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Studies On Development Of Fuel Briquettes Using Locally Avaliable Waste

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ABSTRACT:
The Energy requirement is increasing day by day as the number of industries is increasing proportionately and the present power supply is unable to meet the energy demand. To combat this energy shortage, developed as well as developing countries are putting more efforts into R&D to tap alternative energy sources. State policies are also being formulated to encourage alternative sources of energy. In India alone, it is proposed that 17,000 MW should be produced from biomass. Although other options like gasification can be used for power generation, briquetting of biomass can be considered for its economics, reliability and ease of operation. Briquettes of small size can be used in gasifies for power generation. If the plant sites are chosen properly for easy availability of raw material, the agro-residues can be briquetted to reduce further transportation costs and associated pollution. This also improves the handling characteristics of biomass. The briquettes so obtained are very good fuels for local small scale industries and domestic purposes.

Key Words: Fuel Briquettes, Proximate Analysis, Ultimate Analysis, XRD, SEM

I. Material and methods:

Sugarcane waste: India, as we all know is the second biggest sugarcane growing country in the World, only behind Brazil. Every year, 4 million hectares had been planted with sugarcane. Sugar plant can process 40 million tons sugarcane every year. For each tone of sugarcane crushed, about 300 kg of bagasse is retrieved. Previously bagasse is used as the fuel of sugar production. However only a third of bagasse are flamed, the remaining is discarded. That is to say, making bagasse into briquettes contains huge potential

Teak leaves: The primary benefit of leaf and yard waste is the potential for immediate diversion of a significant portion of the state's solid waste stream from disposal facilities. The economic and environmental benefits which result from eliminating this material from disposal facilities and converting it to briquettes have provided municipalities with the incentive to establish composting operations or other useful operations

Cloth waste: Annual production of cotton or rough textile fibers wastes of one cotton mill ranges from 10 to 200 tons. Usually the waste is stored in the municipal refuse depots in form of blended waste. Increasing of the cotton yarn production results in high amount of waste originated during cotton processing and therefore there are searched ways how that waste could be used

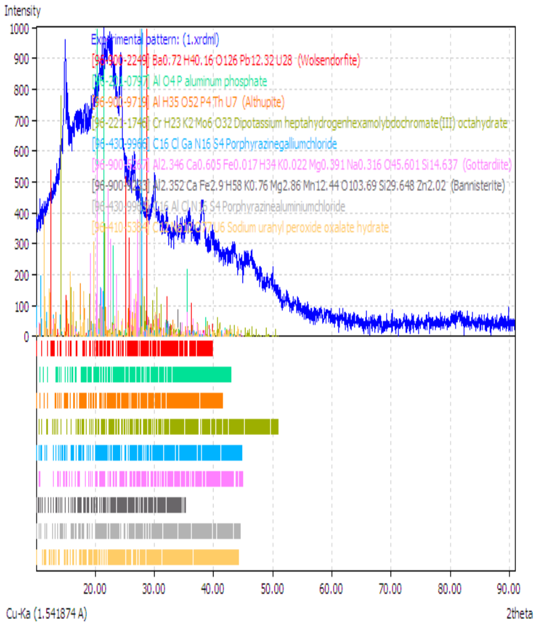
II. Experimental Procedure:

Teak leaves, sugarcane waste, cloth waste are collected .All the wastes are firstly cleaned out thoroughly with water to remove dirt and are dried on open top for 15 days. The dried samples were cut into small pieces (about ½ inch). The samples were soaked in 3 different buckets for 24 hours. After 24 hrs the samples were filtered using a mesh and partially dried for 15 min. The binder taken is Maida (wheat flour). The amount of binder should be added is known while making trails. We found about 100 grams of Maida prepared will be sufficient .In the hot water Maida flour is added slowly and stirred vigorously Such that no lumps are formed. Binder will attain the sticky nature. Maida gives good strength to the samples and thus prevents them from collapsing during firing. The water filtered sample is mixed with the binder. Both are mixed well. Then the mixture is kept into mould which is placed on a wooden plank. After putting all the prepared mixture the mould is closed with lid and kept under fitted bench vise and tightened to apply pressure. The pressure is applied for about 24 hours.After 24 hrs the mould should be carefully removed. A rectangular briquette with high moisture content is obtained. Then it should be dried enough to obtain a rigid briquette. . During drying, the Maida which would have formed a layer over the particles, changes from a semi-solid to a solid form, thus holding the particles together.

