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Assessing the efficiency of a cattle dung dewatering machine

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Abstract
In this study, a cattle dung dewatering machine was assessed for dewatering of readily available fresh cattle dung. A cattle dung dewatering machine was used to remove the moisture content of fresh cattle dung for immediate use as a fertilizer or in the production of insect repellent, diya, briquettes and pots. The cattle dung dewatering machine's performance was evaluated at SVCAET & RS, IGKV, Raipur, Chhattisgarh during year 2022-23. The main frame of the cattle dung dewatering device has a wheel, a hopper, a slotted bar cylinder, a screw press, an outlet unit, a collection tank, a power transmission system and a 5 hp electric motor. The machine's performance was assessed using three parameters, i.e., capacity, dewatering rate and efficiency of the cattle dung dewatering machine. The average moisture content of readily available fresh cattle dung was found to be 80.46%. When compared to the machine drying of fresh cattle dung, the natural sun drying process takes approximately 9 days. For the purpose of evaluating the machine's performance, a sample of fresh cattle dung of various weights was prepared. The machine's capacity ranged from 108.70 kg/h to 130.13 kg/h, with an average capacity of 121.88 kg/h. The machine's dewatering rate ranged from 89.2 kg/h to 103.05 kg/h, with an average dewatering rate of 93.61 kg/h. The machine's efficiency ranged from 35.4% to 47.5%, with an average efficiency of 42.32%. The machine was found to perform satisfactorily. The machine's operating cost was 82.39 Rs/h or 0.6759 Rs/kg. The payback period was 2.63 years and the breakeven point was 467.14 h/year.

Keywords: Cattle dung dewatering machine, capacity, dewatering rate, efficiency

1. Introduction
India ranks number one in cattle and buffalo's population. There are 306.7 million cattle in India as of 2022 and 307.6 estimates for 2023 (Anon, 2023) [1]. A healthy, cow produces 9-15 kilogram of dung per day (Werner *et al*., 1989) [8]. Cattle dung has high percentage of organic material and is rich in minerals and nutrients. Additionally, it contains trace amounts of 24 different minerals, including nitrogen, potassium and trace amounts of iron, magnesium, copper, manganese and cobalt. 3% nitrogen, 2% phosphorus and 1% potassium (3-2-1 NPK) are all present in cow dung. Indian cow dung also contains higher amount of calcium, phosphorus, zinc and copper than the cross- breed cow (Garg and Mudgal, 2007 [3]; Randhawa and Kullar, 2011) [5].
Cattle dung in India is also used as a co-product in agriculture, such as manure, biofertilizer, biopesticides, pestrepellent and as a source of energy. In Indian villages, people direct burn cattle dung for cooking purposes. For insulation in rural homes during the winter and summer, it is also used for plastering walls and floors. Additionally, it shows how valuable cows are socioeconomically and how important they are to village economies. Therefore, in India Cow (B. indicus) is not only milk-producing animal but also truly considered as Gomata (mother of all) and Kamdhenu (Dhama *et al*., 2005) [2].
Cattle dung is the major source of biogas or gobar gas production in India. Cattle dung is used as a purifier, brass polisher, pond pH balancer, teeth powder, disposable and camphor light etc. In the current environment, dewatering digested cattle dung slurry from a biogas plant is crucial since it allows for the conservation of a valuable resource like water and also enables the production of compost or solid fuel. Western nations have recently begun using screw presses for the dewatering of digested sludge. Some tests were conducted to evaluate the behaviour of slurry under pressure in order to build a native design of a screw press (Mahendra *et al*., 2011) [4].
The water content of fresh cattle dung is about 80-90% (Valiela, 1969) [7]. Which increase the difficulty of management. Cattle dung dewatering machine is used for removing unwanted

water from the dung. Dewatered dung is easy to use as a fertilizer or in production of insect repellent, diya, briquettes and pots etc. Dewatered cattle dung is easy to transport and handle. Dewatering is a key process to convert cattle dung into fertilizers as compost. High moisture cattle dung takes long time to convert into compost. In India drying of cattle dung is mostly done by sun drying method but the drying process gets interrupted during rainy season.

This paper presents the performance evaluation of cattle dung dewatering machine of fresh cattle dung for the instant utilization of the cattle dung.

