Studies on development and effectiveness of fuel briquettes as an alternative energy sources

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Abstract - *Energy in the world is on high emergency now days. Energy resources are abundant but exhausted as per present conditions. Search for alternate energy sources has been trending worldwide. Solar and wind energies are of present interest to minimize cost of investment. But utilization of Municipal and Solid waste as an alternate source of energy is vital in research. Producing fuel briquettes with naturally available waste materials which are biodegradable is an asset. The experimentation is carried out for moisture content, ash content, volatile matter, fixed carbon, sulfur, calorific value and water resistance. The waste materials are mixed with all purpose flour in different ratio's. Calorific value is evaluated based on ultimate analysis.*

Key Words: Fuel Briquettes, Porosity, Calorific Value, Proximate Analysis, Ultimate Analysis, XRD, FTIR.

1.INTRODUCTION

The final ejection of biomass wastes from agricultural commotion is usually an environmental problem. One solution for this situation is the reuse of these wastes to produce activated carbon, which is one of the most widely, used materials because of its remarkable adsorbent properties. It is applied in a variety of purification and separation processes, in the lessening of hazardous contaminants, municipal and industrial wastewater treatments. Activated carbon has a practical advantage over other adsorbent material because it may be obtained from a variety of carbonaceous raw materials, including byproducts or wastes from industrial processes [01]. Coal and biomass gives rise to a briquette with better combustion properties and pollutant emission compare to the conventional coal briquette. This type of briquette is known as biocoal briquette. Bio-coal briquette is a type of solid fuel prepared by compacting pulverized coal, biomass, binder, and sulphur fixation agent [02]. Briquetting of biomass is a densification process which improves its handling characteristics, enhances its volumetric calorific value, reduces transportation cost and produces a uniform, clean, stable fuel or an input for further refining processes[03]. Different raw material properties cause different conditions during densification process, and this causes that the final quality of biofuel produced to be very different [04]. Absence of binders can influence final briquette quality negatively [05]. The application of biomass briquetting i.e. transforming the loose biomass into briquettes is an effective way to solve these problems and contribute towards alleviation of energy shortage and environmental degradation [06]. The ultimate analysis gives elemental composition of fuels but it is costly, and needs special arrangement of the experimentation [07]. Proximate analysis gives fixed carbon (FC), volatile matter (VM) and ash content (ASH) as solid, gaseous, and non-combustible components, respectively in any solid fuels [08]. Power generation from biomass becomes attractive way for energy generation due to their high energy potential and less pollutants. Sustainable production and utilization of biomass in power generation can solve the vital issues of atmospheric pollution, energy crisis, waste land development, rural employment generation and power transmission losses [09]. Performance tests are: to determine the (comparative) relative performance of fuel to the stove, to determine the potential and expected fuel savings offered by a stove and to obtain the data necessary for optimization of fuel in relation to its stove [10].

2. MATERIALS AND METHODS

Materials required for fuel briquetting;

(a) Agricultural wastes (b) Hand mould (c) Binding material (plain flour–Maida).

2.1 Selection of Raw Material:

The selection of raw material is most dependent on the easily available materials in surrounding areas where the briquettes made.

2.1.1. Collection and preparation of the samples:

Bauhinia Purpea leaves were collected from Andhra University Engineering College premises .wood waste is collected from carpentry work shops around Gopalapatnam and Papaya Leaves are collected from Gopalapatnam. The samples were then dried in sunlight and are dried on open top for 15 days. Then the dried leaves are cut into small pieces. The dried small pieces are then mixed with water in a bucket and soaked for 24hrs. After 24 hrs the samples were filtered using a mesh and partially dried for 15 min.

2.1.2. Preparation of binder:

The binder we have taken is Maida (wheat flour). By making more trails we found that 100 gms amount of Maida will be sufficient for binder preparation. In the hot water Maida flour is added slowly and stirred vigorously and continuously, making sure 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.

2.1.3. Preparation of Briquettes:

After that the binding material is added and the slurry is poured in the briquette mould (6" length, 5" width and 4" height). After applying pressure with load (0.33 psi), the water leaks through the holes in the mould (four holes) and a brick is formed. This process is applied for three samples.

