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Evaluating Performance of Saw Dust Briquettes of Eucalyptus Tree in A Vertical Wood Fired Water Tube Boiler

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Abstract **–The wood waste generated during timber harvesting and chipping have never been exhaustively explored for utilisation as alternative fuel for the tea industry. This research is aimed at optimizing the utilisation of saw dust of eucalyptus tree species as a fuel in tea industry. The saw dust briquettes were produced from homogeneous sawdust of Eucalyptus tree species bonded with different binders (paper, clay soil and loam soil). Sawdust was mixed with the respective binder at ratios of 90:10. 80:20 and 70:30. The calorific values of the briquettes produced were determined experimentally using adiabatic bomb calorimeter. The calorific value of the briquettes was found to depend on the type of binder and ratio. The paper bonded briquettes of the ratio 7:3were found to have the highest calorific value of 37,841 KJ/Kgcal while clay briquettes were found to have the lowest calorific value of 18,508 KJ/Kgcal at the ratio of 9:1.**

Briquettes and wood fuel were weighed and fed into the vertical wood fired-boiler. Briquettes were found to have a better combustion efficiency than wood fuel having recorded a high of 87% while the wood fuel was of 69% within the same duration of operation at six bars, this is an indicator that briquettes have higher heat intensity. The highest flue gas temperature was observed to be 338.8 ^{0}c and 453.8 ^{0}C for briquettes and wood fuel respectively. The briquettes recorded higher Carbon dioxide emissions than woodfuel indicating better combustion efficiency.

Keywords-- **Performance, Boiler, Briquettes, Calorific Value, Efficiency, Sawdust**

I. INTRODUCTION

The forested area in Kenya has been on the decline since 1963 when it was estimated at 10% of total land area. According to Ojiambo (1978) forests covered 5.2% (30,000 square kilometres of Kenya's land area of 582,646 Square Kilometres. Kenya's closed forest canopy was less than 1.7% as compared to 9% and 21% for the rest of Africa and the world respectively, Republic of Kenya (2002). To reduce pressure upon the forest resources and utilize them rationally / sustainable, a systematic conservation strategy and more scientific efforts are needed urgently (Zhang and Cao, 1995).

Global warming is caused by green house gases which carbon dioxide is among the major contributors. It was shown that increased emission of CO_2 in the atmosphere in the recent time has exacerbated the global warming. Part of the reasons for this can be explained from the fact that the forest resources which act as major absorbers of CO_2 have been drastically reduced owing to the fact that the rate of deforestation i/s higher than the afforestation efforts in the country and the world at large , E.M. Okonkwo and A.N. Eboatu (2002), . According to Akintunde M.A (2013), biomassbriquettes are renewable sources of energy and avoid adding fossil carbon to the atmosphere. Use of biomass briquettes can earn carbon credits for reducing emissions in the atmosphere.

In the last one decade most of the tea industries have switched from fuel oil to wood fuel fired boilers. This switch to wood fuel fired boilers was driven by the ever unpredictable escalating oil prices and need to maximize on returns to remain relevant in the business environment. According to Republic of Kenya (2002) tea industry is the second highest consumer of wood fuel; this was before the transformative switch to wood fuel fired boilers. Kenya Tea Development Agency (KTDA) currently has 120 boilers in its 60 factories and 80 boilers have converted from fuel oil to wood .This has created a high demand for wood fuel and thus a need to incisively check into optimization on utilization of the resource is important not only to tea industry but to the environment at large. According to Mburu (2010), some tea factories like Kagwe have started facing shortage problems with the resource; this necessitates the need for more research so as to optimize industrial utilisation of wood fuel. The increase in consumption of wood fuel directly translated to more generation of related solid wastes.

Majority of briquette projects focus in community and house hold utilization not in industrial uses as an alternative fuel source and highly depend on charcoal dust.

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A lot of research work had been done on the utilization of sawdust for domestic cooking using improved burning stove, Danshehu et al., (1992). While attempts had been made to densify the sawdust briquettes with appropriate equipment, few had been propelled towards understanding their briquette properties, densified biomass utilization for industrial use as a waste management strategy

This study provides a new look in wood waste management strategy for tea industry as alternative fuel hence contribute in sustainable utilization of the resource. This will lead to reduction in the high demand for more wood fuel, reduce environmental pollution in particular carbon emissions, contribute towards economic pillar of vision 2030 through more job opportunities for the youth especially in the urban and peri-urban, and most essential the Engineers shall use the properties in design of cost effective and affordable briquette making machines. As observed by Wamukonya and Jenkins (1995), for briquetting industry to be successful in the less industrialized countries, the equipment should consist of locally designed simple and low-cost machines. The performance of a boiler has widely been researched with respect to wood and fossil fuels but no evidence within the Kenya context have been documented on performance of boiler with briquettes. The overall objective of this study was to optimize the utilization of saw dust of eucalyptus tree species as a fuel in tea industry, in furtherance to that is to evaluate the performance of saw dust briquettes in a vertical wood fired boiler.