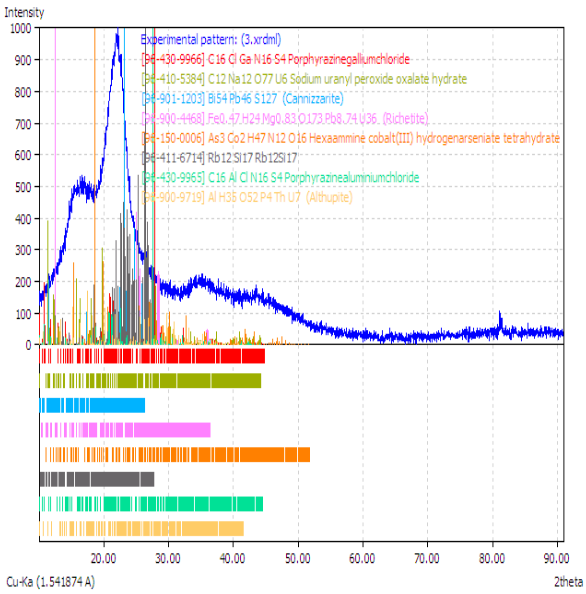
III. RESULTS AND DISCUSSIONS:

Characterization of briquettes:

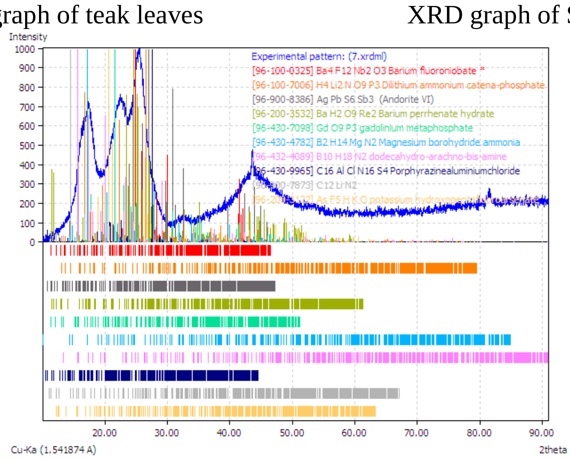
XRD analysis: With the aid of two-positioned STOE proportional sensitive detector (PSD), the x-ray diffraction (XRD) patterns were recorded using a STOE automatic powder diffractometer [22]. With the use of Rietveld technique [23] the produced patterns were refined (using match software) and the matching compounds were detected.[24] . The acquired graphs containing matching components at different intensities are given below along with matching components.



