Coconut Water As An Additive For Enhancing Composting Process Of Municipal Solid Waste

Manju R[1], S. Srikantaswamy[2]
[1]Dept of Studies in Environmental Science,
[2]Associate Professor, Dept of Studies in Environmental Science,
[1, 2] Manasagangothri, University of Mysore, Mysuru, 570006, India

Abstract- *Solid waste disposal is an acute problem faced by bigger cities, towns, municipal corporations in various parts of India and around the world. Composting is one of the best options for management of municipal solid organic wastes. In the current study effect of coconut water as additive on composting process was studied. Addition of additive significantly enhanced the growth of microbial mass that facilitated composting process. The analysis of heavy metals in finished compost revealed that the presence of heavy metals to be within the permissible limits. The quality of finished compost was superior compared to the control compost suggesting the feasibility of coconut water as one of the best additives for solid waste composting.*

Keywords- Additive; solid waste management; coconut water; compost

I. INTRODUCTION

Rapid urbanization, industrialization, population explosion, transformation of peoples' lifestyles including assortments of other human activities has led to tremendous increase in municipal solid waste quantity. Thus its safe management and disposal has become extremely important for moving towards development of more sustainable society. Though there is an extensive interest on part of government and local bodies the disposal of MSW is major environmental problem which needs immediate thought as the existing disposal methods have failed to address the issue completely. [1]. Alarming raise of urban growth of approximately 4% per year in Asian metropolitan cities could be a possible threat for the environmental as handling the solid waste would be very tricky [2]. MSW includes both domestic and commercial waste account for a relatively small part of the total solid waste stream in developed countries [3]. Though composting is commonly practiced mode of MSW disposal all over world more often it is time consuming and labor intensive process that makes

it practically unappealing. However, recent past has witnessed a revitalization of interest in composting due to the progression in composting technology. Co composting using additives is one such technique which has opened up opportunities in modern waste management segment. Additives like mineral nutrients, enzymes, various microorganisms, pH balancing com pounds etc. enhance microbial action during composting [4]. Recent studies on fly ash, phosphogypsum, jaggery, lime, and polyethylene glycol on green waste composting showed additives significantly enhanced the composting process [5]. Yet another study on biomass ash reutilization as an additive demonstrated that composting process and quality of finished compost was improved by ash addition [6]. Use of chemical and mineral additives for co-composting of solid waste was also extensively studied by various research groups [6-10]. All these previous studies have indicated that co composting using additives could enhance composting processes significantly. Coconut water (a complex mixture of various bio-molecules including vitamins, minerals, enzymes etc.) a byproduct of coconut processing industry was used as additive source for municipal solid waste composting in the present study. Coconut water known to possess numerous health benefits and its role on treatment of various physiological disorders including blood pressure, hypertension, Alzheimer's etc. has been studied by numerous researchers across the world [11-14]. It is one of the good sources of sugar and sugar as carbon source results in growth of microbes that fasten the composting process. However so far no studies pertaining to its role as additive have been reported. This is first study reporting the role of coconut water as additive in co composting for best of our knowledge.

II. MATERIALS AND METHODS

A. Study Area

Current work was carried out in Mysore city using municipal solid waste sample generated in the city. The municipal solid waste samples were collected from aerobic compost plant situated in Vidyaranyapuram, Mysore.

B. Collection and processing of composting material

The segregated solid waste rich in organic matter collected from the MSW Site was used as raw material for composting. Composting experiments were carried out at lab scale in 20 litre cement pots. 5 Kgs of organics fraction of MSW (OFMSW) was added to each pot. Coconut water which is used as organic additive was mixed at the rate of 10-60% of total municipal solid waste inputs respectively. The additives are mixed properly and temperature is monitored. Aeration is provided by mixing and turning the solid waste heaps on every 5th day. Excess water was drained out. Necessary care was taken to minimize the external disturbance affecting the composting process. The compost samples were collected at different degradation stage from pots on 5^{th}, 10^{th}, 15^{th}, 20^{th} , 25^{th} and 30^{th} day. Thus obtained samples were oven dried at 100 -105˚ C, ground to 2 mm particle size powder and stored until further analysis.

