ISSN No:-2456-2165

From Waste to Energy; Comparative Assessment of Heat Values of Biomass Briquettes and Fuel Wood for Bio-fuel Utilization and Strategic Waste Management in Ethiopia

Tekola Tessema Delbole
Hawassa University, WGCF-NR
Department of Environmental Science
128, Shashemene, Ethiopia

D. D. Ajayi
Pan African University Life and Earth Science Institute
(PAULESI) Department of Geography
University of Ibadan; Ibadan Nigeria

Abstract:- Organic wastes accumulation and disposal is always creating an environmental crisis. Hence, there is a shortfall of proper management of these wastes. Changing these biomass wastes in to another important product like briquettes is advantageous. Beside this, too much energy Ethiopia consumes comes from sources that are likely to be out of stock in the near future. The traditional way of collecting fuel wood has been going on for long time resulting in the depletion of the forest. The use of biomass as a fuel, however, requires knowledge of its heating performance. This study is therefore aimed to evaluate the heating value of biomass briquettes and conventional fire wood. Briquette from four selected solid wastes (Bagasses, Waste paper, Fruits peels and saw dust) were developed and the heat value of the briquette was compared with eucalyptus fuel wood. Energy evaluation test of briquettes and fuel wood was made using the Parr Isoperibol bomb calorimeter. Results of the investigation showed that, mean value of the bulk density of the selected samples of briquettes and fuel wood are 2.94 g/cm3 and 6.1457 g/cm3 respectively. Average moisture content of biomass briquettes is 3.06% while average moisture content of fuel wood is 7.5%. Mean heat value of briquettes and fuel wood is 16.27kj/g and 20.439kj/g respectively. It is proved that although fuel wood gave the slightly higher average heat value than briquettes, they have similar heat value at 95% level of significance. It is therefore concluded that briquettes with higher calorific value which could make excellent fuel can be produced from biomass solid wastes. Generally, briquettes have adequate thermal calorific values and therefore can substitute the utilization of conventional types of fuels.

Keywords:- *Ash Content, Bulk Density, Heat Value Moisture Content.*

I. INTRODUCTION

Energy is a fundamental input for development and indispensable ingredient for the survival of mankind[1][1]. Biomass is the primary source of energy for almost 50% of the global population. Wood biomass is a major renewable energy source in the developing world, representing a significant proportion of the rural energy supply[2][2]. The term biomass is used to explain every organic matter, produced by photosynthesis that exists on the earth's surface. Any organic matter such as wood, crops, seaweed, animal wastes that can be used as an energy source are therefore considered as biomass energy sources[3][3]. People in the developing world use biomass for the majority of their house hold energy needs. These energy sources are mainly used for cooking, heating water and domestic space heating. Biomass energy resources may encompass residues from agriculture, firewood, charcoal, crop residue, energy crops, animal manure, residues from agro-industrial and food processes, municipal solid wastes, and other biological resources[4][4]. Some studies however recognized six categories of biomass resource for energy assembly: energy crops on surplus cropland, energy crops on degraded land, agricultural residues, forest residues, animal manure and organic wastes[5][5].

Extensive utilization of conventional fuel wood without replenishing causes serious environmental effects in many countries, desertification being the most important[6][6]. Also, population increase in a country like Ethiopia places more stress on energy to light and heat homes, to cook food, to drive transport, communication devices and provide power for industries[7][7]. Solid bio-fuels in the form of briquettes, logs, bales, chips, pellets, etc had become an important source of energy even in the rural communities. The main advantage

1
2
3
4
5
6
7

ISSN No:-2456-2165

of biomass energy sources are their domestic origin, potential for dropping entire reliance on petroleum and natural gas, energy security and waste management, jobs creation and source of income to government and rural farmers[8][8]. It also offers benefits of regional development, and social structure, especially to developing countries like Ethiopia. The bush biomass, agricultural edible and non-edible oil seeds and grains, other agricultural and industrial wastes that are largely produced daily in the country could be employed as raw-materials for both small and large scale solid and liquid bio-fuels production[8]. Recently, the number of countries exploiting biomass opportunities for the provision of energy has increased rapidly which is why biomass has been made an attractive and promising option in comparison to other renewable energy sources[4].

