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Power Generation Analysis by the Combination of Primary and Secondary Fuels

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Abstract:

With the advancement in technology the power consumption is rising steadily. This necessitates that in addition to the existing source of power such as coal, water, petroleum etc. other sources of energy should be searched out and new and more efficient ways of producing energy should be devised. Power generation from biomass becomes attractive way for energy generation due to their high energy potential and less pollutants.

Present work deals with the determination of proximate analysis of different components, such as wood, leaf and nascent branch and energy content of different components of Cajanus cajan (local name-arhar, pigeon pea) and Arachis hypogaea (local name-peanut, ground nut) shell and their power generation potential and land requirement for plantations. These biomass components separately mixed with coal sample in different-different ratio and also their proximate analysis has done and their energy values are determined to find out the best suitable mixture for power generation. Estimation has been made for power generation potential of these biomass species and coal-biomass mixed briquettes for a small thermal power plant on decentralized basis.

Keywords- ***Biomass, coal-biomass briquette, proximate analysis, calorific value, energy value***

INTRODUCTION

Fossil fuels are the major source of power generation worldwide. About 87% of the world's energy supply comes mainly from fossil fuels. The share of fossil fuels is more than 90% in case of India. The demand of energy is increasing by leaps and bound due to rapid industrialization and population growth, the conventional sources of energy will not be sufficient to meet the growing demand. Consumption of fossil fuel causes to emit large amount of pollutants such as carbon dioxide, sulphur oxides, bottom ash, fly ash, etc. which are hazardous for human survival on the earth planet as well as environment. Conventional sources are non-renewable and bound to finish one day. Due to these reasons it has become important to explore and develop non-conventional energy resources to reduce too much dependence on conventional sources and development of alternative sources of energy which are renewable and environment friendly.

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. Thus, the development of biomass-based power generation system is thought to be favorable for majority of the developing nations including India. Unlike other renewable, biomass materials, pre-dried up to about 15% moisture, can be stored for a considerable period of time without any difficulty. Besides electricity supply to the national power grids, biomass offers giant opportunities for decentralized power generation in rural areas at or near the points of use and thus can

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make villagers/ small industries self-dependent in respect of their power requirements. It is observed that the decentralized power generation systems reduce peak loads and maintenance cost of transmission and distribution network. To exploit biomass Species in electricity generation characterization of their various properties like energy values, chemical compositions, reactivity towards oxygen, bulk densities, etc. is essential. Present work deals to determine the proximate analysis, calorific value and energy value of two selected biomass species and mixed-biomass briquette and to find out the best suitable ratio for power generation and land required for plantation.

Biomass Energy

Biomass energy is the utilization of energy stored in organic matter. It is humanity's oldest external source of energy, dating back to prehistoric man's first use of fire. And biomass is still an important part of the world's energy system; the use of traditional biomass-charcoal, firewood, and animal dung-in developing countries accounts for almost 10% of the world's primary energy supply.

Bioenergy can be utilized in varied applications:

- Biomass can be combusted to produce heat (large plants or localized biomass boilers), electricity, or used in combined heat and power (CHP) plants.
- Biomass can also be used in combination with fossil fuels (co-firing) to improve efficiency and reduce the build-up of combustion residues.
- Biomass has potential to replace petroleum as a source for transportation fuels.
- Biomass is also used in conjunction with fossil fuels for electricity generation in "waste-to-energy" projects. These are niche applications, which depend on the biomass having no other commercial value and being in close proximity to the application.

Why Bio-mass energy?

Biomass is an attractive energy source for a number of reasons:

- Biomass is a renewable energy source generated through natural processes and as a by-product of human activity.
- It is also more evenly distributed over the earth's surface than fossil fuel energy sources, and may be harnessed using more cost effective technologies.
- It provides us the opportunity to be more energy self-sufficient and helps to reduce climate change.
- It helps farmers, ranchers and foresters better manage waste material, providing rural job opportunities and stimulating new economic opportunities.

