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Additives Aided Rapid Composting Treatment of Garden Waste

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Abstract - *Municipal solid waste (MSW) generated is increasing day by day due to the growing population and hence, the management of such large quantity of waste is a major issue and challenge which needs to be tackled effectively. The MSW contains significant amount of biodegradable waste which can be turned into a stable material by utilizing composting technique. Composting is a time consuming process involving biological stabilization of waste by the action of waste degrading microbes. By utilizing various additives the composting process can be accelerated so as to get the final compost in shorter time. A Field scale experimental study was performed using High Density Polyethylene (HDPE) composting bags of size 4ft long, 2ft wide and 2ft deep. A comparative study between Normal Composting (NC) and Additive Aided Composting (AC) was done to investigate the effect of various additives such as jaggery, lime, fly ash and bio-culture on garden waste composting. All the parameters of compost quality including gradation test and bulk density favoured use of jaggery and bio-culture as the best additives facilitating rapid composting of garden waste.*

***Key Words*: Additives, Bio-culture, Fly ash; Garden waste composting, Jaggery.**

1. INTRODUCTION

In developing countries, the management of municipal solid waste is a major problem. The MSW contains ~50% of organic waste which can be treated effectively so as to get nutrient rich material called as compost [1]. Composting is the process of waste stabilization by the action of waste decomposing microbes transforming organic waste into stable and safe material called *'compost'*. The compost can be used as source of nutrients and manure/soil conditioner in agricultural applications. In recent years, much importance is given to the composting of MSW due to various advantages such as; easy operational process, low cost, resource generative and eco-friendly. Various disadvantages such as time and space requirement and the manpower needed is a major obstacle in adopting the eco-friendly composting process.

The composting process typically consists of three phases: first is the initial activation stage, followed by thermophilic phase and then maturation phase. The initial activation stage generally lasts for 1–3 days, during which simple organic compounds such as sugars are consumed and mineralized by microbial communities, producing CO_2, NH_3, organic acids and heat due to which the temperature of compost pile increases Peak temperature value up to 60°C is attained during the thermophilic phase. The optimum temperature range for composting process is 40–65°C [3], the pathogens present in the waste are killed at temperature above 55°C. During this phase, thermophilic microorganisms degrade lignin, fats and cellulose structure [2]. Finally, during the maturation stage, temperature of the pile slowly decreases due to reduced microbial activity resulting from a decrease of biodegradable compounds. The temperature profile during composting is influenced by the composition of the initial composition of raw waste, effective aeration through pile turning, moisture content and the addition of additives or bulking agents [4].

Typically, the initial C/N ratio of the raw waste should be maintained in range of 20-40 for the composting of wet waste [5]. The process of composting can be accelerated by shortening the composting time. This can be achieved by co-composting using different wastes, rapid composting using additives and accelerators containing effective microorganisms (EM). Additives are basically a mixture of various microorganisms, nutrients or readily available forms of carbon, enzymes, etc. which enhances the microbial activity when the additives are in contact with the organic waste [6]. The addition of commercially available bio-culture containing effective microorganisms can assist in production of good quality compost [7]. A commercial available microbial inoculum containing EM when used as an additive changed the temperature profile of the composting process and the ammonia emissions due to the increase in the mesophilic and thermophilic bacteria compared to NC [8]. Utilization of jaggery and polyethylene glycol favored composting process as by acting as food for the waste degrading microbes [9]. Addition of lime showed a positive effect on composting process by increasing the temperature and CO_2 evolution without any negative effect on microbial community [10]. Fly ash has water holding capacity due to high porosity which maintains the moisture content required for composting process [11]. Ash increased the rate of mineralization of compost and the formation of humic acids [12]. The addition of low doses (4–8%) of wood ash raised process pH, and enhanced heat production and microbial activity in bio-waste composting [13]. According to their experiment addition of amounts of 4–8% wood ash is sufficient for efficient bio-waste composting process and yields a safe end product. The compost with EM has shown a few significant beneficiary impacts including the improvement of odour control and few parameters (humification process, fat reduction and N content) [14]. One-time addition of inoculum reduced the time required to finish active decomposition period to 30-36 days [15]. Addition of chemical agents glucose (G) and acetic acid (AA) and application of cellulolytic microbial (M) inoculum (Phanerochaete chrysosporium and Trichoderma reesei) were used to facilitated quick decomposition of MSW. The result of the present investigation revealed that the degradation of organic substrates were quick (within 9–12 days) in case of rapid composting as indicated by the reduction (below 20) in C/N ratio by utilizing chemical agents glucose (G) and acetic acid (AA) and application of cellulolytic microbial (M) inoculum (Phanerochaete chrysosporium and Trichoderma reesei) as additives in composting. Whereas, normal composting took more than 20 days to attain C/N ratio of below 20 [16]. Various studies have been carried out previously, clearly indicating the utilization of additives could be beneficial for the composting process. But, a detailed comparative study comprising effectiveness of various additives has not been carried out.

