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Recommendation proposal

Development and evaluation of briquetting machine for carbonized de-oiled cashew nut shell and rice husk

Name of the Scientists: Dr. S. H. Sengar, Assistant Professor
Dr.Y.P.Khandetod , Professor and Head
Dr. A.G. Mohod, Associate Professor

Submitted by

Department of Electrical and Other Energy Sources
Faculty of Agricultural Engineering
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth,
Dapoli, Dist. Ratnagiri

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PART- I: General information

Project Code	
Project Title	Development and evaluation of briquetting machine for carbonized de-oiled cashew nut shell and rice husk
Name of Department Where the project was undertaken a) Name of Department b) Location of Project	 Department of Electrical and Other Energy Sources Faculty of Agricultural Engineering Department of Electrical and Other Energy Sources Faculty of Agricultural Engineering
Name of Scientist	Dr. S. H. Sengar, Assistant Professor Dr. Y.P.Khandetod , Professor and Head Dr. A.G. Mohod, Associate Professor
Objectives	1. Study of properties of raw and carbonized de-oiled cashew nutshell and rice husk for briquetting. 2. Development and evaluation of screw conveyer type briqetting machine for carbonized biomass
Year of start	2009-2010

PART- II: Technical information

Methodology

The deoiled cashew shell, rice husk and grass were selected as major biomass materials for characterization for briquetted fuel. In addition to above major biomass materials saw dust, glyricidia and cow dung were used as minor elements for briquettes formations. The proximate analysis (ASTM 3172-75) of various constituents of biomass for briquetting in as raw, hydrolysed and carbonized form was carried out as per standard procedures. Raw, hydrolyzed and carbonized biomass was used for the preparation of briquetting using 1 hp briquetting machine. Carbonized biomass was found more suitable to prepare the briquettes than raw and hydrolysed biomass in 1 hp screw type briquetting machine (Plate-1) and hence the carbonization processes was further evaluated.

Plate: 1. Briquetting of raw hydrolyzed biomass

Experimental set up for carbonization of cashew nut shell

The carbonization of CNS was carried out in developed small capacity single drum kiln, which accommodated about 5 kg cashew nut shells. The kiln was designed with fifteen hole of 10 mm diameter for supply of the air and with outlet of 10 mm diameter for the oil at the bottom and vent for the exhaust gases at the top (Plate 2). The capacity of kiln was suitable for small amount of material and the kiln can be fabricated locally. Detail technical specifications of kiln is depicted in Table 1. Kiln filled with biomas was burned directly from top and then closed the kiln by lid. Temperatures were observed at different locations of kiln and oil (CNSL) was collected from the bottom side of kiln periodically. Time require to complete carbonization process and amount of char obtained in kiln was measured at the end of process.

Plate: 2. Carbonization process

Table: 1. Overall dimensions of kiln

Particular	Dimensions
A) Kiln cylinder	
1. Total height	51cm
2. Diameter	30cm
3. Thickness	1cm
4. Diameter of bottom vent	0.5cm
5. Material	Mild steel
B) Kiln lid	
1. Total height	2.5cm
2. Diameter	31cm
3. Thickness	1cm
4. Diameter of top vent	0.8 cm
5. Material	Mild steel
C) Overall height of kiln	52 cm

Process for briquette preparation

The carbonized cashew shell, rice husk and grass were used as major constituents for briquetting with 5 % karanj oil as binding agent. The various combinations of major constituents were tried in order to get briquettes of the desired quality. Different combinations as Combination C1-50:25:25, Combination C2-25:50:25 and Combination C3- 25:25:50 for cashew shell, grass and rice husk were made for observing the properties of briquettes. The known quantity of water was added in mixture using thumb rule that the material should get bound by hand pressing after addition of water. The mixture was fed to briquetting machine and briquetting machine was operated at rated 1425 rpm speed and 1 Hp power.

Screw press extruder type briquetting machine

The screw press extruder type briquetting machine was used in the present study. It consisted of driving motor, screw, die, and hopper and power transmission system. Pulley and belt were used to transmit power from motor to the screw. The raw material was fed to the hoppers, which fed it to screw by gravity. As the material was pushed forward, it got compressed and binded material came out of die in the form of briquettes. The detail technical specification of screw extruder type briquetting machine is shown in Table 2. The pictorial views of briquetting machine are shown in Plate 3.

Table: 2. Technical specifications of the screw extruder type briquetting machine

Sr. no.	Particular		Specifications
1	Screw dimensions	No of turns	= 4
		Screw pitch	= 6 cm
		Maximum diameter of screw	= 9 cm
		Minimum diameter of screw	= 6 cm
2	Die dimensions	No of exit tubes	= 3
		Diameter of exit tube	= 2.5 cm
		Length of exit tube	= 4 cm
3	Voltmeter	Analog with range	= 0 to 300V
4	Ammeter	Analog with range	= 0 to 30 A
5	Pulley and belt	Diameter of driven pulley	= 26 cm
		Diameter of driving pulley	= 9 cm
		Belt type	V-belt
6	Motor	Single phase induction motor	
		Power	= 1Hp
		Speed	= 1425 rpm
7	Overall dimensions	Overall length of machine	= 31 cm
		Overall width of machine	= 31 cm
		Overall height of machine	= 62 cm

Plate 3(a) Side view of screw pressed briquetting machine

(b)

Plate: 3(b). Briquetting machine

Analysis of briquetted fuel

Physical properties of briquettes

The dimensions of the briquettes were found using vernier caliper. The physical properties like overall length, diameter of briquettes, density of briquettes (ASTM-873-82), shatter resistance, tumbling resistance, resistance to water penetration were observed for suitability.

Bulk density

The size of samples used for determining bulk density was 30-50mm. Bulk density was determined by pouring the sample from a height of 150 mm into a vessel. The weight of the sample required for filling the vessel, without compaction was measured using electronic balance. The volume of vessel was computed after measuring the dimension of vessel. The bulk density was determined by using the following relationship.

$$\text{Bulk density} = \frac{\text{weight of material}}{\text{volume of vessel}} \qquad \text{--------------(1.1)}$$

Shatter indices

Shatter indices were used for determining the hardness of briquettes. The briquette with known weight and length was dropped on concrete floor from the height of one meter. The weight of disintegrated briquette and its size was noted down. The percent loss of material was calculated. The shatter resistance of the briquettes was calculated by using following relation (1.2).

