ENERGY ESTIMATION AND ELECTRICAL POWER GENERATION POTENTIAL OF AGRICULTURAL BIOMASS RESIDUE

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Abstract: The Indian economy mainly based upon the agriculture and major share of population live in rural areas. It has still many remote places without electricity supply. Researchers and analysts are focusing on local resources available for inhouse power generation. The aim of the paper is to investigate the power potential of agricultural waste such as Soybean, Paddy and Arhar respectively. In this paper, the experimental test is done for calculating the value of calorific value, moisture content, ash content and volatile matter and the net energy content in biomass residue. The results shows net energy content in paddy is higher as compared to other agricultural residue. The power potential for electricity generation and corresponding land requirement are also calculated. Based on results, for soybean, paddy and arhar the land requirement are 3144 hectares, 2040 hectares and 5321 hectares to generate .73 MWh/year. The results are also compared with the coal sample. This comparison reveals much higher power output of agricultural biomass species with less emission of suspended particulate matters.
Keywords: Biomass, Agricultural residue, Power potential, SPM, Energy content

I. INTRODUCTION

India is a developing country and agriculture has always been the mainstay of its economy accounting for 17.8 percent of its gross domestic product during 2007-2008 [1].It constitutes the backbone of rural India where 70% population live in rural areas. As a results lot of agricultural wastes are generated and remain unutilized. Even today there are many remote places in India without any electricity supply. The remoteness and thin population make the grid supply of electricity highly uneconomical. Moreover there is always a growing concern due to fast depletion of fossil fuel resources for power generation and corresponding pollution of the environment. Therefore biomass is one of the alternative sources of electricity generation.

A. Biomass and its classification- Biomass is organic material made from plants and animals. Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. The chemical energy in plants gets passed on to animals and people that eat them. Biomass is a renewable energy source because we can always grow more trees and crops, and waste will always exist. The overall biomass resources can be broadly categorized into two parts based on its availability in the natural form woody and non woody biomass.

B. 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.

C. 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. Biomass resources are undoubtedly the world's largest and most sustainable energy sources for power generation in the 21st century [2]. The share of non-woody biomass is about 60%. Large potentials of non-woody biomass are available in Latin America, Africa and Asia. The total potential of non-woody and non-fodder biomass available for energy in India was estimated to be 5.14 EJ in 1997 [3]. Use of biomass energy in electrical power generation can also solve the problems of unemployment, better utilization of wasteland, and transmission losses in grid. Accordingly, the system of biomass-based power generation is being given priority in most of the developing nations including India. To exploit biomass species in electricity generation, it is necessary to find out their properties like calorific value, volatile matters, moisture content etc. This paper deals with the experimental work on proximate analysis and calorific values of different agricultural biomass species, and their impact on electricity power generation. It also experimentally finds out the ash fusion temperatures to confirm its safe operation in the boiler.

II. EXPERIMENTAL WORK

A. Material Selection

In this work, three different types of non-woody biomass species were collected from the local area and their components (stump, bark, leaf and branch) were removed separately and kept for air drying in a cross ventilated room for about one and half month. The moisture contents of these components reached in equilibrium. The air dried biomass samples were crushed into powders and then processed for their proximate and ultimate analysis and calorific value determination.

B. Proximate Analysis and Calorific Value: One gram of air dried powdered sample of size -72 mess was taken for analysis of ash, moisture, volatile matter and fixed carbon content [4]. For estimation of ash, the sample was burnt in the furnace at temperature of 715-760°C. The sample was heated in the air oven at temperature of 130°C for determination of moisture content. While the determination of volatile matter the sample was heated in the furnace at 855°C. The fixed carbon content in the sample was determined by using the following formula: Fixed Carbon Content (Wt. %) =100-Wt %(Moisture + Volatile matter + Ash) The calorific values of the samples were determined with the help of bomb calorimeter [5]

III. RESULTS

A. Proximate Analysis and Calorific Value

The study of proximate analysis of fuels is very important because it gives an idea about the energy value. The proximate analyses of different component of different agricultural biomass residue are shown in Table I. Comparison shows that arhar branch content high volatile matter as compared to other agricultural residue components. While the soybean branch content more moisture, ash content in paddy leafs is more and paddy stumps content high fixed carbon as compared to other. The calorific value of the fuel is an important criterion for judging its quality for electricity generation. As shown in Table I, the calorific value of arhar stump is much higher as compared to the other.

