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Design and Evaluation of Hand Operated Briquetting Machine

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Abstract: Every year, millions of tons of agricultural waste are generated and often inefficiently disposed of through destruction or burning in loose form, contributing to air pollution. In response to the challenges posed by global warming, briquetting technology has emerged as a renewable energy solution. In India, biomass stands out as the predominant source of energy, particularly in the domestic sector where charcoal and wood fuel are extensively utilized. Despite the substantial generation of agricultural waste in rural areas, the rural population continues to rely on charcoal and wood fuel, leading to deforestation. To address this issue and diminish the dependence on conventional fuels, the use of biomass as an alternative fuel has been proposed. Biomass, in the form of briquettes, can serve as a substitute for traditional fuels. This study involved comparing different biomass ratios for briquette production. The initial sample included rice straw and cow dung in specific proportions, the second sample incorporated rice husk, rice straw, and cow dung, and the third sample featured sawdust, rice straw, and cow dung. These mixtures were used in the production of briquettes through a Hand Operated Briquetting machine. The study then compared the proximate and ultimate analyses of the produced briquettes.
Keyword- Biomass, Briquetting, Potential, Process, Technologies, compacting of Briquetting materials.

INTRODUCTION

The escalating global pollution crisis, primarily fueled by the widespread use of fossil fuels, has prompted a significant push to decrease reliance on these non-renewable resources and explore alternative biomass fuels. Developing nations grapple with substantial challenges in waste management, wherein agro residues like coir pitch, dry leaves, rice husk, and coffee husk contribute significantly. These residues are often disposed of by burning on roadsides or in dump yards, exacerbating pollution. To address this, there is a need to convert these agro residues and sawmill residues into usable fuels.

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However, the transport, handling, and storage of these residues pose logistical challenges, and direct burning results in poor thermal efficiency and increased air pollution. Briquetting technology offers a solution by compacting waste biomass into usable, energy-generating fuel. With concerted efforts, biomass briquettes can serve as a substantial alternative to some fossil fuels, aiding in waste management and reducing air pollution.

Biomass briquetting involves densifying loose agro residues and sawmill residues, with or without binding agents, under pressure to create solid composites of uniform sizes and shapes. The resulting briquettes find applications in various industries, replacing coal for heat applications, power generation through biomass gasification, and domestic uses. Biomass, categorized as organic matter, presents a potential energy source, including agricultural waste, industrial waste, animal residues, and plant residues.

Historically, biomass briquetting technology has developed in two directions, with Europe and the United States focusing on the reciprocating ram/piston press, while Japan pioneered the screw press technology. The latter is universally acknowledged for producing briquettes with superior storability and combustibility. Currently, briquetting technology plays a crucial role in utilizing agro wastes for higher calorific value and energy efficiency.

This study aims to investigate the production of an eco-friendly fuel through the briquetting process, specifically utilizing mustard stalk waste in Rajasthan, a significant contributor to the country's yellow revolution. The proposed efficient briquetting machine could produce biomass briquettes for eco-friendly cooking, gasification for electricity generation, and direct sale in the market for boiler use.

While briquetting technology in India is not yet mature, there is considerable room for design improvements to enhance reliability and reduce energy consumption in agricultural residue briquetting. Moreover, the direct burning of loose agro waste residues leads to low thermal efficiency, fuel loss, and air pollution, issues mitigated by compressing them into briquettes.

Emphasizing the benefits of briquette making for rural communities, this work underscores its role in saving trees, preventing soil erosion and desertification, and providing an alternative to wood burning. Additionally, briquetting agricultural waste offers a valuable resource and creates micro-enterprise opportunities, benefiting individuals involved in the production, supply, and sale of briquettes. Ultimately, the availability of briquettes as an alternative to firewood holds the potential to improve the living conditions of rural women and children by reducing the time spent on collecting firewood, allowing for greater participation in income-generating activities and education.

MATERIALS AND METHODS

This chapter deals with the assumption and methodology adopted for briquetting of biomass. The experiment was carried out at Department of Farm Machinery and Power Engineering, RU, Kanpur. The plan of research work had been briefed here. The methodology followed during the course of this research work was discussed in brief under this chapter. The following methodology was adopted.

