



**ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CHEMICAL AND BIO ENGINEERING
ENVIRONMENTAL ENGINEERING STREAM**

Vermicompost Evaluation of Tannery Sludge Waste Residue for Soil Conditioning

**By
Misgna Amare**

A Thesis Submitted To the School Of Graduate Studies of Addis Ababa University Addis
Ababa Institute Technology in Partial Fulfillment of the Degree of Masters of Science in
Environmental Engineering

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ACRONYM

2FI	Two Factor Interaction
3D	Three Dimensional

AAEPA	Addis Ababa Environmental Protection Authority
ANOVA	Analysis of Variance
APPRC	Ambo Plant Protection Research Center
BOD	Biological Oxygen Demand
C.V	Coefficient of Variation
C/N	Carbon to Nitrogen ratio
CAPs	Cast-Associated processes
CD	Cow dung
CEC	Cation Exchange Capacity
CFUs	Colony Forming Unites
CI	Confidence Interval
Df	Degree of Freedom
DoE	Design of Experiments
EC	Electrical Conductivity
ESSWM	Environmentally Sound Solid Waste Management
GAPs	Gut-Associated Processes
GHGs	Green House Gases
HM	Horse Manure
HSW	Household solid waste
ISWM	Integrated Solid Waste Management
MC	Moisture Content
MM	Metro-Mix

MS	Mean Square
MSWM	Municipal Solid Waste Management
NPK	Nitrogen-Phosphorous-Potassium
OM	Organic Matter
RSM	Response Surface Methodology
SS	Sum of Squares
Std. Dev.	Standard Deviation
TK	Total potassium
TKN	Total Kjeldahl Nitrogen
TC ₁₁	Tannery sludge plus cow dung 1:1
TC ₃₂	Tannery sludge plus cow dung 3:2
TC ₇₃	Tannery sludge plus cow dung 7:3
TH ₁₁	Tannery sludge plus horse manure 1:1
TH ₃₂	Tannery sludge plus horse manure 3:2
TH ₇₃	Tannery sludge plus horse manure 7:3
TOC	Total Organic Carbon
TOM	Total Organic Matter
TP	Total phosphorus
TSW	Tannery Solid Waste
VC	Vermicompost
VIF	Variance Inflation Factor
VS	Volatile Solids

WSD

Worm Stocking Density

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ABSTRACT

Tannery sludge and the effluents in general are of large-scale environmental concern because they color and diminish the quality of soil and water bodies into which they are released. Their disposal into the environment creates adverse effects by altering the normal physiochemical properties of soil and water. This thesis is aimed to investigate potential application of tannery sludge waste residue for soil conditioning through vermicomposting process by *Eisenia fetida* and to address the environmental pollution problems in the leather-manufacturing. The performance of the compost was evaluated by biomass of salad grown on vermicompost. The experiments were conducted in circular plastic containers after earthworm-collection and culturing. The containers were filled with different combinations of tannery sludge in combination with cow dung and horse manure in different ratio. In the experimental period (45 days), different parameters were analyzed within a time interval of 15 days like pH, temperature and moisture during vermicomposting processes. While, electrical conductivity, the Total Nitrogen (%), Available Phosphorus (%) and Total Potassium (%) increased at the end of the process, while the % Organic Carbon decreased as the vermicomposting processes progressed. the research has demonstrated that vermicomposting serves different advantages and applications but the two main purposes for the welfare of humans as it helps in the degradation of tannery sludge waste and the vermicompost produced during this process is used as a natural fertilizer. The application and potential utilization of tannery sludge waste for soil conditioning effect has also shown in the increase a biomass of salad.

Key word: Addis Ababa Tannery, *Eisenia fetida*, soil conditioning, tannery sludge, vermicast, Vermicomposting.

1 INTRODUCTION

1.1 Background

Ethiopia and many other countries are suffering from the entire problems of solid waste due to urbanization, industrialization and population density, deteriorating quality of urban environment is one of its important impacts. Solid waste is complex in character and its volume is greatly increased due to increase of living standards and population density which is a very rapid process and a worldwide phenomenon. Solid waste is the term now used internationally to describe non-liquid waste material arising from domestic, commercial, hospital, industrial, agricultural and mining activities [1].

Hence the importance of efficient “solid waste management” is increasingly recognized. Industries produce a large quantity of wastewater and sledges from each of processing stage. When these industrial wastes come into contact with the environment they produce serious impacts on it. It is difficult to generalize the industrial wastes since their characteristics differ from industry to industry and also from their different processing plants. Before final disposal, one can process and treat the waste so as to reduce the “wasteful wasting of waste”. Some of the techniques available to achieve this objective are volume reduction, recovery of resources, energy recovery and conversion to fertilizers or other wasteful materials or source of energy.

This study has been done for reducing the pollution problems due to solid waste and industrial sludges by converting it into vermicompost by using earthworms. Solid waste comprises countless different materials such as dust, food waste, tannery, paper, metals, plastics, glass, discarded clothing, garden waste etc. a Solid waste includes both combustible and non-combustible waste. Disposal of solid waste should be properly managed. They cause insanitation conditions, and hazard to human being. Day to day management of solid waste is a complex and a costly task. Therefore, there is often a serious waste disposal problem, which can lead to problems with flies and rats around the processing room, if not correctly dealt with. If there are no plans to use the waste it should be vermicomposting or fed to

animals well away from the processing site. One of the main problems in using the tannery sludge waste is to ensure that the waste has a reasonable micro biological quality. Vermicomposting ‘Vermi’ is the Latin word for worm. Vermicomposting is simply composting with worms. Vermicomposting refers to the method of converting organic waste to worm castings. It is one of the most cost efficient and environmentally friendly methods of waste disposal.

In an ideal condition earthworms can consume practically all kinds of organic matter and they can eat their own body weight per day for example one kilogram of worms can consume one kilogram of residues every day. And yet their casts contain eight times as many microorganisms as their feed. And the casts do not contain any disease and pathogens. In the modern age of development the increasing quantity of solid waste is one of the growing environmental problem in both developed and developing countries.

Due to rapid growth in industrialization most of the rural population is shifted toward the urban area in search of employment. Tanning industry is one of the oldest industries in Ethiopia. The industry provides finished and semi-finished leathers from skins and hides. In general, the waste materials of tanning industries are categorized into solid waste and liquid effluent. The liquid waste has been diverted into Effluent Treatment plant for further treatment. The solid waste consists of sludge, salt, hair, lime, flesh, myrob dust, buffing dust and trimmed waste.

Generally fleshing of animal is deemed as major solid wastes that are provided during leather processing while scrapping out the limed hides either by hand or by machine [1]. Fleshings are proteinaceous in nature comprising of cutaneous muscle layers and subcutaneous adhering tissues that are not required in the subsequent operations of leather manufacture. These fleshings from tannery industries can be subjected for fertilizer, bio-methanation, glue manufacture, enzyme, protein and animal feed protection [2]. This assessment insists on a proper treatment of the solid waste before disposal. Some portions of these solid wastes may sold out for further beneficiary uses. In the absence of standard treatment procedures, the solid wastes are stored in heaps within the tannery premises. This major problem needs imperative attention to find out a permanent solution.

🚧 Sources Of tannery sludge waste (Addis Abba Tannery):

Addis Ababa tannery is one of the leather industries found in “Kolfé Keraniyo Sub city Asko Addis Sefer” Addis Ababa Ethiopia. As of estimates made in different literatures; Ethiopia had more than 26 tanneries with different capacities and annual income of leather trade [3]. Some of the tanneries were small or medium with a processing capacity of not more than 2 to 3 tons of hides/skins per day. Pollutants correspond to release of tannery sludge, Chloride, Sulphates, chromium, volatile organic carbon, total dissolved solid, BOD and COD were in a high amount the waste water was treated in three concrete containers but there is no sludge treatment options the sludge dropped in an open area without any treatment and it causes environmental, human health and Maritain life problems [3].

1.2 Statement of the problem

Tanning industry is one of the oldest industries in Ethiopia; the industry provides finished leathers from skins and hides. In general, the waste materials of tanning industries are categorized into solid waste, gasses and liquid effluent. The liquid waste has been diverted into Effluent Treatment plant for further treatment. The solid waste consists of sludge, salt, hair, lime, flesh, myrob dust, buffing dust and trimmed wastes are dumping [3].

Generally fleshing of animal and sludge wastes are deemed as major solid wastes that are provided during leather processing. One metric ton of wet salted hides/skins yields finished leather 300 kg and the remaining 700kg is waste. Out of 700kg 25% is sludge waste the mode of disposal being dumping onto open soil which is hazardous to the environment [4].

Solid waste management by composting using worms has many advantages, It is pollution free, with no odour or leachate problems, conversion of organic wastes into vermicompost by worms is faster than any other composting process, In industries it is a cost effective and pollution abatement technology, no polluting chemicals need to be used or produced, less health hazards, Saving on subsidies to national economy.

Worldwide, there is loss of fertility of the soil and the amount of organic carbon and other minerals soil contain is decreasing, there is need to every opportunity to utilize tannery waste to improve soil conditions. Vermicomposting technology is the modern concept of harnessing an ecosystem for effective utilization of organic residues with the help of earthworms.

In this regard, vermicomposting is a viable, simple, and economical process by which organic and tannery solid wastes can be efficiently managed by converting it into organic manure/soil conditioners. Vermicompost can be used as a fertilizer or as a source of nitrogen for microbial populations which can be beneficial to plant growth, there by solving the problems of pollution from tannery sludge in an environmentally friendly manner with high economic benefits.

1.3 Objectives

1.3.1 General Objective

The general objective of this study is to evaluate vermicomposting of tannery sludge residues for soil conditioning.

1.3.2 Specific Objectives

The specific objectives of the study are:

- ✓ Earthworms collection and selection of required species
- ✓ Breeding of selected species of the earthworms
- ✓ Characterization of tannery sludge, cow dung and horse manure before vermicomposting.
- ✓ Vermicomposting of tannery sludge, cow dung, horse manure and combination
- ✓ Characterization of vermicompost
- ✓ Evaluating performance of vermicompost

1.4 Significance of the study

In any waste or resource management system, we must pay attention to the interaction between human activities and the ecosystem. We have to recognize that human activities including consumption of goods/services, production of wastes, etc., have a serious impact on the carrying capacity of the ecosystem. This in turn affects human health, as the environment deteriorates. The fundamental principles of ESSWM, especially tannery sludge waste has no treatment option in Ethiopia which takes into account economic and social issues along with environmental impact consideration include the following significance:

- o Ensure sustainable development of the ecosystem and human environment.
- o Minimize the impact on the environment and maximize the ecosystem's carrying capacity.
- o Ensure the implementation of ESSWM through environmentally sound technologies like vermicomposting technology.
- o Minimize cost of fertilizer and soil degradation. So that the study will be essential to accommodate all.
- o Improve soil fertility by increasing water holding capacity, porosity, macro and micro nutrient availability.

2 LITERATURE REVIEW

2.1 General Concept of vermicomposting

In the modern age of development the increasing quantity of solid waste is one of the growing Environmental problems for both developed and developing countries. Due to rapid growth in industrialization the most of the rural population are migrated toward the urban area in the search of employment. Sludge wastes from tanneries are generated in the effluent treatment process. These sludge wastes from tanneries contain the highest chromium content and currently being dumped in the open areas, thus creating the solid waste disposal problem in tanneries. This sludge from tanneries can be used for fertilizer.

