A Review on "Briquette (Biocoal) from Crops Residual as A Feasible Energy Conversion Technology"

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Abstract:- **Every year millions of tons of crops residual are generated which are either destroyed or burnt inefficiently in loose form causing air pollution. Agro wastes can be recycled & can provide a renewable source of energy by converting biomass waste into energy sources. Bagasse, ground nut, saw dust, cotton stick grass and rice husk were used as major biomass in the form of raw biomass, hydrolyzed biomass and carbonized biomass. Agro wastes with carbonized biomass were found suitable as compared to raw and hydrolyzed biomass for briquetted fuel. The briquettes were prepared on briquetting machine for different combinations of major biomass. After sun drying of agro wastes converts in briquettes were subjected to various tests for analysis of the quality of fuel. The suitability of briquetted fuel as industrial fuel is studied.**

Keywords— Crop residual, pollution, recycle, hydrolyzed and carconiized biomass, briqette

INTRODUCTION

Many of the developing countries produce huge quantities of agro residual. These wastes are used inefficiently and burn directly which causing extensive pollution to the environment. The major agro residues are bagasse as sugarcane production waste, rice husk, coffee husk, coir pith, jute sticks, groundnut shells, mustard stalks and cotton stalks. These residual can be converted in to briquette. Briquettes can also be called as white coal as per its characteristics. Briquettes can be used in thermal applications. Briquette produced form agro wastes give earning a value addition of minimum 150%. [1]

Briquettes are used in various industries like,

1) Distilleries
2) Dyeing units
3)Tobacco processing
4) Tea processing
5) Leather industries
6) Garment industries.
7) Hotels
8) Power plants
9) Brick kilns
10) Polymer industries
11) Paper mills
12) Cement plants
13) Gasifier
14) Food processing industry
15) Milk dairies
16) Pharmaceutical industry
17) Tire retreading industry
18) Wineries
19) Household boilers
20) Any other boiler application

II. ANALYSIS OF CROPS RESIDUAL

A. Ultimate analysis (analytical chemistry):

It is the determination of the percentage of elements contained in a different biomass. It's including different proximate and ultimate analysis of biomass, which help in to find out different emission components generate after burning of biomass.

Biomass	Ash Contain	C%	H%	N%	O%	Calorific value (Kcal/kg)
Bagasse	4.00	47.00	6.50	0.0	42.50	4200
Rice husk	22.20	36.42	4.91	0.59	35.88	4000
Saw dust	1.20	52.28	5.20	0.47	40.85	4400
Ground nut shell	3.10	33.90	1.97	1.10	59.93	4500
Cotton shell	4.60	44.19	5.87	0.73	44.61	4200
Coconut shell	6.31	46.69	5.89	0.07	41.04	3720

Table 1 Ultimate Analysis of crop residual

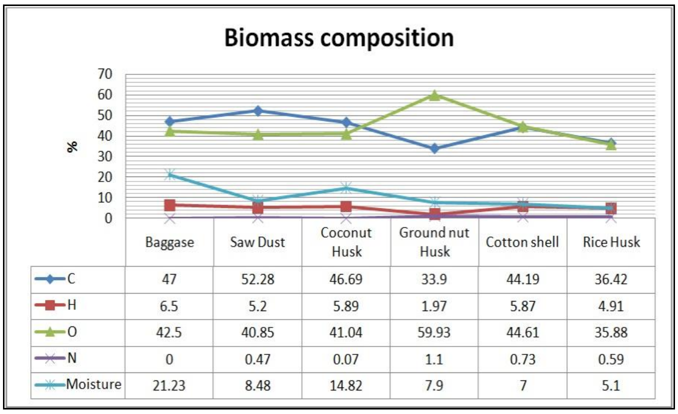

Fig.1 Ultimate analysis of crops residual

B. Proximate analysis:

Analysis for moisture, volatile matter, ash and fixed carbon contents were carried out on samples ground to -72 mess size by standard method. The details of these tests are as follows.

(1) Moisture Determination

One gram of air dried powdered sample of size -72 mess was taken in a borosil glass crucible and kept in the air oven maintained at the temperature 110˚C.The sample was soaked at this temperature for one hour and then taken out from the furnace and cooled in a desiccators. Weight loss was recorded using an electronic balance. The percentage loss in weight gave the percentage moisture content in the sample.

