



ADDIS ABABA UNIVERSITY
COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES
CENTER FOR ENVIRONMENTAL SCIENCE

EVALUATION THE QUALITY OF COMPOST FROM VEGETABLE
WASTE WITH SAWDUST AND POULTRY MANURE

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ADDIS ABABA, ETHIOPIA, 2019

Abstract

This experiment was conducted at Aware TVET to investigate the changes in the principal physico-chemical properties of composting vegetable wastes from fresh vegetable market with locally available amendments. To achieve this objective vegetable wastes having C:N ratio of 36.5:1 and moisture content (about 78%), were composted with sawdust having a high C:N ratio of 49.7: and poultry manure having a low C:N ratio of 11.7:1, at various treatment composition. It was expected that the amendment material combined with vegetable wastes would compensate for the high moisture and adjust the C:N ratios in the vegetable wastes to improve conditions to initiate microbial activity and enhance the rate of composting. Totally Four small bins with three replicates each and have a size 3m x 1m x 0.5m were used as treatment 1, 2, 3 and 4 over 90 days. Treatments were evaluated throughout the experimental period for parameters, such as temperature, pH, volatile solids, moisture content, volatile and C/N ratio. Moreover, additional parameters like average elemental concentrations (nutrients and metals) and germination index for each treatment were determined at the end of the composting. During the process thermophilic temperatures (> 40°C) were reached after 18 days of piling in all treatments, where as the highest mean temperature (> 55.6°C) and early maturation was recorded in T2, and the lowest maximum temperature (<49°C) and rapid fall in temperature was recorded in the T4. The degradation of organic matter was greatest within the first six weeks of active composting and organic matter loss of all stage of composting was highest for T3, (25.71 %) and lowest for T2 (17.95%). pH of all treatments followed the same trend, slightly acidic at the beginning 5.1-7.74 and during composting values increased rapidly and varied between 7.36 and 8.04. T1 and T2 showed a germination index of only 62.21 and 55.82 %, respectively, and the compost of T3 and T 4 showed a germination index value of 92.5 and 98.54 %, respectively. Major reduction in the C:N ratio took place during the second week of composting and highest value was recorded for T1 (from 18.68 to 10.45). High initial moisture content (76.6%) in the T3. In general, the Analysis of various physical and chemical parameters during and at end of composting process, together with initially measured characteristics vegetable waste proved that vegetable waste is a good biodegradable material if certain amendment that absorb excess moisture and correct the C/N ratio was added.

Key words: compost, poultry manure, sawdust and red beet .

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List of Abbreviations

C-Carbon

C/N - Carbon to nitrogen ratio

ds/m- deci Siemens per meter

EC- Electrical Conductivity

K- Potassium

MC- Moisture Content

MSW - Municipal Solid Waste

N- Nitrogen

OM - Organic matter

pH- power of hydrogen

Pm - Poultry manure

SWM - Solid Waste Management

T- Treatment

TN- Total Nitrogen

Chapter One

1. Introduction.

1.1 Background.

Municipal Solid Waste Management is one of the most fundamental issues in our countries, especially in AA. This is due to the alarming increasing rate of SW generation rate with unbalanced Waste Management service. Solid waste is anything discarded, as unwanted or useless material that is not a liquid or gas. It is non liquid, nongaseous material ranging from municipal garbage to industrial waste that contains complex and sometimes hazardous substances. Municipal solid waste consists of household waste, construction and demolition debris, sanitation residue, and waste from streets(Getaneh, 2007).

In ancient cities, food scraps and other wastes were simply thrown into the unpaved streets, where they accumulated. Around 320 B.C in Athens, the first known law forbidding this practice was established and a system of waste removal began to evolve in several eastern Mediterranean cities. As population increased, efforts were made to transport the wastes farther out and the city dump was thus created (Getaneh, 2007).

Today, one of the critical issues accompanying global economic and social development is the significant increase of the amount of waste generated. The global annual increasing rate of MSW is about 2 billion tons. SWM is one of the critical concerns facing the developing countries because of the social, economic and environmental implications once not properly managed. Studies show that only 30-50% of the waste generated in developing countries is collected and managed properly. The rest is either burned or left to decompose in open space or dumped in unregulated landfills, which is damaging(Lim, Lee, & Wu, 2016).

Waste management in Ethiopia is problem that affects water quality and health. Solid waste, which is a consequence of day-to-day activity of human kind, needs to be managed properly. Addis Ababa started its solid waste management some three decades back. But like other city in our countries, faces problems associated with poorly managed solid waste operation. It is estimated that only 65% of the waste generated in the city is collected, with the rest being deposited in open sites, drainage channels, and rivers(Mohammed, and Elias, 2017).The social

waste collection service is unsatisfactory, and scenes of scattered waste are common in most part of the city. As a result, the population has the opinion that the municipal solid waste collection service is not functioning properly. With respect to the organization of operations and management structure, collection and disposal are parts that are poorly organized (Gebreeyessus, & Demissie, 2013). The high organic content in the MSW stream of developing countries is ideal for composting. For example, studies conducted on the composition of solid waste of Addis Ababa city reveals that 90% by volume and 50% by weight is organic decomposable waste Addis Ababa Bureau of Health, 1997 as cited by (Dadi, Sulaiman, & Leta, 2012). Hence, processing of this significant amount of resource into valuable compost enhances the practices of solid waste management of the city. Source separating the municipal solid waste before collection is usually an environmentally and technically better way to improve the quality of the final compost. The aim of composting is to convert solid organic wastes into nutrient rich soil conditioner and organic fertilizer that have reduced odor, phytotoxic chemicals, weed seeds and pathogens. Composting is defined as a process of aerobic thermophilic microbial degradation or an exothermic biological oxidation of various organic wastes by many populations of the indigenous microorganisms which lead to a stabilized, mature, deodorized, hygienic product, rich in humic substances, easy to store and marketable as organic amendment or manure (Suthar, 2007). Composting of solid waste is a useful method of producing a stabilized product that can be used as a source of nutrients and soil conditioner in the field. The composted product has the advantage of improving soil structure, increasing soil organic matter, suppressing soil-borne plant pathogens and enhancing plant growth. Immature composts may contain more growth inhibiting substances than mature composts. Some of these growth inhibiting compounds include salts, free ammonia, phenolic substances, heavy metals, and organic acids. For optimum aerobic composting, moisture is necessary to support the metabolic processes of microorganisms. Composting materials should be maintained within a range of 40–65% moisture. A higher percentage will increase anaerobic decomposition, while lower moisture content will slow down the composting process as microorganisms die or become dormant. Composting is a biochemical process of decomposition of organic matter (OM). Heat, CO₂, and nutrients are released, and humified OM is formed during this process. Integrated activity

of numerous types of indigenous microorganisms is the main factor driving decomposition of OM. The microorganisms are active only at the solid–water interface. Biodegradation performance of aerobic composting at any time depends on physical (temperature, moisture, size and degree of mixing of feed stocks), chemical (O_2 from air) and nutritional (bioavailable N, P, K and C in the feedstock) conditions (Khan et al., 2014). The microbial activity produces gradual changes in physical e.g. temperature, chemical e.g. C/N, and/or biological parameters e.g. seed germination. Hence these parameters may be used as maturity indices that reveal progress of composting.

Compost is considered stable when microbial activity of an end product reduces to an insignificant level; matured when phytotoxins are reduced to a safer level; and finished when both stability and maturity are reached. Temperature (Khan et al., 2014), C/N (Suthar, 2007), DOC(Bernal, F, & Cegarra, 1998), $NH_4^+ -N/NO_3^- -N$ ratio(Khan et al., 2014)are pre-established stability indices of composting.

The main aim of this study was to compost waste materials generated at and evaluating quality of the compost. In this study organic materials (vegetable waste, poultry manure and sawdust) would be collected for composing at Aware TVET institution. The resulted compost can be used for experimental laboratory in AAU and Horticoop Ethiopia (Horticulture)PLC. The basic principles of composting process, the procedures of composting, the factors affecting the process, the materials needed for composting, significance of composting, methodology of data collection and analyzing and other points related to composting process would be discussed in detail in this study.

1.2 Statement of the Problem.

In most developing countries the average generation rate of waste is within the range of 0.3 to 0.5 kg per capital per day (Mohammed et al., 2017). Currently the daily Solid waste Generation in the City of Addis Ababa is estimated to be 0.5 Kg per capital per day, the density ranges from 250 to 370 Kg/m³ and the daily waste generation has reached to 2,750 m³. Therefore considering the cities of population of 3.5 Million people (Getaneh, 2007).It is estimated that approximately one (1) Million m³ of Solid waste is generated per year (Mohammed et al., 2017).The households practicing composting are very few while 95% of

this refuse is largely plant origin of organic waste but from this only 5% composted according to (Brinton, Ph, & Gardner, 2000) as cited in (Mohammed et al., 2017) composting is an ancient practice where more cities in the world nowadays are reclaiming the benefits of reusing solid organic waste material. It is a natural way to prepare the waste for use. The major limitation for not practicing compost is lack of market and a piece of land for urban agriculture.

The households practicing composting are very few while 95% of this refuse is largely plant origin of organic waste but from this only 5% composted according to. From the study of to Region 14 Environmental Health Bureau (AAHB, 1997) composting and methane gas harvesting for energy recovery has been considered as one alternative for Addis Ababa's waste recovery. This methane gas harvesting for energy recovery has been considered from composting is one of the research gap and significance of composting form mitigation climatic change by protecting this GHG.

In Addis Ababa the refuse comprises 30%-35% by weight (equivalent to about 90% by volume) constituent organic matters mainly kitchen wastes and abandoned vegetables and grasses which are important sources for waste recovery. In spite of this fact, composting and energy recovery has not yet been tried. There are some composting activities (tone by Arada Sub City Environmental Cleaner and Sanitation Department in the area commonly called Ferensay Sefere by collecting solid waste in atikelt tera (unpublished information from Arada Sub City Environmental Cleaner and Sanitation Department).

Chemical fertilizers have a serious impact on agriculture and the environment but compost has been reported to be efficient enough in restoration of the soil by increasing of water holding capacity, resistant to wind and water erosion, able to retain more water and easier to till of the soil due to the composting materials contain cellulose, hemicelluloses and lignin that contain moisture.

The addition of compost materials even in a little to the soil have shown a positive effect on the physical, chemical and biological soil properties as a soil conditioner by increasing of the organic content by improve the soil structure. The addition of compost the soil also provides trace nutrients and small quantities of the basic plant nutrients-nitrate and phosphates in the way of modifying the usefulness of artificial fertilizers by holding them in the soil enabling the plants.

In the case of this research making composting providing of financial burden of small stack holders farmers to purchase chemical fertilizers and using this cost efficient compost making self sufficient by maximizing of food .Therefore, this study was have the following objectives .

1.3. Objectives of the study.

1.3.1. General Objective.

The objective of this study is evaluation the compostability of Vegetable waste mixed with sawdust and poultry manure.

1.3.2. Specific Objectives.

The specific objectives of the research were

- ✓ To determine the physical properties of the feedstock.
- ✓ To determine the physical and chemical properties of each treatment (T1- MSW with poultry manure,T2-MSW with sawdust, T3-poultry manure with sawdust and T4 MSW, poultry manure with sawdust)after and before.
- ✓ To determine the change on nutrients (nitrogen, available phosphorus, and available potassium), organic carbon of the composting process.
- ✓ To measure the parameter of compost such as C:N,pH, EC and moisture content.
- ✓ To determine the quality of compost product by referring international standards and guidelines.

1.4 .Research Questions.

My research would try to address the following significant question

What are the properties of compost at different treatment?

Which one is the best quality of compost produced from different organic waste?

1.5. Significance of the Study.

The significance of this study would be:

- To provide knowledge of composting as solid waste management tool.
- To share knowledge of composting process.
- To popularize the use of compost in place of chemical fertilizers.

Chapter Two

2. Literature Review.

2.1. Composting: overview

The composting process generates considerable heat, CO₂ and water vapor into the air while minerals and organic matter are converted into a potentially reusable soil amendment (Cooperband, 2002); (Mohajer, 2008),(Ekling & Kirchmann, 2000). A wide range of biowastes can be composted including materials generated by agriculture, food processing, wood processing, sewage treatment, and industrial and municipal waste.

Prior to 1970 there were very few composting operations except for those producing compost for the mushroom industry and much of the early work was carried out in the USA where there are now over 3,500 green waste composting facilities. Currently, composting of biosolids is conducted as a component of integrated waste management(Frederickson et al., 1997). Composting performs a dual function of waste treatment and production of causing waste products in to a valuable commodity(Rynk & Colt, 1997).Benefits of composting include soil conditioner and fertilizer, saving in transport cost, improved manure handling, improved land application, lower risk of pollution and nuisance complaints, (Dadi et al., 2012).

Despite having a huge benefit, the feasibility of composting as a sustainable method of organic waste recovery necessitates a thorough understanding of the process (Suthar, 2007). The waste material may contain organisms which are potentially pathogenic to humans, animals and plants. Composting also leads to the emissions of malodors and leachate that require special attention. These may occur during the delivery and handling of the raw materials and during the composting processes(Tognetti & Mazzarino, 2007). Depending upon the redox conditions, microbial decomposition of organic materials was lead to the production of (Cooperband, 2002). All of these three gases contribute to the greenhouse effect and may contributions to global climate change. In relation to this, there has been a considerable amount of work throughout the world to develop safe composting systems for both conventional and organic agricultural systems (Sahu, 2016).

