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Studies on Manufacture of Fuel Briquettes and Their Assessment for Higher Calorific Values Estimation

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ABSTRACT

Energy is vital for the growth and development of any country. To fulfill the needs of people, huge energy was being developed and produced but unfortunately, all the natural resources are being extinct. In order to supply and produce more energy, search for alternate fuels was widely entrusted to researchers. Fuel briquettes are manufactured from biomass and this technology was now a day's widespread due to low emissions. Biomass is renewable fuel, while comparing to other renewable fuels biomass is more economical. The present experiment is carried out in such a way that minimization of solid waste and simultaneous power production was beneficial to society. This study incorporated the variables like proximate analysis, ultimate analysis, calorific values and characterization techniques like FTIR and XRD. The results showed that ptp leaves, rice husk and castor stalks were good sources for power production.

Keywords: Fuel briquettes, FTIR, XRD, Ultimate analysis, proximate analysis, Calorific Value

I. INTRODUCTION

To meet present energy needs alternative energy sources are must and should required for humans survival. Fuel briquettes from biomass have higher potential to fulfil present and future energy needs **[1]**. Biomass is used for energy needs like electricity, domestic purpose and providing heat for industrial purposes. The sunlight is stored in biomass as chemical energy by the process of photosynthesis. Biomass is classified into three categories like woody material, non-woody material and animal wastes. Biomass is one of the most important energy sources considered to be alternative to traditional energy sources like petroleum, natural gas, etc. Biomass is an ultimate source of renewable energy that could drastically reduce pollution by producing negligible amount of emissions than traditional fossil fuels and fulfil the needs of present global economy by generating jobs and environmentally friendly technologies **[2]**. Biomass from agricultural wastes is one of the most important resource and available as free. This biomass is not suitable for direct usage. For improving the handling characteristics and volumetric calorific value of the biomass we use briquetting method to form fuel briquettes **[3]**. Combustion characteristics of coal with biomass conclude that the emissions produced from the boiler were in negligible amount which resembles for combustion of coal alone **[4]**. In densification high pressure is applied to compress the biomass to improve energy density, lower the volume **[5]**. In hot densification the solid bridges between the particles were formed by applying heat to soften the internal binders. In cold densification requires no heat. Thus, cold densification was better than hot densification **[6]**. The heat energy produced was used in combustion, gasification and pyrolysis pellets have better fuel applications, easy to feed and maintenance **[7]**. Thermochemical conversion of rice husk to produce heat energy can be achieved via direct combustion, gasification, and pyrolysis .Small-scale gasifier stoves were affordable and burn efficiently. Consumers choose briquettes with hard good burning characteristics **[8]**. The main drawback of biomass is food crops occupy more area than energy crops. For this purpose agricultural residues which are treated as waste were used as energy in most developing countries **[9]**. The present experiment consists of three wastes for manufacturing fuel briquettes and analyzing their properties for higher calorific values along with characterization like FTIR and XRD.

II. MATERIAL AND METHODS

Peltophorum Pterocarpum (PTP) leaves, Rice Husk and Castor Stalk materials were collected to make fuel briquettes. To remove dirt all the three materials were cleaned with water separately. After cleaning those materials were allowed to dry in the presence of sunlight for 10 days. The completely dried materials were cut into small pieces. These small pieces of three different materials were soaked in three different tubs for 1 day. After 1 day the materials were taken out and partially dried for 30 minutes. Maida was taken as a binder. After making many trails the amount of binder used to form fuel briquettes is 100 grams. The Maida powder is added to hot water and stirred for better mixing. Then Maida will get sticky nature. This sticky nature of binder helps to fuel briquettes for better formation and prevents from deformation. The partially dried three materials were added to binder in different buckets. The binder and materials were mixed very well. Then this binder mixed materials were in fuel briquettes moulds, the mould is closed with the help of lid and kept weight on it. After 2 days the moulds were removed carefully. Then high moisture fuel briquette is formed. To reduce moisture content, these briquettes were placed in sunlight. These dried fuel briquettes were sent to proximate & ultimate analysis. The parameters studied in the present experimentation are Characterization (FTIR, XRD), Proximate Analysis (Volatile matter, Ash content, fixed carbon and Moisture content), Ultimate Analysis (C, N, S, O percentages) and Calorific values.