Vermicomposting is the conversion of biodegradable wastes into a high quality chemical free bio-fertilizer with the aid of Earthworms. Where as, the composting is the other way round where the organic part of the refuse is consumed by a series of successive bacteria according to the heat of the system. Earthworms have from time immemorial played a key role in soil biology by serving as versatile natural bioreactors to harness and destroy soil pathogens, thus converting organic wastes into valuable bio-fertilizers, enzymes, growth hormones and proteinaceous worm biomass. The worms do it by feeding voraciously on all biodegradable refuse such as leaves, paper (non-aromatic), kitchen waste, tannery sludge, vegetable refuse. It then burrows deep into the soil, positioning its castings in to the soil thereby enriching the soil with pre-digested, easy to assimilate bio-fertilizer that is now rich with NPK [5].

So when looking for a fertilizer for a farm or garden it would do well if people would consider the revolutionary vermicompost as an option. Certain types of earthworms ingest, digest, and excrete vermicompost with excellent nutrient content. Ingestion ensures the sorting out of only organic matter while the digestion accelerates the maturing process. Excretion ensures the grading of the vermicompost as opposed to any inorganic matter, which may be existing in the waste and not concerned with the biological activity in the earthworm gut.

During the conventional composting process, microorganisms decompose organic compounds, which consist of carbohydrates, sugar, proteins, fats, cellulose and lignin. Carbohydrates are more easily decomposed whereas lignin is more resistant to decomposition. Many factors affect the composting process. Aerobic microorganisms need oxygen, water and nutrients for their metabolism and cell synthesis. As a result of microbial activity heat is liberated and, if contained within the composting mass, the temperature rises. Temperature increases through the mesophilic phase into a thermophilic phase and then back in to the mesophilic phase. During the course of these transitions, the microbial population changes, thereby affecting the rate of organic matter decomposition [5].

Composts are widely used to improve the physical characteristics of soil and are also valuable source of organic matter. Nitrogen provided by the compost and poultry manure influenced plant growth and flowering. Composting controls aerobic biological decomposition of moist organic solid matter to produce a soil conditioner. It has been traditionally proved that organic matter can be converted in the compost within thirty days. Organic material contains minerals, other chemicals and nutrients [5].

However, applying raw organic materials directly to the soil is not the best way to use organic matter and its nutrients. The C/N ratio is narrowed down substantially and nitrogen retention is more in compost prepared with earthworms than without earthworms. Millions of tons of solid wastes like tannery solid waste and domestic wastes are buried or burned annually. Instead of this, if solid waste is being recycled with the help of earthworms, it would not only solve the pollution problem but generate quality manure for agriculture use [6].

Vermicomposting turns many types of solid wastes into nutritious soil for plants. When vermicompost is added to soil, it boosts the nutrients available to plants and enhances the soil fertility. Vermicomposting is considered as an eco-friendly way of solving organic waste problem. This technology has been defined as “Method of converting organic wastes into a useful product through action of earthworms”. Vermicomposting can be called as enhancing the degradation of organic waste by action of earthworms [6].

2.2 Definition

2.2.1 Conventional Composting

Composting is the biological decomposition of organic matter under controlled aerobic condition. Composting in a way is one such method by which we can practically and economically use those waste streams dominated by organic refuse. That there is no universally accepted definition of composting.

It is the biological decomposition and stabilization of organic substrates, under conditions that allow development of thermophilic microorganisms as a result of biologically produced heat, to produce a final product that is stable, free of pathogens and plant seeds, and can be beneficially applied to land. Or simply it can be defines as the biological reduction of the organic waste to humus. In brief we can consider composting as a way of stabilizing the waste.

2.2.2 Vermicomposting

Vermicomposting is a waste management technology utilizing earthworms to convert organic wastes into high quality castings and vermicomposts of high economic values while vermiculture is the art and science of worm rearing. The two main products of vermiculture and vermicomposting are worms and composts. These products are simultaneously produced during the process and can further be transformed into other valuable vermi products [7].

Composting is a biological decomposition of organic matter under controlled aerobic conditions into humus-like stable products. The processing of organic wastes into organic fertilizers via composting is a technique that has been used to address the issues of environmental pollution, reliance on chemical fertilizers, sustainable natural fertility, and minimizing the development of new landfills. Vermicomposting uses worms to convert animal, agricultural, and industrial wastes to useful fertilizers.

The method of employing earthworms in reducing the organic matter present in the waste is called as the vermicomposting. Vermicomposting, also known as worm composting, is simply the way red worms transform decaying organic matter into worm castings. It is also the process involved in the degradation of organic waste into useful components by using earthworms. It is all-together a natural system in which the earthworms play their major roles in degrading the organic portion of the waste. The use of earthworm in solid waste management is called vermicomposting or vermistablization.



Figure 1 Vermicomposting tannery sludge waste

2.2.3 Vermiculture (breeding of selected earthworm species)

Vermiculture is breeding of earthworms to continually increase the number of worms in order to obtain a sustainable harvest. The worms are either used to expand a vermicomposting operation or sold to customers who use them for the same or other purposes. If the goal is to produce vermicompost then we want to have maximum worm population density all the time. If the goal is to produce worms then we keep the population density low enough that reproductive rates are optimized.



Figure 2 vermiculture of *essinia fetida*

Different quantities of earthworms have been inoculated in culturing material and the earthworm response in terms of growth and reproduction rate has been monitored. Earthworm activity during vermicomposting has been monitored by looking at the earthworm biomass gain, cocoon production, weight gain, increase in worm length and worm number as well as the growth rate. Additionally, parameters such as temperature, feed type, earthworm stock density and feedstock loading rate have been studied to see their influence on earthworm activity. The earthworm growth rate during vermicomposting is calculated according to Equation 1 [8]:

$$G = \frac{B_2 - B_1}{T * N} \text{-----(1)}$$

Where:

G = Earthworm growth rate (mg/worm/day)

B1 = Initial biomass of worm (mg)

B2 = Maximum biomass obtained by worm (mg)ⁱ

T = Number of days in which biomass is attained

N = Number of earthworms inoculated The earthworm biomass gained per unit feed mixture (mg/g) is calculated according to Equation 2 [8]:

$$\frac{B_2 - B_1}{W} \text{-----} (2)$$

Where:

W = Total quantity of organic waste taken (g) In addition, the earthworm reproduction rate is calculated according to Equation 3: [8]:

$$R = \frac{C}{E} \text{-----} (3)$$

Where:

R = Earthworm reproduction rate

C = Total number of cocoons produced

E = Total number of earthworms

Vermi-filtration technology involves the use of earthworms as bio-filters in wastewater treatment in addition; the earthworms produced can also be further used in vermin-filtration these earthworms from vermicomposting can also be used in vermi-remediation, which involves the removal of heavy metals in soils [8].

2.3 Vermicomposting Technology

Vermicomposting technology is the modern concept of harnessing an ecosystem for effective utilization of organic and tannery residues with the help of earthworms. Earthworms are creeping animals living in moist soils. Earthworms play a key role in soil biology by serving as versatile nature's bio-reactor to effectively harness the beneficial soil micro flora and destroy soil pathogens,

thus converting organic and tannery wastes in to valuable products such as bio-fertilizer, bio-pesticides, vitamins, enzymes, antibiotics and pertinacious worm bio-mass [9].

Vermicomposting is the degradation of organic wastes utilizing the high metabolic activity of earthworms to achieve the following objectives. In this process, the efficiency & adaptability of earthworms in inhabiting very high percentage of organic material, low incubation period of eggs & rapid multiplication rate is exploited commercially for bio-waste treatment. Solid waste is spread over soil surface for incorporation into the soil in situ. Earthworms help in decomposition & incorporation into the soil.

Wastes are stacked in heaps or bins, treated like compost and earthworms are released into them. This method results in bulk production of worm casts rich in lignocelluloses, usable as manure. This can be mixed with cow dung, poultry waste or pig waste to increase degradation efficiency. Wastes are directly fed into specially designed vermicomposting bins made of wood/plastic/brick masonry thus the treated waste can be used to obtain a finished value added product free of biological & chemical pollutants that can be used as manure. Before the worms can digest the waste partial decomposition is essential. vermicompost is the cast or excreta of epigeic earthworm species, which have been cultured on organic and tannery wastes [9].

2.4 Breeding of earthworms

Vermiculture is the breeding of selected earthworm species. The goal is to continual increase in the number of worms in order to obtain a sustainable harvest. The worms are either used to expand a vermicomposting operation or sold to customers who use them for the same or other purposes. So the goal of this thesis is to produce vermicompost and to solve the environmental problems then I want to have maximum worm population density all of the time. If the goal is to produce worms then we keep the population density low enough that reproductive rates are optimized.

2.5 Types of earthworm species

Species Suitable for Vermicomposting Epigeic species, *Eisenia foetida*, *Eudrilus eugeniae* and *Perionyx excavatus* are appropriate for vermicomposting. The desirable attributes of appropriate vermicomposting species are listed below.

2.5.1 *Eisenia foetida*

Breeding of *Esenia foetida* or more commonly known as the Red worms the initial breeding of these worms are done in an open bucket without shade. There is no special change in the bedding material other than a thin layer of horse manure, which was obtained initially along with the worms. It is seen that these worms grow very fast and have much higher reproductive rate as compared with the local worms [9].

Similarly here also the worms are first bred in an opened system but due to its high reproduction rate, after couple of weeks these worms are shifted to an three open vermibed. The pH of the open vermibed is maintained in the range of (7 ± 1.3) . These worms are latter used in the vermireactor study to determine the total mass reduction and the stabilization of the same and waste.



Figure 3 *Eisenia foetida*

Eisenia foetida, popularly known as red wriggler, red worm, tiger worm etc is perhaps the most widely used earthworm for vermicomposting. The species has also been in wide usages for various toxicological studies as test worm. Mature individuals can attain up to 1500 mg body weight. Each mature worm on an average produces one cocoon every third day and from each cocoon on hatching within 23 days emerge from 1 to 3 individuals [8].

2.5.2 *Eudrilus eugeniae*

This species, popularly known as Night Crawler, can be said to be the second most widely used earthworm for vermicomposting. It grows faster than other species accumulating mass at the rate of 12 mg/day. Mature individuals can attain body weight up to 4.3 g/individual. Maturity is attained over a period of 40 days, and, a week later, individuals commence cocoon laying (on average 1 cocoon/day). Life span in laboratory is estimated to range from 1 to 3 years. Native of Equatorial West Africa, low temperature tolerance of *Eudrilus eugeniae* is lower than that of *Eisenia foetida*, but this species can be used as vermicomposting worm in tropical and sub-tropical regions [8].

2.5.3 *Perionyx excavatus*

In India, this species is quite common in Eastern Himalayas, Western Himalaya, Pilibhit, Bengal and Little Andaman Islands. It is highly adaptable and can tolerate a wide range of moisture and quality of organic matter. Average growth rate of *Perionyx excavatus* is 3.5 mg/day and body weight (maximum) of 600 mg. Maturity is attained within 21-22 days and reproduction commences by 24th day, with 1 to 3 hatchings per cocoon. Scientists opine that this species is amongst the best suited for vermicomposting in tropical climates [8].

Criteria for selecting earthworm species

1. Worm should exhibit high biomass consumption together with a high efficiency of conversion of ingested biomass to body proteins, a physiological trait required for achieving high growth rate.

2. Worm should have wider range of tolerance to environmental factors including adaptation to feed on a variety of organic residues
3. Worm should produce large numbers of cocoons with short hatching time enabling rapid population growth and, linked to this rapid growth, faster composting of organic residues.
4. Life cycle of the worm should be such that mature/adult phase is quickly reached.
5. Using a mixture of species is likely to be more useful than use of single species.
6. Worm should be disease resistant [8].