Percent weight loss = $\frac{w_1 - w_2}{w_1} \times 100$ ---------------(1.2)

% Shatter resistance = 100 - % weight loss

Where,

w_1 = Weight of briquette before shattering

w_2 = Weight of briquette after shattering

Tumbling test

Tumbling test was used for testing the durability of briquetted fuel. The cuboid formed by angle iron frame having dimensions of 30×30×45 cm and fixed over hollow shaft diagonally was used to conduct the tumbling test. The sample of briquettes was put inside and cuboid was rotated for 15 minute. After 15 minutes of tumbling action the briquette was taken out weighed and percent loss was calculated by using relation (1.3).

Percent weight loss = $\frac{w_1 - w_2}{w_1} \times 100$ -----------------(1.3)

Durability Index = 100 - % weight loss

Where,

w_1 = Weight of briquette before tumbling,

w_2 = Weight of briquette after tumbling

Resistance to water penetration

It was measured as percentage water absorbed by a briquette when immersed in water. Each briquette was immersed in water at 27°C for 30 seconds. The percent water gain was then calculated and recorded by using relation (1.4).

% Water gained by briquette = $\frac{w_2 - w_1}{w_1} \times 100$ -----------------(1.4)

Where,

w_1 = Initial weight of briquette

w_2 = Final weight of briquette

% Resistance to water penetration = 100 - % water gain

Degree of densification

Degree of densification is defined as percent increase in density of biomass due to briquetting. Degree of densification represents ability of material to get bind.

$$\text{Density of densification} = \frac{\text{Density of briquette} - \text{Density of raw material}}{\text{Density of raw material}} \text{------------ (1.5)}$$

Energy density ratio

The energy density ratio is the ratio of energy content per unit volume of raw material and the energy content per unit volume of briquetted fuel. The energy density ratio of briquetted fuel was calculated by using following relationship (1.5)

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$$\text{Energy density ratio} = \frac{\text{Energy content of briquetted fuel per unit volume (Kcal/m}^3\text{)}}{\text{Energy content of raw material per unit volume (Kcal/m}^3\text{)}} \text{---------------(1.6)}$$

Thermal properties of briquettes

The important thermal properties of briquette include their calorific value, volatile matter, ash content and fixed carbon content.

The determination of volatile matter, ash content, fixed carbon involves same procedure as that of raw biomass material.

Calorific value

The calorific value (ASTM-711) of briquetted fuel was determined by using bomb calorimeter. The calorific value of briquetted fuel was determined by using following relationship (1.7).

$$\text{Calorific value (Kcal/kg)} = \frac{(W + w) \times (T_1 - T_2)}{X} \text{------------------------------(1.7)}$$

Where,

W = weight of water in calorimeter (kg),
w = water equivalent of apparatus
T_1 = initial temperature of water (ºC),
T_2 = final temperature of water (ºC)
X = weight of fuel sample taken (kg)

The experimental set up of determination of calorific value using bomb calorimeter is shown in Plate 4. Calorific value of briquetted fuel for each treatment was determined.

Plate: 4. Bomb calorimeter

Thermal efficiency using water boiling test

Volume of the pot was measured and filled up to 2/3 by water. utensil was kept on stove and covered with propped lid for minimizing the losses. Thermometer was fixed in central part of utensil. Two kg of briquettes were measured and made into four parts for testing. Ambient temperature (T1) and initial temperature of water in a utensil were measured. Final temperature of water after boiling was observed. The fire was continued by burning briquettes to heat water to vaporize until the given briquettes were used up. Then utensil lid was removed and evaporation was continued till the water in utensil become at its original temperature. utensil from the cook stoves was separated; cooled it for 2 hours and volume of water was measured for the calculation of thermal efficiency as following relationship (1.8) shown in Plate-5.

$$\text{Thermal efficiency} = \frac{\text{Sensible heat + latent heat}}{\text{Quantity of fuel used X calorific value}}$$

$$= \frac{Wi\ Cp\ (T_2 - T_1) + (Wi - Wf) \times L}{\text{Quantity of fuel used X calorific value}} \quad \text{-------(1.8)}$$

Where,

Wi = initial volume of water, kg, Cp = specific heat of water, J/kg °c

T_2 = final temperature of water, °c, T_1 = initial temperature of water, °c

Wi = initial volume of water taken, kg, Wf = final volume of water, kg

L = Latent heat of water = 540 kcal/kg

Plate: 5. Water boiling test on cook stove

Results and Discussions

Proximate analysis of Biomass

Selected biomass was utilized in three forms i.e. raw biomass, hydrolyzed biomass and carbonized biomass for determination of different properties (Table 3-6 and Fig. 1-3). Maximum percentage of fixed carbon (19.53 per cent) was obtained from raw cashew shell, where as in grass and rice husk it was 19.24 per cent and 16.76 per cent respectively. In hydrolyzed biomass, fixed carbon ranged from 5.37 to 15.32 per cent where as in carbonized biomass, it varied from 39.7 to 60.08 per cent. Carbonized biomass was found suitable as compared to raw biomass and hydrolyzed biomass for briquetted fuel.

Table: 3. Proximate analysis of raw biomass

Sr. No.	Sample	Moisture content (%)	Volatile matter (%)	Ash content (%)	Fixed carbon (%)
1	Cow dung	6.93	57.67	19.06	16.34
2	Cashew shell	10.22	69.12	1.135	19.53
3	Grass	7.62	64.57	8.57	19.24
4	Glyricidia	11.71	67.27	10.84	10.18
5	Rice husk	8.74	60.99	13.51	16.76
6	Saw dust	9.29	65.36	22.32	3.03

Table: 4. Proximate analysis of carbonized biomass

Sr. No.	Sample	Moisture content (%)	Volatile matter (%)	Ash content (%)	Fixed carbon (%)
1	Cow dung	3.99	30.42	5.98	59.60
2	Cashew shell	3.13	49.34	0.95	46.58
3	Grass	4.53	52.17	3.94	39.37
4	Glyricidia	4.29	50.91	4.77	40.04
5	Rice husk	3.97	29.99	5.96	60.08
6	Saw dust	4.05	44.22	7.71	44.03