III. RESULTS AND DISCUSSION

To determine the properties of different materials for fuel briquetting mechanism, a number of experiments were conducted.

Characterization of fuel briquettes:

FTIR analysis of ptp leaves:

Infrared spectroscopy belongs to the group of molecular vibrational spectroscopies which are molecule-specific and give direct information about the functional groups, their kind, interactions and orientations. Its sampling requirements allow the gain of information from liquids and gases and in particular from solid surfaces. Even if historically IR has been mostly used for qualitative analysis, to obtain structural information, nowadays instrumental evolution makes non-destructive and quantitative analysis possible with significant accuracy and precision **[10-12]**.

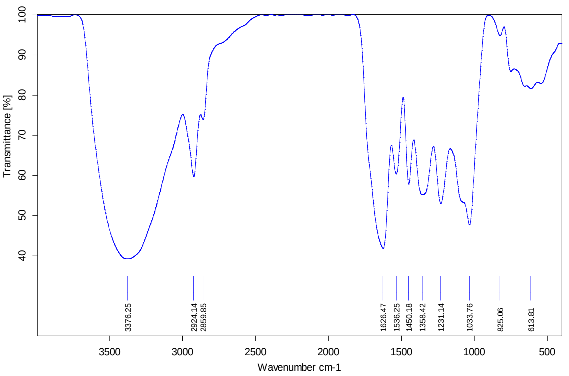


Figure 3.1. FTIR Pattern of PTP leaves Sample Fuel Briquette

The bands at 631.81 and 825.06 cm^{-1} indicates the involvement of C–Cl stretch and Aromatic C–H bending bonds (Fig. 3.1). The bands at 1033.76 obtained at alkyl halide C-F stretch and 1231.14, 1358.42 cm^{-1} stretch assigns amine C-N stretch. The peaks at 1450.18 occur at C-O alcohol bending and, 1536.25 cm^{-1} at an aromatic C-O stretch and 1536.25, 1626.47 cm^{-1} at C=C aromatic and alkyne bending and stretch respectively, in 2859.85, 2924.14, 3376.25 cm^{-1} native biomass designates the presence of, stretching bonds. It indicates the direct involvement of alkanes, alkenes at 2859.85, 2924.14 cm^{-1}. The band at 3376.25 cm^{-1} denotes the presence of alcohol/phenol O-H stretch.

Table 1. FTIR peaks and Bonds

PEAK VALUES (cm^{-1})	BONDS AND FUNCTIONAL GROUPS
613.81	C-Cl stretch
825.06	Aromatic C-H Bending
1033.76	Alkyl Halide C-F stretch
1231.14	Amine C-N stretch
1358.42	Amine C-N stretch
1450.18	Alcohol C-O stretch
1536.25	Aromatic C=C Bending
1626.47	Alkenyl C=C Stretch
2859.85	Alkanes stretch
2924.14	Alkanes Stretch
3376.25	Alcohol/Phenol O-H Stretch

FTIR analysis of rice husk:

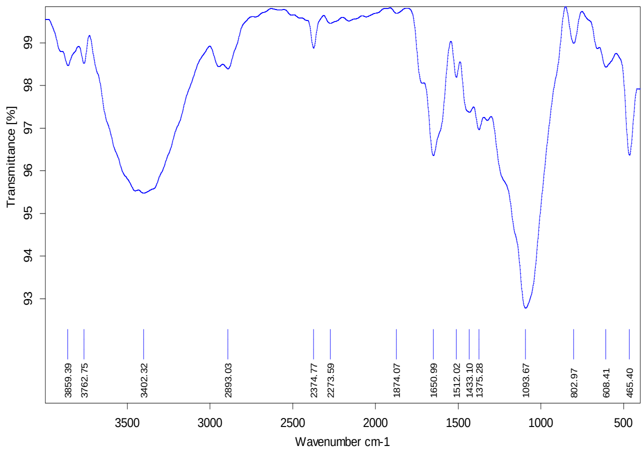


Figure 3.2. FTIR Pattern of Rice Husk Sample Fuel Briquette

The peaks at 465.40, 608.41 cm^{-1} represents the stretching of C-Cl bonds. The sharp peaks loading at 1093.67, 1375.28 represents the stretch of amine C-H bonds. The peaks at 1512.02, 1650.99 cm^{-1}depict the aromatic C = C bending. And carbonyl C= O stretching bonds. The peak at 3402.32 cm^{-1} assigned for alcohol/phenol O-H stretching vibrations as shown.The sharp peak at 3762.75,3859.39cm^{-1} denotes the presence of water O–H stretching bands (Fig. 3.2).

Table 2. FTIR peaks and Bonds

PEAK VALUES (cm^{-1})	BONDS AND FUNCTIONAL GROUPS
465.40	C-Cl stretch
608.41	C-Cl stretch
802.97	Aromatic C-H Bending
1093.67	Amine C-N stretch
1375.28	Amine C-N stretch
1433.10	Alcohol C-O stretch
1512.02	Aromatic C=C Bending
1650.99	Amide C=O Stretch
1874.07	C=O anhydride
2273.59	C=C stretch
2374.77	C=C stretch
2893.03	C-H Stretching Vibrations
3402.32	Alcohol/Phenol O-H Stretch
3762.75	Water O-H Stretch
3859.39	Water O-H Stretch

FTIR analysis of castor stalk:

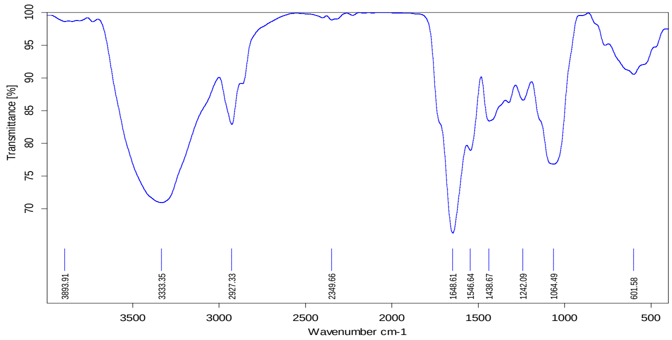


Figure 3.3. FTIR Pattern of Rice Husk Sample Fuel Briquette

The sharp peak at 601.58cm-1represents the stretching of C-Cl stretching bonds shifted to 1064.49 cm^{-1} denoting the involvement and participation of C-O stretching alcohols. The shifting of band from 1242.09 cm^{-1} to 1438.67cm^{-1}indicates the involvement of stretching of C-N amine bonds. The bands at 3333.35, 3893.91 are assigned for the presence of O-H stretch for alcohols, phenols and water (Fig. 3.3).

Table 3. FTIR peaks and Bonds

PEAK VALUES	BONDS AND FUNCTIONAL GROUPS
601.58	C-Cl stretch
1064.49	Alcohol C-O stretch
1242.09	Amine C-N stretch
1438.67	Amine C-N stretch
1546.64	Aromatic C=C Bending
1648.61	Alkenyl C=C Stretch
2349.66	C-H Stretch
2927.33	-C-H stretch
3333.35	Alcohol/Phenol O-H Stretch
3893.91	Water O-H stretch

XRD ANALYSIS:

Rigaku Ultima model IV is an advanced X-Ray Diffractometer for the characterization of sample materials. The powder samples of fuel briquettes are taken in Rigaku Ultima model IV for the X-Ray Diffract grams (XRD).The diffracted X-ray intensities are recorded as a function of 2θ by using copper target (Cu-Kα radiation with wave length, α= 1.5492 A^{0}) at a scan speed of 2^{0}/min. XRD patterns are recorded from 30 to 90^{0}. 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 Centre for Diffraction Data) files**[13-15]**.

