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Performance evaluation of log making machine for production of log by using cattle dung and other agricultural residue

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Abstract
In this study log making machine was tested with different biomass like cattle dung and other agricultural residue. An automatic log making machine suitable for use in a rural community for making long log was selected for its performance evaluation. Cattle dung log can be used in place of fire wood. The performance of log making machine was evaluated for making cattle dung log by using cattle dung as a base material mixed with other agriculture residues rice husk, rice straw, saw dust and cocopeat agricultural waste were used in this study for log production. Logs were produced by using log making machine for different composition of biomass. The properties like moisture content of raw material, bulk density of raw material, total solid content of raw material, friction angle of raw material, capacity of the machine, efficiency of the machine, time to produce one log, analysis of prepared log such as shrinkage in diameter, shrinkage in length and shrinkage in weight were determined for checking the performance of machine. Range of moisture content of raw material was recorded 65% to 85%. Bulk density of raw material was determine in the range of 0.85 g/cm^3 to 1.15 g/cm^3. Friction angle of raw material and total solid content of raw material was determined in the range of 35^o to 50^o and 15.00% to 35.00% respectively. It was observed that machine perform satisfactory with all the treatment. The average efficiency of machine was recorded 84.02%. The cost of power operated log making machine was constant Rs 150.47 per hour for all types of biomass log production. Log produced from treatment L9 using power operated machine was found more profitable compared to other biomass log. It was found that time to produce one log by using different treatments are within the range of 1:00 min to 5:00 min. From energy point of view treatment L1 which is mixture of rice straw and cattle dung was found best. Shrinkage percentage in diameter, length and weight was recorded in the range of 20% to 35%, 3% to 15% and 73% to 83% respectively.

Keywords: Log making machine, bulk density, friction angle, total solid content, machine efficiency

1. Introduction
Energy is an important criterion in the life of a citizen. Today, the lifestyle of citizens is largely dependent on energy. The amount of energy required by the human population and the industrial sector is increasing day by day. The energy requirement will always exceed the energy supply. Thus there is a need to generate energy from various renewable resources to meet the energy demand. India is largely dependent on renewable sources. These renewable energy are solar energy, wind energy, tidal energy, biomass energy and geothermal energy. Biomass is one of the most important renewable energy sources which is easily available in the earth. Total of 320 million tonnes of agricultural waste such as dried sugarcane leaves, rice straw, rice bran, tree bark, wheat straw, mustard waste, rice husk, pigeon-pea stalk, groundnut shell, coffee husk, cotton stalk, sunflower waste, sugarcane bag gases, maize stalk, bajra cobs, cocopeat (coir dust) and corn stalk is produced by India. Similarly forest waste such as wood chip, twinges, saw dust, bamboo, wild grasses, shrubs, leaves and trash are also available. This residue is often burned in the open environment, creating problems of smoke and fly ash. About 100 million tonnes of agricultural waste is burnt in open ground, causing air pollution and huge loss of energy. Hence, alternate arrangement is needed to convert this biomass to generate energy (Patil *et al.*, 2021) [4]. There has been a recent push to restore the burning of fossil fuel with biomass. The replacement of this conventional energy with biomass waste would lower the overall pollution of the world. It is necessary to make strategy to convert biomass into a source of energy. By converting agricultural and forestry waste into useful biomass log can be used as a substitute in place of coal and wood. The waste biomass like rice straw, rice husk, coco peat, saw dust and cattle dung are gathered and used to make cattle dung

long log. By using different agricultural residue energy produced by adopting several processes such as thermo-chemical, biological, or chemical in which direct combustion may provide a direct near term energy solution. (Tabil 1996 [9]; Sokhansanj *et al.* 2006 [8]; Mani *et al.* 2006 [3]; Adapa *et al.* 2009) About 100 million tonnes of agricultural waste is burnt in open ground, causing air pollution and huge loss of energy. Farmers are still using tradition method for preparing cattle dung cake. This cattle dung cake used as a fire wood. In place of cattle dung cake farmers can be used log as a energy sources which is made by log making machine. In place of traditional method, farmers can be used log making machine for preparing cattle dung logs. Sometimes dung mixed with agricultural residue for reduction of moisture content. Cattle dung log is burnt to provide heat and flame for cooking, burning, boiling etc. The smoke from burning cattle dung log has been found to drive away insects including mosquitoes. This has led to the deliberate use of cattle dung as an insect repellent in some area. Due to eco-friendly, the log from cattle dung is very beneficial. This cattle dung log will be used for havan, yagya-pooja, rituals etc. Production rate of cattle dung log will also increase by using cattle dung log making machine. Within short run period of time farmers are able to prepare more number of logs with the help of log making machine. Chhattisgarh government is also focuses on doubling the farmer's income. Cattle dung log making machine will help to achieve this target of government. This paper present the performance evaluation of log making for preparing log by using mixture of cattle dug as a base material and other agricultural waste.