3. Results and Discussions:

3.1. Characterization of Briquettes:

3.1.1. X-Ray Diffraction analysis:

The X-Ray Diffractograms (XRD) of the powder samples are taken using a Rigaku Ultima model IV. The diffracted X-Ray intensities are recorded as a function of 2θ by using copper target (Cu-Kα radiation with wave length, λ=1.5492Aº)at a scan speed of 2º/min. XRD patterns are recorded from 3º to 90º. Different phases of the samples are to be identified by comparing with a set of 'd' values and the corresponding intensities with the standards from the ICDD(International Center for Diffraction) files [11–13].

XRD Pattern of Bahunia Purpea Sample Fuel Briquettes:

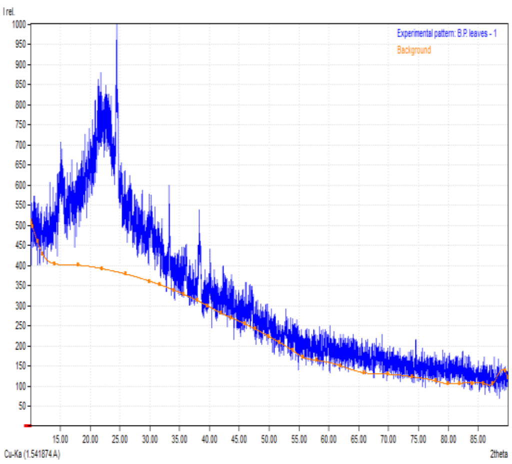

Fig. 1 XRD Pattern of BP leaves sample Fuel Briquette

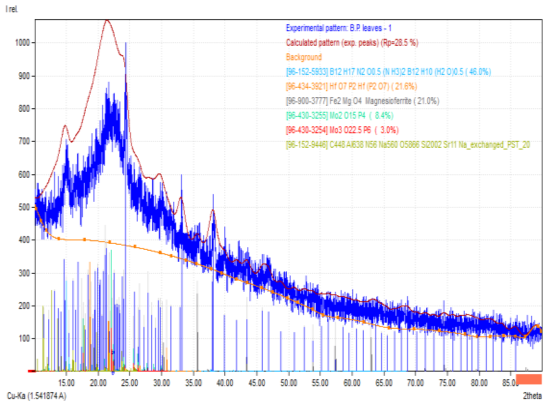

Fig. 2 XRD Pattern of BP leaves sample Fuel Briquette-Matching Compounds

XRD for Bahunia Purpea leaves exhibit good crystallinity, more amorphous nature and increase in surface area and porosity. The peaks at 2θ values of 0.2382, 0.1892, 0.2460, 0.1439, 0.4779 corroborate the presence of $MO_3O_{22.5}P_6$, $MO_2O_{15}P_4$, HFO_7P_2-(HFP_2O_7), $B_{12}H_{17}N_2O_{0.5}$ and Fe_2MgO_4 their corresponding d-values are 3.9825, 3.9820, 3.8552, 5.9235, 4.8388 respectively (Fig. 1 & 2).

XRD analysis of Papaya Leaves:

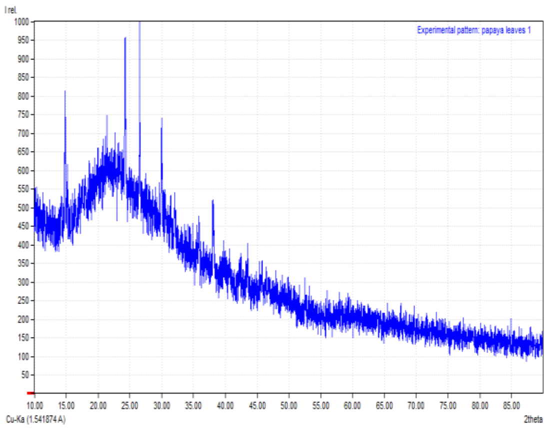

Fig. 3 XRD Pattern of Papaya leaves sample Fuel Briquette

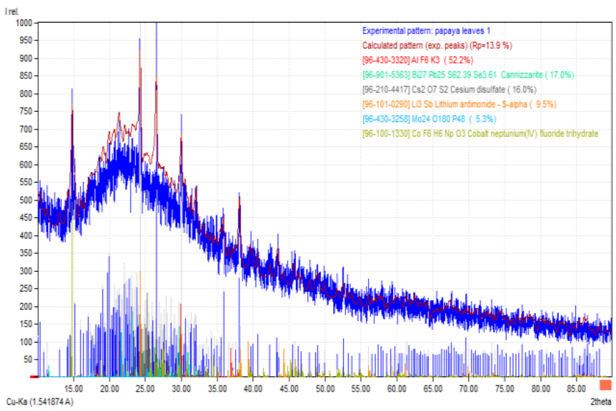

Fig. 4 XRD Pattern of Papaya leaves sample Fuel Briquette-Matching Compounds

The peaks at 2θ values of 0.4164, 0.4912, 0.5272, 0.3991, 0.3697 corroborate the presence of AlF_6K_3, $Bi_{27}Pb_{25}S_{62.39}Sc_3$, li_3sb,$MO_{24}O_{180}P_{48}$, $CS_2O_7S_2$ their corresponding d-values are 3.3917, 3.1233, 4.0746, 5.1285, 4.1588 respectively (Fig. 3 & 4).

XRD analysis of Wood Waste:

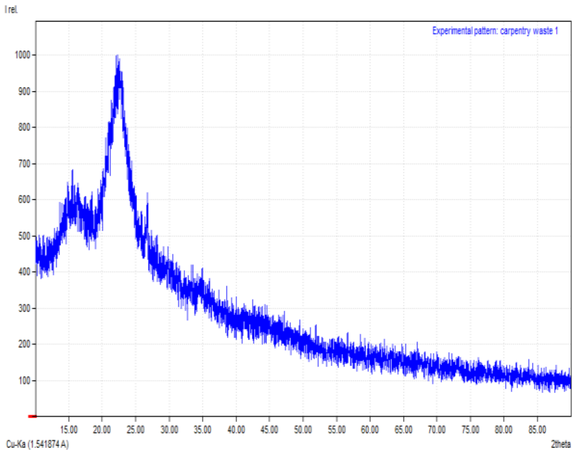

Fig. 5 XRD Pattern of Wood Waste sample Fuel Briquette

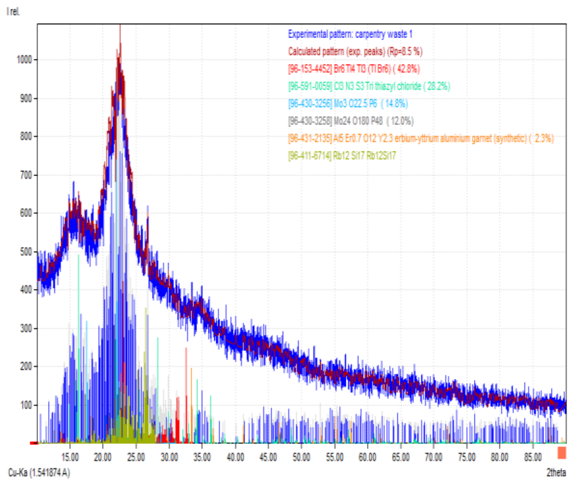

Fig. 6 XRD Pattern of Wood Waste sample Fuel Briquette-Matching Compounds

The peaks at 2θ values of 0.6076, 0.5536, 0.5125, 0.6202 ,0.4867 corroborate the presence of Br_6Tl_4, $Cl_3N_3S_3$, $Al_5Er_{0.7}O_{12}Y_{2.3}$, $MO_3O_{22.5}P_6$, $MO_{24}O_{180}P_{48}$ their corresponding d-values are 3.9200, 1.1608, 4.8902, 3.4920, 5.1454 respectively (Fig. 5 & 6).

3.1.2. FTIR:

FTIR relies on the fact that the most molecules absorb light in the infra-red region of the electromagnetic spectrum. This absorption corresponds specifically to the bonds present in the molecule. The frequency ranges are measured as wave numbers typically over the range 4000 – 600 cm^{-1}[14–15].

