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Vermicomposting Kitchen, Municipal Market and Tea Factory Waste using *EiseniaFetida* Earthworms

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***Abstract*—** *Population increase, urbanization, industrialization and agricultural activities result in accumulation of solid waste. This waste requires sustainable management through techniques such as vermicomposting. The study aimed at determining the rate of vermicomposting of kitchen, municipal market and tea factory waste using Eisenia fetida earthworm species at the University of Embu, Kenya. The study was arranged in completely randomized design replicated thrice. Data was collected on decomposition rate, carbondioxide evolution, earthworm count, nutrient content of vermicompostedwaste and days to vermicompost maturity. SAS version 9.4softwarewas used for statistical data analysis. Treatment means were separated using least significant difference (l.s.d.) at p≤0.05 probability level. Kitchen waste vermicompost had the fastest decomposition rate of 0.6 kg/day. Carbondioxide evolution analysis was done weekly whereby a value of 0 µgCO_2/g vermicompost/m^2/day was recorded at week 15 when the vermicomposts had stabilized. Kitchen and market waste vermicompostshad the highest earthworm countof 169 and 153, respectively.The nutrient contents of the three vermicomposts were not significantly different. The study concluded that kitchen waste had the highest vermicomposting rate as well as earthworm count. Therefore, the study recommends that kitchen waste and market waste can be used where the aim of vermicomposting is earthworm production.*

Keywords*— *Nutrients, earthworms, decomposition, stability.

I. INTRODUCTION

Global waste production is predicted to increase from the current 2 billion tonnes per year to 3.4 billion tonnes in 2050 (Kaza*et al*., 2018). Embu municipality produces approximately 9,344 tonnesof waste per year, out of which only 15% is collected and transported to the dumpsite (Nicholas, 2013). The waste in Embu municipality was found to compose 53% organic/biodegradable waste (Nicholas, 2013).This necessitates adoption of technologies to manage these wastes. Vermicomposting refers to the use of earthworms to convert biodegradable waste into high quality manure (Parekh and Mehta, 2015).Vermicompostprovides macro and micro-nutrients to plants.

Vermicomposted urban green waste has been found to contain: 2.0-3.0% Nitrogen (N), 16000-23000mg/kg Phosphorus (P), and 19000-26000mg/kgPotassium (K) (Sinha *et al*., 2009). In Malaysia, vermicomposted wastes were found to contain 0.87 % to 1.9 % N, 2300 -4600 mg/kg P, 4000-27400 mg/kg K and 168800 - 321400 mg/kg C (Jamaludin&Mahmood, 2008). In Kenya, manure based-vermicompost was found to contain 1.9% N, 3000 mg/kg P and 27000 mg/kg K (Savala, 2007). However, the nutrient content depends on the quality of organic waste(Kumar *et al*., 2018). Vermicompost takes about two months to mature, for instance, that of agricultural waste (Nagavallema*et al*., 2004).Vermicompost is applied to high value crops as a source of plant nutrients. For instance, agro-based waste vermicompost has been utilized for greenhouse kale productionin the Central highlands of Kenya (Karuku et *al*., 2016).

Vermicomposting is solid waste management technique which converts organic wastes into organic fertilizer (Rosman*et al*., 2017).Vermicomposting is thus efficient environmentally, economically and socially, making it a global waste reduction technique (Parekh & Mehta, 2015).Suitable earthworm species for vermicomposting include: *Eisenia Andrei*, *Eiseniafetida* and *Lumbricusrubellis* (Dominguez & Edwards, 2010).The vermicomposting earthworms are characterized by high organic matter consumption rates, high reproduction rates, high environmental stress tolerance, rapid hatching, growthand maturation(Malińska*et al*., 2017).

