Enhanced Composting of Market Waste using Effective Microorganisms

Eswary Devi[1], R. Mugilvannan[2]

[1]*Faculty of Civil Engineering, Rajalakshmi Engineering College, Chennai, Tamil Nadu, India.*
[2]*Assistant General Manager, SPR RG Constructions, Chennai, Tamil Nadu, India.*

---***---

Abstract – *Municipal solid waste management is a challenge faced by many developing countries. Composting appears to be an effective means of recovering useful byproduct "compost" from biodegradable organic waste thereby reducing the wastes disposed in landfills. But due to long processing time, only fewer wastes are treated by composting. The use of effective microorganisms (EM) in composting reduces the processing time. EM was inoculated during different phases of vegetable and fruit market waste composting, and its effect on compost maturity, processing time and cost was studied. Three different mixtures, mixed vegetable waste, banana waste and mixed fruit waste were composted in bins. One set was inoculated with EM as "Treated" and other set was mixed with cow dung slurry as "Control". Using a wide range of physico-chemical parameters (pH, Temperature, Total Organic Carbon, Total Kjeldahl Nitrogen, C/N ratio, nutrient analysis and heavy metal analysis) and plant germination studies, the stability and maturity of the compost derived from EM treatment was analyzed. Inoculation with EM shortened the composting cycle to 30 days. C/N ratio decreased more rapidly in the EM treated trials than control. The compost derived from EM- treated had high nutrient values when compared to control and can be used as a good source of fertilizer. The germination and plant growth studies also confirmed that the composts prepared from EM-treated had phytonutrient and phytostimulant properties. Finally, the cost evaluation showed that much cheaper compost can be prepared from EM inoculation, thereby increasing the feasibility of the end product. Therefore, inoculation with EM during composting presents an efficient and economically viable strategy for converting market waste into mature and nutrient-enriched compost rapidly.*

***Key Words*: Compost, effective microorganisms, mixed vegetable waste, banana waste, mixed fruit waste, carbon to nitrogen ratio, control, biodegradation.**

1. INTRODUCTION

Municipal Solid Waste Management (MSWM) is a challenging problem worldwide particularly in developing countries like India. Urban India produces about 42 million tonnes of MSW annually. The highest per capita solid waste generation rate in India is in Chennai (0.6 kg/d) (Esakku et al, 2007 [1]). The management of MSW is going through a critical phase due to increasing volume of waste generation, increasing cost of waste collection and dwindling financial resources for treatment and disposal. Unscientific disposal causes adverse impact on environment and human health. Consequently, the management of the MSW needs to be revamped to ensure the longevity of the environment. In many nations there are now strict mandatory targets to reduce the amount of biodegradable municipal waste (BMW) entering landfill due to the lack of available landfill space and increasing concerns about climate change. More than one-fourth of the solid municipal waste produced in Indian metropolis comprises of vegetable waste generated from Markets. The Koyambedu Wholesale Market, Chennai is Asia's biggest vegetable, fruit and flower market spread over an area of 60 acres with total waste generation of 150 tonnes per day. The major components of wastes generated include vegetable wastes (21%), fruit wastes (15%), flower wastes (10%), banana stem and related materials (38%) and packing materials (hay, straw, paper etc) (16%). Nearly 70 to 80 tonnes of vegetables and fruit wastes are dumped along with municipal solid wastes resulting in loss of potentially valuable materials that can be processed as fertilizer (Sri Bala Kameswari et al, [2]). Composting appears to be an effective means of recovering the value from waste. But due to constraints such as high investment, long processing time and unstable products, only fewer and fewer wastes are treated by composting. Hence, innovative but cost-effective technology is needed to hasten the composting period without compromising on the quality and cost of compost produced. As microbial community plays key role in the biodegradation process, application of microbial culture can accelerate the process. It has been shown in literatures that inoculation with proper microorganisms will activate the biodegradation of organic matter and improve the quality of compost (Zeng et al, [11]).

The concept of 'Effective Microorganisms' was developed in 1982 by Professor Dr. Teruo Higa, at the University of the Ryukyus, Okinawa, Japan. Effective Microorganisms is a combination of 80 coexisting beneficial microorganisms that were selected from more than 2000 species isolated from various environments. EM is a liquid culture that consists of a wide variety of effective, beneficial and non-pathogenic (aerobic and anaerobic) microorganisms produced through a natural process and not chemically synthesized or genetically engineered. EM preparations include populations of lactobacilli, yeast, photosynthetic bacteria, filamentous fungi and actinomycetes etc. Employing EM during composting of Vegetable and Fruit market waste will hasten the process and yield a high quality end product. The aim of this study was to compost the vegetable and fruit market waste using inoculation of EM and compare its effect on quality, processing time and cost of compost with that of control.