TABLE I
Proximate analysis and calorific value of different components of different agricultural residue

Component	Proximate analysis wt %, air dried basis				Calorific value (kcal/kg, dry basis)
	Moist.	V.M.	Ash	F.C.	
Soybean					
Stump	7.3	68	1.3	15.5	4721
Leaf	3.5	69	19.20	11	3000
Bark	11	61	11.75	14.5	3425
Paddy					
Stump	7.5	54	18.25	17.50	3478
Leaf	6.75	55.75	23.25	8.5	3472
Arhar					
Stump	8.2	66	8	14.75	5806
Leaf	9.5	73	8.5	13	4028
Branch	8	70	12	14.5	5598

B. Ash Fusion Temperature of Agricultral Biomass Residue

Ash fusion temperature of solid fuel is an important parameter affecting the operation temperature of boilers. Clinker formation in the boiler usually occurs due to low ash fusion temperature and this hampers the operation of the boiler. The study of the ash fusion temperature of solid fuel is essential before its utilization in the boiler. In the present study the ash fusion temperature in terms of four terminologies like IDT, ST, HT and FT. The four characteristic ash fusion temperatures were identified as: (i) Initial deformation temperature (IDT) – first sign of change in shape; (ii) Softening temperature (ST) – rounding of the corners of the cube and shrinkage; (iii) Hemispherical temperature (HT) – deformation of cube to a hemispherical shape; and (iv) Fluid temperature (FT) – flow of the fused mass in a nearly flat layer. The results of AFT Shows in Table II from which may be concluded that the value of AFT of soybean is lower than the paddy and arhar and the boiler operation with soybean residues can be carried out safely (without clinker formation) up to the temperature of 850°C. The boiler operation with paddy and arhar residues can be carried out safely (without clinker formation) up to the temperature of 940°C.

TABLE II
AFT of Different Agricultural Biomass Residues

Biomass Residue	Ash Fusion Temperature (°C)			
	IDT	ST	HT	FT
Soybean	825	920	1135	1160
Paddy	920	1070	1140	1185
Arhar	940	1120	1145	1170

C. Estimation of decentralize power generation structure in rural areas

For the estimation of power generation to meet the electricity requirement of villages, a group of 10-12 villages consisting of 2500 families may be considered for which one power station could be planned. The electricity requirement is 20,000 kWh/day for 10-12 villages. The design of energy plantation of Soybean, Paddy, Arhar for power plant of 20 MWh/day capacity has been presented in Table III and Appendix. The results indicate that the yearly power requirement of 7.3 MWh for a group of 10-12 villages, approximately 3144 hectare (in case of Soybean), 2040 hectare (in case of Paddy)and 5320 hectare (in case of Arhar) of land is required for power generation.

TABLE III
Total energy contents from Soybean plant, Paddy plant and Arhar plant

Component	Calorific Value (kcal/t, Dry basis)	Biomass Production (t/ha, Dry basis)	Energy value (kcal/ha)
Soybean			
Stump	4721×10^3	1.2	5665.2×10^3
Leaf	3000×10^3	0.92	2760×10^3
Bark	3425×10^3	0.24	822×10^3
Paddy			
Stump	3478×10^3	3.1	10781.8×10^3
Leaf	3472×10^3	1.0	3472×10^3
Arhar			
Stump	5806×10^3	0.53	3077.18×10^3
Leaf	4028×10^3	0.37	1490.36×10^3
Branch	5598×10^3	0.16	895.68×10^3

D. Comparison with Coal

The results of proximate analysis and calorific values of locally available non-coking coal being used for electricity generation in M.P. (India) shown in Table IV. This table also shows that the calorific values of Arhar components (except Leaf) are superior than that of coal of Singrauli mine. The ash content in this coal sample is much higher (34.5) and this is expected to pollute the environment heavily with SPM (suspended particulate matter). On the other hand, all components of soybean, paddy and arhar have ash content much less than the available coal listed in Table IV.