2.6 Physico-chemical changes in wastes during vermicomposting

Various studies have been conducted in yesteryears to study biochemical changes in the organic matter during vermicomposting process. The most commonly studied parameters in these studies included pH, organic carbon, NPK, enzymes, heavy metals etc. A brief review of these parameters is given below:

2.6.1 pH

pH of organic matter has a significant impact on the efficiency of overall process and it could be the limiting factor for the survival and growth of earthworms. After vermicomposting usually pH decreases from alkaline to acidic or neutral. The pH change towards neutrality may be due to the mineralization of nitrogen and phosphorus into nitrites or nitrates and orthophosphates. Bioconversion of organic materials into intermediates species also another factor for the decrease of pH during vermicomposting decomposition of organic matter leads to the formation of ammonium (NH_4) ions and humic acids. The presence of carboxylic and phenolic groups in humic acids caused lowering of pH and ammonium ions increased the pH of the system.

The combined effect of these two oppositely charged groups regulates the pH of vermicompost leading to a shift of pH towards neutrality. Lower pH in vermicomposts might be due to the production of CO₂ and other organic acids by microbial activity during bioconversion of wastes substrates. The shift in pH could be due to microbial decomposition during the process of vermicomposting. Production of CO₂ and organic acids by microbial decomposition during vermicomposting lowers the pH of substrate [11].

2.6.2 Nitrogen content

In soil nitrogen exists in two major forms; organic nitrogen and inorganic nitrogen. Plants fulfill their nitrogen requirements from the inorganic fraction. The organic fraction serves as a reservoir of nitrogen in plant nutrition and released only after decomposition and mineralization of organic matter. Inorganic nitrogen mainly nitrates and ammonia is available nitrogen forms which are used by plants. Losses in organic carbon due to substrate utilization by microbes and earthworms and their metabolic activities as well as water loss by evaporation during mineralization of organic matter might be responsible for nitrogen addition.

Decreases in pH may be another important factor in nitrogen retention as nitrogen is lost as volatile ammonia at higher pH values. It has also been suggested that the final nitrogen content of vermicompost is dependent on the initial nitrogen content present in the organic wastes and the extent of decomposition. Addition of nitrogen in the form of mucus, nitrogenous excretory substances, body fluids, growth stimulating hormones and enzymes from earthworms has also been reported. The enhanced population of nitrogen fixers in vermin-beds, while working on vermicomposting of tannery sludge wastes [11].

2.6.3 Organic carbon

Organic carbon (OC) decreases in the organic wastes during vermicomposting. Earthworms break and homogenize the ingested material through muscular action of their foregut and, also add mucus and

enzymes in ingested material, this increase the surface area for microbial action. The combined action of earthworms and microorganisms may be responsible for OC loss from the organic wastes in the form of CO₂.

Earthworms promote such microclimate conditions in the system which it increases the loss of organic carbon from substrates to microbial respiration. Earthworms and microorganisms use large portion of carbon as sources of energy and nitrogen for building cell structure brings about decomposition of organic matter [11].

2.6.4 Phosphorus content

Phosphorous is an essential plant nutrient which is required for photosynthesis, energy transfer within plants and for good flowering and fruit growth. It is taken up by plants in the form of inorganic ions: $\text{H}_2\text{PO}_4^{4-}$ and $\text{H}_2\text{PO}_4^{2-}$. It is more important for plant maturation than plant growth. Phosphorus content is usually higher in vermicompost than parent material, for example an increase in 25% in phosphorous content of paper waste sludge, after worm activity. Increase in phosphorus content was attributed to direct action of worm gut enzymes and indirectly by stimulation of the micro flora. Addition of phosphorus to vermicompost also prevents nitrogen loss through ammonia volatilization.

Vermicomposting can be an efficient technology for the transformation of unavailable forms of phosphorous to easily available forms for plants. Micro flora presents in the feed material play an important role in enhanced phosphorous in worm cast. If the organic materials pass through the gut of earthworms then some of phosphorus being converted to such forms that are available to plants. Increase in phosphorus during vermicomposting is probably through mineralization and mobilization of phosphorus by bacterial and phosphatase activity of earthworms the release of available P content from organic waste to earthworm gut phosphatases, and P-solubilizing microorganisms present in worm casts [11].

2.6.5 Potassium content

Potassium is one of the essential nutrients for plant growth along with nitrogen and phosphorus. It is used by plants in several physiological processes including manufacturing and movement of sugars, cell division, root development etc. There are contradictory reports regarding the potassium content in vermicomposts obtained from different organic wastes. Lower potassium content in coffee pulp waste after vermicomposting this might be due to leaching of potassium by excess water that drained through the feeds.

Higher potassium content is found in the sewage sludge vermicomposts. The leachate collected during vermicomposting process had higher potassium concentration an increase in potassium in vermicomposts after bioconversion of sugar industry waste. These differences in the observations can be attributed to the differences in the chemical nature of the inorganic wastes used in vermicomposting system [11].

2.6.6 C: N ratio

C: N ratio is one of the most widely used indices for maturity of organic wastes. The loss of CO₂ in the process of respiration and production of mucus and nitrogenous excrements are responsible for C:N ratio changes during vermicomposting have reported that a decline in C:N ratio to 20 indicates organic waste stabilization, its maturity and stability. The ratio of carbon to nitrogen is important for the proper growth of any plant.

All studies on vermicomposting have reported a decrease in C:N ratio of organic wastes, although decrease in C:N ratio is different for different organic wastes. The utilization of vermicomposts as soil amendment may hold a good promise for improving the soil health, crop productivity and reducing the waste disposal problem. Vermicompost quality is closely related to its stability and maturity, the maturity implies a potential for the development of beneficial effects when they are used as growth media.

A large numbers of chemical and biological changes that occur during vermicomposting and several methods have been suggested for maturity. Maturity and stability means the absence of phytotoxic compounds and plant or animal pathogens. Water-soluble organic carbon generally decreases with time and is often used as another indicator of compost stability. Various parameters can be used to assess the stability and maturity of vermicomposts including C:N ratio, cation exchange capacity, humus content, oxygen consumption by microorganisms and the carbon dioxide evolution from the finished products (composts/ vermicomposts).

Germination index, which is a measure of phytotoxicity was as a reliable indirect quantification of vermicompost maturity. In general, decrease in C:N ratio can be taken as a reliable index of compost maturity when combined with other parameters such as CO₂ evolution from mature compost, water soluble C and content of humic substances. But, C:N ratio cannot be used as an absolute indicator of compost maturity, since the values for well composted materials present a great maturity variability, due to characteristics of the waste used. During vermicomposting, carbonaceous and nitrogenous compounds are transformed through the activities of successive microbial populations into more stable complex organic forms which chemically and biologically resemble humic substances [11]

2.7 Vermicomposting process

It is an aerobic, bio-oxidation, non-thermophilic process of organic waste decomposition that depends upon earthworms to fragment, mix and promote microbial activity. The basic requirements during the process of vermicomposting are [8].

- Suitable bedding
- Food source
- Adequate moisture
- Adequate aeration
- Suitable temperature
- Suitable pH

a) Bedding

Bedding is any material that provides a relatively stable habitat to worms. For good vermicomposting, this habitat should satisfy the following criteria:

- ✓ High absorbency: As worms breathe through skin, the bedding must be able to absorb and retain adequate water.
- ✓ Good bulking potential: The bulking potential of the material should be such that worms get oxygen properly.
- ✓ Low nitrogen content (high Carbon: Nitrogen ratio): Although worms consume their bedding as it breaks down, it is very important that this be a slow process. High protein/nitrogen levels can result in rapid degradation and associated heating may be fatal to worms.

b) Food Source

Regular input of feed materials for the earthworms is most essential step in the vermicomposting process. Earthworms can use a wide variety of organic materials as food but do exhibit food preferences in adverse conditions, earthworms can extract sufficient nourishment from soil to survive. However earthworms feed mainly on dead and decaying organic waste and on free living soil microflora and fauna.

Under ideal conditions, worms can consume amount of food higher than their body weights, the general rule-of-thumb is consumption of food weighing half of their body weight per day. Livestock excreta, goat manure, cattle dung, horse manure or pig manure is the most commonly used worm feedstock as these materials have higher nitrogen content.

When the material with higher carbon content is used with C: N ratio exceeding 40: 1, it is advisable to add nitrogen supplements to ensure effective decomposition. The food should be added only as a

limited layer as an excess of the waste many generate heat. From the waste ingested by the worms, 5-10% is being assimilated in their body and the rest are being excreted in the form of vermicast.

c) Moisture

Perhaps the most important requirement of earthworms is adequate moisture. They require moisture in the range of 65-85%. The feed stock should not be too wet otherwise it may create anaerobic conditions which may be fatal to earthworms.

d) Aeration

Factors such as high levels of fatty/oily substances in the feedstock or excessive moisture combined with poor aeration may render anaerobic conditions in vermicomposting system. Worms suffer severe mortality partly because they are deprived of oxygen and partly because of toxic substances (e.g. ammonia) produced under such conditions. This is one of the main reasons for not including meat or other fatty/oily wastes in worm feedstock unless they have been pre composted to break down the oils and fats.

e) Temperature

The activity, metabolism, growth, respiration and reproduction of earthworms are greatly influenced by temperature. Most earthworm species used in vermicomposting require moderate temperatures from 10 – 35^o C. While tolerances and preferences vary from species to species, Earthworms can tolerate cold and moist conditions far better than hot and dry conditions. For *Eisenia foetida* temperatures above 10°C (minimum) and preferably 15°C are maintained for maximizing vermicomposting efficiency and above 15°C (minimum) and preferably 20°C for vermiculture. Higher temperatures (> 35°C) may result in high mortality. Worms will redistribute themselves within piles, beds or windrows such that they get favorable temperatures in the bed.

f) pH

Worms can survive in a pH range of 5 to 9, but a range of 7.5 to 8.0 is considered to be the optimum. In general, the pH of worm beds tends to drop over time due to the fragmentation of organic matter under series of chemical reactions. Thus, if the food sources are alkaline, the effect is a moderating one, tending to neutral or slightly acidic, and if acidic (e.g., coffee grounds, peat moss); pH of the beds can drop well below 7. In such acidic conditions, pests like mites may become abundant. The pH can be adjusted upwards by adding calcium carbonate.

g) Other Important Parameters

There are a number of other parameters of importance to vermicomposting and vermiculture:

7.1. Pre-composting of organic waste: Scientists reported the death of *Eisenia foetida* after two weeks in the fresh cattle solids although all other growth parameters such as moisture content, pH, electrical conductivity, C: N ratio, NH_4 and NO_3 - contents were suitable for the growth of the earthworms. They attributed the deaths of earthworms to the anaerobic conditions which developed after two weeks in fresh cattle solids. It is established that pre-composting of organic waste is very essential to avoid the mortality of worms.

Salt content: Worms are very sensitive to salts, preferring salt contents less than 0.5% in feed. If seaweed is used as a feed (and worms do like all forms of seaweed), then it should be rinsed so as to reduce salt content. Some manure has high soluble salt contents (up to 8%). This is not usually a problem when the manure is used as a feed, because the material is usually applied on top and worms can avoid it until salts are leached out. If manures are to be used as bedding, they can be leached first to reduce the salt content. This is done by simply running water through the material for some time. If the manures are pre-composted outdoors, salts will not be a problem.

Urine content: If the manure is from animals raised or fed off in concrete lots, it will contain excessive urine because the urine cannot drain off into the ground. This manure should be leached before use to remove the urine. Excessive urine will build up toxic gases like ammonia in the bedding.