2. EXPERIMENTAL WORK

2.1 Composting materials

The Koyambedu Wholesale Market in Chennai, India has different sections for sale of Vegetables, Banana and other Fruits and the wastes generated are disposed at different places. As such, a combination of three different types of waste were chosen for composting study; (i) Mixed Vegetable waste (ii) Banana waste (fruit and peel) and (iii) Mixed Fruit waste. The largest quantity of waste generated is Banana, Cabbage leaves and Cauliflower leaves. The microbial catalyst EM was activated with jaggery and water in the ratio of 1:1:20 for 4-7 days till the colour changed to reddish brown and pH dropped below 4. Cow dung was collected from suburban areas.

2.2 Experimental setup

Vertical stacking arrangement was designed with slotted steel channel sections to stack two thermocole bins of size 75 x 50 x 45 cm one above the other. Stacking of bins was done to reduce the space required for composting. A total of 9 bins of 170 L capacity were used to compost 50 Kg of three different types of wastes using inoculation of EM and cow dung. Provision for draining out leachate was made through holes in the bottom of the bins. Initial loading of the waste was done in the upper bin and after one week when there was no leachate generation, the partially stabilized composting mass was transferred to the bottom bin. Subsequently fresh waste was loaded in the upper bin. The finished compost was finally withdrawn from the bottom bin.

2.3 Composting process

The collected market wastes were chopped into small pieces of less than 3 cm size and 50 kg of each substrate was filled in two different sets of compost boxes. In one set of boxes, the composting substrate was mixed with cow dung as control and in another set of boxes composting mass was inoculated with EM as treated. The different formulations are : (i) mixed vegetable waste + cow dung (V1) serving as control (ii) mixed vegetable waste + EM (V2) serving as EM-treated (iii) banana waste + cow dung (B1) control (iv) banana waste + EM (B2) EM treated (v) mixed fruit waste + cow dung (F1) control and (vi) mixed fruit waste + EM (F2) EM treated. The average characteristics of the fresh wastes fed in all the bins were as follows: mixed vegetable waste: pH 5.9±0.1, moisture content 63±0.05%, carbon 43±7%, nitrogen 1.27±12% and C/N ratio 30±6; banana waste: pH 5.2, moisture content 55±4%, carbon 50±4%, nitrogen 1.24±3% and C/N ratio 39±3; mixed fruit waste: pH 4.8±0.5, moisture content 60±7%, carbon 42±5%, nitrogen 0.95±3.5% and C/N ratio 43±3. The materials were left undisturbed for one week and thereafter turned daily throughout the composting period. Moisture content was periodically replenished to optimum.

2.4 Monitoring and Analysis

The temperature of the composting material was monitored every day using a hand-held mercury thermometer. The pH was determined by measuring slurry of a 1:10 ratio of compost to water using a pH meter. Moisture content was determined by oven drying at 65˚C. Compost samples were collected once a week (0, 7, 14, 21, 30 and 45 days) from the composting mass, air dried, ground for homogeneity and used for analysis. Total Organic Carbon was determined by Walkley Black method, Total Kjeldahl Nitrogen estimated by Macro Kjeldahl Method and C/N ratio determined from values of TOC and TKN (Sarkar et al, [4]). Total phosphate was also estimated by acid digestion method and flame photometer respectively. Heavy metal and nutrient analysis was done using Atomic Absorption Spectrophotometer and titration methods.

2.5 Plant germination study

Seed germination and root elongation of cluster beans (*Cyamopsis tetragonoloba*) species in water extracts of compost samples was used to evaluate the quality of compost. Ten seeds were placed in Petri dish lined with filter paper and moistened with compost extracts and incubated in dark for 5 days (Somjai et al, [5]). Relative seed germination (SG), relative root elongation (RE) and germination index (GI) were calculated as per Zeng et al [11] using the following formula.

$$GI(\%)=\frac{\text{Seed germination}(\%)\times\text{Root length of treatment}\times 100}{\text{Seed germination of control}(\%)\times\text{Root length of control}}\times 100$$

3. RESULTS AND DISCUSSION

3.1 Temperature profile

Temperature is an important indicator of the efficiency of the composting process (Somjai et al, [5]). The temperature profile during composting of different market waste substrates is shown in Charts 1, 2 and 3. Higher temperatures were attained faster and higher temperature process was prolonged in EM treated trials over control. Excessive heat and water vapour were given off while turning the EM treated composting mass. Temperature >50˚C should be sustained for one week for disinfection against pathogens and this criteria was met only in EM treated trials.