XRD graph of teak leaves



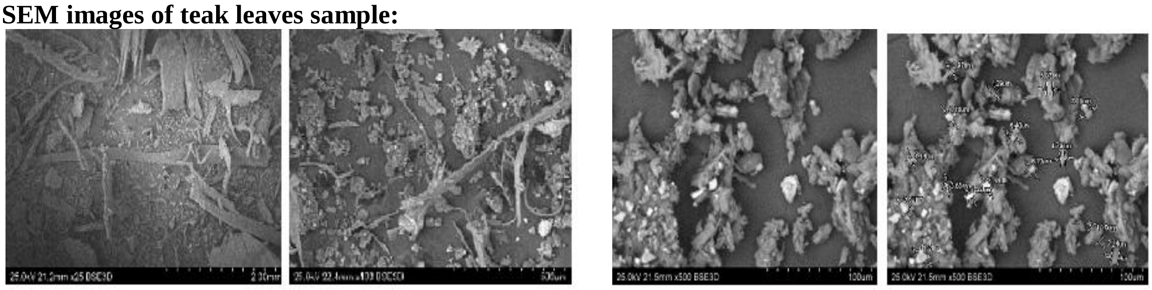
XRD graph of Sugarcane waste



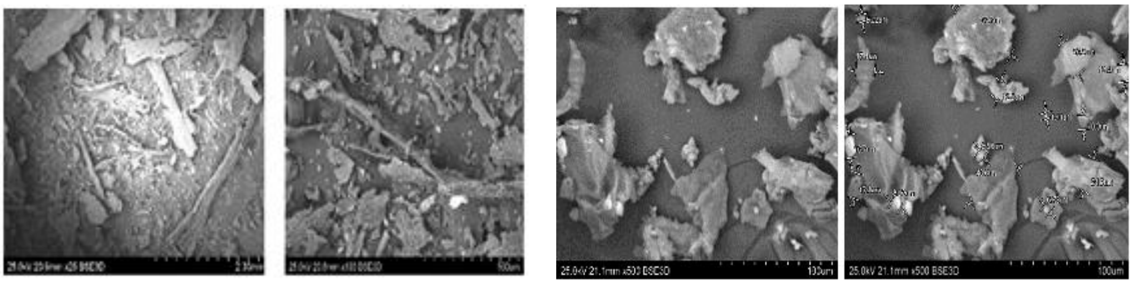
XRD graph of cloth waste

Scanning Electron Microscope:

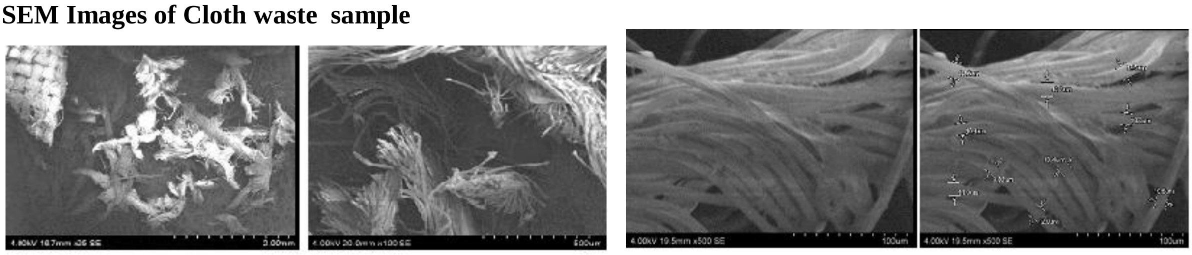
SEM images of teak leaves sample:



SEM images of suagarcane sample:



SEM Images of Cloth waste sample



The morphology structure of the waste briquettes was determined by using scanning electron microscope. The morphological structure of the teak leaves showed uniform short fibrous and coarser structure. Whereas sugarcane wastes images showed large and small dens granulated structures respectively. Further image indicated long uniform fibrous lingo cellulosic structure. The morphology structure of material waste studies helps to predict their agglomeration properties in order to be briquetted.

Proximate analysis:

MOISTURE CONTENT: The total energy that is needed to bring a briquette up to its pyrolytic temperature is dependent on its moisture content which affects the internal temperature within the briquette due to endothermic evaporation [1]. According to [2], moisture content is one of the main parameters that determine briquette quality. A lower moisture content of briquettes implies a higher calorific value. The problem of too high moisture content of the raw material can significantly increase production costs. Biomass moisture most often occurs as a result of inadequate protection against atmospheric conditions during storage. Particularly affected by this problem is the raw material stored in the form of stacks. The problem of too high raw-material moisture can be solved using the dryers in the production process. However, this solution requires investment, and increases expenditures on production.[3]

The moisture content of raw biomass was determined by calculating the loss in weight of material using hot air oven dying method at 105℃ to 110℃ for one hour and up to constant weight loss (Dara S.S.)[4]

$$Moisture\ content(\%wb) = \frac{w2-w3}{w2-w1} \times 100,$$

Where, w1 = weight of crucible, g w2 = weight of crucible + sample, g w3 = weight of crucible + sample after heating.

The moisture content of the cloth waste briquette was determined to be 16.83, Sugarcane waste, teak leaves briquettes have 16.40 and 15.82 respectively. A lower moisture content of briquettes implies a higher calorific value. This is good forth storability and combustibility of the briquettes as recommended by [6]. From this we can say that cloth waste will take more time for heating and will have lower calorific value. Also it will be consumed more for a certain heating purpose than other briquettes .The value obtained is also corroborated by [2] who reported a moisture content of 5% for durable briquettes [7]. The total energy that is needed to bring a briquette up to its pyrolytic temperature is dependent on its moisture content which affects the internal temperature within the briquette due to endothermic evaporation [1].