(2) Volatile Matter Determination

One gram of air dried powdered sample of size -72 mess was taken in a volatile matter crucible (made of silica) and kept in the muffle furnace maintained at the required temperature of 925°C.The sample was soaked at this temperature for seven minutes and then crucible was taken out from the furnace and cooled in air. Weight loss in the sample was recorded by using an electronic balance having a sensitivity of 0.001grams.The percentage loss in weight – moisture present in the sample gives the volatile matter content in the sample.

(3) Ash Content Determination

One gram of air dried powdered sample of size -72mess was taken in a shallow silica disc and kept in the muffle furnace maintained at the temperature of 775-800°C.The sample was kept in the furnace till complete burning. Weight of ash formed was noted down and the percentage ash content in the sample was determined.

(4) Fixed Carbon Determination

The fixed carbon content in the sample was determined by using the following formula:

Fixed Carbon Content (Wt. %) =100 - Wt %(Moisture + VM + Ash)

(5) Calorific Value Determination

The calorific values of the biomass samples were measured in a Bomb calorimeter apparatus. In this test an over dried sample briquette of weight 1gm (approx.) was taken in a bomb and oxygen gas was filled into this bomb at a pressure of 25-30 atm. The sample was then fixed inside the bomb and rise in temperature of water was noted with the help of Beckman Thermometer. The calorific value was calculated by using the following formula:

Gross Calorific value = (W.E X T) / W_o – (fuse wire + thread connections)

Where,

W.E = water equivalent of the apparatus

T = Maximum rise in temperature in ˚C.

W_o = Initial weight of briquette sample. [2]

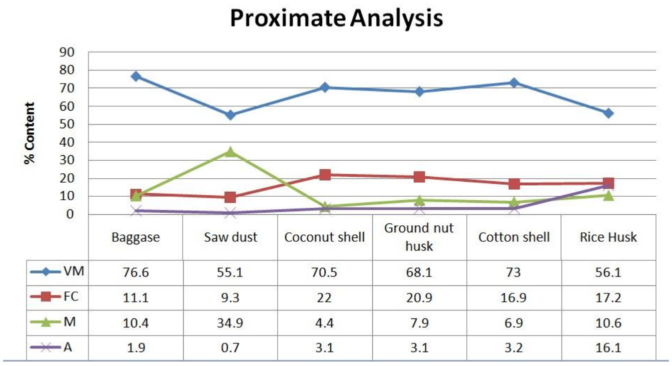

Fig.2 proximate analysis of crop

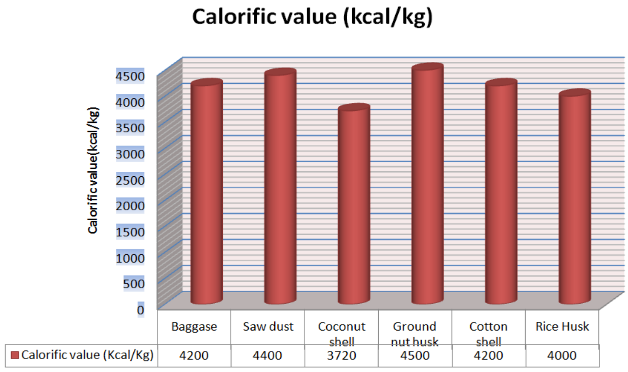

Fig.3 Calorific value

III. BRIQUETTING OF BIOMASS

A. *Briquetting technique*

Briqutting is densification of the loose biomass; this is achieved by subjecting the biomass to heavy mechanical pressure to form compact cylindrical form known as briquettes. Owing to high moisture content direct burning of loose bagasse in conventional grates is associated with very low thermal efficiency and widespread air pollution. The conversion efficiencies are as low as 40% with particulate emissions in the flue gases in excess of 3000 mg/ Nm^3 In addition, a large percentage of unburnt carbonaceous ash has to be disposed off.