Chart-1: Temperature profile during Mixed Vegetable waste composting

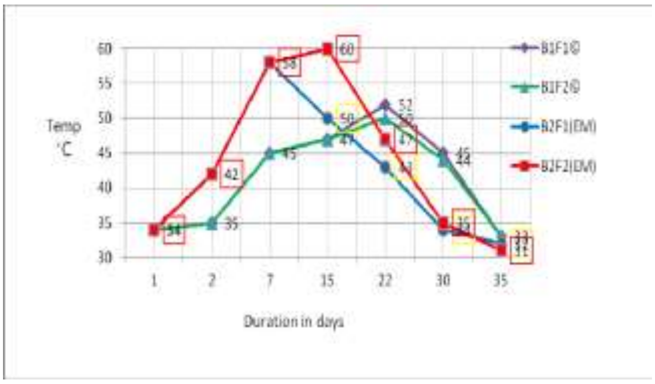

Chart-2: Temperature profile during Banana waste composting

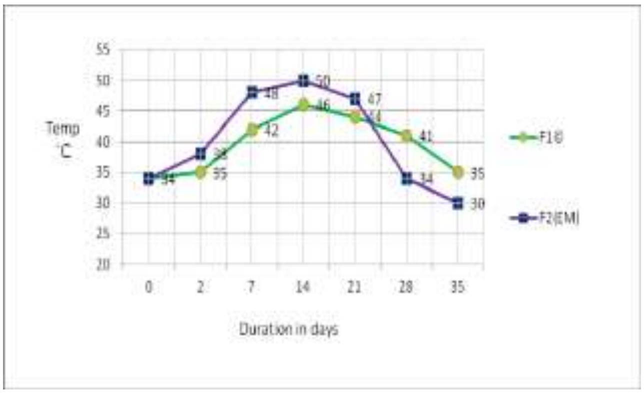

Chart-3: Temperature profile during Mixed Fruit waste composting

3.2 Variation in pH

Most composts have a pH value between 6 and 8 (Ajay et al, [6]). The initial pH of all the trials ranged from 4.8 to 6.0. There was initial drop noticed in all EM treated trials probably due to the acidic nature of EM and release of organic acids. The pH subsequently increased at the thermophilic stage attributed to faster degradation of organic materials along with ammonification of nitrogen (Chhotu et al, [7]). The final pH values were in the neutral range meeting the compost quality criteria (CPHEEO, [10]).

3.3 Variation in Moisture

Moisture loss during the high rate composting can be viewed as an index of decomposition rate, since the heat generation during decomposition drives the vaporization. The continuous decrease in moisture content during composting is an indication of organic matter decomposition. However, the composting materials should have certain moisture content in it for the organism to survive (Ajay et al, [6]). Initial moisture content of the waste mixtures varied between 55 to 66% and addition of extra water was not required. There was gradual decline in the moisture content in all the trials with higher loss in EM treated attributed to the high rate of vaporization of water as a consequence of excessive heat generation.

3.4 Total Organic Carbon during composting

Total carbon content is useful for estimating the age and properties of the compost. Organic carbon decreases during composting as CO_2 is emitted as a metabolic end product (Ajay et al, [6]). Change in TOC during market waste composting is presented in Charts 4, 5 and 6. In Mixed Vegetable waste, initial TOC in V1(control), V2 (EM treated) was 43%. On the 30th day of composting, there was higher TOC reduction of 49% in EM-treated trials V2, whereas only 30% reduction was noticed in V1-control. In Banana waste, initial TOC in B1(control) and B2(EM treated) was 50% and 52% which reduced to 36% and 24% respectively after 30 days. Higher reduction of 54% was noticed in EM treated trial than 28% reduction in control. Similarly, in Mixed Fruit waste also, the initial TOC in F1(control) and F2(EM treated) was 42% and 44% respectively and higher reduction of 39% was achieved in EM treated on the 30th day whereas it was only 17% reduction in control.

