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Characterization of Household Solid Waste Compost Inoculated with Effective Microorganisms

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Abstract: The huge quantity of organic waste can be converted into reusable by-product through composting. This study was conducted to assess and characterize the household organic waste compost inoculated with Effective Microorganisms (EM). The compost was prepared using organic waste collected from 50 households situated in the suburban-Zanzibar. Three compost piles were made; treated as compost without EM (control), compost with EM and compost with EM plus chicken manure. The compost were analyzed for pH, Electrical Conductivity (EC), Organic matter (OM), Organic Carbon (OC), N, P, K, Ca, Mg, Na and C/N ratio. Results revealed that the compost inoculated with EM consortium decomposed faster (40 days) compared to 60 days for control compost. The physicochemical data showed that pH and EC of the compost decrease as EM consortium inoculated to the compost. N and K contents of the compost treated with EM were slightly higher that ranges between 0.19%-0.28% and 0.3%-0.6% compared to control which were 0.16% and 0.06% respectively. However, P contents remained the same in all treatments while C/N ratio for all treatments ranged between 11:1 to15:1, which is a typical value for compost manure. This research suggests that the application of EM is suitable for enhancing decomposition process and influencing the physicochemical properties of the compost.

Key words: household waste, effective microorganisms, compost characteristics

1. Introduction

Household solid waste (HSW) is the one of the constituents of Municipal Solid Waste (MSW), which accounts for the waste in developing countries [1]. MSW generated in developing countries disposed of in the open dump is a threat to public and environment [2]. The decomposition of organic waste (OW) particularly, food waste in landfills and uncontrolled dump produce a greenhouse gas (methane gas) that affects the Earth climate [2, 3].

Characteristics of Household waste depend on household income level and area characteristics [4]. For example; high-income areas usually produced more inorganic materials [5] since, they consume processed food and packed in cans, jars, bottles, plastic containers while low-income areas, residents consume natural food like fresh fruits and vegetables [6]. Therefore, developing countries contain a large percentage of Organic Materials (OM) three times higher than that of industrialized countries [6].

The huge quantity of HSW in developing countries can be reduced by converting the organic component of the waste into a valuable and reusable product without adverse affecting the environment. Composting of household solid waste (HSW) is now being encouraged as one of the low-cost alternatives for reducing the organic waste being discarded and sent to the landfills in many parts of the world [7] and also can restore the value of the MSW [8]. It has been shown that composting of Organic waste (OW) increases the organic matter (OM) level of the soil, improve soil

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physical characteristics and enhance soil microbial biomass [9].

Decomposition of organic materials occurs due to the action of naturally occurring microorganisms (bacteria and fungi). The decomposition can be influenced by Effective Microorganisms (EM). EM has been identified as a new technology to assist and promote the recycling of organic wastes [10]. Composting was the first concept for using EM in environmental management [11] and can be applied in both aerobic and anaerobic conditions [12].

EM refers to the specific mixed cultures of known beneficial microorganisms that are being used effectively as microbial inoculants. EM contains selected species of microorganisms including the predominant population of lactic acid bacteria, yeasts and a smaller number of photosynthetic bacteria, actinomycetes and other types of organisms [13]. All of these microorganisms are mutually compatible with one another and can coexist in liquid culture [13].

The reported beneficial effects of EM include; increases the rate of organic matter decomposition [14, 15]. EM in composting increases the macro and micronutrients contents such as Organic Carbon (OC) content, Total Nitrogen (TN), P and K in the soil [16-18]. EM also emits gasses of offensive smell such as hydrogen sulfide (H_2S), ammonia (NH_3) as a result it removes the malodor from the decomposed garbage [10, 19]. EM also can suppress diseases in the soil whereby reducing the requirement of chemical fertilizer and pesticides [13, 14, 20]. Moreover, EM can detoxify and decontaminate of our landfills and environment and promote highly sustainable closed-cycle agricultural organic waste treatment [21].

In 2005, a study of domestic waste composition in Stone town, Zanzibar has shown that 86w% of domestic waste is Organic waste. Hence this organic waste particularly, food waste when decompose in uncontrolled dump produce a methane gas which is one of the constituents of greenhouse gases (GHGs) [2]. As the large fraction of MSW of Zanzibar consists of a large percentage (86%) of organic materials, it is important to design an effective technique that can utilize organic waste. However, the potential of organic household waste as useful resources has not yet been utilized in Zanzibar. Therefore, this study was undertaken to characterize and assess the physicochemical properties of the compost produced from household organic waste inoculated with EM consortium.