Other toxic components: Different feeds can contain a wide variety of potentially toxic components. Some of the more notable are:

- **De-worming medicine:** in manures (particularly horse manure): Most modern deworming medicines break down fairly quickly and are not a problem for vermicomposting or vermiculture. However, application of fresh manure from recently de-wormed animals could prove harmful.
- **Detergent cleansers industrial chemicals, pesticides.** These can often be found in feeds such as sewage or septic sludge, paper-mill sludge, or some food processing wastes.
- **Tannins.** Some trees, such as cedar and fir, have high levels of these naturally occurring substances. They can harm worms and even drive them away from the beds. It has been pointed out that pre-composting of wastes can reduce or even eliminate most of these threats. However, pre-composting also reduces the nutrient value of the feed.

Pests and Diseases

Moles prey on earthworms and hence are often a problem when using windrows or other open-air vermicomposting systems. Damage due to rats and moles can be prevented by putting some form of barrier, such as wire mesh, paving, or a good layer of clay, under the windrow. Putting some type of windrow cover over the material will eliminate damage to worms by birds, apart from improving moisture retention and excessive leaching likely during high rainfall events. Centipedes eat compost worms and their cocoons.

Fortunately, they do not seem to multiply to a great extent within worm beds or windrows. If they do become a problem, one method suggested for reducing their numbers is to heavily wet (but not quite flood) the worm beds. The water forces centipedes and other insect pests (but not the worms) to the surface, where they can be destroyed by means of a hand-held propane torch. Ants are more of a problem because they consume the feed meant for the worms. This problem can be checked by

avoiding sweet feeds in the worm beds and maintaining a pH of 7 or slightly higher. White and brown mites compete with worms for food and can thus have some economic impact, but red mites are parasitic on earthworms.

They suck blood or body fluid from worms and they can also suck fluid from cocoons. The best prevention for red mites is to make sure that the pH of the bedding is neutral or slightly alkaline. This can be done by keeping the moisture levels below 85% and through the addition of calcium carbonate, as required. Sour crop or protein poisoning happens when worms are overfed leading to protein build up in the bedding and production of toxic acids and gases due to protein decay. The better option is to

Maintain proper feed quality and micro-environmental conditions which rule out any possibility of sour crop [8].

2.8 Factors Affecting Vermicomposting

2.8.1 Effect of temperature

According to kinetics of biochemical reaction and amount of energy production in bio organisms, biological activity is depended on temperature. Bacteria activity is greatly depended on temperature. It plays a vital function in compost and vermicompost process. Also, the worms' activities are widely affected by temperature. Whole the process which named vermicomposting indeed is playing natural role of worms and bacteria in their life to live.

So, this process depends on temperature. We know that the bacterial activity multiplies by two per each 10°C increase in temperature and the worms have well activity around 15-30°C. Several studies showed that a temperature range around 15-25°C is more appropriate for vermicomposting. The most decrease in carbon percentage and C:N ratio have obtained in this range of temperature in a study among three temperature ranges of 5-15, 15-25 and 25-35°C. Also it has been the best temperature for the worms' growth.

2.8.2 Effect of moisture content

The bacteria need water to proceed biochemical reactions and many of essential substances are solved in water for transmission through membrane into bacterial cytoplasm. It's known that, the bacterial activity extremely decreases in moisture content lower than 40% in a composting process and it almost stops in lower than 10%. Also we know, the worms need to be in a moist ambient because they need to keep their skin wet for respiration through it.

Recommended moisture for bacterial activity in compost process is around 55%, but the worms need some more moist to have their maximum growth and activity. It's known that, there is a relationship between moisture content and temperature in effecting on vermicompost process. In a comparative study on vermicomposting process and the worms' growth in various ranges of temperature and moisture, results showed 65-75% is a suitable range of moisture for all ranges of vermicomposting temperature.

2.8.3 Effect of pH

Many kinds of bacteria can live in low pH and some live in a pH as low as 2 or even lower. Other kinds of microorganisms which are active in compost and vermicomposting are fungi which can keep their activity in lower pH around 4. Also some bacteria tolerate higher pH than neutral. However, recommended pH range for compost is around 6.5-7.5. In vermicomposting the worms are sensitive to pH and they don't tolerate a wide range of pH and they prefer neutral pHs. Although, some studies showed that the worms can be alive in some higher or lower pHs, but the recommended pH for vermicomposting is around 6-7. In lower pH the bacterial activity decrease and worms which don't like it will escape to a place with better condition if they can find or most probably die.

2.8.4 Effect of C: N ratio

The major effect of C: N ratio in vermicompost is on bacterial activity, high C:N ratio decrease bacterial activity because of nitrogen shortage that is essential for bacteria and takes part in proteins,

amino acids and other structural substances of bacteria. On the other hand low C:N ratio will led to loss of the nitrogen as in form of NH_3 to atmosphere. The worms also hate the high concentration of ammonia and will escape from it.

Vermicomposting process will progress properly by starting the process with a C:N ratio around 25-30 and it will decrease during the process. Carbon reduces because heterotrophic bacteria use organic material as source of electron and carbon is oxidized to CO_2 and releases to atmosphere. However, bacterial nitrogen usage is so less than carbon and some kind of bacteria can stabilize atmospheric nitrogen into compost. Also, autotrophic bacteria use ammonia as source of electron and convert it to nitrite and nitrate which remain in compost unless an anoxic condition occurs. In this condition nitrate and nitrite reduced and nitrogen releases to atmosphere as N_2 .

2.8.5 Effect of preparation time on vermicompost

Before feeding the worms with organic waste materials, organic materials are composted for a while without worms. This causes the of organic matter decomposition spent thermophilic level and the worms which are sensitive to high temperature will not damage. Also, the compost production process forward faster, and many of pathogens are destroyed in thermophilic phase. Duration of the preparation is impressive on quality of the resulting compost, vermicomposting process and space and facilities needed for preparation.

2.8.6 The effect of worm population on vermicomposting

In vermicomposting process the worms have a vital function. So, the worms' population in waste is effective on vermicomposting process and quality. So, a question about vermicompost is how many worms must be applied for vermicomposting to get a prefect process and fine vermicompost? Some researchers have done efforts to find the answer. It is clear that, each species of worms have individual properties and the answer may be different. Some on vermicomposting of food waste. In this study four populations of worms including, 6, 12, 18 and 24 worms set in 70g of food waste and a blank,

food waste with no worm, were monitored for a month of vermicomposting. The results showed that, increasing in number of worms can be effective in maintenance of pH around neutral range.

It is important during vermicomposting process. Also, it is important for the obtaining vermicompost to be at the standard range of a class's range, 6.5-8.4, more number of worms can much aerate the waste and prevent process from anaerobic condition which reduces pH. Also, in aerobic condition ammonia is consumed and this can prevent from much pH increasing. Best result about C:N ratio in this study has seen in the population of 18 worms per 70g of waste . The C:N ratio declined with increasing of worm population until 18 worm and then increased in population of 24 worms. This result may be due to no more increasing of number and activity of bacteria in presence of more worms, or slaking of worms' activity which some limiting factors such as food or other factors can be causes of that [12].

2.9 Benefits of Vermicomposting Technology

Composting is an effective 'zero waste' method for treating organic wastes, which follows nature's way of recycling. There are several advantages of composting such as; a safe treatment option for high nutrient waste and the production of natural fertilizer as an end product. Aerobic composting is controlled and rapid while anaerobic composting is slow. However, it is high energy intensive process as requires continuous air supply. Aerobic conditions in vermicomposting is controlled and managed by earthworms, whereas man power, electrical energy and expensive engineering system are required for aerobic composting the benefits of vermicomposting technology can be seen in different aspects but in generally categorized in economic, health, and environmental perspectives.[12]

2.9.1 Economic

By returning nutrients back into the soil, vermicompost reduces the need for expensive chemical fertilizers. Vermicomposting conserves water as penetration and retention are improved, erosion and runoff are reduced.

Expensive landfill sites can be used for longer periods. The amount of waste you send to the landfill will be reduced by about 1/3. The cost of garbage collection services paid by municipal taxes could decrease as disposal and processing costs are reducing [14].

Composting is free and easy, requiring very little if any cost to set up and Vermicomposting is Energy independent technology Enhanced soil productivity It can be additional income for commercial activity Vermicomposting Technology is easy transfer and adoption.

2.9.2 Health aspects

Reducing waste causing disease like smoke borne diseases: headache, eye-irritation, respiratory tract infections etc. improved and cleaned environment easier, clean cooking and better hygiene protect from heavy metal accumulation due to water

2.9.3 Environmental (Ecological) Benefits

Vermicomposting acts like a sponge, helping soil retain moisture and nutrients. Soils rich in compost experience less erosion and reduced quick runoff. Vermicomposting helps break down heavy clay soils allowing better root penetration and improving drainage. Vermicomposting improves moisture retention in sandy soils so water loss and leaching are reduced or eliminated.

Vermicompost promotes fertility by providing higher quantities of macro and micro nutrition, as well as improving the availability of the nutrition. Compost stabilizes and regulates pH at optimum level for nutrient availability. Compost eliminates or reduces the need for chemicals, which may pollute ground water [14].

There is no toxic or harmful residual in vermicomposting. Vermicomposting reduces harmful greenhouse gas emissions. Compost stimulates plant root development. Overall root environment is improved due to better structure, porosity, and density of the soil. Vermicomposting adds, stimulates, and diversifies microbial biomass. This helps control or suppresses soil-borne plant pathogens [14].

Reduction of green-house gases and prevention of land fertility degradation due to excessive use of chemical fertilizers, Prevent aesthetic value of the environment, decreases unpleasant smell of the environment, and protect ground water from leachet pollution.

2.10 Advantages of vermicompost of over chemical fertilizers

In current practices we are using the chemical fertilizer to fulfill the plant nutrients requirement which have a serious impact on the soil and water bodies. The salinity of soil is one of the major threats by using utilizing excessive chemical fertilizer. The chemical fertilizers have a serious impact on as follows.....

- o Loss of soil fertility (reducing food production),
- o Plants can utilize only 20 - 30% nutrients, the balance either evaporates or is washed into water bodies (i.e. ground water, surface waters, etc.), and Ground water and surface water pollution,
- o Destruction of marine life (declining fish populations, reducing a major source of protein for human consumption), and Loss of biodiversity on land and in water,
- o Global warming and ozone depletion, when nutrients form gases that escape into the atmosphere and they are either sterile or have negligible microbiological activity, and Salinity of soil.
- o It restores microbial population which includes nitrogen fixers, phosphate solubilizers etc.
- o Provides major and micro- nutrients to the plants and Improves soil texture and water holding capacity of the soil.
- o Provides good aeration to soil, thereby improving root growth and proliferation of beneficial soil microorganisms.
- o Decreases the use of pesticides for controlling plant pathogens and Improves structural stability of the soil, thereby preventing soil erosion.
- o Enhances the quality of grains/ fruits due to increased sugar content.
- o It is more vulnerable to environmental pressures, such as temperature, freezing Conditions and drought [12].

3 MATERIALS AND METHODS

3.1 Materials

3.1.1 *Eisenia foetida*

Healthy Earthworms belong to phylum- Annelida, sub class- Oligochaeta. Are collected from Ethiopia agricultural research Ambo plant protection research center maintained in the laboratory with horse manure as culturing material for more than two months. In the present studies the well known species of earthworm used was *Eisenia foetida*.

They are invertebrate in nature. Adult earthworms commonly known as red wigglers were randomly picked (Clitellated or un-clitellated) for use in the experiments from three stock cultures containing 80-120 earthworms in each twelve bin and zero earthworms for the control.