C. Analysis of compost samples

The finely ground, dried and powdered compost samples were analyzed for various physicochemical parameters such as pH, bulk density, conductivity, moisture content, organic carbon, C: N ratio, total nitrogen, potassium and phosphate. The pH of compost was determined in pH meter using deionized water with 1:10 w/v ratio of compost and water [15]. The organic carbon content of compost was estimated by combustion method [16, 17]. Bulk density was determined by using pycnometer method (Blake et al., 1986) and calculated using the following formula [18, 19].

Bulk density g/cm^3=Weight of sample in gram/Volume in sample in cm^3.

Electrical conductivity by instrument method (1:5 water extract) using conductivity meter [20], moisture content (%) by gravimetric method [21]. Phosphorous in the compost was determined through Olsen method [22], Total nitrogen by Kjeldahls method /phenol disulfonic acid method [23], total potassium by flame photometer (model no.). Total nitrogen in C/N ratio were calculated by adding the three forms determined (organic, nitrate and ammonium using standard procedures for analysis [24-26].

D. Statistical analysis:

The data obtained from triplicates experiments were analyzed using Origin Pro Software, version 8 with average standard deviation of <5%. Graphical representation was statistically interfaced with error bars.

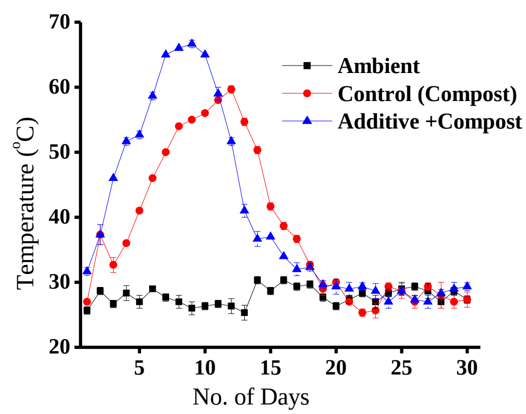
III. RESULTS AND DISCUSSION

3.1 Processing of raw compost and additive

The composting material used in the present study was segregated municipal solid waste which consisted of approximately 55% of organic matter. The coconut water obtained from desiccated coconut powder manufacturing unit used as organic additive is mixed with proportionate ratio of 10-60% of OFMSW. The powdered final additive aided compost samples are taken for physicochemical studies and heavy metal analysis.

3.2 Effect of additives on Temperature during composting

Continuous monitoring of temperature in different compost pots using thermometer was done during the composting period. The temperature variation in control and additive based composting was recorded and is represented in Fig.1. The temperature shot to 52˚C from 30˚C after 24 hours. Thermophilic phase lasted for 12 days (6 days in control) with maximum temperature reaching upto 56˚C. Temperature of 56˚C lasted for 4 days that helped in destruction of all the pathogens and weed seeds present in the compost.



.

Fig. 1. Effect of Temperature during composting Process

The early set up and prolonged period of thermophilic phase in coconut water treated compost could be attributed to the instantaneous supply of sugars by coconut water to the composting matrix which enhanced the microbial growth ultimately leading to development of metabolic heat. Our observations are comparable to many earlier studies on similar line [5, 27, 28]. This phase was followed by cooling phase where in temperature began to decline and evened out on 22^{nd} day. After 22^{nd} day temperature of compost was equal to that of ambient with no significant change. Similar observations were made by studies carried out by Rynak et al., 1992, Hsu et al.,1999) which reported that use additives in composting resulted early and extended duration of thermophilic phase that helps in boosting up the microbial metabolism leading to heat generation and killing of microbial mass resulting in better compost [29, 30]. The presence of three phases during the composting stages showed that the pattern was typical to that exhibited by many different composting system

3.3 Effect of additives on pH during composting

Fig. 2 demonstrates the effect of additive on pH during composting process. The pH value changes during composting, due to changes in the chemical composition. In general, the pH falls below neutral in the beginning due to the formation of organic acids and later rises above neutral because the acids are consumed and because ammonium is produced [31]. In the present study there is no much difference in pH pattern of control and additive based compost.