XRD analysis of ptp leaves:

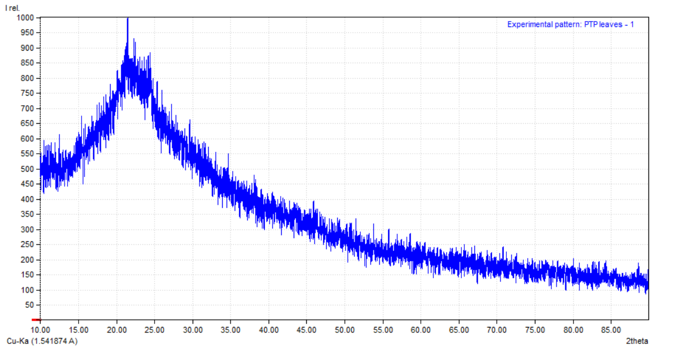


Figure 3.4 XRD Pattern of PTP leaves Sample Fuel Briquette

XRD patterns of ptp leaves powder are shown in figs 3.4 & 3.5. XRD patterns shown in figure do not indicate any sharp peaks, less crystallinity and exhibit little amorphous nature. The peaks at 2θ values of 0.6688, 0.7431, 0.6402, 0.5552 and 0.4750 corroborate the presence of $C_6Cl_3M_3O_6$, $CS_{247}SP$, $MO_{24}O_{180}P_{48}$, $BiBr_{0.558}Cl_{5.322}Tl_3$ and $Ba_{0.74}H_{16}O_{126}$ (ICDD files). Their corresponding d-values are 3.5973, 3.7734, 4.0496, 3.9560 and 3.5506.

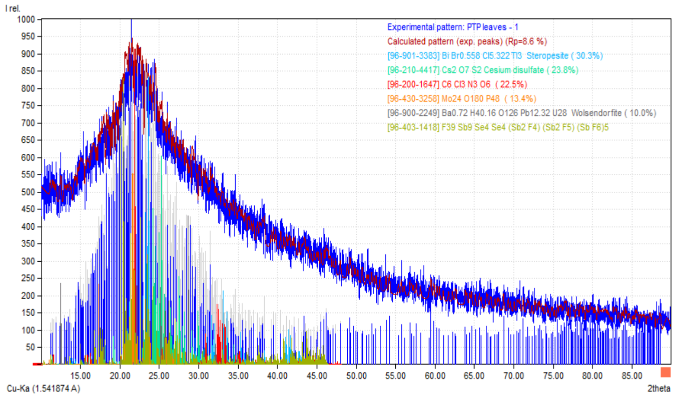


Figure 3.5 XRD Pattern of PTP leaves Sample Fuel Briquette-Matching Compounds

XRD analysis of rice husk:

The peaks at 2θ values of 0.6310, 0.5664, 0.6287, 0.5696 and 0.5132 corroborate the presence of Steropsite, Tri cesium Bismuth hexa-chloride, $MO_3O_{22.5}P_6$, $MO_{24}O_{180}P_{48}$ and $COB_{12}O_{10}S$ their corresponding d-values are 3.5973, 3.7734, 4.0496, 3.9560and 3.5506 respectively (Fig. 3.6 & 3.7).

