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ORIGINAL ARTICLE

Organic Fraction of Municipal Solid Waste Management with spent wash as inoculum and utilization of compost obtained

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ABSTRACT
In this study, comparison study was made to compost the organic fraction of municipal solid waste without inoculum and with spent wash as inoculum. During this study, composting is administrated in a vertical aerobic bench-scale reactor of volume 20L capacity for various ratios of organic fraction of municipal solid waste with the bulking agent and spent wash. To speed up the process, the spent wash is employed. The experimental study aims to spot the microorganism present in organic fraction of municipal solid waste and also the performance parameters like Carbon, Nitrogen, Phosphorous and Carbon / Nitrogen ratio (C/N), Temperature and moisture content are studied. The whole Kjeldhal nitrogen value was 1 for both the reactors and gradually it was increased to 1.2% for both the experiments. Phosphorous was 0.3% and 0.32% at an initial stage and it reached 0.39% and 0.43% at the final stage for reactor 1 and reactor 2, respectively. Potassium was 0.26% for both the reactors at the beginning and it reached 0.38% and 0.42% at final for reactor 1 and reactor 2, respectively. The decrease in TOC indicates that the aerobic microbes which were present utilized the carbon source as its food, hence the downward curve was observed. The obtained compost was used as a fertilizer to test the growth of plant and it was at its satisfactory level.
Keywords: Aerobic reactor; Composting; E-coli bacteria; Organic Municipal Solid Waste; Spent wash

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INTRODUCTION

The rise in population, industrialization and urbanization had led to the accumulation of a huge amount of solid waste everywhere on the planet [22,35]. In the developing countries, the municipal solid waste generated belong to house-holds (55–80%), commercial areas or market (10–30%) [1]. In India, a study was administrated by the Central Pollution Control Board on the management of Municipal Solid Waste to calculate the waste generation from the current 48 MT annually was estimated to extend to 300 MT by the year 2047 [12]. There are many challenges and problems to handle the municipal solid waste generated. The intense environmental problems like heating, well water pollution and common nuisance are being created by the overflowing landfill and their leachate from the uncontrolled dumpsite of solid wastes within the outskirts of cities [13,23]. It becomes mandatory to handle the generated organic portion of the solid waste because it accumulates huge space and irks the public [36,1]. There are many methods available to handle the organic waste generated. Composting is a process during which organic matter present in waste is converted into enriched organic nutrients [14, 29, 34]. During this process, the pathogenic bacteria will be eliminated while handling the municipal solid waste [18]. The manure obtained should have high nitrogen, phosphorus and potassium content [10, 21,33]. About 40,522 million tons of Phosphorous, 104,252 million tons of nitrogen and 27,435 million tons of potassium are being used throughout the world during every season [16]. The composting is the controlled decomposition of organic material by microorganisms in the presence of oxygen [19]. Composting also have economical values as it involves in converting the waste to fertilizer [37]. The different techniques adopted for the process of composting of the different types of organic wastes can be

listed as container composting handling organic municipal solid waste [27], pile composting handling flower waste [32], chamber composting handling human excreta [25] and tower composting handling fruit bunch wastes [15] and inoculum is added to enhance the process of degradation that produce valuable compost. In this study, aerobic batch reactor was designed to handle the organic fraction of municipal solid waste using spent wash as inoculum.

The current work was done to check the aerobic composting of organic fraction of municipal solid waste (organic fraction of municipal solid waste) with and without inoculum. The idea of this study is to handle the organic wastes and to deliver the product with fertilizing property as a result. The physical, chemical and biological characteristics will be analyzed for the organic wastes collected from the dump yard located in Chidambaram municipality at initial and end stage of the composting process. Two different combinations of mix ratios were tried among organic and industrial waste. The primary one was Organic waste: Bulking Agent within the ratio of 90:10 (Trial 1-without inoculum) and also the secondary combination was Organic waste: Bulking Agent: Inoculum within the ratio of 88:10:2 (Trial 2-with inoculum) were considered based on the previous studies with different bulking agent and spent wash [27].