Experimental Site

An experimental set up of pellet briquetting system installed by the Department of Farm Machinery and Power Engineering, RU, Kanpur.

3. About the Briquetting Machine

It is designed to produce briquettes of 79 mm diameter and 32mm thickness and 25mm diameter passing through the central axis of the briquette length. The goal in this design is to design an efficient briquetting machine capable of compacting biomass by applying pressure. The machine will be manually operated. The design will be transportable, storable.

Table 3.1: Specification of Briquetting Machine

PART	PCS	DESCRIPTION
A	1	Vertical Support Height-1090mm, Width-100mm, Diameter-5mm
B	1	Top Spacer Lenth-200mm, Width-100X 50mm
C	1	Pusher Lever Lenth-1080mm, Diameter-30mm
D	1	Base plate Lenth-200mm, Width-175mm
E	1	Mold box, Lenth-200mm, Diameter-110mm, holes on 3mm centre
G	1	Mold box Cover, Lenth-450mm, Height-150mm
H	1	Piston, Lenth-310mm, Diameter-105mm, hole 32 mm Deep.

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I	1	Center pipe Height-700mm, Diameter-30mm.

Fig: 3.1 Hand operated piston press briquetting machine.

Briquetting process

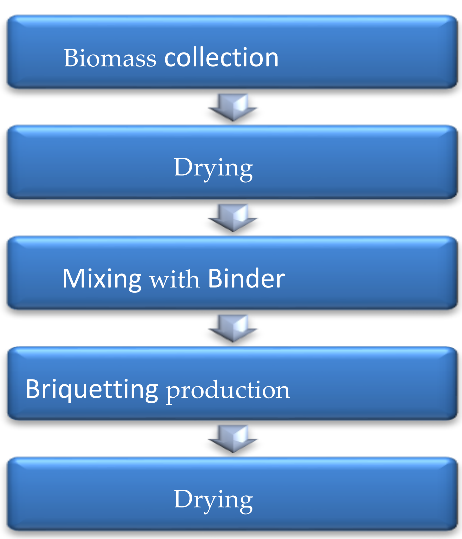

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Fig 3.2 Flow chart for briquette process

3.4.2. Raw material used:

Rice straw stands out as one of the most abundant lignocellulosic crop residues globally, and it holds significant prevalence in India. As a major field residue, it represents a substantial energy resource. However, despite the escalating fuel prices and the pressing need to curb greenhouse gas emissions and air pollution, rice straw is seldom utilized as a source of renewable energy.

Fig .3 Rice Straw

- **Rice Husk:**

Rice husk refers to the tough and protective outer shell enveloping the rice kernel. With each ton of polished rice produced, approximately 280 to 300 kg of rice husk is generated. Although it possesses a moderate calorific value, rice husk exhibits high ash content. The tubular structure of husk, enriched with silica, hinders uniform and complete combustion, leading to a significant percentage of residual carbon in the ash. This characteristic is especially pronounced in conventional furnaces like the step grate furnace. Additionally, rice husk is highly abrasive in nature.

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Fig 3.4 Rice husk

•Saw Dust:

Sawdust is composed of fine particles of wood, resulting from the cutting of wood with a saw, hence its name. The particle size typically falls within the range of 0.3 to 0.6 mm. As a raw material, sawdust boasts a calorific value of approximately 3600 kcal/kg..

Fig 3.5 Saw Dust

3.4.3 Binder materials

•Cow dung:

Cow dung is itself a good fuel when dried in the sun . It can be used as a binde material along with the raw materials. It is a sticky in nature and is recommended to used as binder in proportions ranging from 50 – 85 % with the raw material. The calorific value of fuel can be increased by using the cow dung as its calorific value I also higher

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Fig 3.6 Cow Dung

3.4.4 Mixing with binder

The binding material is used for strengthening the briquettes. The rice straw is mixed with binder. Cow dung was used as binding material, the various combination of measure constituents were tried in order to get briquettes of the desired quality. The different combination **B1** rice straw and cow dung as (10:40), **B2** rice husk, rice straw and cow dung (10:05:40) and B3 saw dust, rice straw and cow dung as (20:05:40) by weight was used for briquette production .The measure quality of water was adds in mixture using thumb rule for that the material should get bind by hand pressing after addition of water.