The densification of the biomass can be achieved by any one of the following methods: (i) Pyrolysed densification using a binder, (ii) Direct densification of biomass using binders and (iii) Binder-less briquetting. [3] Depending upon the type of biomass, three processes are generally required involving the following steps:

(a) Sieving - Drying - Preheating - Densification - Cooling – Packing

(b) Sieving - Crushing - Preheating - Densification - Cooling –Packing

(c) Drying - Crushing - Preheating - Densification - Cooling – Packing

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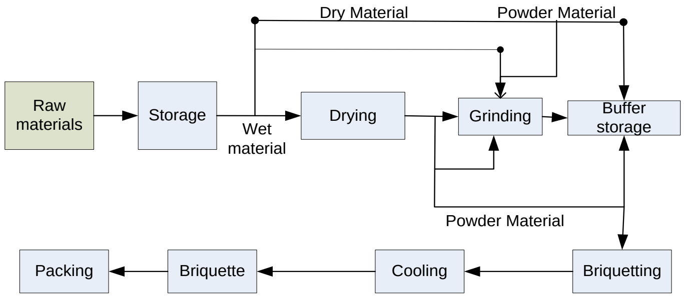

Fig. 4 Briquette making processes

When sawdust is used, process A is adopted. Process B is for agro- and mill residues which are normally dry. These materials are coffee husk, rice husk, groundnut shells etc. Process C is for materials like bagasse, coir pith (which needs sieving), mustard and other cereal stalks.

B. *Advantages and disadvantages of briquetting*

***Advantages*:**

a) High calorific value ranges between 3,500-5,000 Kcal/Kg.
b) Moisture percentage is very less (2-5%) compared to lignite, firewood & coal where it is 25-30%.
c) Economic to users compared to other forms.
d) Briquettes can be produced with a density of 1.2g/cm³ from loose biomass of bulk density 0.1 to 0.2 g/ cm³.
e) Easy in handling and storage due to its size.
f) Consistent quality.

***Disadvantages*:**

a) High investment cost and energy consumption input to the process
b) Undesirable combustion characteristics often observed e.g., poor ignitability, smoking, etc.
c) Tendency of briquettes to loosen when exposed to water or even high humidity weather text into it.

IV. METHOD OF BRIQUETTE MAKING

A. Binding less techniques for briquette making

1. *The screw extrusion:* The Prepared homogenous raw material is fed to briquetting press by screw conveyor for regular feeding. In briquetting press it passes through toper die and due to high pressure & heat, powder form is converted into solid cylindrical briquettes. Although both technologies have their merits and demerits, studies have shown that the screw pressed briquettes are superior to the ram pressed solid briquettes in terms of their storability and combustibility. However the screw extrusion machines have low production capacity (150 – 200 kg/hr) and high operational cost, due to the possibility of screw breakages.

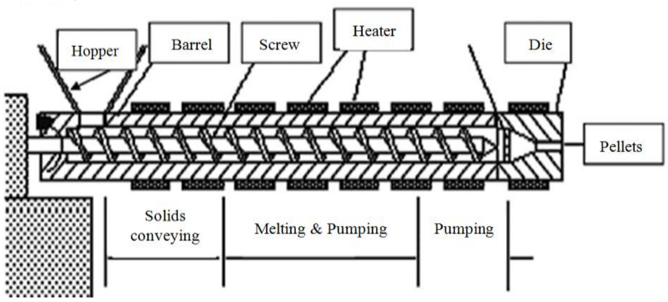

Fig. 5 Screw extruder

2. *The reciprocating ram/piston press (briquetting press):* Piston press (ram) machine has higher production capacity (above 1000kgs/hr) as compared to screw machines, the briquettes are completely solid and screw press briquettes on the other hand have a concentric hole which gives better combustion characteristics due to a larger specific area. The screw press briquettes are also homogeneous and do not disintegrate easily. Having a high combustion rate, these can substitute for coal in most applications and in boilers.

The energy to the piston is transmitted from an electric motor via a high pressure hydraulic system. The throughput of a hydraulic press is lower than that of a mechanical press since the cycle of the cylinder is slower. In addition, the briquettes have a lower bulk density 6 (<1000 kg/m³) due to the fact that pressure is limited. However, these machines can tolerate higher moisture contents than the usually accepted 15% for mechanical piston presses **Fig 6** represent making of briquette by hydraulic piston press machine.