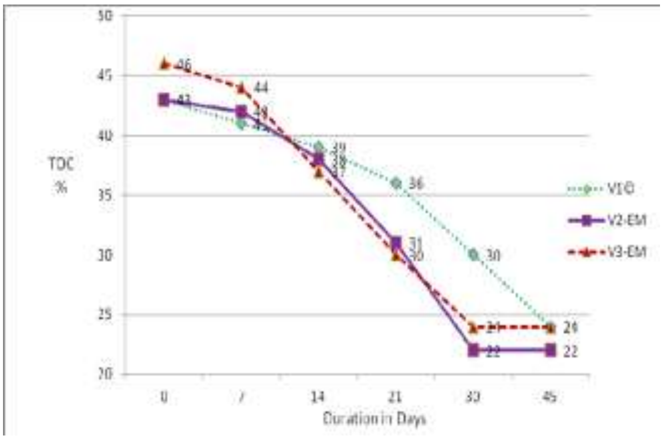

Chart-4: TOC during Mixed Vegetable waste composting

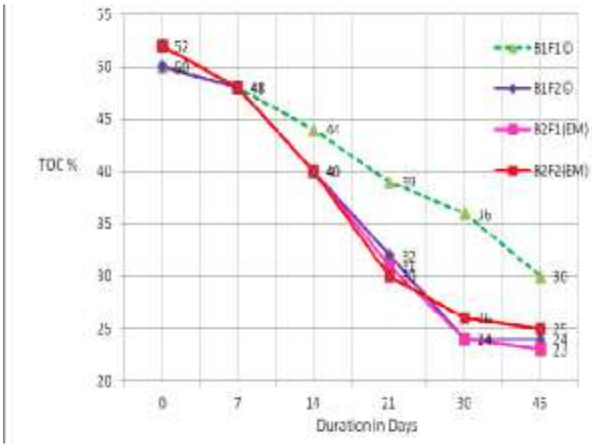

Chart-5: TOC during Banana waste composting

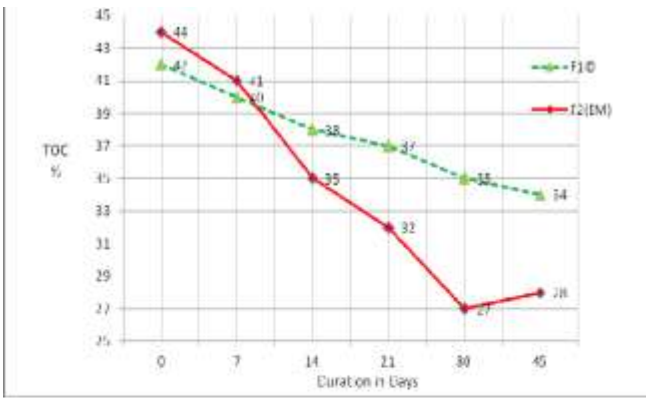

Chart-6: TOC during Mixed Fruit waste composting

The TOC reduction trend in this study is similar to previous works; Ajay [6] reported TOC degradation of 27-30% during 7-day rotary drum composting of vegetable waste; Meena [8] reported 16-59% reduction during 45 day vermicomposting of vegetable waste; Jia Liu [9] reported TOC reduction from 39.6% to 26.6% during 30-day composting of cow manure inoculated with CDM under artificial ventilation. In the present study, higher reduction in TOC between 39-54% was observed in EM treated trials over just 17-30% reduction in control.

3.5 Total Kjeldahl Nitrogen (TKN) during composting

Total Nitrogen (TN) generally increases during composting due to net loss of dry mass as CO_2 and water loss by evaporation during oxidization of organic matter. Nitrogen fixing bacteria might also contribute to increase in TN in later stage of composting (Ajay et al, [6]). In Mixed Vegetable waste, the initial TKN in V1(control), V2 (EM-treated) was 1.4% and 1.36% respectively with lower initial value in EM treated.