TABLE IV
Proximate analysis and calorific value of non coking coal from coal mine of M.P. (India)

Coal mine	Proximate analysis (wt.%, dry basis)			Calorific value (kcal/kg) dry basis
	Volatile matter	Ash	Fixed carbon	
Singrauli Mine	28	34.5	38.25	4755

IV. CONCLUSIONS

The main conclusions of the present work are outlined below.

- In case of soybean residue stump has higher calorific value, which is higher than leaf and bark respectively.
- In case of paddy residue stump and leaf have approximately the same calorific value.
- In case of arhar residue stumps has higher calorific value followed by leaf and branch respectively.
- Calculation results have demonstrated that nearly 3144 hectares, 2040 hectares, 5320 hectares of land would be required for continuous generation of 20,000KWh electricity per day from soybean, paddy and arhar agricultural residue respectively.
- As per the results, the agricultural residue shows the higher energy value as compared to the available coal from mine. This indicates higher power generation potentials in biomass than coals.
- The present study could be useful in the exploration of agricultural residue based biomass species for power generation.

V. APPENDIX

Calculation of land requirement for Energy plantations:
Referring data from Table III,
On oven dried basis, total energy from one hectare of land for Soybean

= (5665.2 + 2760 + 822) × 103
= 9247.2 × 103 kcal

It is assumed that the conversion efficiency of wood fuelled thermal generators is 27 % and Overall efficiency of the power plant is 80 %.

Energy value of the total functional biomass obtained from one hectare of land at 27% conversion efficiency of thermal power plant
= 9247.2 × 103 × 0.27
= 2496.74×10^3 kcal
= $2496.74 \times 10^3 \times 4.186 / 3600$
= 2903.15 kWh

Power generation at 80 % overall efficiency
= 2903.15 × 0.80
= 2322.52 kWh/ha

Land required to supply electricity for whole year
= $7.3 \times 10^6 / 2322.52$
= 3143.13 hectares

On oven dried basis, total energy from one hectare of land for Paddy
= $(10781.8 + 3472) \times 10^3$
= 14253.8×10^3 kcal

It is assumed that the conversion efficiency of wood fuelled thermal generators is 27 % and Overall efficiency of the power plant is 80 %

Energy value of the total functional biomass obtained from one hectare of land at 27% conversion efficiency of thermal power plant
= $14253.8 \times 10^3 \times 0.27$
= 3848.52×10^3 kcal
= $3848.52 \times 10^3 \times 4.186 / 3600$
= 4474.98 kWh

Power generation at 80 % overall efficiency
= 4474.98 × 0.80
= 3579.98 kWh/ha

Land required to supply electricity for whole year
= $7.3 \times 10^6 / 3579.98$
= 2039.11 hectares

On oven dried basis, total energy from one hectare of land for Arhar
= $(3077.18 + 1490.36 + 895.68) \times 10^3$
= 5463.22×10^3 kcal

It is assumed that the conversion efficiency of wood fuelled thermal generators is 27 % and Overall efficiency of the power plant is 80 %

Energy value of the total functional biomass obtained from one hectare of land at 27% conversion efficiency of thermal power plant
= $5463.22 \times 10^3 \times 0.27$
= 1475.06×10^3 kcal
= $1475.06 \times 10^3 \times 4.186 / 3600$
= 1715.16 kWh

Power generation at 80 % overall efficiency
= 1715.16 × 0.80
= 1372.13 kWh/ha

Land required to supply electricity for whole year
= $7.3 \times 10^6 / 1372.13$
= 5320.19 hectares

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