Table: 5. Proximate analysis of hydrolyzed biomass

Sr. No.	Sample	Moisture content (%)	Volatile matter (%)	Ash content (%)	Fixed carbon (%)
1	Cow dung	34.91	38.72	18.85	7.52
2	Cashew shell	33.84	53.68	0.94	11.55
3	Grass	38.56	44.62	7.11	9.7
4	Glyricidia	45.98	32.02	9.85	12.15
5	Rice husk	39.35	44.15	11.13	5.37
6	Saw dust	35.36	28.91	20.42	15.32

Table. 6 Higher calorific Value of biomass

Sr. No.	Sample	Raw kcal/kg	Carbonized kcal/kg
1	Cow dung	2821.18	3021.10
2	Cashew shell	4300.00	6200.29
3	Grass	3108.52	3753.39
4	Glyricidia	3155.26	3585.79
5	Rice husk	3267.03	3575.96
6	Saw dust	*3703.47*	3965.2

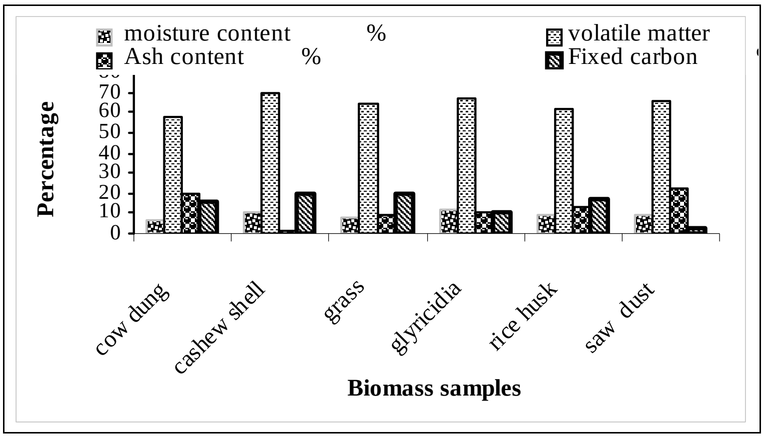

Fig. 1. Proximate analysis of raw biomass

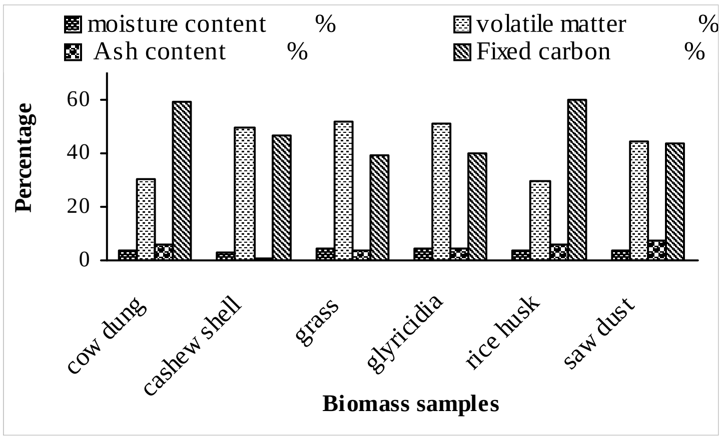

Fig. 2. Proximate analysis of carbonize biomass

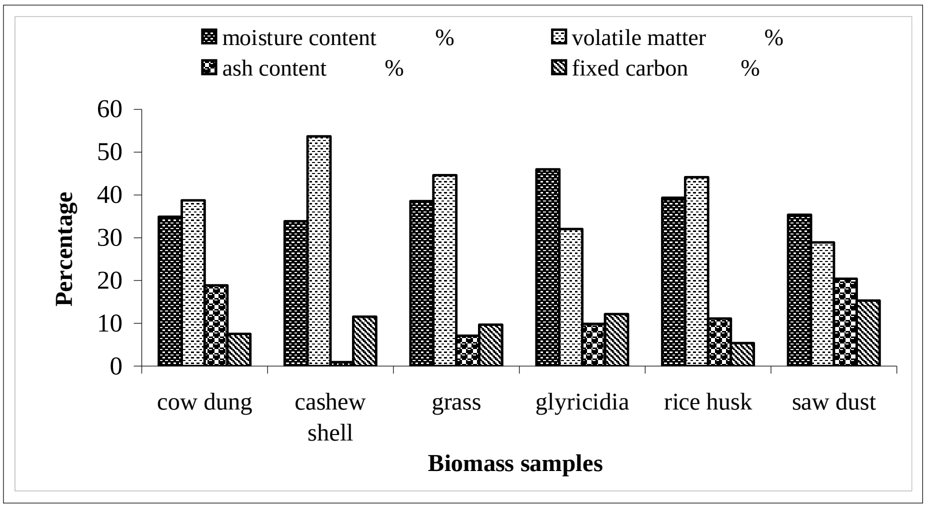

Fig. 3. Proximate analysis of hydrolyze biomass

Direct heating method of carbonization

Sample of the cashew nut shell was weighed and recorded. Developed kiln was checked for any leakage. The wire mesh grate was kept for support at the bottom of the kiln. The height of the grate support was 6 cm above the bottom. The air was allowed through grate for oxidation, which would make heat flow inside the kiln more effective. Kiln was closed after placing the CNS for the carbonization. Initial start up firing was carried out using wood chips that would transfer the heat to the CNS. Continuous observations were noted to know the transfer of heat. The kiln air inlet size was adjusted based on the changes observed at the exhaust. Inside temperature of the CNS, outside temperature of the kiln and temperature of the exhaust fumes were recorded for the every 60 minutes. The time was recorded and the carbonization stage changes were noticed.

The kiln was continuously observed to see the smoke colour change from blue to light blue, it found that as all the CNS turned into charcoal; the light blue smoke would become clearer. The kiln was allowed to cool down for 8 hours. After that, ash and char were separated, weighed and recorded.

It was observed from the Fig. 4 that time required to reach maximum temperature inside the kiln for obtaining CNS char was 14-15 hours. Inside temperature varied more drastically than outside exhaust temperatures. Average temperature of shell at core part of kiln varied from 86°C to 445°C. Average exhaust temperature at the top vent varied from 172°C to 218°C and outside temperature of the kiln was recorded in the range of 44°C to 60°C. It was also observed that smoke colour gradually changes from blackish to white and then from white to colourless when all CNS turned to charcoal at the temperature 350°C onwards in this method.