BIOMASS: CLASSIFICATION

Woody biomass

Woody biomass is characterized by high bulk density, less void age, low ash content, low moisture content, high calorific value. Because of the multitude of advantages of woody biomass its cost is higher, but supply is limited. Woody biomass is a preferred fuel in any biomass-to energy conversion device; however its usage is disturbed by its availability and cost.

Non-woody biomass

The various agricultural crop residues resulting after harvest, organic fraction of municipal solid wastes, manure from confined livestock and poultry operations constitute non-woody biomass. Non-woody biomass is characterized by lower bulk density, higher void age, higher ash content, higher moisture content and lower calorific value. Because of the various associated drawbacks, their costs are lesser and sometimes even negative.

Energy Generation from Biomass

A brief description of the technologies for energy generation from biomass is as follows.

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(a) Combustion

In this process, biomass is directly burned in presence of excess air (oxygen) at high temperatures (about 800°C), liberating heat energy, inert gases, and ash. Combustion results in transfer of 65%–80% of heat content of the organic matter to hot air, steam, and hot water. The steam generated, in turn, can be used in steam turbines to generate power.

(b) Transesterification

The traditional method to produce biodiesel from biomass is through a chemical reaction called transesterification. Under this method, oil is extracted from the biomass and it is processed using the transesterification reaction to give biodiesel as the end-product.

(c)Alcoholic Fermentation

The process of conversion of biomass to biofuels involves three basic steps:

1. Converting biomass to sugar or other fermentation feedstock
2. Fermenting these biomass-derived feedstock using microorganisms for fermentation.
3. Processing the fermentation product to produce fuel-grade ethanol and other fuels.

(d)Anaerobic Digestion

In the absence of air, organic matter such as animal manures, organic wastes and green energy crops (e.g. grass) can be converted by bacteria-induced fermentation into biogas (a 40%-75% methane-rich gas with CO2 and a small amount of hydrogen sulphide and ammonia). The biogas can be used either for cooking/heating applications, or for generating motive power or electricity through dual-fuel or gas engines, low-pressure gas turbines, or steam turbines.

(e) Pyrolysis

Pyrolysis is a process of chemical decomposition of organic matter brought about by heat. In this process, the organic material is heated in absence of air until the molecules thermally break down to become a gas comprising smaller molecules (known collectively as syngas).

The two main methods of pyrolysis are “fast” pyrolysis and “slow” pyrolysis. Fast pyrolysis yields 60% bio-oil, 20% bio-char, and 20% syngas, and can be done in seconds. Slow pyrolysis can be optimized to produce substantially more char (~50%) along with organic gases, but takes on the order of hours to complete.

(f) Gasification

In this process, biomass reacts with air under extreme temperatures and results in production of producer gas, to produce power (or) react with pure oxygen to produce synthesis gas for fuel production. The combustible gas, known as producer gas, has a calorific value of 4.5 - 5.0 MJ/cubic meter. A wide range of biomass in the form of wood or agro residue can be used for gasification.

Aims and Objectives of the Present Project Work

1. Selection of non-woody biomass species and estimation of their yield by field trial.
2. Determination of proximate analysis (% moisture, % volatile matter, % ash and % fixed carbon contents) of their different components, such as wood, leaf and nascent branch.
3. Mixed these biomass components separately with coal sample in different-different ratio.
4. Characterization of these biomass components for their energy values (calorific values).
5. Characterization of coal mixed biomass components for their energy values (calorific values).
6. Estimation of power generation potentials of these biomass species for a small thermal power plant on decentralized basis.

Comparative study of coal and mixed coal-biomass in different ratio of 95: 05, 90: 10, 85: 15 and 80: 20 with respect to selected biomass species.