3.4.5 Briquetting production

The rice straw, rice husk ad saw dusts were used as major constitutes for briquetting with cow dung as a biding material. For the production of briquettes; hand operated machine was use source of power. The material was push forward due to geometry of piston.

3.5 Cost Analysis

The cost analysis was carried for complete briquetting production from

rice straw, rice husk, and cow dung by piston press technology. In order to compare the cost of production of different briquettes, the cost of operation of power operated system was also consider for economic analysis. The detailed cost of economic of briquette production is given in Appendix A (C). Following economic indicators were used for cost analysis of briquettes prepared under this study.

Table 3.2- Cost of Fabrication of Hand Operated Briquetting Machine

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Sr. No.	Material Specification	Quantity	Rat e	Cost
1	**Steel metal** 1.Vertical Support	1	1000	1000
	2.Base stand	1	1500	1500
	3.Base Plate	1	300	300
	4.Piston	1	200	200
	5.Pressure lever	1	700	700
	6.Top Spacer	1	900	900
				4600
2	**Material**			
	1.Mold	1	1100	1100
				1100
3	**Other Material** 1.Brush	1	100	100
	2.Colour	2	350	700
				860
	Total Cost			**Rs. 6560**

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RESULT AND DISCUSSION

The chapter deals with the results and discussion regarding physical, combustion properties and proximate analysis, ultimate analysis of the produced biomass briquettes. Cost analysis and machine performance.

4.1 Comparison of different ratio of biomass

It is obvious that, there different ratio of raw material **B1-** rice straw and cow dung (10:40), **B2** – rice husk, rice straw, cow dung (10:05:40) and **B3-** saw dust, rice straw, cow dung (20:05:40) was used to produce briquettes have little different in dimension of briquettes. The **B3-** saw dust, rice straw, cow dung in proportion of (10:05:40) produced heavier briquettes as compare to the other two ratio. Diameter of briquettes in each case is same. But little different in length was observed. Longest briquettes (6.19) are produced with the **B3-** saw dust, rice straw, and cow dung (20:05:40) followed by the first and second ratio of materials.

4.2 Physical Properties of Produced Briquettes

4.2.1 Density of briquettes

Density of briquettes was determine for relative compactness, easy to transportation and improves the burning quality of briquettes and also used for increase It is clear that rice straw briquette has more density as compare to other biomass. Average weight of briquettes was found different with the different biomass used .it was found maximum for B3 and minimum for the briquette .Average volume of the briquette was also found different for the each type of briquette because of shrinkage of briquette in diameter , it depend on the moisture content of the biomass . Hence the density of B3, briquettes was found maximum 0.91g/cm^3 , this show that means it is more durable and has higher strength for transportation as well as higher burning time as compare to other biomass briquettes.

Table 4.1: Density of briquettes

Briquettes	Average Weight of briquette, (gm)	Average Volume of briquettes, (cm^3)	Average Density of briquette, (kg/m^3)
B1	500	28.09	1.7
B2	450	22.77	1.9
B3	400	28.09	1.4

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4.3 Combustion Characteristics

4.3.1 Proximate Analysis

The value of proximate analysis of fuels is important because they give an approximate idea about the energy values and extends of pollutant emission during combustion. The percentage is proximate value of the different contents. Data recorded that the maximum moisture content 7.64% was found in B1 briquette and minimum 6.18% in B3 briquette as comparison to other biomass. B1 briquette left maximum ash content (16.23%) as residue while minimum (9.56%) ash content was observed in B3 briquette after combustion. The optimum volatile matter was found in B1 briquette (66.09%) and minimum (63.29%) for B3. The B3 briquette content maximum (18.97%) fixed carbon percentage and minimum (10.01%) was observed on briquettes. The higher calorific value was obtained maximum for B3 as 4086 kcal/kg which emits the high energy as compare to other briquettes and the maximum value was found for B1 as 3356 kcal/kg