The current study aims to investigate the effect of various additives such as jaggery, lime, fly ash and bio-culture on the composting process. A field scale comparative study between NC and AC was done. Based upon test results of the compost sample, most suitable and effective additive for accelerating the composting process is suggested.

2. MATERIALS AND METHODS

2.1. Raw waste and additives

The garden waste (GW) mainly consisting of grass trimmings and fallen leaves collected from the garden area of Government College of Engineering, Amravati was used as raw material for composting. The collected waste was then shredded by using the garden waste shredder machine for reducing the volume of waste. Additives utilized for the experimentation include jaggery, powdered lime, fly ash and commercially available bio-culture procured from Excel Industries, Mumbai.

2.2. Experimental setup

The field scale composting experimentation was carried out by using 15 nos. of HDPE composting bags of size 4 ft. long, 2 ft. wide and 2 ft. deep. The collected waste was then shredded by using the garden waste shredder machine for reducing the volume of waste. The composting bags were filled with shredded waste and 5% of each additive (lime, jaggery and fly ash) was added on dry weight basis. Commercially available bio-culture was added as per directions i.e. 1 kg culture for 1 MT of waste. The waste was then sprinkled with water to attain optimum moisture content (MC) of 40-60% and further on the MC was maintained by adding water when the waste becomes dry. Three replicates were maintained for each additive and proper care was taken to eliminate any external disturbance affecting the composting process.

2.3 Waste characterization and analysis

The particle size distribution of raw waste was done by sieve analysis (approx. 100 g of waste) using sieves of 2 mm to 12 mm mesh sizes for 5 min and cumulative percentage passing (CPP) through 12 mm was calculated as:

$$CPP = 100 - \%\ retention$$

$$\%\ Retention = \frac{\text{Weight of sample retained in sieve}}{\text{Weight of sample retained in sieve}}$$

Bulk density of the waste was determined using pycnometer method and calculated using formula,

$$Bulk\ Density = \frac{\text{Weight of sample in gram}}{\text{Volume of sample retained in cm}^3}$$

During the composting process temperature was monitored using a battery operated digital thermometer (Naitik Creations, India). Moisture Content (MC) was determined by drying the waste samples in a hot air oven (model STXLO95 Stericox systems, India)

The chemical analysis was performed on oven dried powdered samples in the laboratory. pH and Electrical Conductivity (EC) was measured by mixing 1 gram of powdered sample with 10 ml of distilled water for 15 min (Hach Dual pH-conductivity meter, model HQ440D, USA). The carbon and nitrogen content was determined using Mridaparikshak testing equipment developed by Indian Institute of Soil Science.

All the analysis were carried out in triplicate and the mean values with standard deviation was calculated using Microsoft excel. Graphical representations of pH, Temperature, C/N ratio, EC were also statistically interfaced with error bars.

3. RESULTS AND DISCUSSION

3.1. Raw waste characterization

The results of gradation test on the raw waste it was inferred that CPP through 12 mm sieve size was 45.88%. Initial C/N ratio of the raw waste was found to be 28.30 (optimal range i.e. 20-40). MC was found to be 58% (optimum range of 40-60% for start of the compost process). The average pH and EC were measured as 5.80 and 1.81 dS/m. The bulk density of raw shredded waste was found to be 0.65 g/cm^3.

3.2. Characterization of waste mixed with additives

The additives (jaggery, powdered lime, fly ash and bio-culture) were mixed in a definite proportion with raw waste. The characteristics of the raw waste mixed with additives are presented in Table 1.