2. Materials and Methods

During the year 2022-2023, the performance of cattle dung dewatering machine was evaluated in Swami Vivekananda College of Agricultural Engineering & Technology and Research Station, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur. A fresh dung of specified weight was gathered from dairy barn for the testing of dewatering machine for determination of machine capacity, dewatering efficiency and dewatering rate. Fresh dung sample and naturally sun-dried samples were taken for determination of moisture content in percentages to compare the machine's performance to the natural drying performance. The cost of operation, breakeven point and payback period was also calculated to evaluate the performance of cattle dung dewatering machine. The specification and CAD design of cattle dung dewatering machine was presented in Table 1 and Fig. 1. respectively.

Table 1: Specification of cattle dung dewatering machine

SI. No.	Part	Dimensions/power
1	Frame	815×530×680 mm
2	Main cylinder	600 mm & 128 mm Ø
3	Shaft	1040 mm & 90 mm Ø
4	Shaft auger	575 mm
5	Pulley	L 300 & S 80 mm
6	AC motor	5 hp
7	Belt	1250 mm
8	Hopper	740×400×290 mm
9	Spring	160 mm
10	Bearing block	555 mm & 600 mm Ø
11	Dewatering Tank	450×450×225 mm
12	Cylinder cover	500×360×290 mm
13	Pulley cover	585×425×240 mm
14	Wheel	40 mm & 130 mm Ø

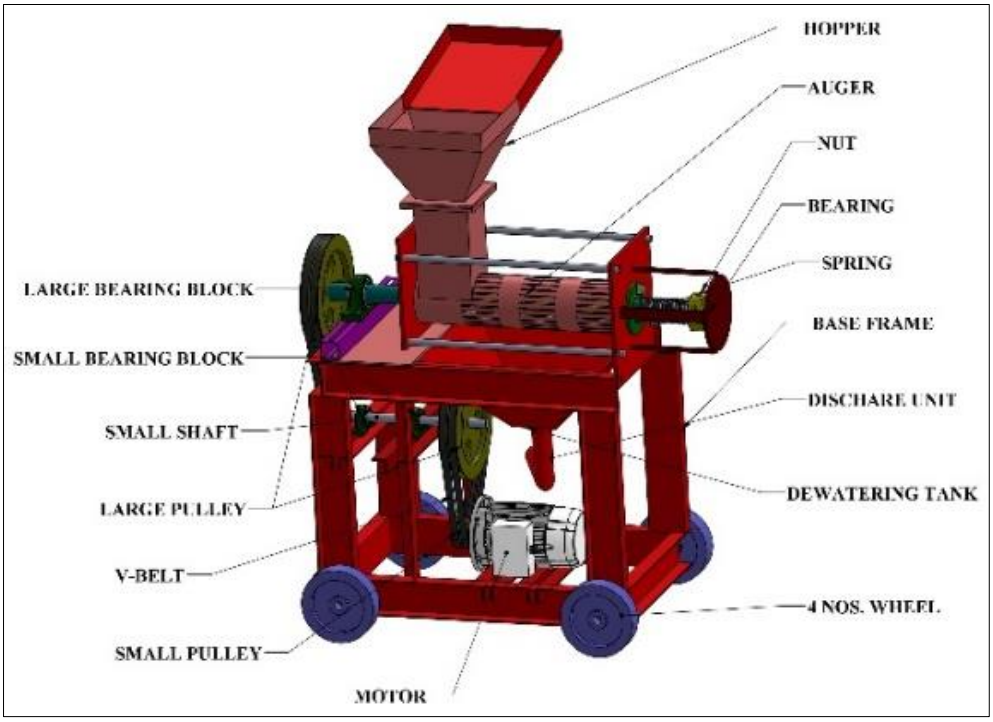

Fig 1: CAD design of Cattle dung dewatering machine

2.1 Dewatering capacity

A fresh batch of cattle dung was collected from the dairy barn of Department of Farm Machinery and Power Engineering, IGKV, Raipur. The machine was kept constant and supplied power. The dewatering of dung was done for five samples and the time was also noted.

Then the capacity of the machine was calculated by using following relation given in equation 1.

$$C = \frac{w_d}{t} \quad (1)$$

Where,

C = Actual capacity, (kg/h)

W_d = Weight of dewatered cattle dung, (kg)

t = Time taken, (h)

2.2 Dewatering efficiency

It is another important parameter to evaluate the performance of cattle dung dewatering machine. It is expressed as the ratio of weight of slurry of cattle dung to the total weight of the cattle dung.