On the other hand, organic wastes accumulation and disposal is creating environmental problem[9][9]. Appropriate management of these wastes required, hence, converting them to other helpful products like biomass briquettes for domestic fuel is pleasing. Sometimes uncontrolled burning of these wastes leads to bushfires thereby causing more havoc. Combustion of biomass materials as a means of waste management affects soil below biodiversity, geomorphic process and volatilizes large amount of the nutrients accumulated in the soil including organic matter[10][10]. Black carbon and other particulate matters are also emitted into the atmosphere during combustion is another thing to worry about[11][11]. Organic waste can be generated from household resides, conventional markets, hospitals, offices, etc. change of this wastes into biogas and fertilizer has been carried out in order to minimize the extent of this wastes[12][12]. In developing countries like Ethiopia this wastes still possesses environmental and health problems; hence it commonly left uncollected beside the roads, usually on large scale. As indicated by UNDP (1999), Addis Ababa, Ethiopia, with the current growth rate of urban population in the country, the population of most urban areas especially small urban centers is doubling-up every 15-25[13][13]. As solid waste generation increases with economic development and population growth, the amount in these urban areas will double within a similar time range. On the other hand, a detailed survey conducted in 1986 concluded that only 21.6 per cent of waste had been collected[14][14].

Broadly, materials consisting carbon can be converted into fuel. This carbon can be found as well in organic wastes. Raw material of organic wastes exist everywhere for free, therefore the easiest way to propose an optional energy is by converting the wastes into briquettes. Therefore, biomass briquette is one of the important renewable bio-energies. Grover (1996) has shown that biomass briquetting is a technology to change biological wastes into useful and valuable energy. The technology is an agglomeration process that can be classified as densification process which makes the bulk density of wastes to be compact and dense[1]. Therefore, utilization of bio-fuels including biomass briquette is well thought-out to be a good source of energy. However, use of biomass as a fuel requires knowledge of its heating performance. Moisture content and density of raw material which are physical properties of biomass fuels have a great influence on heat contents of fuels[15][15]. Generally there is the information gap in literatures on heating properties of biomass briquettes made of different materials. From scientific standpoint, finding out these thermal properties is imperative for validation and verification of combustion models. There is a need therefore for further work on the thermal properties of biomass briquettes in relative to fuel woods. It is thus aimed to compare the heating performance of the briquettes with the conventional fire wood, eucalyptus. Biomass briquette fuels from four selected solid wastes (Bagasses, Waste paper, Fruits peels and saw dust) were developed and the heat value of the briquette was compared with eucalyptus fuel wood for proficient Bio-fuel utilization and strategic waste management. Energy evaluation test of briquettes and fuel wood was done using the Parr Isoperibol bomb calorimeter and it was verified that briquettes have adequate thermal calorific values and therefore can substitute the utilization of conventional types of fuel**.**

II. MATERIALS AND METHODS

A. The study area

This study was conducted in Hawassa University, Wondo Genet College of Forestry and Natural Resources (WGCF-NR). Wondo Genet College of Forestry and Natural Resources (WGCF-NR), which is one of the five campuses of Hawassa University (HU), is situated in southern Ethiopia, 264 km from the capital, Addis Ababa, and 14 km from the nearest town, Shashemene. Currently, there is a stationary sawmill which processes wood from logs harvested from different compartments of plantation forests on 80 hectare land of the campus. Wondogenet College uses Eucalyptus fuel wood for food preparation. The college is also burning large quantity of waste paper twice or more in a year.

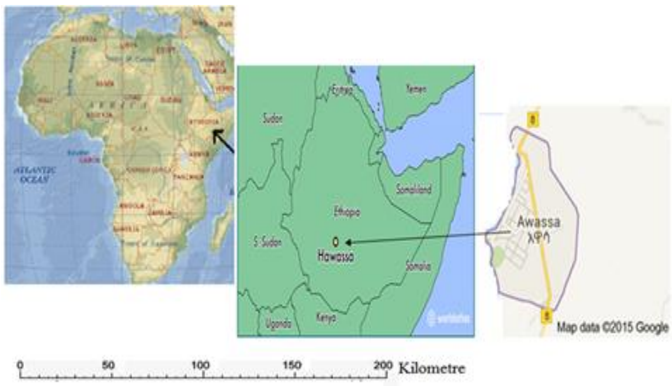

Figure 1: The Study Area

8
9
10
11
12
13
14
15

ISSN No:-2456-2165

B. Methodology

1) Briquetting Machine Production

Hand- press wooden briquetting machine was locally produced in furniture producing workshop of Hawassa University Wondo Genet College of Forestry and Natural Resource, southern Ethiopia as shown in cross section in Fig. 2.