2.2 Basic composting principles

Composting is the manipulation or control of the natural decomposition of organic matter. It requires optimizing the conditions for the mixed population of microorganisms (mainly bacteria, fungi and actinomycetes) responsible for the decomposition. These microbes, normally found on the surface of leaves, grass clippings and other organic materials, thrive in a warm, moist, aerobic (oxygen rich) environment pathogen destruction, disease suppression, generation of employment, and extension of landfill lifespan(Mohajer, 2008).

During decomposition, the microorganisms multiply and liberate carbon dioxide (CO₂), water, other organic products and energy. Some of the energy is used in metabolism and the remainder is given off as heat. Eventually, the readily-available food supply is exhausted, microbial growth and heat generation decrease, and a humus-like material remains. This material is called compost(Smith, 2009).

2.3 The role of microorganisms

Composting is a succession of microbial activities where by the environment created by one group of microorganisms invites the activity of successor groups. Different types of microorganisms are therefore active at different times in the composting pile. Bacteria have the most significant effect on the decomposition process, and are the first to take hold in the composting pile processing readily decomposable nutrients (primarily proteins, carbohydrate and sugars) faster than any other type of microorganism (Montej et al., 2015).

Fungi, which compete with bacteria for food, play an important role later in the process as the pile dries, since fungi can tolerate low moisture environments better than bacteria. Some types of fungi also have lower nitrogen requirements than bacteria and are therefore able to decompose cellulose materials, which bacteria cannot.

Microorganisms also play a role in composting process. Rotifers, nematodes, mites, springtails, sowbugs, beetles and earthworms reduce the size of composting feedstock by foraging, moving in the compost pile or chewing the composting materials. These actions physically breakdown the materials, creating greater surface area and sites for microbial action to occur (Jayasinghe et al., 2010).

The bacteria and fungi important in decomposing the feedstock material can be classified as mesophilic and thermophilic. Mesophilic microorganisms or mesophiles (those that grow best at temperatures between 25 and 45⁰ C (77 to 113⁰ F) are dominant throughout the composting mass in the initial phases of the process when temperatures are relatively low. These organisms use available oxygen to transform carbon from the composting feedstock to obtain energy, and, in so doing, produce carbon dioxide (CO₂) and water. Heat also is generated as the microorganisms metabolize the composting feedstock. As long as the compost pile is of sufficient size to insulate internal layers from ambient temperatures and no artificial aeration or turning occurs most of the heat generated by the microorganisms will be trapped inside the pile. In the insulated center layers, temperatures of the composting mass was eventually rises above the tolerance levels of the mesophilic organisms. When the temperatures reach toward 45⁰ C (113⁰ F), mesophiles die or become dormant, waiting for conditions to reverse.

At this time, thermophilic microorganisms or thermophiles (those that prefers temperatures between 45 and 70⁰C (113 and 158⁰ F) become active, consuming the materials readily available to them, multiplying rapidly, and replacing the mesophiles in most sections of the composting pile. Thermophiles generate even greater quantities of heat than mesophiles, and the temperatures reached during this time are hot enough to kill most pathogens and weed seeds. Many composting facilities maintain a temperature of 55⁰ C (131⁰ F) in the interior of the compost pile for 72 hours to ensure pathogen destruction and to render weeds in viable.

The thermophiles continue decomposing the feedstock materials as long as nutrient and energy sources are plentiful. As these sources become depleted, however, thermophiles die and the temperature of the pile drops. Mesophiles then dominate the decomposition process once again until all readily available energy sources are utilized (Montejo et al., 2015).

2.4 Composting methods

Composting can be carried out in a number of different ways, including static piles, passive aerated windrows, aerated static pile, in-vessel, pit, vermin composting and windrows systems (Sahu, 2016). Each method is summarized below for comparison.

2.4.1 Static Piles

This is the oldest and most common form of composting manure, yet it is also the least

effective. The static pile, as the name suggests, is simply a pile of raw materials, except none of the conditions affecting the composting process are actively controlled. This method works best when bedding, such as straw or sawdust and is used as a bulking ingredient, thus increasing the carbon to nitrogen (C:N) ratio of the manure and decreasing the moisture content. It is recommended that piles not exceed six feet high (1.86 m) and twelve feet wide (3.7 m), which allows air to move through the pile (Tognetti & Mazzarino, 2007). This method of composting is slow, increases the chance of odors, and usually yields an inferior product.

2.4.2 Aerated Static Pile

In this method, air is forced through the compost pile by a blower. These piles are five to eight feet high (1.6 to 2.5 m) and seventy to ninety feet long (21.7 to 27.9 m). With this technique the pile is not turned and is again formed over a bed of wood chips or chopped straw which contains the perforated aeration pipe. The pipe is connected to a blower that either pushes or pulls air through the pile. The pile need to be covered with fresh composted manure to maintain moisture, reduce heat loss, and to minimize flies and odors, while also filtering out some ammonia (Burg et al., 2011)

2.4.3 Windrow Composting

This is a relatively simple process that involves placing a mixture of manure and bulking materials into windrows or piles that are turned regularly. Windrow composting consists of placing the mixture of raw materials in long narrow piles called windrows that are agitated or turned on a regular basis (Walker, 1914). The turning operation mixes the composting materials and enhances passive aeration. Typically, the windrows are from 0.9 m high for dense materials such as manures to 3.60 m high for light, voluminous materials such as leaves (Lin, 2008).

Windrows aerate primarily by natural or passive air movement (convection and gaseous diffusion). The rate of air exchange depends on the porosity of the windrow. Therefore, the size of a windrow that can be aerated effectively is determined by its porosity. A windrow of leaves can be much larger than wet windrow containing manure. Where the windrow is too large, anaerobic zones occur near its center. These release odours when the windrow is turned.

On the other hand, small windrows lose heat quickly and may not achieve temperatures high enough to evaporate moisture and kill pathogens and weed seeds (Rynk & Colt, 1997). For small- to moderate-scale operations, turning can be accomplished with a front-end loader or a bucket loader on a tractor or manually using forks.

The frequency of turning depends on the rate of decomposition, the moisture content and porosity of the materials, and the desired composting time. Because the decomposition rate is greatest at the start of the process, the frequency of turning decreases as the windrow ages. Turning releases trapped gases, water vapor, and excessive heat that may exist in the compost mixture (Mohajer, 2008). With the windrow method, the active composting stage generally lasts three to nine weeks depending upon the nature of the materials and the frequency of turning.

2.4.4 In-Vessel system

These include bin composting, rectangular agitated bins, and silos. In-vessel composting system was first developed by Becari and modified by Verdier and Bordas, and latter several such systems have been developed (Mohammed et al., 2017). The main advantage of this system is process rapidity, low land requirement, complete process control and consistency of end-product. The main feature of in-vessel composting systems is that the compost materials are mixed and the mass advanced and aerated automatically and mechanically. In-vessel methods confine the compost mixture to buildings, containers or vessels, and tend to rely on numerous forced aeration and mechanical turning methods which accelerates the composting process (Singh & Sharma, 2002). In-vessel composting is both very sophisticated and expensive, and relatively uncommon despite its good results. They are costly to install and operate, and need intensive and skillful management.

2.4.5 Vermicomposting

The term vermicomposting means the use of earthworms for composting organic residues. Earthworms can consume practically all kinds of organic matter and they can eat their own body weight per day, e.g. 1 kg of worms can consume 1 kg of residues every day (Mohammed et al., 2017). The excreta (castings) of the worms are rich in nitrate, available forms of P, K, Ca and Mg. Common worm species for this type of composting are *Eisenia foetida* and *Lumbricus rubellus*. These are sometimes called "red wigglers" or manure worms. These worms are added to the feedstock materials to assist in the decomposition of the organic matter and transform it into worm castings.

2.4.6 The pit method

Composting can be carried out in a circular or rectangular pit. Crop residue, animal manure, aquatic weeds or green manure crops are used and often silt pumped from river beds is mixed with the crop residues. The pits are filled layer by layer, usually, the first layer is of a green manure crop or water hyacinth, the second layer is a straw mixture and the third layer is of animal dung (Lin, 2008). These layers are alternated until the pit is full, when a top layer of mud is added; a water layer of about 4 cm depth is maintained on the surface to create anaerobic conditions which help to reduce losses of nitrogen. Three turnings are required, the first after a month of piling, the second after another month and thirdly after two weeks of turning.

2.5 Factors affecting the composting process

The compost pile must be monitored and the appropriate adjustments must be made throughout the composting period. This is necessary to sustain a high rate of aerobic microbial activity for complete decomposition with a minimum of odors as well as maximum destruction of pathogens, larvae, and weed seeds. Microorganisms are essential to composting, so environmental conditions that maximize microbial activity was maximize the rate of composting. Microbial activity is influenced by oxygen level, particle size of the feedstock material, nutrient levels and balance (indicated by carbon-to-nitrogen ratio), moisture content, temperature and acidity and alkalinity (PH). These basic considerations apply no matter which technology is used. Any changes in these factors are interdependent; a change in one parameter can often result in changes in others (Suthar, 2007).

2.5.1 Particle size

The particle size of the feedstock affects the composting process. The size of feedstock materials entering the composting process can vary significantly. In general, the smaller the shreds of composting feedstock, the higher the composting rate. Smaller feedstock materials have greater surface areas in comparison to their volumes. This means that more of the particle surface is exposed to direct microbial action and decomposition in the initial stages of composting. Smaller particles within the composting pile also result in a more homogeneous mixture and improve insulation (Chang & Tsai, 2006). Increased insulation capacity helps maintain optimum temperatures in the composting pile. At the same time, however, the particles should not be so small as to compact too much, thus excluding oxygen from the void

spaces. Thus it is important to shred the feedstock materials before the beginning of composting to proper size to have a good porosity which allow ventilation and enhance microbial activity.

2.5.2 Temperature

Temperature is a critical factor in determining the rate of decomposition that takes place in a composting pile. composting temperatures largely depend on how the heat generated by the microorganisms is offset by the heat lost through controlled aeration, surface cooling, and moisture losses (Farrell & Jones, 2009). The most effective composting temperatures are between 45 and 59°C (113 and 138°F) (Richard, 1992a). If temperatures are less than 20°C (68°F), the microbes do not proliferate and decomposition slows. If temperatures are greater than 59°C (138°F), some microorganisms are inhibited or killed, and the reduced diversity of organisms results in lower rates of decomposition (Finstein et al.,1986; Strom,1985). Microorganisms tend to decompose materials most efficiently at the higher ends of their tolerated temperature ranges.The rate of microbial decomposition therefore increases as temperatures rise until an absolute upper limit is reached. As a result, the most effective compost managing plan is to maintain temperatures at the highest level possible without inhibiting the rate of microbial decomposition (Richard, 1992a; Rynk et al., 1992).

2.5.3 Oxygen

Composting can occur under aerobic or anaerobic conditions, but aerobic composting is much faster (10 to 20 times faster) than anaerobic composting (EPA, 1994). Anaerobic composting also tends to generate more odorous because gases such as hydrogen sulfide and amines are produced. Methane also is produced in the absence of oxygen. Microorganisms important to the composting process require oxygen to break down the organic compounds in the composting feedstock. Without sufficient oxygen, these microorganisms was diminish, and anaerobic microorganisms was take their place. To support aerobic microbial activity, void spaces must be present in the composting material. These voids need to be filled with air. Oxygen can be provided by mixing or turning the pile, or by using forced aeration systems. The amount of oxygen that needs to be supplied during composting depends on the stages of the process and the type, particle size and moisture content of the feedstock (Lorraine, 2003).

2.5.4 Nutrient levels and Balance (C:N ratio)

For composting to proceed efficiently, microorganisms require specific nutrients in an available form, adequate concentration, and proper ratio. The essential macronutrients needed by microorganisms in relatively large amounts include carbon (C), nitrogen (N), phosphorus (P), and potassium (K). Microorganisms require C as an energy source. They also need C and N to synthesize proteins, build cells, and reproduce. P and K are also essential for cell reproduction and metabolism. In a composting system, either C or N is usually the limiting factor for efficient decomposition (Richard, 1992a). Composting organisms also need micronutrients, or trace elements, in minute amounts to foster the proper assimilation of all nutrients. The primary micronutrients needed include boron, calcium, chloride, cobalt, copper, iron, magnesium, manganese, molybdenum, selenium, sodium, and zinc (Boyd, 1984). While these nutrients are essential to life, micronutrients present in greater than minute amounts can be toxic to composting microorganisms. Even if these nutrients are present in sufficient amounts, their chemical form might make them unavailable to some or all microorganisms. The ability to use the available organic compounds present depends on the microorganism's enzymatic machinery (Boyd, 1984). Some microorganisms cannot use certain forms of nutrients because they are unable to process them. Large molecules, especially those with different types of bonds, cannot be easily broken down by most microorganisms, and this slows the decomposition process significantly. As a result, some types of feedstock break down more slowly than others, regardless of composting conditions (Gray et al., 1971a). For example, lignin (found in wood) or chitin (present in shellfish exoskeletons) is very large, complex molecules and is not readily available to microorganisms as food. These materials therefore decompose slowly. The C:N ratio is a common indicator of the availability of compounds for microbial use. The measure is related to the proportion of carbon and nitrogen in the microorganisms themselves. High C:N ratios (i.e., high C and low N levels) inhibit the growth of microorganisms that degrade compost feedstock. Low C:N ratios (i.e., low C and high N levels) initially accelerate microbial growth and decomposition. With this acceleration, however, available oxygen is rapidly depleted and anaerobic, foul-smelling conditions result if the pile is not aerated properly. The excess N is released as ammonia gas. Extreme amounts of N in a composting mass can form enough ammonia to be toxic to the microbial population, further inhibiting the composting process (Tognetti & Mazzarino, 2007). Excess N can also be lost in leachate, in either nitrate, ammonia, or organic forms.

