Comparative Study of Different Techniques of Composting and their Stability Evaluation in Municipal Solid Waste

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Summary: Spatial differences in the physical and chemical characteristics related to maturity of composted organic matter are strongly influenced by composting methods. For evaluation of compost maturity three locally fabricated composters (aerobic, mixed type, anaerobic) processes were examined at seven days interval up to 91 days by loading MSW along with bulking agent. Gradual changes in physico chemical characteristics (temperature, pH, moisture, CEC, humification) related to stability and maturity of compost were studied and compared**.** Increase in ammonia nitrogen level due to rise in temperature was maximum in aerobic process**.** Substantial increase in CEC in aerobic process was earlier which leads to establish the optimal degree of maturity as compared to other processes. FA and HI decrease rapidly as composting progressed. Optimal level in stability and maturity parameters like **C:N**, HA, DH and HR were attained earlier in aerobic process as compared to mixed type and anaerobic processes due to continuous aeration.
The parameters (HR, DH, FA, HA), which indicate the compost stability were correlated among themselves. The parameters defining maturity such as CEC, ammonia nitrate and **C:N** ratio were also related to above mention parameters. The compost from the aerobic process provided good humus and micronutrients. Result from this study will assist in method optimization and quality of the compost product.

Introduction

Composting is the controlled biological decomposition of organic substrate carried out by successive microbial populations combining both mesophilic and thermophilic activities, leading to the production of a final product sufficiently stable for storage and application to land without adverse environmental effects [1].

Slew of studies have mentioned the differences in quality of end product of different common feedstock. Differences in results of some physical (temperature, colour, odour) and chemical (C: N ratio, ammonia, nitrate, HA and CEC,) parameters have been observed in different methods of composting [2, 3].

Composting methods differ in duration of decomposition and potency of stability and maturity. Mechanical composting physically breaks up organic matter yielding a texturally and chemically homogenous end product in less time. Static passively aerated composting is another method, which is less laborious than mechanical method and requires less time as compared to Windrow process [4]. Various techniques have been developed for forced aeration system to control odour and minimum processing time [5].

The stability of compost is the degree to which the organic fraction is stabilized during the decomposition process. Compost is considered unstable if it contains a high fraction of biodegradable matter and under pin microbial activity. Stability is an important aspect of composting in relation to its field application, potential of odour generation and pathogen regrowth [6]. Stability prevents nutrients from becoming tied up in rapid microbial growth allowing them to be available for plant need [7].

Maturity indices of MSW compost are still not developed. A number of criteria and parameters have been proposed for testing compost stability and maturity, but no single method has been universally applied to all compost due to the variation in feed stock composition and composting processes [8]. Physical characteristics such as colour, odour and temperature give general idea of decomposition stage but little information regarding the degree of maturation. For this, chemical methods are widely used including measurement of C: N ratio, organic nitrogen, CEC, and degree of organic matter humification.

C: N ratio has been used as an index of compost maturity [9]. Jimenez and Garcia [10] have compared initial to final C: N ratio to relate them to maturity. Charpentier and Vassout [11] have reported 30:1 C/N ratio for raw material and 13:1 for mature compost**.** Inoko *et al.* [12], recorded the decrease of total carbon including hemicelluloses, cellulose and

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increase in total nitrogen, crude ash and lignin during maturation of city refuse compost.

Nitrification is the oxidation of ammonium NH_4^+ to NO_3^- by microorganisms [13]. Chefetz *et al.* [14], reported, the total amount of soluble nitrogen decrease during composting and it represents mineralization. During maturation the ammonium nitrogen level continues to decrease while the nitrate level increases. The increased ratio of $N\text{-}NO_3^-$/ $N\text{-}NH_4^+$ ratio is an indicator of compost maturity [15-16].

Cation exchange capacity describes the quantity of negative charges in the matrix to hold cations. CEC is one of the factors used in describing the properties of soil and their importance to determine the compost maturity. CEC is reported to increase during composting [17]. Significant correlation was noted between CEC and C/ N ratio of city refuses compost. CEC greater than or approximately 60 is considered to be sufficiently matured for the application to cropland [18].

Humification is the key factor in improving the quality of compost because of the importance of the humic substances to soil ecology, fertility and structure and their beneficial effects on plant growth [19]. It is the sum of degradation of lignin to aromatic unit, which occur mainly during the thermophilic phase [20].

Humic acid- like fractions that generally increase during composting reveals the humification of organic matter. These fractions also show slight decrease in mixtures. The C_{HA} /C_{FA} ratio increase during the process in most of the mixture mainly due to the pronounce decrease in the C_{FA} [21].

The objective of this study was to evaluate the physical and chemical differences that resulted from composting a MSW using different techniques for stability and maturity of compost. This study will assist the method optimization in compost operation and quality of end product.