FTIR analysis of B.P Leaves:

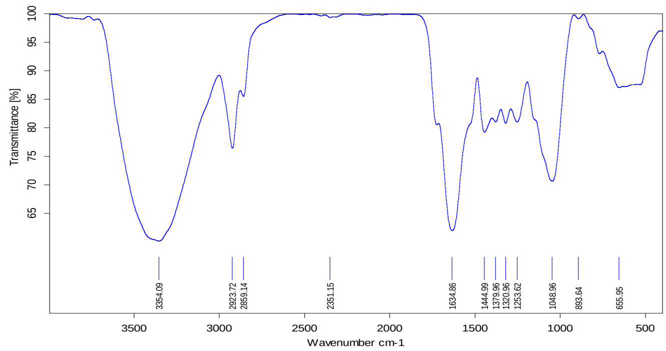

Fig. 7 FTIR pattern of BP leaves sample Fuel Briquette

The Sharp Peaks (Fig. 7) of 655.95 C-Cl stretch arose after carbon-chlorine involvement , 893.64 Alkene =C-H bending, 1048.96 Alkyl Halide C-F stretch, 1253.62 1320.96 and 1379.96 Amine C-N stretch, 1444.99 Alcohol C-O stretch 1634.86 Amide C=O Stretch, 2351.15 C≡N in the Poly Acryl Nitrile,2859.14 C-H Stretching Vibrations , 2923.72 CH_2Stretching Vibrations , 3354.09 Alcohol/Phenol O-H for alcohols,ketones, amines,halides, nitrates,alkenes has been obtained (Table 1).

Table -1: FTIR Peaks and Bonds

S.NO	PEAK VALUES	BONDS AND FUNCTIONAL GROUPS
1	655.95	C-Cl stretch
2	893.64	Alkene =C-H bending
3	1048.96	Alkyl Halide C-F stretch
4	1253.62	Amine C-N stretch
5	1320.96	Amine C-N stretch
6	1379.96	Amine C-N stretch
7	1444.99	Alcohol C-O stretch
8	1634.86	Amide C=O Stretch
9	2351.15	C≡N in the Poly Acryl Nitrile
10	2859.14	C-H Stretching Vibrations
11	2923.72	CH2 Stretching Vibrations
12	3354.09	Alcohol/Phenol O-H Stretch

FTIR analysis of Papaya Leaves:

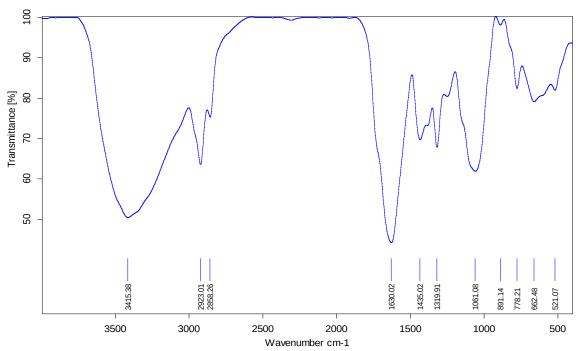

Fig. 8 FTIR pattern of Papaya leaves sample Fuel Briquette

The sharp peaks (Fig. 8) of 521.07 arose after loading of C-Br stretch due to the involvement of C-O Alcohols, alkenes,ketones and phenols respectively. Further four additional peaks of 662.48 Aromatic C=C,778.21 Aromatic C-H Bending ,891.14 Alkene =C-H bending, 1061.08 Alcohol C-O stretch for Bromo Carbon the bending vibrations has been suddenly appreared.The peak appearing at 1319.91 Amine C-N stretch,1435.02 Alcohol C-O stretch,1630.02 Amide C=0 Stretch,2858.26 and 2923.01 CH_2 Stretching vibrations, 3415.38 Alcohol/Phenol O-H stretch has been obtained (Table 2).