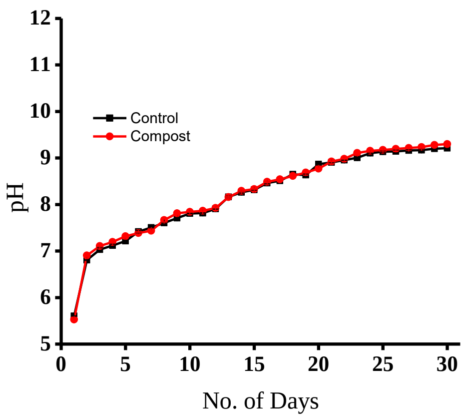


Fig.2. Graph depicting Effect of pH during composting Process.

3.4 Effect of additives on bulk density during composting

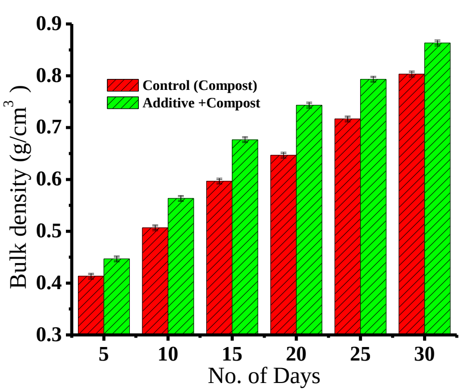


Fig.3 Graphical representation of bulk density of control and additive based compost

Bulk density is a measure of degradation of loosely arranged raw material into finer particles. Progressive increase in bulk density was observed in additive based composting and control compost. Current studies revealed range of bulk density to be 0.45 g/cm^3 to 0.86 g/cm^3 in additive based compost where as 0.41 to 0.77 g/cm^3 in control compost suggesting the bulking effect of additive rather than degradation effect. The range of bulk density is well within the standard range of Indian Fertilizer Control Order, 1985. Similar observations were done by Himanem et.al.2009 and Jagdish et al.,2012 [4, 5].

3.5 Effect of additives on Electrical conductance / total conductance during composting

The electrical conductance (EC) of compost is mainly depending on the amount of the soluble salts like, sodium, potassium, chloride, nitrate, soluble sulphate, calcium and magnesium present in the compost [32]. The range of electrical conductance varied from 1.3 to 6.4 ds/m in additive based compost and 1 to 5.5 ds/m in control compost (Fig 4). The higher electrical conductance compared to recommended standards in control and test samples may be attributed to increased salt concentration due to organic matter degradation [33].

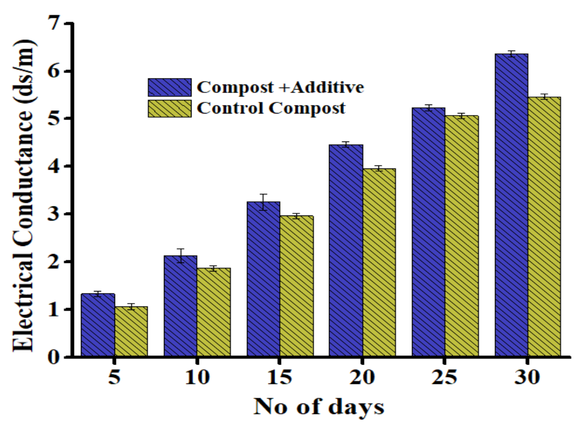


Fig.4 Graphical representation of electrical conductance of control and additive based compost

3.6 Effect of additive on Moisture content, Organic Carbon and C: N Ratio during composting

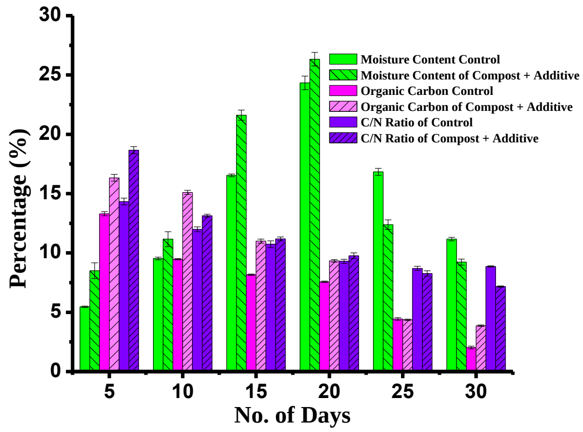


Fig. 5 Graphical representation of percentage moisture content, organic carbon and C/N ratio of compost

A. Moisture content

Moisture content of compost is important environmental factor that transports nutrients for metabolic activities of microbes. With prolonged maturation, moisture content increased progressively. This might enhance microbial and enzyme activity leading to speedy composting process [34, 35]. In the present investigation, moisture content enhanced in the maturation phase of 20th day (Fig. 5).