Table 4.2: Proximate Analysis of Produce briquettes

Sr. No	Briquette	Parameters				
		MC (%)	Ash (%)	VM (%)	FC (%)	CV (kcal/kg)
1.	B1	9.77	24.44	64.44	1.35	2389.86
2.	B2	12.00	20.00	63.00	5.00	3188.1
3.	B3	6.66	15.00	62.22	16.12	3227.52

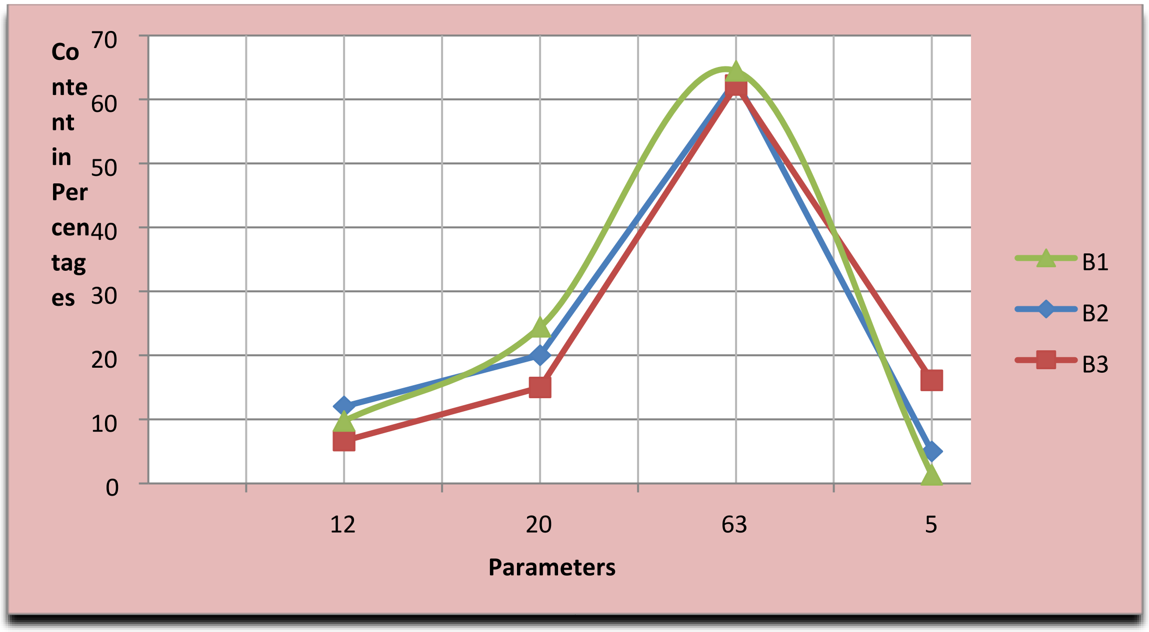

Fig 4.1: Proximate analysis of Briquette

4.4 Ultimate analysis

The ultimate analysis indicates the various elemental chemical constituent such as carbon, hydrogen, oxygen, sulphur. It is useful in determining the quantity of air required for combustion rate and the volume and combustion gases. The composition of the briquette analysis on an as – received basis showed B1 briquette 43.26% carbon, 5.2% hydrogen, 32.72% oxygen, 2.16% nitrogen, and 0.43% sulphur, and B2 briquette 46.46% carbon, 5.6% hydrogen, 30.3% oxygen, 2.27% nitrogen, and 0.56% sulphur.

Table 4.3: Ultimate analysis of briquettes

Sr. No	**Content**	**Briquettes**		
		B1	**B2**	**B3**
1	C	43.26	46.42	49.86
2	H	5.2	5.6	5.72
3	O	32.72	30.3	33.16

4	N	2.16	2.27	1.31
5	S	0.43	0.56	0.39

And B3 briquette 49.86% carbon, 5.72% hydrogen, 33.16% oxygen, 1.31% nitrogen and 0.39% sulphur. The results agree with the observation made by Chaney (2010) who reported that analysis of biomass using the gas analysis procedure reveled the principle constituents as carbon, which comprises between 30% to 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 normally makes up less than 1% of dry biomass.