Important parameters for breeding

As discussed in introduction, the reproduction of earthworm depends on several important parameters, which we should always monitor whenever necessary. The most important of all parameters are temperature, moisture and the pH. The following parameters shown in Table1 are measured once a week for a period of four weeks and the average values are considered.

Table 1 Regulated parameters during the breeding of earthworms.

S/N	Parameters.	Optimum range	Average
1	Temperature	(16 ^o c-25 ^o c)	18 ^o c
2	Moisture	65%-85%	72%
3	pH	5.5 – 9	6.8

3.1.2 Solid tannery sludge (STS)

Fresh STS was obtained from the wastewater treatment plant of a tannery industry located near “kolfe keraniyo sub-city asko adis sefer” Addis Ababa, Ethiopia.

The main characteristics of STS were: total solids: pH (1: 10 ratio): 8.23, TOC: 11.14 %, TKN: 2.271% and C: N ratio: 5.91, the sludge was dried in shade prior to use for vermicomposting.

3.1.3 Cow dung (CD)

Fresh CD was collected from the “yeka sub-city” kotebe around 02 kebele private diaries Addis Ababa Ethiopia. It was prepared and and pre-composted. The main characteristics of CD were: pH (1: 10 ratio) 7.79, total organic carbon (TOC): 11.14 g/kg, total Kjeldhal nitrogen (TKN): 2.271 g/kg and C: N ratio: 4.91

3.1.4 Horse manure (HM)

Fresh horse manure was collected from Addis Ababa arada sub-city “janmeda” sport center pre-composting Anaerobically digested horse manure was procured from Addis Ababa Jalmeda square. The raw material used in the biogas plant was the cow dung collected from an intensively live stocked cow farm at village Agroha, Hisar, India. The main characteristics of BPS were: pH (1: 10 ratio) 8.30, total organic carbon (TOC): 11.14 g/kg, total Kjeldhal nitrogen (TKN): 2.271 g/kg, and C: N ratio: 4.905.

3.1.5 Calculation organic and total carbon

Percent total carbon (TC)

$$TC (\%) = \frac{\text{carbon (g)}}{W (g)}$$

Where, W (g) = dry sediment analysis weight (g)

Percent total organic carbon content (TOC)

$$\text{TOC (\%)} = \frac{\text{organic carbon (g)}}{W \text{ (g)}}$$

Percent Total Inorganic Carbon Content (TIC)

$$\text{TIC (\%)} = \text{TC (\%)} - \text{TOC (\%)}$$

Table 2 Composition of tannery sludge with cow dung and horse manure

s/n	Initial earthworm density(0.9g/individual)	Tannery sludge(g)	Caw dung(g)	Horse manure(g)
1	80	500	500	0
2	100	600	400	0
3	120	700	300	0
4	80	500	0	500
5	100	600	0	400
6	120	700	0	300

3.2 METHODS

3.2.1 Experimental design

Vermicomposting of tannery sludge biomass was conducted under laboratory conditions (in darkness, at an average temperature of $18 \pm 5^\circ\text{C}$, and a substrate moisture content of (65-85%). Three -Litter test circular plastics (with 2 duplications for each tannery sludge combination) were filled with horse manure and cow dung. Into each reactor, 80,100,120 individuals [around 50% adult and 50% immature of *E. fetida* of known biomass (80 ± 5.1 g)] were introduced. Three treatments with three levels were established: (1) tannery sludge + horse manure (1:1, 3:2, 7:3 dry weight), (2) tannery sludge + cow dung (1:1, 3:2, 7:3 dry weights) earthworm proportion for each sample compositions (80, 100, 120). Earthworms were utilizing the same type of wastes.

3.2.2 Experimental procedures

Experiments were performed in worm-bins measuring 0.21 m ´ 0.11 m ´ 0.13 m (length´ width´ depth). This provided 0.003 m³ of exposed top surface. Known weights of earthworms (*Eisenia foetida*), commonly known as red wigglers, were introduced into each of the similar worm-bins, to provide the desired stocking densities. To affect the four desired stocking densities mentioned above, earthworm live-biomass loadings were 80, 100, and 120 individuals, respectively.

Two duplicates for each of the twelve stocking densities were made. Each of the Two duplicates for every stocking density were, all the systems were fed for six weeks and thereafter fed continuously on a weekly basis until the six week. During the first two weeks, feed consisted of four parts biosolids to three parts tannery sludge, by dry weight. The mixture of tannery sludge, cow dung and horse manure was used to provide bedding for the earthworms as well as a carbon supplement.

The experiments were conducted in Addis Ababa University Addis Ababa Institute of technology environment engineering laboratory whose temperature was 17°C in average. The substrate material was maintained moist by spraying/ sprinkling the surface with water every five days using a spray can.

In all the worm bins, moisture was maintained at an average of 65% - 85%. At every feeding, the following feed parameters were determined: moisture content of the feed material, pH, temperature, moisture, C: N ratio the volatile solids and the ash contents.

These analyses were carried out immediately after the samples were obtained. To minimize microbiological decomposition until analyzed. The samples were preserved after collection and brought to the laboratory for characterization. The characteristics of the solid waste will determine in accordance with Standard methods for the analysis of tannery solid waste. The characterization of the dried solid waste (sludge, shavings and buffing dust) such as pH, moisture content, ash content, chemical oxygen demand (COD), Total Organic Carbon (TOC), Cow dung (CD) and horse manure were used as feed mixtures.

3.2.3 Parameter analysis

Weight of compost, chemical analysis of compost and the state of earthworms' populations was examined. Using manual substrate segregation (with all specimens counted and weighed plus cocoons counted), average numbers and total biomasses of earthworm populations were determined. The data were expressed as means with standard deviations. The hypothesis of equal variances in both studied populations was tested using an appropriate version of Student *t*-test, at a significance level 0.05. The composition of tannery sludge vermicomposting was also determined, with 12 samples of each vermicomposting taken for analysis.

Standard methodologies were applied for all parameters. Wonjji Sugar Factory Research Department soil and water management team soil laboratory was used to perform the following determinations: organic carbon (OC), total organic carbon (TOC) by the wet dichromate potassium oxidation method, pH and electrical conductivity measured at a 1:5 sample/water ratio. A batch aerobic reactor under optimum pH, moisture and mesophilic condition for a vermicomposting period of 40 to 45 days will be used in the laboratory.

Compost performance was determined by water holding capacity, porosity and for micro and macro nutrients. Water holding capacity and nutrient availability was measured by vegetation cultivation. Organic matter content was estimated from weight lose upon ignition at 550°C for three hours. pH by pH meter , temp by thermometer total nitrogen by Kjeldhal method phosphorus by extraction in 0.5M Na HCO₃ and was analyzed by standard calorific method or vanado-molybdate method. The total amounts of phosphors, K and Na was determined by the photometric method has digest the samples in HNO₃:HClO₄:H₂SO₄ at a different ratio in a TECATOR device.

Table 3 the initial characteristics of tannery sludge, cow dung and horse manure

S/N	Lab code	Clintes' code	pH (1:10)	EC (dS/m)	OC (%)	TN (%)
1	01	Cow dung	7.79	2.61	10.21	1.291
2	02	Horse Manure	7.90	5.43	28.59	1.879
3	03	Tannery Sludge	8.23	10.29	11.14	2.271

3.2.4 Statistical Analysis

Data was analyzed using Microsoft excel and correlation analysis. Considering the treatments as in dependent variables, a significance level of $p < 0.05$ was considered throughout the study.

4 RESULT AND DISCUSSION

4.1 Results

The results of this studies showed that the feed materials and time of preparation is proper for pre-composting. This time seems to be enough for pass the initial composting thermophilic period and also for loss of most pathogens. In present study, the impact of preparing time on vermicomposting was investigated in tannery sludge waste with different amendment had been made on it by adding cow dung and horse manure for better aeration or adjust C:N ratio.

In this study, tannery sludge wastes were mixed with different proportion cow dung and horse manure. The preparation time of different days have entered in Vermicomposting process and were monitored during the process. Results showed that, duration of preparation is effective on changes in C:N ratio during the vermicomposting process. Best results and lowest C:N ration obtained along the end of vermicomposting days of preparation. If sufficient aeration and well composting conditions provided during preparation by material amendment, aeration or by any means, anaerobic condition was not occurs in longer preparation duration.

The initial physico-chemical analysis of tannery sludge, horse manure and cow dung was done in Wonjji Sugar Factory Laboratory used in the experiments is presented in the table (4) the tannery effluent was characterized.

4.1.1 Characterization of Compositions

Table 4 Initial physico-chemical analysis compositions

s/n	Code of treatment	pH (1:10)	EC (ds/m)	OC (%)	TN (%)	C:N ratio
1	Tc ₁₁	8.01	6.45	10.675	1.781	5.9932
	Tc ₃₂	8.054	7.218	10.768	1.879	5.7307
3	Tc ₇₃	8.098	7.986	10.861	1.977	5.4937
4	Th ₁₁	8.065	7.86	19.865	2.075	9.5735
5	Th ₃₂	8.098	8.346	18.12	2.1142	8.5706
6	Th ₇₃	8.131	8.832	16.375	2.1534	7.6043

Before vermicomposting the composition had electrical conductivity (EC) from 6.45 dSm⁻¹ to 8.832 dSm⁻¹, Total N content of 1.781g kg⁻¹ 2.1534 g kg⁻¹ and total organic carbon from 10.675% to 16.375% and pH of the composition was from 8.01 to 8.131 were characterized. This result shows the maturity of the composition not reached to the standards of fertilizer. It has a low C/N ratio but finally the expected results should be in a standard form because of vermicomposting process.

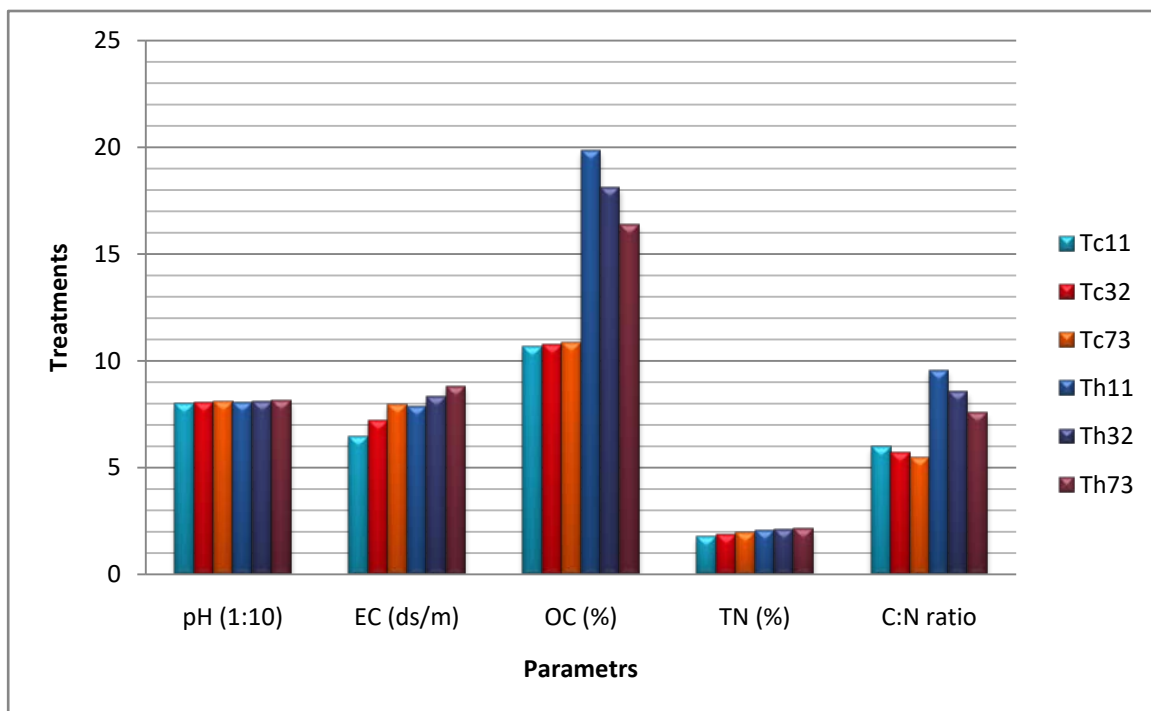


Figure 4 Initial physico-chemical analysis compositions

The initial pre-composted compositions of the sample tannery sludge and the feed mixtures (horse manure and cow dung) with a pH of 8.01, to 8.131 had a C: N ratio, electrical conductivity, less than an optimum range for vermicomposting (Figure 4). After 45 days, the vermicompost had achieved the characteristics of non-chemical fertilizer or vermicompost.