Figure 2 ***locally produced manual hand press briquetting machine***

2) Biomass Briquette Production Process

Briquettes were produced tagging along the steps which are presented as follows;

a) Residue Selection

The residues that were utilized in this experiment were obtained from the College and solid waste dumping areas of Hawassa town. Saw dusts of *Grevillea robusta and Cordia africana* were selectively collected from sawmills in the college. Although paper was selected as the input material for in the study it is considered to be biomass, hence it is a fiber material made of grass or wood. Waste and out-of-date papers from printing units were used. Bagasses and Fruits peels were collected from solid waste dumping sites. Eucalyptus fuel wood for comparison was collected from the College student's cafeteria kitchen. The residues were chosen because they are produced in large quantity in the area and most often they are dumped or flared resulting in health hazards to both human and ecology.

b) Pulping

In order to produce briquettes from biological wastes, bio-material are required to be grinded and pounded to provide a arbitrary allotment of fibers, ahead of being reformed into briquettes. Biological wastes are required to be chopped, partly decomposed, soaked and pulped. This is just to form a charge of wet material for the mould, Materials particularly bagasses, Fruits peels and saw dust collected were sundried to reduce moisture content to approximately 12% which is within the tolerable operating limit for briquetting [16][16]. Grinder was used to reduce the materials to smaller sizes and paper was manually chopped in to pieces.

Figure 3 ***Materials broken down with a grinder***

Sieve was used to obtain uniform sizes of the materials. Sieve size corresponding to 0.5 mm was chosen for this research.

c) Compression

Biomass briquettes were developed by solidifying the mash in the mould using locally developed manual hand press briquetting machine. Twenty biomass briquettes were essentially developed in the Laboratory of the college. An illustrative view of the briquettes produced is presented below.

Figure 4 ***produced briquettes***

d) Drying

Briquettes are required to be sun dried after they are ejected from the mould. In this research, briquettes were sun dried.

e) Sampling Procedure

The selection of sample for this study was based on random sampling techniques. Twenty biomass briquettes were essentially developed from which ten samples were randomly picked for the study.

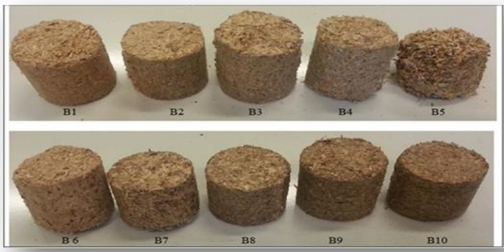

Figure 5 ***Sample selected briquettes***

16

ISSN No:-2456-2165

Fuel wood sample was also randomly chosen from the whole cord of eucalyptus fuel woods for comparison.

Table 1 ***Result of Physical Characteristics of the Samples***

Physical characteristics	Samples	
	Briquettes	**Fuel wood**
Average Mass(g)	537.50	524.90
Average Volume(cm^3)	2.25	96.31
Average Density (g/cm^3)	2.94	6.15

3) Experimental investigation of samples

a) Weight, Volume and density of samples

Weights of biomass briquettes and fuel wood materials were determined on the balance. Dimensions of each sample were measured using calipers.

Then, the volume of the samples was determined by a simple calculation based on the direct measurement of diameter, and thickness (height) of the briquettes.

The density of each briquette after drying was then computed as the ratio of the measured mass to the calculated volume.

b) Moisture content

The moisture content of the ground material was determined using oven drying methods.

Moisture content is the deference result of the weight before oven dried and weight after oven dried.

c) **Heat value and Percentage Ash Content**

Heating values of each sample were estimated using Parr Isoperibol bomb calorimeter model 6200EF/230V interfaced with a microcomputer. The procedure in accordance with ASTM Standard E711-87 (2004) was followed. Following the procedure, heat value of both samples were recorded and then subjected to analysis.

Ash Content of the biomass samples was estimated following ASTMD 1102–84 guidelines. This was done by examining the bomb interior if unburned sample or sooty deposits are found.