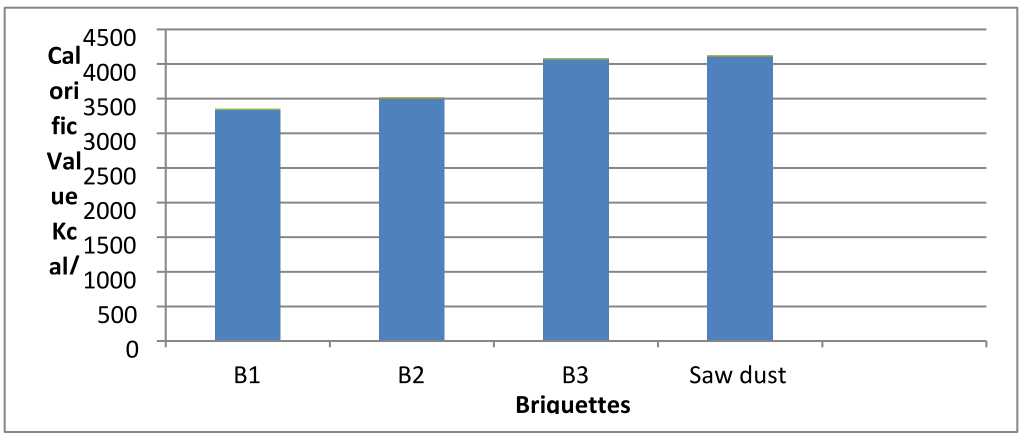

Fig 4.2: Calorific Value of briquette

4.5 Cost Analysis

Data on cost of production of briquettes with different biomass is presented. It is clear that cost of production varies with the different type of biomass used for briquette production.

Table 4.4: Cost analysis of briquette production.

Sr. No	Briquette	Cost of production. Rs. (Machine unit+ briquetting)	Gross income (Rs/h)	Net income (Rs/h)	Cost of production (Rs/kg)
1	B1	123.63	164	40.37	0.98
2	B2	128.63	184	55.37	1.2

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3	B3	138.63	188	49.37	1.05

The cost of operated machine was remaining constant Rs. 23.63 per hour for all types of biomass briquette production, while cost of production of briquettes was determined different for each biomass due to its purchasing rate. Cost of production by power operated machine was found maximum for the production of B3 briquettes as Rs. 138.63 per hour and minimum for the B1 briquette as Rs. 123.63 per hour. The gross income (Rs/h) from the selling of briquettes @ 4 Rs/kg was found maximum for the B3 briquettes as Rs.188 per hour and minimum for the B1 and briquettes as Rs. 164.00. The net income generated was found maximum for the B2 briquettes as Rs. 55.37 per hour and minimum for the B3 Rs. 49.37 per hour. Hence, the briquette production from the B2 using power operated machine was found more profitable compared to other biomass briquettes.

•Cost of operation of Production:

The cost of operation of briquetting production by power operated machine was calculated by piston press machine.

Rice Straw= Rs 1 /kg

Rice Husk= Rs 1 /kg

Cow Dung = Rs 1 /kg

Saw Dust= Rs 2 /kg

1) **B1 (Rice straw + Cow dung): (10:40)**

Material cost = 10×1+40×1

= 10+40

= 50

Cost of production = labor cost + material cost

= 50+ 50

= 100 /hr.

Income from briquette sold @4 Rs/kg

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Production = 41 kg/hr.

Gross income = 41×4

= Rs 164 /hr

Net income = Gross income – Cost of production

= 164-100

= Rs 64 /kg.

Cost of production of 1 kg briquette = 64/41

= 1.56 Rs/kg.

2) **B2 (rice husk + rice straw + cow dung): (20:5:40)**

Material cost = 10×1+ 5×1+ 40×1

= 10+5+40

= 55

Cost of production = labor cost + material cost

= 50+ 55

= 105 /hr.

Income from briquette sold @ 4 Rs/kg

Production = 46 kg/hr.