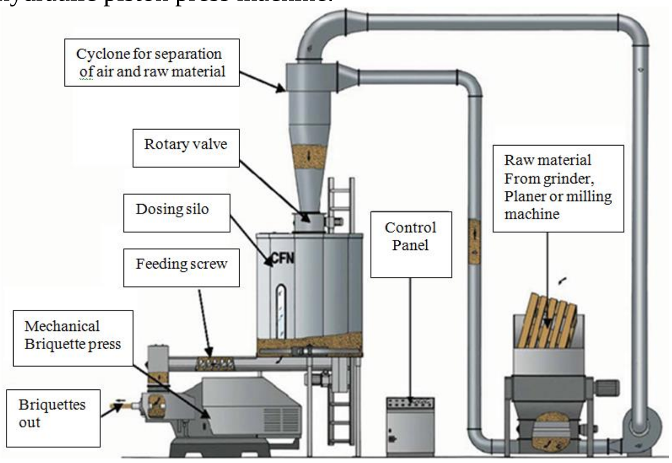

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Fig. 6 Different Types of Feedstock for Piston Press Type Briquetting Machine

Another roll press type includes Densification of biomass using roller presses works on the principle of pressure and agglomeration, where pressure is applied between two counter-rotating rolls. Ground biomass, when forced through the gap between the two rollers, is pressed into a die, or small pockets, forming the densified product. Design parameters that play a major role on the quality of the densified product are the diameter of the rollers, the gap width, the roller force, and the shape of the die.[4]

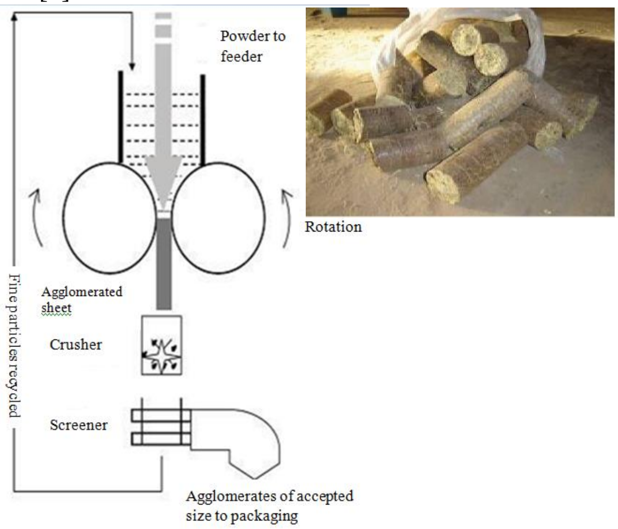

Fig. 7 Roll press type briquetting

In the case of agglomerate production, by using smooth rolls, the machine output can be a sheet having a specific thickness based on the gap provided between the rollers. The sheet produced is used to produce the agglomerates, as shown in Fig. 7 and the fines are again recycled back to the feeder.

B. With Binding material techniques for briquette making

Pelletizing is similar to briquetting except that it uses smaller dies (~ 30 mm) to produce smaller densified products called pellets.

Size	6 to 12 mm Diameter with variable length of 10mm to 50mm
Ash contains	Max 8%
Moisture contains	Max 6%
Density	1150-1400 Kg/m^3
Bulk density	600-650 Kg/m stereo
Calorific value	4400+200 Kcal/Kg
Sulfur & phosphorus contains	Almost nil

There are two main types of pellet presses: ring die and flat die. In general the die remains stationary and the rollers rotate. However, some pellet mills have dies that rotate and rollers that remain stationary during production. The die of a pelletizer is made of hardened steel that is perforated allowing the biomass to be forced through by the rotating die or rollers. The various pellet mill components are shown in Fig. 8 shows the dimensions of a commercial pellet mill die and shows pellet make from crops residual. In principle, the incoming feed from the feeder is delivered uniformly to the conditioner for the controlled addition of steam or binders such as molasses to improve the pelletization process. Unlike piston or screw presses, commercial pelletizers are not restricted by the density of the raw material having capacities in the range of 200 kg/h to 8000 kg/h and power consumption in the range of 15-40 kWh/ton.