Table - 1: Characteristics of the waste mixed with additives

Parameter	Jaggery	Bio-culture	Lime	Fly ash
pH	5.60 (0.11)	5.87 (0.06)	11.19 (0.20)	8.85 (0.10)
C/N ratio	31.40 (0.70)	26.10 (0.46)	28.47 (0.80)	27.20 (1.25)
EC (dS/m)	1.98 (0.07)	1.88 (0.04)	1.74 (0.17)	2.13 (0.05)

Note: The values indicate mean with standard deviation in parenthesis *(n=3)*

3.3. Effect of additives on temperature profile during composting process

Temperature is one of the important parameter to assess the progress of composting process as it indicates the heat released by the metabolic activity of the microbes [15]. The change in temperature throughout the composting process is presented in Chart 1. The initial temperature in case of addition of lime was maximum compared to control unit and other additives. Due to the exothermic reaction of lime with water the mean initial temperature observed was 33.7°C. The maximum mean temperature during thermophilic phase (TP) observed in case of bio-culture and jaggery treatments were 60.7°C and 53.3°C respectively on 6th day. Due to the presence of effective microorganism (EM) required for composting process during initial stage maximum rise in temperature occurred in case of bio-culture treatment. Whereas the early rise in temperature in case of jaggery treatment compared to control unit and other treatments could be due to the availability of food (carbon source) to the waste degrading microbes that boosted their growth leading to increase in metabolism activity and temperature. The duration of TP also extended up to 8 days in case of AC (jaggery and bio-culture) against 4 days in NC. The addition of fly ash inhibited the rise in temperature during TP by increasing the water holding capacity of the compost.

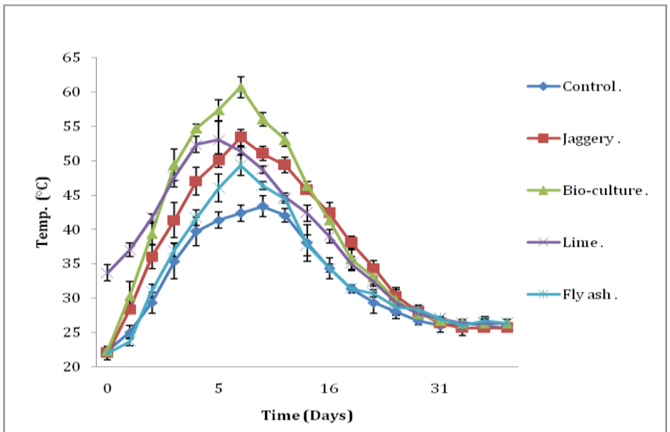

Chart – 1: Effect of additives on temperature profile during composting process

3.4. Effect of additives on pH during composting process

The effect of various additives during the composting process is illustrated in Chart 2. The initial mean pH in all treatments was in the range of 5.6 to 5.87, excepting lime and fly ash treatment wherein it was 11.19 and 8.85 respectively. During the initial days the pH value decreased probably due to the formation of acidic substrates by the action of microbes. Later on the pH started increasing from acidic to neutral level in case of control unit, jaggery and bio-culture treatment. Notably, in lime and fly ash treatment the pH decreased up to 5.7 and started rising as with other treatments. Bio-culture and jaggery treatments maintained low ph value throughout the composting period, probably due to the accelerated action of microbes generating acidic substrates.

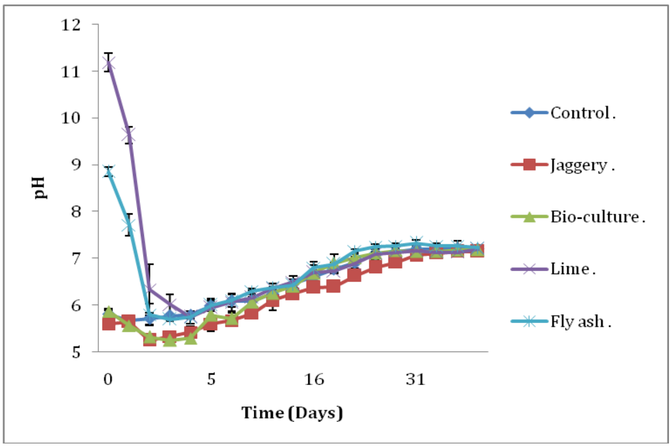

Chart – 2: Effect of additives on pH during composting process

3.5. Effect of additives on MC during composting process

Initial moisture content in all the treatments was found to be in range of 51-58%. During the whole composting cycle the moisture content was maximum in case of fly ash treatment due to its high water holding capacity. Whereas in lime treatment maximum moisture loss occurred due to exothermic reaction of lime with water.