Gross income = 46×4

= Rs 184 /hr

Net income = Gross income – Cost of production

= 184-105

= Rs 79 /kg.

Cost of production of 1 kg briquette = 79/41

= 1.92 Rs/kg.

3) **B3 (Saw dust + rice straw + cow dung): (10:5:40)**

Material cost = 10×2 + 5×1+ 40×1

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= 20+5+40

= 65

Cost of production = labor cost + material cost

= 50+ 65

= 115 /hr.

Income from briquette sold @ 4 Rs/kg

Production = 47kg/hr.

Gross income = 47×4

= Rs 188 /hr

Net income = Gross income – Cost of production

= 188-115

= Rs 73 /kg.

Cost of production of 1 kg briquette = 73/47

= 1.55 Rs/kg.

CONCLUSIONS

Recent estimate state that the total agro- residue availability in India is more than 500 million metric tons per annum. Around 20-25 % of it is used to produce energy (Murali et al,2015). Fossil based technology is the primary source in India that meets the energy requirement in small as well as large industrial applications. Briquetting is a technology for densification of agricultural residues or wastes to increase their bulk density reduce their moisture and make briquettes of uniform sizes and shapes for easy handling, transport and storage. Briquettes can be defined as a product formed from physic- mechanical conversion of loose and tiny particle size materials with or without binder in different shapes and sizes.

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In this study, an appropriate, cost effective an low density briquette produce by different biomass like rice straw, and saw dust on the basis of varies studies conducted in the present research work following result are obtained.

1. Comparison of different biomass ratio of the briquette production was carried out. The B3 – saw dust, rice straw, and cow dung in proportion of (20:05:40) produced heavier briquette as compared to the other two ratio. Diameter of briquette in the each case are same. But little in length observed. Longest briquette (6.19cm) is produced with the B3 briquette followed by the first and second ratio of material.

2. The physical properties and proximate analysis was carried out for produced briquette. Maximum compressed density 0.91 g/cm^{3}wasobtained in B3 briquette. Maximum moisture content (63.11%) was found in B2 – rice husk, rice straw, cow dung (10:05:40), briquette and minimum moisture content (53.64%) B3 briquette.
3. Maximum (16.23%) and minimum (9.56%) ash content was obtained in B1 rice straw and cow dung (10:40), briquette and B3 briquette respectively. Optimum volatile material was found in B1 briquette as 66.09% and minimum 63.2% for

B3 briquette, maximum fixed carbon percentage (18.97%) and minimum (10.03%)was determined in B3 and B1 briquette respectively. The higher calorific value was obtained for B3 briquette as 4086 kcal/kg which emits the higher energy as
compared to other biomass.

4. Ultimate analysis indicate the various elemental chemical constituent such as carbon, hydrogen, oxygen, sulphur, in B1 briquette 43.26% carbon, 5.2% hydrogen, 32.72% oxygen, 2.16% nitrogen, 0.43% sulphur, and B2 briquette 46.46% carbon, 5.6% hydrogen, 30.3% oxygen, 2.27% nitrogen, and 0.56% sulphur, and B3 briquette 49.86% carbon, 5.72% hydrogen, 33.16% oxygen, 1.31% nitrogen, and 0.39% sulphur.
5. Comparison of combustion behavior of produced or commercial briquette that the for B3 briquette have highest highest calorific value among B1 and B2 that is 4086 kcal/kg, but it is less as compared to coal (4726 kcal/kg), and it is also show that the ratio of water evaporated to fuel used coal contains the higher value that is 0.61 ml/g that the rest three.

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6. The cost of briquette production per hour was maximum Rs 135.63 for B, Rs 123.63 and Rs. 128.63 for B1 and B2 briquettes respectively.

Conclusion-2

1. Rice straw produced in large quantity as a byproduct of crop production can be converted into high quantity and durable soil fuel briquette that will be suitable for both domestic and industrial energy production.
2. The power operated machine can be used to produce low density briquette which can use as domestic fuel in local stove and for industrial purpose.
3. The heating value calculated at the optimum biomass binder ratio were sufficient to produce heat required for household cooking in rural communities and small scale industrial application like furnace and boiler.

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