2.5.5 Moisture

The moisture content of a composting pile is interconnected with many other composting parameters, including moisture content of the feedstock, microbial activity within the pile, oxygen levels, and temperature. Microorganisms require moisture to assimilate nutrients, metabolize new cells, and reproduce. They also produce water as part of the decomposition process. If water is accumulated faster than it is eliminated via either aeration or evaporation (driven by high temperatures), then oxygen flow is impeded and anaerobic conditions result (Gray et al., 1971 b). This usually occurs at a moisture level of about 65 percent (Rynk et al., 1992). Water is the key ingredient that transports substances within the composting mass and makes the nutrients physically and chemically accessible to the microbes. If the moisture level drops below about 40 to 45 percent, the nutrients are no longer in an aqueous medium and easily available to the microorganisms. Their microbial activity decreases and the composting process slow. Below 20 percent moisture, very little microbial activity occurs (Haug, 1980). So, it is important to control the moisture content of the pile by adding water on the pile when it decreases and turning the pile when it increases, because microorganisms will thrive in an aqueous environment which will lead to a faster degradation.

2.5.6 Acidity/Alkalinity (pH)

The pH of a substance is a measure of its acidity or alkalinity (a function of the hydrogen ion concentration), described by a number ranging from 1 to 14. A pH of 7 indicates a neutral substance, whereas a substance with pH level below 7 is considered to be acidic, and a substance with a pH higher than 7 is alkaline. Bacteria prefer a pH between 6 and 7.5. Fungi thrive in a wider range of pH levels than bacteria, in general preferring a pH between 5.5 and 8 (Boyd, 1984). If the pH drops below 6, microorganisms, especially bacteria, die off and decomposition slows (Wiley, 1956). If the pH reaches 9, nitrogen is converted to ammonia and becomes unavailable to organisms (Rynk et al., 1992). This too slows the decomposition process.

Like temperature, pH levels tend to follow a successional pattern through the composting process. Most decomposition takes place between pH 5.5 and 9 (Rynk et al., 1992; Gray et al., 1971 b). During the start of the composting process, organic acids typically are formed and the composting materials usually become acidic with a pH of about 5. At this point, the acid-tolerating fungi play a significant role in decomposition. Microorganisms soon break down the

acids, however, and the pH levels gradually rise to a more neutral range, or even as high as 8.5. The role of bacteria in composting increases in predominance again as pH levels rise. If the pH does not rise, this could be an indication that the compost product is not fully matured or cured.

2.6 Quality of Compost

Various parameters, which may have a significant influence on compost quality, are discussed below.

2.6.1 pH

The pH value of compost is important, since applying compost to soil may alter the soil pH and therefore have an effect on the availability of nutrients to plants. As cited in (Bordna Mona 2003) recommends a range of pH from 6.9-8.3. Efforts was need to be made to lower the pH of compost if it exceeds this range. If it is so, adding additional organic matter or composted material was reduce the pH, in the meantime ammonia volatilization of ammonia and odour problems was reduced.

2.6.2 Organic Matter

Organic matter is an important ingredient in all soils and has an important role to play in maintaining soil structure, nutrient availability and water holding capacity. It is usually expressed as a percentage of dry weight. There is no absolute value of organic matter, which is ideal for compost. It may range from 30-70% (US Composting Council, 2003). I suggest that this figure is extremely important for the compost quality, in which I proved that compost having values between these range is problem free for plants, which enhance plant growth and development.

2.6.3 Moisture Content

Moisture content is a measure of the amount of moisture present in a compost sample and is expressed as a percentage of fresh weight. Compost with low moisture content (<35%) may be too dry and dusty and irritating when handled. Compost with too high a moisture content (>65%) can become too clumpy and difficult to transport which will limit its chances of being marketed as a quality product (US Composting Council, 2003).

2.6.4 Electrical Conductivity

Conductivity is the measure of a solutions ability to carry electrical charge, that is, a measure

of the soluble salt content of compost. The salt content of compost is due to the presence of sodium, chloride, potassium, nitrate, sulphate and ammonia salts (Brinton, 2003). Some soluble salts may be detrimental to plants whereas, other plant nutrients supplied to plants exist in salt form and are essential for plant growth. Though excessive amounts of soluble salts in compost used in growing media or applied to the land may inhibit crop growth and affect crop yield (Barker, 1997). Herity, (2003) report that the recommended range for conductivity in compost is between 2-6 mS/cm .

2.6.5 C:N Ratio

The C:N ratio is not a test within itself, it is rather a test for organically bound carbon and for total nitrogen. The ratio of these two can be used to provide an indication of the rate of decomposition of the feedstock and to determine when ripeness has been reached. Therefore, C:N ratios should be used in conjunction with some other relevant parameter for testing compost maturity (Wood End Research Laboratory, 1998). The EPA acknowledges this and specifies within a waste licence that the C:N ratio of compost must be below 25.

2.6.6 Nutrient Content of Compost

Nitrogen, phosphorous and potassium are the nutrients, which are utilised, in the greatest quantities by plants. Knowledge of the nutrient content of compost is important because the nutrient content of compost can vary widely and also because it allows facility operators to determine an appropriate end use for the compost. In general, nutrients are organically bound within compost and are slowly released over a period of time as a result of microbial activity. This ensures a continuous supply of nutrients to the plant (US Composting Council, 2003). Total nutrient content is usually expressed as a percentage on a dry weight basis.

2.6.6.1 Nitrogen

Nitrogen is an essential nutrient for successful plant production. The concentration and availability of nitrogen in compost is a very important factor to be assessed when considering its agronomic value. Körner and Stegmann (2003) state that certain parameters such as pH, temperature and moisture significantly influence the rate of nitrogen turnover from proteins in bio-waste to inorganic and organic forms. They found that the highest concentration of ammonia could be measured during the thermophilic stage while mature compost contains more nitrogen in the inorganic form as $\text{NO}_3\text{-N}$. Hence, by regulating the

composting process, compost with a more predictable nitrate content can be produced. To report compost as having fertilising capabilities and for it to be used in agriculture the TN content must be over 1%, dry weight (Barker, 1997). If compost contains TN of less than 1%, supplemental nitrogen fertiliser was required if the compost is to be used as a soil improver or in potting media. If the TN in compost is approximately 0.6% or less there is a chance that nitrogen immobilisation was occur. Thus, compost with low TN levels is better used as mulch (Mohammed et al., 2017). The typical range of TN in compost is 1.0-3.0%, dry wt. Compost over 3% TN is usually found to be immature and ammoniacal (Barker, 1997).

2.6.6.2 Phosphorous

Phosphorous is also an important nutrient for plant growth. Phosphorus is essential for cell reproduction and metabolism. Total phosphorous (TP) is usually expressed in terms of percentage concentration per dry weight. According to (Bordna Mona 2003) the range of TP is usually between 0.4 - 1.1%, dry wt for bio-waste and green waste compost.

2.6.6.3 Potassium

Potassium is a very abundant nutrient in plants. Potassium in its available form in compost exists as K_2O . The amount of potassium in compost depends on the feedstock but also on the composting process (Barker, 1997). Compost usually does not contain a great concentration of potassium because due to its high water solubility it can be easily leached from the feedstock during the composting process. state that as cited in (Tognetti & Mazzarino, 2007). the typical range of total potassium (TK) in bio-waste and green waste compost is between 0.6-1.7%, dry weight.

2.6.7 Maturity and Stability

Compost stability/maturity is increasingly recognised as an important characteristic. In specific situations, immature, poorly stabilised composts may be problematic. Continued active decomposition when these composts are added to soil or growth media may have negative impacts on plant growth due to reduced oxygen in the soil-root zone, reduced available nitrogen, or the presence of phytotoxic compounds. Consequently, tests have been developed to evaluate the maturity of compost materials.

Compost maturity and stability are often used interchangeably. However, they each refer to specific properties of these materials. Stability refers to a specific stage or decomposition or

state of organic matter during composting, which is related to the type of organic compounds remaining and the resultant biological activity in the material. The stability of given compost is important in determining the potential impact of the material on nitrogen availability in soil or growth media and maintaining consistent volume and porosity in container growth media. Most uses of compost require a stable to very stable product that was prevent nutrient tie up and maintain or enhance oxygen availability in soil or growth media.

Maturity is the degree or level of completeness of composting. Maturity is not described by a single property and therefore maturity is best assessed by measuring two or more parameters of compost. Maturity is in part, affected by the relative stability of the material but also describes the impact of other compost chemical properties on plant development. Some immature compost may contain high amounts of free ammonia, certain organic acids or other water soluble compounds which can limit seed germination and root development. All uses of compost require a mature product free of these potentially phytotoxic components (LIFE 05 TCY/MA/000141, 2008). According to Zucconiet al. (1981) the GI, which combines the measure of relative seed germination and relative root elongation of radish seed (*Lepidium sativum L*) is an integrated biological indicator, which is regarded as the most sensitive parameter used to evaluate the toxicity and degree of maturity of compost. Herity (2003) recommended the germination of cress seeds in compost must be >90% of the germination rate of the control sample.

Table1. Plant Phytotoxicity tests

	Units Rating		
Test methods	Very mature	Mature	Immature
Seed germination % of control	>90	80-90	<80

Source: California environmental protection Agency (2002) and Brinton (2000)

2.6.8 Heavy Metals

Compost can contain high concentrations of heavy metals, and potentially toxic elements (PTEs) depending on the sources of the raw materials. For instance, if sludge from a mixed

industrial-domestic source is used in the compost, concentrations of lead, zinc, and nickel may be very high (Chi, 2005). Hence limits for organic compost derived from municipal waste have been established in many countries. Fig. 3 shows the maximum permissible concentration of six heavy metals of concern: lead (Pb), copper (Cu), cadmium (Cd), zinc (Zn), Mercury (Hg), Chromium (Cr) and Nickel (Ni).

Table 2. Standards on Heavy Metals in Some Countries

Heavy metals	Unit (ppm)	USA	Canada	Australia	Spain	Italy	Germany
Pb		300	150	500	1200	140	75
Cu		1500	100	400	1750	300	50
Cd		39	3	4	40	1.5	0.75
Zn		2800	500	1000	4000	500	200
Hg		17	0.8	4	25	1.5	0.5
Ni		420	62	100	400	50	30
Cr		1200	210	150	750	100	75

Source: Brinton et al. (2002); Brinton (2000)

2.7. Environmental benefits of Composting

The most considerable environmental benefit of composting is that the amount of waste going to landfill is reduced, since landfills cause serious environmental impacts. Water forms leachate when percolating through the waste and becomes contaminated by substances originating in the waste. This leachate contains oxygen depleting substances, toxic organic substances and metals, and can pollute ground and surface water. Lining and covering the landfill can in a short perspective prevent this, but in the long run some leakage is inevitable (Strömberg, 1995). Another environmental impact is gas emissions. When water enters the landfill, biological activity starts and landfill gas is formed, including hydrogen sulphide and methane, which is an aggressive greenhouse gas (The Swedish Environmental Protection Agency, 1993).

Composting biologically degradable waste not only reduces the amount of waste put on landfill, but can also reduce the environmental impact of the remaining waste at the landfill, since putting less organic matter in the landfill will reduce methane production (The Swedish Environmental Protection Agency, 1993). There are also suggestions that less organic material in the landfill will reduce the negative environmental impact of leachate (Laine-Ylijoki et al., 2005). A fire on landfills is another factor with large environmental impact. With less organic waste going to landfill, the risk of fire can be reduced.

Compost has the potential of being organic fertilizer and can thus be environmentally beneficial by substituting artificial fertilizers (Montemurro et al., 2005). On the agricultural front, a lot of concerns have been raised about the effect of chemical fertilizers on human health and the environment coupled with its high price, pollution of water bodies, and its residual effect on crops and on non-target microorganisms in the soil (Samuel.K 2011). To what degree the compost will enhance the nutrient status of the soil depends on both the waste that the compost is made from and the treatment technology (Gutser et al., 2005). Even if the compost is low in nutrients it can be valuable since application of compost, or any other form of humic material, effectively enhances soil structure, improves the water holding capacity and reduces the sensitivity to erosion (Manser & Keeling, 1996). Several tests also show that application of compost represses plant diseases in the field (Ros et al., 2005). Composting thus reduces the risks of environmental degradation, but can also have other positive side effects, including economizing with limited natural resources. Composting is therefore an interesting option for municipalities developing their waste management by minimising and recycling waste that today ends up on landfill (Lotten and Kristina, 2007).