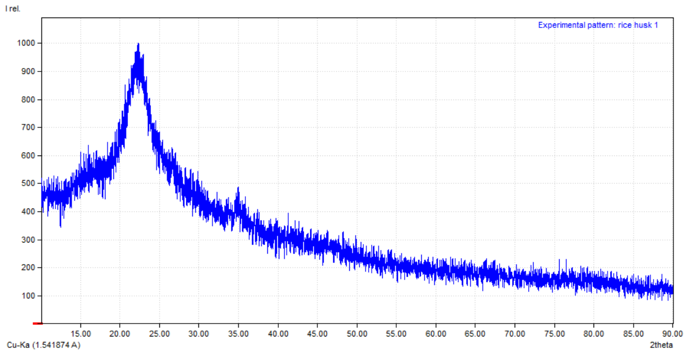


Figure 3.6 XRD Pattern of Rice husk Sample Fuel Briquette

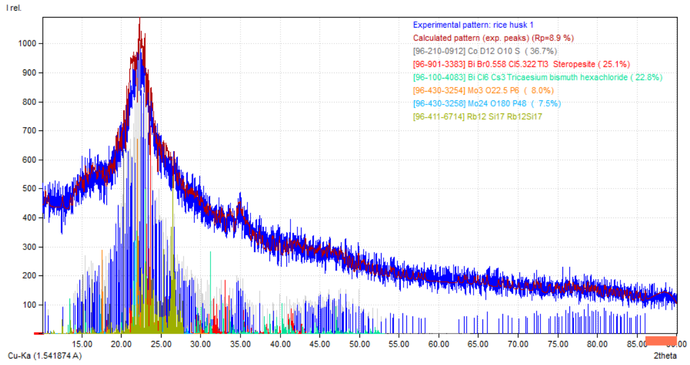


Figure 3.7 XRD Pattern of Rice husk Sample Fuel Briquette-Matching Compounds

XRD analysis of castor stalk:

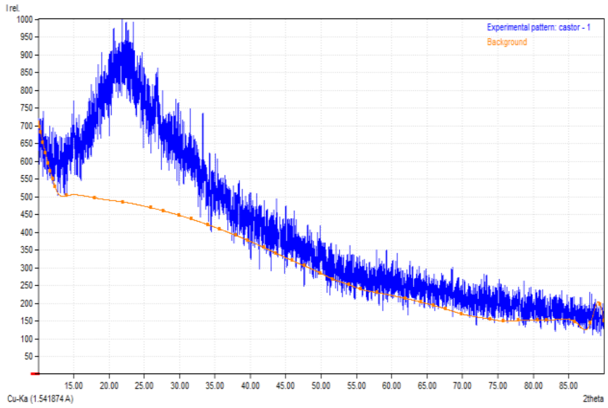


Figure 3.8 XRD Pattern of Castor stalk Sample Fuel Briquette

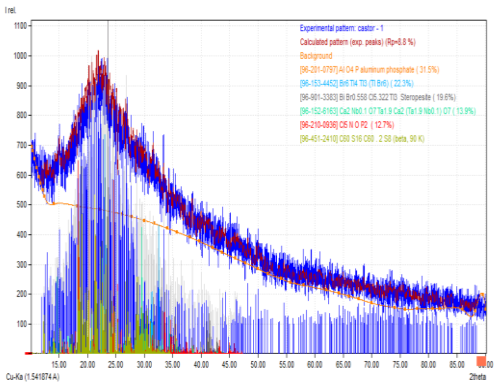


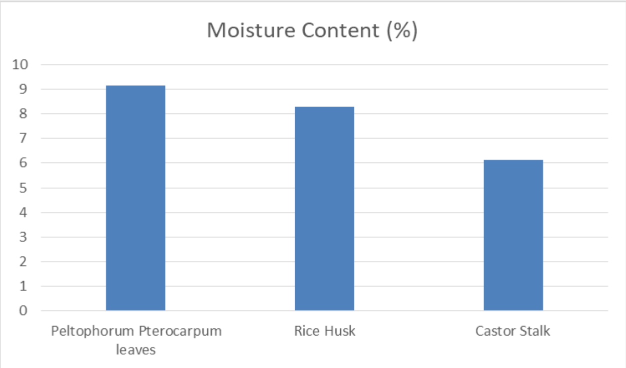
Figure 3.9 XRD Pattern of Castor stalk Sample Fuel Briquette-Matching Compounds

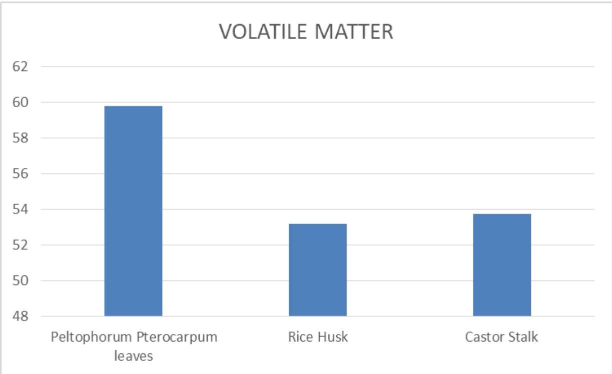
The peaks at 2θ values of 0.6639, 0.6930, 0.6530, 0.7238 and 0.6857 corroborate the presence of Cl_5NOP_2, $Ca_2mB_{0.1}O_7Ta_{1.9}$, Aluminium Phosphate, Br_6Tn_4 and Steropesite their corresponding d-values are 3.1019, 3.2210, 3.8617, 3.1677 and 3.0267 respectively (Fig. 3.8 & 3.9).