Soot/ash was carefully removed and then cooled in desiccators and weighted to represent the ash content of the sample. The percentage ash content was then calculated.

III. RESULT AND DISCUSSION

A. Result

1) Physical Characteristics of Briquettes

Physical properties of the materials were estimated and results of each parameter are presented in Table 1 below.

Volume and density of briquettes are determined using the following formulas

$$V = \pi(D)h \qquad (1)$$

$$\text{Density} = \frac{M}{V} \qquad (2)$$

Volume and density of Fuel wood are determined using the following formulas

$$V = L \times W \times H \qquad (3)$$

$$Dnsity = \frac{M}{V} \qquad (4)$$

Density of briquettes is very essential factor in biomass briquette heat value reflection. It depends on the density of the original substrate. Results in table 1 showed that the mean value of the bulk density of sample briquettes is 2.94g/cm^3. Average values of density found in this study fell in values obtained in earlier studies.

The average weight and volume of the briquette is 537.5g and 183.69 cm^3 respectively, while the average weight and volume of the fuel wood is 524.9g and 96.3135cm^3 respectively.

2) Moisture, Heat Value and Ash Content of the Samples

Among the major factors influencing quality of biomass fuel in terms of heat value is moisture content. In this study moisture content of the ground material was determined using oven drying methods.

Table 2 ***Result of moisture, heat value and ash content of samples***

Physical characteristics	Samples	
	briquettes	**Fuel wood**
Percentage moisture content (%)	3.06	7.50
Average Heat Value (kj/g)	16.27	20.44
Percentage ash content (%)	5.92	3.23

Moisture content of the samples was estimated as the equation shown below;

$$\text{MC} = \text{WBOD} - \text{WAOD} \qquad (5)$$

$$\%\ \text{MC} = \frac{\text{WBOD} - \text{WAOD}}{\text{WAOD}} \times 100 \qquad (6)$$

Where;

MC= Moisture content

WBOD=Weight before oven dried

WAOD = Weight after oven dried

Calorific value or heat value determines the energy content of a fuel. It is the property of fuel which depends on its chemical composition and moisture content. The most important fuel property is its calorific or heat value. Measured calorific value of the briquettes is 16.27kJ/g while 20.439kJ/g is the mean heat value for fuel wood.

Table 2 revealed that, although the mean calorific value of the fuel wood is more than that of briquettes, the difference is not this mach outsized. This indicates that biomass briquettes can generate enough energy or heat per gram as almost to the same amount of wood.

Hypothesis Testing

As seen it is seen above, sample heat values of briquettes are different from the samples of fuel wood. Therefore, it needs an independent sample hypothesis test. It is also a two tailed test as there is no ground to assume that one of the two Biomass fuels is higher or lower in calorific heat value than the other.

The testing procedure begins with stating hypothesis statement as follows.

Hypothesis

H_0: Heat content of biomass briquettes is not significantly high as heat content of Eucalyptus fuel wood at 95% confidence interval.
H_1: Heat content of biomass briquettes is significantly high as heat content of Eucalyptus fuel wood at 95% confidence interval.

That means;

H_0: $\mu 1 \neq \mu_2$
H_1: $\mu 1 = \mu_2$

Test statistics

Test statistics that should be applied to prove this hypothesis is t-test and it is calculated as follows.

$$tcal = \frac{\overline{X}_2 - \overline{X}_1}{SE} \quad (7)$$

The test is simply an extension of a one sample hypothesis t test procedure. $\overline{X}_1$ and $\overline{X}_2$ are the means of the two groups of data. Also the SE in the denominator refers to standard error value. Since there are two standard error values associated with the respective group mean, the standard error in the denominator is the sum of the standard errors of the two group means.