Table -2: FTIR Peaks and Bonds

S.NO	PEAK VALUES	BONDS AND FUNCTIONAL GROUPS
1	521.07	C-Br stretch
2	662.48	Aromatic C=C
3	778.21	Aromatic C-H Bending
4	891.14	Alkene =C-H bending
5	1061.08	Alcohol C-O stretch
6	1319.91	Amine C-N stretch
7	1435.02	Alcohol C-O stretch
8	1630.02	Amide C=O Stretch
9	2858.26	CH2 Stretching Vibrations
10	2923.01	CH2 Stretching Vibrations
11	3415.38	Alcohol/Phenol O-H Stretch

FTIR analysis of Wood Waste:

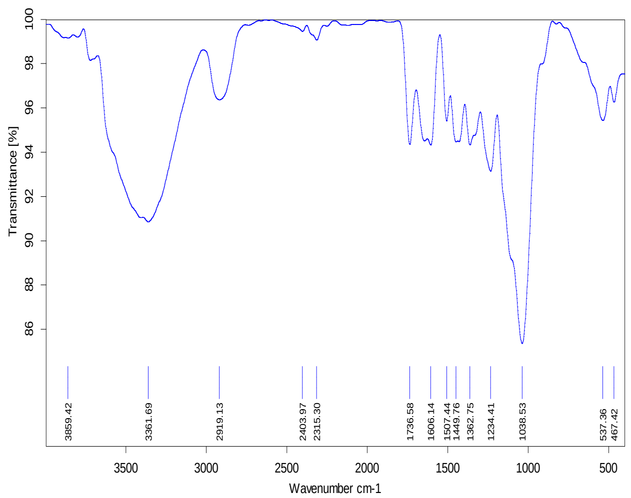

Fig. 9 FTIR pattern of wood waste sample Fuel Briquette

The sharp peaks (Fig. 9) of 537.36 C-Br stretch , 1038.53 Alkyl Halide C-F stretch , 1234.41 and 1362.75 Amine C-N stretch , 1449.76 Alcohol C-O stretch of Bromides, Halides amides,alcohols with ketones and cyclic rings has been obtained (Table 3).

Table -3: FTIR Peaks and Bonds

S.NO	PEAK VALUES PEAK VALUES	BONDS AND FUNCTIONAL GROUPS D FUNCTIONAL GROUPS
1	467.42	1,4 swinging in-plane
2	537.36	C-Br stretch
3	1038.53	Alkyl Halide C-F stretch
4	1234.41	Amine C-N stretch
5	1362.75	Amine C-N stretch
6	1449.76	Alcohol C-O stretch
7	1507.44	Aromatic C=C Bending
8	1606.14	Aromatic C=C Bending
9	1736.58	Ester C=O Stretch
10	2315.30	Furan 1,4 cyclo octatereane ring breathing in phase
11	2403.97	Furan 1,4 cyclo octatereane ring breathing in phase
12	2919.13	Furan 1,4 cyclo octatereane ring breathing in phase
13	3361.69	Alcohol/Phenol O-H Stretch

Proximate analysis:

The proximate analysis of all the 3 samples, Papaya Leaves,Bahunia Purpia Leaves and Wood Waste which were carried out following the Indian Standard procedure (Fig. 10–13). The percentages of moisture(M), volatile matter(VM) and ash content(A) of all the samples have been shown in figure . It may be observed from table 4 that the BP leaves has the highest moisture content (8.44%) and Wood waste has the lowest(3.77%). It was also found that BP leaves have the highest volatile matter content (67.6%) respectively, where as Wood waste has the lowest volatile matter content (18.18%). It has been observed in the past that briquettes with high volatile-matter content ignite easily and are highly reactive in combustion applications. The ash content of the samples varied to a large extent form 9.96 for BP leaves to 64.8 for Wood waste. The fixed carbon content which has a direct relation with the calorific value varied between 21.07 (Wood waste) and 9.32 (Papaya leaves)**[16–25].**

Table 4 Proximate analysis results

S. NO	NAME OF THE SAMPLE	MOISTURE CONTENT (%)	ASH CONTENT (%)	VOLATILE MATTER (%)	FIXED CARBON (%)
1	Bahunia Purpea Leaves	8.44	9.96	67.6	14
2	Papaya leaves	7.59	19.72	63.37	9.32
3	Wood Waste	3.77	64.8	18.18	21.07