2. Materials and Methods

The study was conducted at Swami Vivekananda College of Agricultural Engineering and Technology and Research Station Raipur in the year of 2021-22. Log making machine was developed at college which is used in this study for its performance evaluation. Biomass namely saw dust, rice straw, rice husk, cocopeat and cattle dung was used in this study. Cattle dung was used as a base material. Different compositions of these biomass are presented in table 1. Performance of log making machine is depended upon the properties of raw material. properties of raw material such as moisture content, bulk density, friction angle, total solid content are highly affects the performance of log making machine. The machine efficiency, machine capacity, energy consumption, cost of operation are parameter of this study to evaluate the machine. The technical specification of the log making machine used in this study is depicted in table 2. Shrinkage percentage was also recorded during the entire research work. For preparing log, mixture was fed into hopper, which transfers material to screw auger by gravity. As material convey, it got compressed and mixed material comes out through exit tube in the form of particular size of log.

Table 1: Different composition of raw material for making log

Treatment	Composition	Ratio
L1	Cattle dung and Rice straw	10:1
L2	Cattle dung only	10:0
L3	Cattle dung and Saw dust	10:1
L4	Cattle dung and Rice husk	10:1
L5	Cattle dung, Saw dust and Cocopeat	67:2:1
L6	Cattle dung and Cocopeat	10:1
L7	Cattle dung, Rice husk and Cocopeat	67:2:1
L8	Cattle dung, Rice straw and Rice husk	67:2:1
L9	Cattle dung, Rice husk and Saw dust	67:2:1
L10	Cattle dung, Saw dust and Rice straw	67:2:1
L11	Cattle dung, Cocopeat and Rice straw	67:2:1
L12	Cattle dung, Rice husk, Cocopeat and Saw dust	65:1:2:2
L13	Cattle dung, Rice husk, Cocopeat and Rice straw	65:2:2:1
L14	Cattle dung, Rice straw, Saw dust, Rice husk and Cocopeat	70:1:1:2:1

2.1 Determination of Moisture Content

Oven dry method was used to determine moisture content of raw material on wet basis. Three sample of each mixed raw material were collected in the container for determination of moisture content. Initial weight of sample (W_I) was recorded than sample was dried at 104 ^{0}C to 106 ^{0}C under the oven for 24 hours to obtain bone dry (final) weight (W_f). Moisture content on wet basis was then calculated by using following formula (Singh and Sahay, 2019).

$$\text{Moisture Content}(\%) = \frac{Wi - Wf}{Wi} \times 100 \quad (1)$$

Where,
W_i = Initial weight of sample, g
W_f = Final weight of sample, g

2.2 Bulk Density

Core cutter method was used to determine bulk density of raw material. Bulk density of mixed raw material is its mass per unit volume. Bulk density of raw material is determined by using standard method IS: 4333-1967.Height and diameter of core cutter was 12 cm and 8cm respectively. Volume of core cutter was obtained 603.18 cm^3. Core cutter was filled with the sample. Getting the weight of sample by subtracting the total weight to weight of the core cutter then the density was determined for each sample as a ratio of weight of sample to the volume of core cutter. This method was repeated three times for each treatment to find out more accurate bulk density.

$$\text{Bulk density}\left(\frac{kg}{m^3}\right) = \frac{W}{V} \quad (2)$$

Where,
W = Weight of raw material, kg
V = Volume of core cutter, m^3

2.3 Total Solid Content

Total solid content of a sample is the mass of solids remaining

after a sample has been oven dried at temperature of 104 ^{0}C to 106 ^{0}C for 24 hours to obtain bone dry weight divided by the original mass of sample. Three sample of each treatment were collected for obtaining more accurate data. Total solid content sometimes referred as dry matter content (Singh and Sahay, 2019).