MATERIAL AND METHODS

Sample collection

The waste was collected from the dumpsite of Chidambaram Municipality, Chidambaram, Cuddalore District during April 2019. The sampling was done at surface level from the dump yard located at Omakulam of Chidambaram municipality using quadrant method. The collected waste was segregated for its organic fractions which contains much of market waste, paddy straw, paper and wood debris of about 15 kg and shredded manually into pieces of 25-30 mm size to expedite the microbial process. The spent wash was collected from M/s Thiru Arooran Sugars LTD., Distillery Division, Thirumandangudi, Tanjavur District. Segregated organic fraction of municipal solid waste and spent wash were analyzed for physical and chemical characteristics with the method of APHA [3] and using coupled plasma mass spectrometer (Table 1). The segregated and shredded organic fraction of municipal solid waste, bulking agent and inoculum at above mentioned mix ratios were mixed manually and loaded within the workbench scale reactor. The composting was administered for 15 days. The speed of composting was monitored by collecting samples through the sampling ports on alternate days. The temperature was monitored through the sampling port using a digital thermometer.

Experimental setup

The aerobic batch reactor was fabricated using a highly durable plastic material which was used for this composting process (Figure 1). The batch reactor was designed for the capacity of 20 litres and 15kg of the organic fraction of municipal solid waste (organic fraction of municipal solid waste) was taken for the study. The dimensions of the reactor were 26 cm diameter and 40 cm height, which was placed on a flat surface. The cylindrical reactor with a gap at the highest end for feeding of raw materials. The sampling ports were provided at four places along the cylindrical side at various heights. The leachate collection will be done at the bottom and also the opening for removal of compost was given at the bottom of the cylinder. Air would be provided using an air pipe provided at the base of the reactor, which was connected to the compressor. Gases will be let out through the vent provided at the top. The composting of organic fraction of municipal solid waste was applied with dry leaves as bulking agents and spent wash as inoculum. The dry leaves were used as a bulking agent to reduce the leachate formation and also to maintain the aerobic condition for the reactor set up. Similarly, dry leaves were used as bulking agent by Sharma and Yadav [31]; Manu *et al,* [20] and obtained better results. The setup of organic fraction of municipal solid waste, bulking agent has been named as 'R1' for easy understanding. The experiment was applied for varying mix ratios of organic fraction of municipal solid waste, bulking agent and inoculum by supplying an optimum rate of aeration. This setup has been named as 'R2'. For homogenous mixing, manual shaking off the bench-scale reactor was given two times per day. The parameters like Temperature, Moisture Content (MC), pH, Electrical Conductivity (EC), Ash content, Volatile Solids (VS), Total Organic Carbon (TOC), Total Kjeldahl Nitrogen (TKN), Phosphorous, Potassium and Carbon to Nitrogen ratio (C/N ratio) were determined for the collected samples in line with APHA [3]. The parameters like zinc, copper and iron were estimated using coupled plasma mass spectrometer. All the parameters were measured in triplicates and the average value is being mentioned in this study.

Identification of bacteria

The pH of the reactor 'R1' was adjusted from 7.2 to 7.4. Further, the medium was added to the broth and it was dissolved by steaming. It was then distributed in 5 ml quantities into culture tubes. The tubes were plugged with non-cotton and they were autoclaved 15 lbs/sq inch pressure 121^{o}C/ 20 minutes. The

sample was serially diluted using sterile tubing from 10^{-1} to 10^{-6} dilution. Only one form of bacteria was predominant within the raw municipal solid waste and 2ml spent wash was added to it. For enumeration of bacteria medium containing peptone (5 g/L), yeast extract (1.5 g/L), binary compound (5 g/L), agar (15 g/L) were used. For enumeration of fungi potato, dextrose agar containing potato (200 gm), dextrose (20 gm), agar (15 gm), H_2O (1000 ml) at pH 5.6 were used. It was incubated at 37°C for twenty-four hours. The isolated bacteria were identified by colony morphology, gram staining, microscopic observation and confirmation test.

Figure 1. Experimental set up of aerobic batch reactor

RESULTS AND DISCUSSION

The pH of organic fraction of municipal solid waste was 6.2 and spent wash 4.01 with organic fraction of municipal solid waste nearby to the neutral range whereas spent wash in acidic range. The TOC of organic fraction of municipal solid waste was higher than the spent wash as it contains more decaying matter. C/N ratio and manganese were found below detection level in spent wash on the other hand these parameters were present in organic fraction of municipal solid waste. The parameters like EC, nitrogen, Phosphorous, potassium, calcium, magnesium, zinc, iron and copper of organic fraction of municipal solid waste were much lower than the spent wash (Table 1). The laboratory result of both the trials with 10% bulking agent and the waste with 2% of industrial spent wash in addition to the bulking agent has been discussed in the below section.