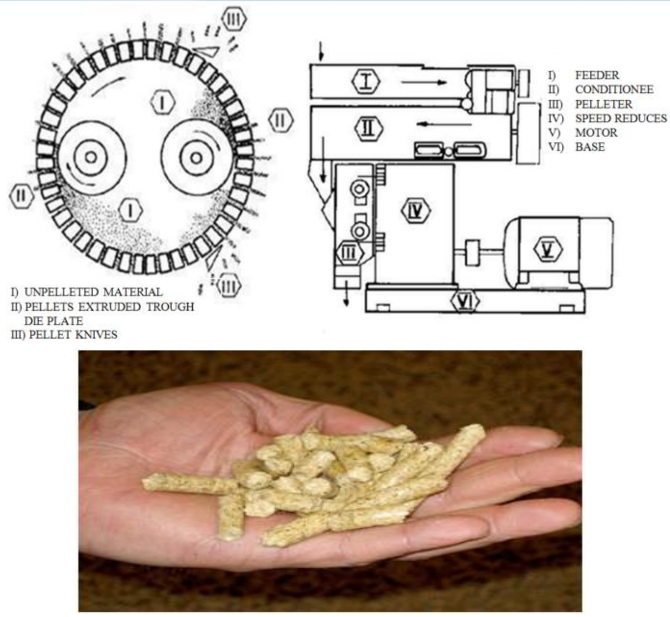

Fig. 8 Pelletizing process

	Screw press	Piston Press	Roller press	Pellet mill
Optimum moisture content of the raw material	8–9%	10–15%	10–15%	10–15%
Particle size	Smaller	Larger	Larger	Smaller
Wear of contact parts	High	Low	High	High
Output from machine	Continuous	In strokes	Continuous	Continuous
Specific energy consumption (kWh/ton)	36.8–150	37.4–77	29.91–83.1	16.4–74.5
Through puts (ton/hr)	0.5	2.5	5–10	5
Density of briquette	1–1.4 g/cm³	1.2 g/cm³	0.6–0.7 g/cm³	0.7–0.8 g/ cm³
Maintenance	Low	High	Low	Low
Combustion performance of Briquettes	Very good	Moderate	Moderate	Very good
Carbonization of charcoal	Makes good charcoal	Not possible	Not possible	Not possible
Suitability in Gasifier	Suitable	Suitable	Suitable	Suitable
Suitability for co-firing	Suitable	Suitable	Suitable	Suitable
Suitability for biochemical Conversion	Not-Suitable	Suitable	Suitable	Suitable
Homogeneity of densified Biomass	Homogenous	Not homogenous	Not homogenous	Not homogenous

Table 2 Comparison of Briquetting technique

C. Manual Presses and Low pressure Briquetting

There are different types of manual presses used for briquetting biomass feed stocks. They are specifically designed for the purpose or adapted from existing implements used for other purposes. Manual clay brick making presses are a good example. They are used both for raw biomass feedstock or charcoal. The main advantages of low-pressure briquetting are low capital costs, low operating costs and low levels of skill required to operate the technology. Low-pressure techniques are particularly suitable for briquetting green plant waste such as coir or bagasse (sugar-cane residue). The wet material is shaped under low pressure in simple block presses or extrusion presses. The resulting briquette has a higher density than the original material but still requires drying before it can be used. The dried briquette has little mechanical strength and crumbles easily. The use of a binder is imperative.
Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

V. ANALYSIS OF BRIQUETTE

After making of briquette determination of the percentage of elements contained in a briquette. It's including different chemical components of biomass, which help in to find out different emission components generate after burning of briquette.

Biomass	Ash Contain	C%	H%	N%	O%	Calorific value (Kcal/kg)
Bagasse	2.88	57.26	3.98	1.84	37.78	4700
Rice husk	16.10	45.20	5.8	1.02	47.6	3626
Saw dust	2.6	53.07	4.10	0.28	39.6	4654
Ground nut shell	5	16.49	16.42	0.28	68.79	4500
Cotton shell	14.8	40.52	8.61	0.2	38.90	4566
Coconut shell	9.8	46.6	4.4	1	42	4146

Table 3 Ultimate Analysis of crop residual Briquette

Biomass	VM	FC	M	A	Calorific value (Kcal/kg)
Bagasse	69.84	21.04	5.42	2.88	4700
Rice husk	68.20	15.7	12.67	16.10	3626
Saw dust	71	20.7	5.7	2.6	4654
Ground nut shell	88.47	6.53	9.18	5	4500
Cotton shell	75.56	9.64	5.2	14.8	4566
Coconut shell	53.55	18.1	18.65	9.8	4146

Table 4 Ultimate Analysis of crop residual Briquette [5][6][7][8][9]

III. CASE STUDY

"Vasudhara Dairy" Co-firing system of steam-coal and Bio-coal.