$$TSC = \frac{\text{Weight of bone dried sample}}{\text{Intial weight of sample}} \times 100 \quad (3)$$

Moisture content (%) + Total solid content (%) = 100%

2.4 Friction Angle

Standard inclined plane method was used for measuring friction angle of sample. Three sample of each composition was selected for measuring friction angle. Friction angle was measured with MS sheet. Sample was placed on MS sheet and MS sheet placed on flat surface. Coefficient of friction of MS sheet was negligible. One end of MS sheet was tilted until the sample just tends to slide. This method was used for finding angle of friction of sample. Angle formed by the sheet with the horizontal surface is called angle of friction of sample and calculated by following relationship (Sahu *et al*., 2020) [6].

$$B = \sqrt{L^2 + H^2} \quad (4)$$

$$F = \tan^{-1}\frac{H}{B} \quad (5)$$

Where,
B = Base width of triangle formed, cm
L = Length of mild steel sheet, cm
H = Vertical height of free end of mild steel sheet, cm
F = Friction angle,

Table 2: Technical specification of cattle dung based log making machine

S. No.	Particulars	Details
1	Name of implement	Cattle dung log making machine
2	Overall dimension	945 mm × 550 mm × 940 mm
3	Power source	5 hp/ 3.7 kW electric motor
4	Dimension of hopper	325 mm × 325 mm × 250 mm
5	Conical auger length	190 mm
6	Dimension of tray	366 mm × 115 mm × 400 mm
7	No. of exit hole	1
8	Driven pulley (diameter, thickness)	230 mm, 50 mm
9	Driver pulley (diameter, thickness)	80 mm, 50 mm
10	Transmission system	Belt and pulley
11	Weight of machine	144 kg
12	Cost of the machine	40,000 Rs/-
13	Labour requirement	4

2.5 Machine Efficiency

The efficiency of the log making machine was estimated in terms of weight of log prepared per hour and length of specific diameter prepared in one hour. Machine efficiency was also estimated by using following relationship given by Sahu in the year of 2015.

Efficiency (%) = Output (kg)/ Input (kg) x 100 (6)

2.6 Operational Energy

The energy used in log making machine is human energy, electrical energy and machine energy. Energy was calculated by using following relationship given by Thakur, (2016) [10].

1) Human energy = Number of labour × Energy coefficient × Time, h (7)

2) Electricity input = RP × HOU/ 0.85 kWh (8)

Where,
RP = Rated power of the electric motor, kW
HOU = Useful life of electric motor, h

$$3)\ \text{Machine energy} = \frac{TMW}{LH} \times HOU \times EE \quad (9)$$

Where,
TMW = Total machine weight, kg
LH = Total useful working life of machine, h
EE = Energy equivalent
HOU = Useful life of machine, h

2.7 Cost Analysis

Cost of operation was measured by straight line method with two main points known as fixed cost and operational cost. In fixed cost depreciation cost, interest cost, housing cost, insurance cost, taxes was determined and in operational cost repair and maintenance cost, electric cost, labour cost is determined. The cost analysis was carried out for complete production of log from rice straw, rice husk, saw dust, cocopeat and cattle dung by using developed log making machine. Cost economics was also estimated for different tested treatment. The detailed analysis of cost for log production is given in table 4.

3. Analysis of Prepared Log

3.1 Physical parameter of log

The physical parameter of log such as shrinkage in diameter, shrinkage in weight and shrinkage in length of prepared cattle dung log was determined as per standard methodology adopted by Sahu in the year of 2015.

3.1.1 Shrinkage in diameter

Due to density and moisture content of mixed raw material diameter of log was observed little bit different for different composition of log. Shrinkage in diameter was determined by using following relationship.

$$\text{Shrinkage in diameter (\%)} = \frac{D - d}{D} \times 100 \quad (10)$$

Where,
D = Diameter of log just after removal from the machine, cm
D = Diameter of log after sun drying, cm

3.1.2 Shrinkage in weight

Weight of sample just after removal from the log making machine was measured with the help of digital weighing machine. Log was dried at 32 ^{0}C to 40 ^{0}C for 3 to 4 days. After drying weight of dried log was determined by using digital weighing machine. Following formula was used for determination of shrinkage in weight of log.