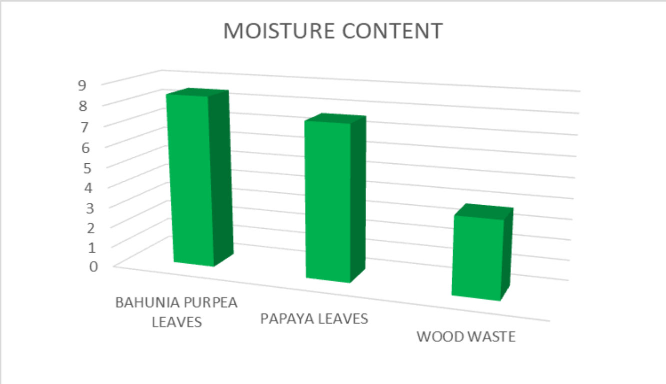

Fig. 10 Moisture Content

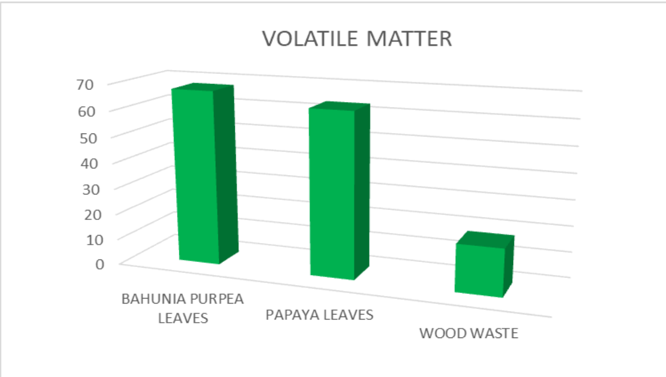

Fig. 11 Volatile Matter

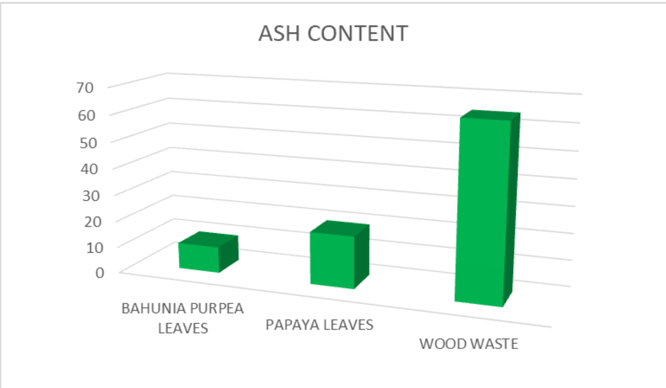

Fig. 12 Ash Content

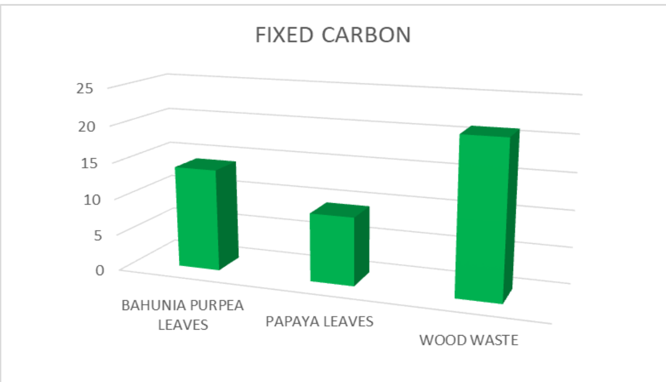

Fig. 13 Fixed Carbon

Effect of Ultimate Analysis:

The composition of the ash-free organic component of biomass is relatively uniform. The major components are carbon, oxygen, and hydrogen. Most biomass also contains a small proportion of nitrogen and sulphur. Table 5 presents the average range of percentages. The carbon (C), hydrogen (H), oxygen (O), sulphur(S) and nitrogen (N) determination in biomass represents the so called elementary analysis. These elements are detected by an elemental analyzer. About 200 mg of sample are burned at 900 ° C in an oxygen atmosphere, so the C is converted into CO_2, H in H_20, S into SO_2 and the N in N2. The first three compounds are detected quantitatively by an IR detector, while N_2 is determined by a thermal conductivity detector .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 composition of the Wood waste briquette analysed on an 'as-received basis' showed 46.49% carbon, 6.56% hydrogen, 45.67% oxygen, 0.99% nitrogen and 0.29% sulphur (Fig. 14–18). The results agree with the observations made by Chaney 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. The amount of carbon and hydrogen content in the sample examined is an indication that they will contribute immensely to the combustibility of the charcoal briquette as suggested by According to 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 .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 [26–35].