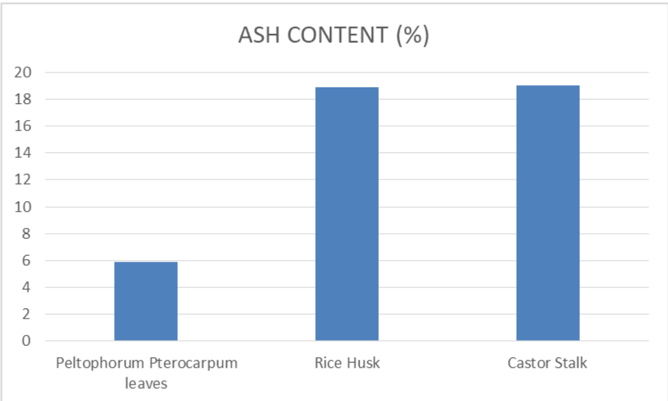
Effect of proximate analysis:

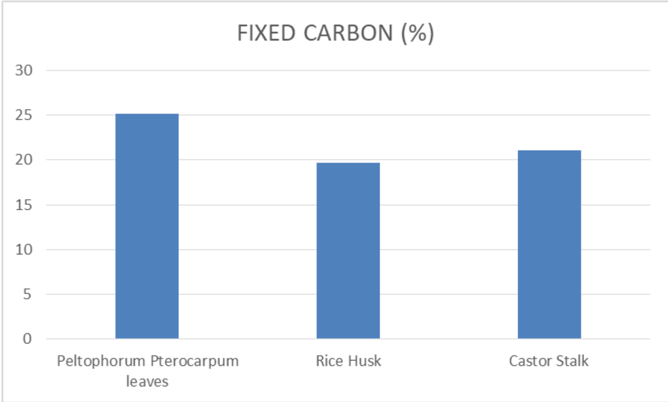
The proximate analysis of ptp leaves, rice husk and castor stalk were carried out to find percentages of Moisture, volatile matter and ash content and fixed carbon **[16-23]**.

PTP Leaves has the highest moisture content (9.16%) and Castor stalk has the lowest (6.14%). It was also found that PTP Leaves has the highest volatile matter content (59.8%) whereas Rice husk has the lowest volatile matter content (53.17%). Briquettes with high volatile-matter and low moisture content ignite easily and best for combustion. The ash content of the samples varied to from 5.86% for PTP leaves to 19.02% for Castor stalk. The fixed carbon content calculated directly. The Fixed Carbon is maximum for PTP leaves as 25.18% and minimum for Rice Husk as 19.69%.