$$\text{Shrinkage in weight (\%)} = \frac{W - w}{W} \times 100 \quad (11)$$

Where,
W = Initial weight of prepared log, g
W = Weight of dried log, g

3.1.3 Shrinkage in length

Initial length of log just after removal from the log making machine was same for all composition of log. Final length of log after drying was changed due to removal of moisture from the sample. Three sample of each composition of log were selected for find more accurate result. The formula used for measurement of shrinkage in length is given below.

$$\text{Shrinkage in length (\%)} = \frac{L - l}{L} \times 100 \quad (12)$$

Where,
L = Initial length of log (50cm)
l = Length of dried log, cm

4. Result and Discussion

4.1 Performance Evaluation of Log Making Machine

Performance evaluation of log making machine includes operational parameter of raw material and operational parameter of machine. Physical properties of raw material such as density of raw material, moisture content of raw material, total solid content of raw material, friction angle of raw material, efficiency of machine, time to produce one log and percentage of shrinkage in diameter, length and weight was determined by using standard procedure. Cost of operation was also estimated and presented in following sub section.

4.2 Bulk density of raw material

Density of log was important for determination of burning quality of log, relative compactness and also important for easy transportation. Density of raw material is also used for increasing the combustion properties of produced log. Density of different log is presented in fig 1. Bulk density of raw material affects handling of raw material in the machine.The highest bulk density was observed in L1 as 1.13 g/cm^3 which means L1 is more durable and has higher strength for transportation. Lowest bulk density was recorded in L6 as 0.86 g/cm^3.

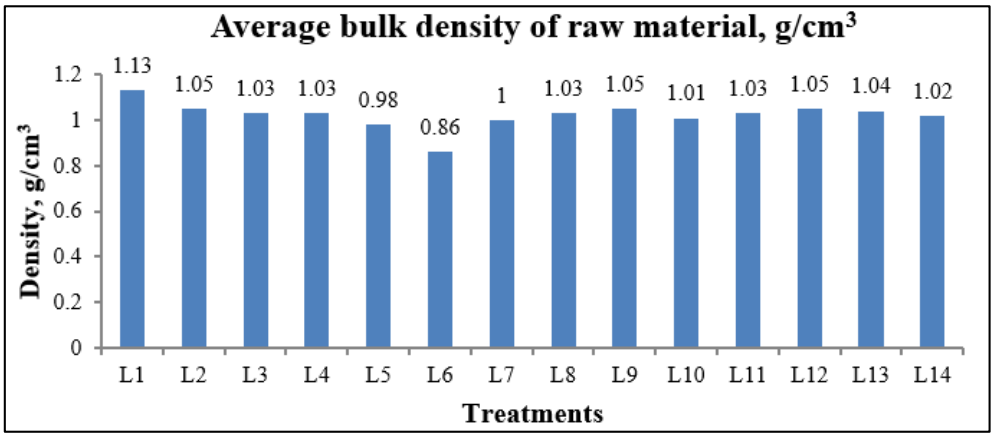

Fig 1: Determination of average density of raw material

4.3 Moisture content of raw material

Moisture content of raw material was used to determine how much water present in particular raw material at initial position for preparing perfect log. Moisture content is inversely proportional to dry matter content which is also known as solid matter content. If moisture content is high than total solid content is low and vice versa. Moisture content is used to measure the drying rate of log. Specific level of moisture content is better for preparing proper shape Of log. In the range of 65% to 85% of moisture content on mixed raw material was good for preparing proper shape of cattle dung log. Lower than 65% of moisture content had shattering problem. So, it's important to maintain proper level of moisture content on mixed raw material for preparing specific shape of cattle dung log. It was observed that moisture content for treatment L6 was highest as 83.76% and lowest for treatment L1 as 68.75%.