Then the dewatering efficiency of the machine was calculated by using following relation given in equation 2.

$$D_e = \frac{ws}{W} \quad (2)$$

Where,

D_e= Dewatering efficiency, (%)

W_s = Weight of slurry of cattle dung, (kg)
W= Total weight of cattle dung, (kg)

2.3 Dewatering rate
It is the amount of water removed from the dung. It is represented as the ratio of the quantity of water removed from the cattle dung with respect to time.
The dewatering rate of the machine was calculated by using following relation given in equation 3.

$$Dr = \frac{W - W_d}{t} \quad (3)$$

Where,
D_r= Dewatering rate, (kg/h)
W = Total weight of cattle dung, (kg)
W_d= Weight of dewatered cattle dung, (kg)

2.4 Moisture Content of Available Cattle Dung
The moisture content is the amount of water present in sample. The moisture content is determined under prescribed conditions. Moisture content is the ratio of the weight of water contained by the cattle dung to the bone-dry weight of the cattle dung, expressed as a percent. Fresh cattle dung samples and the naturally sun-dried samples were taken. To determine the moisture content of the cattle dung sample it was weighed and kept in the oven at 105°C for 24 hours. The moisture content was determined by using the following formula given in equation 4 (ASAE standards, 2002).

$$\text{M.C. (W.b., \%)} = \frac{W_w - W_d}{W_w} \times 100 \quad (4)$$

Where,
M.C. = Moisture content of cattle dung (Wet basis), (%)
W_w = Weight of wet cattle dung, (g)
W_d = Weight of dried cattle dung, (g)

2.5 Operating Cost of the Machine
Whenever a new machine is introduced, it is very important to know the operating cost of the machine. Operating cost explains how the machine would be affordable and how much it will cost to operate. The fabrication cost and the cost of operation were estimated to establish the economics of dewatering machine. The unit fabrication price, yearly use, salvage value, interest rate, maintenance cost and life of the implement were used to compute the hourly cost of operation.

2.6 Breakeven point
The point at which the total cost of the machine equals the entire costs or expenses, which includes repair, maintenance etc. and when there is no profit or loss is known as the break-even point The breakeven point was determined by using the following formula given in equation 5 (Reddy *et al.*, 2003) [6].

$$BEP = \frac{FC}{CH - C} \quad (5)$$

Where,
BEP= breakeven point, h/year
FC = Annual fixed cost, Rs/year
C = Operation cost, Rs/h
CH = Custom hiring charges, Rs/h

2.7 Payback period
The amount of time it takes to recoup the cost of your investment is payback period. In non- scientific term, it is the amount of time it takes for an investment to reach to its break-even point. The payback period was determined by using the following formula given in equation 6 and 7 (Reddy *et al.*, 2003) [6].

$$PBP = \frac{IC}{ANP} \quad (6)$$

Where,
PBP = Payback period, year
IC = Initial cost of machine, Rs
ANP= Average net annual profit =$(CF - C) \times AU$

$$PBP = \frac{IC}{(CF - C) \times AU} \quad \textbf{(7)}$$

3. Results and Discussion
Performance evaluation of cattle dung dewatering machine includes capacity, dewatering efficiency, dewatering rate, moisture content to compare the natural sun drying process with the machine drying performance, cost of operation, breakeven point and payback period. Fig. 2 shows the dewatering of cattle dung in cattle dung dewatering machine.