On the 30th day of composting, the TKN values were 1.62% and 1.74% in V1(control), V2(EM treated) bins with higher increase of 27% and 37% in EM treated over 14% rise in control. In Banana waste, initial TKN was 1.27% and 1.24% in B1(control) and B2(EM treated) respectively with lower initial value in EM treated. The final values were 1.81% and 2.13% in B1 and B2 respectively. The final TKN value in EM treated was 17% higher than that of control. Further greater increase in TKN of 68% was observed in EM treated over only 42% increase in control. Similarly in Mixed Fruit waste, the initial TKN was 0.98% and 0.95% in F1(control) and F2(EM treated). The final values were 1.47% and 1.42% in control and EM treated respectively with higher increase of 53% in EM treated over 50% increase in control. Charts 7, 8 and 9 show the TKN trend in Mixed Vegetable waste, Banana waste and Mixed Fruit waste. In all the waste mixtures, the initial TKN was low in EM treated but higher increase in TKN and higher final TKN value was observed in EM treated over the control trials. In EM-treated trials the increase in TKN was 27-68% whereas it was only 14-50% in control.

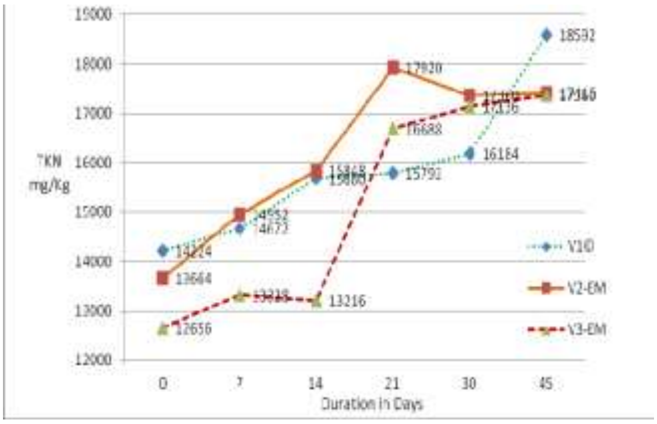

Chart-7: TKN during Mixed Vegetable waste composting

The TKN trend is in agreement with previous works; Ajay [6] reported TN increase from 1.4 to 1.7% and 1.8 to 2.6% during rotary drum composting followed by vermicomposting of vegetable waste and dry leaves; Chhotu [7] reported an increment in TN from 1.06% to 1.33% during vermicomposting of vegetable waste in hydro-operating bioreactor; Jia Liu [9] reported TN increase from 1.32 to 1.6% in 30 days during the composting of cow manure inoculated with CDM. In the present study, the final TKN values ranged between 1.45% to 2.09% in EM treated trials and increase in TKN was higher in the range of 27-68% in EM treated trials.

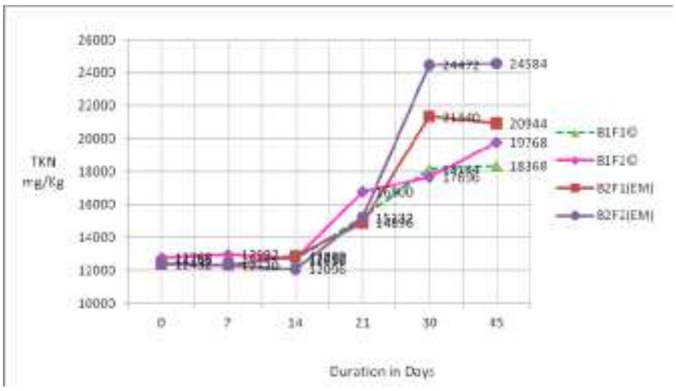

Chart-8: TKN during Banana waste composting

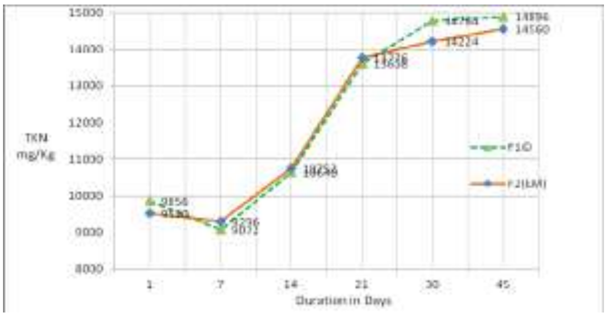

Chart-9: TKN during Mixed Fruit waste composting

3.6 Variation in Carbon to Nitrogen ratio

C/N ratio is considered as an indicator of compost maturity. The change in C/N ratio reflects the organic matter decomposition and stabilization achieved during composting. The C/N ratio generally decreases during composting due to losses of carbon as CO_2 and increase in Nitrogen content. The final C/N ratio should be less than or equal to 20 (CPHEEO, [10]).