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LITERATURE SERVEY

Combustion converts coal into useful heat energy, but it is also a part of the process that engenders the greatest environmental and health concerns. Combustion of coal at thermal power plants emits mainly carbon dioxide (CO_2), sulphur oxides (SO_x), nitrogen oxides (NO_x), CFCs, other trace gases and air borne inorganic particulates, such as fly ash and suspended particulate matter (SPM). CO_2 produced in combustion is perhaps not strictly a pollutant (being a natural product of all combustion), nonetheless it is of great concern in view of its impact on global warming. The carbon dioxide emitted as a product of combustion of coal (fossil fuels) is currently responsible for over 60% of the enhanced greenhouse effect. For every ton of fossil fuels burned, at least three quarters of a tone of carbon is released as CO_2. It has been found that 0.8–0.9 kg/kW h CO_2 is emitted in Indian power plants.

The use of biomass to provide partial substitution of fossil fuels has an additional importance as concerns global warming since biomass combustion has the potential to be CO_2 neutral. This is particularly the case with regard to agricultural residues or energy plants, which are periodically planted and harvested. During their growth, these plants have removed CO_2 from the atmosphere for photosynthesis which is released during combustion. Biomass materials with high energy potential include agricultural residues such as straw, bagasse, coffee husks and rice husks as well as residues from forest-related activities such as wood chips, sawdust and bark. Residues from forest-related activities (excluding wood fuel) account for 65% of the biomass energy potential whereas 33% comes from residues of agricultural crops. Biomass can supply heat and electricity, liquid and gaseous fuels. A number of developed countries derive a significant amount of their primary energy from biomass: USA 4%, Finland 18%, Sweden 16% and Austria 13%. Presently biomass energy supplies at least 2 EJ year-1 in Western Europe which is about 4% of primary energy (54 EJ). Estimates show a likely potential in Europe in 2050 of 9.0–13.5 EJ depending on land areas (10% of useable land, 33 Mha), yields (10–15 oven-dry tones (ODt) ha-1), and recoverable residues (25% of harvestable). This biomass contribution represents 17–30% of projected total energy requirements up to 2050. The relative contribution of biofuels in the future will depend on markets and incentives, on continuous research and development progress, and on environmental requirements. Land constraints are not considered significant because of the predicted surpluses in land and food, and the near balance in wood and wood products in Europe.

In a case study of Haryana state (Chauhan Suresh,2010) discussed that being an agricultural state, Haryana has a huge potential of biomass availability in the form of crop residue and saw dust. In the agricultural sector, a total 24.697 MTy-1 of residue is generated, of which 71% is consumed in various domestic and commercial activities within the state. While in agro based industrial sector, a total of 646 KT y-1 of sawdust is generated, of which only 6.65% is consumed in the state. Of the total generated biomass in the state, 45.51% is calculated as basic surplus, 37.48% as productive surplus and 34.10% as net surplus. The power generation potential from all these three categories of surplus biomass is 1.499 GW, 1.227 GW and 1.120 GW respectively.

In an another case study of Punjab state (Chauhan Suresh,2012) discussed that around 40.142 Mt y_1 of the total crop residue is generated from various major and minor crops, of which around 71% is consumed in various forms, resulting in 29% as a net surplus available for power generation. Basic surplus and net surplus crop residues for power generation potential were estimated in each district. Sangrur, Ferozpur, Amritsar, Patiala and Ludhiana are the major surplus biomass potential districts, while Rupnagar, Nawashahar, Hoshiarpur, Fatehgarh Sahib, Faridkot and Kapurthalla are least surplus biomass potential districts within the state. It has been estimated that

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around 1.510 GW and 1.464 GW of power in the state can be generated through basic surplus and net surplus biomass respectively.