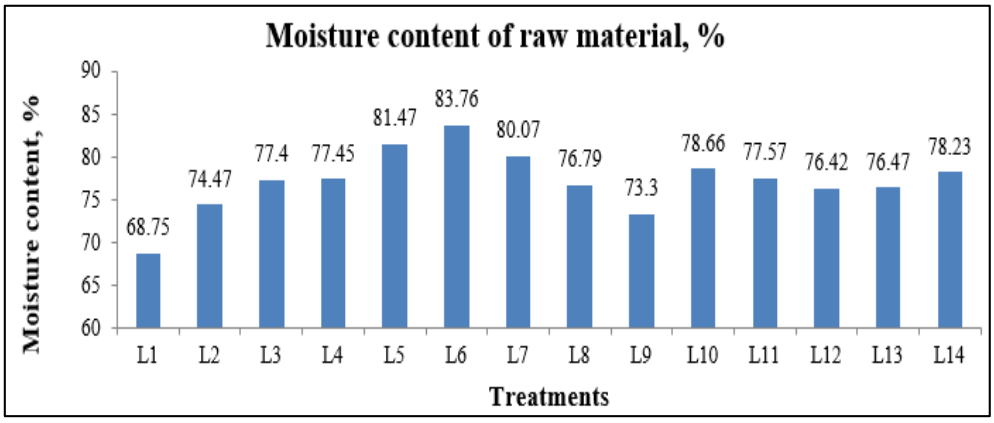

Fig 2: Determination of moisture content of raw material

4.4 Total solid content of raw material

Total solid content give brief information about dry matter present in particular raw material. Dry matters of log are participated in burning characteristics. Total solid content of raw material was observed highest for treatment L1 as 31.25% and lowest for treatment L6 as 16.24%.

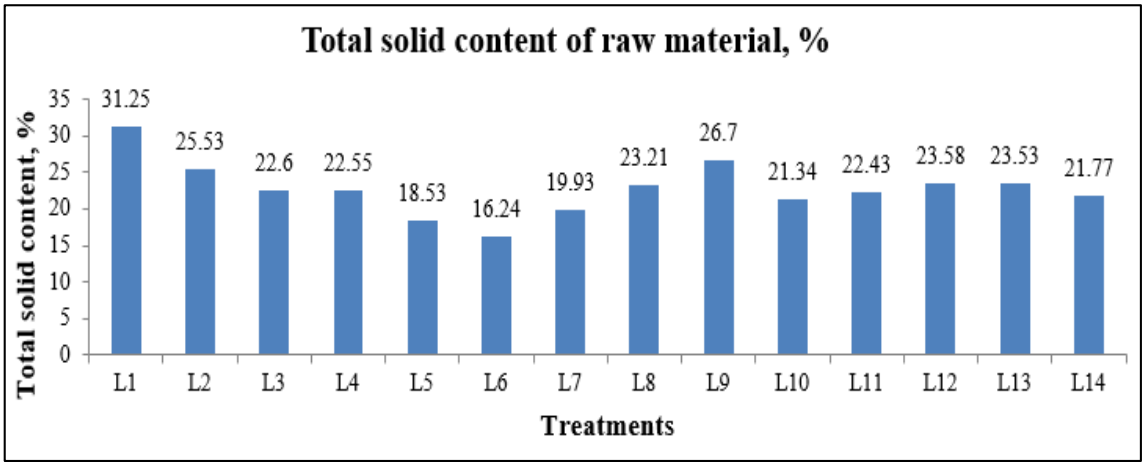

Fig 3: Determination of total solid content of raw material

4.5 Friction angle of raw material

Friction angle of raw material is used to measure the friction property of different composition of cattle dung and raw materials for checking performance of log making machine. Friction property such as friction angle of wet log just after removal from the machine was varied for different composition. Friction angle of different raw materials are presented in fig 4. Friction angle of raw material was observed highest for treatment L1 as 050.93^0 and lowest for treatment L11 as 35.43^0.