Tea is the major cash crop in Kenya, contributingabout 11% economic growth in the agricultural sector and supportingapproximately 5 million livelihoods (Kaiyaga, 2015). Tea waste produced in Rukuriri Tea factory totals to 9.125 tonnes a year (Rukuriri Factory Tea Waste Records, 2018). This waste is a potentially valuable resource that can be utilized for preparation of vermicompost, a soil amendment.Organic wastes generated during tea processing include refuse tea, shade tree lopping's, tea pruning's and weeds (Hitinayake *et al*., 2018). Green tea leaves were used for vermicomposting in the study.The University of Embu Kitchen generates 365 tonnesof waste annually (Mochache, 2016). This is a big resource that can be vermicomposted to supply nutrients for sustainable crop production.Embu town market generates approximately 2.6 tonneswasteannually(Environment and Natural Resource Department, Embu County Government, 2017).The 53% organic waste generated in Embu town market can be transformed into vermicompost for increasing crop productivity.

The basis of formulating this study was to prepare and analyze vermicompost from three organic wastes: kitchen waste, municipal market waste and tea factory waste. The study therefore aims at determining the rate of vermicomposting of kitchen, market and tea factory wastes using *Eisenia fetida* earthworm species.

II. MATERIALS AND METHODS

Study Area

The study site was the University of Embu, Embu County, Kenya. The site is located3 km from Embu Town along the Embu-Meru highway. The site lies at an elevation of 1, 350 metres (Kenya Information Guide, 2015). Embu has a bi-modal rainfall pattern receiving long rains between March and June and short rains between October and December (Embu County Government, 2013).The University of Embu receives an average annual rainfall of 1232 mm and has a mean annual temperature of 18.7 °C (Jaetzold*et al*., 2006).HumicNitisolswith moderate to high fertility characterize the study site(Verde *et al*., 2013).

Vermicompost preparation

Each vermicompost type was prepared in three plastic 120 litres capacity bins.Kitchen waste was obtained from the University of Embu kitchen, market wastefrom Embu Town Market and tea waste from Rukuriri Tea Factory in Embu. Earthworms were obtained from a commercial worm grower in Juja, Kenya and transported in a bucket containing worm casts and organic residues on top as earthworm feed.The experiment was conducted at room temperaturein a dark room. 100g banana leaves were placed as the worm bedding, 2.5 kilograms(1250 earthworms) placed on the bedding, followed by 2kg cattle manure then 1kg of waste (from the kitchen, market and tea factory). A three months pre-composting was done to preserve worm mortality and ensure multiplication. Vermicomposted kitchen waste comprised carrots peelings and cabbage and kales leaves. Vermicomposted market waste comprised banana, potato and fruit peelings. Vermicomposted tea waste comprised the green leaves. A cover of 100gdry banana leaves was added at the top. The vermicompost was kept at 60-70% moisture content by adding a litre of water once per week. The duration of the experiment was seventeen weeks for the first season and fifteen weeks for the second season.This was because in both seasons, stabilization took place by the fifteenth week whereby no further carbondioxide evolution was observed.

Study Design

The study was carried out for two seasons, July 2018 and November 2018 for the first season and November2018 and February2019 for the second season. The vermicomposting vessels were arranged in completely randomized design replicated three times. The treatments were: vermicomposted kitchen waste, vermicomposted market waste and vermicomposted tea factory waste.

Data Collection

Data collection was done on carbon dioxide evolution, earthworm count, decomposition rate and days to vermicompost maturity and nutrient content (N (%), P(mg/kg), K (mg/kg) and C %) of the three vermicomposts.

Carbondioxide Evolution

Carbon dioxide evolution (µgCO_2/g vermicompost/m^2/day) was done weekly(as from the second week of the setup) following the procedure modifiedby Strotmann *et al*. (2004). Sodium hydroxide (20 ml) was placed in a vial which was suspended on the vermicomposting bin to collect carbondioxide overnight for a period of 24 hours and afterwards analyzed by titrating with Hydrochloric acid (1M) to obtain the carbon dioxide evolved from the experiment.

Earthworm Count

Earthworm sampling was done weekly on the different vermicomposts using the method ofBouché and Gardner

(1984). This was done by isolating, hand sorting and physical counting of the earthworms to determine their numbers once per week.

Nutrient Analysis

Nitrogen (%), Phosphorus (mg/kg), Potassium (mg/kg) and Carbon (mg/kg) were determined in the vermicomposts. Total nitrogen was analyzedfollowing the procedure of Page *et al*. (1982).The elements P and K were analysed following the procedures of Mehlich*et al*. (1962). Potassium was determined with a flame photometer and Phosphorus spectrophotometrically.Total organic carbon (TOC) analysis was analysedfollowing the procedure of Anderson & Ingram (1993).