In Mixed Vegetable waste, initial C/N ratio was 30:1 and 31:1 in V1(control) and V2(EM treated) respectively. After 30 days of composting, the C/N ratio reduced to 19:1 and 13:1 in V1 and V2 respectively with higher reduction of 58% noticed in EM-treated (V2) over 37% reduction in control (V1). In the Banana waste, initial C/N ratio was 39:1 and 42:1 in B1(control) and B2(EM treated) which reduced to 20:1 and 11:1 respectively after 30 days of composting. The C/N reduction in EM treated was 74% whereas it was 49% in control. In Mixed Fruit waste, initial C/N was in the higher range of 43:1 and 46:1 in F1(control) and F2(EM treated) which reduced to 24:1 and 19:1 after 30 days with higher reduction of 59% in EM treated over 44% reduction in control.

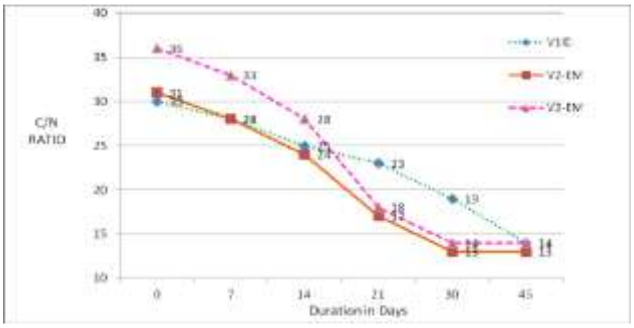

Chart-10: C/N ratio during Mixed Vegetable waste composting

The C/N reduction trend in different market wastes is shown in Charts 10, 11 and 12. In all the waste mixtures, rapid reduction in C/N occurred in EM- treated trials (58-74%) over control (37-49%).

The C/N reduction trend is supported by previous works; Zeng [11] reported C/N decrease from 29.6 to 16 after 35 days during agricultural waste composting inoculated with *P.chrysosporium*; Jia Liu [9] reported C/N reduction from 30 to16.6 in 30 days during composting of cow manure inoculated with CDM; Frank [12] reported C/N reduction from 30 to 12 during 8-9 week composting of banana peel using poultry litter; Meena [8] reported C/N reduction by 42 to 71% during vermicomposting of vegetable waste amended with cattle manure. Comparatively, faster and higher reduction in C/N of 58% to 74% has been achieved using EM inoculum in a period of 30 days.

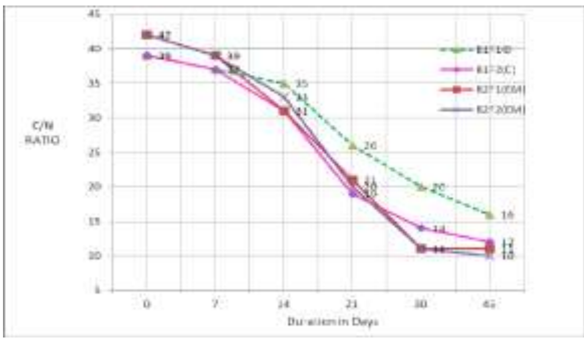

Chart-11: C/N ratio during Banana waste composting

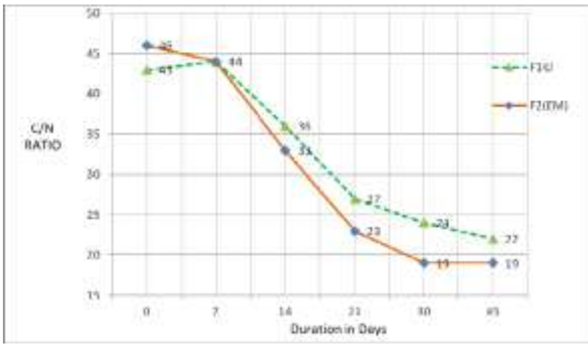

Chart-12: C/N during Mixed Fruit waste composting

3.7 Germination Study

The germination index (GI) is a factor of relative seed germination and relative root elongation. It has been proved to be one of the more sensitive parameters, which is able to account for both low toxicity affecting root growth and high toxicity affecting germination and finally the degree of compost maturity. In general, the decrease of phytotoxicity during composting results due to the degradation of phytotoxic substances by microorganisms. It had been proposed that: if the GI<25, then the substrate is characterized as very phytotoxic, if 26<GI<65 then the substrate is characterized as phytotoxic, if 66<GI<100 then the substrate is characterized as non-phytotoxic, stable and can be used in agricultural purpose, and if GI>101 the substrate is characterized as phytonutrient-phytostimulant and can be used in agricultural purposes as fertilizer (Rashad et al, [13]). Germination study with cluster beans (*Cyamopsis tetragonoloba*) species showed that the composts derived from different market waste had very high GI>100% values and were found to be non-phytotoxic. The composts can also be characterized as phytonutrient-phytostimulant and safe to use for agricultural purposes.