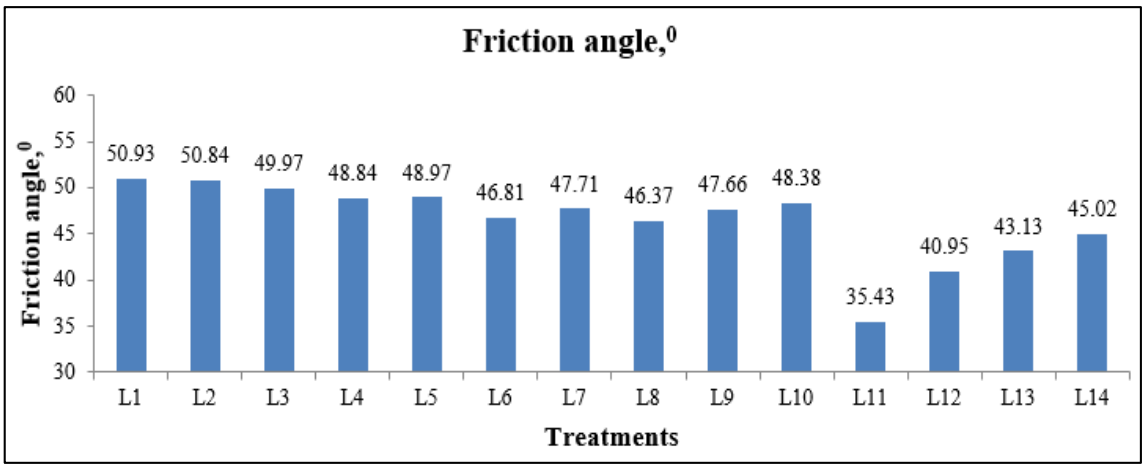

Fig 4. Determination of friction angle of raw material

4.6 Machine Efficiency

In general machine performed satisfactory for all producing cattle dung log by using different agricultural residue. Table 3 presented that feeding rate and machine output was different for different composition of log. It was seen that machine efficiency was higher for L1 due to composition of only cattle dung and lower for L2 due to presence of rice straw which was clogged during the operation. Rice straw has one more drawback after clogging machine got heated very soon. Average efficiency of machine was found 84.02%.

4.7 Time to Produce One Log

Time required to produce one log of 50 cm long was recorded with the help of stop watch for each treatment and obtained data is presented in Table 3. Average values for time required to produce one log under different treatment are presented in table 3. The maximum 5 min 12 s time was needed in treatment L10 for making log of 50 cm while minimum 1 min 1 s time was recorded in treatment L9. Results showed that more number of logs was produced in 1 hour in case of treatment L9. Production rate of machine with treatment L10 was less compared to other treatments.

Table 3: Machine efficiency and time to produce one log

S. No.	Treatment	Machine efficiency,%			Time to produce one log (min)
		Feeding rate (kg/h)	Machine output (kg/h)	Machine efficiency (%)	
1	L1	66	54.0	81.81	2:06
2	L2	66	58.0	87.87	2:15
3	L3	66	57.0	86.36	2.27
4	L4	66	56.0	84.84	2.32
5	L5	70	58.2	83.14	1:22
6	L6	66	56.0	84.84	2.24
7	L7	70	60.0	85.71	1:26
8	L8	70	56.6	80.85	1:45
9	L9	70	60.8	86.85	1:11
10	L10	70	58.6	83.71	5:12
11	L11	70	59.2	84.57	1:02
12	L12	72	58.0	80.55	1.07
13	L13	72	59.6	82.78	1:39
14	L14	75	61.8	82.40	0.14

4.8 Operational Energy

Operational energy of developed log making machine was determined to know about the energy consumption of machine. The overall operational energy of log making machine was determined 318.82 MJ/h. This energy includes machine energy, motor energy, human energy and electrical energy. The maximum energy was contributed by machine in overall operational energy of the developed machine as 175.50 MJ/h followed by motor energy (64.8 MJ/h), human energy (62.72 MJ/h) and electrical energy (15.80 MJ/h).