Co-firing is combustion of two different types of materials at the same time. One of the advantages of co-firing is that

- An existing plant can be used to burn a new fuel, which may be cheaper or more environmentally friendly. For example, biomass is sometimes co-fired in existing coal plants instead of new biomass plants.
- Co-firing can also be used to improve the combustion of fuels with low energy content. For example, landfill gas contains a large amount of carbon dioxide, which is non-combustible. If the landfill gas is burned without removing the carbon dioxide, the equipment may not perform properly or emissions of pollutants may increase.
- Co-firing it with natural gas increase the heat content of the fuel and improves combustion and equipment performance. As long as the electricity or heat produced with the biomass and landfill gas was otherwise going to be produced with non-renewable fuels, the benefits are essentially equivalent whether they are co-fired or combusted alone.
- Co-firing can be used to lower the emission of some pollutants. For example, co-firing biomass with coal results in less sulphur emissions than burning coal by itself. **[10][11]**

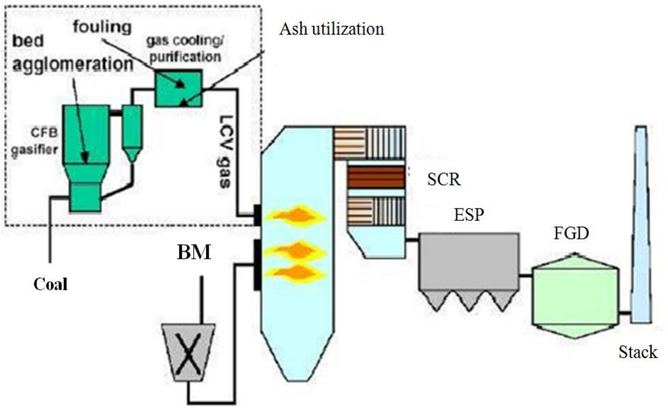

Fig. 9 Co-firing system of "Vasudhara Dairy"

Cost effectiveness with use of steam-coal and Bio-coal as a Boiler fuel.

Name of supplier	**Material**	**Name of testing Lab**	**GCV**	**DOS**
M/s Narayan Traders	Steam coal	Premier Analytical Laboratory, Nagpur	5168 Kcal	02.01.2010
M/s Jayshree Traders	Steam coal	Premier Analytical Laboratory, Nagpur	4809 Kcal	09.01.2010
M/s Renewal Bio-Energy	Bio coal	Mantra, Surat	4790 Kcal	17.02.2010

Table: 5 Biocoal details used at Vasudhara dairy

1) The consumption ratio of steam coal: Biocoal = 1 : 1.19
2) The GCV comparison of steam coal : Biocoal = 5100 : 4700 (1 : 0.92)
3) The Rate comparison of steam coal : Biocoal = 4100 : 3550 (1 : 0.86)

Example of trial during April 2010

Sr. No.	**Parameter**	**Steam Coal (Actual)**	**Biocoal (Expected)**
1	Consumption	173.400 MT	206.346 MT
2	Rate	4100/ Ton	3550/Ton
3	GCV	5100	4700
4	Total Cost	Rs. 7,10,940	Rs. 7,32,528
5	Saving	Rs. 21,588.30	

Table: 6 Boiler trials during April 2010

SR NO.	**Rate different**	**Steam coal**	**Biocoal**	**Saving**
1	550	Economic	Costly	21588
2	655	At par	At par	0
3	700	Costly	Economic	9363
4	800	Costly	Economic	29998
5	900	Costly	Economic	50632
6	1000	Costly	Economic	71267

Table: 7 Rate different of steam coal & Biocoal with respect to GCV

Sr. No	Month	Milk Throuput(Lit)	Cones of Steam coal+ Bio Coal(Kg)	Total	Rate/Ton(Rs) Landed	Total Cost(RS)	Milk proc./Kg coal	Coal/Lit (Rs.)	Qty of Cond. Recovery per day.
1	Jan 10	1,10,20,788	203116+0	203116	4000+0	812464	54.25	0.073	11351
2	Feb 10	97,68,185	21352+189632	210984	4000+3550	758601	46.29	0.077	9371
3	Mar 10	1,07,33,252	12580+209758	222338	4000+3550	794960	48.27	0.074	13167
4	Apr10	1,05,00,000	173400+0	173400	4100+0	710940	60.55	0.067	12897