3.6. Effect of additives on EC during composting process

The determination of EC of compost sample is important as it indicates salt concentration of a sample and influences its use as a fertilizer. The precipitation of mineral salts occur as the organic matter degrades [17] resulting in higher pH values. In the present study, initial mean EC of waste was in range of 1.81 to 2.13 dS/m. Due to the degradation of organic matter by microbial activity transforming it into mineral salts the mean EC was increased to 3.57 dS/m. The value of EC greater than 4 dS/m is not advisable for using as soil conditioner. Chart 3 illustrates the effect of additives on EC during composting process.

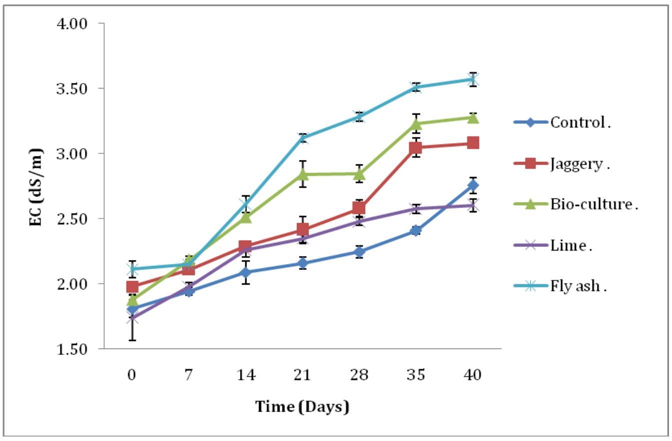

Chart – 3: Effect of additives on EC during composting process

3.7. Effect of additives on C/N ratio

The effect of additives on C/N ratio is presented in Chart 4. C/N ratio was found to be less than 20 in all AC whereas it took 40 days for NC to attain C/N ratio < 20. Maximum reduction in C/N ratio on 40th day was observed in case of bio-culture (9.90) followed by jaggery (11.20). The reduction rate of C/N ratio on 40th day was found to be 64.33%, 62.06%, 41.2% and 38.34% in case of jaggery, bio-culture, lime and fly ash respectively. Whereas, a reduction of 25.4% in C/N ratio was observed on 40th day in case of NC.

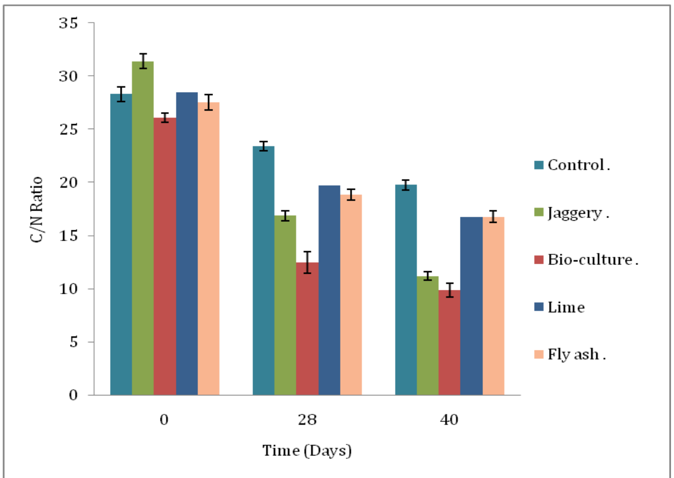

Chart – 4: Effect of additives on C/N ratio during composting process

3.8. Effect of additives on bulk density of final compost

The initial bulk density (BD) of raw waste was 0.65 g/cm^3, which at the end of composting process increased to the range between 0.82 g/cm^3 to 0.96 g/cm^3 in all treatments. Maximum increase in BD was observed in case of bio-culture (0.96) followed by jaggery (0.93). All the treatments utilized in AC showed a significant increase in BD as compared to NC. Table 2 presents the effect of various additives on the BD of finished compost.