Results and Discussion

Numerous scientists studied the criteria for the assessment of compost maturity but still no general conclusion is present. Based on physical and chemical parameters, various standards are proposed for mature compost, but these cannot be generalized for all types of composting due to difference in methodologies and substrate compositions.

The comparisons of the results for analyzed compost after every seven-day was carried out for a period of 91 days. The variations in the parameters during different times of study were documented graphically and tabulated for three composters (aerobic, mixed type and anaerobic) process are discussed below.

Composting is an exothermic process and the temperature rise is an integral part of this process. In addition, the high temperature is an essential component towards sanitation of compost [22]. A rise of temperature after seven day resulted from microbial activity was observed in all types of composters (Fig. 1) followed by decline due to less availability of organic carbon, these results are also described by Hagerty *et al.*[23]

Variation in temperature with respect to ambient was recorded in all types of composters. In aerobic composter maximum temperature increase was 59.1^{o}C on 5th week where as in mixed type composter the temperature 43.1^{0}C was on sixth week (Fig. 1) The temperature of anaerobic composter was lowest as compared to other composters due to its more moisture contents, because there was no place to escape the leachate hence it is accumulated, as discussed by Iyengar *et al.* [1]

Change in pH is due to metabolic activities resulted in the production of organic acids and release of ammonia. Different organic wastes suitable for composting have a range of pH from 5-12 [24], but no specific pH is required for composting process [25]. The pH of the raw material (7.65) dropped in all types of composters (Fig 2) at early stage due to the production of organic acids by the fermentation of carbohydrates and lipids due to microorganisms. Hagerty et al [23], have also stated the same views. The pH becomes neutral again when organic acids are converted to CO_2 by microbial activity, which is in agreement with the observation made by Seo [26]. At maturity, aerobic process pH was 7.25 where as mixed type process and anaerobic show the acidic nature due to incomplete degradation. Aerobic results agree with Hernando *et al.* [27]. However, pH cannot be considered as a good parameter to assess compost maturity [28].

The Central Public Health and Environment Engineering Organization [29] enumerated that the nitrogen, phosphorous and potassium (NPK) contents for compost should be more than 1% each. Total Potassium gradually increased with time in all composting processes but maximum value (1.51%) was attained in aerobic process. The value of potassium comes within limits (1-1.5%) of Anthonis [30]. No significant difference was found at the end of this process in all types of composting.

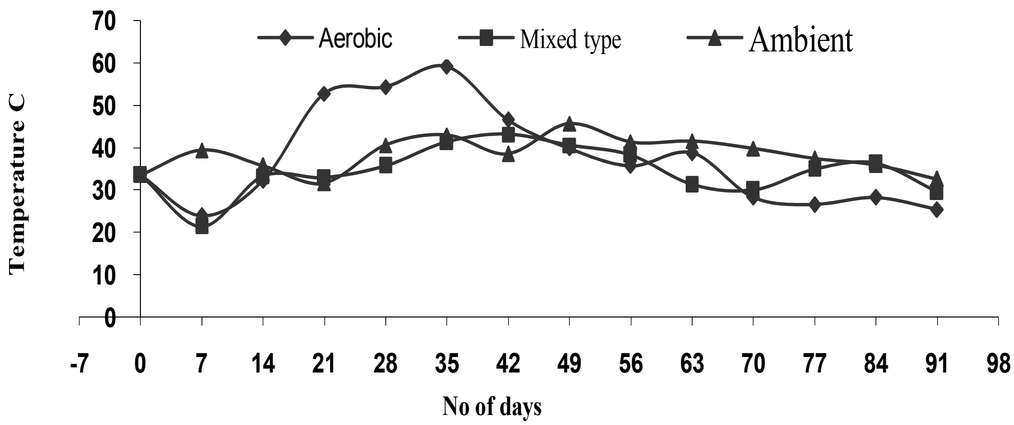

Fig. 1: Variation in temperature of different type of compost with time.

