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Preparation and Performance Evaluation of Low Density Briquettes of Multinutrient Feed for Biogas Plants

[1]S. Tyagi, [2]N.S. Rathore and [1]S.P. Singh

[1]Biomass and Waste Management Laboratory, School of Energy and Environmental Studies, Devi Ahilya Vishwavidyalaya, Khandawa Road, Indore (Madya Pradesh)-452017, India
[2]College of Dairy and Food Science Technology, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan)-313001, India

Abstract: Densification of the feeds could be a solution to feedstock deficiency for biogas plants and ultimate option for waste management. This paper deals with development of a environmentally and farmer's friendly technology for sustainable use of waste,through densification and development of a package of integration of nutrients, alternate waste and binder etc with cow dung for biogas plant. The lab study was conducted to examine the feasibility of dry and powdered optimal mix feeds with cow dung to form low-density quality briquettes using starch as binder for accelerating biogas production. The optimal mix feeds of C/N balanced mixture of wastes found suitable for enhancing gas production. The optimal mix was densified into multinutrient briquettes by adding Mg metal nutrient/catalyst. The density, water solubility of the briquettes and volatile fatty acid content of the supernatant were the parameters used to evaluate performance of briquettes after addition of binder in different proportions. All the proportions formed good quality briquettes. The water solubility was almost same for all the ratios of mix feed and starch and was highest for cow dung to starch ratio of 3:1. The volatile fatty acids were also highest for feed to starch ratio of 3:1, concluding the ratio of 3:1 to be optimum for forming good quality briquette and providing environment for maximal bacterial growth for ultimate enhanced biogas production. The economic analysis of the whole process concludes it is a beneficial activity which can be popularized and commercialized for extension and demonstration for mass adoption and for upliftment of the poor in rural areas.

Key words: Densification · Low-density briquettes · Multinutrient feed · Biogas plants · Economic · Feasibility · Popularization · Commercialization · Training · Environmentally sustainable

INTRODUCTION

In India cattle dung is the sole feedstock used for biogas generation [1] and has now been found to be the main reason for dysfunctionality of biogas plant due to the under feeding or overfeeding of plant capacity [2].

Cow dung is available mainly in rural areas. In urban areas, either it is not available or is restricted to outskirts of the city where farms are located or populations of nearby village reside. Thus, generation of biogas from renewable sources in the form of organic residues such as agricultural residues and agro-industrial wastes is gaining importance for supplementing the fuel requirements and efforts to develop alternative feed stocks have thus received major attention for research and development [3,4].

Keeping in view the importance of biogas for semi urban and urban areas and identification of supplementary raw material for enhanced biogas production, a technique for densification of low density multinutrients feed has been developed The low-density briquetting for biogas feed must be strong enough to resist the breakage in handling and should be porous enough for faster dispersion into water during slurry preparation.

METHODS AND MATERIALS

The work was carried out to compare the briquetting of optimal mix feeds using different proportions and starch as binder and to know its effect on the densification characteristics such as density of briquettes,

Corresponding Author: S. Tyagi, Biomass and Waste Management Laboratory, School of Energy and Environmental Studies, Devi Ahilya Vishwavidyalaya, Khandawa Road, Indore (Madya Pradesh)-452017, India.

Fig. 1: Powdered /grounded feedstocks , stored for study

Fig. 2: Performance evaluation of Multinutrient Feed briquettes

Fig. 3: Performance evaluation of Cowdung briquettes

water solubility, volatile acids concentration. Optimal mix feed was prepared by drying and grinding animal wastes and agro residues and then mixing together, in C/N balanced proportion, after pretreatment of agro residue [5].