ASH CONTENT: The residual sample in the crucible was heated without lid in a muffle furnace at 700 ± 50℃ for one half hour. The crucible was then taken out, cooled first in air, then in desiccators and weighed. Heating, cooling and weighing was repeated, till a constant weight obtained. The residue was reported as ash on percentage basis [4].

$$\text{Ash content } (\%wb) = \frac{w3-w1}{w2-w1} \times 100$$

Where, w1 = weight of the empty crucible, g w2 = weight of empty crucible + sample, g w3 = weight of the crucible + ash, g

Ash, which is the non-combustible component of biomass, was found for waste cloth, take leaves and sugarcane waste as 8.9, 19.4, 15 respectively. According to [11], ash has a significant influence on the heat transfer to the surface of a fuel as well as the diffusion of oxygen to the fuel surface during char combustion. As ash is an impurity that will not burn, fuels with low ash content are better suited for thermal utilization than fuels with high ash content. Higher ash content in a fuel usually leads to higher dust emissions and affects the combustion volume and efficiency. According to [12], the higher the fuel's ash content, the lower is its calorific value.[5]. Higher ash content in a fuel usually leads to higher dust emissions and affects the combustion volume and efficiency. According to [4], the higher the fuel's ash content, the lower is its calorific value. From the results we can say that Teak leaves will have low calorific value.

VOLATILE MATTER:

Determination of volatile matter: The dried sample left in the crucible was covered with a lid and placed in an electric furnace (muffle furnace), maintained at 925 ± 20℃ for 7 minutes. The crucible was cooled first in air, then inside a desiccators and weighed again. Loss in weight was reported as volatile matter on percentage basis. (Dara S.S.)

$$\text{VOLATILE MATTER}(\%WB) = \frac{W2-W3}{W2-W1} \times 100,$$

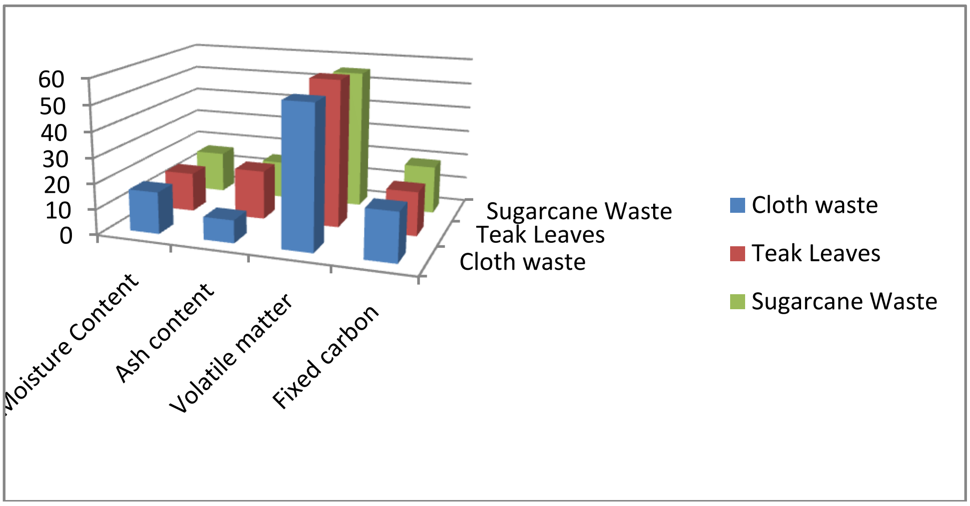
Where, w1 = weight of the empty crucible, g w2 = weight of empty crucible + sample, g w3 = weight of the crucible + sample after heating.

Biomass generally contains a high volatile matter content of around 70% to 86% and low char content. This makes biomass a highly reactive fuel giving a faster combustion rate during the devolatisation phase than other fuels such as coal [15]. As reported by [16], low-grade fuels, such as dung, tend to have low volatile content that results in smoldering which other authors [17] described as an incomplete combustion which leads to a significant amount of smoke and release of toxic gases. However, for the sawdust charcoal briquette, a volatile content of 71% is high and an indication of easy ignition of the briquette and proportionate increase in flame length as suggested by [15]. The high volatile matter content indicates that during combustion, most of the teak leaves briquette will volatize and burn as gas in the cook stove. From the results Teak leaves have highly 57.78. So it will be highly reactive fuel than the other two briquettes which have lower volatile matter than it.