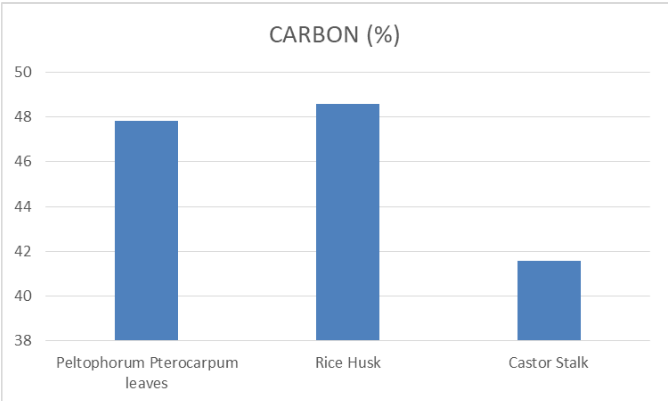


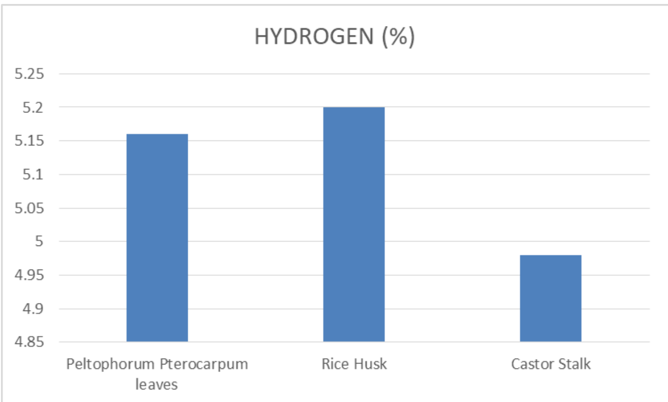


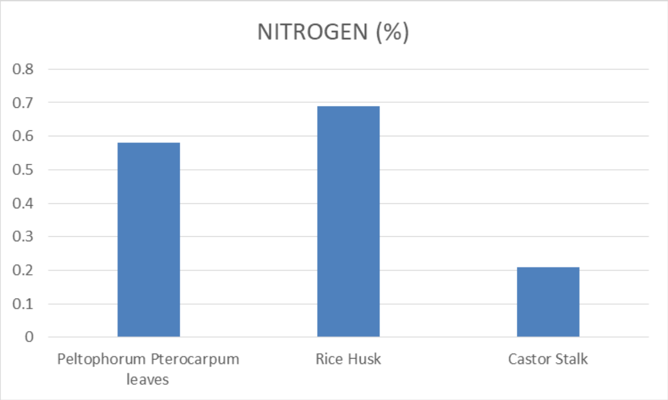
Material	Moisture Content (%)	Volatile Matter (%)	Ash Content (%)	Fixed carbon (%)
Peltophorum Pterocarpum leaves	9.16	59.8	5.86	25.18
Rice Husk	8.28	53.17	18.86	19.69
Castor Stalk	6.14	53.75	19.02	21.09

Effect of ultimate analysis:

The Ultimate analysis was performed to find percentages of Carbon, Hydrogen, Nitrogen, Sulphur and Oxygen. Maximum percentages obtained were highlighted in the below table **[24-33]**.







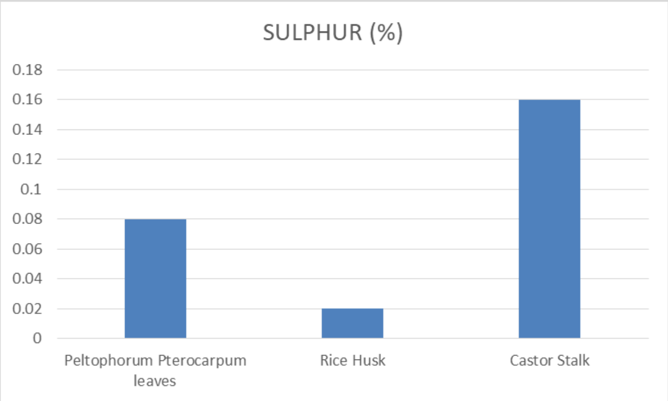


Table 4 Proximate analysis results

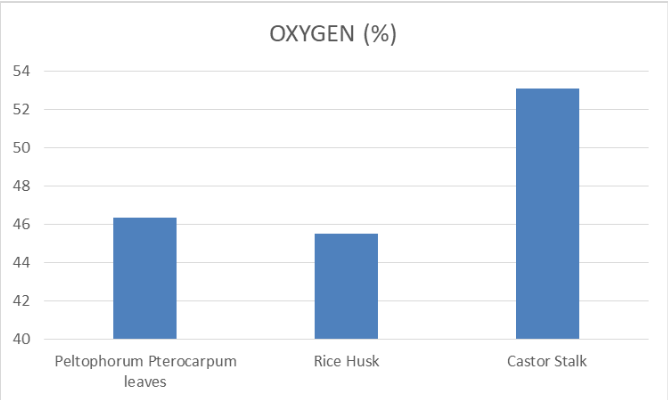


Table 5 Ultimate analysis results

MATERIAL	%C	%H	%N	%S	%O
Peltophorum Pterocarpum leaves	47.83	5.16	0.58	0.08	46.35
Rice Husk	48.58	5.20	0.69	0.02	45.51
Castor Stalk	41.58	4.98	0.21	0.16	53.07