Preparation of Feed Material for Densification: The cow dung cake, chopped straw and maize cobs were sun dried and grounded in hammer mill to get particle size of less than 10 mesh with moisture content of less than 6 percent (w.b.) used for making briquettes as densified products as shown in Fig. 5. The grounded agro waste was then given alkali pretreatment (8g NaOH/100g substrate, liquid to solid ratio of 4:1) and kept for ten days [6]. The pretreated agro waste was then mixed with powdered cow dung cake in quantity of 6% maize cobs and 5% wheat straw to obtain C/N balanced optimal mix feed for study.

Starch was taken as binder on account of its low cost and easy availability. Being non-toxic to microorganisms and being water-soluble were, two other criteria of selection, as process of biomethanation is microbially mediated.

Preparation of Briquettes with Binder: Different proportions of optimal mix feed to starch viz. 1:1, 3:1, 6:1, 10:1, 14:1, 18:1 and 22:1 on weight basis were used. The Mg metal catalyst, found for enhancing biogas production from optimal mix, was also added to the mix for its concentration in the slurry to be equal to, 226.5 mg/liter of slurry [7, 8].

A minimum quantity of water was also added to the mixture for making a paste. The mixture was then molded, by hand, into briquettes of 1-inch dimensions with the help of iron molds specially made for the purpose. Little pressure was applied to properly fill the mold with the mixture. The briquettes of cow dung powder and starch as binder were also made in the same way for comparison purpose. The same process was repeated for making briquettes of powdered optimal mix and its individual components viz cow dung, alkali pretreated maize cobs and wheat straw (without addition of binder). A plastic sheet or an oil film was placed in the mould for preventing the block from sticking to the wall and allows easy removal from the mould. The mixture took 48 hrs to set in the ventilated room. After removing from moulds, the briquettes were kept for another 48 hrs at room temperature, for complete removal of moisture. Dried briquettes were then weighed and placed in beaker by adding water to give a solid concentration of 8% of slurry. Water solubility of the briquettes and volatile acid concentration of the solution after 24 hrs, were chosen for performance evaluation as shown in Fig. 2 and Fig. 3.

Water solubility was measured by filtering the solution followed by drying and weighing the filtrate as given in standard test method for measurement of aqueous solubility [9]. The percent loss in the weight is expressed as water solubility of the briquette. Volatile fatty acid was measured by method of Dillalo and Albertson [10].

RESULTS AND DISCUSSION

All the mixtures and individual substrates such as cow dung, alkali pretreated maize cobs and wheat straw were used to form the briquette. The results of the study are shown in Table 1.

The Fig. 1 shows bulk densities were higher for briquettes of multinutrient feed (0.428 – 0.774 g/cc) and cow dung (0.445 - 0.460 g/cc) with higher percentage of binder (14-50% binder).

As seen from Table 1 and Fig. 5, for both kind of feed briquettes the water solubility increases with binder percentage up to 25% and then decreases. As shown in Fig. 6, the highest solubility was found for feed to starch ratio of 3:1 and minimum for 18:1 and 22:1. The water solubility of the control briquettes (without any binder) of multinutrient mix and cow dung was 11.79% and 7.16% respectively.

The volatile acids also showed a pattern similar to that of water solubility on varying the ratio of substrate to binder. The volatile acid increases with binder percentage up to a substrate to binder ratio of 3:1 and then decreased, as shown in Fig. 4. The pH of the supernatant for analysis was found decreasing from substrate to starch ratio of 22:1 to 1:1. In case of cow dung briquettes the pH varied from 7.42 to 6.22 which was lowest at 3:1. In case of optimal mix feed it varied from 8.74 to 8.09 (alkaline) and lowest at 3:1. The pH was alkaline because of the alkali pretreatment given to slowly degrading alternate feed material. This could be the reason for obtaining low volatile fatty acid content in case of treated multinutrient briquettes in comparison to untreated cow dung briquettes.