Table - 2: Effect of additives on BD of final compost

Treatment	Bulk density (g/cm^3)
Control	0.78 (0.014)
Jaggery	0.93 (0.021)
Bio-culture	0.96 (0.010)
Lime	0.82 (0.008)
Fly ash	0.85 (0.011)

Note: The values indicate mean with standard deviation in parenthesis *(n=3)*

3.9. Effects of additives on particle size distribution of final compost

Sieves of size 2 mm to 12 mm were used to fractionate the material to calculate CPP and the results are presented in Table 3. Normally, best compost should have 90% cumulative percentage passing (CPP) through 12.6 mm sieve [18]. The compost with cumulating passing more than 15 mm sieve is not to be applied into field. The results showed that CPP through 12 mm sieve size was greater than 90% in all the treatments. Particle size reduction was observed maximum in case of bio-culture followed by jaggery.

Table – 3: Effect of additives on particle size distribution of final compost

Fraction	Initial	Control	Jaggery	Bio-culture	Lime	Fly ash
12.5 mm	45.88	88.77	97.75	98.90	94.33	94.05
8.00 mm	13.63	62.31	78.00	83.20	68.68	71.50
4.00 mm	1.17	9.75	35.55	41.95	34.22	29.95
2.00 mm	0.12	1.62	6.75	6.20	4.37	7.30

3.10. Characteristics of final compost and cost of HDPE bags

The final compost samples were characterized and compared with the standards mentioned in Solid Waste Management Rules (2016) [19] as illustrated in Table 4. In case of final compost obtained by AC all the mean values of MC, pH, EC and C/N ratio were 16.8-20.2%, 7.15-7.23, 2.6-3.57, 9.2-16.77 which were found to be within the prescribed limit whereas the final compost from NC contained C/N ratio of 20.11 which was not per the standards. The %yield of the final compost was determined on the basis of fractions finer than 4mm and it was found to be in the range of 29.95-41.95%. Whereas a yield of 18.75% was obtained in case of NC.

The present study demonstrated the comparative analysis of whole composting process carried out by utilizing various additives. The production of good quality compost was obtained in less duration achieving rapid waste composting.

The whole study was carried using 15 HDPE bags (length 4ft, width 2ft and depth 2ft) each costing INR 300/- costing a total amount of INR 4500/-. The life cycle of the HDPE bags generally lies between 3-5 years depending upon exposure to sun.

Table - 4: Comparison of final compost parameters with standard values as per SWM rules 2016

Para meter	Control	Jaggery	Bio-culture	Lime	Fly ash	SWM Rule 2016
pH	7.21 (0.01)	5.60 (0.11)	5.87 (0.06)	11.19 (0.20)	8.85 (0.10)	6.5-7.5
MC (%)	21.3 (0.58)	17.25 (1.53)	16.55 (0.85)	22.45 (1.40)	18.62 (1.15)	15-20
C/N ratio	20.10 (0.26)	31.40 (0.70)	26.10 (0.46)	28.47 (0.80)	27.20 (1.25)	≤ 20
EC (dS/m)	2.76 (0.06)	1.98 (0.07)	1.88 (0.04)	1.74 (0.17)	2.13 (0.05)	≤ 4
Yield (%)	18.75	35.55	41.95	34.22	29.95	-

Note: The values indicate mean with standard deviation in parenthesis *(n=3)*

4. CONCLUSIONS

The present study evaluated the performance of additives used for composting process and the results were compared with the control unit. The additives utilized in the composting process accelerated the growth of waste degrading microbes and stimulates the enzymatic activity. This in turn accelerated the composting process and quality of finished compost as well. Among the different additives the maximum reduction in C/N ratio obtained in case of jaggery and bio-culture indicated the rapid composting process. On the other hand, lime and fly ash did not show any negative effect on composting process but enhanced the composting process compared to the NC. The additives used in the study reduced the composting time by a minimum value of 30% as AC required 28 days whereas NC took 40 days as indicted by C/N ratio <20 . Hence, the utilization of additives in the composting process hastened the composting process achieving rapid composting. Considering the compost parameters throughout the composting process bio-culture and jaggery are the most effective additives suggested for rapid composting of GW.

The future studies can focus on using combination of two additives so as to get combined positive effects, co-composting with other types of waste (food waste, sewage sludge) and effective aeration to the compost unit.

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