2.8. Composting practice in Ethiopia: Trend, challenges and opportunities

Ethiopia is one of the least developed countries in the world and its economy is based mainly on agriculture (Bekalo and Bangay, 2001). The country currently faces a number of environmental challenges resulting directly or indirectly from human activities due to agricultural practices, rapid population growth and the consequent increase in the exploitation of natural resources (Devi et al., 2007). The challenges range from land degradation to environmental pollution. So, environmentally sound farming system is the vision for the society to cope up the problems of chemical based farming system (UNEDP, 1995).

Pit Composting of the farm waste and its immediate vicinity, together with domestic animal dropping is being introduced as a new technology in Tigray, Northern Ethiopia by ISD and EPA, which aimed at stimulating local communities to intensify production and the results were remarkable. In the local community, while comparing the impacts of different inputs, Composting increases yield two to three times, comparing favorably with no Fertilizers input, and in the case of some crops , use of compost out-performs chemical fertilizers (ISIS, 2002). This result is comparable with the ILRI study in the highland of Tigray, in which the use of compost increases crop productivity by 16% (Berhanu et al., 2001).

What the farmers now realize is that the effect of chemical fertilizers disappears often even before one season is out, while the effect of compost is cumulative over several consecutive years. Their experience in all four communities at the farm and its immediate vicinity, together with domestic animal dropping give enough compost for intensifying food production without incurring any debt" (ISIS, 2002).

On top of that, their finding (ISD) indicates that using compost has made difference especially during drought period as the organic matter in the compost improve the water holding capacity of the soil. In the Kindo Kosha, south of the country, women collect household refuse, cow dung, and chopped enset leaves for making compost, while men collect leaf litter and grass. Both men and women are responsible for taking the compost to the fields (Bierwirth et al., 2001).

But there are challenges from the economic perspective; the economic failure is the inability to obtain an income from the sale of compost product or even to give the product away at zero cost. The perceived value of the end product depends up on many factors including; its quality in comparison with competing products, proximity to end users and of course the cost. The perceived value of the waste -derived compost is low.

2.9. Comparison of Environmental and Economic benefits of compost and chemical fertilizer

2.9.1 Environmental performance and economic benefit of compost

The emission of landfill gases (LGs) produced by the anaerobic and aerobic Decomposition of organic matter is a major source of Greenhouse gases (GHG) which are responsible for global warming and ozone depletion. Composting is one of the simplest ways to prevent emissions of

methane because the organic fraction of the waste stream is diverted from landfill. While composting does release carbon dioxide, it is currently considered to be a neutral process since the removal of carbon dioxide from the atmosphere by photosynthesis to produce organic matter is also not considered (Hoornweg et al.,2000).

Composting rarely generates profits on its own. However, when viewed as a component of an integrated solid waste management program, composting can provide economic benefits on a much larger scale. The costs of composting includes raw materials, production, marketing, and hidden environmental costs; whereas the benefits involve the market value of the compost, savings from avoided waste disposal costs, as well as various positive environmental impacts. When considering the large quantities of organic matter generated in developing countries, governments can save money by reducing the amount of waste requiring collection, transport, and disposal. The extent of these savings are dependent on how the waste management system incorporates composting initiatives, including the elimination of temporary dumping sites, rerouting of collection vehicles, and the redirection of labor (Economist, 1998).

2.9.2 Environmental performance and Economic benefits of chemical fertilizers

Emissions during production of urea: considerable amount of CO₂ is emitted during the production of urea and much of the CO₂ emission is associated with ammonia synthesis, modern urea factories emit 3.1kg CO₂-eq/kg-11-1N (Wood and Cowie,2004).

Emissions during transportation: the emission due to transportation does not directly related to urea synthesis but other factors such as truck or ship used for transportation and amount of fuel consumed per km during transportation of the product, European average 0.1 kg CO₂-eq kg-1N (www.yara.com, 2010).

Emissions during application:due to application of urea fertilizer nitrogen is emitted as N₂O-N which is deemed as highly effective greenhouse gas with a global warming potential of 310 times stronger than CO₂ (IPCC, 1996). The default emissions factor for direct N₂O emission (N₂O-N) is 1% of the applied nitrogen, plus another 0.325% due to indirect emission, occurring elsewhere from nitrogen that has been leached or emitted, thus 0.01325 kg of applied nitrogen is emitted as N₂O-N (Edi et al., 2003). This is equivalent to 6.45 kg CO₂-eq kg-1N with the conversion factor of N₂O-N to N₂O, 44/28 (IPCC, 1996) The production of fertilisers

demands much energy and generates considerable greenhouse gas (GHG) emissions. Kongshaug (1998) estimates that fertilizer production consumes approximately 1.2% of the world's energy and is responsible for approximately 1.2% of the total GHG emissions. All the above factors indicates that there is an advantage in using compost as fertilizer than using chemical fertilizer both in terms of economic and environment aspects, which is very useful strategy for the current development program of the country.

Chapter Three

3. Materials and Method.

3.1. Description of the experimental site

The composting trials were conducted at Aware TVET in Kebena woreda 7 Arada Sub-city, of Addis Ababa. The area is located 3Km away from the center of Addis Ababa and the total land coverage of the site is about 1000 meter square.

3.2. Experimental design

3.2.1. Treatments design

This experimental study was conducted in four treatments and bins composting was conducted at a temperature of 22.8°C from February to may,2010 E.C. Four different treatments each having three replicates in Randomized complete block design with the total of 12 bins were prepared with different composition of vegetable waste, poultry manure, and sawdust waste. Treatments are assigned at random to the subjects in the blocks.

Table 3 Treatments design

Block 1	T1	T2	T	T	T	T4
Block 2	T2	T3	T	T	T	T3
			4	3	4	

T1-Vegetable waste with Poultry manure

T2-Vegetable waste with sawdust

T3-sawdust with Poultry manure

T4-Vegetable waste, Poultry manure with sawdust

Figure 1: Wooden Bin composting

The composts base area was 3m² and 1m long (2m³ in volume).



Different composts were prepared by mixing VW with poultry manure and with sawdust wastes in proportions of 2:1 (on fresh weight basis) taking into account their C to N ratios. The principle of ‘‘2 parts Green (Nitrogen rich matter) to 1 part Brown (carbon rich matter) in volume’’ is used to get the correct proportion (Maurice, 2003).

Table 4 Composition of different mixtures

Components	T1	T2	T3	T4
Vegetable waste kg	4	8		4
Poultry manure kg	8		8	4
Sawdust kg		4	4	4

3.2.2. Experimental material sources and collection

Vegetable leftovers were segregated, collected and brought from restaurant around kebona where daily raw wastes were collected and ready for disposal at the composting site these wastes were properly mixed using pitchforks and spade before using as raw material. During homogenization non-compostable materials mainly plastic bags, glasses and cans were screened from the wastes. Sawdusts and dry Poultry manure were collected from the Aware TVET and poultry production enterprise around kebona respectively.

3.2.3 Turning and monitoring

Since the composting process is aerobic, the bin was turned once in every week for the first 2 week and once in every 2 week for the following weeks to provide air to the bin (TMECC, 2000). This was conducted manually with the aid of shovels and spade. The turning of the bin in some cases was done particularly when the bin temperature drops below 25°C during its first week and in some case when the weather was rainy. The compost Bin was turned and watered twice per week uniformly for all the treatments for the first two months and once per week later on. The Bin was turned on less windy relatively calm weather, damp days to reduce the dissipation of process odors (Edwards, 2003;Bidlemaier, 1996).

Temperature monitoring was conducted daily for the first two weeks and measured in a three days interval during the next period using thermometer positioned at three points of each bins (15 cm gap in each position) and taken the highest value. A digital thermometer was inserted in the bin up to 15cm using a stick and leaving the thermometer there for one minute and then the temperature was recorded. shovels and spade the turning of the bin in some cases was done particularly when the bin temperature drops below 25°C during its first week and in some case when the weather was rainy. Temperature monitoring was conducted daily for the first two weeks and measured in a three days interval during the next period using thermometer positioned at three points of each bins (15 cm gap in each position) and taken the highest value. A digital thermometer was inserted in the bin up to 15cm using a stick and leaving the thermometer there for one minute and then the temperature was recorded.

3.5. Methods and Procedures of Physicochemical Analysis

The following physicochemical properties power of hydrogen (pH), Electrical Conductivity (EC), Total potassium (TK), Total phosphorus (TP), percentage of moisture content (MC), dry matter (DM), organic matter (OM), total carbon (TC), total nitrogen (TN) and carbon to nitrogen (C:N) ratio were analyzed and calculated for the raw feedstock, processing composts after 14 days and matured compost after 90 days for all composting bins, and the results were reported in mean.

Composite samples from each treatment were blended and split in two components in the laboratory. One portion of the sample (fresh compost) was segregated to remove the course material and analysed for pH, EC and Moisture content. The other portion of the sample was dried in a forced air oven set at 105 °C for 24 hours until a constant weight was obtained. The sample was then grounded to obtain particle size of less than 2 mm and analysed for heavy metals, plant nutrients, total volatile solids, organic carbon and Germination index using standard laboratory techniques (Downie, 2007).

The ash content was determined by muffle furnace at 550°C for 6hr approximately 5 g of oven dried compost. After cooling in the dissector remaining solids (ash) was weighed (Rehrah *et al.*, 2017).

$$Ash(\%) = \frac{RS(g) * 100}{OC(g)}$$

RS = mass of remaining solid (ash), O =mass of ordinal carbon (compost)

3.5.1 Procedure for measuring temperature

Temperature was measured using volume expansion thermometer until the composting process has been complete at compost bin. The thermometer probe was inserted to 15 cm depth inside the compost at three points and the average was reported as data of the temperature of that day for compost process.

Temperature was measured using digital thermometer daily for the first 90 days on the site. The frequency of measuring the temperature of the bin reduced then after within a range of 5 to 8 days at the final stage while the composting process progressed and the data were recoded. During measurement the thermometer probe was inserted 15cm depth inside the bin at three points and the average of three readings was recorded.

3.5.2 Moisture content

To determine moisture content of the compost the wet compost sample was weighted as total wet weight, and then it was place in an oven at 105⁰ c for 24 hours. The dried sample was reweighted to calculate the moisture content in percentage (cooperband, 2002).

$$\text{Moisture content (\%)} = \frac{\text{wet mass} - \text{dry mass}}{\text{Wet mass}} \times 100$$

Squeezing was a sample technique to test moisture content of compost at composting bin. When the compost has been squeezed and if the compost does not release water but crumbles apart when released it was too dry and required addition of water. Compost from all treatments was examined for moisture content in every 1-2 weeks throughout the experimental study. Samples of (20gm) fresh compost were weighted using digital balance (SCALTEC, SBA 32) and placed in a forced-air oven (TRITEC, HANNOVER) at 105⁰ C for 24 hours. Oven dried samples were cooled in a desiccators for 1hr. and reweighed. The percentage moisture content was calculated from the equation

(TMECC, 2000; Epstein,1997. Rynk *et al.*, 1992):

$$\text{MC(\%wb)} = \frac{\text{Wetmass} - \text{drymass}}{\text{Wetmass}} \times 100$$

Residue remaining after water is removed from waste material by evaporation was determined by drying at 105 °C for 24h in an oven and expressed as:

DM (%) = (Oven dry sample weight / wet sample weight) x100 (Method 03.09, TMECC, 2000; Rynk *et al*, 1992).

3.5.3. pH and Electrical conductivity

The pH of the compost was measured after dissolving the compost using distilled water. A Portable pH meter was used to measure pH of the compost extract every 2 weeks until composting process was complete. The constituent in the ratio of compost to water is not universally accepted. A solution of 5g of compost in 25ml water was prepared by shaking for 10 seconds and allowing stand for measurement (Rehrah *et al.*, 2016).

The pH of compost samples collected in every 1-2 week of composting and EC of the compost sample collected after experimental period of 90 days was determined using conductivity meter (HANNA Instruments). A water extract of 1:5 (wet mass basis) was made by mixing fresh compost of 5gm to 25ml of de-ionized water in a 250ml flask. The flask was capped and shaken mechanically at 180 rev/min for 20min. using mechanical shaker, filtered to determine pH using Portable pH-meter and Electrical conductivity using a conductivity-meter (HANNA Instruments). Variations in composting temperature was measured using the digital thermometer. For the determination of EC values of the compost samples, the compost samples was diluted with H₂O using a mass ratio of 5:1 (water: dry compost) and shaken mechanically for 20 minutes, measure EC in slurry orextract. For the determination of heavy metals the AAS (Atomic Absorption Spectro photometry)Buck scientific model 210 VGP flame atomicabsorption spectrometer wereused. The Total N, Total P, Exchangeable K and organicmatter, of the compost samples was determined using the Kjelttec System, Sodium Hydroxide fusionmethod, Ammonium Acetate Extraction Method and Walkley and Black method, respectively.

Olsen extractable phosphorus (P) was determined using Olsen P method (Olsen etal.,1954). Then, extracted P was filtered through Whatman filter paper 42 and P concentration was measured by addition of ammonium molybdate-ascorbic acid (mixed color developing reagents) using a spectrophotometer optimization with the wavelength 882 nm.