As seen from Table 1 and Fig. 7, the highest volatile solid concentration was observed for briquettes of multinutrient feed (330 mg/liter) and cow dung (548 mg/liter) at substrate to starch ratio of 3:1. The volatile acid concentration of supernatant of the control

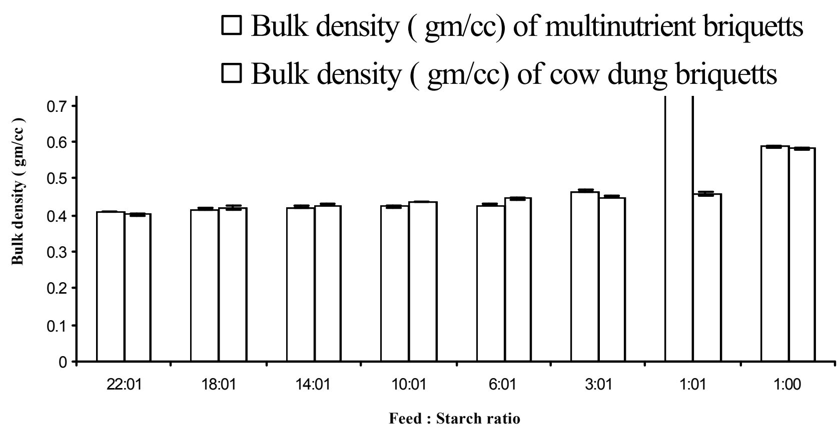

Fig. 4: Effect of variation in Feed to starch ratio on bulk density of briquettes