B. Organic Carbon:

Organic carbon content in the present study decreased with increasing maturation stages of composting. This decrease in percentage organic carbon can be attributed to waste decomposition by microbes to larger extent and CO_2 evolution partly [36, 37]. In the present investigation, the total organic carbon percentage varied from 16.45 to 3.9 % and maximum reduction in TOC was observed on 20th day. In comparison to the recommended standards obtained values were well within the stipulated limits.

C. C: N Ratio:

Organic matter decomposition and stabilization during composting process is dependent on C:N ratio. The results of effect of coconut water as additive on C:N ratio during composting process is presented in Fig.5. There was significant reduction in C:N ratio from 18.65% to 7.15% during different maturation phase compared to control. C:N ration of equal of less than 20 is considered as acceptable value for compost maturity [38]. Results obtained are well within the stipulated range of the recommended standard.

3.7 Analysis of Total nitrogen, potassium and Phosphorous during composting process.

A. Total nitrogen

Organic and inorganic forms of nitrogen in compost comprises of total nitrogen. The total nitrogen content in the additive based compost ranges from 0.18 to 0.55% as shown in Fig 5.
This indicates enhanced rate of organic conversion of the compost. The incremental enhancement in total nitrogen content during the composting can be accredited to decrease in carbon substrate due to decomposition of organic matter [39].

B. Total potassium

Potassium which is highly soluble in is one of the indispensable soil nutrients that helps in plant growth and. The insoluble potassium can be solubilised by the disintegration of waste. The concentration of potassium in different maturation stages increased during the composting period. Variation of potassium concentration in control compost and additive based compost is presented in Fig.6.

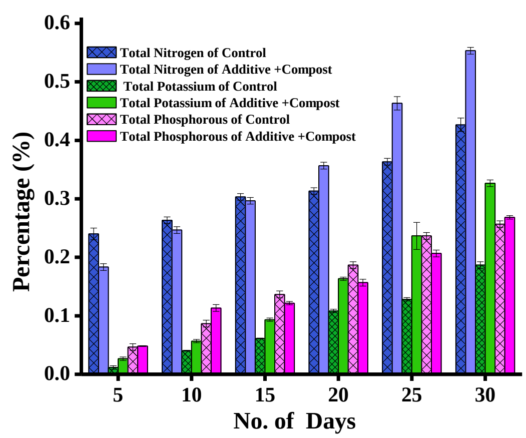


Fig.6: Graph depicting % total nitrogen, phosphorous and potassium

C. Total Phosphorous

Total phosphorous is one of the well-known plant nutrient among Nitrogen, Phosphorous and potassium which assist in growth of plants. The concentration of total phosphorus in present study ranges between 0.048 to 0.27 % which is well within the stipulated range of recommended standard (Fig.6). The steady increase in phosphorus content is seen with progression of maturation phases of compost and any decreases due to humification. Similar observations were also noted in earlier studies [24].

3.8 Heavy Metal analysis of the compost

Table 1: Heavy metal concentrations at different compost maturity phases, control MSW sample along with CPCB recommended standard for city compost

.

Parameters (mg/Kg)	Control (MSW Compost)	No. of Days						CPCB Standard
		5	10	15	20	25	30	
Arsenic (As_2O_3)	2.2	1.5	1.2	0.9	0.6	0.01	0	10
Mercury (Hg)	0.06	0.07	0.05	0.04	0.01	0	0	0.15
Cadmium (Cd)	1.9	1.8	1.4	0.8	0.4	0.1	0.1	5
Chromium (Cr)	4.2	3.8	3.3	3.2	2.9	2.2	2	50
Copper (Cu)	52	40	34	32	28	21	14	300
Nickel(as Ni)	40.4	39.2	38.1	32.1	24.3	22.2	20.5	50
Lead (As Pb)	9	7	6	4.5	3.1	1.8	0.7	100
Zinc (as Zn)	315	274	215	240	164	152	140	1000

Table 1 depicts the heavy metal concentrations at different maturity phases of additive aided composting along with control. The availability of heavy metals in all the maturity stages are well within the permissible limits of recommended standards by Central Pollution Control Board for the city compost. The concentration of heavy metals in additive based compost at different maturity levels were generally decreasing or below detectable limit suggesting compost toxicity to be low or negligible due to heavy metals presence which is also comparable to earlier studies by various researchers [4-6].