The Walkley and Black,(1934) an examination method determining OC content by proposed modification chromic acid titration method treating of compost sample with K₂Cr₂O₇ and H₂SO₄. Finally Orthophosphoric acid (H₃ PO₄) and diphenylamine was used as indicator just before titration ,then it was back titrated against standardized Ferrous sulphate solution

($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$), till to give sharper end point of green including to the blank the OC content. The percent OM was obtained by multiplying percent soil OC by factor of 1.724.

Total nitrogen (TN) was analyzed using the Kjeldahl method by oxidizing the organic matter in the presence of catalyst mixture of selenium powdered treated with conc. H_2SO_4 was to digest quantitatively to the macro-Kjeldahl.

CEC were determined by flame atomic absorption spectrometer with the method of ammonium acetate extract method that the sample was mixed with sodium acetate at 150 rpm on a mechanical shaker for 5min, sequentially with sodium acetate followed isopropanol then ammonium acetate to displace adsorbed sodium ions.

The Ca^{2+} and Mg^{2+} were determined by atomic absorption spectrometer method of EDTA titration with ammonium acetate extract.

The flame photometry was used to Na^+ and K^+ in ammonium acetate extract method after leaching each sample with ammonium acetate (Mitchell *et al.*, 2013).

3.5.4 Phytotoxicity Test and Rate of Germination

A seed germination assay was carried out by spreading 8 seeds were placed over surface of Petridis by Triplicate petrish dishes were filled with 30 g of soil as control and 0.2g compost was added onto the top of the seeds by covering with whatman filter paper 42 incubated for 3 day and deionized water was added every 24 h under darkness in the laboratory then number of germinated seed was counted (Sun *et al.*, 2014)

Table 5: some common feedstock's and their characteristics (adopted from Cooperband, 2002)

Feed stock materials	Moisture content	C:N ratio	Bulk density
High Carbon			
-sawdust	20-60	200-700	350-450
-news paper	3-8	400-800	200-250
-straw	5-20	40-150	50-400
High in Nitrogen			
-Dairy manure	80	5-25	1400
-poultry manure	20-40	5-15	1500
-vegetable wastes	-	10-20	-

3.9. Research methods.

3.9.1. Sampling of raw waste

Composite samples were taken from incoming material after thoroughly mixing, chopping and splitting of as many sub-samples as possible from different locations of waste receiving area, then placing approximately 150g of sample size in plastic bags to maintain the moisture content, pH of the samples using shovels and spade for various analysis.

3.9.2. Sampling of compost

Sub-samples from the compost bin were taken from three different depths from the uppermost surface. To obtain a representative sample, three point samples from each of the three depths (top, middle, and bottom) were placed on a plate and completely mixed and then the composite samples were quartered and mixed two times and finally a 12 representative sample of approximately 300g was placed in a small labeled plastic bag from each bin.

3.11. Data Analysis .

The data was analyzed with one-way analysis of variance (ANOVA) using SPSS version 22.0 software to detect whether there was significance effect on compost .In all the analyses, confidence level was held at 95% using Turkey HSD post Hoc multiple comparisons at the $p < 0.05$ significant levels in SPSS. In addition, the composition of parent material (VwPm, VwSd, PmSd and VwPmSd) were fixed as the between-subject factor, and the composting time was fixed as the within-subject factor variation between the mean levels of different compost samples was be tested and Mean \pm standard deviation was determined .

Chapter Four

4. RESULTS AND DISCUSSION

Composting of vegetable wastes with poultry manure and sawdust waste was conducted for a total of 90 days, from February 06,2010- may 06, 2010 E.C. Characterization of raw material was the first task to be conducted for adjustment of parameters that have a big impact on the composting process. Moreover; characterization of processing compost and matured compost for various parameters was conducted to have the knowledge about the ongoing process and to compare the results obtained with other research work and with that of the standards of different.

4.1 Physico-chemical characteric of feedstock

The Raw waste waste used for this study as shown in Fig. 2, was dominated by the organic component consisting of mainly cabbage, potato, onions, sawdust, poultry manure remains and certain amount of vegetable refuse.

Figure.2. organic component



Table 6. Physico-chemical characteristic of raw feedstock

Treatment	Day	Moisture content(%)	Volatile solid(%)	pH	C	Total N(%)	C:N
vegetable	0	78	85.4	5.53	47.4	1.3	36.5:1
poultry manure	0	60	58.8	7.713333333	32.7	2.8	11.7:1
sawdust	0	45	92.2	5.863333333	51.2	1.03	49.7:1

Table 6 indicated that the compost feedstock contains 5.53 pH of vegetable waste lies in the acidic range, which is not suitable for effective composting unless some adjustment was made to increase the pH because for effective composting of green wastes the pH should be in the range of 5.5 to 7.7. Where as the amendments (poultry manure) used are in the alkaline range (7.713333). The results indicated that the compost feedstock is good compost material (Motsara and Roy,2009).

4.2 Physico-chemical characteristic of compost

During composting process the compost parameters like temperature, moisture content, pH, conductivity, carbon to nitrogen ratio and nutrients were determined to monitor the process. The results against sampling days were presented in table 7 as shown below.

Table 7. Physico-chemical characteristic of compost

	Day	T1	T2	T3	T4
Moisture content(%)	0	74.50	76.23	76.67	73.87
	14	57.72	67.37	68.55	69.52
	28	53.42	66.55	67.60	68.45
	42	50.82	63.65	65.55	67.30
	54	49.40	62.08	65.13	65.03
	70	54.07	58.98	62.08	62.29
	90	52.62	58.49	65.10	62.36

	Day	T1	T2	T3	T4
Dry matter(%)	0	30.45	26.88	23.08	26.08
	14	46.00	34.92	31.67	30.67
	28	46.58	33.45	32.40	31.55
	42	49.18	36.35	34.45	32.70
	54	50.60	37.92	34.87	34.97
	70	45.93	38.02	37.58	32.98
	90	50.90	39.50	34.89	37.63

	Day	T1	T2	T3	T4
Volatile solid(%)	0	70.00	84.00	78.00	88.00
	14	57.33	78.67	70.00	84.00
	28	52.73	76.27	66.00	81.07
	42	51.60	69.40	60.20	78.00
	54	53.80	62.40	57.00	61.20
	70	41.80	57.00	54.20	68.80
	90	36.00	49.00	47.00	59.00

	Day	T1	T2	T3	T4
Ash content %	0	37.00	49.00	41.00	48.00
	14	31.00	43.89	38.89	46.67
	28	29.30	42.37	35.99	45.03
	42	28.67	38.56	33.44	43.33
	54	24.74	30.62	33.18	33.55
	70	23.22	31.67	30.11	38.22
	90	20.00	27.22	26.11	32.78

Day	T1	T2	T3	T4
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pH	0	7.41	5.10	7.74	7.46
	14	9.14	8.55	8.72	8.54
	28	9.10	8.63	8.66	8.56
	42	9.22	8.89	8.71	8.72
	54	8.75	8.54	8.46	8.52
	70	8.26	8.38	8.30	8.43
	90	8.05	7.36	7.59	7.59

	Day	T1	T2	T3	T4
EC (dS/cm)	0	6.27	1.69	5.00	4.33
	14	4.26	0.72	2.47	0.95
	28	4.29	0.50	1.85	0.90
	42	2.45	0.31	1.55	0.74
	54	2.89	0.36	1.67	0.66
	70	3.78	0.46	1.76	0.59
	90	3.23	0.96	1.83	1.28

	Day	T1	T2	T3	T4
Total N(PPM)	0	1.12	1.87	1.35	1.60
	42	1.27	1.04	1.35	1.25
	54	1.25	1.05	1.20	1.10
	90	1.10	1.35	1.37	1.55
	Day	T1	T2	T3	T4

O.C	0	20.92	20.76	15.58	17.46
	42	13.27	10.41	14.91	13.35
	54	14.07	9.85	11.35	10.01
	90	11.86	15.30	14.70	17.05

	Day	T1	T2	T3	T4
O.M %	0	28.83	35.80	26.85	30.10
	42	22.87	17.95	25.71	23.01
	54	24.26	16.99	19.57	17.26
	90	20.45	26.38	25.35	29.40

	Day	T1	T2	T3	T4
Av.P %	0	0.32	0.232	0.38	0.34
	90	0.8	0.23	0.3	0.4
Av.K %	90	8678.74	2897.46	5847.90	3866.45
Na (Cmol(t)Kg-1	90	42.88	4.75	16.23	10.25
K %	90	0.98	0.1	0.17	0.11
Ca (ppm)	90	44.02	35.90	46.54	44.09
Mg (ppm)	90	19.31	6.95	17.19	13.69

Heavy metal mg/Kg(ppm)

	Day	T1	T2	T3	T4
Hg	90	38	20	33	27
Cr	90	38	17	31	22
Cd	90	12	13	12	12
Sn	90	216	95	165	124
As	90	103	33	78	51
Ni	90	76	64	54	54
Pb	90	168	369	207	197

macronutrient and micronutrients mg/kg(ppm)

P	90	6,381.56	530.36	4,518.95	2,829.16
K	90	9,979.08	2,537.69	5,364.68	3,372.09
Ca	90	17,398.70	6,601.93	15,275.20	11,302.10
Mg	90	4,073.77	716.60	3,064.22	1,945.93
S	90	1,177.02	161.42	407.56	242.31
Fe %	90	133.07	124.46	116.57	102.61
Mn	90	231.35	265.76	240.96	222.11
Zn	90	173.05	83.25	159.74	127.50
B	90	11.93	2.34	6.77	4.25
Cu	90	10.59	1.93	6.86	5.45
Mo	90	0.23	0.11	0.12	0.10
Na	90	1,870.86	170.30	845.04	416.62
Si	90	186.71	400.73	179.97	249.73

4.2.1 Temperature

The temperature profile as compared to the ambient air temperature of the treatments containing the different mixtures during composting is shown in Table 8 and Fig.3

The temperature of the compost bin was low at the beginning of the process for the first two weeks. In these days the microorganisms may not be enough to decompose the organic materials which release heat as product to raise compost bin temperature.

Table 8. Recorded ambient and mean temperature of the bins (° C)

Day	Treatments Temperature(°C)					
	Ambient tempreture(OC	T1	T2	T3	T4	
1	24	15.33333333	15.66666667	15.33333333	14.66666667	
2	23	15.66666667	16.66666667	16.33333333	15.66666667	
3	24	16.33333333	17	16.66666667	16.33333333	
4	25	17	17.33333333	17.33333333	17.33333333	
5	24	17.66666667	18	17.66666667	18	
6	23	20	18	18	22	
7	21	21	19	19	22	
8	21	22	21	22	23	
9	22	25	26	28	28	
10	20	28.16666667	28	28.66666667	28	
11	22	29	29.33333333	30	29	
12	21	30.33333333	30	33	31	
13	21	35	35	34	34	
14	22	36.33333333	36	34	35	
18	22	40	42	40	40	
21	23	44	46	45	44	
24	25	45	48	45	49.33333333	
27	23	50	55.66666667	49.33333333	49	
30	23	51	52	50	50	
33	21	49	47	45	46	
36	22	45.33333333	45	46	45	
39	22	43	42	42.33333333	42	
42	23	37	36	35	38	
45	25	34	36	34.33333333	36	
48	24	31	32	32.33333333	33.66666667	
51	23	29	28	29	30	

55	26	27	26	27	28
58	25	24	24	25	26
61	26	23	22	23	24
64	25	21	23	22	23
67	24	20	23	23	22
70	22	20	20	19	20
73	21	19.33333333	22	20	20
76	23	20	23	21	19
79	21	20	21	20	19
82	22	19	20	19	19
85	22	19	20	20	18
88	21	19.33333333	19	20	19
90	22	20	20	19	19

As shown in Fig. 3, the temperature of the composting mass increases rapidly during the third weeks, remaining at the thermophilic range for 3 to 5 weeks and then decreases gradually to a constant temperature. These temperature variation patterns were similar to the findings of (Montejo et al., 2015). and typical for green waste composting. For all compost mixtures, thermophilic temperatures (above 40 °C) were reached after 18 days of bins, and lasted for about 21 days in compost mixtures in compost mixtures T1 (Vegetable waste with Poultry manure), T2 (Vegetable waste with sawdust), T3 (sawdust with Poultry manure) and T4 (Vegetable waste, Poultry manure with sawdust). During which period temperature as high as 51°C and 55.66°C were recorded in T1 and T2 respectively, whereas the T3 and T4 reached maximum Temperature of 50°C. The periodical short-term drop in temperature observed such as in day 42 and so on, in all compost mixtures was caused an indicator of the organic matter in compost bin has been decreased by the activity of microorganism and conversion in to nutrient rich product called compost (Rynk et al, 2003).