Decomposition Rate

Decomposition rate was determined using the equation of (Rovira&Rovira, 2010):

$-k = dX/dtX$, where-k -decomposition rate constant, dX -change in initial litter mass, dt -change in time and X -initial litter mass

Data Analysis

SAS software version 9.4 was used for statistical data analysis (SAS, 2013). Data was subjected to two-way analysis of variance using SAS GLM code of the model CRD, to determine the difference inearthworm count and carbondioxideevolution at the beginning and end of the study. Statistically significant($p \leq 0.05$)treatments meanswere separated using l.s.d.

III. RESULTS AND DISCUSSION

Vermicomposting rate of the wastes

Maturity indicates suitability of vermicompost for plant growth (Majlessi*et al*., 2012).The vermicompost from the three organic wastes took 107 days to maturein the first season. In the second season, the three vermicomposts took 98 days for kitchen waste, 105 days for market and tea waste to reach maturity; this was because of the differences in the C: N ratio of the materials. Nurhidayati (2018) reported that compost reached maturity when the C: N ratio was <20. According to Alidadi *et al*. (2016) the adequate time for municipal solid waste vermicompost maturation was reported to be 75 days. Similarly, Aynehband*et al*. (2017) vermicomposted cereal wastes in 90 days, whereas Gopal *et al*. (2018) vermicomposted coconut wastes for 80 days. The differences in the vermicomposting rates in the different studies may be related to temperature differences. The higher the environmental temperatures the higher the decomposition rates consequently the faster the maturity.

In the first season kitchen waste was found to have the highest decomposition rate at 0.51 kg/day, tea waste followed at 0.48 kg/day and market waste had the lowest decomposition rate at 0.45 kg/day. In the second season kitchen waste still maintained a higher decomposition rate at 0.6 kg/day as compared to tea waste 0.54 kg/day and market waste 0.53 kg/day. The different vermicomposting rates of the residues may be related to residue quality as suggested by Aynehband*et al*. (2017).Wardle *et al*.(2009) and Moore *et al*.(2011)found that chemical composition differences in residues such as, lignin content, organic Carbon content, C: N ratio and lignin affected decomposition rates.Residues with a high C: Nratios have slower decomposition rates and those with high N content have high rates of decomposition (Ali,2011).

Earthworm Count

Earthworms multiply under suitable ecological conditions as well as suitable food, temperature and oxygen (Chanda *et al*., 2013). In season one, kitchen waste had a significantly higher ($p \leq 0.05$)earthworm count of 572earthworms per kilogram of vermicompost compared to market waste vermicompost at 364earthworms and tea waste vermicompost at 352earthworms at the end of the study. In the second season, significant differences ($p \leq 0.05$)were also observed at the end of the study, whereby kitchen and market waste vermicomposts had a significantly higher ($p \leq 0.05$)earthworm count of 676 and 612 earthworms respectively, per kilogram of vermicompost, compared to tea waste vermicompost at 432 earthworms.

In both seasons of the present study the initial number of earthworms was low but at the end of the study the number of earthworms had increased by over 50% for each type of vermicompost.In season one;tea waste recorded the highest earthworm increase at283%, followed by kitchen waste at 211% and market waste followed at 63%. In season two, kitchen waste vermicompost recorded the highest increase in earthworm count at273%, followed by market waste vermicompost at 248% increaseand tea waste vermicompost at 212%. High numbers of earthworms were recorded in kitchen waste as it is a rich inorganic feeding material ideal for earthworm growth and reproduction (Albasha, 2015).

This corresponds to the findings of Lalander*et al*.(2015), who foundan increase of 65 %,Abu Bakar *et al*. (2014)who found a 92 % increase,Mathivanan*et al*., (2017)who found a 77 – 94% increase andGopal *et al*. (2018) who found a 300 fold increase in earthworm numbers on vermicomposting.The results of the present study indicating differences in earthworm numbers based on the type of

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residue agree with those of Aynehband*et al*. (2017) who found differences in earthworm number and activity on using different wastes.