In view of high energy potentials in non-woody biomass species and an increasing interest in their utilization for power generation (Kumar and Patel, 2008), an attempt has been made in this study to assess the proximate analysis and energy content of different components of Ocimumcanum and Tridaxprocumbens biomass species (both non-woody) and their impact on power generation and land requirement for energy plantations. The net energy content in Ocimumcanum was found to be slightly higher than that in Tridaxrocumbens. In spite of having higher ash contents, the barks from both the plant species exhibited higher calorific values. The results have shown that approximately 650 and 1,270 hectares of land are required to generate 20,000 kWh/day electricity from Ocimumcanum and Tridaxprocumbens biomass species. Coal samples, obtained from six different local mines, were also examined for their qualities and the results were compared with those of studied biomass materials. This comparison reveals much higher power output with negligible emission of suspended particulate matters (SPM) from biomass materials.

EXPERIMENTAL WORK

Selection of Materials

In the present project work, two different types of non-woody biomass species Cajanus cajan (local name-arhar, pigeon pea) and Arachis hypogaea(local name-peanut, ground nut) shell has been collected from the local area. These biomass species were cut into different pieces and there different component like leaf, nascent branch and main branch were separation from each other. These biomass materials were air-dried in cross ventilator room for around 30 days. When the moisture contains of these air-dried biomass sample came in equilibrium with that of the air, they were crushed in mortar and pestle into powder of -72 mess size. Coal sample for making the blend was collected from Lingaraj mines of Orissa. These materials were than processed for the determination their proximate analysis and Energy values.

Figure 3.1.1: Samples of Groundnut Shells and Powder

Figure 3.1.2: Samples of Pigeon Peas Powder and Coal

Proximate Analysis

Proximate Analysis consist of moisture, ash, volatile matter, and fixed carbon contents determination were carried out on samples ground to -72 mess size by standard method. Proximate analysis is the most often

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used analysis for characterizing a fuel in connection with their utilization. The proximate analysis of the sample was determined in accordance with the Indian Standard Method. It consists of the determination of the followings:

i. Percentage of moisture content
ii. Percentage of ash content
iii. Percentage of volatile matter
iv. Percentage of fixed carbon content

Determination of Moisture

The moisture content is an undesirable constituent in the carbonaceous materials. It unnecessarily increases the weight of the carbonaceous material and increases energy consumption during its combustion in a boiler. The moisture content is expressed as either dry basis or wet basis. In wet basis, the combined content of water, ash and ash free matter is considered whereas in dry basis, only ash and ash free matter is expressed as weight percentage. As the content of moisture is a determining factor for selection of a biomass fuel, the basis on which moisture is determined must be always mentioned.

One gm. (1 gm.) of air dried -72 mess size powder of the above said materials was taken in borosil glass disc and heated at a temperature of 110 0C for one hour in air oven. The discs were then taken out the oven and the materials were weight. The percentage loss in weight was calculated which gives the percentage (%) moisture contains in the sample.

$$Percentage\ of\ moisture\ content = Wt.\ loss \times 100 Intial\ wt.of\ sample$$

Determination of Ash Content

One gm. (1 gm.) of -72 mess size (air dried) was taken in a shallow silica disc and kept in a muffle furnace maintained at the temperature of 7750C. The materials were heated at this temperature for one hour or till complete burning. The weight of the residue was taken in an electronic balance. The percentage weight of residue obtained gives the ash contained in the sample.

$$\%\ Ash = Wt.\ of\ residue\ obtained \times 100\ /\ Initial\ wt.\ of\ simple.$$

Determination of Volatile Matter

Volatile matters are the products exclusive of moisture given off by the specimen when heated under high temperatures in the absence of air. It is a mixture of various gases like CO, CO2, H2S, hydrocarbons, etc. It also has got some energy value. The implicit knowledge of volatile matter can be used to establish rank of coals, to indicate coke yields on carbonization process and to establish burning characteristics. Char formed by combustion of materials are affected by volatile matter. The lower the volatile matter, the higher will be the char formation. Biomass usually has higher content of volatile matter as compared to coals which may go up to 80 %.