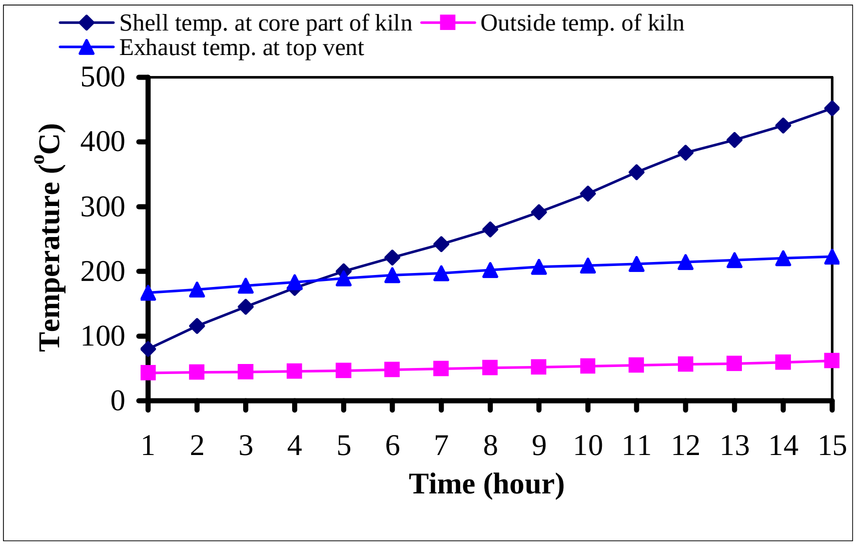

Fig. 4. Variation of carbonization temperature with time during direct method

Similarly, average char percentage, oil percentage and ash percentage were observed and recorded. From the Fig.5, it was observed that maximum oil percentages obtained as 20.1 per cent and maximum char and ash percentages were recorded as 20.4 per cent and 3.1 per cent respectively.

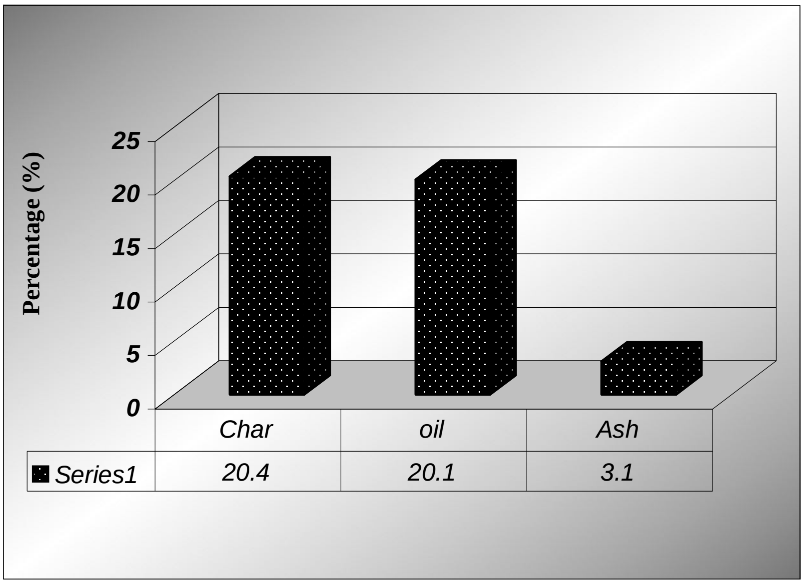

Fig. 5. Product of cashew shell during carbonization process.

Performance evaluation of briquetting machine

Performance evaluation of briquetting machine included operational parameters of raw material and operational parameters of machine. The performance of briquetting machine was carried out using three combinations of raw material as mentioned above.

Plate: 6. Sample of briquettes

The operational parameters of raw material for each combination during briquetting were recorded. The results obtained are depicted in Table 7.

It was observed that the total quantity of fresh briquette (Plate-6) obtained was found to be maximum for combination C-2 (0.8kg). The material output in the form of fresh briquettes was least in case of combination C-3 (0.5kg). Amount of unused material was highest for combination C- 3 (0.75kg) and was least for combination C-1(0.55kg). The moisture content of fresh briquettes coming out also ranged between 41.9 to 59.5 per cent, where as moisture content of dried briquettes ranged between 6.81 to 8.43 per cent. The drying of briquette was carried out in shade for a week.

Table: 7. Operational parameters of raw material

Particulars	Combinations		
	C_1	**C_2**	**C_3**
Weight of sample taken (kg)	0.5	0.5	0.5
Water added in raw material (kg)	0.7	1	0.75
Total weight of raw material and water (kg)	1.2	1.5	1.25
Weight of unused material (kg)	0.55	0.7	0.75
Weight of fresh briquettes obtained (kg)	0.65	0.8	0.5
Moisture content of fresh briquettes (%)	41.9	59.5	53.57
Moisture content of dried briquettes (%)	8.43	6.81	6.92

Operational parameters of briquetting machine

The operational parameters of briquetting machine were recorded during the productions of briquettes from each combination of raw material. The results obtained are depicted in Table 8.

Table: 8. Operational parameters of machine

Parameters	Combinations		
	C_1	C_2	C_3
Voltage, V	220	220	220
Current, A	3	3	3
Power consumed, kW	0.66	0.66	0.66
Time required (Sec)	65	70	80
Capacity of machine (Kg/hr)	36.11	41.14	22.5
Energy consumption kcal/kg	15.72	13.80	25.23
(kW-h/kg)	(0.0183)	(0.0161)	(0.0293)

It was observed that there was a smooth operation of briquetting machine and no operational difficulties were observed during the operation The average capacity of briquetting machine was about 35 kg/hr with average energy consumption of about 0.021 kWh/kg of briquetted fuel.

Analysis of briquetted fuel

The various properties of briquetted fuel were tested to analyze the briquetted fuel as follows.

Physical properties of briquettes

The physical properties of briquetted fuel after eight days of sun drying were recorded. The result obtain was depicted in Table 9.

Table: 9. Physical properties of briquettes

Properties of briquettes	C_1	C_2	C_3
Average length (cm)	6.05	5.3	4.98
Average diameter (cm)	2.25	2.27	2.24
Average weight of briquettes occupied in vessel (g)	742	560	675
Average volume of vessel(cm^3)	1500	1500	1500
Average density (g/ cc)	0.495	0.373	0.450

It was observed that the average length of briquettes varied from 4.98cm to 6.05 cm. The average diameter of briquettes varied from 2.24 cm to 2.27cm. The average bulk density of briquettes was maximum for combination C-1 (0.495 g/cc)) as compared to combination C2 (0.895 g/cc) and combination C-3(0.450 g/cc) briquettes.