2. Materials and Methods

2.1 Sample Collection

Household samples were randomly selected from 50 households situated at Kiembesamaki, Zanzibar suburban. Two different containers were supplied per household, one container for collecting biodegradable (kitchen organic waste) and the other one for collecting non-biodegradable waste. The organic waste mainly included vegetable peel, fruit peel, leftover food, and eggshells. Household solid wastes were collected and calculated by weighting and were subjected to the composting process.

2.2 Preparation of the Compost

Household organic waste was composted aerobically and anaerobically using EM Stock solution. Activation of EM involves the addition of 20 L of water and 2 kg of jaggery (pure can sugar) to IL of dormant EM [21]. The solution was placed in airtight plastic container with no air left in the container and kept away from direct sunlight at ambient temperature for about 10 days.

Three compost piles were made; treated as compost without EM (CONT), compost with EM (EM) and compost with EM plus chicken manure (EM + CM).

For compost inoculated with EM; biodegradable waste was placed in the pile and activated EM solution was spread over the top of the waste, the process was repeated to a height of 100cm and then covered with a plastic sheet.

For compost inoculated with EM and Chicken manure (CM); a thin layer of 10 kg of biodegradable waste was placed in the pile and activated EM was sprayed over the layer. The second layer of 1kg of Chicken manure was spread over the previous layer followed by activated EM stock solution; this layering process was repeated to a height of about 100cm, and then covered with plastic sheet.

At least five times the composting pile has to be turned up during the process time [22]. This turning loosens mixes and adds moisture to homogenize and aerated the materials in the pile [23].

2.3 Sample Preparation

The samples of the compost were collected, dried and grinded to pass 2mm sieve; then the sample were selected by quartering technique and kept into a plastic bag for physicochemical analysis [18, 21].

2.4 Laboratory Analysis of the Compost Samples

The analytical and laboratory work was carried out at Ardhi University, Dar-es-salaam, Tanzania, and Kizimbani Agricultural Institute for Chemical analysis of the compost, Zanzibar. The physicochemical parameters of the compost samples were carried out using standard procedures. The electrical conductivity (EC) and pH of the compost samples was measured in suspension ratio of 1:2 (compost to water) by using Electrode method. The Organic Carbon (OC) was analyzed using the Black and Walkley method, in which the compost samples were oxidized at a temperature of about 120°C with a mixture of Potassium dichromate ($K_2Cr_2O_7$) and concentrated sulphuric acid (H_2SO_4). Nitrogen (N) was determined by Kjeldahl method after digestion with concentrated H_2SO_4 in the presence of selenium catalyst. Phosphorous (P) in the sample was determined using the blue ammonium-molybdate method with ascorbic acid. Potassium (K), Calcium (Ca), Magnesium (Mg) and Sodium (Na) were analyzed by Atomic Absorption Spectrophotometer (AAS) after samples were digested with Nitric acid (HNO_3) and C/N ratio was calculated out of the ratio of total amount of Carbon and Nitrogen.

3. Results and Discussion

The result has shown that biodegradable organic waste is more generated (85%) than non-biodegradable waste (15%). This result supports the finding from the other studies as the waste generated in developing countries particularly low-income level contains a larger percentage of organic waste [5, 6, 23].

3.1 Duration of Composting

The rate of the decomposition of biodegradable organic waste into manure was accelerated quickly within 40 days due to the inoculation of EM consortium when compared to control compost without EM consortium that took two months for the formation of compost. The increase of decomposition is may be due to the availability of microorganisms, bacteria and enzymes essentially for the increased decomposition activity and nutrient availability.

3.2 Characterization of Compost

The average physicochemical properties of the compost are presented in Table 1.

3.3 pH and Electrical Conductivity (EC)

The pH values as shown in Table 1 are 9.10, 8.10 and 6.85 of control compost, EM+CM and EM

Table 1 Physicochemical properties of the compost.

	CONT	**EM+CM**	**EM**
Ph	9.10	8.10	6.85
EC (mS/cm)	6.21	4.48	3.59
PO_4(%)	0.005	0.004	0.004
K (%)	0.06	0.30	0.60
N (%)	0.16	0.28	0.19
C (%)	2.40	3.16	2.72
OM (%)	9.08	22.18	26.86
C/N	14.90	11.29	14.45
Ca %	9.10	4.90	1.50
Mg %	0.50	0.35	0.10
Na %	0.18	0.14	0.06