Table 5 Ultimate analysis results

Sl. no	Name of the sample	%C	%H	%N 2	%S	%O
1	Bhunia Purpia Leaves	55.85	3.4	3.59	0.01	37.15
2	Papaya leaves	48.10	3.58	4.1	0.02	44.2
3	Wood Waste	46.49	6.56	0.99	0.29	45.67

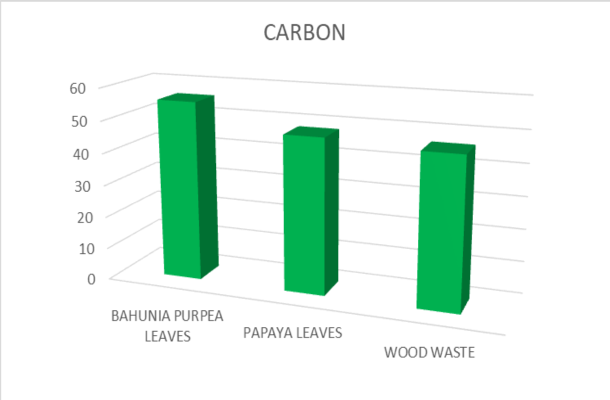

Fig. 14 Carbon percentage

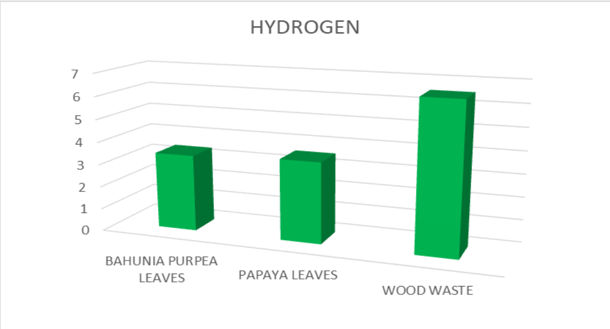

Fig. 15 Hydrogen percentage

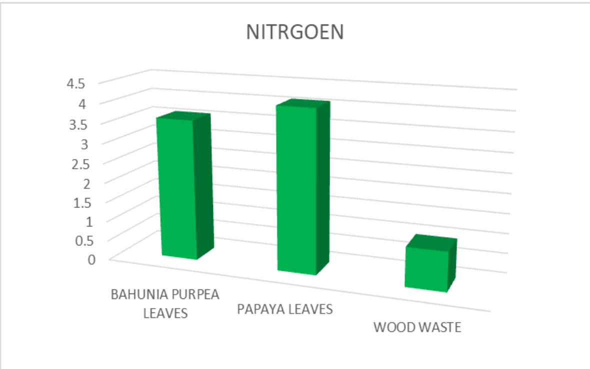

Fig. 16 Notrogen percentage

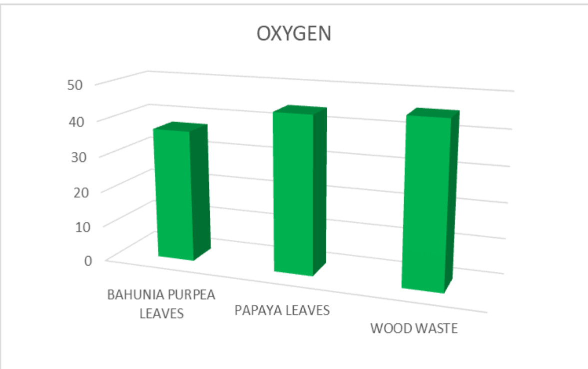

Fig. 17 Oxygen percentage

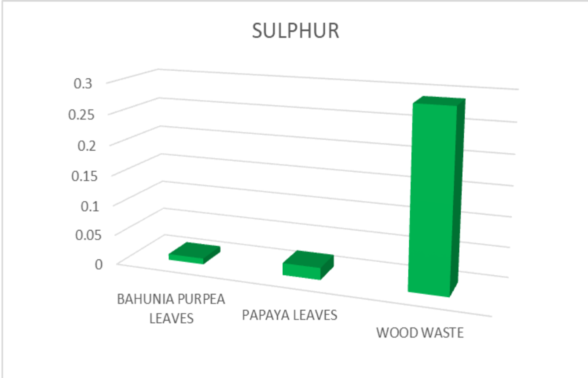

Fig. 18 Sulphur percentage

Effect of porosity:

The porosity values (Fig. 19) for Bahunia Purpea Leaves, Papaya leaves, Wood Waste are 70.3%, 60.55%, 58.55% respectively (Table 6)[36–45].