Plant growth profile using compost derived from different markets wastes and Organica (market sold organic compost) was studied in 11 pots. The growth of lady's finger (*Abelmoschus esculentus*) was observed over 10-day period. Composts from EM treated and control showed good growth pattern. However, the control (pure red soil) and Organica (market sold compost) showed poor growth profile viz., germination of seeds took more than 6 days and shoot growth was also minimum when compared to compost derived in this study from market waste.

3.8 Nutrient Analysis of compost

The macro and micro-nutrients required for plant growth are Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Iron, Copper, Zinc etc. As per CPHEEO [10] standards for compost quality, the NPK should be more than 1% each. The nutrient content of final compost prepared from different market wastes and market sold organic compost were compared. The EM derived composts had higher NPK values N:1.42-2.13%, P:0.43-0.57% and K:1.1-7.68% whereas control had N:1.47-1.81%, P:0.41-0.42% and K:1.14-5.63%. NPK of market sold product was lower than compost derived from EM treated market waste (N-1.2%, P-0.06% and K-0.83%). Though phosphorus value is less than 1% in market waste compost, it has high N and K content and can be used as a good source of N and K fertilizer. The values of other nutrients viz., Calcium, Magnesium, Iron, Copper and Zinc showed mixed results for each substrate and treatment. The highest values however were achieved in EM treated composts; Calcium was as high as 16000 mg/Kg in B2(EM treated banana waste), Magnesium was highest 14600 mg/Kg in V2 (EM treated vegetable waste), Iron was highest –113 mg/Kg in F2(EM treated fruit waste), Copper–89 mg/Kg highest in V2 (EM treated) and Zinc 154 mg/Kg in V2 (EM treated). But it cannot be concluded that EM treated trials had higher nutrient values over Control. However, the compost derived from EM treated vegetable and fruit market waste was higher than the market sold product.

3.9 Heavy Metals in compost

High levels of heavy metals (eg. Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel and Zinc) in composts represent an obvious concern if they are to be applied to food crops. Heavy metals do not degrade throughout the composting process and frequently become more concentrated due to the microbial degradation and loss of carbon and water from the compost. The levels at which these elements are found can vary from negligible background levels in 'clean' composts such as source-separated food waste to potentially toxic levels in some mixed waste based composts.

As per MSWM Rules 2000 [3], compost with heavy metal concentration exceeding the prescribed limits shall not be used for food crops. In all the samples, Arsenic and Mercury were non-deductable; Copper, Lead, Nickel and Zinc were below the concentration; Cadmium was in the range of 11-14 mg/Kg slightly exceeding the concentration limit of 5 mg/Kg in all composts including market product; Cr was in the range of 58-66 mg/Kg exceeding 50 mg/Kg only in Banana waste and market product. The higher concentration of Cd and Cr were found in Control, EM-treated composts and market product. Hence, inoculation with EM has no influence over this and it is attributed to contamination of market waste substrate. The compost derived from market waste does not exceed the tolerable levels for heavy metals except Cd which was slightly higher than standard concentration.

3.10 Cost Analysis

The cost evaluation showed that composts derived from EM treated market waste was much cheaper Rs. 7.50/- per kg when compared to composts derived from control Rs. 8.80/- per kg. In the Agri-Horticultural Society and local markets the organic compost is sold at Rs. 15/- per kg. Comparatively, compost derived from EM treatment was much cheaper (Rs. 7.50/-) over the market sold compost, indicating that inoculation with EM during composting is a feasible alternative to classical method of composting.