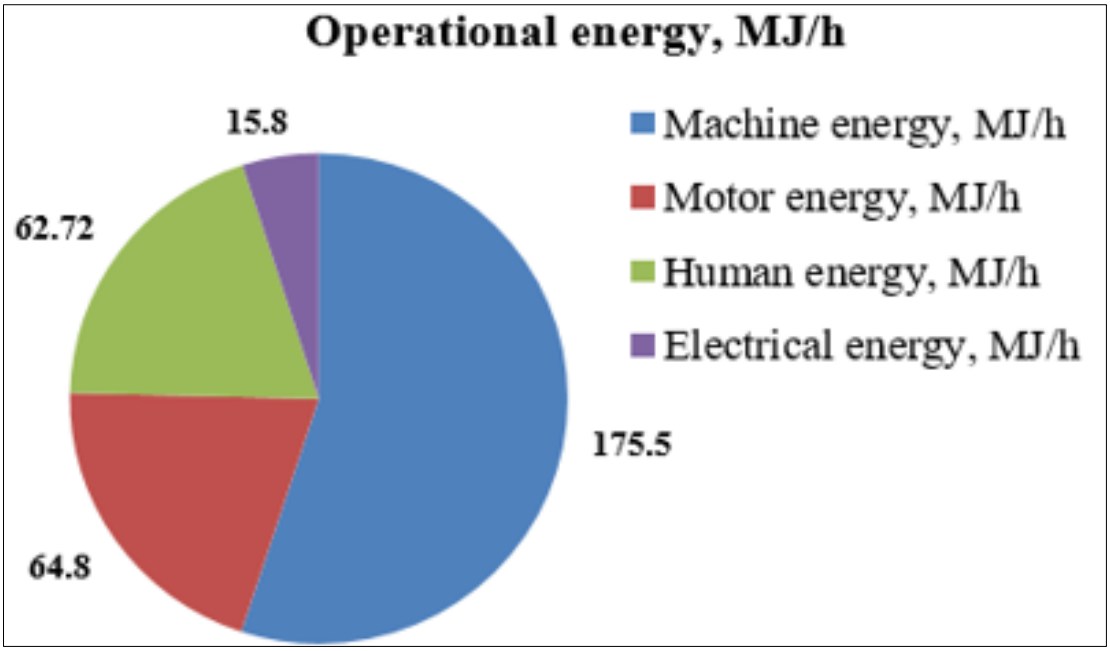

Fig 5: Operational energy consumed by machine

4.9 Cost Analysis

For estimation of net social benefits and cost of a project or policy, economists were developed cost analysis technique. It is a method to estimating the expenses and benefits of a project, which is used to further examine the decision. One of the most important features of cost benefit analysis is that it provides the decision maker with various options to get the maximum possible return on investment. It expresses all the pros and cons of all the option to choose the best approach to get maximum possible benefit. Cost of operation of developed log making machine and cost of production of logs under different treatment was determined and given in table 4. Cost of operation of developed log making machine was estimated as 150.47 ₹ / h. existing market selling price of cattle dung based log is 15 ₹ / kg. Cost analysis of production of log by using developed machine and with different mixture of raw materials, net income and profit is presented in Table 4.

Table 4: Cost analysis of log production

Treatment	Cost analysis				
	Material cost (₹ / h)	Production cost (₹ / h)	Gross income (₹ / h)	Net income (₹ / h)	Profit (₹ / kg)
L1	126	276.47	810	533.52	9.88
L2	132	282.47	870	587.52	10.13
L3	132	282.47	855	572.52	10.04
L4	132	282.47	840	557.52	9.95
L5	236	382.47	870	487.52	8.40
L6	420	570.47	840	269.52	4.81
L7	188	338.47	900	561.52	9.36
L8	138	288.47	849	560.52	9.90
L9	140	290.47	912	621.52	10.22
L10	139	289.47	879	589.52	10.06
L11	235	385.47	888	502.52	8.49
L12	240	390.47	870	479.52	8.26
L13	235	385.47	894	508.52	8.53
L14	197	347.47	927	579.52	9.38

Cost of log making for each treatment was determined as different types of biomass are used in different treatments and have different purchasing cost. Cost of production of log by power operated log making machine was found maximum for treatment L6 as ₹ 570.47 per hour and minimum for the treatment L1 ₹ 276.47 per hour. The gross income (₹ / h) found maximum for the treatment L14 as ₹ 927 per hour and minimum in case of treatment L1 as ₹ 810 per hour. The net income generation was found maximum for the logs prepared under treatment L9 as ₹ 621.525 per hour while minimum under treatment L6 as ₹ 269.525 per hour. Hence, the log production from L9 by using power operated machine was found more profitable compared to other biomass log.

4.10 Analysis of Prepared Log

Shrinkage in diameter, length and weight of prepared log is depicted in table 5.After sun drying shrinkage percentage in diameter was found higher as 34.98% in case of treatment L11 and lower as 20.30% in case of treatment L12. Maximum reduction in length of log after drying was observed in treatment L14 as 13.34% and minimum in L10 as 3.42%. Reduction in weight after drying was maximum for treatment L11 as 81.70% and minimum for L12 as 74.35%.