FIXED CARBON: The fixed carbon content of the coal is the carbon found in the material that is left after volatile materials are driven off. This differs from the ultimate carbon content of the coal because some carbon is lost in hydrocarbons with the volatiles. Fixed carbon is used as an estimate of the amount of coke that will be yielded from a sample of coal. Fixed carbon is determined by removing the mass of volatiles determined by the volatility test, above, from the original mass of the coal sample. It is used as %C in computation for calorific value.

Percentage of fixed carbon = 100 - % (moisture content+ volatile matter + ash)[4][10]

The fixed carbon of charcoal ranges from a low of approximately 50% to a high of around 95%. The charcoal for domestic use is recommended that it should contain 80.5% of fixed carbon, while the industrial charcoal is recommended to have 86.7% of fixed carbon. On the other hand, the quality smokeless domestic wood charcoal has been specified to consist 75% of fixed carbon or more than this while the industrial wood charcoal has been specified to contain not less than 85% of fixed carbon. The proportion of fixed carbon can be controlled through maximum temperature and its residence time during the carbonization process and the charcoal produced from high temperature will be higher in fixed carbon than the charcoal produced at lower temperature. In addition, the charcoal having high volatile matter has lower fixed carbon, which low fixed carbon tends to be harder, heavier, stronger and easier to ignite than charcoal containing high fixed carbon [10].The briquettes made from teak leaves, sugarcane waste and cloth waste have 17.3, 18.9, 19.1.

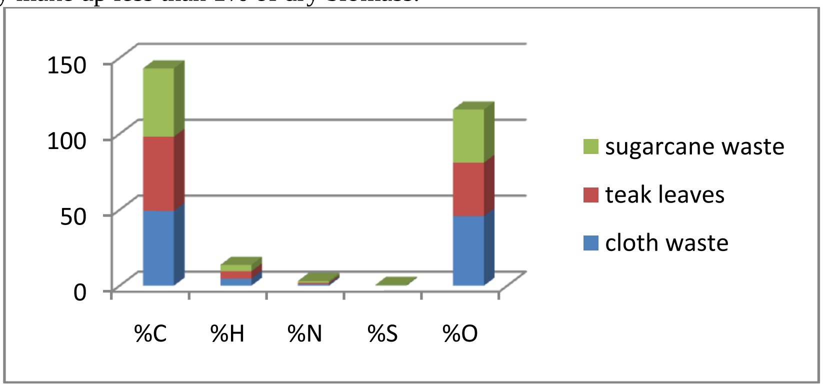


ULTIMATE ANALYSIS:

The ultimate analysis indicates the various elemental chemical constituents such as carbon, hydrogen, oxygen, sulphur, etc. It is useful in determining the quantity of air required for combustion and the volume and composition of the combustion gases. The chemical compositions of composite waste briquettes include carbon, hydrogen, oxygen, nitrogen and sulphur among others. The ultimate analysis or the determination of their percentage compositions were carried out using standard methods. Thus, ASTM D5373-02 method was used for the determination of percentage composition of carbon, hydrogen and nitrogen, ASTM D4239-02 method was used for the determination of percentage composition of sulphur and ASTM D5142-02 method was used for the determination of percentage ash content of individual composite briquette samples. The percentage oxygen content of the individual composite agricultural waste briquette was determined by difference as follows . (1) Where C, H,S, N ,O and Ash are the carbon, hydrogen, sulphur , nitrogen, oxygen and ash content of the composite agricultural waste briquettes respectively [11]

$$\%O=100-\%(C+H+S+N+ASH)$$

The composition of the cloth waste briquette analyzed as showed 49.25% carbon, 4.698% hydrogen, 45.86% oxygen, 0.966% nitrogen and 0.154% sulphur. The results agree with the observations made by Chaney [12] who reported that analysis of biomass using the gas analysis procedures revealed the principal constituent as carbon, which comprises between 30% and 60% of the dry matter and typically 30% to 40% oxygen. Hydrogen, being the third main constituent, makes up between about 5% and 6%, and nitrogen and sulphur (and chlorine) normally make up less than 1% of dry biomass.