3. CONCLUSION

In this study, EM was inoculated during composting of vegetable and fruit market waste and its effect on the enhancement of the composting process was studied. The results of the study confirmed the following:

- Processing Time : Rapid degradation occurred in EM treated trials attaining higher level of maturity and stability much faster than control. EM inoculation significantly reduced the composting cycle to 30 days.
- Quality**:** The composts derived from EM treated trials had comparatively higher nutrient value N-2.13%, P-0.57% K-7.68%, Ca- 16000 mg/Kg, Mg–14600 mg/Kg, Iron–113 mg/Kg, Cu–89 mg/Kg and Zn–154 mg/Kg and lower concentrations of heavy metal. It can therefore be used as a good source of fertilizer to crops other than food crops. The EM treated composts had positive effect in stimulating plant growth. The quality and nutrient value of EM treated market waste compost was much better than Organic a sold at Agri-Horticultural Society and local markets.
- Cost**:** Composts can be produced at much cheaper cost at Rs. 7.50/- per kg and even less if done on large scale using EM inoculation thereby increasing the feasibility of end product.

Hence, it is concluded that inoculation with EM is an efficient, sustainable and economically viable technology to transform the significantly large quantities of biodegradable market waste into compost of high nutritional value for application as fertilizer to non-edible crops.

REFERENCES

[1] Esakku S., Swaminathan A., Parthiba Karthikeyan, Kurian J. and Palanivelu K., “Municipal Solid Waste Management in Chennai City, India”, Proceedings of Eleventh International Waste Management and Landfill Symposium – Sardinia, 2007.

[2] Sri Bala Kameswari K., Velmurugan B., Thirumaran K. and Ramanujam R.A., “Biomethanation of Vegetable Market Waste – Untapped Carbon Trading Opportunities”, Proceedings of the International Conference on Sustainable Solid Waste Management, India, 2007, pp. 415-420.

[3] Municipal Solid Waste (Management and Handling) Rules, Ministry of Environment and Forests, GOI, 2000 and 2016.

[4] Sutripta Sarkar, Rajdeep Banerjee, Sunanda Chanda, Pradeep Das, Sandipan Ganguly and Subrata Pal., “Effectiveness of inoculation with isolated Geobacillus strains in the thermophilic stage of vegetable waste composting”, Bioresource Technology, Vol. 101, 2010, pp. 2892-2895.

[5] Somjai Karnchanawong and Nakorn Suriyanon, “Household organic waste composting using bins with different types of passive aeration”, Resources, Conservation and Recycling, Vol 55, 2011, pp. 548-553.

[6] Ajay S. Kalamdhad, Yatish K. Singh, Muntjeer Ali, Meena Khwairakpam and Kazmi A., “Rotary drum composting of vegetable waste and tree leaves”, Bioresource Technology, Vol. 100, 2009, pp. 6442-6450.

[7] Chhotu D. Jadia and Fulekar M.H., “Vermicomposting of vegetable waste: A biophysicochemical process based on hydro-operating Bioreactor”, African Journal of Biotechnology, Vol. 7 (20), 2008, pp. 3723-3730.

[8] Meena Khwairakpam and Ajay S. Kalamdhad, “Vermicomposting of vegetable wastes amended with cattle manure”, Research Journal of Chemical Sciences, Vol. 1(8), 2011, pp.49-56.

[9] Jia Liu, Xiu-hong Xu, Hong-tao Li and Ying Xu, “Effect of microbiological inocula on chemical and physical properties and microbial community of cow manure compost”, Biomass and Bioenergy, Vol. 35, 2011, pp.3433-3439

[10] CPHEEO Manual on Municipal Solid Waste Management, Central Public Health and Environmental Engineering Organization, New Delhi, 2000.

[11] Guang Ming Zeng, Hong Li Huang, Dan Lian Huang, Xing Zhong Yuan, Rong Qing Jiang, Man Yu, Hong Yan Yu, Jia Chao Zhang, Ren You Wanga and Xiao Lan Liu., “Effect of inoculating white-rot fungus during different phases on the compost maturity of agricultural wastes”, Process Biochemistry, Vol. 44, 2009, pp. 396-400.

[12] Frank Kalemelawa,Eiji Nishihara,Tsuneyoshi Endo, Zahoor Ahmad, Rumana Yeasmin, Moses M. Tenywa and Sadahiro Yamamoto (2012), “An evaluation of aerobic and anaerobic composting of banana peels treated with different inoculums for soil nutrient replenishment”, Bioresource Technology, 2012.

[13] Rashad Ferial M., Saleh Walid D. and Moselhy Mohamed A., “Bioconversion of rice straw and certain agro-industrial wastes to amendments for organic farming systems: Composting, quality, stability and maturity indices”, Bioresource Technology, Vol. 101, 2010, pp. 5952-5960.