Table 6 porosity results

S.no	Name of the sample	Porosity(%)
1	Bahunia Purpea Leaves	70.3
2	Papaya leaves	60.55
3	Wood Waste	58.55

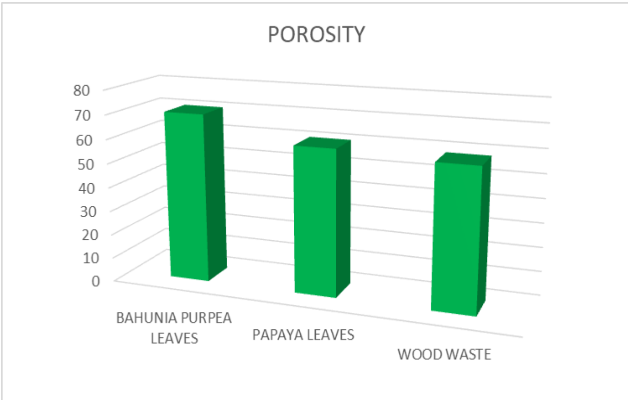

Fig. 19 Porosity values

Effect of Calorific Value:

The calorific value (Fig. 20) were found out using bomb calorimeter. It was found that BP Leaves 15.411 have the highest calorific values which are also consistent with the fact that they fixed carbon content in the higher range and low ash content. Wood Waste has 10.3372 found to have the low calorific values, they also have the ash% in the higher range (Table 7) [46–50].

Table 7 Calorific value results

S.no	Name of the sample	Calorific Value (MJ/Kg)
1	Bahunia Purpia Leaves	15.411
2	Papaya leaves	13.021
3	Wood Waste	10.3372

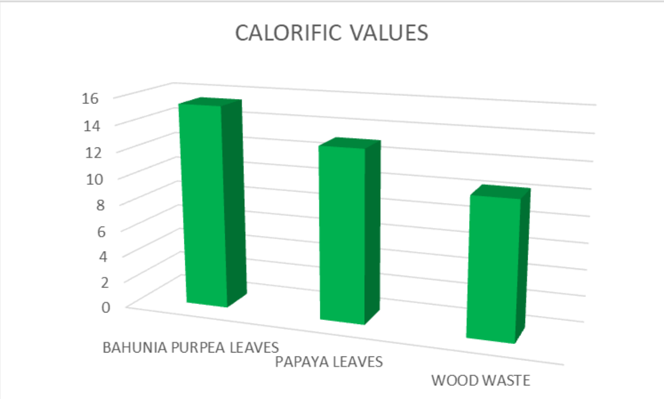

Fig. 20 Calorific Values

3. CONCLUSIONS

Since the quality of any fuel briquette depends on its ability to provide sufficient heat at the necessary time, to ignite easily without any danger, generate less dust (ash) as this will cause nuisance during the use of briquette. Hence, the cost of the fuel depends on the users demands. The percentage of the fixed carbon obtained are 14.0%, 9.32%, 21.07% for Bahunia Purpea leaves, Papaya leaves, wood waste respectively. The calorific values of briquettes produced from 3 samples are 13.021, 10.3372, 15.1044 KJ/Kg. The wood waste has low moisture content of 3.77% than Bahunia Purpea leaves (8.44%) and Papaya leaves (7.59). From all the 3 sample examined, wood waste exhibited great properties of less moisture content, fixed carbon, volatile matter, total ash content, gross calorific value, mass, density, compressive strength, shearing stress etc.. The development of phases and microstructures for selected fixed briquettes were characterized using FTIR and XRD analysis. Considering the present work, the fuel briquettes have great environmental benefits which reduces degradation of trees, reduces emissions and this enhances better management of waste. Therefore, it is recommended that this technology has great potential for biomass into a superior fuel both economically and environmentally.

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