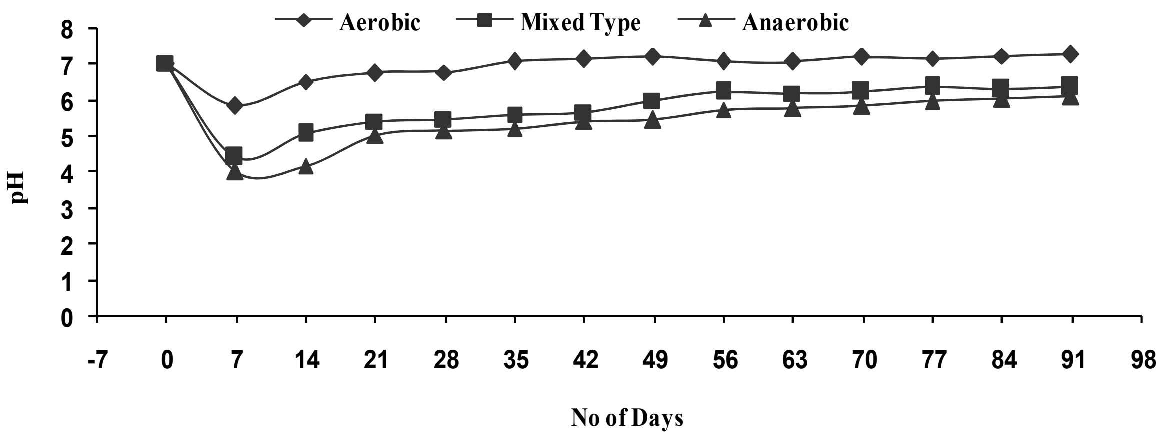

Fig. 2: Variation in pH of different type of compost with time.

Phosphorous contents show the same trend as of potassium. Potassium percentage amount in different composting process as were aerobic > mixed > anaerobic [Table-1]. Only anaerobic compost did not meet with the specification (0.5-1%) of Anthonis [30], which was described for best mature compost. MSW contains food waste of much fibrous material, which can absorb large quantity of water and prevent loss of nutrients (K, P) from compost.

The ratio of C/N of organic waste is critical and traditionally used for the degree of maturity in the composting process [31]. Reduction of carbon was greater as compared to N in all types of composting processes because microorganisms used carbon as the source of energy and N for building cell structure in decomposition process. The percentage reduction in C/ N ratio value was 47.5%, 24.7% and 14.83% for aerobic, mixed and anaerobic composters, respectively (Fig 3). The results were in agreement with Epstein [32]. Higher reduction of carbon and nitrogen ratio in aerobic composter was due to nature of aeration and become stable earlier than in all other process. In anaerobic process the final C/ N ratio was higher than recommended values (10-15). Anaerobic compost is not suitable for land application. However, excess carbon, nitrogen would be utilized in the soil to build cell protoplasm resulting the loss of nitrogen in the soil.

Table-2 present the total carbon, total nitrogen, ammonia, nitrate and ammonium nitrate ratio in mg/kg of waste matter composted in different composters at different time intervals.

Table-1: Elemental analysis of mature compost

Parameters	Aerobic Method	Mixed Method	Anaerobic Method
Na %	2.13 ± 1.1	1.72 ±0.73	0.91 ±1.5
K %	1.51 ± 0.50	1.13 ± 1.0	1.07 ±0.2
Phosphorus%	0.72± 0.02	0.55 ±0.5	0.23 ± 0.05
Zn mg/kg	57.65 ± 3.5	34.1 ± 0.9	23.7 ± 3.0
Mn mg/kg	41.7 ± 1.0	37.4 ± 1.1	19.76 ± 1.3
Fe mg/kg	639.3 ± 11.3	569.2 ±9.6	406.3 ±6.9
Moisture %	31.9 ±5.7	42.9 ±5.0	78.9 ±14.7

Results are expressed as mean ± SD of three replicates

Ammonia nitrogen concentration was also an indicator of compost maturity. Its concentration was highest during the first 28 days in aerobic composting reflecting more organic matter decomposition as compared to mixed and anaerobic composting. In anaerobic process, the ammonia was low due to slow decomposition. Mostly ammonia nitrogen present during aerobic composting was derived from rapidly decomposition of waste. When ammonia concentration decreases and nitrate appears in composting material and is considered ready to be used as compost [15].

Nitrate–N concentration rises gradually during composting and is a limiting factor in assessing compost maturity [10]. Morisaki *et al.* [33] also reported that the greatest decrease of ammonia nitrogen occurred after thermophilic stage leading to an increase of nitrate concentration through nitrification. In aerobic process the percentage conversion of ammonia to nitrate was highest than other processes due to continuous aeration of waste.

Ammonia to nitrate ratio of less than one is generally considered an indicative of mature compost [21]. The aerobic samples had lower ammonia to nitrate ratio than mixed type and anaerobic samples. The results of present study of aerobic process come with in the prescribed limit of Bernal *et al.* and Lerney *et al.* [3, 21] but mixed type and anaerobic results are different from it.

CEC increases as compost approaches to stability [34]. It not only reflects the decomposition rate but also measures the capacity of compost to hold nutrients. Changes in the inorganic constituents during composting process and represent useful parameters for estimating the degree of maturity**.** CEC value in all types of composters, except anaerobic, gradually increased from 7-10 week and there after became constant. Higher CEC in aerobic sample during active composting stage is another indicator of more rapid decomposition of organic matter than other composter. Mixed type and anaerobic composters did not show stability in CEC value due to incomplete decomposition of waste and hence their compost matter was not of good quality for application.