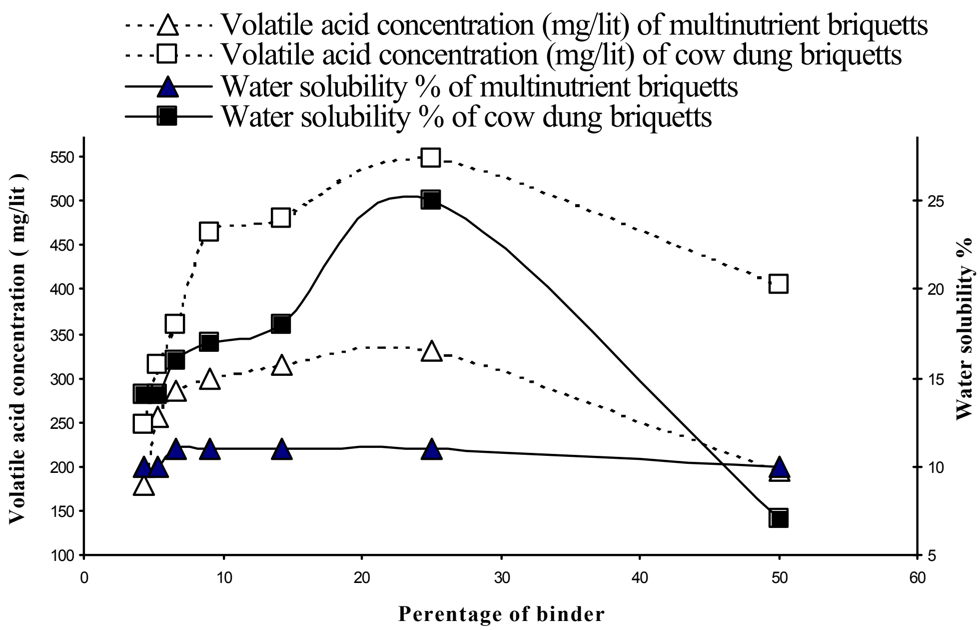

Fig. 5: Water solubility and Volatile acid concentration of briquettes

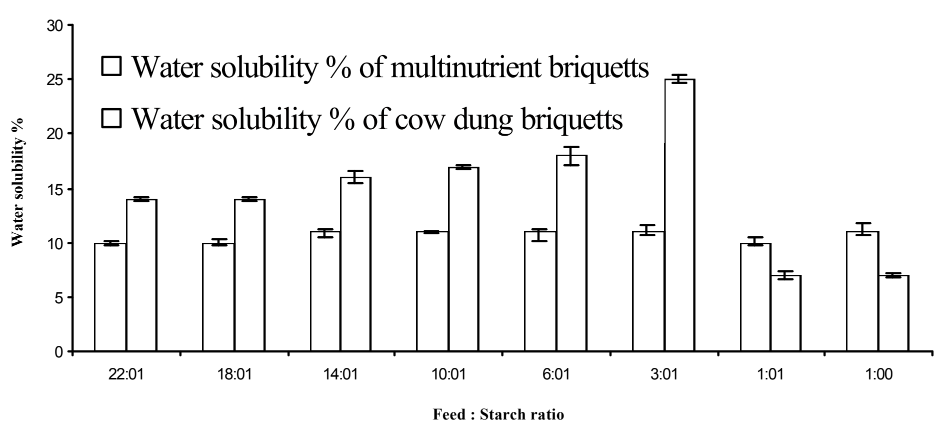

Fig. 6: Effect of variation in Feed to starch ratio on water solubility of briquettes.

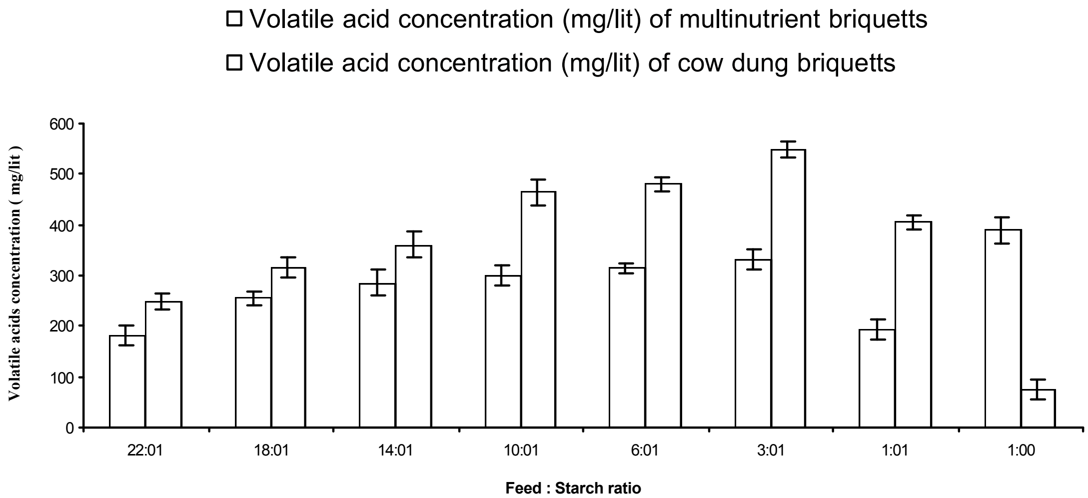

Fig. 7: Effect of variation in Feed to Starch Ratio on Volatile acid concentration of briquettes