Calorific value

The Calorific value of briquetted fuel shows in Table 10, the calorific value of combination C-1 briquettes was found highest (5154.58 kcal/kg) and briquettes from combination C-3 had least calorific value of 4188.64 kcal/kg depicted in Fig 6.

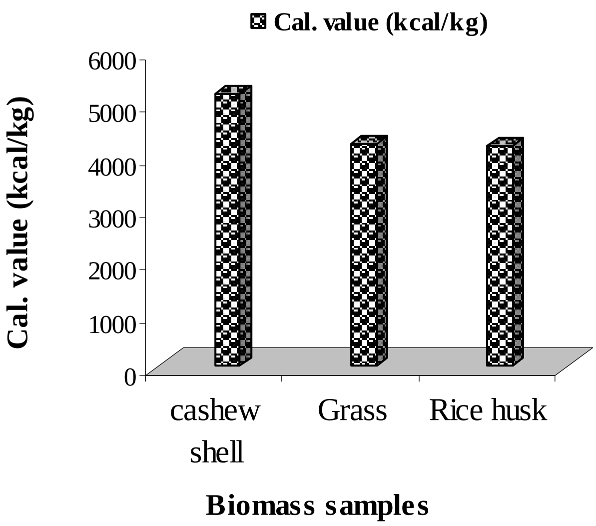

Fig. 6. Calorific value of briquetted fuel

Table. 10 Higher calorific Value of Briquetted fuel

Sr. No.	Sample	Proportions	Briquettes	kcal/kg
1	Cashew nut shell : Other biomass	50:50	Not formed	-
2	Rice husk: Other biomass	50:50	Not formed	-
3	Grass: Other biomass	50:50	Not formed	-
4	Cashew nut shell : Other biomass	75:25	Not formed	-
5	Rice husk: Other biomass	75:25	Not formed	-
6	Grass: Other biomass	75:25	Not formed	-
7	Cashew nut shell : Other biomass	100:0	Not formed quality	6200
8	Rice husk: Other biomass	100:0	Not formed quality	3576
9	Grass: Other biomass	100:0	Not formed quality	3753
10	Cashew nut shell: Grass: Rice husk	50:25:25	Better Quality briquettes formed	5155
11	Cashew nut shell: Grass: Rice husk	25:50:25	Quality briquettes formed	4218
12	Cashew nut shell: Grass: Rice husk	25:25:50	Quality briquettes formed	4189

Shatter indices of briquetted fuel

It was observed from Fig.7; out of three combinations the briquettes from combination had good shatter indices with retention of 97.33 per cent of its weight on concrete floor. Where as the percent retention of briquettes from combination C-3 was about 94.4 per cent of its weight, which was least among all the combinations.

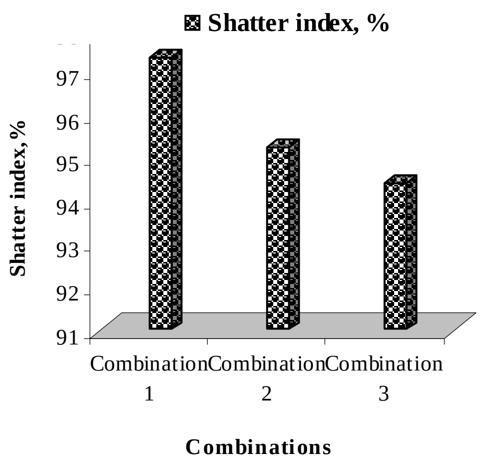

Fig. 7. Shatter indices of briquetted fuel

Tumbler Test

From the result of tumbling test it was observed that briquette from combination C-2 have least durability (92.12 per cent) compared to highest durability index of 95.83 per cent for briquettes from combination C-1 Shown in Fig.8. It may due to oil content in cashew shell raw material, which acted as its own binding properties.

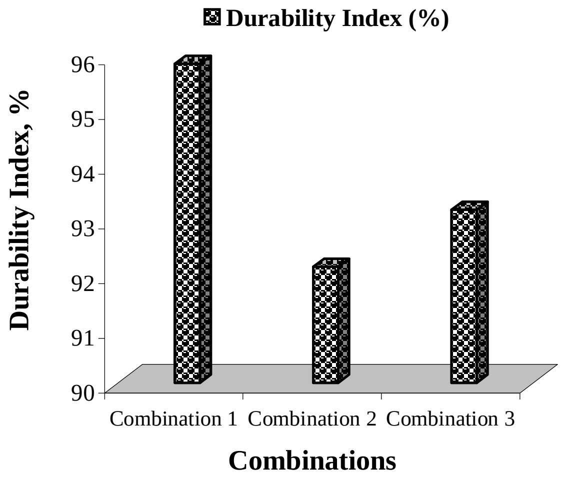

Fig. 8. Durability indices of briquetted fuel

. **Degree of densification**

The degree of densification was found least for briquettes for combination C-3 (25.17 per cent). The briquettes from combination 1 had highest degree of densification of 32.79 per cent depicted in Fig. 9.

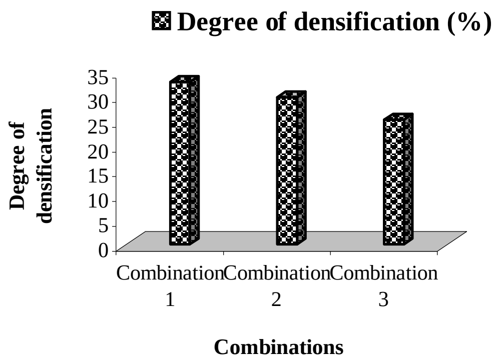

Fig. 9. Degree of densification of briquetted fuel

Energy density ratio

Energy density ratio was observed to be maximum for combination C-1 briquettes having energy density ratio of 1.83 followed by combination C-2 and combination C-3 briquettes having energy density ratio of 1.59 and 1.51 respectively.

Least energy density ratio was reported for combination C-3 briquettes as 1.84 Shown in Fig.10.