Effect of porosity:

The porosity indicates how much water is observed by the fuel briquettes If porosity is high, the rate of infiltration of Oxidant and out flow of combustion/pyrolysis products during Combustion are high and the burning rate of the briquette also high **[34-44]**.The maximum porosity for Rice Husk 61.15% and minimum for Castor Stalk is 24.66%

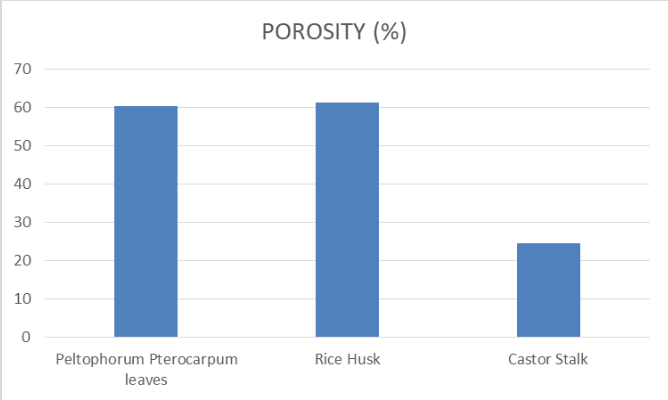


Table 6. Porosity Results

MATERIAL	POROSITY (%)
Peltophorum Pterocarpum leaves	60.20
Rice Husk	61.15
Castor Stalk	24.66

Effect of calorific value:

Calorific value is one of the most essential property and it determines the energy content of fuel briquettes. It is depend upon chemical composition and moisture content **[34-37]**. The maximum calorific value observed ptp leaves.

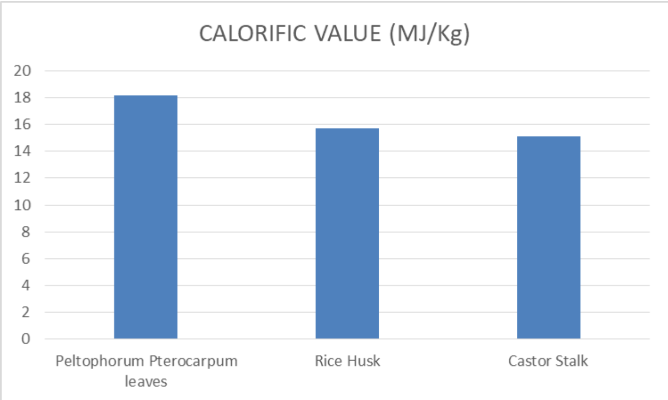


Table 7. Calorific value results

MATERIAL	CALORIFIC VALUE(MJ/Kg)
Peltophorum Pterocarpum leaves	18.1807
Rice Husk	15.6886
Castor Stalk	15.1044

IV. CONCLUSIONS

The following conclusions were drawn for the present experiment: Castor stalk briquette has low moisture content and high ash content. Rice Husk briquette also had good properties like less moisture content, fixed carbon, volatile matter and has uniform fibrous lignocellulosic structure. Whereas ptp briquette have high volatile matter and moisture content but it has large and small dens granulated structures i.e., they give good mechanical property but fails in combustion properties. The development of phases and microstructures of selected fired briquettes were characterized using X-ray diffraction (XRD). Based on this work, Fuel briquettes have environmental benefits that include reduced tree degradation, better management of waste and reduced emissions. Therefore, it is recommended that this technology has a great potential for converting waste biomass into a superior fuel in a flexible, advantageous and ecofriendly manner.

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