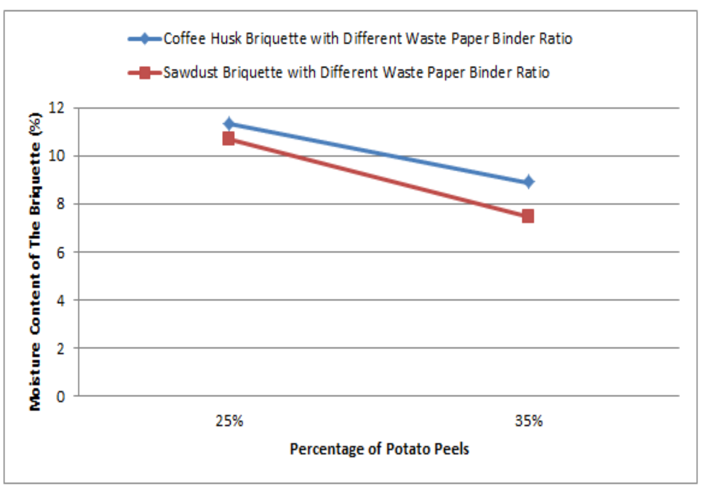

Fig. 6. The Moisture Content of the Briquette with Potato Peels as a Binder

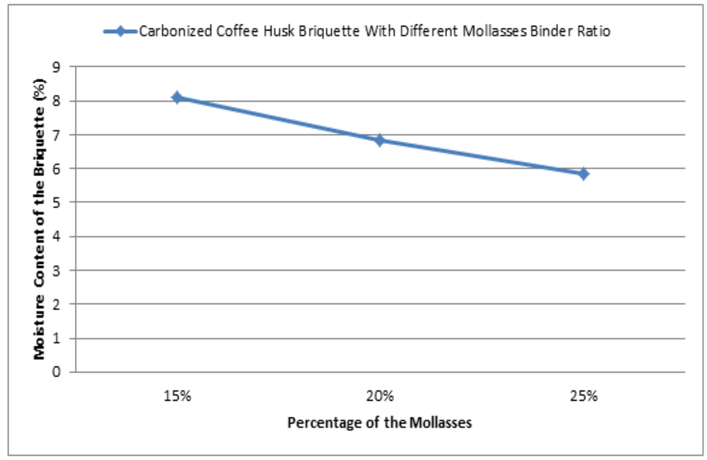

Fig. 7. The Moisture Content of the Briquette with Molasses as a Binder

3.2.2. Ash content

The ash content of the briquettes in this study was lower than the ash content of briquettes produced from rice husk which was 16.10% [39]. Yet, a typical ash content of fine quality lump charcoal is about 3% [12]. However, the ash content of the briquettes produced in this study was less than the specified range. This might be due to the effect of the binder used to bind the biomass which was combustible (Waste papers, potato peels and molasses). This suggestion is consistent with the proposition that using anon-combustible binder results in the production of more ash than using a combustible binder [10]. The ash content is an indicator of slugging behavior of the biomass. Hence, the larger the ash content, the larger will be the slugging behavior. From the analysis conducted the lowest ash content was obtained for pure waste paper briquettes.

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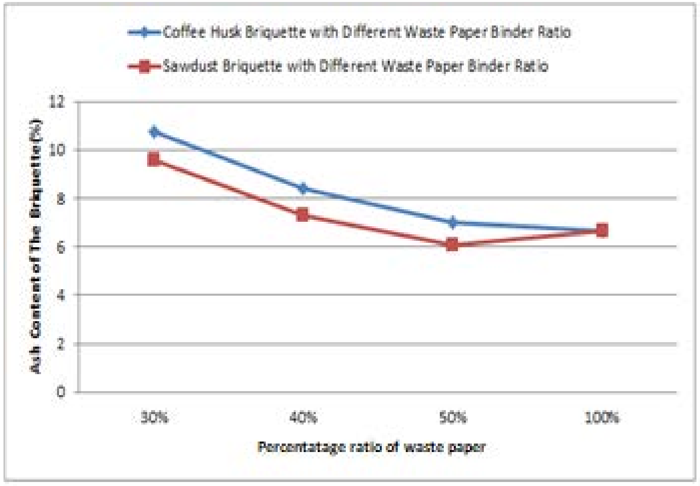