II. MATERIALS AND METHODS

Percentage Ash Content (PAC)

This was done in University of Nairobi, Mechanical Engineering workshop, foundry laboratory. The PAC was determined by weighing a briquette sample, placed it in an electric oven at a temperature of 900^0c for 2 hrs and it's weight taken after cooling. PAC was hence calculated in accordance with ASTM D-3173 Specification using the equation (1) below.

The Percentage Ash Content was determined:

$$PAC = \frac{D}{B} * 100 \quad (1)$$

Where

PAC = Percentage ash content,

B = the initial weight of the sample

D = weight of ash

Determination of Calorific Value (CV) Using Adiabatic Bomb Calorimeter

This was done in University of Nairobi, Mechanical Engineering workshop, heat laboratory. The calorimeter was dismantled; the crucible was cleaned and dried. The crucible was weighed when empty and I gm was of a homogeneous briquette extract. The fuse wire was installed with an attached cotton wool to assist ignition. The fuse wire was touching the briquette sample but not the crucible. Then 10 cc of water was added in the bomb to saturate the space inside the bomb which was meant to ensure complete condensation of water vapour of combustion.

The bomb was re assembled and charged with oxygen to about 25 atmospheres. The bomb was checked for leaks by immersing in water and then dried hence placed in the bomb jacket. Then 1700 cc of water was put into the calorimeter following with installation of the stirrer and the thermometer (Beckman) was immersed at least 3'' in water and not nearer that ½'' from the bomb. The stirrer was started and allowed to run for three minutes for temperature stabilization of water in the bucket. The temperature readings were taken for intervals of one minute for 5 minutes. The purpose of the reading was to establish the heat exchange in the jacket. The firing switch was instantly closed and released as soon as the indicator of the ammeter went back. The temperatures were recorded in every 30 seconds until the maximum temperature was reached. The falling temperatures were then read after every minute for five minutes. The procedure was followed for the other samples.

Table1:
Bomb Calorimeter Data

Description	Results
Weight of the empty crucible	10gm
Weight of fuel	1 gm
Weight of fuel and crucible	11 gm
Volume of water in calorimeter	1750 gm
Water equivalent of bomb	520 gm
Total equivalent of water	2270 gm

According to Eastop and McConkey (1993) while using a bomb calorimeter to determine the calorific value of a fuel, the following equation is applicable:

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$M_f * GCV_f = (M_w+W_{eq})*T_c*W_{sp}$ (2)

M_f = Mass of fuel

GCV_f=Gross Calorific Value of fuel

M_w+W_{eq} =(mass of water +water equivalent of bomb)

T_c =corrected temperature rise (cooling correction + uncorrected temperature rise)

W_{sp} = specific heat capacity of water.

According to Regnault and Pfaundler the cooling correction can be determined as follows:

Cooling correction = nv + $(\frac{v1\_v}{t1\_t})\{\sum_1^{n-1}(t) + 1/2(t0 + tn)\_nt\}$(3)

Where n is the number of minutes between the time of firing and the first reading After the temperature rise begins to fall from the maximum v the rate of fall of temperature per minute during the pre firing period, the rate of fall of temperature per minute after the maximum temperature , t and t_1 the average temperatures during the pre-firing and final periods respectively, $\sum_1^{n-1}(t)$ the sum of the readings during the period between the firing and the start of cooling , and ½ (t_0+t_n) the mean of temperature at the moment of firing and the first temperature after the rate of change in temperature rise becomes constant. The pre – firing and the final periods are of the same duration.

Evaluating performance of a vertical wood fired boiler using saw dust briquettes as the fuel.

This was carried out in Upper Kabete campus, milk processing plant according to the British Standard BS845:1987 which describes the methods and conditions under which a boiler should be tested to determine its combustion efficiency. The saw dust briquettes were arranged in the boiler oven and ignited similarly to wood fuel. The boiler was operated under steady load conditions (generally full load) for a period of one hour after which readings were taken during the next hour of steady operation. This was done using a digital gas analyzer model Kane-455, the boiler was fed with the fuel and the probe was inserted on the port near the boiler at the exhaust (stack). The flue gas analyser was switched on and allowed. When the boiler attained the maximum operating pressure of 6 bars, load of 200 hundred litres of water was heated until it attained 100 ^{0}c. When the digital gas analyser was stable, a print out was generated, the readings were taken after every 15-30 minutes and a print out was made within those intervals.