Other results of ultimate analysis for teak leaves gave 48.879%, 4.826%, 35.139%,0.944%, 0.1096% for contents of carbon, hydrogen, oxygen, nitrogen, and sulfur, respectively, while the corresponding values for sugarcane waste briquette in the order listed above were 44.926%, 4.1930%, 35.01%, 1.196%, and 0.295%, respectively.[13]

On average, the carbon and hydrogen elements contents in the samples were found to be 47% and 4.57% respectively. These values are higher than values of common low grade coal reported by Guoqing Lu [14]. In general, the increase in carbon and hydrogen content leads to an increase in the HHV [15,16]. The mean percentage of nitrogen available in the PS samples was approximately 1%. The nitrogen content in PS was found to be lower than coal as reported in [14], and this decrease will fortunately doesn't require additional controls on temperature, pressure and air concentration during the thermal conversion process to reduce the NOX emissions. The mean percentage of sulfur in the PS samples was almost 0.1, and this will results in low SO2 emissions from incineration [14]. In general, the fuel characterization results suggested that fuel briquettes made from PS can be used in power generation or process heating supply due to its high calorific value and acceptable chemical composition for emissions controls.[17]

The amount of carbon and hydrogen content in the sample examined is an indication that they will contribute immensely to the combustibility of the briquette as suggested by [18]. According to [19], the resulting composition Of biomass affects its combustion characteristics as the total overall mass of the fuel decreases during the volatile combustion phase of the combustion process, as the hydrogen to carbon ratio of the fuel increases and, to a lesser extent, as the oxygen to carbon ratio increases. Nitrogen, sulphur and chlorine are significant in the formation of harmful emissions and have an effect on reactions forming ash [10]. The sulphur and nitrogen contents reported which are below 1% is a welcome development as there will be minimal release of sulphur and nitrogen oxides into the atmosphere, thereby limiting the polluting effect of the briquettes [20][21].

Calorific Value: Heat value or calorific value determines the energy content of a fuel. It is the property of biomass fuel that depends on its chemical composition and moisture content. The most important fuel property is its calorific or heat value [2]. The computed calorific value for the cloth waste briquette was 6003 kJ/kg. Sugarcane waste and cloth waste briquettes have 6239 and 6132 kJ/kg respectively. This energy value can produce enough heat required for household cooking and small-scale industrial cottage applications.

Porosity Index: Porosity of the briquettes increases with increase in the biomass concentration. Biomass has higher inherent porosity due to its fibrous nature coupled that after pulverization, its particle sizes were relatively bigger than that of coal. These two factors offered it the ability of increasing the number of pores in the briquette. The sample containing 0% biomass, cloth waste has the least porosity index, 0.2211 while the one comprising 100% biomass, teak leaves and sugarcane waste both have the high porosity, 37.23 and 34.12. Low porosity will hinder mass transfer during combustion due to fewer spaces for mass diffusion. The higher the porosity, the higher the rate of infiltration of oxidant and out flow of combustion/pyrolysis products during combustion and the higher will be the burning rate of the briquette. [21]

Conclusion:

Good quality and highly storable/durable briquettes can be produced from cloth waste, Teak leaves and sugarcane waste.

1. Cloth waste briquette has high moisture content, low in ash content and has high fixed carbon amount than the other two briquettes. This briquette may be unstable for longer periods
2. Teak leaves briquette has low moisture content and high ash content. This briquette is ready to burn due to high volatile matter and has high calorific value
3. Sugarcane waste briquette is the stable briquette which is stable for longer periods.

Therefore, it is recommended to use these briquettes in small scale Industries and for household purposes.