Fig. 8. The Ash Content of the Briquette for Different Paper Binder Ratio

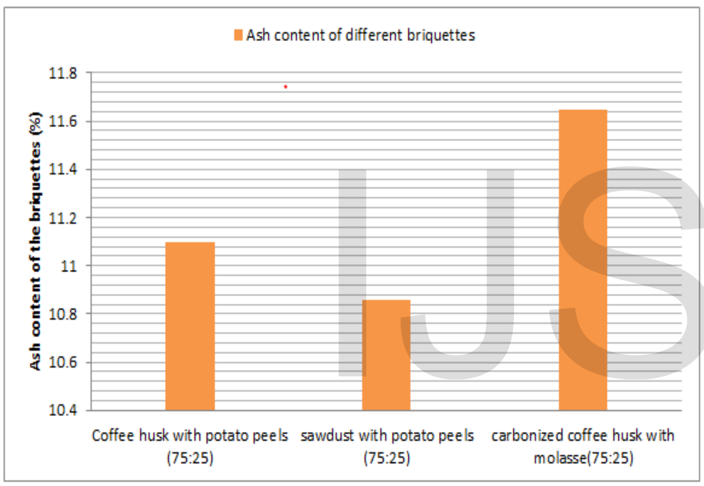

Fig. 9. The Ash Content of the Briquette for Different Composition

3.2.3. *Volatile matter*

The volatile matter of briquettes obtained from this study was greater than the volatile matter of briquettes produced from charcoal briquettes using bagasse and clay as binder which was 27.2% [10]. Hence, the volatile matter of all briquettes obtained from this research paper has acceptable volatile matter. The pure 100% coffee husk briquette had the largest volatile matter. The variation of the volatile matter depending on the composition and binder material ratio.

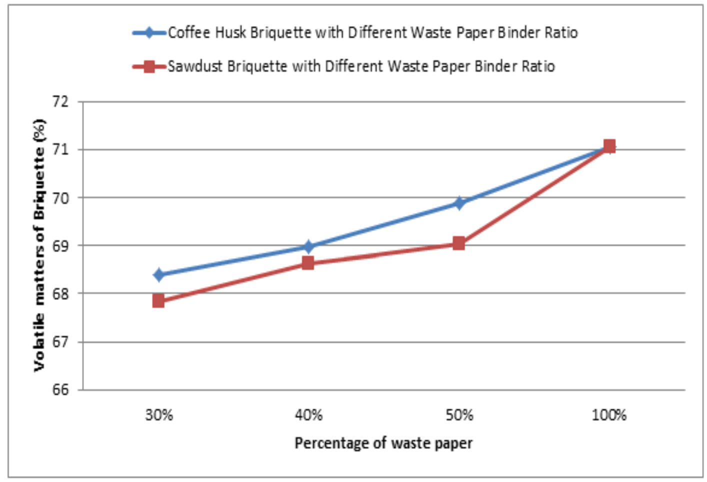

Fig. 10. The Volatile Matters of the Briquette for Different Waste Paper Binder Ratio.

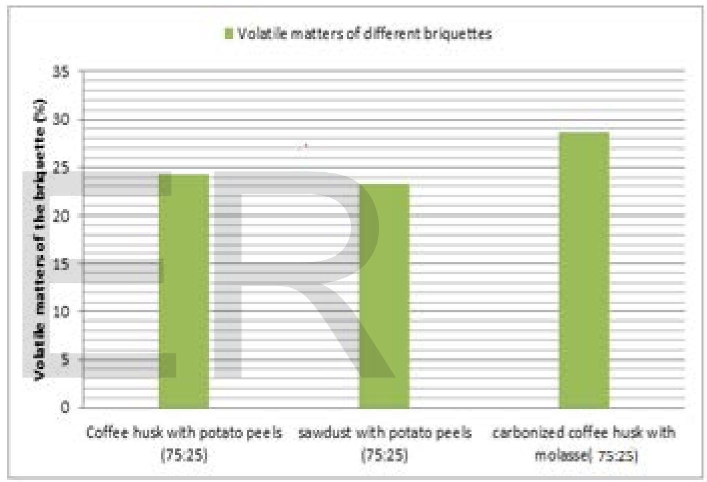

Fig. 11. The Volatile Matters of the Briquette for Different Composition.

3.2.4. *Fixed carbon content*

The fixed carbon content of the briquettes obtained from this study was lower than the fixed carbon content of briquettes produced from coffee husk which was a fixed carbon content of 57.71% [13]. The variation of the fixed carbon depending on the composition and binder material ratio.