Effect of operating parameters

The temperature was monitored during the composting process on alternate days through the portholes provided along the sides at various levels. Both the trials were in the mesophilic phase till day 5. The reactor with inoculum reached thermophilic phase at day 7 and continued till the end. On the other hand, the reactor without inoculum continued to be in the mesophilic phase till day 9 and it was shifted to thermophilic phase from day 11 onwards. The trial R1 attained the maximum temperature of 48.5°C on 15th day whereas trial R2 has attained 52°C on 13th day. In trial R2, there was a decrease in temperature at 15th day because all carbon must be utilized so the temperature was in a decrease phase in Table 2. A similar observation was reported by Zhang *et al,* [38] from Beijing, China and Sarkar *et al,* [30] from India, stated that the decrease in temperature was due to the fact that carbon was exhausted and the rate of decomposition of organic matter was also slowed down.

The moisture content of trial R1 and trial R2 was 50% and 52%, respectively where the limit lies between the optimum ranges. It was very obvious that the increase in temperature had led to a decrease in moisture content and they are interdependent factors. The permissible moisture content is within the range of 40 to 60%. A similar result was quoted by [8] from Pondicherry, India stated that the optimum moisture content for the solid waste system should be 50 to 60 %. When the moisture content is above 60%, the compost pile will not be heated up and aerobic condition will prevail in the windrow method. Likewise, if it falls below 30%, microbial activity nearly ceases. Another study involving organic fraction

of municipal solid waste were treated in full scale reactor obtained moisture content nearby 40 at the end of their experiment [6]. Table 2 shows the effect of moisture content in the reactor with and without inoculum, respectively.

The pH of the sample with inoculum added had a drastic change when compared with the reactor without inoculum. The initial pH of the reactor without inoculum was 5.95 and the pH of the reactor with inoculum was 4.7. The increase in temperature has led to an increase in pH and also the addition of spent wash has boosted the pH to alkalinity range. The decrease in pH in the reactor without inoculum was because of the formation of low molecular fatty acids and CO2 during organic matter degradation (Table 2). Similar results were observed by [26] Pathak *et al,* from India composted municipal solid waste and found that pH of the sample was increased after the addition of the inoculum.

The measurement of EC helps to determine the salinity of the composting product which relates to the plant growth Fang and Wong [7]. In this study, the initial value of the EC in trial R1 was 12.4 mmhos cm^{-1} and it came down to 10.08 mmhos cm^{-1} likewise, the EC value for trial R2 was 13.2 mmhos cm^{-1} and it came down to 11.0 mmhos cm^{-1} at the end of the treatment. Table 2 shows the pattern of EC on R1 and R2, respectively. These values indicate that they can be applied to the soil as they have good EC value. Garcia *et al,* [9] stated that EC values must be greater than 2 mmhos cm^{-1} for the good plant growth. TOC in both the trials followed a downward curve with an increase in time as displayed in Table 2. The addition of spent wash as inoculum had boosted the system to degrade the wastes at a rate faster than the trials without inoculum. There was a sudden decrease till 5th day and thereafter a steady decrease. The obtained results were similar with the experiment conducted with the composting of organic municipal solid waste by [5] from India. All the substrates available might have been utilized by the aerobic microbes present in the reactor which ultimately led to the decrease of organic carbon.

Total Kjeldhal Nitrogen, Phosphorous and Potassium reading were mentioned in the Table 2. The Total Kjeldhal Nitrogen is found to increase from 1.02% to 1.28% and 1.02% to 1.26% in trial R1 and trial R2, respectively. The decomposition and mineralization of the organic matter led to an increase in the nitrogen content. The aerobic bacteria enhance the nitrogen profile which adds value to the degraded substances. The results obtained were similar to Jain *et al,* [17] from India when studying the composition of municipal solid organic waste. Phosphorous was found to increase steadily in a trial R1 and was increasing in trial 2 also. On the other hand, Potassium was also found to increase in trial R1 and trial R2 reactors. Narkhede *et al,* [24] Maharastra, India did a combined composting of municipal solid waste and sewage sludge and found the compost to contain 1.8% and 2.2% for Phosphorous and Potassium, respectively. Poongodi and Damodharan [27] obtained similar results when handling organic waste with different bulking agent found increase in Phosphorous and Potassium contents.