One gm. (1 gm.) of -72 mess size (air dried) powder of the above said materials was taken in a volatile matter crucible (cylindrical in shape and made of silica). The crucible is covered from top with the help of silica lid. The crucible were placed in a muffle furnace, maintained at the temperature of 9250 C and kept there for 7 minute. The volatile matter crucibles were then taken out from the furnace and cooled in air. The de-volatized samples were weighted in an electronics balance and the percentage loss in weight in each of the sample was calculated. The percentage volatile matter in the sample was determined by using the following formula

$$\%\ volatile\ matter\ (VM) = \%\ lass\ in\ weight - \%\ moisture$$

Determination of Fixed Carbon

Fixed carbon is the solid combustible residue that remains after a coal particle is heated and the volatile matter is expelled. The fixed carbon content of any fuel is determined by subtracting the sum of percentages of moisture, volatile matter, and ash in a sample from 100. The fixed carbons in the simple were determined by using the following formula.

$$\%\ FC = 100 - (\%\ M + \%\ VM + \%\ Ash)$$

Where, FC: Fixed carbon, M: Moisture, VM: Volatile Matter

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Experimental Procedure:

1. First, prepare the briquetted samples as shown below.

Figure 3.4.1: Briquetted Samples

2. Attach the fuse to the bomb: Set the bomb head on the support stand and fasten a 10 cm length of fuse wire between the two electrodes.
3. Insert the ends of the wires into the eyelet at the end of each electrode stem and push the cap downward to pinch the wire into place.
4. Place the fuel capsule with its weighed sample in the electrode loop and bend the wire downward toward the surface of the charge.
5. It is not necessary to submerge the wire in a powdered sample.
6. In fact, better combustion will usually be obtained if the loop of the fuse is set slightly above the surface.
7. When using samples, bend the wire so that the loop bears against the top of the pellet firmly enough to keep it from sliding against the side of the capsule.
8. It is also good practice to tilt the capsule slightly to one side so that the flame emerging from it will not impinge directly on the tip of the straight electrode.
9. Close the bomb: Care must be taken not to disturb the sample when moving the bomb head from the support stand to the bomb cylinder.
10. Check the sealing ring to make sure it is in good condition and moistens it with a bit of water so that it will slide freely into the cylinder.
11. For easy insertion, push the head straight down without twisting and leave the gas release valve open during this operation.
12. Set the screw cap on the cylinder and turn it down firmly by hand to a solid stop.
13. Finally, switching on the current through the fussed wire and the rise in temperature of water was automatically recorded.
14. By using the above GCV formula find out the energy values of samples like specified briquettes and mixed briquettes.

RESULT AND DISCUSSION

Proximate analysis of presently selected plant components obtained from agricultural residue:

It is important to determine the moisture contents, ash contents, volatile matter and fixed carbon of a fuel energy source to know their power generation potential. Thus the study of proximate analysis of fuels energy sources gives an approximate idea about the energy values and extent of pollutant emissions during combustion. Agricultural based biomass has large amount of free moisture. To decrease the transportation cost and increase the calorific value which must be removed. In the plant species selected for the present study the time required to bring their moisture contents into equilibrium with that of the atmosphere was found to be in the range of 25-30 days during the summer season (temp 35 –420C, humidity 12-25 %).

Table 4.1.1: Proximate analysis and calorific values of Groundnut shell, different component of pigeon pea and coal

Component	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
Groundnut Shell					
Shell	6.00	65.00	10.00	19.00	3654.59
Pigeon Peas					
Stump	9.00	68.00	9.50	13.50	5815
Branch	10.00	69.00	7.50	13.50	4081
Leaf	9.00	65.00	10.50	15.50	5630
Bark	5.00	74.00	8.50	12.50	3846
Seed cover	10.00	65.00	10.00	15.00	4081
Coal					
Lingaraj Mines	8.90	21.70	41.20	29	4237