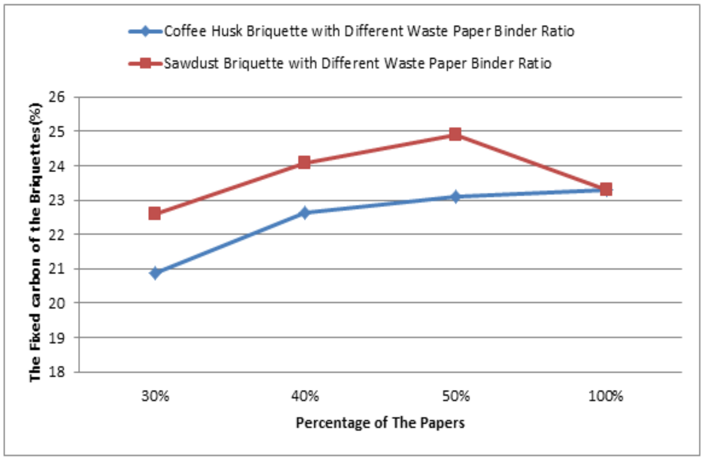

Fig. The fixed carbon of the briquette for different paper binder ratio

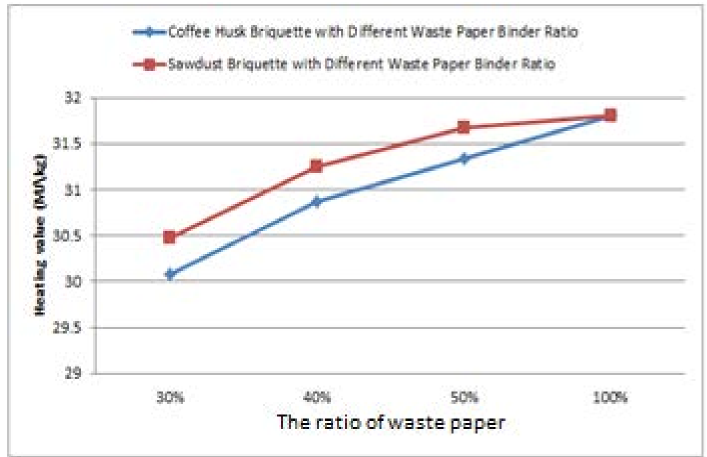

Fig. 13. The Heating Value of the Briquette for Different Paper Binder Ratio

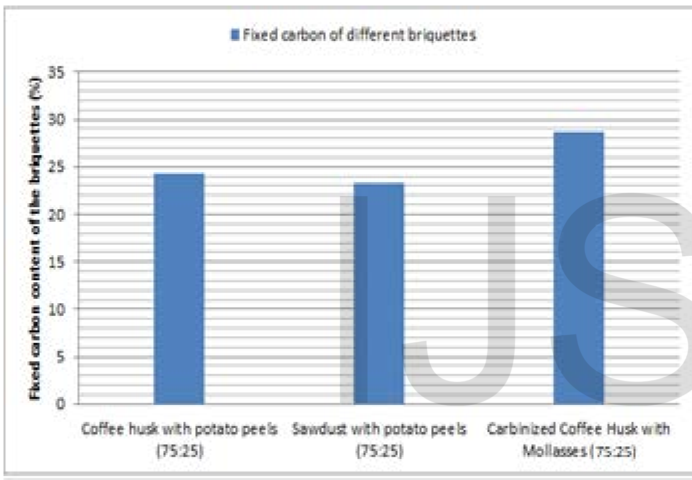

Fig. 12. The Fixed Carbon of the Briquette for Different Composition

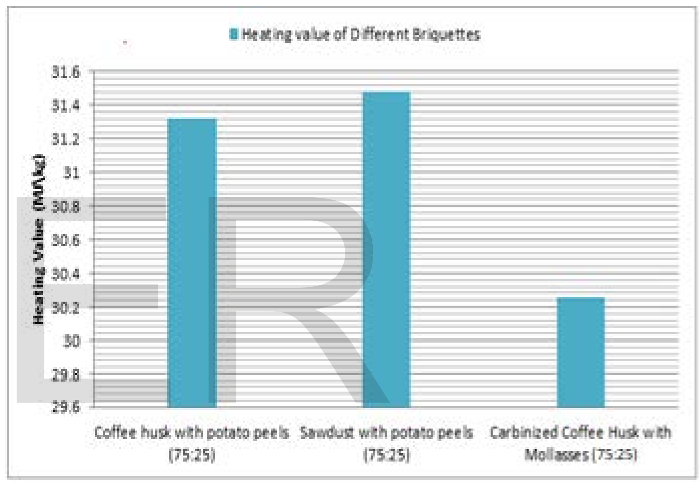

Fig. 14. The Heating Value of the Briquette for Different Composition

3.2.5. Heating value

The gross or high heating value is the amount of heat produced by the complete combustion of a unit quantity of fuel. The heating value of the briquette in this study is greater than the heating value of the briquette produced from Groundnut Shell and Waste Paper Admixture [14]. The heating value was found to be in range (30075.39-31796.94) kJ/Kg for the above selected biomass with different ratio of waste paper, molasses and potato peel binders.

4. Conclusion

From the result observed and calculated value through proximate analysis coffee husk and sawdest Can be converted into good quality, highly storable and durable high-grade solid fuel briquettes. Potato peels which is one of the major waste from institutional and house hold kichen from cooking wat in our country was investigated as one of the best binding material for biomass briquette production. It was also observed that potato peel is more applicape for uncarbonized material than the the other binder like molasses. A

25:75 ratio (by weight) of mollases and carbonized coffee husk had the highest density and ash content and lowest moisture content compared to other briquettes produced in this study. The solid fuel briquettes consisting of 100% (by weight) of waste paper had the highest heating value. It was also observed that briquette samples produced from carbonized coffee husk with molasses binder had highest fixed carbon. The density of briquette produced from sawdust and coffee husk with binder of potato peels was greater than the sawdust briquette produced with banana peels and cassava peels.

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