respectively. This indicates that the pH values of compost sample (EM and EM+ CM) are slightly alkaline in nature and were within the standard limits of 5.5-8.5 as has been reported by Rawat M., Ramanathan A. and Kuriakose T. (2013) [8]. CH +EM compost had the higher value as compared to EM compost this could have been due to the addition of chicken manure that is typical for chicken manure having pH in alkaline condition. For control compost, the pH value was higher as an acceptable limit. This result shows that application of EM in composting might lower the pH value. According to results obtained by Higa T. and Wididana (1991) [14], in general, the pH at the initial stage of decomposition decreased to acidic condition for several days and then it increased to about alkaline condition. The decrease in pH could be attributed to the modified chemical production of organic acid [9] which serves as substrates for succeeding microbial populations and the rise of pH at the end of the composting is due to the utilization of the organic acid by microorganisms. The EC values shown in Table 1 are 6.21 mS/cm, 4.48 mS/cm and 3.59 mS/cm for control compost, EM+CM and EM compost respectively [12, 24], revealed that the higher EC of the finished compost correlated with the increased concentration of salt present in the food wastes as a result of degradation of organic matter during the composting process that results in the release of bases and nutrient contents. The EC for CM +EM and EM compost in this study accords with other research that reported the EC values ranging from 3.90 to 5.10 mS/cm [23]. Those values of the composts treated with EM consortium were within the agreed with International standard for good quality compost of 2-4 mS/cm [25], while the EC values for control and compost is beyond the acceptable limit [26], suggest that EC levels more than 5 mS/cm may lead to phytotoxicity, and it has been reported that the highest value of EC in MSWC inhabit the plant growth particularly seed germination [8]. Therefore, compost inoculated with EM is suitable for use in the agricultural application.

3.4 Organic Matter (OM) and Carbon Content (C)

The OM of the compost produced as shown in (Table 1) are 9.08%, 22.18% and 22.86%, and the Carbon content of the composts are 2.40%, 3.16% and 2.72% for Control, CH+EM, and EM compost respectively. The OM and C content of the composts were higher compared to control compost. However, the C content of all composts treated with and without EM were lower compared to raw materials used. The result has shown that C content may be lost due to the either bio-oxidation, in which carbonaceous materials are lost as CO_2 or mineralization of C in which inorganic carbon is converted to OC [27]. The lower values of OC obtained in all compost are near to the value (5.4%) obtained from other studies [28].

3.5 Nutrients Contents (NPK) of the Composts

The values of Total N, P and K of the compost amended with chicken manure using EM consortium (CM+EM) were 0.28%, 0.004% and 0.30% respectively, for the compost inoculated with EM consortium (EM) the N, P, and K values were 0.19%, 0.004% and 0.60% respectively and the NPK values for control compost (CONT) were 0.16%, 0.005% and 0.06% respectively. The values were lower than those reported from other findings that revealed Total N in the range of 4-6% after composting of food waste and poultry manure treated with EM [12]. Other study revealed TN content of 1.2% N content of the final compost from raw kitchen waste treated with EM [2]. However, the TN values of this study exceeded the value 0.067% reported in some findings [22]. Comparatively, the nutrient contents, TN of the compost treated with EM amended with chicken manure had higher value than EM compost indicating that the raw chicken used had much N content. This result may also attributed to the volatilization of ammonia [23, 27] during the composting of OM.

In the case of K content, the results of the compost inoculated with EM consortium were in consistency with those reported by Saravan P. et al. (2013) and, Sekeran V. et al. (2005) [2, 21]. The increase of K may be due to the influence of EM consortium during composting of organic waste. The result of the K content of both compost treated with EM is in line with the recommended standard set for the quality parameter of compost, 0.2% set by Epstein E. (1997) [29] and 0.6-1.7% set by Na Mona B. (2003) [25]. A low value will need K added to support plant growth while high level may contribute to a soluble condition that restrict root growth and cause plant injury [29].

Regarding P as PO_4, the result has shown that the P content was almost the same for both control compost and EM compost. In generally the values of all compost were lower as compared to other studies [2, 14, 21]. The low value of P might be due to the presence of high Ca^{2+} content leading to the precipitation of Calcium phosphate [30]. In correlation between all composts, the control compost had high P value compared to compost. Similar observation reported by Namasivayam S. K. R. and Bharani R. S. A. [22], which got a higher result in control compost compared to the EM treated compost. The result indicates that no effect of EM in compost inoculated with EM consortium.

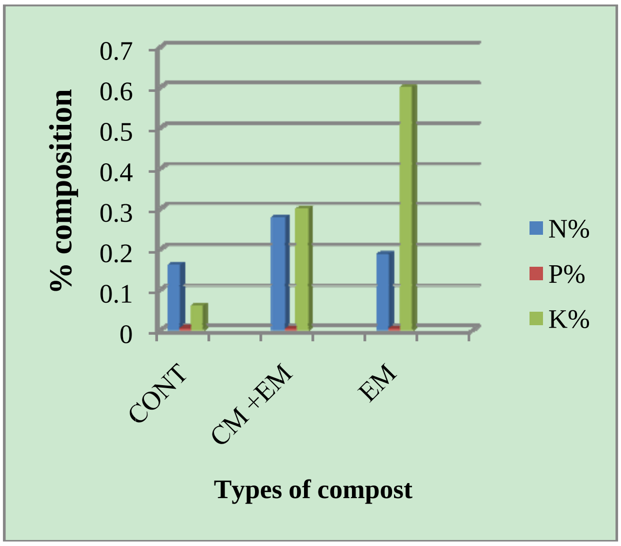

Fig. 1 Percentage composition (%) of TN, P and K.