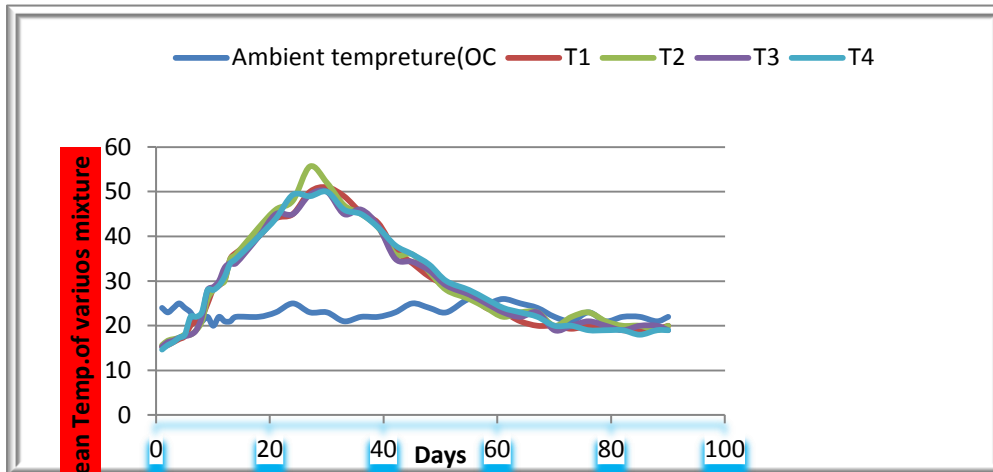


Fig. 3. Change in Ambient Temperature and mean temperature of various mixtures

4.2.2 Moisture content

The moisture content of composting process was monitored during turning of compost materials and recorded in 14th day interval. The mean percentage moisture contents of treatment bins were graphically shown by Fig 4. here below. As shown in the Fig.4 the moisture content of compost materials declined continuously in all four treatments during the composting process. Similar trend in variation of moisture content was reported by (Kulch and Yaldiz 2005) in composting of chicken manure and vineyard wastes.

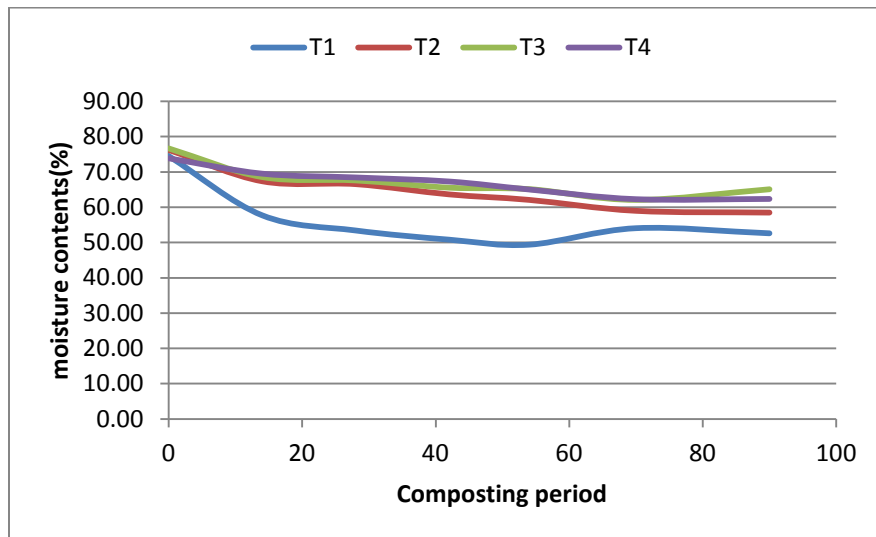


Fig .4. Mean moisture content of bins during composting

The initial moisture content of the waste mixtures varied between 74 % and 77% (wet basis). T3 contained the highest 77% moisture at the beginning of the process where as T4 contained the lowest T4 contained the highest moisture at the beginning of the process, whereas T2 contained 74% and at the end of the experimental period the moisture content was declined from 75% to 53%, from 76% to 58%, from 77% to 65%,from 74% to 62% for T1,T2,T3 and T4respectively.Thisindicatedthatthe

Reduction in moisture content is lowest in T3 and highest in T4. From figure 4, it was also seen that throughout the composting period the moisture content of T3 and T4 was higher than the moisture content of T1 and T2. Even though the highest moisture content reduction was and observed in T4 during First and second week of the composting (during the active composting phase) the reduction in moisture content was highest in T1 (from 75% to 58%), and lowest in T4 (from 74% to 69%). This might be due to the evaporation of water as a consequence of microbial heat generation when they utilize the organic waste (Kulcu and Yaldiz, 2005). This suggests that composting under the conditions of T1 after increasing the ratio of Vegetable wastes to poultry manure helped to absorb the high moisture and effectively created porosity for aerobic composting that has a strong effect on the rapid microbial heat generation and composting performance (Jolanunet *al.*, 2005).

It is supported by Epstein (1997) that microbial composting cannot proceed with more than 70% moisture because the compost can go anaerobically and create odour problems. Villini *et al.* (1993) also conclude that composting of green wastes at high moisture content (80%) can release larger amount of leachate as a result causing the mixture to compact and eventually leads to system failure. The highest moisture content reduction observed in the T3 specially starting from day 70 might be due to the material properties (such as low level of DM) as the various materials to be composted may differ widely in their water holding capacity (Gray *et al.*, 1971).

4.2.3. pH

The pH value indicates the acidity or alkalinity of the organic materials, and affects microorganism growth. A pH ranging between 6.0 and 7.5 is preferred by bacterial decomposers while a pH ranging from 5.5 to 8.0 is a good working environment for fungal decomposers (Rynk, 1992). The PH varied with time during the composting process. A decrease in pH was observed at the early stage of composting, although it increases at later stage. The decrease in pH is attributed to the formation of organic acids (typically due to the anaerobic conditions that are established in the waste materials before the beginning of the composting process. As these acids are degraded the pH begins to rise due to the production of ammonia during ammonification and mineralization of organic nitrogen as a result of microbial activities (Samuel.K, 2011).

The pH of all treatments was found to be within 7.36-8.04. This result is in agreement with the compost quality standards for compost used in agriculture in Switzerland (pH < 8.2) and Great Britain (7.5-8.5) (OVAM, 1999). In addition, it is in the recommended range for the quality compost used by the countries such as Dutch, Belgium & Italy that is 6.5-8.5. Hence the matured compost of this study is very promising, since no chemicals are required to balance the pH before applying to soils. Its trend is indicated here below in figure 5

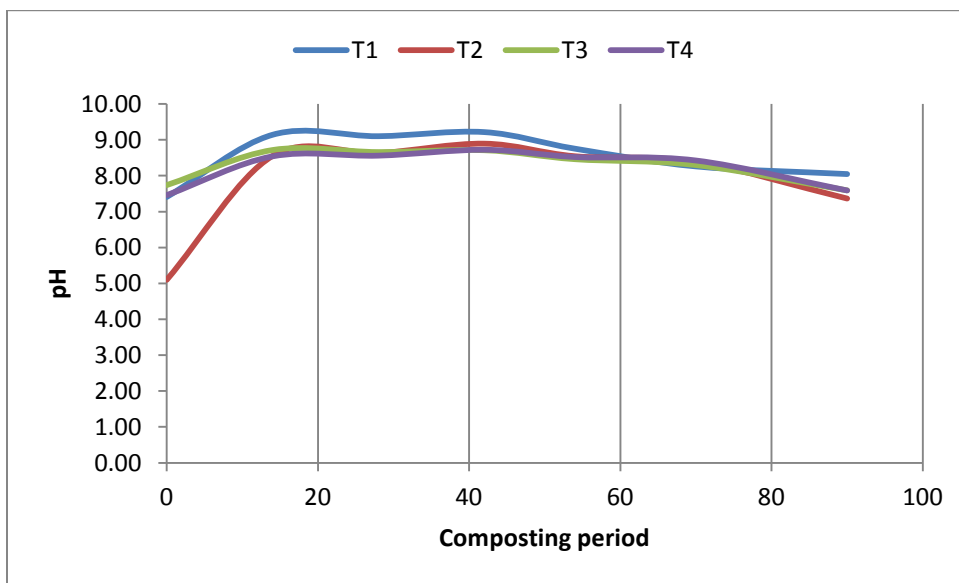


Fig .5.pH of bins during composting

4.2.4 Electrical conductivity

Electrical conductivity of the compost is the measure of amount of soluble salts of sodium, potassium, chlorides, nitrates and sulphates. Generally, increase in EC was observed in the present study slightly from initial composting period to the final composting stage. The increase in EC could be due to the release of mineral salts such as phosphates and ammonium ions through the decomposition of organic substances and water loss, thus increasing the concentration of relative soluble salts (Huang et al., 2004). Study by Anandavalli et al., (1998) on recycling of banana Pseudo stem as compost also show similar EC increment as the composting process proceeds. The mean EC values of all the treatments of matured composts were found to be between 0.96-3.23 dS/m, in which the highest value of EC was recorded at T4. The difference may be originated from the quantity of feedstock materials and content of ions responsible for the electrical conductivity of compost samples. This result is in agreement with the quality compost used by the countries such as Dutch, Belgium and Italy that is < 5 dS/m (OVAM, 1999). Similarly, this result is in the recommended range by Mona (2003 as cited by Herity, 2003) within 2-6 dS/m. Therefore, the compost cannot inhibit the growth of plants. The mean EC analysis results of bins changing trends during composting are shown in Figure 6 below.

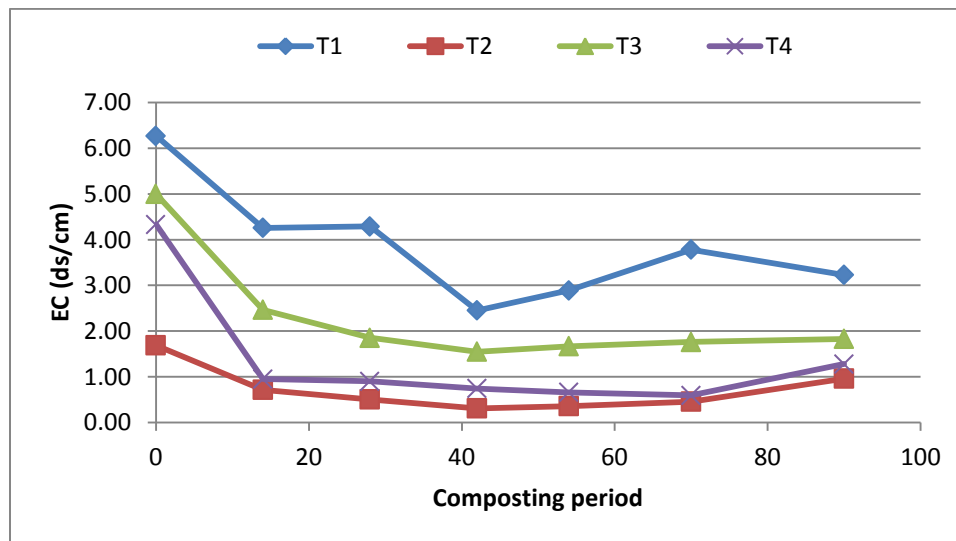


Fig . 6. Electrical conductivity of bins during composting

4.2.5 Total organic carbon

The total organic carbon in all test treatments showed a declining trend. Composting time had a significant effect on the total organic carbon (TOC) content in all composts, but this effect varied depending on the starting raw material. Initially the total organic carbon content of the bins was 20.92%, 20.76%, 15.58%, and 17.46%, and reduced to 11.86%, 15.3%, 14.7% & 17.05% respectively. The highest TOC reductions were found in T1 reflecting a notable mineralisation of organic matter over time. In this study, T4 had the lowest TOC reduction probably because of the higher concentration of recalcitrant compounds. This bin contained no additional organic matter that could fuel the kinetic process; hence, its decomposition occurred more slowly. At the beginning of biodegradation process TOC reduction of the compost displayed a similar trend in all treatments, which decreased rapidly while the temperature of the bins was at peak. It was followed by a gradual decrease showing an overall loss of total organic carbon in the composting process. The organic carbon content of the compost bins are indicated in Table 9 here below.

Table.9 Total organic carbon of bins during composting

Day	T1	T2	T3	T4
0	20.92	20.76	15.58	17.46
42	13.27	10.41	14.91	13.35
54	14.07	9.85	11.35	10.01
90	11.86	15.30	14.70	17.05

4.2.6 Organic matter content

The organic matter content decreases significantly from the initial composting period to the final composting stages for all the treatments as shown in table 10. The reason for the reduction in total organic matter in compost sample is mineralization of initial organic matter to CO₂ during the composting process, by microorganisms leading to a faster decrease in total organic matter at the beginning of the process because of the degradation of the most easily

biodegradable organic matter fractions (Cooperband, L. 2002).

The initial organic content was 28.83%, 35.8%, 26.85%, and 30.1%, and reduced to 20.45%, 26.38%, 25.35%, and 29.4% in T 1, 2, 3 and 4 respectively, at the end. The lower organic matter content was recorded in T1. This might be due to the presence of additional bulking agents that used to increase porosity, decrease phytotoxic material and maintain optimum level of C:N, which pave the way for the right C:N ratio and create suitable conditions for microbial activity. However, the result obtained in all treatments is in agreement with the quality compost criteria, which is used by the countries such as Dutch, Belgium and Italy that is >20%. Similarly the mean content of organic matter in all types of composts analysed were all greater than the lowest critical threshold level of 30% as specified by the EPA. The changes in organic matter content of all treatments through time are indicated in table 10 below.