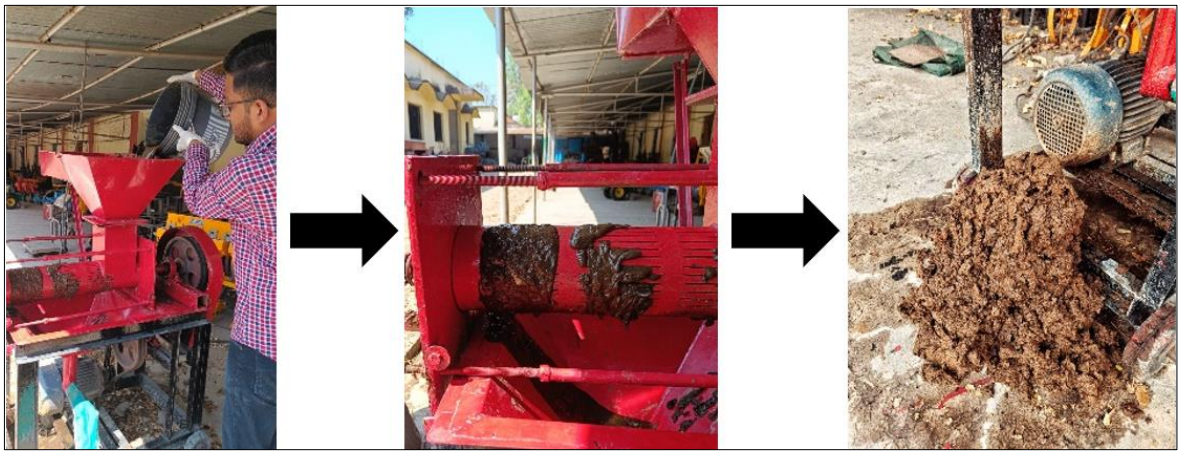

Fig 2: Drying of cattle dung in cattle dung dewatering machine

3.1 Capacity of cattle dung dewatering machine

The machine was tested for dewatering of different samples of the dung to determine the capacity of the machine, the highest capacity of the machine was observed in the case of 22 kg fresh dung at 6.32 min, the lowest capacity of the machine was observed in the 6 kg fresh dung at 1.42 min and the average capacity of the machine was determined 121.88 kg/h.

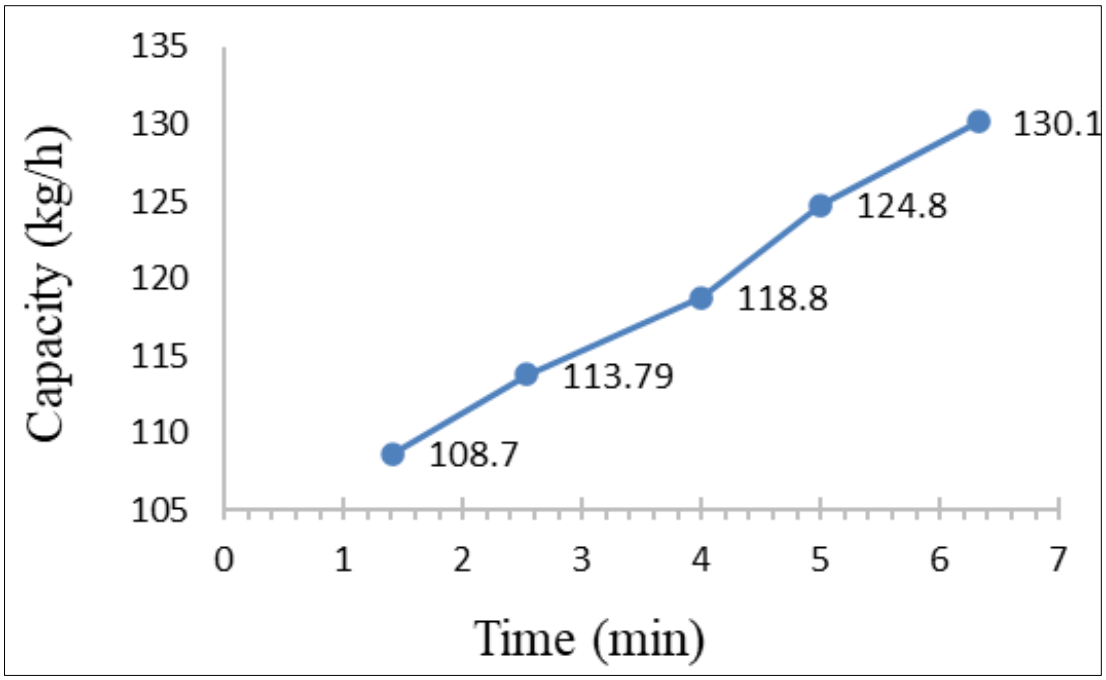

Fig 3: Relation between capacity (kg/h) and time (min) of the modified cattle dung dewatering machine

3.2 Dewatering efficiency of cattle dung dewatering machine

The machine was tested for dewatering efficiency of different samples of the fresh cattle dung in which the highest efficiency was observed in the case of 3.08 kg slurry weight from the 6 fresh dung in 1.42 min, the lowest was observed in the case of 14.12 kg slurry weight from the 22 fresh dung in 6.32 min. The average efficiency of the machine was determined as 42.32%.