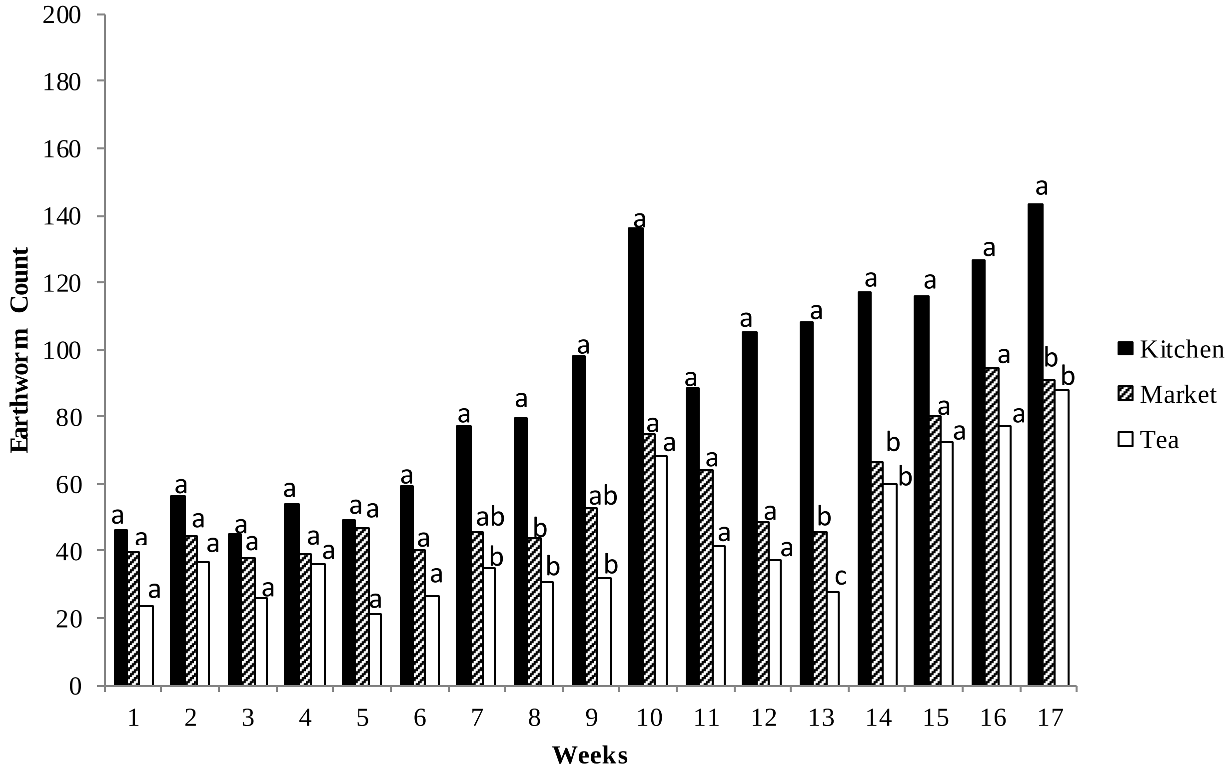

Fig.1: Season 1 Earthworm Count

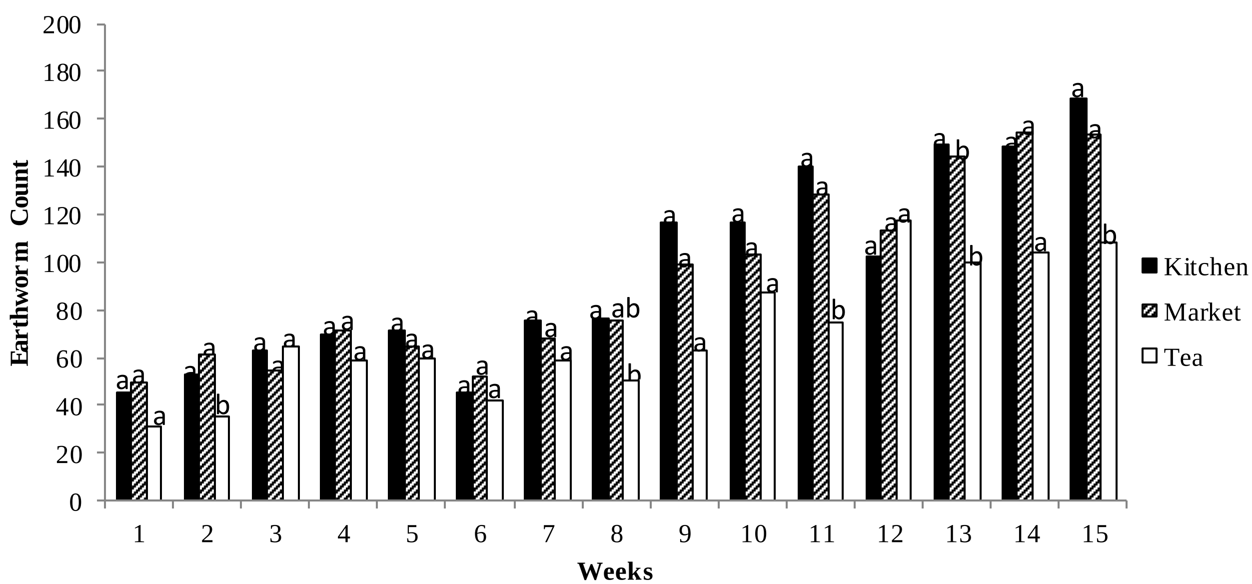

Fig.2: Season 2 Earthworm Count

Carbon Dioxide Evolution

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In the first season, there was no significant difference in carbondioxide evolution by the seventeenth week ($p \geq 0.05$). However, significant differences ($p \geq 0.05$) were observed in weeks 1 and 11, whereby in week 1, tea wastevermicompost had a significantly higher carbondioxide evolution (12767 μgCO_2/g vermicompost/m^2/day) compared to kitchen waste vermicompostat 5133 μgCO_2/g vermicompost/m^2/day and market waste vermicompost at 2033 μgCO_2/g vermicompost/m^2/day. In week 11, market waste vermicompost had a significantly higher carbondioxide evolution of 5668 compared to kitchen waste vermicompost at 800 μgCO_2/g vermicompost/m^2/day and tea waste vermicompost at 0μgCO_2/g vermicompost/m^2/day. By the end of the second season, there was no significant difference in the carbondioxide evolution of the treatments ($p \leq 0.05$). In the second season, significant differences in the carbondioxide evolution were observed in weeks 1 and 5, whereby kitchen waste vermicompost had a significantly higher carbondioxide evolution at 14567μgCO_2/g vermicompost/m^2/day and 10967μgCO_2/g vermicompost/m^2/day ($p \geq 0.05$) compared to market and tea waste vermicomposts at 10500μgCO_2/g vermicompost/m^2/day and 8833 μgCO_2/g vermicompost/m^2/day respectively.The three vermicompost types stabilized at week 15 whereby a value of 0 μgCO_2/g vermicompost/m^2/day was recorded (Figure 3, 4).

This was done to indicate vermicompost stability. In both seasons as indicated by Figures 3 and 4, high values of carbondioxide evolution were observed among the kitchen, municipal market and tea vermicompost at the beginning of the experiment, but values gradually reduced until they were constant towards the end of the experiment, thus indicating that vermicompost had stabilized. This corresponded to the findings of Nayak *et al.*(2013) whereby lower values of carbondioxide evolution indicated more vermicompost stabilization. Increased carbondioxide evolution rates indicated higher earthworm and microbial respiration rate as well as aerobic biological activity (Kalamdhad*et al.*, 2008; Sonawane, 2016). Lower carbondioxide evolution values were as a result of reduced metabolic activity which results in decreased respiration rate of microbes and earthworms (Nayak *et al.*, 2013).