IV. CONCLUSION

Results from present study projected scope for additive based composting as new technology for solid waste management. Presently this technique is gaining attention as an environmentally sound approach to manage organic waste especially in countries like India, where 45-50% of solid waste comprises of organic/green waste. Use of coconut water as additive in municipal solid waste improved the composting process and enhanced quality of finished compost. Current study highlights use of coconut water as an economical additive for composting resulting in enhanced soil fertility, better crop yield and management of solid waste, thus providing new approach for composting technology.

Conflict of interests: The authors have no conflict of interest to declare.

Acknowledgements: The authors are thankful to Mysore University for providing facility to carry out the present research work.

REFERENCES

[1] Sharholy, M., et al., *Municipal solid waste management in Indian cities–A review.* Waste management, 2008. **28**(2): p. 459-467.
[2] Idris, A., B. Inanc, and M.N. Hassan, *Overview of waste disposal and landfills/dumps in Asian countries.* Journal of material cycles and waste management, 2004. **6**(2): p. 104-110.
[3] Hargreaves, J., M. Adl, and P. Warman, *A review of the use of composted municipal solid waste in agriculture.* Agriculture, Ecosystems & Environment, 2008. **123**(1): p. 1-14.
[4] Himanen, M. and K. Hänninen, *Effect of commercial mineral-based additives on composting and compost quality.* Waste management, 2009. **29**(8): p. 2265-2273.
[5] Gabhane, J., et al., *Additives aided composting of green waste: effects on organic matter degradation, compost maturity, and quality of the finished compost.* Bioresource technology, 2012. **114**: p. 382-388.
[6] Asquer, C., et al., *Biomass ash reutilisation as an additive in the composting process of organic fraction of municipal solid waste.* Waste Management, 2017. **69**: p. 127-135.
[7] Aboltins, A., O. Karps, and J. Palabinskis. *BIOMASS ASH UTILIZATION OPPORTUNITIES IN AGRICULTURE*. in *International scientific conference RURAL DEVELOPMENT 2017*. 2018.
[8] Karnchanawong, S., T. Mongkontep, and K. Praphunsri, *Effect of green waste pretreatment by sodium hydroxide and biomass fly ash on composting process.* Journal of Cleaner Production, 2017. **146**: p. 14-19.
[9] Margaritis, M., et al., *Improvement of home composting process of food waste using different minerals.* Waste Management, 2017.
[10] Juárez, M.F.-D., et al., *Co-composting of biowaste and wood ash, influence on a microbially driven-process.* Waste management, 2015. **46**: p. 155-164.
[11] Sandhya, V. and T. Rajamohan, *Beneficial effects of coconut water feeding on lipid metabolism in cholesterol-*

fed rats. Journal of medicinal food, 2006. **9**(3): p. 400-407.

[12] Fernando, W.M.A.D.B., et al., *The role of dietary coconut for the prevention and treatment of Alzheimer's disease: potential mechanisms of action.* British Journal of Nutrition, 2015. **114**(1): p. 1-14.

[13] Bhagya, D., L. Prema, and T. Rajamohan, *BENEFICIAL EFFECTS OF TENDER COCONUT WATER ON BLOOD PRESSURE AND LIPID LEVELS IN EXPERIMENTAL HYPERTENSION.* Journal of Cell & Tissue Research, 2010. **10**(1).

[14] Yong, J.W., et al., *The chemical composition and biological properties of coconut (Cocos nucifera L.) water.* Molecules, 2009. **14**(12): p. 5144-5164.

[15] Sasaki, N., et al., *Effects of CN ratio and pH of raw materials on oil degradation efficiency in a compost fermentation process.* Journal of bioscience and bioengineering, 2003. **96**(1): p. 47-52.

[16] Nelson, D. and L.E. Sommers, *Total carbon, organic carbon, and organic matter1.* Methods of soil analysis. Part 2. Chemical and microbiological properties, 1982(methodsofsoilan2): p. 539-579.