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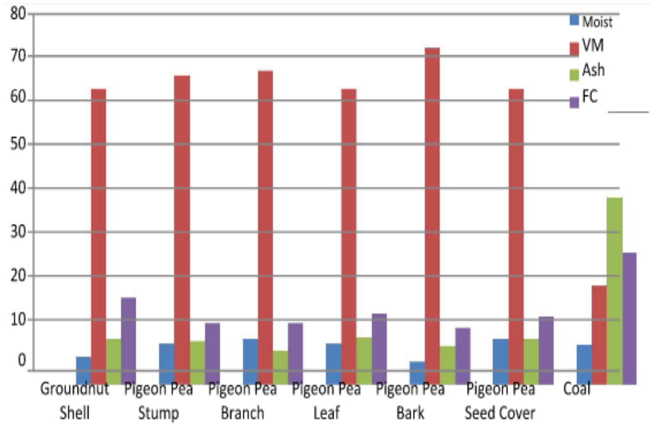

Figure: 4.1.1 Variation of Proximate Analysis of Groundnut Shell, Pigeon Pea and Coal

The proximate analysis and calorific values of different components of pigeon pea and groundnut shell, coal and coal-biomass mixed briquette in different ratios are presented in tables 4.1.1 to 4.1.7 and variation of proximate analysis of mixed coal-biomass briquettes are shown in figure 4.1.1 to 4.1.7 Which shows that both the biomass species has less ash content and high volatile matter when mixes with coal in the ratio of 80:20.In conventional power plant bottom ash produced by the combustion of coal is a major problem, so it is always desires to use less ash content fuel.

Table 4.1.2: Proximate analysis and calorific values of Coal-Biomass (Pigeon Pea Stump) mixed briquette in different ratios

Ratio (Coal: Biomass)	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
95:05	8.90	24.10	39.62	27.38	4315.90
90:10	8.91	26.33	38.03	26.73	4394.80
85:15	8.92	28.65	36.45	25.98	4473.70
80:20	8.93	30.96	34.86	25.25	4552.60

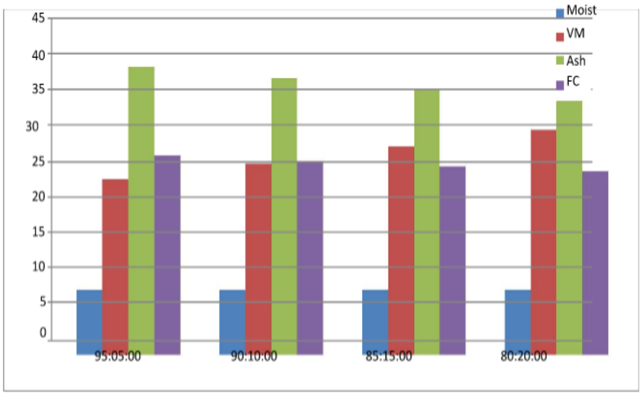

Figure: 4.1.2 Variation of Proximate Analysis of Mixed Coal-Biomass (Pigeon Pea Stump)

Table 4.1.3: Proximate analysis and calorific values of Coal-Biomass (Pigeon Pea Branch) mixed briquette in different ratios

Ratio (Coal: Biomass)	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
95:05	8.95	24.06	39.52	27.50	4229.20
90:10	9.01	26.43	37.83	26.73	4221.40
85:15	9.06	28.79	36.14	26.00	4213.60
80:20	9.12	31.16	34.46	25.26	4205.80

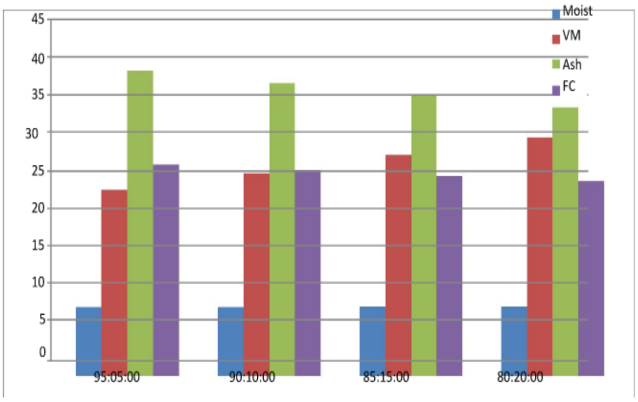

Figure: 4.1.3 Variation of Proximate Analysis of Mixed Coal-Biomass (Pigeon Pea Branch)