The emission levels of the briquette fuel were captured as follows: Percentage of CO_2 or O_2 in flue gas, Percentage of CO in flue gas and Temperature of flue gas.\ using a digital gas analyzer.

III. Results And Discussions

The survey conducted in selected tea factories found that none of them has ever utilized saw dust briquettes as alternative fuel for energy production. The amount of wood waste generated by the various tea factories has not been established but majority estimated at between 1 – 5% of wood fuel consumed. All the ten sampled factories have fully switched from Heavy furnace oil to wood fuel fired boilers, majority of the factories have forest reserves and also are facing fluctuation in supply of wood fuel form suppliers.

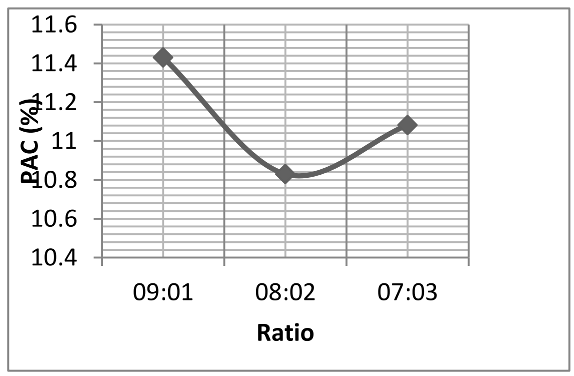

Figure 1: Variation of PAC for paper briquettes

In Figure 1 above the PAC for the selected paper bonded samples ranged from 9.68% - 12.50%. It was found that the percentage ash content decreases up to 20% upon which there is an increase in content. The average PAC was found to be 11.145%, 10.83%, and 11.023% for ratios 9:1, 8:2, 7:3 respectively.

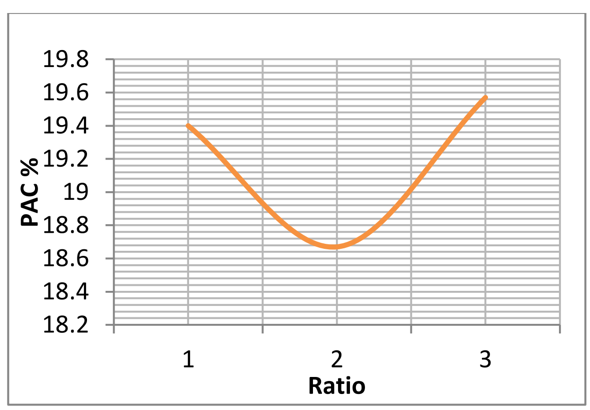

Figure 2: Variation of PAC for loam soil briquettes

Figure 2 indicates that briquettes made from loam soil as the binder were observed to reduce PAC with an increase in binder ratio. The average PAC was 19.3133%, 18.99% and 18.146% for ratios 9.1, 8.2 and 7.3 respectively. It can be deducted that increase in binder ratio i.e. loam soil lead to decrease in PAC.

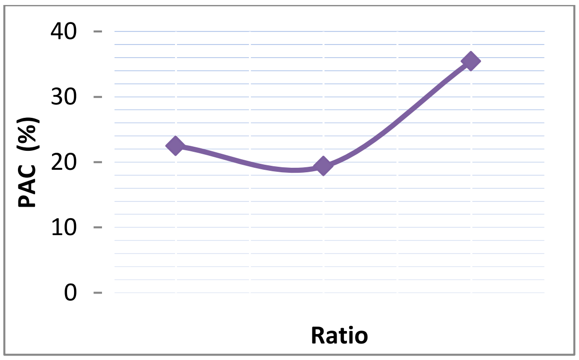

Figure 3: Variation of PAC for Clay soil briquettes

Figure 3 above shows that briquettes made from clay soil as the binder were observed to reduce PAC with an increase in ratio up to 20% where an increase in binder content was noted to be proportional to PAC. The average PAC was 22.995%, 19.367% and 35.446 % for 9:1, 8:2 and 7:3 ratios respectively.

Briquettes made from loam soil as the binder were observed to reduce PAC with an increase in ratio up to 20% where an increase in binder content was noted to be directly proportional to PAC. We can deduct that clay briquettes have the highest ash content followed by loam soil and paper respectively.