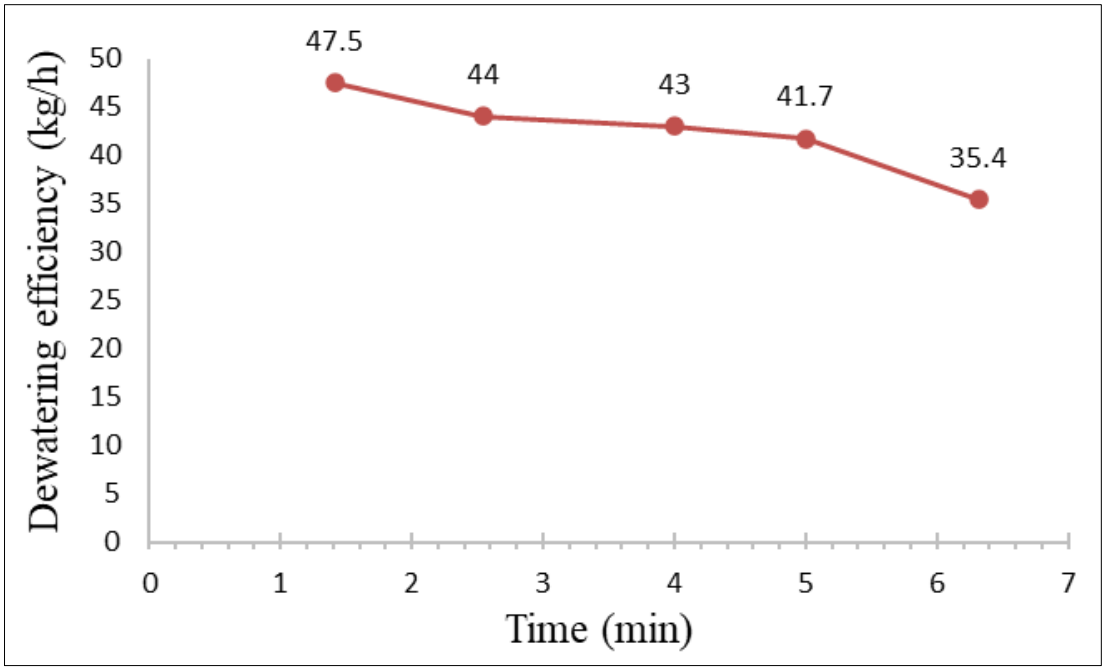

Fig 4: Relationship between time (min) and efficiency (%) of the modified machine

3.3 Dewatering rate of cattle dung dewatering machine

The machine was tested for dewatering rate of different samples of the dung in which the highest dewatering rate of the fresh cattle dung was observed in the case of the 3.08 kg slurry weight form the 6 kg fresh dung in 1.42 min, the lowest was observed in 14.12 kg slurry weight form the 22 kg fresh dung in 6.32 min and the average dewatering rate of the machine was determined 93.61 kg/h.