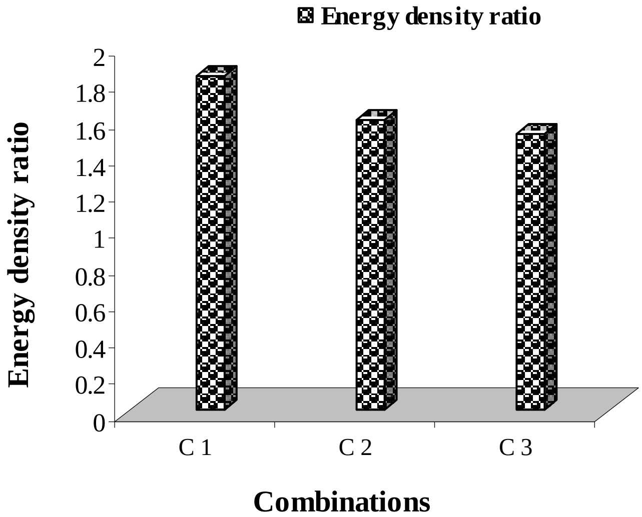

Fig. 10. Energy Density ratio of briquetted fuel

Resistance to water penetration

After analysis the various properties of briquetted fuel from each combination, it was observed that the briquetted fuel from combination C-1 had desirable good properties as compared to the briquetted fuel from other two combinations. The briquetted fuel from combination C-1 required minimum energy than combination C-3 for production and low water absorption properties shown in Fig.11 and Table 11. The best shatter and durability indices showed that the briquette have good shock and impact resistance and are good for handling and transportation. The combination C-1 briquette also have good density ratio. Out of three, combination C-1 briquettes observed highest calorific value, hence selected for thermal efficiency test on cooking stove.

Table 11 Resistance to water penetration test of briquetted fuel

Combination No.	Initial weight, w_1 (g)	Final weight, w_2 (g)	% Water gain (w.b.)
Combination 1	9.25	10.09	9.12
Combination 2	6.01	8.41	39.82
Combination 3	7.03	10.05	43.28

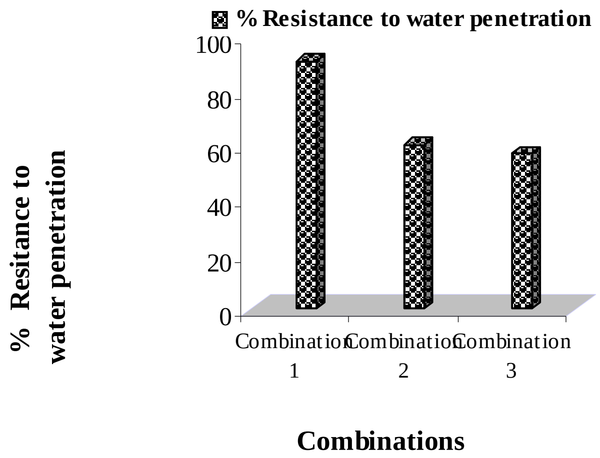

Fig. 11. Resistance to water penetration of briquettes

Water boiling test of briquetted fuel

Briquettes of combination C-1 were selected for water boiling test for checking their suitability in domestic use as fuel. It was observed the briquettes were burnt completely in Vikram stove and gave uniform flame. Very little ash was left after burning. The thermal efficiency of Vikram cooking stove using Cashew shell briquetted fuel was found to be 15.5 per cent.

Energy balance of briquetting of carbonized biomass

Energy balance was carried for process of briquetting by using measured calorific value of raw and carbonized cashew nut shell, grass and rice husk. The input and output heat balance was carried out on the basis of actual amount of carbon available in selected biomass and its utilization. Preparation of 10 kg briquettes using 50 :25:25 combination of cashew nut shell, grass and rice husk char, 45 kg (25:10:10) raw material was required which had a calorific value was 1,71,255 Kcal. Raw material produced only 8563 kcal with 5 per cent combustion efficiency. In concerning to production of energy from loose biomass, it is difficult to storage and hence biomass is converted into carbonization for additive advantages for suitability of storage. Energy reach char (49323 kcal) was produced from carbonization process. Energy required to processes the energy reach char was 5127 kcal (470 kcal manual + 4657 kcal oil energy). After processing of biomass, it produced 10 kg briquettes (51550 kcal) and 1 kg cashew nut shell oil (9955 kcal) which contain 61505 kcal energy shown in Fig.12.