3.6 Calcium (Ca), Magnesium (Mg) and Sodium (Na) Contents

The values obtained in this study were 9.10% Ca, 0.50% Mg and 0.18% Na for control compost and 4.90% Ca, 0.35% Mg and 0.14% Na for EM + CM compost and 1.50% Ca, 0.10% Mg and 0.06% Na for EM compost. In comparison the value of Ca content was very higher in all degradation stage of compost but according to the international standard limit of Ca set for good quality compost the Ca value range between 1-4% hence the Ca values of CH+EM and EM compost were within the acceptable limit. Ca is required by plants in maintaining the structure of plant cell and soil condition [31]. The concentration of Mg was found to be lower than Ca, which regarded as nontoxic to human health. Na concentration was lower in all composts as compared to Ca and Mg. Na concentration was highly soluble and readily leached, and parts of its salts get solubilised during decomposition [31]. There was no adverse effect, but a higher concentration of Na may affect the soil structure as well as permeability that lead to alkaline salts and become toxic to plants [31]. The results obtained in this study has shown that compost treated with EM had a lower concentration of Ca, Mg, Na levels and were within the acceptable limit as compared to control compost this is may be due to the inoculation of EM solution while composting.

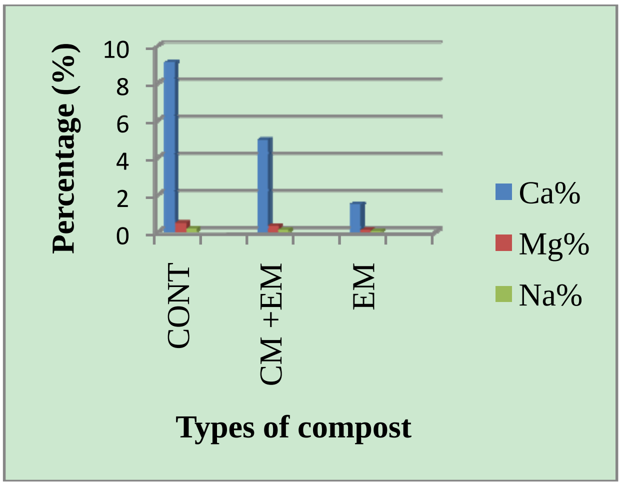

Fig. 2 Percentage (%) composition of Ca, Mg and Na of the composts.

3.7 Carbon to Nitrogen Ratio (C/N) of the Composts

The nutrient analysis in Table 1 showed that C/N ratios of the composts are 14.90, 11.29 and 14.45 for CONT, CH+EM, and EM composts respectively. The results have shown that the C/N ratio of all compost range between 11:1-15:1 which is in an acceptable range. The C/N ratio provides an indication of the degree of decomposition. This indicates that enhancement of OM decomposition with EM results in lowering C/N ratio [21, 28]. Some studies revealed that the decreased of C/N ratio after composting process is expected as the rate of C loss is higher than that of N [14]. Low C/N ratio at the end of composting was due to the depletion of easily degradable carbon compound present in chicken manure and according to Sekeran V., Balaj C., Pushpa T. B. (2005) [21], a low C/N ratio accelerates the rate of decomposition. C/N ratios obtained in this study were comparable with those reported by Park K. (2011) [12], and this may be due to the nature of raw materials used during composting.

4. Conclusion

In conclusion, the household organic waste is suitable for composting because of the high percentage (85%) of biodegradable organic waste. This practice can reduce the amount of waste disposal to the landfill or open dump. The physicochemical data of this study show that pH and EC of the compost inoculated with EM consortium were lower pH (6.85-8.1) and EC (3.59-4.48) compared to control compost (pH 9.10) and (EC 6.21). The range of TN (0.19%-0.28%) and K (0.30%-0.6%) of the compost inoculated with EM consortium were slightly higher compared to control which had (TN 0.16%) and K (0.06%). However the P contents remained the same in all treatments, while C/N ratio for all treatments ranges between 11:1-15:1. Therefore, the study revealed that the application of EM is suitable to enhance the decomposition process of organic waste and influence the physicochemical characteristics of the compost. Finally, it is concluded that composting of organic household waste can be adapted country wide for the recovery of valuable and economical organic fertilizer to be applied as a soil amendment.

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