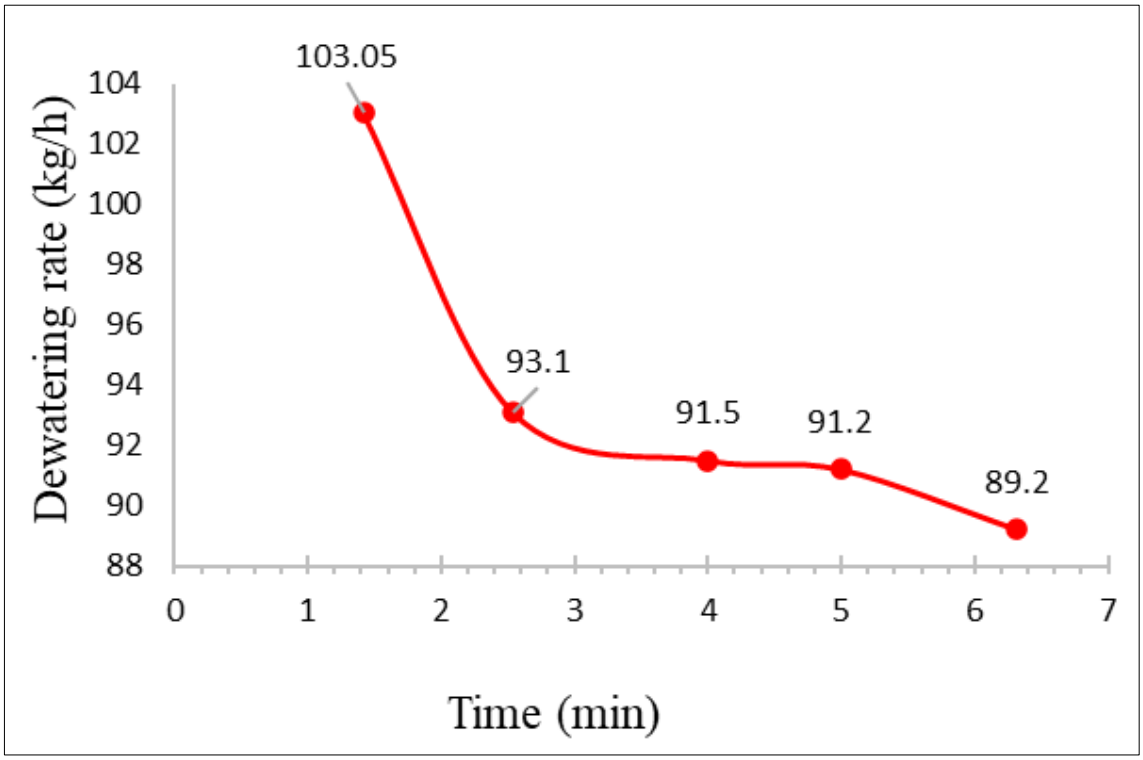

Fig 5: Relation between dewatering rate (kg/h) and time (min) of the modified machine

3.4 Moisture content of cattle dung

Moisture content was determined for fresh dung sample and naturally sun-dried samples: -

The average moisture content in fresh dung sample (80.47%), 1-day sun dried sample (76.43%), 2-day sun dried sample (71.07%), 3-day sundried sample (70.37%), 4-day sun dried sample (65.67%), 5-day sun dried sample (62.33%), 6-day sundried sample (58.53%), 7-day sun dried sample (54.97%), 8-day sun dried sample (51.47%) and 9-day sundried sample (46.37%).

The highest percentage of moisture content was observed in case of fresh dung sample (80.46%) and the lowest percentage of moisture content was observed in case of day 9-day sun dried sample (46.37%). The results are shown in the Table 1.

Table 1: Moisture content of cattle dung

Moisture content (%)						
S. No.	**M1 (%)**	**M2 (%)**	**M3 (%)**	**Average (%)**	**SD**	**CV (%)**
Fresh dung sample	80.70	80.50	80.20	80.47	0.25	0.31
1-day sun dried sample	76.10	75.70	77.50	76.43	0.95	1.24
2-day sun dried sample	70.90	72.60	69.70	71.07	1.46	2.05
3-day sun dried sample	70.80	71.20	69.10	70.37	1.12	1.58
4-day sun dried sample	65.70	64.40	66.90	65.67	1.25	1.90
5-day sun dried sample	63.10	62.60	61.30	62.33	0.93	1.49
6-day sun dried sample	59.50	57.20	58.90	58.53	1.19	2.04
7-day sun dried sample	56.80	53.90	54.20	54.97	1.59	2.90
8-day sun dried sample	50.90	52.40	51.10	51.47	0.81	1.58
9-day sun dried sample	47.10	46.90	45.10	46.37	1.10	2.38

3.5 Comparison of natural sun drying to the machine drying performance

The moisture content of the fresh cattle dung is 80.46%, when the fresh cattle dung is dried in the machine at an efficiency of 42.32% the moisture content in the dung remains 46.67% and during the natural sun drying process after 9 days of drying it was observed that the moisture content was 46.37% so it was concluded that during the natural sun drying process it takes approximately 9 days compared to machine drying of fresh cattle dung.