Fig. 8: Briquettes of different shapes and sizes

Fig. 9: Moulding (Wooden Mould outlined) and drying of briquettes

Fig. 10: Storage of briquettes after drying for further use

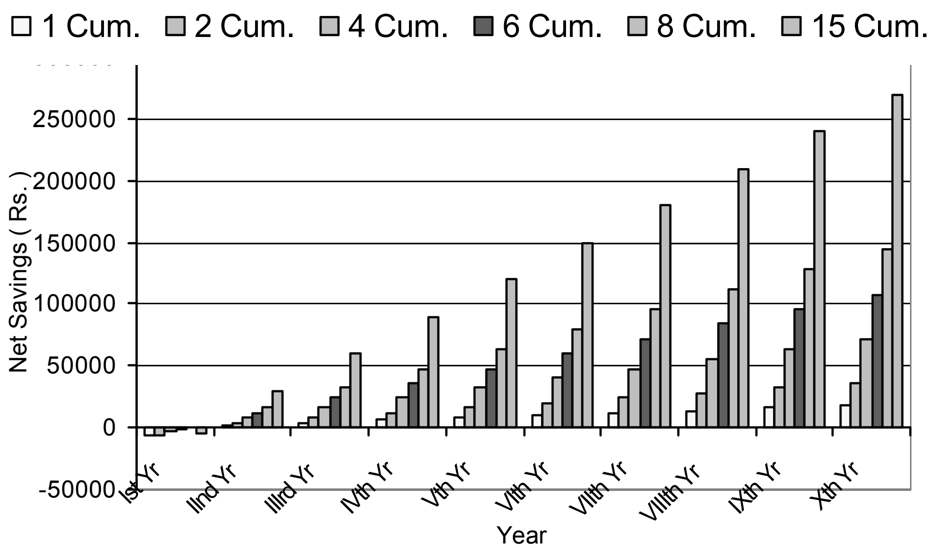

Fig. 11: Cumulative Net Savings for Domestic level Biogas plant with multinurient Feed

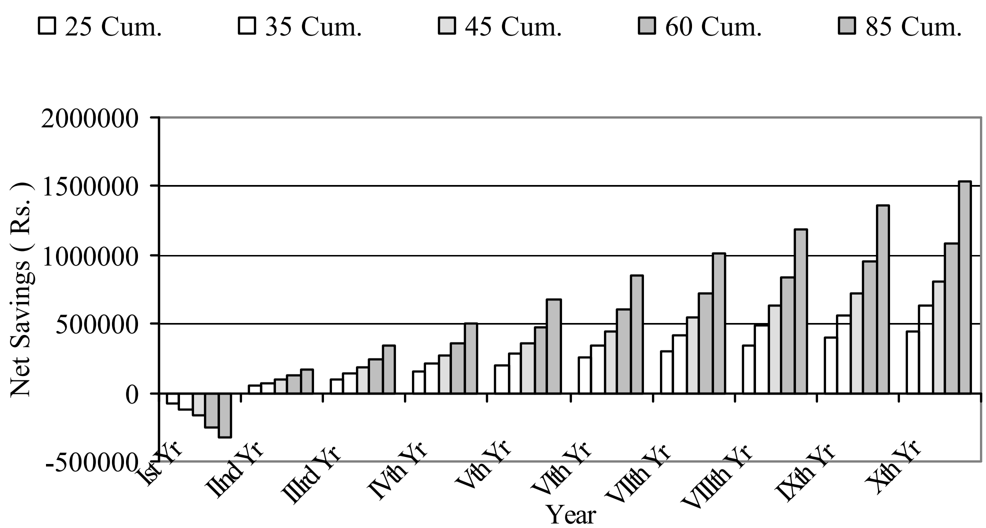

Fig. 12: Cumulative Net Savings for Commercial level Biogas plant with multinurient Feed.

Table 1: Comparative performance of cow dung and multinutrient feed briquettes on varying Feed to Starch ratio

Feed to Starch ratio	Bulk density (gm/cc)		Water solubility %		Volatile acid concentration (mg/lit) of supernatant	
	Multinutrient	Cow dung	Multinutrient	Cow dung	Multinutrient	Cow dung
22:1	0.410±0.001	0.401±0.002	10±0.19	14±0.20	180±20	248±15
18:1	0.415±0.003	0.422±0.005	10±0.30	14±0.22	255±15	315±20
14:1	0.422±0.001	0.427±0.003	11±0.00	16±0.50	285±25	360±25
10:1	0.423±0.001	0.435±0.001	11±0.06	17±0.20	300±20	465±25
6:1	0.428±0.003	0.445±0.003	11±0.22	18±0.80	315±10	480±15
3:1	0.466±0.002	0.449±0.002	11±0.65	25±0.40	330±20	548±15
1:1	0.774±0.003	0.460±0.005	10±0.46	7±0.30	195±20	405±15
1:0	0.588±0.002	0.582±0.003	11±0.79	7±0.25	390±25	75±20