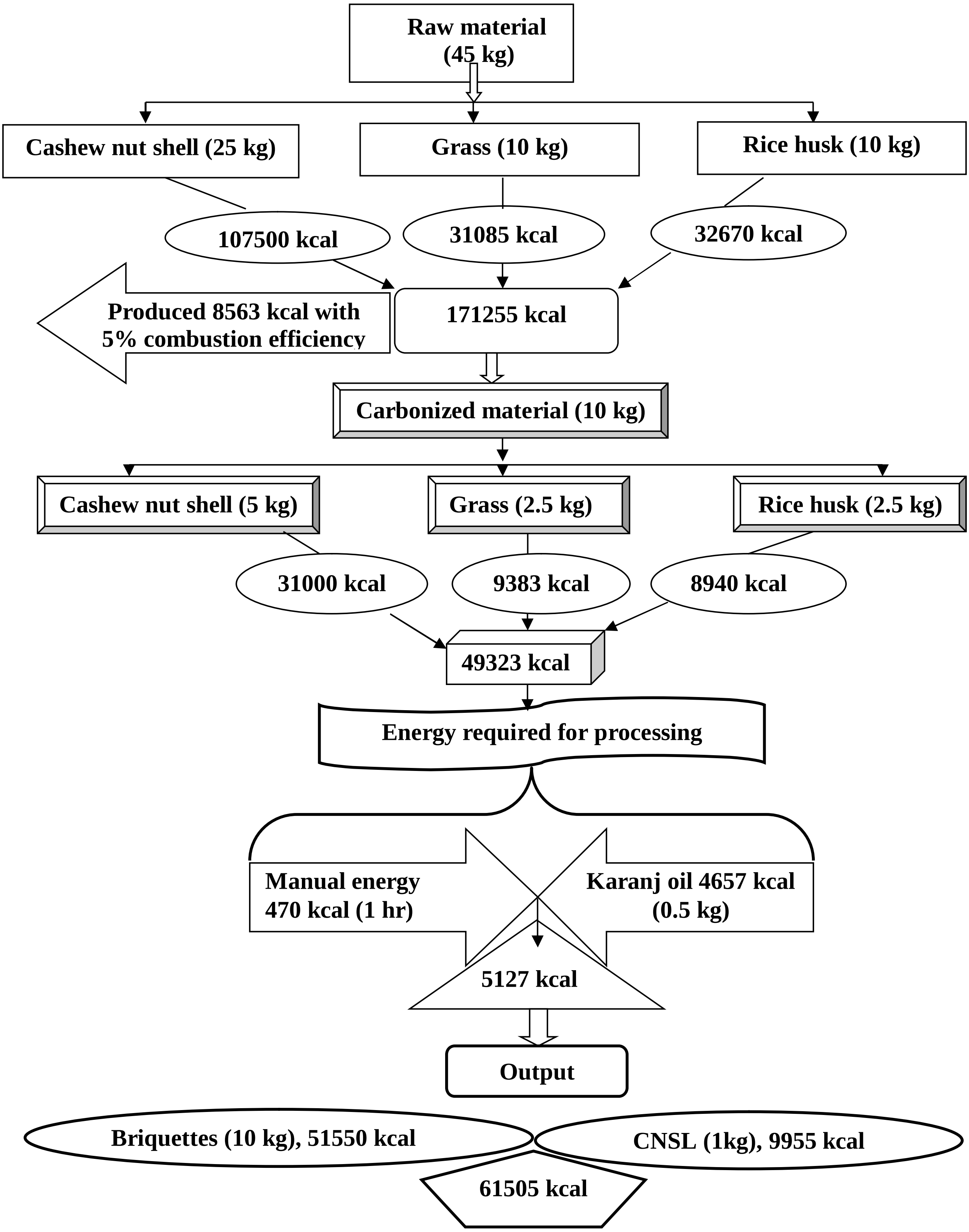

Fig. 12 Flow chart for energy balance for preparation of 10 kg briquettes

Economics

Cost economics

Cost analysis was carried out to check economic acceptability of briquetting plant by considering following assumptions:

1. Proportion of carbonized material to raw material is 1:3.3 i.e. is 30% of raw material.
2. Cost of briquetted fuel was 10 Rs/kg.
3. Output of machine was 36 kg/hr, 41 kg/hr, and 22.5 kg/hr for cashew shell, grass and rice husk respectively.
4. Initial cost of fabrication of machine was Rs. 15000.
5. Total electricity used during operation of plant was 2 kwh/day

1\. Total days for plant operation was 300 days

7\. Cost of electricity unit was 5 Rs.

8\. Plant operated 5 hrs in day.

9\. Karanj oil required 2700 kg.

10 Cost of Karanj oil 40/kg

Cost of installation of cashew briquetted fuel plant grass briquetted plant and rice briquetted fuel plant is depicted in Table 12, 13, 14 respectively. It includes total cost of screw extruder machine and cost of total labour required during days for plant operation on the market value, cost of briquette was formed as 10 Rs/ kg of briquetted fuel.

Electricity required to operate the plant, energy required to crush the carbonized material, cost of binding material as another biomass and particular raw biomass for briquetted fuel and repair and maintenance were consider for finalization of total revenue generated from briquetted fuel. Detail of income expenditure for different briquetted fuel is depicted in Table 15, on the basis of income and expenditure of briquetted fuel present worth of cashew outflow present worth of cash inflow and net present worth were calculated for cashew shell, grass and rice husk show in Table 16, 17 and 18 respectively.

Table 12 Cost of installation of briquetting plant for cashew shell

Sr. No.	Item	Quantity	Rate	Cost (Rs.)
1	Cost of casing + cost of motor	1	15000 Rs.	15000
2	Labour	300 days	150 Rs.	45000
3	Raw material	178200 kg (36 kg/hr)	2 Rs./kg	356400
	Total			**416400**

Table 13 Cost of installation of briquetting plant for grass

Sr. No.	Item	Quantity	Rate	Cost (Rs.)
1	Cost of casing +cost of motor	1	15000 Rs.	10000
2	Labour	300 days	150 Rs.	45000
3	Raw material	202950 kg (41 kg/hr)	1 Rs./kg	202950
	Total			**262950**

Table 14 Cost of installation of briquetting plant for rice husk

Sr. No.	Item	Quantity	Rate	Cost (Rs.)
1	Cost of casing +cost of motor	1	15000 Rs.	10000
2	Labour	300 days	150 Rs.	45000
3	Raw material	111375 kg (22.5kg/hr)	1 Rs./kg	111375
	Total			**171375**

Table 15 Details of income and expenditure for different briquetted fuel

Sr. No.	Particulars	Cashew shell	Grass	Rice husk
1	Briquettes (kg)	54000	61500	33750
2	Total revenue from briquetted fuel (Rs.)	540000 +1425600 =1965600	615000	337500
3	Cost of briquette preparation (oil, water, labour etc) (Rs.)	356400+45000 +108000 = 509400	202950+45000 +123000 =370950	111375+45000 +67500 =223875
4	Initial investment of (Rs.)	15000	15000	15000
5	Cost of electricity (Rs.)	5000	5000	5000
6	Total operation and maintenance cost (Rs.)	500	500	500

Table 16 Cash flow for carbonized cashew shell briquetted fuel (C1-50:25:25)

Year	Cash outflow	PW of Cash outflow	Cash inflow	PW of Cash inflow	NPW
1.0	2.0	3.0	4.0	5.0	(5)-(3)
0.0	529400	529400.0	0.0		-529400.0
1.0	514400.0	459285.7	1965600	1755000.0	**1295714.3**
2.0	514400.0	410076.5	1965600	1566964.3	1156887.8
3.0	514400.0	366139.8	1965600	1399075.3	1032935.5
4.0	514400.0	326910.5	1965600	1249174.3	922263.8
5.0	514400.0	291884.4	1965600	1115334.2	823449.9
6.0	514400.0	260611.0	1965600	995834.1	735223.1
7.0	514400.0	232688.4	1965600	889137.6	656449.2
8.0	514400.0	207757.5	1965600	793872.9	586115.3
9.0	514400.0	185497.8	1965600	708815.1	523317.3
10.0	514400.0	165623.0	1965600	632870.6	467247.6
11.0	514400.0	147877.7	1965600	565063.0	417185.3
12.0	514400.0	132033.7	1965600	504520.6	372486.9
13.0	514400.0	117887.2	1965600	450464.8	332577.6
14.0	514400.0	105256.4	1965600	402200.7	296944.3
15.0	514400.0	93979.0	1965600	359107.8	265128.8
16.0	514400.0	83909.8	1965600	320631.9	236722.2
17.0	514400.0	74919.4	1965600	286278.5	211359.1
18.0	514400.0	66892.4	1965600	255605.8	188713.5
19.0	514400.0	59725.3	1965600	228219.5	168494.2
20.0	0.0	0.0	1965600	203767.4	203767.4
TOTAL		**3788955.6**		**14681938.4**	**10892982.8**