However as SE values are derived from variance and are not directly additive, they should be converted into variance of means and the latter are added.

$$S_{\overline{X}1} = \sqrt{\frac{S_1^2}{n_1}} \quad (8)$$

$$S_{\overline{X}2} = \sqrt{\frac{S_2^2}{n_2}} \quad (9)$$

Hence SE = $S_{\overline{X}1} + S_{\overline{X}2} = \sqrt{\frac{S_1^2}{n_1}} + \sqrt{\frac{S_2^2}{n_2}} = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}$

In the above formula, it is recommended to use the average of the two sample variances in place of the respective sample variance. The average of the two sample variance is referred as pooled variance (S^2_P) and it is calculated as follows;

$$S_P^2 = \frac{S_1^2 + S_2^2}{2} \qquad \text{If } n_1 = n_2$$

Using the result table above;

$\overline{X}_1$=16.27 $\overline{X}_2$=20.439

n_1 = 10 n_2 = 10

σ^2_1= 2.394 σ^2_2 =2.038

Since in the present case $n_1 = n_2$, we average the two variances directly as:

S_P^2 = (2.394 +2.038)/2 = 2.216

Then the standard error used as a denominator is computed as

$$\text{SE} = \sqrt{\frac{S_P^2}{n_1} + \frac{S_P^2}{n_2}} \quad (10)$$

$$= \sqrt{(2.216/10) + (2.216/10)} = \mathbf{0.6658}$$

Accordingly; $t_{cal} = \frac{\overline{X}_2 - \overline{X}_1}{SE}$

$$= \frac{20.439 - 16.27}{0.6658} = \mathbf{6.2616}$$

$t_{tab} = t_{\alpha/2}(n_1 -1 +n_2 -1)$, α is given as 0.05

The degrees of freedom is the sum of the tow within group degrees of freedoms i.e.; n_1 - 1 and n_2 - 1

$t_{tab} = t_{0.05/2}(9 +9) = t_{0.025}(18) = 2.101$

Decision:
Reject Ho if $t_{cal} \geq t_{\alpha/2}(n_1 -1 + n_2 -1)$ or $-t_{cal} \leq -t_{\alpha/2}(n_1 -1 + n_2 -1)$
Here 6.2626 > 2.101, hence reject Ho

Conclusion: Heat content of biomass briquettes is significant as heat content of Eucalyptus fuel wood at 95% confidence interval.

Biomass briquettes have higher ash content than fuel wood. Percentage of ash content of biomass briquettes is 5.92% while 3.2787% is for that of fuel wood. Percentage ash content (PAC) was determines as;

$$PAC = \frac{Wight\ of\ the\ soot(graham)}{Weght\ before\ burning} \times 100 \quad (11)$$

ISSN No:-2456-2165

B. Discussion

Physical features of solid biomass fuels can determine the quality of the solid biomass fuels. In this study, quality of briquettes was good based on specific physical features and some of the parameters. External surface of the briquettes was smooth and the structure of their cross-section was compact and homogenous. Density is one very imperative parameter in briquette calorific heat value. Density of bio-briquettes depends on the density of the original substrate. Higher the density, higher is the energy to volume ratio.

Results in table (1) demonstrated that mean values of bulk densities of the selected sample briquettes is 2.94 g/cm^3 while 6.1457 g/cm^3 is for that of fuel wood. Average density values of obtained in this study fell within values obtained in earlier studies. Densities found in this work compared well with density of notable biomass fuels such as coconut husk briquette 6.30 g/cm3[17][17]; banana peel 6.00g/cm3[5], and groundnut shell briquette 5.24 g/cm3 [6]. Studies also indicated that the lower the value of relaxation ratio and the higher the value of relaxed density, the higher is the stability of briquettes [18][18]. Generally, all the densities obtained are good enough and they are close to the values obtained by Musa (2007)[19].

Similarly, moisture content of biomass material is among the main factors affecting biomass fuel quality in terms of heat value. Mean value of moisture content of the biomass briquettes studied is 3.06% which is within the acceptable quality of briquettes while the average moisture content of the fuel woods studied is 7.5%. Moisture content of briquettes fall under the range of values reported by Wamukonya and Jenkins (1995)[20] for sawdust and wheat straw briquettes, and the ranges of values (12-20%, wet basis) recommended for good storage and combustion of briquettes. Moisture content of the briquettes is also within the limits of 15 % which is recommended by Grover and Mishra (1996)[21] and Kaliyan and Morey (2009)[22] for agro-residues, while the moisture contents of the briquettes found in this study are also acceptable as they are within the limits recommended by Yang et al. (2005)[23], which stated that the difference between the moisture content of agro-residues and their briquettes ideally should be in the region of about 2%

Moisture content in excess of 20% would result in considerable loss of energy required for water evaporation during combustion at the expense of the calorific value of the fuel. Such a fuel may not also be stable in storage.