4.1.2 Reproduction rate of earth worm during Vermicomposting

Table 5 Reproduction rate of *Eisenia foetida* in different treatments

s/n	Treatment(T) No	Mean initial worm density	Maximum No worm after 40 days	Growth rate/worm/day
1	T _{C11}	80	92	+0.30/day
2	T _{C32}	100	116	+0.40/day
3	T _{C73}	120	135	+0.375/day
4	Th ₁₁	80	96	+0.40/day
5	Th ₃₂	100	122	+0.55/day
6	Th ₇₃	120	143	+0.575/day

The vermicomposting was dark brown in color and earthy odour after 45 days of earthworm's activity. The changes in worm biomass for all the treatments over the experimentation period are illustrated in Table5. At the end of the 40-45 days, the earthworm biomass had increased in all the treatments. In general, the maximum biomass gain was recorded in Th₇₃ (120±0.575 worm /day) and Th₃₂ (100±0.55 worm /day) treatments. Similarly, the maximum growth rate was achieved in Th₇₃ (0.575 worm/day) and Th₃₂ (0.55 worm /day) than the other treatments. There was no statistical significant difference among Th₇₃ and Th₃₂ treatments for number of worms ($P < 0.05$). The growth rate has been considered as a good comparative index to compare the growth of earthworms in different feeds [21].

In the present study addition of cow dung and horse manure in the tannery sludge results an increase in number of *Eisenia foetida*. Growth and reproduction of earthworms require OC, N, adequate temperature, moisture, and pH which are obtained from cow dung, horse manure and tannery sludge [21]. In the present study higher growth rate of earthworms during vermicomposting may be due to the more palatability of feed by worms and the slow growth rate in other treatments with *Eisenia foetida* was possibly due to the presence of some growth retarding substance in it.

Table 6 Average reproduction rate of earth worms

s/n	Treatment(T) No	Mean initial worm density	Maximum No of worm after 40 days
1	Tc ₁₁	80	92
2	Tc ₃₂	100	116
3	Tc ₇₃	120	135
4	Th ₁₁	80	96
5	Th ₃₂	100	122
6	Th ₇₃	120	143

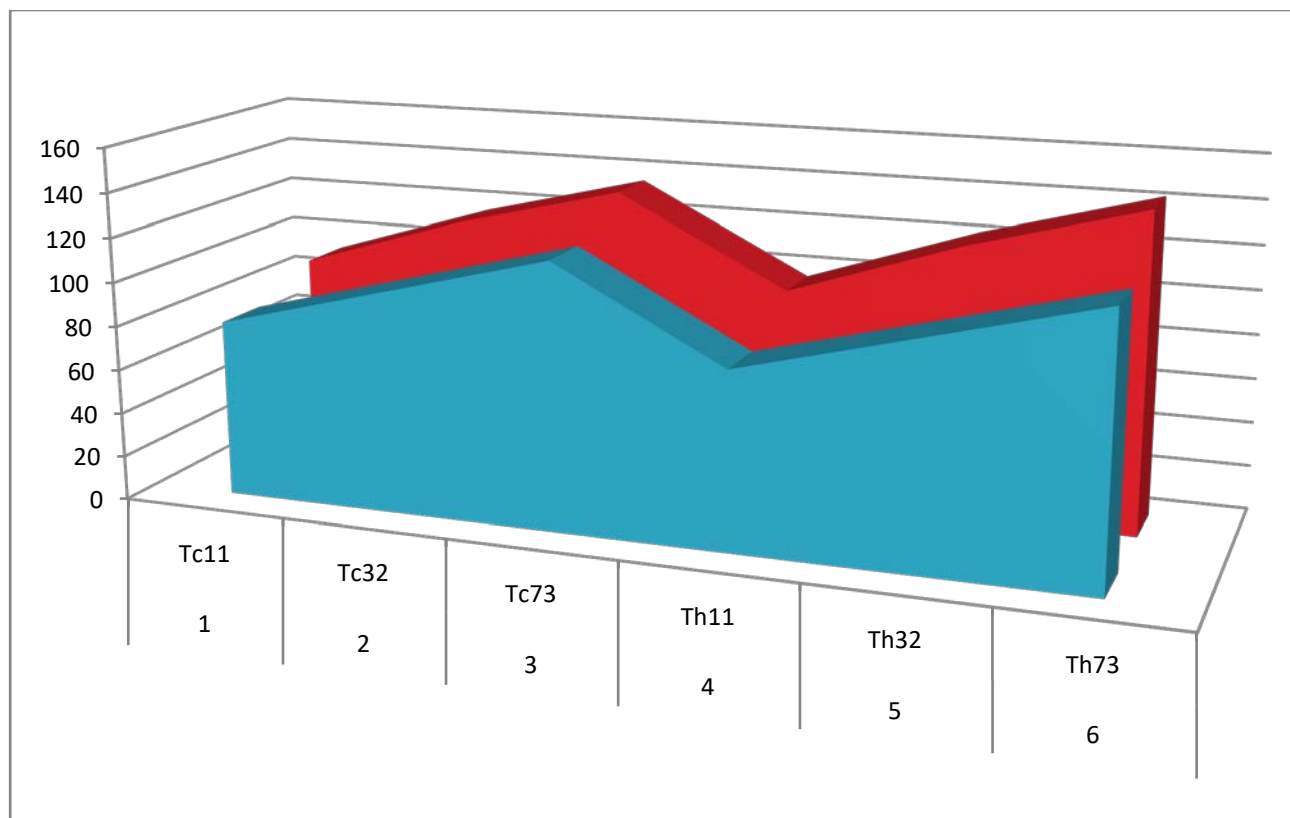


Figure 5 Reproduction rate of *Eisenia foetida*

Figure 5 describes the reproduction rate of *Eisenia Foetida* during vermicomposting process and also shows the maximum and minimum number of worms in tannery sludge mixing with cow dung and horse manure at the same time in different ratios, relatively the reproduction rate is maximum in the composition of horse manure and tannery sludge than that of cow dung and tannery sludge Because in aeration system horse manure preferable than that of cow dung.

4.1.3 Experimental results of vermicomposting (Observations)

The final experimental results of vermicomposting were done in Wonji Sugar Factory soil and water management team soil laboratory all the results like OC (%), pH (1:5), Ec ds/m(1:5), TN (%), P, K were described in table 6.

Table 7 Experimental results and observations

s/n	Lab code	pH (1:5)	Ec ds/m(1:5)	OC (%)	TN (%)	C:N	P	K
1	Th11	8.78	15.46	26.15	1.74	15.03	0.98	0.73
2	Th11	8.47	14.20	21.00	1.69	12.43	0.91	0.62
3	Th32	8.20	17.74	22.39	1.56	14.35	0.88	0.70
4	Th32	8.22	20.10	22.59	1.64	13.77	0.94	0.65
5	Th73	8.22	16.30	23.18	1.78	13.02	0.78	0.59
6	Th73	8.31	16.02	22.19	1.83	12.13	0.93	0.55
7	Tc11	8.20	11.86	20.01	1.29	15.51	0.89	0.61
8	Tc11	8.31	11.33	17.63	1.18	14.94	0.77	0.68
9	Tc32	8.20	13.62	16.25	1.33	12.22	0.83	0.66
10	Tc32	8.38	10.25	18.23	1.23	14.82	0.90	0.56
11	Tc73	8.33	10.59	19.22	1.44	13.35	0.85	0.64
12	Tc73	8.23	13.78	15.85	1.06	15.54	0.79	0.50

Electrical conductivity and pH of vermicomposting also indicates the maturity of the final product so that two of the indicators are in recommended value. The next (Table 7) and (figure 6) shows the value of electrical conductivity and pH of vermicomposting.

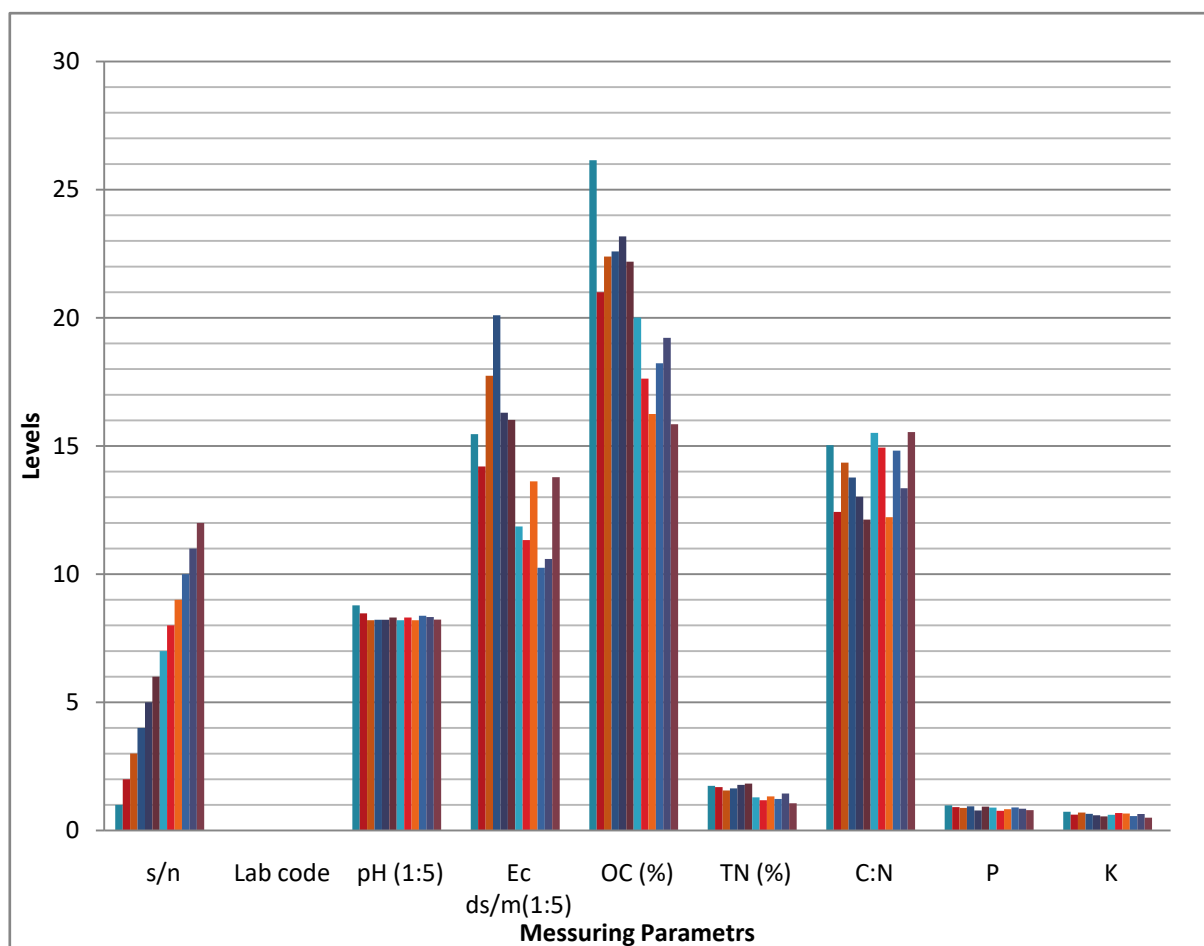


Figure 6 combined representation of all measuring parameters

Figure 6 shows the main characteristics of chemical or bio fertilizers like nitrogen, phosphorus, potassium, pH, electrical conductivity and carbon to nitrogen ratio and also the micro-nutrients are recommended to present in the fertilizer so, because of these reason the content of vermicompost in this study was checked all the nutrients specially the macro- nutrients the results are in the recommended range of bio-fertilizer. Earthworms have the ability to absorb heavy metals by nature so, that heavy metal accumulation of the vermicompost is also not above the standard.