Table 5: Comparison of different physical parameter of cattle dung log

Treatment	Wet log			Dried log			% Shrinkage		
	Avg. dia. (cm)	Avg. length (cm)	Avg. Weight (g)	Avg. dia. (cm)	Avg. length (cm)	Avg. weight (g)	Avg. dia. (%)	Avg. Length (%)	Avg. Weight (%)
L1	7.76	50	1960.30	5.43	44.04	467.37	30.41	11.92	76.15
L2	7.72	50	1803.44	5.60	45.32	456.63	27.46	9.36	74.68
L3	7.46	50	1962.07	5.40	45.08	475.05	27.61	9.84	75.78
L4	7.66	50	1980.11	5.47	44.72	421.89	28.19	10.56	78.69
L5	7.26	50	1963.73	5.33	45.85	495.95	26.99	8.30	74.74
L6	7.25	50	1892.91	5.60	44.84	439.95	22.76	10.32	76.75
L7	7.17	50	1985.25	5.43	45.75	409.82	24.69	8.50	79.35
L8	7.70	50	1999.00	5.70	46.74	423.8	25.97	6.52	78.79
L9	7.57	50	1929.06	5.80	45.76	474.74	23.38	8.48	75.39
L10	7.27	50	1890.37	5.10	48.29	365.83	29.85	3.42	80.64
L11	7.69	50	1869.81	4.97	43.85	342.19	34.98	12.30	81.69
L12	6.65	50	1799.90	5.27	43.88	461.57	20.30	12.24	74.35
L13	6.66	50	1980.27	5.33	45.62	465.96	20.42	8.76	76.46
L14	7.77	50	2000.21	5.30	43.33	441.17	31.79	13.34	77.94

5. Conclusion

On the basis of different parameters observed in this study, it was found that the performance of log making machine was worked satisfactorily with different composition of biomass for producing log. The moisture content of raw material for different log varies between 65% - 85% (approx). Bulk density of raw material varies with the range of 0.7g/cm^3 to 1.5 g/cm^3. Lowest density of raw material was 0.85 g/cm^3 for treatment L6 and highest density of raw material was 1.13 g/cm^3 for treatment L1. Total solid content of raw material varies with the range of 15% to 35%. Minimum total solid content in treatment L6 as 16.24% and maximum solid content in treatment L1 as 31.25% was determined. Friction angle of mixed raw material was highest for treatment L1 as 50.93 ^{o} and lowest for treatment L11 as 35.43^o. After sun drying shrinkage in diameter, length and weight was determined in the range of 20% to 35%, 3% to 15% and 73% to 83% respectively. Capacity of machine was highest for treatment L14 as 61.8 kg/h and lowest for treatment L1 as 54 kg/h. Efficiency of machine was high for treatment L2 as 87.87% and lowest for treatment L12 as 80.55%. In general, average machine capacity for making cattle dung log was found 58.13 kg/h and efficiency as 84.02%.

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7. References

1. Adapa P, Tabil L, Schoenall G. Compression characteristics of selected ground agricultural biomass. Agricultural Engineering International CIGRE Journal, 2019, 11.
2. Indian Standard Institution. Methods of analysis of food grains. IS- 4333 (part- III). 1967.
3. Mani S, Tabil LG, Sokhan Sanj S. Specific energy requirement for compacting corn stover. Bioresources Technology. 2006;97(12):1420-1426.
4. Patil RA, Deshannavor UB, Ramasamya M, Emani S, Issakhon A, Khalilpoor N. Briquetting of dry sugarcane leaves by using press mud cow dung and buffalo dung as binders. International Journal of Chemical Engineering, 2021, 1-12.
5. Sahay KM, Singh KK. Textbook of Unit Operations of Agriculture Processing. Vikas Publication House Ltd. Noida, U. P, 2017.
6. Sahu M, Victor VM, Verma A, Agrawal S. Study on physical and frictional properties of farm yard manure (FYM) to develop mechanizes application and handling unit of FYM. The Pharma Innovation Journal. 2020;9(1):101-106.
7. Sengar SH, Mohod AG, Khandetod YP, Patil SS, Chendake AD. Performance of briquetting machine for briquette fuel. International Journal of Energy Engineering. 2012;2(1):28-34.
8. Sokhansanj SS, Mani M, Stumbarg R, Samson, Fenton J. Production and distribution of cereal straw on the Canadian prairies. Canadian Bio-systems engineering. 2006;48(3):3.39-3.46.
9. Tabil LG, Sakhansanj Jr, S. Compression and compaction behaviour of alfalfa grind. Power Handling and Processing, 1996, 8(2).
10. Thakur Y. Studies some engineering properties of rice straw based briquettes. M. Tech. Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur, 2016.