This study demonstrated that, mean heating value of briquettes found from biomass wastes using oxygen bomb calorimeter is 16.27kj/g and mean heat value of fuel wood is 20.439kj/g. As it is tested above, and can be seen from the results (table2), that fuel wood gave the slightly higher energy value. In table 1 above, it can also be seen that fuel woods have higher density than briquettes. Thus, calorific values of the biomass materials are influenced by their density. Higher the density, greater the heat value acquired.

Although the average calorific value of fuel wood is higher than that of briquettes, they have a comparable heat value at 95% level of significance. Average values obtained in this study compared with values searched in literatures indicating slight differences. For instance, many studies have been made on sawdust briquettes and agricultural products briquettes respective to their heating performances. Calorific heat values ranges between 15kJ/g – 20kJ/g [3, 10] for briquettes developed from sawdust mixed with palm kernel shells and also those given by [17] for some other biomass materials.

It is distinguished that ash content of samples studied is lower than 6%, which is the value beyond ash content of biomass fuel not to be considered as adequate according to the Austria ÖNORM M7135, as cited in [1]

IV. CONCLUSION

Problem of energy is well recognized and natural resources and prime sources of energy are becoming in short supply. In order to provide better outcome from energy supply, innovative and optional energy sources are becoming essential. In this sense, solidification of biomass wastes to briquettes can provide an admirable energy and can be an environmental save combustible fuel. This point of fact incited the present study which is aimed at comparing the heating values of briquettes produced from locally available biological wastes using locally produced manual hand pres briquetting machine with locally available fuel wood. Solidification of biomass wastes is one alternative method which can aid in achieving the utilization of biomass and urban wastes into a useful product. In this study, heat value of biomass briquettes was compared with heat values of fuel wood. Thus, densification process had adequate heat values and handling characteristics of briquettes. Production of briquettes from biomass solid waste can contribute to environment safety, reduction of desertification and reduce health hazard associated with the use of fuel wood and charcoal. Therefore, combination of solid biomass wastes is very suitable for briquette production for domestic and industrial uses. Technologies can change solid bi-wastes into cleaner, more convenient energy forms such as briquettes.

This study, properties of fuel were investigated in terms of calorific heat content of briquettes developed from biomass wastes and the heat value of the briquette was compared with the heat value of typical hardwood species, eucalyptus. From the result, it can be concluded that both the biomass fuels studied had sufficient heat value ranging from 12.89kj/g to 22.22kj/g. However, percentage of ash produced from the biomass materials ranged from 1.6% to 8.33%. This range is still acceptable if compared to 6%, that is, the value beyond which the ash content of the biomass fuel is considered not adequate according to the Austria standard for

17
18
19
20
21
22
23

fuel pellet and briquettes. The results further indicated that eucalyptus fuel wood gave the slightly higher energy value with average fuel rating of 20.439kj/g.

In this study, it has been recognized that, briquettes produced from the biomass wastes have lower moisture content, higher ash content and relatively lower heat value than the fuel wood of eucalyptus.

Although briquettes have less calorific value than fuel wood they could make admirable fuel. The study proved that, even if the mean heat value of fuel wood is more than that of briquettes, they have comparable heat value at 95% level of significance. The energy value of the briquette is adequately enough to produce amount of energy required for household cooking and small scale industrial cottage applications. Comparison of sample heat values with heat values reviewed in literature indicated a slight difference. It is therefore generalized that stable briquettes with higher calorific value which could make excellent fuel can be produced from biomass solid wastes.

This study further demonstrated that briquettes can be utilized instead of other traditional fuels. The results confirm the option of utilizing biological solid wastes as fuel briquette of good source that support combustion. The briquettes possess the high material strength as well as high value combustible fuel, which qualify them as alternative to firewood.

This study have also revealed that biological solid wastes habitually generated in large and uncontrolled quantities can be converted into high-quality, easily storable and durable high-grade solid fuel briquettes which can be suitable energy production for heat generation. In this sense, production of briquettes from biological wastes can provide an alternative energy sources in Ethiopia. It can also used as a means of reducing environmental risks which are created by improper biological waste disposal. In addition, it helps in reducing the extensive utilization of fire wood which poses an adverse effect on the environment (deforestation). Converting wastes like waste papers, biological solid wastes and sawdust using a simple technology such as the hand press briquette molder has therefore great prospects when utilized as fuel for household use and eventually as substitute fuel to fuel wood.