Table 8 Electrical conductivity and pH of Vermincomposting

s/n	Lab code	pH (1:5)	Ec ds/m(1:5)
1	Th11	8.78	15.46
2	Th11	8.47	14.20
3	Th32	8.20	17.74
4	Th32	8.22	20.10
5	Th73	8.22	16.30
6	Th73	8.31	16.02
7	Tc11	8.20	11.86
8	Tc11	8.31	11.33
9	Tc32	8.20	13.62
10	Tc32	8.38	10.25
11	Tc73	8.33	10.59
12	Tc73	8.23	13.78

The above table describes the functionality of electrical conductivity and pH of the vermicompost after the whole process taken place these results are in recommended value or under the standards of bio-fertilizer.

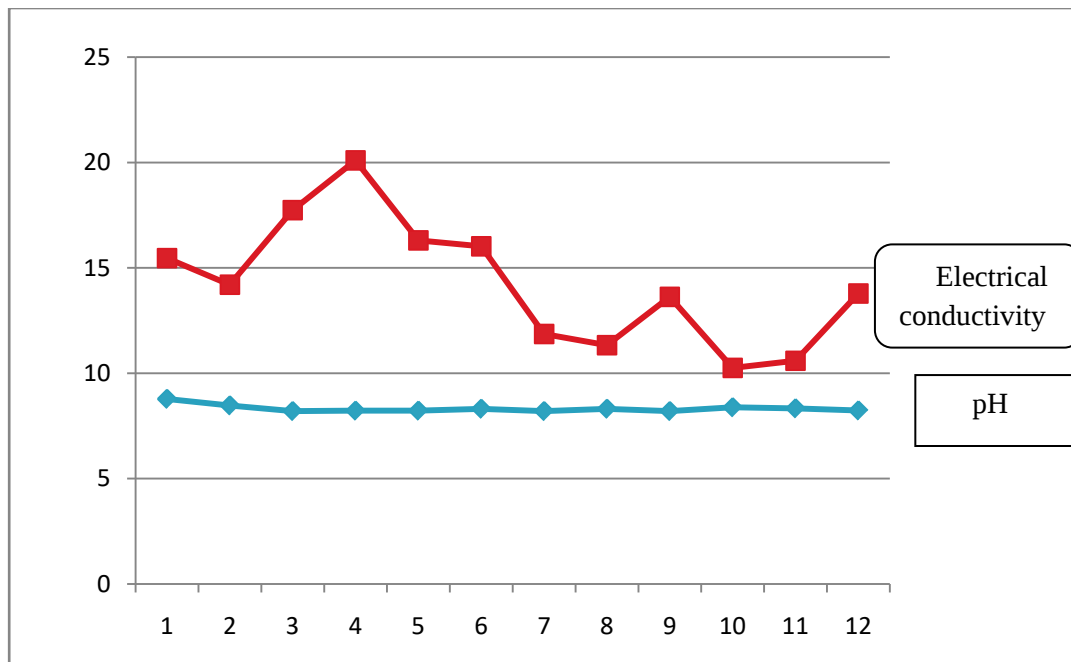


Figure 7 Electrical conductivity and pH chart

Figure 7 shows electrical conductivity and pH of vermicomposting the red color shows electrical conductivity and the blue one shows pH of the vermicompost y-axis indicates the level of the vermicompost and x-axis indicates number of treatments. So, that having recommended electrical conductivity and pH value (5.5-9) shows the maturity of vermicompost. The electrical conductivity is done in (1:5). To measure electrical conductivity in accurate manure it needs sample to solvent ratio (1:1) but there is a laboratory equipment limitation so, the option is to measure (1:5) ratio.

4.1.4 Performance measurement of vermicomposting

Performance evaluation of this these is done by cultivating salad within two months in three different plastic containers having 0% soil+100% vermicomposting, 50% soil+50% vermicomposting, 100% soil+0% vermicomposting.

Table 9 weight of cultivated salad for performance evaluation

Treatments	No of leaves	Leaf weight in gram
T1	04	121.50
T2	04	167.80
T3	04	203.40
T2-T1	No difference	46.30
T3-T2	No difference	35.60
T3-T1	No difference	81.90

Table nine mainly describes the effect of vermicomposting of tannery sludge on the biomass of salad and clearly shows the performance vermicomposting by measuring the weight of cultivated salad after 53 days. As the vermicompost increases from 0% - 100% the biomass of the salad also increases proportionally.

Table 1 leave weight deference of treatments

S/n	Treatments	Leaf weight in gram
1	T1	121.5
2	T2	167.8
3	T3	203.4

Vermicomposting contains plant growth promoters with other nutrients and improves physical, chemical and biological properties of soil on repeated application. Many important factors, such as the presence of beneficial microorganisms or biologically active plant growth influencing substances such as phytohormone are released by beneficial microorganisms present in the vermicompost rich soil. Root initiation, increased root biomass, enhanced plant growth and development and sometimes, alterations in plant morphology are among the most frequently claimed effects of vermicompost treatment [23].

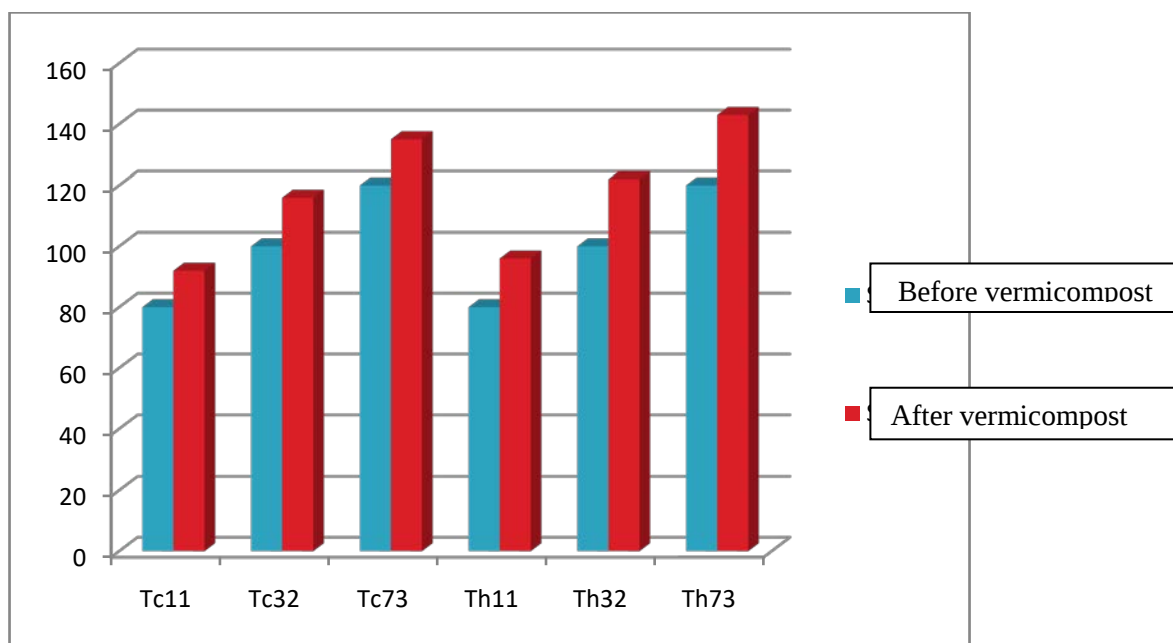


Figure 8 direct effect of vermicomposting on biomass salad

Figure 8 describes the effect of vermicomposting on the cultivated salad, by measuring the weight of the same number of leaves in the same condition and calculating the difference from every treatment. The product or vermicomposting of tannery sludge waste had appositive impact on salad leave. The weight of salad leaves increased as the proportion of vermicomposting increased. Vermicompost had direct effect on the bio-mass of salad.

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As a processing system, the vermicomposting of organic waste is very simple. Worms ingest the waste material - break it up in their rudimentary gizzards - consume the digestible/ putrefiable portion, and then excrete a stable, humus-like material. Vermitechnology can be a promising technique that has shown its potential in certain challenging areas like augmentation of industrial waste, waste recycling, management of solid wastes etc.

Tannery wastes generation is increasing every year and a suitable method for tannery sludge management is necessary in order to decrease this environmental problem. It has great potential as fertilizer apart from its hazardous and phytotoxic nature. The toxicity is due to very high content of microelements, salts and heavy metals.

Application of tannery sludge in agriculture or for soil reclamation is an effective solution for its management. This potential was screened using different species of earthworms and bulking materials the vermicomposted tannery sludge may be suitable to use as a source of essential nutrients to the plants and a good soil conditioner. The effect of tannery sludge vermicompost (VC) rates on growth, nodulation and N fixation of salad was investigated.

- ▶ Effective disposal and reuse of waste and industrial sludges are possible.
- ▶ This process can eliminate the odour, environmental, social and economical problems.
- ▶ It is a cost effective, fast and eco-friendly method of waste disposal.

5.2 Recommendation

There is no tannery sludge treatment option in Ethiopia up-to-date utilization of these wastes used to minimize or avoiding pollution effect on the environment and human health on the other hand, vermicomposting of tannery sludge had a greater potential as organic biofertilizers for the growth and development plants and vegetables for the sustainable agriculture and ecological advantages. Despite of the next limitations vermicomposting technology is a best option.

- Since tannery sludge has a serious environmental problem, it is possible to convert to bio-fertilizer and replacing the chemical fertilizer, but additional research including optimization of parameters should be regulated.
- Different bulking materials rather than horse manure or cow dung having high carbon content may be best options to improve the standards of vermicomposting in micro and macro nutrients because tannery sludge has high nitrogen content to balance the carbon to nitrogen ratio.
- Laboratory equipments like, atomic absorption spectroscopy (AAS), chromatography and mass spectrometry as well as the time schedule for under graduate and postgraduate must be recommended to cope up the research within the time schedule.
- This research is viable and recommendable to field work for solve the entire problems of handling tannery sludge waste.