The decrease of total organic carbon and increase of total extractable carbon and humic acid indicate the evaluation of composting towards the humification process [35]. HA contents are used to evaluate compost maturity. The HA increased linearly with time. The maximum HA concentration was observed in aerobic process than mixed and anaerobic due to the optimum temperature attained earlier. In anaerobic process temperature was not raised due to excessive moisture hence HA formation percentage was minimum. The stability in HA value was attained earlier in aerobic as compared to others. In mixed type, and anaerobic process the HA was not stable due to slow decomposition process. Tejada *et al.* noted the same kinds of observations [36] (Table-3).

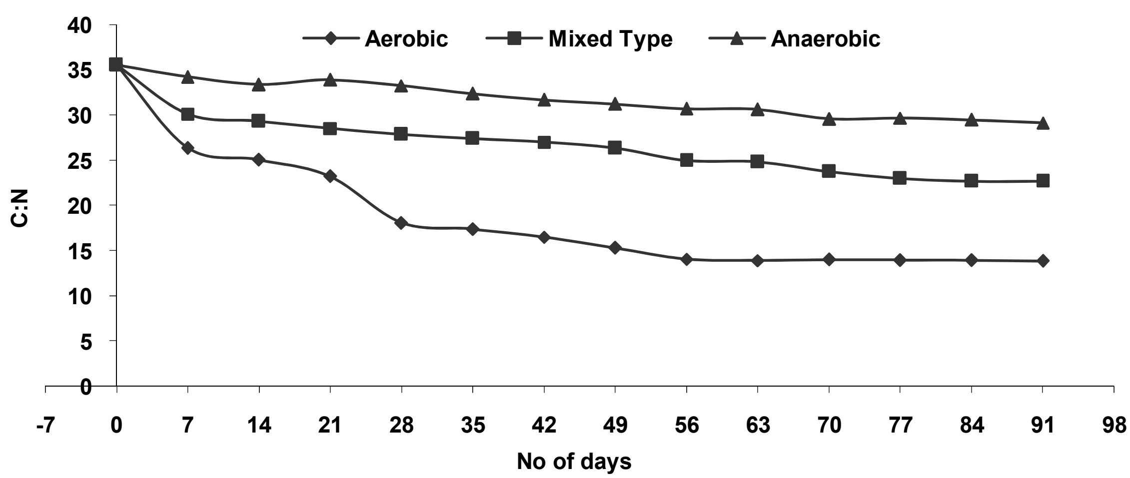

Fig. 3: Variation in **C:N** of different0 types of compost with time

Table-2: Chemical characteristics of organic waste at different composting time.

No of days	C gm/kg	Nt gm/kg	NH^{+}_{4}–N mg/kg	NO^{-}_{3}-N mg/kg	NH_4^+/NO^-_3	CEC meq/100gm
Aerobic Method						
7	390.7± 0.15	14.81 ± 0.20	45.32 ± 0.79	9.22 ± 0.43	4.92 ± 0.14	15.25 ± 0.64
28	280.4± 0.49	15.56 ± 0.68	62.71 ± 0.94	15.74 ±1.05	3.99 ± 0.21	23.83 ± 0.29
49	249.6± 0.90	16.30 ± 0.10	30.43 ± 0.57	22.35 ± 0.49	1.36 ± 0.05	45.09 ± 0.13
70	239.1± 0.49	17.0 ± 0.49	21.50 ± 0.63	31.7 ± 0.45	0.68 ± 0.03	45.91 ± 0.03
91	235.1± 0.48	17.3 ± 0.21	17.25 ± 0.28	40.28 ±1.07	0.43 ± 0.00	45.95 ± 1.01
Mixed Method						
7	398.4± 0.76	13.2 ± 0.22	12.69 ± 0.58	2.31 ± 0.06	5.50 ± 0.12	5.96 ± 0.05
28	385.0 ±0.51	13.8± 0.40	15.20 ± 1.09	3.75 ±0.05	4.06 ±0.34	13.96 ± 0.45
49	368.7 ±0.28	14.2 ± 0.20	28.75 ± 0.56	9.85 ±0.05	2.92 ±0.04	24.02 ± 0.07
70	349.7 ±0.65	14.7 ± 0.45	24.32 ± 0.67	15.33 ±0.80	1.59 ±0.13	25.17 ± 0.16
91	341.0 ±0.25	15.0 ± 0.07	19.54 ± 0.28	16.76 ±0.13	1.17 ±0.03	28.99 ± 0.09
Anaerobic Method						
7	421.2 ±0.93	12.3 ± 0.25	2.17 ± 0.03	0 ± 0.00	0.00 ± 0.0	7.37 ± 0.36
28	412.7 ±0.18	12.4 ± 0.35	7.35 ± 0.05	1.32 ±0.03	5.58 ±0.07	8.95 ± 0.10
49	393.5 ±0.35	12.6 ± 0.60	21.82 ± 0.93	5.07 ± 0.06	4.30 ±0.23	14.62 ± 0.20
70	387.7 ±0.82	12.9 ± 0.55	34.73 ± 0.84	6.11 ± 0.06	5.68 ±0.08	17.36 ± 062
91	365.3 ±0.56	13.2 ± 0.22	39.54 ± 0.53	11.64 ± 1.75	3.44 ±0.48	23.66 ± 0.44