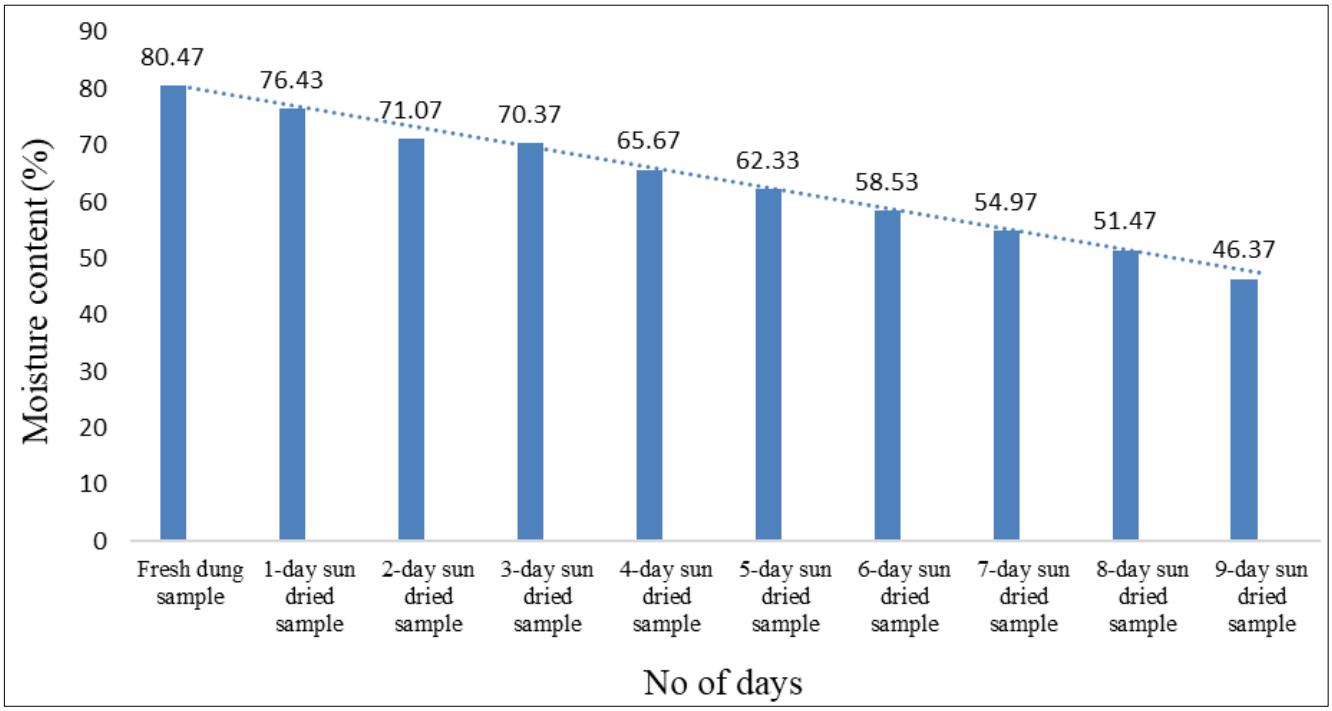

Fig 6: Comparison of drying process

3.6 Cost of operation

The cost of operation of the machine was found 82.39 Rs/h and 0.6759 Rs/kg. The total fixed cost of the machine which includes the depreciation, interest on investment and the charges on insurance, was 20.67 Rs/h. The total variable cost, which includes the repair and maintenance, wages of operator and cost of electricity was 61.72 Rs/h. Hence the total cost summed up to 82.39 Rs/h.

4. Conclusion

Performance of the cattle dung dewatering machine has been successfully done and it worked satisfactorily. The average capacity of the modified cattle dung dewatering machine was 121.88 kg/h. The average dewatering efficiency of modified cattle dung dewatering machine was 42.32%. The average dewatering rate of modified cattle dung dewatering machine was 93.61 kg/h. The highest percentage of moisture content was observed in case of fresh dung sample (80.46%) and the lowest percentage of moisture content was observed in case of day 9-day sun dried sample (46.37%) which concluded that natural sun drying process it takes approximately 9 days compared to machine drying of fresh cattle dung. The cost of operation was 82.39 Rs/h or 0.6759 Rs/kg. The breakeven point was 467.14 h/year and the payback period was 2.63 year.

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