[17] Walkley, A. and I.A. Black, *An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method.* Soil science, 1934. **37**(1): p. 29-38.

[18] Blake, G.R. and K. Hartge, *Bulk Density1.* Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods, 1986(methodsofsoilan1): p. 363-375.

[19] Choudhary, M., et al., *Changes in soil biology under conservation agriculture based sustainable intensification of cereal systems in Indo-Gangetic Plains.* Geoderma, 2018. **313**: p. 193-204.

[20] Eigenberg, R., et al., *Electrical conductivity monitoring of soil condition and available N with animal manure and a cover crop.* Agriculture, ecosystems & environment, 2002. **88**(2): p. 183-193.

[21] McCartney, D. and J. Tingley, *Development of a rapid moisture content method for compost materials.* Compost science & utilization, 1998. **6**(3): p. 14-25.

[22] Watanabe, F. and S. Olsen, *Test of an ascorbic acid method for determining phosphorus in water and NaHCO3 extracts from soil 1.* Soil Science Society of America Journal, 1965. **29**(6): p. 677-678.

[23] Nelson, D. and L. Sommers, *Determination of Total Nitrogen in Plant Material 1.* Agronomy Journal, 1973. **65**(1): p. 109-112.

[24] Shyamala, D. and S. Belagali, *Studies on variations in physico-chemical and biological characteristics at different maturity stages of municipal solid waste compost.* International Journal of Environmental Sciences, 2012. **2**(4): p. 1984.

[25] Saha, A.K., *Methods of physical and chemical analysis of soil.* 2008: Kalyani Publishers.

[26] Jackson, M., *Soil Chemical Analysis (Ed.) Prentice Hall of India Private Limited.* New Delhi, 1967.

[27] Raut, M., et al., *Microbial dynamics and enzyme activities during rapid composting of municipal solid waste–a compost maturity analysis perspective.* Bioresource Technology, 2008. **99**(14): p. 6512-6519.

[28] Awasthi, M.K., et al., *Beneficial effect of mixture of additives amendment on enzymatic activities, organic matter degradation and humification during biosolids co-composting.* Bioresource technology, 2018. **247**: p. 138-146.

[29] Hsu, J.-H. and S.-L. Lo, *Chemical and spectroscopic analysis of organic matter transformations during composting of pig manure.* Environmental Pollution, 1999. **104**(2): p. 189-196.

[30] Rynk, R., et al., *On-farm composting handbook*. 1994, New York, US: Northeast Regional Agricultural Engineering Service, Cooperative Extension.

[31] Beck-Friis, B., et al., *Composting of source-separated household organics at different oxygen levels: Gaining an understanding of the emission dynamics.* Compost Science & Utilization, 2003. **11**(1): p. 41-50.

[32] Brinton, W., *Interpretation of Waste and Compost Tests.* Journal of the Woods End Research Laboratory, 2003. **1**(4): p. 1-6.

[33] Campbell Jr, A.G., R.L. Folk, and R.R. Tripepi, *Wood ash as an amendment in municipal sludge and yard waste composting processes.* Compost Science & Utilization, 1997. **5**(1): p. 62-73.

[34] Parveen, A.A. and C. Padmaja, *Bioconversion of municipal solid waste (MSW) and water hyacinth (WH) into organic manure by fungal consortium.* Journal of sustainable Development, 2010. **3**(1): p. 91.

[35] Tiquia, S., N. Tam, and I. Hodgkiss, *Microbial activities during composting of spent pig-manure sawdust litter at different moisture contents.* Bioresource Technology, 1996. **55**(3): p. 201-206.

[36] Geisseler, D., et al., *Pathways of nitrogen utilization by soil microorganisms–a review.* Soil Biology and Biochemistry, 2010. **42**(12): p. 2058-2067.

[37] Cabrera, M., D. Kissel, and M. Vigil, *Nitrogen mineralization from organic residues.* Journal of environmental quality, 2005. **34**(1): p. 75-79.

[38] Huang, G., et al., *Transformation of organic matter during co-composting of pig manure with sawdust.* Bioresource Technology, 2006. **97**(15): p. 1834-1842.

[39] Bernai, M., et al., *Maturity and stability parameters of composts prepared with a wide range of organic wastes.* Bioresource technology, 1998. **63**(1): p. 91-99.