Results are expressed as mean ± SD of three replicates

Table-3: Chemical analysis of the organic matter of the waste at different composting time.

No of days	C_{FA} %	C_{HA} %	C_{HA}/C_{FA}	HI %	H R %	D H %
Aerobic Method						
7	5.51±0.02	3.08 ±0.02	0.56±0.002	3.55±0.04	21.98±0.2	20.2±0.2
28	5.93±0.23	4.32 ± 0.34	0.73 ± 0.03	1.74±0.20	36.58±2.6	48.8±6.6
49	4.07±0.04	6.11 ± 0.03	1.50 ± 0.01	1.45±0.08	40.81±1.3	82.9± 4.7
70	3.70±0.11	6.67 ± 0.05	1.81 ± 0.04	1.31± 0.01	43.38±0.2	98.6±1.6
91	3.85±0.04	6.92 ± 0.07	1.80 ± 0.0	1.18±0.07	45.85±1.4	108.9±6.1
Mixed Method						
7	3.13 ±0.07	1.90 ± 0.06	0.61 ±0.03	6.92±0.13	12.62±0.2	10.91±0.5
28	3.80 ±0.05	2.18 ± 0.02	0.57 ±0.01	5.44 ±0.14	15.54±0.3	13.41±0.3
49	3.95 ±0.03	2.41 ± 0.04	0.61 ±0.00	4.79±0.10	17.27±0.3	15.83±0.4
70	3.02 ±0.04	3.83 ± 0.06	1.27 ±0.04	4.11±0.11	19.59±0.4	27.28±1.1
91	2.30 ±0.03	4.07 ± 0.05	1.77 ±0.01	4.35±0.11	18.70±0.3	29.4±0.71
Anaerobic Method						
7	1.20 ±0.05	0.31 ± 0.19	0.26 ± 0.17	27.23±3.35	3.58±0.42	1.53±0.98
28	1.93 ±0.03	0.78 ± 0.06	0.40 ±0.02	14.26±0.36	6.56±0.15	4.04±0.25
49	1.90 ±0.03	1.07 ± 0.04	0.56 ± 0.03	12.28±0.08	7.53±0.04	5.86±0.14
70	2.15 ±0.05	1.53 ± 0.37	0.71 ± 0.16	9.61±0.95	9.48±0.88	8.71±2.0
91	1.98 ±0.07	2.70 ± 0.24	1.36 ± 0.08	6.83±0.38	12.80±0.6	16.95±1.4

Results are expressed as mean ± SD of three replicates

The decrease in FA content with time is due to the transformation of FA in to HA since it is normal sequence of humification. [37]. The same trend was found in present study except a minor variation in anaerobic process. The C_{HA}/C_{FA} ratio increased during the process in all the cases of the study due to pronounce decrease of the C_{FA} during humification.

A rapid decrease in humification index was observed in the early stages of composting process. Later it became stable due to humification of the organic matter. [18-28,38-39]. The initial HI of compost was 3.55%, 6.92%, and 27.23% in aerobic, mixed type and anaerobic, respectively and gradually declined. The results of aerobic were in the range (0.2-1.2) of Saviozzi *et al.* [39] except anaerobic and mixed type processes.

Two other parameters, (DH, HR), for evaluating the levels of humification of compost have been proposed by Ciavatta *et al.* [40]. DH and HR both tend to increase as the humification proceeds, indicating the stabilization of the end product [20]. The stability of these parameters indicated the cease of microbial activity.

The volume change depends upon the input of waste and the type of composting technology. Maximum volume reduction was observed in aerobic type composter than mixed type and anaerobic composters (Table-4) due to continuous aeration. Iyengar *et al.* [1] also noted more than 90% reduction of volume in aerobic reactor as compared to 12.58% in anaerobic reactor.