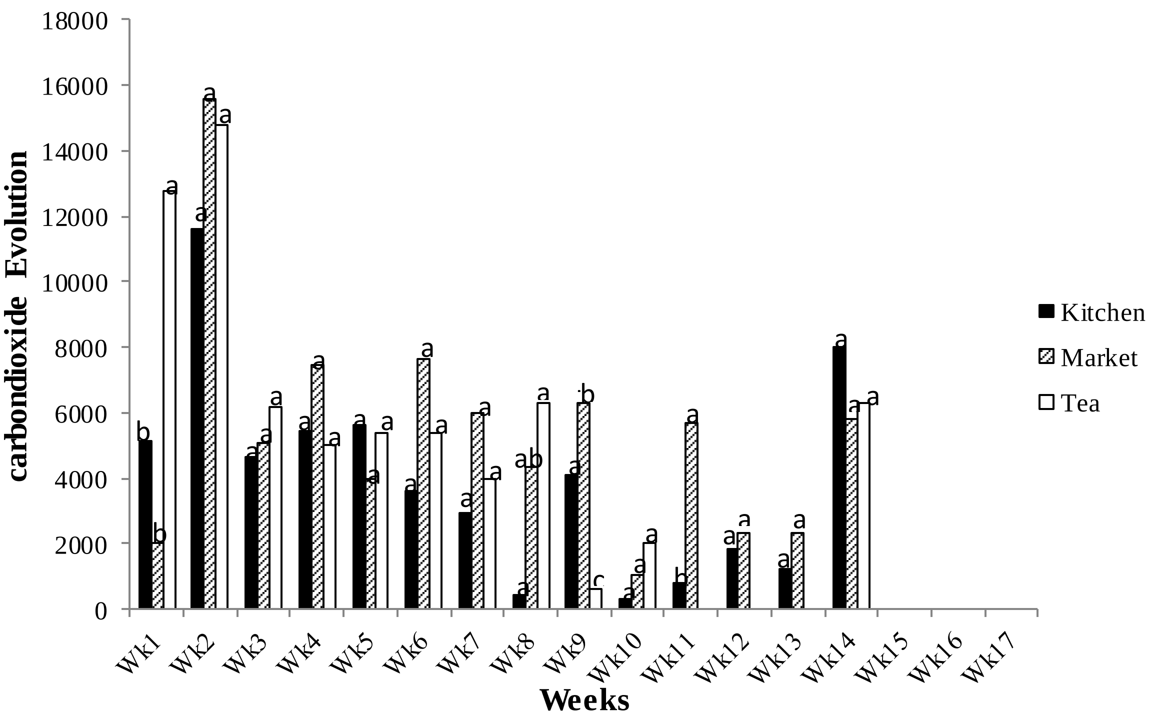

Fig.3: Season 1 Carbondioxide Evolution

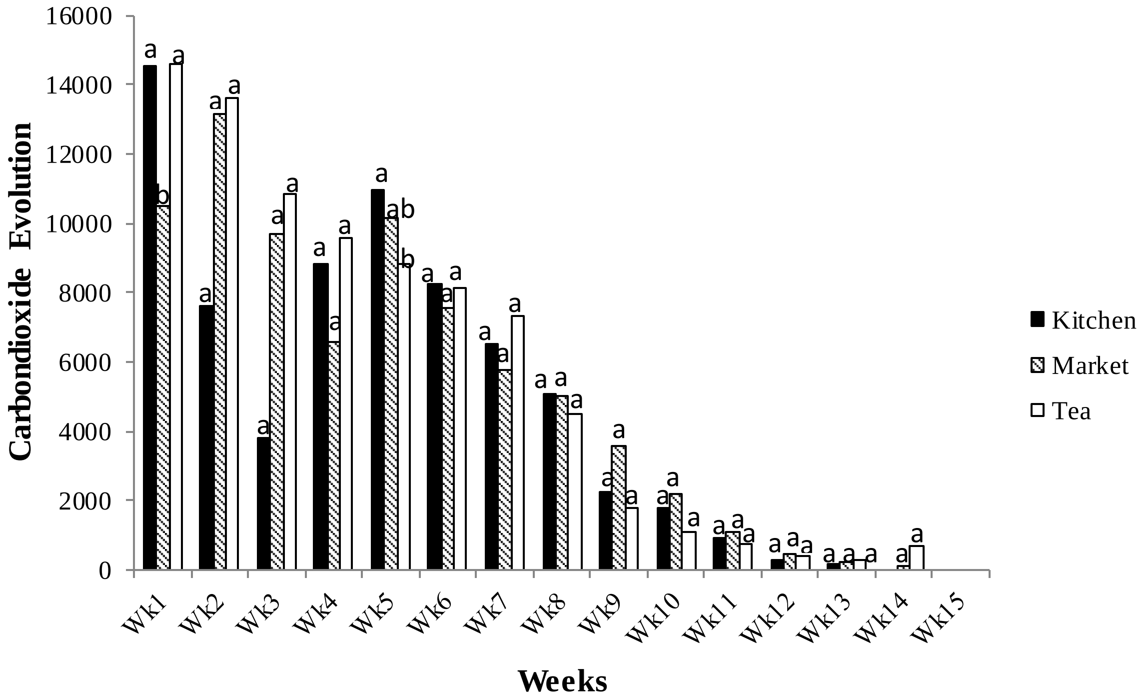

Fig.4: Season 2 Carbondioxide Evolution

Vermicompost Nutrient Analysis

Table 1 indicates the statistical analyses of the nutrient content of the vermicomposts.

Table 1 Vermicompost nutrient content

Treatment	Nitrogen (%)	Phosphorus (mg/Kg)	Potassium (mg/Kg)	Organic Carbon (mg/kg)
Kitchen	0.5067[a]	8067[a]	27433[a]	150000[a]
Market	0.8167[a]	7667[a]	19700[a]	153330[a]
Tea	0.7767[a]	7600[a]	24167[a]	150670[a]
P-value	0.1066	0.9354	0.1382	0.9499
l.s.d	0.3199	0.3362	0.8025	2.5525

Though the nutrient contents were statistically similar ($p \geq 0.05$)among the treatments, (Table 1), N content was higher in market waste than tea and kitchen waste vermicomposts by 5.1% and 64% respectively. Phosphorus content was higher inkitchen waste vermicompost than market and tea waste vermicomposts by 5.2% and 6.1% respectively. Kitchen waste vermicompost had the higherK content than tea and market waste vermicomposts by 13.5% and 39.3% respectively. Organic carbon content was higher in market waste vermicompost than tea and kitchen waste vermicomposts by 1.8% and 2.22% respectively.

An *et al*. (2014)found vermicomposted kitchen waste (food scraps) containing 0.5% available N, 2400 mg/kg available P, 3000 mg/kg available K, 0.6% Mg and 0.2% Ca. Additionally, Wani and Rao, (2013) found vermicomposted tea waste containing an organic carbon content of 133,000 mg/kg. The results of the present study on the N content of kitchen wastes agree with those of An *et al*. (2014).The higher P and K contents in the present study may be due