Table 17 Cash flow for carbonized grass briquetted fuel (C2-25:50:25)

Year	**Cash outflow**	**PW of Cash outflow**	**Cash inflow**	**PW of Cash inflow**	**NPW**
1.0	2.0	3.0	4.0	5.0	(5)-(3)
0.0	390950	390950.0	0.0		-390950.0
1.0	375950.0	335669.6	615000.0	549107.1	**213437.5**
2.0	375950.0	299705.0	615000.0	490274.2	190569.2
3.0	375950.0	267593.8	615000.0	437744.9	170151.1
4.0	375950.0	238923.0	615000.0	390843.6	151920.6
5.0	375950.0	213324.1	615000.0	348967.5	135643.4
6.0	375950.0	190468.0	615000.0	311578.1	121110.2
7.0	375950.0	170060.7	615000.0	278194.8	108134.1
8.0	375950.0	151839.9	615000.0	248388.2	96548.3
9.0	375950.0	135571.3	615000.0	221775.2	86203.8
10.0	375950.0	121045.8	615000.0	198013.5	76967.7
11.0	375950.0	108076.6	615000.0	176797.8	68721.2
12.0	375950.0	96497.0	615000.0	157855.2	61358.2
13.0	375950.0	86158.0	615000.0	140942.1	54784.1
14.0	375950.0	76926.8	615000.0	125841.2	48914.4
15.0	375950.0	68684.7	615000.0	112358.2	43673.5
16.0	375950.0	61325.6	615000.0	100319.8	38994.2
17.0	375950.0	54755.0	615000.0	89571.3	34816.3
18.0	375950.0	48888.4	615000.0	79974.3	31086.0
19.0	375950.0	43650.3	615000.0	71405.7	27755.3
20.0	0.0	0.0	615000.0	63755.1	63755.1
TOTAL		**2769163.8**		**4593707.8**	**1824544.0**

Table 18 Cash flow for carbonized rice husk (C3-25:25:50)

Year	Cash outflow	PW of Cash outflow	Cash inflow	PW of Cash inflow	NPW
1.0	2.0	3.0	4.0	5.0	(5)-(3)
0.0	243875.0	243875.0	0.0		-243875.0
1.0	228875	204352.7	337500.0	301339.3	**96986.6**
2.0	228875	182457.7	337500.0	269052.9	86595.2
3.0	228875	162908.7	337500.0	240225.8	77317.1
4.0	228875	145454.2	337500.0	214487.4	69033.2
5.0	228875	129869.8	337500.0	191506.6	61636.7
6.0	228875	115955.2	337500.0	170988.0	55032.8
7.0	228875	103531.4	337500.0	152667.9	49136.4
8.0	228875	92438.8	337500.0	136310.6	43871.8
9.0	228875	82534.6	337500.0	121705.9	39171.3
10.0	228875	73691.6	337500.0	108666.0	34974.3
11.0	228875	65796.1	337500.0	97023.2	31227.1
12.0	228875	58746.5	337500.0	86627.8	27881.3
13.0	228875	52452.2	337500.0	77346.3	24894.0
14.0	228875	46832.4	337500.0	69059.2	22226.8
15.0	228875	41814.6	337500.0	61660.0	19845.4
16.0	228875	37334.5	337500.0	55053.6	17719.1
17.0	228875	33334.3	337500.0	49155.0	15820.6
18.0	228875	29762.8	337500.0	43888.4	14125.6
19.0	228875	26573.9	337500.0	39186.0	12612.1
20.0	0.0	0.0	337500.0	34987.5	34987.5
TOTAL		**1685842.2**		**2520937.2**	**835095.0**

Table 19 Economic indicators for three combinations of briquetted fuel

Particulars	**Cashew shell**	**Grass**	**Rice husk**
Net Present Worth (Rs)	10907714.3	1949762.2	551512.6
Pay Back Period (months)	3.6	8.5	9.7
Internal Rate of Return (%)	81	80	77
BCR for first year	3.8	1.6	1.4

All economic indications for different biomass briquetted fuel as Internal Rate of Returns (IRR), Pay Back Period (PBP), Benefit Cost Ratio (BCR), and Net Present Worth (NPW) are summarized in Table 18. It was observed from Table 18 that the cost of the plant is recovered within 3.6 to 9.7 months only i.e. the payback period of the plant was only 3.6 and 8.5 months for cashew shell and grass briquetted fuel respectively and after that the unit will produce net profit. Whereas payback period of rice husk briquetting plant is 9.7 months.

Conclusions

1. Fix carbon of carbonized cashew nutshell and rice husk were found as 47 per cent and 60 per cent.
2. Maximum percentage of fixed carbon in raw cashew nut shell was 19.53 per cent where as in raw grass and raw rice husk was 19.24 per cent and 16.76 per cent respectively
3. Carbonized biomass of deoiled cashew nut shell and rice husk was more useful for briquetting than raw cashew nut shell and raw rice husk.
4. Time required for obtaining CNS char was 14-15 hours inside the prototype kiln.
5. Carbonized biomass was found suitable as compared to as raw and hydrolyzed biomass for briquetted fuel.
6. It was observed that carbonized cashew nut shell briquettes had better shattering indices test, tumbling test, water boiling test as compared to grass and rice husk briquettes.
7. Calorific value was found more in carbonized cashew shell briquetted fuel as 5154.58 kcal/kg.

Recommendation

Carbonized de-oiled cashew nut shell, grass and rice husk powdered in proportion of 50:25:25 with addition of 5 % Karanj oil is recommended for briquette preparation of 2.25 cm diameter on screw type extruder machine.

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Scientists involved

.

(S. H. Sengar)
Assistant Professor

(A.G. Mohod)
Associate Professor

(Y.P.Khandetod)
Professor and Head

(Dilip MAHALE)
Associate Dean

Director of Research
Dr. Balasaheb Sawant Konkan Krshi Vidyapeeth,
Dapoli