Table-4: Volume reduction obtained in composting process

S.No	Type of Technique	Volume Reduction
1	Aerobic Method	73.9 % $\pm$5.3
2	Mixed Method	47.3 % $\pm$4.8
3	Anaerobic Method	21.29 % $\pm$6.2

Results are expressed as mean $\pm$ SD of three replicates

Compost prepared in all types of composters was analyzed and compared. Aerobic and mixed type compost had earthy odour, brownish black colour and soil like texture after maturation where as anaerobic compost product had decaying smell, brownish green colour and of marshy texture due to undigested organic matter and excessive moisture contents.

Compost contributes to increased soil nutrients availability, to improve soil fertility, for better crop production and water conservation. The elemental concentration increased during composting process because decomposition frees the available nutrients in MSW compost for plants. Elemental concentration of compost reflects the effect of input material on the properties of the end product [41].

The anaerobic compost was not considered suitable for application to agriculture land because the nutrients level was lowest indicating the low fertilizing potential (Table-5) as compared to aerobic. The same results were reported by Kokkora [41].

Table-5: Physical and chemical properties of MSW used in composting process

Parameters	Concentration
pH	7.65 $\pm$ 0.05
Total Nitrogen (g/kg)	11.54 $\pm$0 .76
Total Carbon (g/kg)	417.7 $\pm$ 0.3
C:N	36.19
Potassium (%)	0.14 $\pm$ 0.03
Phosphate (%)	0.19 $\pm$ 0.05
Moisture (%)	72-86 $\pm$1.2

Results are expressed as mean $\pm$ SD of three replicates

Correlation between Maturity and Stability Parameters of Different Compost.

Correlations have been found between the characters of different types of compost at their different stages. It was noted that HA and FA were correlated with each other and correlation of both exist with humification rate and degree of humification due to their close independence [Table-6]. Iglesias–Jinenz and Perez Garcia [10] also found that these parameters were correlated with other chemical parameters only when the evolution of each compost was studied individually, since they depend on the origin of starting material. CEC based on the organic matter and was correlated with large number of factors including HA, C_{HA}/C_{FA} ratio, HR, DH because the increase of CEC was caused by the increase of humic fraction produce by degradation of organic matter. Wan *et al.* [42] reported a significant correlation between CEC and humification fractions but there was no correlation between FA, HI, C/N ratio, and ammonia nitrate ratio. Harada *et al.* [43] found negative correlation between C/N ratio and CEC. This suggests that this factor is the most suitable for describing the compost maturity.

Table-6: Pearsons correlation between chemical characteristics and maturity indices

	FA	HA	C_{HA}/C_{FA}	CEC	HI	C:N	NH^+_4/NO^-_3	HR	DH
FA	1	.731**	n.s	n.s	n.s	n.s	n.s	.765**	.89**
HA		1	.776**	.776**	n.s	n.s	n.s	.968**	.957**
C_{HA}/C_{FA}			1	.898**	n.s	n.s	n.s	.747**	.815**
CEC				1	n.s	n.s	n.s	.814**	.814**
HI					1	.708**	n.s	n.s	n.s
C:N						1	0.587**	n.s	n.s
NH^+_4/NO^-_3							1	n.s	n.s
HR								1	.938**
DH									1

* Correlation is significant at the 0.05 level (2-tailed) n.s:non- significant
** Correlation is significant at the 0.01 level (2-tailed)

Experimental

MSW collected from Sunday bazaar and cafeteria of the University of Punjab Lahore, Pakistan was hauled to the composting site at PCSIR Laborites Complex Lahore. Animal manure was obtained from animal farm and bulking agent, saw dust, peanut shell and baggase (0.5-4.5 cm long) was purchased from the local market. The process of composting was studied by using three different types of locally fabricated composters. The composters were loaded with food waste, bulking agent as well as segregated organic matter from cafeteria, which were homogenized by cutting the material to approximately 8-15 cm in length and loaded for 91 days. The chemical analysis of loaded sample was also analyzed (Table-6).

The technologies used in the study were as fellows.

Aerobic Method

In order to study the compost stability on laboratory scale, a composter of 20 L capacity was used. The main unit of the composter i.e. the drum was of 610 mm in length and 480 mm diameter, made of a 3 mm thick stainless steel sheet. (Fig.4). The inner side of the drum was covered by anti corrosive coating. The drum was mounted and fixed on iron metal stand. In order to provide appropriate mixing of waste, steel angles were welded horizontally inside the drum. To regulate the temperature a hot water jacket covered drum. In addition to that two holes of 400 mm and 203 mm on upper and lower portion of the drum were made, respectively. The mixed organic waste with cow dung was loaded into the composter by means of plastic containers and filled up to 75% of the total volume. Rotation was provided on continuous basis to ensure proper mixing and aeration by electrical gearbox of variable rpm. Temperature was monitored regularly from thermocouple attached to the composter. After 4^{th} weeks sample was taken out from composter and left for curing up to 91 days.