Table 4.1.4: Proximate analysis and calorific values of Coal-Biomass (Pigeon Pea Leaf) mixed briquette in different ratios

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Ratio (Coal: Biomass)	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
95:05	8.90	23.86	39.66	27.58	4306.65
90:10	8.91	26.03	38.13	26.93	4376.30
85:15	8.92	28.19	36.59	26.30	4445.95
80:20	8.93	30.36	35.06	25.65	4515.60

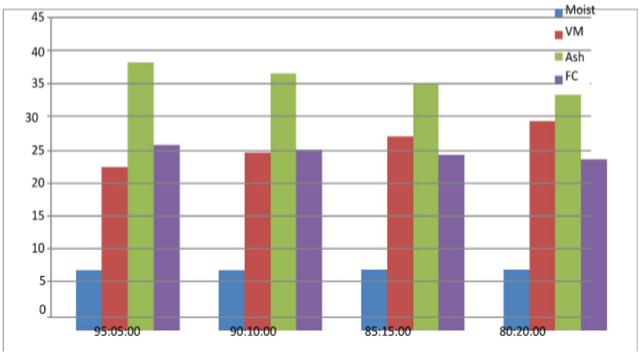

Figure: 4.1.4 Variation of Proximate Analysis of Mixed Coal-Biomass (Pigeon Pea Leaf)

Table 4.1.5: Proximate analysis and calorific values of Coal-Biomass (Pigeon Pea Bark) mixed briquette in different ratios

Ratio (Coal: Biomass)	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
95:05	8.70	24.31	39.56	27.43	4217.45
90:10	8.51	26.93	37.93	26.63	4197.90
85:15	8.31	29.54	36.29	25.86	4178.37
80:20	8.12	32.16	34.66	25.06	4158.80

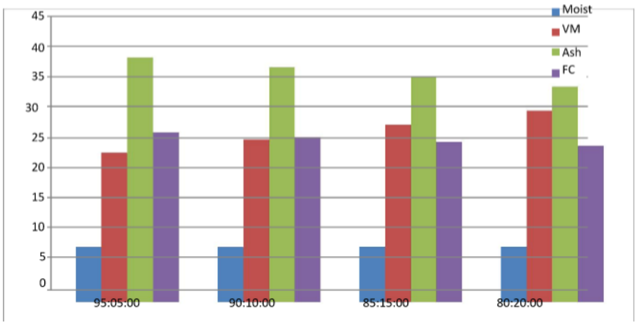

Figure: 4.1.5 Variation of Proximate Analysis of Mixed Coal-Biomass (Pigeon Pea Bark)

Table 4.1.6: Proximate analysis and calorific values of Coal-Biomass (Pigeon Pea seed cover) mixed briquette in different ratios

Ratio (Coal: Biomass)	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
95:05	8.95	23.86	39.64	27.55	4229.2
90:10	9.01	26.03	38.08	26.88	4221.4
85:15	9.06	28.19	36.52	26.23	4213.6
80:20	9.12	30.36	34.96	25.56	4205.8

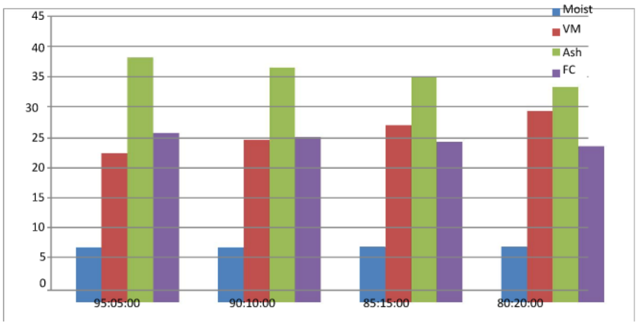

Figure: 4.1.6 Variation of Proximate Analysis of Mixed Coal-Biomass (Pigeon Pea seed cover)