Table.10. Organic matter content of bins during composting

Day	T1	T2	T3	T4
0	28.83	35.80	26.85	30.10
42	22.87	17.95	25.71	23.01
54	24.26	16.99	19.57	17.26
90	20.45	26.38	25.35	29.40

4.2.7 Change in C/N ratio

The C/N ratio (i.e., the TOC to TKN) indicates the availability of nitrogen for the biological decomposition of a compost mixture, and the decrease in this ratio with composting time has been widely accepted as an index of compost stability and maturity. The C/N ratio decreased significantly over time, especially in the co-composted bins, as C was lost in the form of CO₂ through microbial respiration and N was recycled (Ryckeboer et al., 2003). The final value for C:N is 10.78, 11.33, 10.7 and 11 in T 1,2,3 and 4 respectively. A higher C:N ratio at the end of the composting process for the vegetable waste and sawdust (T2) was found.

The C/N ratio of the studied compost samples are in agreement with the compost quality

standards used by the countries such as Dutch, Belgium and Italy that is less than 18. Similarly all studied compost samples are in the range of the recommendations of Ontario Compost quality standards that is less than 22. Again, the result is within the range of the Ethiopian Federal EPA guidelines that recommended the C/N ratio of good quality compost to have a final C: N ratio of 29:1 or less (FEPA, 2004). The difference in C:N ratio may be originated from the difference in geographical location, which results in a different climatic condition countries may set their own standards which may be proved by measuring the necessary macronutrients at different level of C:N ratio. The C:N ratio trend during composting period is indicated here below in table 11

Table. 11 Changes in C/N ratios of various mixtures at different periods of composting

Day	T1	T2	T3	T4
0	18.68	11.1	11.5	10.9
42	10.45	10	11.04	10.68
54	11.56	9.38	9.45	9.1
90	10.78	11.33	10.7	11

4.3 Nutrient content of compost

4.3.1 Total Kjeldahl Nitrogen (TKN,%)

Total nitrogen (TN) percentage showed an increasing trend with composting duration, which is due to the concentration effect caused by carbon loss associated with mineralisation of the organic matter. The apparent increase in total nitrogen from initial to matured compost is not only due the reduction in weight because of decomposition. Similar justification was given by (parveen, 2010) as cited by (Cooperband, L. 2002), for increment of total nitrogen during composting process. The increase in TN may be due to the net loss of dry mass as CO₂ evolution and moisture loss by generation of heat by microbial action on organic matter. The higher nitrogen for this study is recorded in T4 . The recorded total nitrogen content of the trials was 1.1%, 1.35%, 1.37% and 1.55%, for trial 1, 2, 3 and 4 respectively. This result is in agreement with the quality compost criteria, which is used by the countries such as Dutch, Belgium and Italy that is >0.7%. Similarly, the result is in conformity with recommendations for total N in compost by Barker (1997 as cited in Herity ,2003) that is 1-3. dry weight and Ontario ministry of the environment (2004) that recommended the typical minimum concentration % of Total N as 0.6. Similarly, the result is in agreement with compost quality standards for compost used in agriculture in Switzerland (> 1 %) and India (> 0.8 %). Therefore, since the compost samples have Total N over 1%, they have fertilizing capability and can be used in agriculture and hence no supplemental N is needed. The mean percentages of TN content of the matured compost are shown in table 12.

Table. 12. Total Kjeldahl Nitrogen (TKN,%) of various treatment

Day	T1	T2	T3	T4
0	1.12	1.87	1.35	1.60
42	1.27	1.04	1.35	1.25
54	1.25	1.05	1.20	1.10
90	1.10	1.35	1.37	1.55

4.3.2 Total phosphorus

Available phosphorus also showed a gradual concentration increment from raw feedstock to matured compost. The increase of TP concentration during the composting process was attributed to the solubilization of inorganic phosphate by different species of *Trichoderma*, *Aspergillus* and *Penicillium* (as Cited in Mekuria, 2011).

The Total P % content of the matured composts for all the treatments were found to be in between 0.23 – 0.8 %. The highest phosphorus content is recorded in T1, from the overall physicochemical observation of composting process unavailable form of nutrients found in raw feedstock might be converted into available form of nutrients through composting process and recovered in matured composts. The result obtained in this study is in conformity with the recommendations of Ontario ministry of the environment (2004) that recommended the typical minimum concentration (percentage dry weight) of total P as 0.25. In addition, the result obtained was in agreement with the recommendations of Mona,2003 as cited in Herity, 2003.who recommended that the range of Total P to be 0.4-1.1%.

4.3.3 Total potassium

Potassium in finished compost is much more available for plant uptake than nitrogen and phosphorus since potassium is not incorporated into organic matter. The increase of TK concentration during composting process might correspond to the parent materials, enrichment of nutrients and potassium releasing fungus species. *Aspergillus fumigants* have been reported to be a potassium releasing fungus (as cited in mekuria, 2011). Study by

(Anandavalli et al., 1998) on recycling of banana Pseudo stem as compost also showed Total K increment as the composting process proceeds. The value of potassium for the studied compost ranges from 0.1-0.97 in percent, in which T1 is recorded as the highest possibly due to parent material variation from the others that accelerate decomposition. The results obtained in this study is in conformity with the quality compost criteria, which is used by the counties such as Dutch, Belgium and Italy that is >0.75%, except T1 which is out of the recommended range of most countries.

4. 4 Compost Maturity evaluation

4.4.1 Compost phytotoxicity test

Immature compost may contain phytotoxins that was often kill seed embryos. Seeds grown in immature compost won't sprout or may die immediately after sprouting. Seed germination and plant growth bioassay are the most common techniques used to evaluate compost phytotoxicity (Kapanen and Itavaara 2001)quality.The germination percentage and index of red beet seeds grown on samples extracted from compost collected from various mixtures and distilled water as control are shown in Table 13.

Table 13 phytotoxicity test of compost by germination of red beet seeds

Treatment	Composting period	G %	% germination index(GI)	Maxurity Index
T 1	90 days	82.6	62.21	not matured
T 2	90 days	69.56	55.82	not matured
T 3	90 days	95.65	92.5	matured
T 4	90 days	104.34	98.54	matured

From Table 13,it can be seen that compost from T1 and T2 showed a germination indexof only

62.21 and 55.82%, respectively. Whereas the compost of T3 and T4 showed a germination index value 92.5 and 98.54%, respectively. The low GI value of T1 and T2 might be due to composts may contain, ammonia and/or low molecular weight organic compounds that may reduce seed germination and also inhibit root development (Bernal, 1998); Brinton, 2000). Considered a mature compost to be one where the germination percentage is over 90% and a GI values greater than 80%. Therefore T1 and T2 cannot consider as mature compost, whereas T3 and T4 considered as phytotoxin-free as having completed maturity. Therefore it can be concluded that T3 and T4 were stabilized enough at day 90, whereas T1 and T2 required further composting for longer time than 90 days to reach stabilization.

4.5. The Compost Quality test

The mean values of each parameter for the matured composts and standards of compost quality parameters for quality compost taken from European countries (<http://www.compost.org/pdf/Certifica.PDF>) and Composting Council of Canada, 2002, and USA standards) are presented in Table 14 below.

Table. 14. Compost Quality test

Standards	Units	T1	T2	T3	T4	Limits
Moisture content	%	52.62	58.49	65.10	62.36	35-55
pH		8.05	7.36	7.59	7.59	6.5-8.5
Color		dark brown	golden	dark brown	brown	Dark brown
Odour		putried odour	earthy odour	earthy odour	earthy odour	earthy odour
EC	dS/cm	3.23	0.96	1.83	1.28	<2.5
O.M	%	20.45	26.38	25.35	29.4	>20
O.C	%	11.86	15.3	14.7	17.05	NA
TKN	%	1.1	1.35	1.37	1.55	>= 0.7
Av.P	%	0.76	0.23	0.29	0.37	0.4-0.8 %
K	%	0.98	0.09	0.17	0.11	0.5-2.0
Ca	ppm	44.02	35.9	46.54	44.09	...

Mg	ppm	19.31	6.95	17.19	13.69	...
Fe %	%	133.07	124.46	116.57	102.61	...
Mn	%	231.35	265.76	240.96	222.11	...
Zn	ppm	173.05	83.25	159.74	127.5	210-4000
Hg	ppm	38	20	33	27	...
Cr	ppm	38	17	31	22	70-1200
Cd	ppm	12	13	12	12	0.7-39
Sn	ppm	216	95	165	124	...
As	ppm	103	33	78	51	...
Ni	ppm	76	64	54	54	20- 420
Pb	ppm	168	369	207	197	70-1000
Cu	ppm	10.59	1.93	6.86	5.45	70-1500

4.5.1 Heavy Metals

The concentrations of the selected heavy metals (Hg,Cr, Ni, Cu, Zn, Sn,As, Cd and Pb) in the vegetable,poultry manure and sawdust compost were tested, and their concentrations are shown in Table 15

Table 15 Heavy metals concentration in the final product

Standard	Units	Treatments				Limit
		T1	T2	T3	T4	
Hg	ppm	38	20	33	27	...
Cr	ppm	38	17	31	22	70-1200
Cd	ppm	12	13	12	12	0.7-39
Sn	ppm	216	95	165	124	...
As	ppm	103	33	78	51	...
Ni	ppm	76	64	54	54	20- 420
Pb	ppm	168	369	207	197	70-1000
Cu	ppm	10.59	1.93	6.86	5.45	70-1500
Zn	ppm	173.05	83.25	159.74	127.5	210-4000

As shown in Table 15, the mean concentration of Lead(Pb) was the highest with 230 ppm. A concentration of Cadmium is less than 14ppm. Higher levels of almost all heavy metals especially Pb were recorded in the T2 than other mixtures.

The relatively high concentrations of Zn, Sn, Pb and As in the compost might be due to the vegetable wastes collected from warehouse along Piassa main road may contaminated with Pb and other heavy metals, as organic waste was poorly separated at source. (Jones *et al.* 1978) also stated that organic materials in municipal residues have a capacity to absorb significant amounts of heavy metal cations. Poultry manure used as additives might also contained high levels of Zn and Cu depending on the feed matter (Brinton, 2000). However further investigation is necessary to explain the causes of this high level of heavy metals.

As compared with maximum allowable concentrations of heavy metals required by many countries that are listed in Table 2, those concentrations of the trial compost are in the acceptable range. For instance, the acceptable concentrations of total Pb and Zn for composts produced in Spain were 1200 and 4000 ppm, respectively. These levels were far too high compared to that found in the composted vegetable wastes in the trial (Table 2).

4.5.2 Nutrient analysis

Vegetable waste compost contained substantial concentrations of plant essential nutrients in Table 16. All treatments contained high concentrations of Fe (102.61- 133.07 ppm) in final products due to the presence of these elements in larger quantity in the raw waste. Most nutrients are found in higher quantities for T1, T3 and T4 with additives Poultry manure than the T2 (without Poultry manure). For instance, the treatments with additives Poultry manure (T1, T3 and T4) compost contained of phosphorus than the compost without additives Poultry manure due to presence of large amount of Poultry manure provided higher nutrient content, especially nitrogen and phosphorous. On the other side compost from T1 had nutritional values equivalent or in most cases exceeding other compost products such as compost from T3 and T4. Therefore mixing of vegetable waste with appropriate proportion of poultry manure on composting not only enhance composting rate but also can improve the compost quality greatly. As compared with the allowable concentration of those countries total N, P & K concentration of the bin compost was below the limit. This low level of N, K, and P in the final product might be due to leaching from the feed stock during the composting process since composting occurred in uncovered bins and during the rainy season. The result obtained, however, fulfills the required minimum concentration recommended by Ontario Ministry of environment (2004). The recommended values for total N, total P, and total K as 0.6, 0.25 and 0.2 respectively (% dry weight).

Table 16 Nutrient concentration in the final product

Standard	Units	Treatments				Limit
		T1	T2	T3	T4	
TKN	%		1.35	1.37	1.55	≥ 0.7
Av.P	%	0.76	0.228	0.294	0.37	0.4-0.8 %
K	%	0.9769	0.0854	0.1695	0.1121	0.5-2.0
Ca	ppm	44.02	35.9	46.54	44.09	...
Mg	ppm	19.31	6.95	17.19	13.69	...
Fe %	%	133.07	124.46	116.57	102.61	...

4.6 Others characteristics

Other important physical and chemical parameters of the produced compost are examined below with emphasis on parameters such as pH, color and odor, organic matter content, moisture content and conductivity (Table 17).

Table 17 Nutrient concentration in the final product

Standard	Units	Treatments				Limit
		T1	T2	T3	T4	
Moisture content	%	52.61667	58.49	65.09667	62.35667	35-55
pH		8.046667	7.364444	7.592222	7.589889	6.5-8.5
Color		dark brown	golden	dark brown	brown	Dark brown
Odour		putriedodour	earthy odour	earthy odour	earthy odour	earthy odour
EC	dS/cm	3.23	0.96	1.83	1.28	<2.5
O.M	%	20.45	26.38	25.35	29.4	>20

compost from T1 and T3 appeared to be mature with a dark brown colour and earthy odour, whereas T2 are putriedodour. The pH value of compost is important, since applying compost to soil may alter the soil pH and therefore have an effect on the availability of nutrients to plants. With pH ranging of 8 to 10, the compost was alkaline, which is suitable for acidic soil. Minimum pH is recorded for T2. As

indicated in Table 17, the level of compost organic matter 21.61%, 26.23%, 22.05%, & 21.67 %, respectively, T1 is lower than the acceptable range of Canada and Australia. Nevertheless, it was similar to some Plants and Projects in Vietnamas reported by (Chi,2005), and is in the acceptable range of Italy and Sweden, constituting a good organic corrective for agricultural Soils as recommended by many researchers.