The calorific value of briquettes of paper: ratio of 7:3 was having the highest calorific value of 37,841 kj/kg while clay of the same ratio was found to be the lowest with 18,508 kj/kg. While the loam soil of ratio 7:3 was found to have 28,140 kj/kg which concurs directly with PAC generated. It was observed that loam soil has better combustion characteristics than clay while paper is the best.

A load of 200 litres took 30 minutes to achieve a temperature of 100 ^{0}C under briquettes while it only took 20 minutes for wood fuel. The fuel consumption was 40 kilogram's for wood fuel and 35 kilograms for briquettes, this indicating that the briquettes burn slowly hence cost saving in terms of quantity. This observation showed that briquettes burn slowly while wood fuel is in aflame. The briquettes were having the highest efficiency of 87% while the wood fuel was of 69% within the same duration of operation.

The highest flue gas temperature was observed to be 338.8 ^{0}c and 453.8 ^{0} c for briquettes and wood fuel respectively. This is an indicator that briquettes have higher heat intensity and they burn slowly. Briquettes emitted more co_2 than wood fuel, indicating that briquettes burning behavior is better than wood fuel. Wood fuel has a higher carbon dioxide emission than briquettes, proofing that briquettes have better combustion efficiency than wood fuel was observed to have emitted the highest CO at 4842 ppm while briquettes was 1266 ppm within the same duration of operation. The CO/CO_2 ratio for wood fuel was found to be higher than briquettes with a high ratio of 0.0554 while for the briquettes was 0.0234, this implies that briquettes have a better burning characteristics than wood fuel.

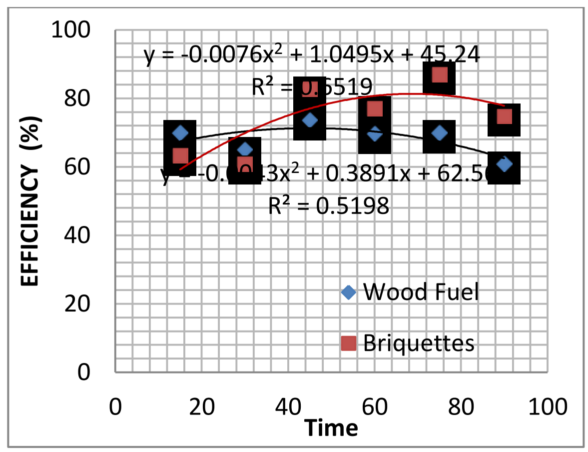

Figure 4: Comparing boiler combustion efficiency of briquette and wood fuel

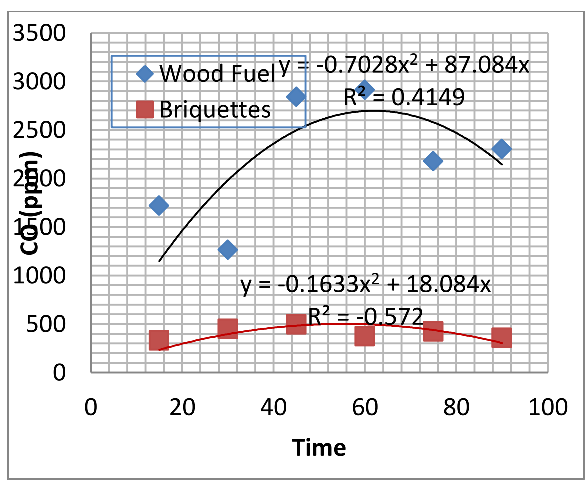

Figure 5: Carbon Monoxide Emission Profiles for briquettes and wood fuel

Figures 1and 2 above shows that briquettes were observed to have a higher efficiency than wood fuel throughout, the carbon dioxide emission was higher than briquettes. It can thus be deducted that briquettes have a better combustion characteristics that wood fuel.

IV. Conclusions And Recommendations

This research has found that PAC decreases up to 20% upon which there is an increase in content. Briquettes made from loam soil as the binder were observed to reduce PAC with an increase in ratio. The calorific value for paper: saw dust ratio was found to increase with an increase in ratio of binder which was vice versa for clay soil which was found to decrease with an increase in binder ratio. The briquettes were found to burn better than wood fuel; the carbon emissions by briquettes were lower than the wood fuel. The research recommends utilization of the saw dust briquettes as alternative fuel in tea industry due its established better performance than wood-fuel with minimal carbon emissions; higher combustion efficiency, reduced pressure on our forests among others. The sustainable use of forests will get a boost as the wastes that have been on disposal chain as saw dust can now be utilized as an alternative fuel. Briquette performance in a boiler needs in depth study for a longer period in a boiler installed with steam meter and feed water temperature gauge for determination of thermal efficiency using direct method,

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