References:

[1.] Zaror, CA, Pyle, PD: The pyrolysis of biomass: a general review. Sadhana Acad. Proc. Eng. Sci. 5(4), 269–285 (1982)
[2.] Aina, OM, Adetogun, AC, Iyiola, KA: Heat energy from value-added sawdust briquettes of Albiziazygia. Ethiopian Journal of Environmental Studies and Management 2(1), 42–49 (2009)
[3.] Wojciech ŻARSKI " economic aspects of production of fuel briquette from agro biomass" 2011, Issue 44, p134-143. 10p.
[4.] S. H. Sengar, A. G. Mohod1, Y. P. Khandetod1, S. S. Patil2, A. D. Chendake " Performance of Briquetting Machine for Briquette Fuel" International Journal of Energy Engineering 2012, 2(1): 28-34 DOI: 10.5923/j.ijee.20120201.05
[5.] Kim, HJ, Lu, GQ, Naruse, I, Yuan, J, Ohtake, K: Modeling combustion characteristics of bio-coal briquettes. J. Energy Resour. Technol. 123, 27–31 (2001)
[6.] Loo, SV, Koppejan, J: The Handbook of Biomass Combustion and Co-firing. Earthscan, London (2008).
[7.] Joel Chaney "combustion characteristics of briquettes" EWB-UK National Research & Education Conference 2011 UK National Research & Education Conference 2011 'Our Global Future' 4th March 2011
[8.] Hand book of loo and koppajen "biomass combustion and co-firing" Issn-978-1-84407-249-1.

[9.] Loo, SV, Koppejan, J: The Handbook of Biomass Combustion and Co-firing. Earth scan, London (2008)

[10.] Pallavi.H.V, Srikantaswamy.S*, Kiran B.M, Vyshnavi.D.R and Ashwin.C.A “Briquetting Agricultural Waste as an Energy Source” JECET; December 12-February 2013; Vol.2.No.1, 160-172.

[11.] Nicholas Akhaze Musa, “ Determination of Chemical Compositions, Heating Value and Theoretical Parameters of Composite Agricultural Waste Briquettes” International Journal of Scientific & Engineering Research Volume 3, Issue 6, June-2012 1 ISSN 2229-5518.

[12.] Chaney, J: Combustion Characteristics of Biomass Briquettes. University of Nottingham, Dissertation (2010)

[13.] J.T. Oladeji “Fuel Characterization of Briquettes Produced from Corncob and Rice Husk Resides.” The Pacific Journal of Science and Technology Volume 11. Number 1. May 2010 (Spring)

[14.] A. B. A. Ibrahima, M. S. Arisb, Y. S. Chin “Development of Fuel Briquettes from Dewatered Poultry Sludge” 2012 International Conference on Future Electrical Power and Energy Systems Lecture Notes in Information Technology, Vol.9

[15.] C. Y. Yin, “Prediction of higher heating values of biomass from proximate and ultimate analyses,”Fuel 90, 1128-1132, January 2010.

[16.] C. Sheng, J. L. T. Azvedeo,”Estimating the higher heating value of biomass fuel from basic analysis data, “Biomass and bioenergy 28, 499-507, November 2004.

[17.] G. Lu, H. Kim, J. Yuan, I. Naruse, and K. Ohtake, ”Experimental study on self – Desulfurization characteristics of bio briquettes in combustion, “Energy and Fuels 12,689-696, 1998.

[18.] Musa, NA: Comparative fuel characterization of rice husk and groundnut shell briquettes. NJREDI 6(4), 23–27 (2007)

[19.] Grover, PD, Mishra, SK, Clancy, JS: Development of an appropriate biomass briquetting technology suitable for production and use in developing countries. Energy Sustain. Dev. 1(1), 45–48 (1994)

[20.] Enweremadu, CC, Ojediran, JO, Oladeji, JT, Afolabi, LO: Evaluation of energy potential in husks from soy-bean and cowpea. Sci. Focus 8, 18–23 (2004)

[21.] Joseph O Akowuah1*, Francis Kemausuor1 and Stephen J Mitchual2 “Physico-chemical characteristics and market potential of sawdust charcoal briquette” Akowuah et al. International Journal of Energy and Environmental Engineering 2012, 3:20

[22.] Wölfel, E. R., 1983, J. Appl. Crystallogr., 16, pp 341-348.

[23.] Rietveld, H. M., 1969, J. Appl. Crytst. V2, pp 65 – 71.

[24.] S. A. Ibitoye and A. A. Afonja “Characterization of Cold Briquetted Iron (CBI) By X-Ray Diffraction Technique” Journal of Minerals & Materials Characterization & Engineering, Vol. 7, No.1, pp 39-48, 2007.