Table: 8 Vasudhara dairy- co-firing system data

Year	Price of fuel(Rs./TR)	
	Biocoal	Steam coal
2006	2800	3500
2010	3550	4100
2013-2014	5000	6300

Table: 9 Price of fuel used at Vasudhara dairy in boiler during different year

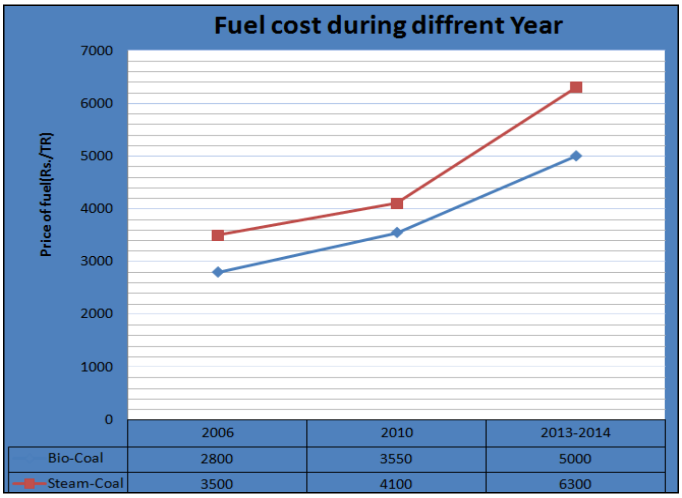

Fig. 10 Fuel cost of Vasudhara dairy

CONCLUSION

- From this paper conclusion can be made maximum percentage of fixed carbon (21.04 %) was obtained from bagasse based briquette where as in sawdust and coconut shell was 20.7 % and 18.1% respectively. Carbonized biomass was found suitable as compared to as such and hydrolyzed biomass for briquetted fuel. Calorific value was found more in bagasse briquetted fuel as 4700 kcal/kg.
- To produce good quality briquettes of selected crop residues which have the characteristics of fuel and are suitable for gasification and combustion and are also easy to handle transport and store.
- Conduct field evaluation of briquettes as fuel for combustion and gasification and work out cost economics and energy analysis.
- Briquette from crop residual can be replace coal in thermal system for producing heat and briquette can also be used in co-firing system, which result in reduction of fossile fuel consumption.

REFERENCES

[1] *"Briquetting plant for Biomass material such as mixture of Saw Dust, Coffee Husk, Ground Nut Shell And many other Agro waste", Book*

[2] *"BIOMASS, Thermo-chemical characterization"* Published by IIT, New Delhi.

[3] P.D.Grover, S.K Mishra, "Regional Wood Energy Development Programme in India, *Proc. International Workshop on Biomass Briquetting"*, New Delhi, April 1995.

[4] Jaya Shankar Tumuluru, Christopher T. Wright, Kevin L. Kenney and J. Richard Hess, *"A Technical Review on Biomass Processing: Densification, Preprocessing, Modeling, and Optimization"* June 2010 ASABE Annual International Meeting at U.S.

[5] *"Physio chemical characteristics and market potential of sawdust charcok briquette.",* International journal of energy and environment engineering, 2012

[6] *"The physical proximate and ultimate analysis of rice husk briquettes produced from a vibratory block mould briquette machine",* International journal of innovation science, engineering and technology, vol 2, issue 5, may 2015.

[7] *"Studies on devlopment of fuel briquettes for house hold and industrial purpose",*International journal of research in engineering and technology ISSN: 2319-1163

[8] *"Comparative study of briquetting of few selected agro residues commanly found in Nigeria",* Pacific journal of science and technology, vol13 No. 2, Nov-2012

[9] *"Briquetting of agro-residuues", I*ournal of science and industrial reseach,, vol. 2, Jan 2013, PP 5861.

[10] "A Review on Biomass Densification Technologies for Energy Application" June 2010 ASABE Annual International Meeting at U.S.

[11] R. Saidur, E.A.Abdelaziz, A.Demirbas, M.S.Hossain, S.Mekhilef, "A review on biomass as a fuel for boilers" Renewable and sustainable Energy Review 15 (2011) 2262-2289