Table 2: The cost of feeding the plants

Plant Capa -city m^3	Cow Dung (Rs.)	Wheat straw (Rs.)	NaOH (Rs.)	Grinding (Rs.)	Binder (Rs.)	Magnesium (Rs.)	Total Cost (Rs. /day)	Annual Cost (Rs.)	General Annual cost(Rs.)
1 m^3	2	2.5	7.2	6	16	11	45	16,245	6857
2 m^3	4	5	14.4	12	33	21	89	32,489	13713
4 m^3	8	10	28.8	24	65	42	178	64,978	27427
6 m^3	12	15	43.2	36	98	63	267	97,467	41140
8 m^3	16	20	57.6	48	130	84	356	1,29,956	54854
15 m^3	30	37.5	108	90	244	158	668	2,43,668	102851
25 m^3	50	62.5	180	150	406	264	1113	4,06,113	171418
35 m^3	70	87.5	252	210	569	369	1558	5,68,558	239985
45 m^3	90	112.5	324	270	731	475	2003	7,31,003	308552
60 m^3	120	150	432	360	975	633	2670	9,74,670	411402
85 m^3	170	212.5	612	510	1381	897	3783	13,80,783	582820

Table 3: The benefit in the form of fertilizer obtained

Plant capacity	Input slurry (Tons)	Manure (Ton)	Effluent slurry (Ton)	Urea* (Rs.)	Superphosphate* (Rs.)	Potash* (Rs.)	Total fertilizer (Rs.)
1m^3	18.25	13.69	5.48	1243	1280	3212	5,734
2 m^3	36.5	27.38	10.95	2485	2560	6424	11,469
4 m^3	73	54.75	21.90	4970	5119	12848	22,937
6 m^3	109.5	82.13	32.85	7456	7679	19272	34,406
8 m^3	146	109.50	43.80	9941	10238	25696	45,875
15 m^3	273.75	205.31	82.13	18639	19197	48180	86,016
25 m^3	456.25	342.19	136.88	31065	31995	80300	1,43,359
35 m^3	638.75	479.06	191.63	43491	44792	112420	2,00,703
45 m^3	821.25	615.94	246.38	55916	57590	144540	2,58,047
60 m^3	1095	821.25	328.50	74555	76787	192720	3,44,062
85 m^3	1551.25	1163.44	465.38	105620	108781	273020	4,87,421

*The present market rates of the Urea (Rs. 5.22/kg), Superphosphate (Rs. 2.20/kg) and Potash (Rs. 8.80/kg) were taken into account for analysis

Table 4: The annual benefits in terms of gas cylinder saved and fertilizer obtained

Plant Capacity	Gas Cylinder (Rs.)	Manure (Rs.)	Total Saving (Rs.)	Installment* Cost of plant (Rs.)	General Annual Cost (Rs.)	Net ** Savings(Rs.)
1m^3	3,120	5,734	8,854	8,500	6857	-6502
2 m^3	6,240	11,469	17,709	9,500	13713	-5505
4 m^3	12,480	22,937	35,417	11,550	27427	-3559
6 m^3	18,720	34,406	53,126	13,000	41140	-1014
8 m^3	24,960	45,875	70,835	16,550	54854	-569
15 m^3	46,800	86,016	1,32,816	35,000	102851	-5035
25 m^3	78,000	1,43,359	2,21,359	1,25,000	171418	-75058
35 m^3	1,09200	2,00,703	3,09,903	1,87,500	239985	-117582
45 m^3	1,40,400	2,58,047	3,98,447	2,50,000	308552	-160105
60 m^3	1,87,200	3,44,062	5,31,262	3,75,000	411402	-255140
85 m^3	2,65,200	4,87,421	7,52,621	5,00,4000	582820	-330199

* Survey Book.