Mixed Type Method

The mixed type composter was similar in dimensions as of aerobic but fixed on iron stand in vertical position. The only difference was that holes were present on the upper lid of the composter (Fig. 4). The upper portion of the composter was aerobic while lower and middle portion were anaerobic. It contained both types of conditions i.e. aerobic and anaerobic. The loading of the waste was also on the same pattern as in aerobic type composter but no mixing was done during the process. Temperature of the waste was also monitored regularly on the same pattern as in aerobic and anaerobic process.

Anaerobic Method

This composter was dimensionally similar to the mixed type composter but the only difference was that no perforations were made on the body of the composter. The mixing and loading of waste were same as mixed type comoposter. The composter was not opened at all. Three replicates of composters were prepared and used for sampling and analysis at different time intervals in the study. Each replicate was sampled only once in the study. Temperature was monitored through airtight ports on the composter at different heights and average was reported.

Analytical Methods

Samples from each composter were collected after every seven days interval up to 91 days, and recorded the changes in different parameters. The dried compost sample (75°C) was ground to pass through 2mm sieve.

An overview of the analytical methods used in the study is summarized below.
Measurement of total N and total C in compost were carried out on the dried sample by catalytic tube combustion using Vario Macro elementar CHNS analyzer (S.N: 11046079). The C/N ratio was calculated as the quotient of total C over total N. Total organic carbon was also calculated by loss of weight by ignition at 550^0C.

Fresh samples were extracted with deionized water in an extraction ratio 1:5 for the pH measurement. The pH of the suspension was recorded by using the pH meter (Jenco: 6173). The Na^+ and K^+ were determined by using flame photometer (Jenway PFP). The leachate characteristics (BOD, COD, volatile solids, total solids, pH) and ammonium nitrogen, nitrate were determined by using the standard methods of water and waste water APHA, (2005) [44-46]. The ammonium nitrate ratio was calculated by taking the quotient of ammonium over nitrate.

Phosphorous was determined by spectrophotometer (Analytikjena) the organic material (0.1g) was digested with sulphuric acid and hydrogen peroxide [47]. After digestion, volume was made up to 50 ml with distilled water, filtered and used for determination of phosphorous. The extract (2ml) was dissolved in 2ml of Barton reagent and total volume was made to 50ml. The samples were kept for an hour for colour development and optical density was measured at 460 nm. The Barton reagent was prepared as described by Ashraf *et al.* [48]

Nitric-perchloric acid digestion was performed following the procedure recommended by AOAC method [49] One gram of the sample was placed in 250 ml digestion flask and 10 ml of concentrated HNO_3 was added. The mixture was boiled gently for 30-45 minutes to allow all oxidizing matter to oxidize. After cooling, 5ml of 70% perchloric acid was added and boiled gently until dense white fumes appeared. After cooling, 20ml of distilled Water was added and the mixture was boiled further to release any fumes. The solution was cooled, filtered through Whatman No.42 filter paper and <0.45um Millipore filter paper and transferred quantitatively to 25 ml volumetric flask by adding double distilled water. The concentrations of metals (Zn, Mn, Fe,) in the solution were determined by an atomic absorption spectrometer (AAS, Varion).

Cation exchange capacity was determined by taking five gram compost samples in centrifuge tubes and washed thrice with sodium acetate (1N), ethanol and ammonium acetate (1N), while giving washing with ammonium acetate supernant, volume was made up to 100ml. Sodium concentration of this liquid was determined by using flame photometer (Jenway) [50].