The high salinity values, particularly of T1 (3.23) mS/cm and in T 2,T3 and T4(0.96,1.83,1.28mS/cm) restrain the composts use as fertilizers (2.5 mS/cm at 25°C maximum allowed value) according to Rynk (1992), and imposing important care such as it would have to be diluted with other materials before it could be used for certain plants (Brinton, 2000).The level of moisture content is important characteristics that determine the quality of the final product, since it avoid water transport and helps sieving and storage (Matoet *al.*, 2003). Compared with the standards of the above mentioned countries, the moisture content value of the final product of the compost trial is in the acceptable range.

Chapter Five

5. Conclusions and Recommendations

5.1 Conclusions

The Analysis of various physical and chemical parameters during and at end of composting process, together with initially measured characteristics of vegetable wastes proved that vegetable waste is a good biodegradable material in which recovery will take place in a short period of time. However certain amendments that absorb excess moisture, correct the C/N ratio and acidic nature of the waste should be added.

According to the experimental results the mixing ratio of 2: 1 (2 for green and 1 for brown waste) in wet volume basis was better for composting of fruit and vegetable wastes than the other mixture ratios. Besides the compost obtained from this mixture was appeared to be matured and suitable for agriculture use in 90 days of composting using the bin method.

The compost produced from treatment two had acceptable concentrations of heavy metals and met phytotoxicity requirement when compared with the standards in Australia, North American, and Europe. Although the major reasons for high levels of heavy metals and greater nitrogen, phosphorous and potassium loss needs further investigation.

The composting trial proved that composting of vegetable waste is possible with minimum use of amendments , however further study should be conducting to keep the temperature for longer days and hence enhance the rate of degradation.

Since the compost trial was conducted in the summer (from February to May, 2010 E.C.), and the waste collection was conducted from Piassa vegetable market and from restaurant around Kebene, the results may not represent all sources vegetable waste and may not be true for other seasons.

5.2 Recommendations

Composting of vegetable waste, poultry manure with sawdust waste for 90 days is important for maturity and to have the necessary plant macronutrients. More research is needed on leachate control mechanism during composting process which I didn't consider in this thesis work due to time constraints. Not only leachate control, but also there is a need to optimize the process affecting factors on small scale level.

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ANNEXES

Appendix 1 :Overview of compost for laboratory for Compost phytotoxicity test

Treatment	No. Radish seeds	normal germination after days	normal germination after days	fresh germination	abnormal germination	Root length	mean root length	mean germination	G %	rRL	GI
T 1											
R 1		5	5		2	3.75	4	6.3333333	82.6	78.95	62.21
R2					-						
R3					-						
T2											
R1		6			1	3.45	4.0666666	5.3333333	69.56	80.26	55.82
R2											
R3											
T3											
R1		8	8		-	4.5	4.9	7.3333333	95.65	96.71	92.5
R2					-						
R3					-						
T4											
R1		8	8		-	4.25	4.78333	8	104.34	94.44	98.54
R2					-						
R3					-						
control											
R1		8	8		-	5.2	5.066667	7.6666667			
R2					-						
R3					-						

GI - germination index

rRL -relative root length

Appendix 2: Overview of compost for laboratory for Change in moisture contents(%) of various treatments during composting

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
						D0	T1		
	T2	3	49.57	.404	.233	48.56	50.57	49	50
	T3	3	66.67	2.082	1.202	61.50	71.84	65	69
	T4	3	40.53	1.387	.801	37.09	43.98	39	42
	Total	12	52.82	9.916	2.863	46.52	59.12	39	69
D14	T1	3	57.72	1.806	1.043	53.23	62.20	56	59
	T2	3	67.37	2.940	1.697	60.06	74.67	64	70
	T3	3	68.55	.527	.304	67.24	69.86	68	69
	T4	3	69.52	4.345	2.508	58.72	80.31	65	72
	Total	12	65.79	5.474	1.580	62.31	69.27	56	72
D28	T1	3	53.42	1.663	.960	49.29	57.55	52	55
	T2	3	66.55	3.507	2.025	57.84	75.26	63	69
	T3	3	67.60	.477	.275	66.42	68.78	67	68
	T4	3	65.92	3.406	1.967	57.45	74.38	64	70
	Total	12	63.37	6.428	1.856	59.29	67.45	52	70
D42	T1	3	50.82	7.162	4.135	33.03	68.61	43	57
	T2	3	63.65	8.363	4.829	42.87	84.43	54	69
	T3	3	65.55	1.432	.827	62.00	69.11	64	66
	T4	3	67.30	3.243	1.872	59.24	75.36	64	70
	Total	12	61.83	8.382	2.420	56.50	67.16	43	70
D54	T1	3	49.40	2.249	1.298	43.81	54.99	48	52
	T2	3	62.08	2.935	1.695	54.79	69.37	59	64
	T3	3	65.13	4.052	2.339	55.07	75.20	61	69
	T4	3	65.03	4.152	2.397	54.72	75.35	62	70
	Total	12	60.41	7.372	2.128	55.73	65.10	48	70

D70	T1	3	54.07	2.630	1.518	47.53	60.60	51	57
	T2	3	58.98	5.065	2.924	46.40	71.57	54	64
	T3	3	62.08	6.775	3.912	45.25	78.91	54	67
	T4	3	62.29	5.421	3.130	48.82	75.76	58	68
	Total	12	59.36	5.626	1.624	55.78	62.93	51	68
D90	T1	3	52.62	2.757	1.592	45.77	59.47	51	56
	T2	3	58.49	5.886	3.398	43.87	73.11	52	62
	T3	3	65.10	3.610	2.084	56.13	74.06	61	68
	T4	3	62.36	3.327	1.921	54.09	70.62	59	65
	Total	12	59.64	6.001	1.732	55.83	63.45	51	68

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
D0	Between Groups	1068.297	3	356.099	213.553	.000
	Within Groups	13.340	8	1.667		
	Total	1081.637	11			
D14	Between Groups	267.511	3	89.170	11.485	.003
	Within Groups	62.115	8	7.764		
	Total	329.626	11			
D28	Between Groups	400.679	3	133.560	19.861	.000
	Within Groups	53.798	8	6.725		
	Total	454.477	11			
D42	Between Groups	505.170	3	168.390	5.034	.030
	Within Groups	267.613	8	33.452		
	Total	772.783	11			
D54	Between Groups	503.116	3	167.705	14.175	.001
	Within Groups	94.650	8	11.831		
	Total	597.766	11			
D70	Between Groups	132.488	3	44.163	1.638	.256
	Within Groups	215.711	8	26.964		
	Total	348.198	11			
D90	Between Groups	263.416	3	87.805	5.294	.026
	Within Groups	132.686	8	16.586		
	Total	396.102	11			

Appendix 3: Overview of compost for laboratory for Change in pH of various treatments during composting

Descriptives								
Day		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum
						Lower Bound	Upper Bound	
D0	T1	3	7.46	.050	.029	7.34	7.59	7
	T2	3	5.18	.076	.044	4.99	5.37	5
	T3	3	7.72	.021	.012	7.66	7.77	8
	T4	3	7.42	.032	.019	7.34	7.50	7
	Total	12	6.95	1.071	.309	6.27	7.63	5
D14	T1	3	9.14	.180	.104	8.69	9.59	9
	T2	3	8.72	.344	.199	7.87	9.58	8
	T3	3	8.72	.227	.131	8.15	9.28	8
	T4	3	8.54	.093	.054	8.31	8.77	8
	Total	12	8.78	.303	.087	8.59	8.97	8
D28	T1	3	9.10	.047	.027	8.99	9.22	9
	T2	3	8.65	.031	.018	8.57	8.72	9
	T3	3	8.66	.064	.037	8.50	8.82	9
	T4	3	8.56	.075	.044	8.37	8.75	8
	Total	12	8.74	.226	.065	8.60	8.89	8
D42	T1	3	9.22	.148	.086	8.85	9.58	9
	T2	3	8.96	.019	.011	8.91	9.01	9
	T3	3	8.71	.147	.085	8.35	9.08	9
	T4	3	8.72	.057	.033	8.58	8.86	9
	Total	12	8.90	.235	.068	8.75	9.05	9
D54	T1	3	8.01	1.147	.662	5.16	10.86	7
	T2	3	8.56	.002	.001	8.55	8.56	9
	T3	3	8.46	.101	.058	8.21	8.71	8
	T4	3	8.52	.132	.076	8.19	8.85	8
	Total	12	8.39	.545	.157	8.04	8.73	7
D70	T1	3	8.26	.189	.109	7.79	8.73	8
	T2	3	8.36	.075	.043	8.17	8.55	8
	T3	3	8.30	.133	.076	7.97	8.63	8
	T4	3	8.43	.116	.067	8.14	8.71	8
	Total	12	8.34	.132	.038	8.25	8.42	8
D90	T1	3	8.05	.040	.023	7.95	8.15	8
	T2	3	7.36	.082	.048	7.16	7.57	7
	T3	3	7.59	.302	.175	6.84	8.34	7
	T4	3	7.59	.042	.024	7.49	7.69	8
	Total	12	7.65	.293	.085	7.46	7.83	7

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
D0	1.743	3	8	.235
D14	2.357	3	8	.148
D28	.958	3	8	.458
D42	3.042	3	8	.093
D54	12.688	3	8	.002
D70	1.251	3	8	.354
D90	7.331	3	8	.011

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
D0	Between Groups	12.589	3	4.196	1707.010	.000
	Within Groups	.020	8	.002		
	Total	12.609	11			
D14	Between Groups	.586	3	.195	3.693	.062
	Within Groups	.423	8	.053		
	Total	1.009	11			
D28	Between Groups	.536	3	.179	55.251	.000
	Within Groups	.026	8	.003		
	Total	.562	11			
D42	Between Groups	.512	3	.171	14.470	.001
	Within Groups	.094	8	.012		
	Total	.606	11			
D54	Between Groups	.581	3	.194	.577	.646
	Within Groups	2.685	8	.336		
	Total	3.267	11			
D70	Between Groups	.048	3	.016	.880	.491
	Within Groups	.145	8	.018		
	Total	.192	11			
D90	Between Groups	.740	3	.247	9.714	.005
	Within Groups	.203	8	.025		
	Total	.943	11			

Multiple Comparisons

LSD

Dependent Variable	(I) pH	(J) pH	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
D0	T1	T2	2.280	.040	.000	2.19	2.37
		T3	-.253	.040	.000	-.35	-.16
		T4	.040	.040	.352	-.05	.13
	T2	1	-2.280	.040	.000	-2.37	-2.19
		T3	-2.533	.040	.000	-2.63	-2.44
		T4	-2.240	.040	.000	-2.33	-2.15
	T3	1	.253	.040	.000	.16	.35
		T2	2.533	.040	.000	2.44	2.63
		T4	.293	.040	.000	.20	.39
	T4	1	-.040	.040	.352	-.13	.05
		T2	2.240	.040	.000	2.15	2.33
		T3	-.293	.040	.000	-.39	-.20
D14	T1	T2	.418	.188	.057	-.02	.85
		T3	.426	.188	.053	-.01	.86
		T4	.601	.188	.013	.17	1.03
	T2	1	-.418	.188	.057	-.85	.02
		T3	.008	.188	.968	-.43	.44
		T4	.183	.188	.358	-.25	.62
	T3	1	-.426	.188	.053	-.86	.01
		T2	-.008	.188	.968	-.44	.43
		T4	.176	.188	.377	-.26	.61
	T4	1	-.601	.188	.013	-1.03	-.17
		T2	-.183	.188	.358	-.62	.25
		T3	-.176	.188	.377	-.61	.26
D28	T1	T2	.456	.046	.000	.35	.56
		T3	.442	.046	.000	.34	.55
		T4	.542	.046	.000	.44	.65
	T2	1	-.456	.046	.000	-.56	-.35
		T3	-.013	.046	.781	-.12	.09
		T4	.087	.046	.099	-.02	.19
	T3	1	-.442	.046	.000	-.55	-.34
		T2	.013	.046	.781	-.09	.12
		T4	.100	.046	.063	-.01	.21
	T4	1	-.542	.046	.000	-.65	-.44
		T2	-.087	.046	.099	-.19	.02
		T3	-.100	.046	.063	-.21	.01
D42	T1	T2	.258	.089	.020	.05	.46
		T3	.506	.089	.000	.30	.71
		T4	.493	.089	.001	.29	.70
	T2	1	-.258	.089	.020	-.46	-.05
		T3	.248	.089	.023	.04	.45
		T4	.236	.089	.029	.03	.44
	T3	1	-.506	.089	.000	-.71	-.30
		T2	-.248	.089	.023	-.45	-.04
		T4	-.012	.089	.894	-.22	.19
	T4	1	-.493	.089	.001	-.70	-.29
		T2	-.236	.089	.029	-.44	-.03
		T3	.012	.089	.894	-.19	.22
D54	T1	T2	-.545	.473	.282	-1.64	.55
		T3	-.451	.473	.369	-1.54	.64

Appendix 4 :Overview of compost for laboratory for laboratory analysis