to the quality of the kitchen wastes used. The nutrient content of municipal solid waste was found by Pattnaik and Reddy (2009) to be 0.5% N, 3000mg/kg P, 2000mg/kg K and 796 000mg/kg organic C.The N, P, K contents of the present study are much higher than those of Pattnaik and Reddy (2009). This could be due to differences in the quality of the market residues in the present study. Vermicomposted tea waste is reported to contain 0.9% N, 6000 mg/kg P, 51000mg/kg K, and 259000mg/kg C (Abbiramy*et al*., 2015). The tea waste vermicompost N and P contents in the present study are similar to those of (Abbiramy et *al*.,

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2015)but the K contents are lower. This may be due to differences in the quality of the leaves.

IV. CONCLUSION

The study determined the decomposition rates of vermicomposted kitchen, municipal and tea factory waste. Kitchen waste had a higher vermicomposting rate compared to tea and market waste. Kitchen waste and market waste vermicomposts had higher earthworm count compared to tea waste vermicompost. Stability of the vermicomposted waste was determined by carrying out carbondioxide evolution, whereby low carbondioxide evolved indicated stability of the vermicompost. Kitchen wastes and market wastes can be used to rear earthworms for use in vermicomposting or livestock feed. This study therefore recommends kitchen and market wastes where the aim of vermicomposting is earthworm production.Market, kitchen and tea waste can be used as soil amendments as they have statistically similar nutrient contents ($p \geq 0.05$).

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