Briquettes produced are environmental friendly, reduce desertification and its environmental implication and reduce health hazard associated with the use of fuel wood. Therefore, combinations of biological solid wastes are very suitable for briquette production for domestic uses.

It could further be concluded from the study that, an assessment of fuel properties of biomass materials need to be done holistically taking into consideration all the factors that will impact on the energy value and environment as well as health issues. With the addition of biomass briquettes have an acceptable fuel properties and lower moisture content. Therefore, briquettes are easier to ignite. They can be successfully used for cooking as well as space heating in cold and mountainous regions. Many developing countries are facing environmental problems from the combustion of low grade coal with high sulfur content being used is combustors and boilers and kilns. These countries also use a lot of fuel wood as the main source of energy. Shifting slowly from raw coal and fire wood to bio-briquettes could not only solve to some extent the environmental problem but also utilize the enormous amount of biomass residues.

The use of wood on the other hand is highly regarded as a fuel because it has the potential to be environmentally neutral, in that if wood is replaced at the same rate it is used then the amount of carbon released would be negated by the new trees. Where the consumption is greater than the supply as in most cases, there is an overall increase in carbon emissions. Solid waste management is there if using waste to as the raw material for the production of briquette. The energy produced when properly molded bio-briquettes are combusted is comparable to traditional fuels. Therefore this study practically proved that, bio-fuels can be made from renewable and readily available materials, and their production should result in a reduced environmental impact when compared to traditional fuels being replaced.

Based on the results obtained and findings of this study, the following conclusions can be drawn:

- ✓ Biomass Briquettes from biomass materials have sufficient heat content and would be good biomass fuels with good thermal calorific value.
- ✓ When biomass briquettes are properly molded and combusted, its energy value is almost equivalent to traditional fuels.
- ✓ Briquettes produced from the biological wastes cannot easily disintegrate during transportation and storage because their densities are low.
- ✓ Biomass briquettes can be produced easily and its combustion do not emit significant effluents.
- ✓ Briquettes are easy to store, handle and transport; this is due to their compact size.
- ✓ Percentage of ash content of biomass briquettes is in an acceptable limit.
- ✓ It is admirable that reuse of agricultural or biomass wastes can lead to ineffective way of biomass waste management.
- ✓ In this view, we can prevent deforestation, forest degradation and conserves natural forest resource.

Generally, briquettes have more positive attributes of biomass fuels. Briquettes make use of organic materials which are common and renewable. Hence, we are ensured of the sustainability of such fuel source. They have adequate thermal calorific values hence they offer even and consistent combustion. Briquettes have negligible amount of moisture hence offers excellent combustion. This type of fuel does not cause a large amount of environmental pollution as compared to fire wood fuels. This can be of assistance in preventing release of too much carbon dioxide into the atmosphere. Therefore briquettes can substitute the utilization of conventional types of fuel.

ACKNOWLEDGEMENT

First and foremost, I would like to thank the almighty God who gives me complete health to perform this research work, thank you Lord!

I would like to express my feelings of gratitude to my advisors O.Adenikinju and Dr. D.D.Ajayi for their unfailing support, consultation, passionate advice, guidance and understanding throughout the study and follow up since the start of my work. I thank you for the many helpful discussions, for your regular interests, support, and training me to make my own research decisions. Really, they have been amazing and an inspiration.

I would like to extend my acknowledgment to the Head of Department of Geography in University of Ibadan, Professor C.O. Ikporupo and Professor M. K. C. Sridhar for their help, encouragement and cooperation supportive comments on this work research.

I am also thankful to the Ministry of Mineral and Energy and Hawassa University from where I received all kind of resource support.

Finally, I would like to express my feelings which I have for my friends, Garedew Kayola, Kayrale Kalale, my mama, Otaya Duko and my companion Kachawa Elaya for their guidance, advice, encouragement and support. I would like to convey my special thanks to my partners, friends and families for their constant encouragement and help.

CONFLICT OF INTEREST

The author asserts that there is no conflict of interests with regard to the publication of this manuscript.