Table 1. Physical and chemical parameters of organic fraction of municipal solid waste and spent wash (n=1)

Parameters Quantity	Organic fraction of municipal solid waste	Spent wash
pH	6.2	4.01
EC (mmhos cm^{-1})	5.4	8.64
TOC (%)	22.58	4.11
Nitrogen (%)	0.68	560
Phosphorous (%)	0.15	1625
Potassium (%)	0.41	5102
Carbon – Nitrogen ratio	27.63	BDL
Calcium (%)	0.49	16932
Magnesium (%)	0.21	6593
Zinc (mg l^{-1})	23	29.16
Iron (mg l^{-1})	11.30	63.22
Manganese (%)	0.36	BDL
Copper (mg l^{-1})	10.92	55.33

BDL=Below Detection Limit

C/N ratio of both the trials tends to follow the downward curve from the start till 15th day of the experiment. This confirms that the system is stabilized and steady in the composting process. The reduction of C/N ratio till 20 displays the satisfactory output. Table 2 shows the result of C/N ratio on

both the reactors R1 and R2, respectively. Similar results were displayed when composting of municipal solid waste done using the composting bioreactor by AL-Saedi et al, 2019. The C/N ratio decrease over time and this reduction will be fast in the active phase due to the carbon mineralization to CO2 and slows down during the curing stage [39,11].

Table 2. Physical and chemical analysis of Municipal Solid Waste without and with Inoculum in two reactors respectively

Days		1	3	5	7	9	11	13	15	Mean	standard deviation
Temp (^{o}C)	R1	34.50	35.00	35.60	37.50	38.60	45.80	48.00	48.50	40.44	5.99
	R2	33.50	34.10	35.20	46.20	50.00	50.30	52.10	52.00	43.80	8.35
MC (%)	R1	52.26	48.26	47.23	45.47	44.65	38.01	33.64	30.89	42.55	7.54
	R2	50.56	48.25	47.30	46.10	44.73	43.36	42.47	37.97	45.09	3.90
p^H	R1	5.95	6.63	6.54	6.24	6.16	7.00	7.14	7.22	6.61	0.48
	R2	4.70	6.00	6.70	6.90	6.95	7.15	7.18	7.28	6.61	0.87
EC (mmhos cm^{-1})	R1	12.40	11.15	11.90	11.80	11.60	11.64	11.10	10.08	11.46	0.69
	R2	13.20	12.30	13.20	13.60	12.65	12.66	12.25	11.00	12.61	0.80
Ash (%)	R1	26.79	28.72	31.30	32.47	32.91	33.80	36.50	39.18	32.71	3.97
	R2	26.34	28.10	36.80	39.82	40.31	42.30	44.60	45.80	38.01	7.24
V_S (%)	R1	73.81	71.28	68.7	67.53	67.09	66.2	63.5	60.82	67.37	4.10
	R2	73.66	71.9	63.2	60.18	59.69	57.59	55.4	54.2	61.98	7.25
TOC (%)	R1	40.20	39.6	38.16	37.51	37.27	36.77	35.27	33.78	37.32	2.11
	R2	41.5	40.5	35.11	33.43	33.16	32.05	31.55	30.22	34.69	4.16
TKN (%)	R1	1.00	1.03	1.05	1.10	1.12	1.16	1.18	1.28	1.12	0.09
	R2	1.02	1.05	1.07	1.12	1.13	1.15	1.20	1.26	1.13	0.08
P (%)	R1	0.30	0.32	0.35	0.37	0.38	0.37	0.36	0.39	0.36	0.03
	R2	0.32	0.34	0.36	0.38	0.39	0.40	0.41	0.43	0.38	0.04
K (%)	R1	0.26	0.28	0.30	0.32	0.34	0.35	0.37	0.38	0.33	0.04
	R2	0.26	0.28	0.32	0.33	0.36	0.38	0.40	0.42	0.34	0.06
C/N	R1	40.20	38.44	36.34	34.1	33.27	31.69	29.88	26.39	33.79	4.54
	R2	40.11	38.03	32.81	29.84	29.34	27.86	25.64	23.89	30.94	5.72

Three types of bacteria were predominant in the raw municipal solid waste. The isolated bacteria were identified by gram staining, colony morphology, microscopic observation and confirmation test. The identified bacteria were Enterococci sp, Bacillus sp, E. coli. These organisms were found in municipal solid waste during composting [28, 4].

CONCLUSIONS

The reactors without inoculum and with spent wash as inoculum were operated for 15 days to handle the organic fraction of municipal solid waste. The factors like temperature, pH and moisture content were in the permissible range at the end of 15th day. C/N ratio was nearly 20 at the end of the experiment. The TKN value, Phosphorous content and Potassium were also found to increase. The obtained compost was used as a fertilizer to check the growth of the plant and it was at a satisfactory level. The addition of inoculum increased the properties of the compost when compared with the compost obtained from reactor without inoculum and hence spent wash could be recommended for future usage to increase the nutrient value.

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CONFLICT OF INTEREST

There is no conflict of interest.

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