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Production and Characterization of Charcoal Briquette from *Oxytenanthera abyssinica*, *Arundinaria alpina*, *Acacia melifera* and *Prosopis juliflora*

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ABSTRACT

Production of sustainable and renewable energy source from locally available biomass feedstock's provides great opportunities to achieve sustainable growth and development in economic, social and environmental aspects for all nations across the globe. This study focused on production and characterization of charcoal briquettes from forest biomasses such as Oxytenanthera abyssinica, Arundinaria alpina, Acacia mellifera and Prosopis juliflora, which were collected from different regions of Ethiopia (Amhara, Oromia and Somali). The experiment was conducted to determine moisture content (MC), volatile matter (VM), ash content (AC), calorific value (CV), fixed carbon (FC) and sulfur content (SC). The results were analyzed by using Statistical Analysis System (SAS) software. The analysis indicated that the effect of parameters considered in the experiment (i.e. Temperature, Binder ratio, Number of press and pressure) on the four species type and sample types were significant at level of probability, P=0.0001.

Key words: *Briquette; Oxytenanthera abyssinica; Arundinaria alpina; Acacia melifera; Prosopis juliflora*

Introduction

Energy is vitally necessary to harness the life of human being and makes significant contributions for economic, social and environmental aspects of human development. Sustainable and renewable energy sources are considered as a better option preferable to the non-renewable sources because the non-renewable energy sources such as gasoline, coal, kerosene, diesel, etc. have no capability to be replenished and would be exhausted. Furthermore, the environmental impacts as a result of emissions of greenhouse gases (GHG), CO2, SOx, and NOx etc. during combustion and utilization of the non-renewable energy resources is a driving force towards the use of alternative, renewable and sustainable energy sources for domestic cooking, urban households' particularly in developing countries [1].

Materials and Methods

The study was conducted in Pawe, Injibara and Borena areas of Ethiopia. The study sites were selected based upon adequate resource availability; and considered as potential representative sites for the selected species across the regions of Ethiopia. Sample of *P. juliflora* stem with 3-4 cm in diameter was collected from Afar region in February, 2013. Sample of *A. melifera* was collected from Borena region in 2015 and samples of bamboo species (*O. abyssinica* and *A. alpina*) were collected from Pawe and Injibara areas in 2016 [2]. Then, the collected samples of specified species were chopped into suitable size, and then dried for further milling, washed in tap water to remove impurity from outer part of the stem and dried in oven dryer at a temperature of 650℃ for 48 h. The carburization of the strip wood was carried out in the furnace at temperature of 500℃ for 60 and 90 mins, respectively. Then, the charcoal was removed immediately from the furnace and cooled under tap water. The cooled charcoal was spread over the floor and thereby dried in a naturally ventilated room with relative humidity (RH) of 86-89% at an ambient temperature of 250℃-300℃ for three days [3]. The prepared powder samples were taken turn by turn and proportionally mixed with the binder to make briquette. Acacia seyal gum Arabic was used as a binding agent for making briquette during the experimentation [4]. The binder concentration of 5% was prepared and manually mixed with the prepared charcoal powder with solid to volume ratio in the range of 0.65-0.87 g/ml. The molds were then filled up to the edge of the mold tube and it was pressed by the Peterson Press. Percentage of the moisture content (PMC) was determined using standard method of American Society for Testing Materials (ASTM D 4442-07) on basis of dry biomass was found by weighing samples of obtained briquette (W1) and oven drying it at 105℃ and intermediate weight of sample was recorded in every 60 min until the constant weight was obtained (W2). Then, the difference in weight (W1-W2) was calculated to determine the sample's percentage moisture content using the following equation.

$$PMC=(W1-W2)/W1 \times 100$$

Where, W1=Initial weight of sample before drying W2=Final weight of sample after drying PMC=Percentage Moisture Content.

The percentage of volatile matter (PVM) content was determined using the standard method CEN/TS 15148. Two grams of sample was pulverized and oven dried at 105℃ until its weight was constant. Then, the sample was heated at 550℃ for 10 min and weighed after cooling in desiccators. The PVM was calculated using the following equation.

$$PVM=(W1-W2)/W1 \times 100$$

Where, PVM=Percentage of Volatile Matter, W1=Initial weight of sample, W2=Final weight of the sample after cooling.