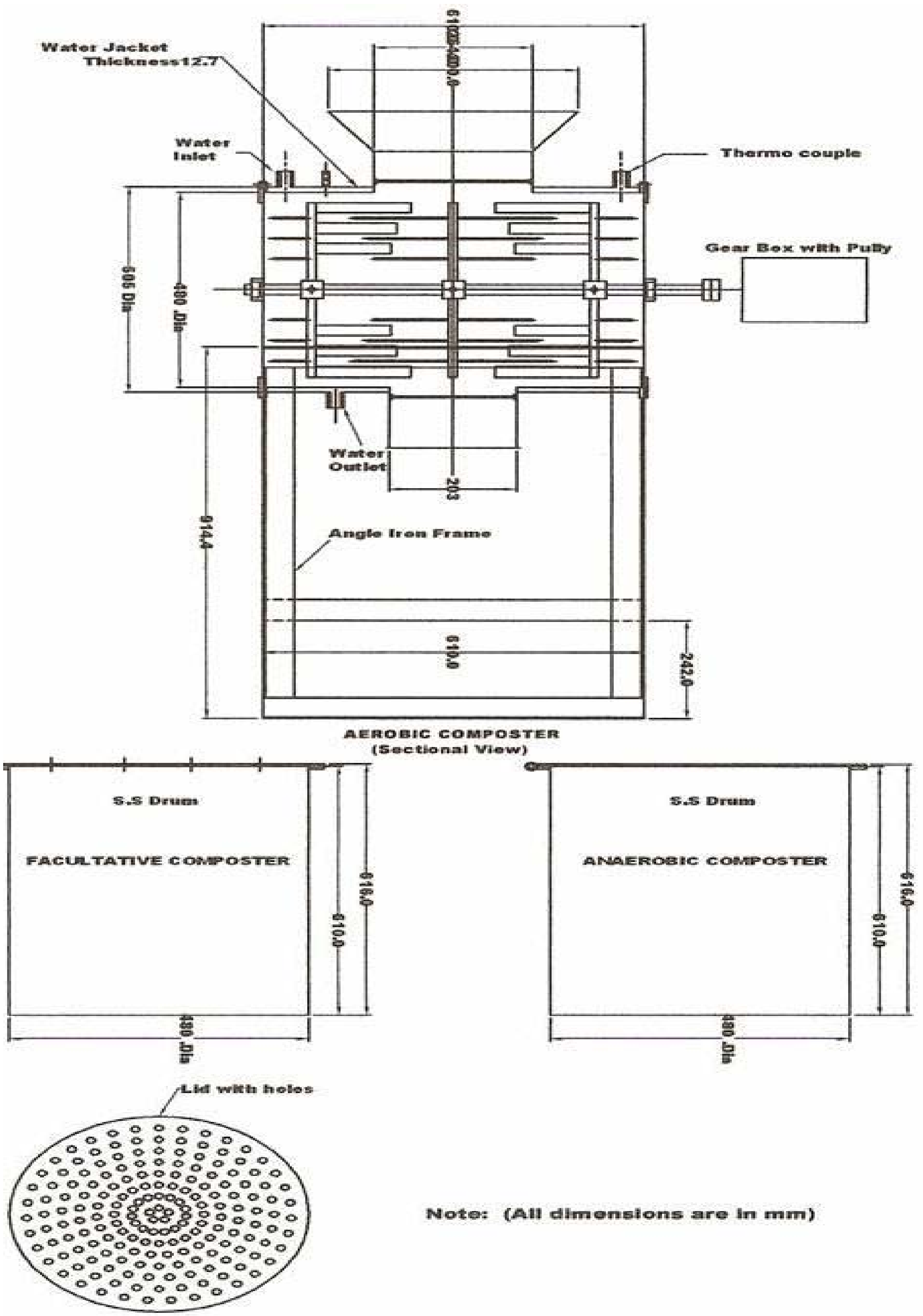

Fig. 4: Sectional View of Composters.

Total extractable carbon (TEC), humic acid (HA) and fulvic Acid (FA) were analyzed for C by the dichromate oxidation method [51-53].

The humic acid to fulvic acid ratio was calculated by taking the quotient of humic acid over fulvic acid.

Humification index is the ratio between the non-humified and humified fraction as given below.

$$HI=NH/ HA+FA \quad (1)$$

NH (Non humic)

Two other parameters for evaluating the levels of humification of compost have been proposed by Ciavatta et.al, [40] 1- Degree of humification (DH), 2- Humification Rate (HR) can be calculated as under

$$DH \% = HA+HA/TEC \times 100 \quad (2)$$

$$HR \% = HA+FA/TOC \times 100 \quad (3)$$

Statistical Analysis:

Each MSW parameters characterized was averaged from three analysis, where triplicate samples were analyzed twice to measure the sampling and analytical error. Calculated using excel (Microsoft 2000), standard deviation were reported along with the average value. SPSS 11.5 was used for the pearson correlation between FA, HA, HA/FA, CEC, HI, C/N, ammonia/nitrate, HR DH.

Conclusions

From the above comparison, it was concluded that compost prepared in aerobic type composter showed the high level of nutrients and reached an acceptable degree of maturity earlier as compared to mixed type and anaerobic composter.

Anaerobic composter failed to qualify because of the poor quality of compost produced, and low level of volume reduction. The parameter that indicates the compost stability was correlated among themselves. These include HA, FA, HR, DH and HI. The parameters defining maturity such as CEC, ammonia nitrate and C/N ratios were also correlated with above parameters. CEC was positively correlated with degree of degradability of MSW. However, the compost prepared by different methods yield chemically different products. Utilization of various production methods may help to optimize composting strategies to conserve the nutrients and provide appropriate and cost-effective compost product for plant application.

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