REFERENCES

[1] S. J. Mitchual, K. Frimpong-mensah, and N. A. Darkwa, "Evaluation of Fuel Properties of Six Tropical Hardwood Timber Species for Briquettes," no. March, pp. 1–9, 2014.
[2] J. Chaney and M. Physics, "Combustion Characteristics of Biomass Briquettes," no. May, 2010.
[3] V. K. MOKA, "ESTIMATION OF CALORIFIC VALUE OF BIOMASS FROM ITS ELEMENTARY COMPONENTS BY REGRESSION," 2012.
[4] USAID, "BIOMASS BRIQUETTING IN SUDAN : A FEASIBILITY STUDY," no. August, pp. 1–95, 2010.
[5] J. T. Oladeji and D. Ph, "Comparative Study of Briquetting of Few Selected Agro-Residues Commonly Found in Nigeria .," vol. 13, no. 2, pp. 80–86, 2012.
[6] U. Sadiq and R. Nasiru, "Investigation on the Effects of Addition of Binder and Particle Size on the High Calorific Value of Solid Biofuel Briquettes," vol. 3, no. 12, pp. 30–35, 2013.
[7] B. W. Barbre, "BIOMASS FUEL-BRIQUETTES AND IMPROVED STOVES IN DINSHO , ETHIOPIA," 2013.
[8] GTZ, "Target Market Analysis; Ethiopia ` s Bioenergy Market," 2009.
[9] R. M. Singh, H. Kim, M. Kamide, and T. Sharma, "Biobriquettes-an Alternative Fuel for Sustainable Development," vol. 10, pp. 121–127, 2009.
[10] E. Journal, E. Studies, and M. Vol, "Heat Energy From Value-Added Sawdust Briquettes Of Albizia Zygia. *Aina, O.M., Adetogun, A.C. And Iyiola, K.A.," vol. 2, no. 1, pp. 42–49, 2009.
[11] J. Sui, X. Xu, B. Zhang, C. Huang, and J. Lv, "A Mathematical Model of Biomass Briquette Fuel Combustion," vol. 2013, no. July, pp. 1–5, 2013.
[12] L. Center for Energy Studies Institute of Engineering Tribhuvan University Pulchowk, "Efficiency Measurement of Biogas , Kerosene and LPG Stoves," no. July, 2001.
[13] UNDP, "Joint UNDP / World Bank Energy Sector Management Assistance Program; Country: Ethiopia," 1999.
[14] SIDA, "BRIQUETTING OF AGRICULTURAL WASTE FOR FUEL," 2010.
[15] J. O. Akowuah, F. Kemausuor, and S. J. Mitchual, "Physico-chemical characteristics and market potential of sawdust charcoal briquette," vol. 3, no. 1, p. 1, 2012.
[16] M. K. S. Sastry, J. Bridge, A. Brown, and R. Williams, "Biomass Briquettes : A Sustainable and Environment Friendly Energy Option for the Caribbean," pp. 1–8, 2013.
[17] A. Olorunnisola, "Production of Fuel Briquettes from Waste Paper and Coconut Husk Admixtures," vol. IX, pp. 1–11, 2007.
[18] A. N. Efomah and A. Gbabo, "The Physical , Proximate and Ultimate Analysis of Rice Husk Briquettes Produced from a Vibratory Block Mould Briquetting Machine," vol. 2, no. 5, pp. 814–822, 2015.
[19] ASTM International (2012) ASTM Standard E711-87, Standard Test Method for Gross Calorific Value of Refuse-De- rived Fuel by the Bomb Calorimeter. http://ia600806.us.archive.org/23/items/gov.law.astm.e711.1987/astm
[20] Wamukonya L. and B. Jenkins 1995. Durability and relaxation of sawdust and wheat – straw briquettes as possible fuels for Kenya. Biomass and Bioenergy 8 (3): 175- 179.
[21] Grover, P. D. and S.K. Mishra. 1996. "Biomass Briquetting, Technology and Practices, Regional Wood Energy Development Programme in Asia". Field document No. 46. FAO: Bangkok, Thailand.
[22] Kaliyan N. and R.V. Morey. 2009. "Factors Affecting Strength and Durability of Densified Biomass Products". Biomass and Bioenergy. 2009(33):337-359.
[22] Yang, B.Y., R. Changkook, and K. Adela. 2005. "Effect of Fuel Properties on Biomass: Combustion (Part II) Modelling Approach- Identification of the Controlling Factors". Fuel. 84:2116-2130.