**Net Savings (Rs.) = Total Savings (Rs.) – [(Installment cost (Rs.) + General cost (Rs.)]

Table 5: Cumulative net savings fed with multinutrient feed

Plant capacity	IstYr	Iind Yr	IIIrd Yr	IVth Yr	Vth Yr	VIth Yr	VIIthYr	VIIIth Yr	IXth Yr	Xth Yr
$1m^3$	-6502	1998	3995	5993	7991	9988	11986	13984	15981	17979
2 m^3	-5505	3995	7991	11986	15981	19977	23972	27967	31963	35958
4 m^3	-3559	7991	15981	23972	31963	39953	47944	55934	63925	71916
6 m^3	-1014	11986	23972	35958	47944	59930	71916	83902	95888	107874
8 m^3	-569	15981	31963	47944	63925	79906	95888	111869	127850	143832
15 m^3	-5035	29965	59930	89895	119860	149825	179789	209754	239719	269684
25 m^3	-75058	49942	99883	149825	199766	249708	299649	349591	399532	449474
35 m^3	-117582	69918	139836	209754	279672	349591	419509	489427	559345	629263
45 m^3	-160105	89895	179789	269684	359579	449474	539368	629263	719158	809053
60 m^3	-255140	119860	239719	359579	479439	599298	719158	839017	958877	1078737
85 m^3	-330199	169801	339602	509403	679205	849006	1018807	1188608	1358409	1528210

briquettes (without any binder) of multinutrient feed and cow dung feed was 390 and 75 mg/liter. Volatile fatty acids were in favorable range of 50 to 250 mg/liter [as acetic acid] for methane bacteria [11] and if exceeding, are within normal range of 250 to 500 mg/lit. Only cow dung to starch ratio of 3:1 was exceeding the limit (548 mg/lit) but to a controllable level. So largely, it can be concluded that volatile fatty acids were not inhibitory during early stages of hydrolysis and this ensures the normal start up of digestion after feeding the low density briquettes of multinutrient feed.

The briquettes can be made in different shapes and sizes as shown in Fig 8. The cuboids briquettes were made for performance evaluation of multinutrient feed in field biogas plant. The molding, drying and storage of briquettes is shown in Fig. 9 and Fig. 10 respectively.

After observing the satisfactory performance of the low-density briquettes at lab scale, experiments were extended to domestic & commercial level plants for evaluating economic analysis of the process and to find out the benefits and expenditure for the domestic and commercial level plants. The domestic level plants of 1, 2, 4, 6, 8 and 15 m^3 were taken for economic analysis. Among commercial level, the plants of capacities 25, 35, 45, 60 and 85 m^3 were taken for analysis. The Table 2 shows the daily and annual cost of feeding the plants of domestic and commercial capacities.

The benefits, from all the plant capacity were calculated in terms of manure obtained and cooking gas cylinder saved as given in Table 3 and 4.

The cumulative net savings for plants of different capacities fed with multinutrient feed were calculated, which is shown in Table 5 and shown graphically,it is given in Fig. 11 and Fig. 12 for domestic & commercial level biogas plant respectively.

From Fig. 11 and 12, it is concluded that for the first year after installation the net savings are not positive. After first year, net savings are positive. Also, the saving amount increased with the plant capacity. This leads to conclusion that use of multinutrient feed briquettes is very useful and beneficial in case of biogas plants of higher capacity.

CONCLUSIONS

The study of preparation and performance evaluation of multinutrient feeds for enhancing biogas production has come out to be beneficial. It is concluded that study indicates that the low-density briquetting of feedstock after pretreatments is a better way of storing, feeding and waste management and for enhanced biogas production. The experiment with briquettes has shown to produce favorable conditions for hydrolysis in the early stage of digestion.

The use of multinutrient feed in the form of briquettes is environmentally sustainable, practically feasible and easy to use and store. The economic analysis support its applicability in the field.

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