Table 4.1.7: Proximate analysis and calorific values of Coal-Biomass (Groundnut Shell) mixed briquette in different ratios

Ratio (Coal: Biomass)	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
95:05	8.75	23.865	39.64	27.74	4207.87
90:10	8.61	26.03	38.08	27.28	4178.75
85:15	8.46	28.19	36.52	26.82	4149.63
80:20	8.32	30.36	34.96	26.36	4120.51

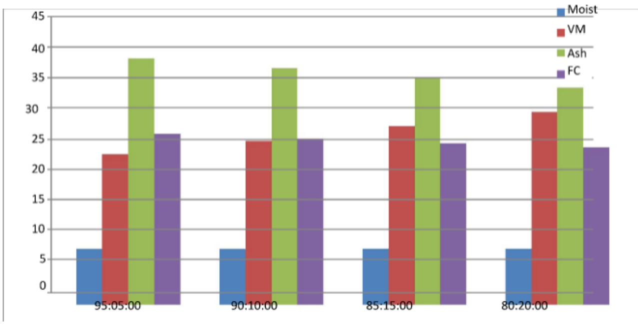

Figure: 4.1.7 Variation of Proximate Analysis of Mixed Coal-Biomass (Groundnut Shell)

CONCLUSIONS

In the present work two non-woody biomass species pigeon pea and ground nut shell were selected. Experiments to determine the proximate analysis, calorific values and ash fusion temperature was done on each of the components of the selected species such as stump, bark, branch, leaf and nascent branch were performed. Estimation has done to analyze how much power can be generated and land requirement for plantation for each of these species. The following are the different conclusions drawn from the present work: Both plant species (pigeon pea and ground nut) showed almost the similar proximate analysis result for their components .Pigeon pea has higher calorific value than groundnut shell.

Groundnut shell has lower calorific value, ash content and higher volatile matter than selected coal sample due to that when the percentage of groundnut shell increases in the coal-biomass briquette calorific value and ash content decreases and volatile matter increases. In case of pigeon pea biomass calorific value and volatile matter is higher and ash content is lower than selected coal sample due to that when percentage of pigeon pea increases in the coal-biomass briquette calorific value and volatile matter increases and ash content is decreases. The pigeon pea biomass species showed highest energy values for their branch, followed by wood, leaf and nascent branch.

Amongst the four different ratio80:20 gives the less ash content and higher volatile matter and energy value compared to 95:05, 90:10, 85:15. Energy values of coal mixed pigeon pea biomass component were found to be little bit higher than that of coal mixed groundnut shell biomass. In order to meet the yearly power requirement of the order of 73 x 105 kWh for a group of 10-15 villages, 4315 ha (in case of use of pigeon pea residue) and 5024.84 ha (in case of use of groundnut shell) land are required for plantation but when coal-biomass mixed briquette is used as fuel for power generation in the ratio of 80:20 it is found that it requires 197.91 ha (in case of use of coal-pigeon pea briquette) and 891.33 ha land(in case of use of coal-groundnut shell briquette). This study could be positive in the exploitation of non-woody biomass species for power generation.

SCOPE FOR FUTURE WORK

1. Similar type of study can be extended for another non-woody biomass species available in the local area or can be select from the table1.7.1
2. Pilot plant study on laboratory scale may be carried out to generate electricity from biomass species.
3. The powdered samples of these biomass species may be mixed with cow dunk and the electricity generated potential of the resultant mixed briquettes may be studied.
4. New techniques of electricity generation from biomass species may be developed.

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