The percentage of ash content (PAC) was determined using CEN/TS14775 standard method. The percentage of ash content (PAC) was also determined by heating 2 g of the pulverized sample in the furnace at a temperature of 550oc for 4hrs and weighed after cooling in a desiccator to obtain the weight of ash. The PAC was determined using the following equation.

$$PAC=(W2)/W1 \times 100$$

Where, W1=Initial weight of dry sample, W2=Final weight of ash obtained after cooling sample, AC=percentage of Ash content.

Determination of fixed carbon

The percentage of fixed carbon (PFC) was calculated by subtracting the sum of percentage volatile matter (PVM) and percentage ash content (PAC) and percentage moisture content from 100 % as shown in the following equation.

$$\text{Fixed Carbon}=100\%-(PAC+PMC+PVM)$$

The calorific value of briquette determines the amount of heat energy present in the material. The calorific value was determined in line with the moisture content, ash content, and volatile matter on the briquettes. The calorific value (kJ/kg) of the samples under test was calculated from the temperature rise of the briquettes when burnt and its heat capacity [5,6]. A calorimeter apparatus was used to determine the calorific value of the produced briquettes. Sulfur content was determined by Eschka method using ASTM-D 3177 standard. One gram sample was put into a porcelain crucible and mixed with 3.00 g of Eschka mixture. The mixture was then covered with 1.00 g of Eschka mixture. The crucibles were then put in a muffle furnace and heated gradually to 800℃ for 60 min [7-9]. A total of the four tree species (*O. abyssinica*, *A. alpina*, *A. melifera* and *P. juliflora*) treatments with three replications and 6 measurement parameters were designed in the experiment. Statistical analysis of data was carried out using SAS Software, Version 9 and Microsoft Excel (2010) computer software. Means that exhibited significant differences were compared using Least Significant Difference (LSD) at ($P<0.001$) level [10-12].

Results and Discussion

Table 1 showed the the proximate analysis such as moisture content, volatile mater, fixed carbon and ash content of the four species where highly significant at probability, P=0.0001, and affected by sample type and species type, whereas, the ultimate analysis (caloric value and sulfur content) among the selected species were also significant at level of probability, P=0.0001, and affected by sample type and species type. The interaction effect of the moisture content between the speciestypes and sample type has shown significant value at P=0.001, with the corresponding average moisture content of sawdust (6.82%), charcoal (5.60%) and briquette (6.09%), respectively. Regarding the species of *A. melifera* and *P.juliflora*, it has been shown that statistically similar and significantly higher values of moisture contents were recorded as 8.55% for sawdust of *A. melifera* and 7.95% for saw dust of *P. juliflora.* Fixed carbon is the major quality measuring parameter that determines the energy behaviors in the production of densified biomass briquettes. It hasbeen shown that the interaction effects of fixed carbon between sample types and species types is of significant value at level of probability, P=0.0001. The calorific value is the principal quality index for fuels. The calorific value of densified biomass briquettes relies on the moisture content, ash content and fixed carbon content in relation with other factors such as, species types, raw materials' pretreatment, types of binding agent, particle's size, solid to liquid ratio and the nature ofbriquetting machine. Hence, mixing of pretreated biomass species with appropriate ratio of binding agent is helpful to produce the DBB with better fuel characteristics. The sulfur content in the produced DBB contributes to emission of compounds of SOx into atmosphere during utilization of the fuel. The interaction effect among species type and sample type on the amount of sulfur content has shown significant value at level of probability, P=0.001. The overall mean value of DBB produced from all species was recorded to be 0.05 %. This value was relatively lower than the value of sulfur content in charcoal (0.16%) and saw dust (0.25%).

Table 1: Description of site study.

Study site	Regional state	Altitude inmasl.	Mean annual temperature
Pawe	Amhara region	1050	16-32
Injibara	Amhara region	2540-3000	16.25
Borena	Oromia	1350-1800	19
Afar	Somali	980	25.8

Conclusion

The increases in number of human population and depletion of non-renewable energy resources have necessitated the exploration of sustainable, renewable and environmentally friendly energy sources. Another driving force behind this research is the need to address the environmental consequences and health hazards associated with the use of solid fuels such as fuel wood and coal and also to develop an effective means of recycling and managing forest products.

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