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APPNDIX₁

Laboratory procedures and principles

Procedures for Soil and Plant Analysis By Sahlemedhin Sertsu And Taye Bekele (2000)
National Soil Research Center Ethiopian Agricultural Research Organization

Soil pH

Principle

The pH is defined as the negative log of the hydrogen ion activity. Since pH is logarithmic, the H-ion concentration in solution increases ten times when its pH is lowered by one unit. The pH range normally found in soils varies from 3 to 9. Various categories of soil pH may be arbitrarily described as follows: strongly acid (pH < 5.0), moderately to slightly acid (5.0 - 6.5), neutral (6.5 - 7.5), moderately alkaline (7.5 - 8.5), and strongly alkaline (> 8.5).

Significance of pH lies in its influence on availability of soil nutrients, solubility of toxic nutrient elements in the soil, physical breakdown of root cells, cation exchange capacity in soils whose colloids (clay/humus) are pH-dependent, and on biological activity. At high pH values, availability of phosphorus (P) and most micronutrients, except boron (B) and molybdenum (Mo), tends to decrease.

Acid soils are rare in semi-arid dryland areas of the world; they tend to occur in temperate and tropical areas where rainfall is substantial; conversely, soils of drier areas are generally alkaline, i.e., above pH 7.0, as a result of the presence of calcium carbonate (CaCO_3); they visibly effervesce (fizz) when 10% hydrochloric acid is added dropwise to the soil. Calcareous soils with gypsum have somewhat lower pH values, while those with excess sodium (Na) have values over 8.5 (sodic soils).

Thus, soil pH is one of the most common measurements in soil laboratories. It reflects whether a soil is acid, neutral, basic or alkaline.

Apparatus

- pH meter with Combined Electrode.
- Glass rod.
- Glass beaker.

Reagents

- Deionized water.
- pH 7.0 buffer solution.
- pH 4.0 buffer solution.

Procedure

1. Weigh 50 g air-dry soil (< 2-mm) into a 100-mL glass beaker.
2. Add 50 mL DI water using a graduated cylinder or 50-mL volumetric flask
3. Mix well with a glass rod, and allow to stand for 30 minutes.
4. Stir suspension every 10 minutes during this period.
5. After 1 hour, stir the suspension.
6. Put the Combined Electrode in suspension (about 3-cm deep). Take the reading after 30 seconds.
7. Remove the Combined Electrode from the suspension, and rinse thoroughly with DI water in a separate beaker, and carefully dry excess water with a tissue.

Soil Electrical Conductivity (EC)

Principle

Soil salinity refers to the concentration of soluble inorganic salts in the soil. It is normally measured by extracting the soil sample with water (1:1 or 1:5 soil: water ratio, w/v) or in an saturated paste extract. However, soil: solution ratios of a 1:1 or wider ratio are more convenient where the soil sample is limited. Such extracts are rapid and salinity is measured by electrical conductivity (EC) using a conductivity bridge. The total salt content of a soil can be estimated from this measurement.

A more precise method involves evaporation of the aqueous extract and weighing the residue. Salinity is an important laboratory measurement since it reflects the extent to which the soil is suitable for growing crops. On the basis of a saturation extract, values of 0 to 2 dS/m (or mmhos/cm) are safe for all crops; yields of very sensitive crops are affected between 2 to 4 dS/m; many crops are affected between 4 and 8 dS/m; while only tolerant crops grow well above that level (Richards, 1954).

While salinity is largely a concern in irrigated areas and in areas with saline soils, it is not so important in rainfed agriculture. However, with increasing use of irrigation, there will be greater emphasis on EC measurement. The methodology of EC measurement is given in USDA Handbook 60 (Richards, 1954).

Apparatus

- Vacuum filtration system.
- Conductivity bridge.

Procedure

1. Prepare a 1:1 (soil: water) suspension, as for pH determination.
2. Filter the suspension using suction. First, put a round Whatman No. 42 filter paper in the Buchner funnel. Second, moisten the filter paper with DI water and make sure that it is tightly attached to the bottom of the funnel and that all holes are covered.
3. Start the vacuum pump.
4. Open the suction, and add suspension to Buchner funnel.
5. Continue filtration until the soil on the Buchner funnel starts cracking.
6. If the filtrate is not clear, the procedure must be repeated.
7. Transfer the clear filtrate into a 50-mL bottle, immerse the Conductivity Cell in the solution, and take the reading.
8. Remove the conductivity cell from the filtration, rinse thoroughly with DI water, and carefully dry excess water with a tissue.

Soil Organic Matter (SOM)

Principle

Soil organic matter represents the remains of roots, plant material, and soil organisms in various stages of decomposition and synthesis, and is variable in composition. Though occurring in relatively small amounts in soils, organic matter (OM) has a major influence on soil aggregation, nutrient reserve and its availability, moisture retention, and biological activity.

Organic carbon (OC) ranges from being the dominant constituent of peat or muck soils in colder regions of the world to being virtually absent in some desert soils. Cultivated, temperate-region soils normally have more than 3 - 4 % OM, while soils of semi-arid rainfed areas have normally less than 1% OM.

Most laboratories perform analysis for soil organic matter. The most common procedure involves reduction of potassium dichromate ($K_2Cr_2O_7$) by OC compounds and subsequent determination of the unreduced dichromate by oxidation-reduction titration with ferrous ammonium sulfate (Walkley, 1947; FAO, 1974). While the actual measurement is of oxidizable organic carbon, the data are normally converted to percentage organic matter using a constant factor, assuming that OM contains 58% organic carbon. However, as this proportion is not in fact constant, preferably report results as oxidizable organic carbon, or multiplied by 1.334 as organic carbon.

Apparatus

- Magnetic stirrer and teflon-coated magnetic stirring bar.
- Glassware and pipettes for dispensing and preparing reagents.
- Titration apparatus (burette).

Reagents

- a. Potassium Dichromate Solution ($K_2Cr_2O_7$), 1N

- Dry potassium dichromate in an oven at 105°C for 2 hours, cool in a desiccator (silica gel), and store in a tightly stoppered bottle.
 - Dissolve 49.04 g potassium dichromate in DI water, and bring to 1-L volume with DI water.
 - b. Sulfuric Acid (H_2SO_4), concentrated (98 %, sp. gr. 1.84)
 - c. Orthophosphoric Acid (H_3PO_4), concentrated.
 - d. Ferrous Ammonium Sulfate Solution [$(\text{NH}_4)_2\text{SO}_4 \cdot \text{FeSO}_4 \cdot 6\text{H}_2\text{O}$], 0.5 M
 - Dissolve 196 g ferrous ammonium sulfate in DI water, and transfer to a 1-L volume, add 5 ml concentrated sulfuric acid, mix well, and bring to volume with DI water.
 - e. Diphenylamine Indicator ($\text{C}_6\text{H}_5)_2\text{NH}$
 - Dissolve 1 g diphenylamine indicator in 100 mL concentrated sulfuric acid. Procedure
1. Weigh 1 g air-dry soil (0.15 mm) into a 500-mL beaker.
 2. Add 10 mL 1 N potassium dichromate solution using a pipette, add 20 mL concentrated sulfuric acid using a dispenser, and swirl the beaker to mix the suspension.
 3. Allow to stand for 30 minutes.
 4. Add about 200 mL DI water, then add 10 mL concentrated orthophosphoric acid using a dispenser, and allow the mixture to cool.
 5. Add 10 - 15 drops diphenylamine indicator, add a teflon-coated magnetic stirring bar, and place the beaker on a magnetic stirrer.
 6. Titrate with 0.5M ferrous ammonium sulfate solution, until the color changes from violet-blue to green.
 7. Prepare two blanks, containing all reagents but no soil, and treat them in exactly the same way as the soil suspensions.

Calculations

Percentage Organic Matter in soil:

% Oxidizable Organic Carbon (w/w) OC

$$OC = \frac{(V_{\text{blank}} - V_{\text{sample}}) \times 0.3 \times M}{W_t} \dots\dots\dots (1)$$

$$M = \frac{10}{V_{\text{blank}}} \dots\dots\dots (2)$$

$$\% \text{ Total Organic Carbon (w/w)} = 1.334 \times \% \text{ Oxidizable Organic Carbon} \dots\dots (3)$$

$$\% \text{ Organic Matter (w/w)} = 1.724 \times \% \text{ Total Organic Carbon} \dots\dots\dots (4)$$

Where:

M = Molarity of ferrous ammonium sulfate solution (approx. 0.5 M)

V_{blank} = Volume of ferrous ammonium sulfate solution required to titrate the blank (mL)

V_{sample} = Volume of ferrous ammonium sulfate ferrous ammonium sulfate solution
required to titrate the sample (mL)

W_t = Weight of air-dry soil (g)

0.3 = $3 \times 10^{-3} \times 100$, where 3 is the equivalent weight of C.

Macronutrients

Nitrogen

Principle

The Kjeldahl procedure is based on the principle that the organic matter is oxidized by treating soil with concentrated sulfuric acid, nitrogen in the organic nitrogenous compounds being converted into ammonium sulfate during the oxidation. The acid traps NH₄⁺ ions in the soil, which are liberated by distilling with NaOH. The liberated NH₄⁺ is absorbed in boric acid and back titrated with standard H₂SO₄.

Potassium sulfate is added to raise the boiling point of the mixture during digestion and copper sulfate and selenium powder mixture is added as a catalyst. The procedure determines all soil nitrogen (including adsorbed NH_4^+) except that in nitrate form.

Apparatus

- Digestion block
- Semi-micro Kjeldahl distillation unit
- Burettes
- Pipettes
- Erlenmeyer flasks – 250 ml
- Magnetic stirrer
- Kjeldahl flasks -300 ml

Reagents

1. Concentrated sulfuric acid Sp. Gr. 1.84 (96%).
2. Catalyst mixture: Mix by grinding in mortar 100 parts Na_2SO_4 or K_2SO_4 with 10 parts of copper sulfate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) and 1 part of selenium powder, mix thoroughly.
3. Sodium hydroxide, 40%: Dissolve 400g NaOH in about 800 ml of distilled water in a 1 lit volumetric flask: Cool the solution with the flask stoppered to prevent absorption of atmospheric CO_2 Bring to volume with distilled water.
4. Boric acid solution, 2%: Dissolve 20 g of boric acid in 600 ml of distilled water in a 1 l volumetric flask and make to volume with distilled water.
5. Mixed indicator: Dissolve 0.5 g bromocresol green + 0.1g methyl red in 100 ml of 95% ethanol.
6. Sulfuric acid solution 0.1 N: Pipette 2.82 ml of conc. H_2SO_4 (96%, $d= 1.84$) in a 1 l volumetric flask and make to volume with distilled water. Standardize with 0.1 N NaOH.
7. Oxalic acid, 0.05 m: Dissolve 6.3035 g $\text{HOCCOOH} \cdot 2\text{H}_2\text{O}$ in distilled water in a 1 liter volumetric flask and make to volume with distilled water.
8. Phenolphthalein indicator, 0.1 %: Dissolve 100mg phenolphthalein in 100 ml 95% ethanol.

9. Sodium hydroxide, 0.1 N solution: Dissolve 4 g of NaOH in distilled water. Cool and make to 1 liter with distilled water. Standardize with oxalic acid.

Procedure

1. Accurately weigh 1 g soil sample (<0.5mm sieve) and transfer into a digestion tube. For soils rich in organic matter (> 10% organic matter) weigh in 0.5 g. In each batch, include a reference sample and two blanks.
2. Add 2 g (1/2 Spoon) of catalyst mixture and few carborundum boiling stones, mix well and rinse with a little water just enough to moisten the mixture.
3. Add 7 ml of conc. H_2SO_4 and mix by swirling.
4. Place the digestion tub stand with the samples beside the block digester and fit the exhaust manifold on top of it
5. Place the tubes with rack and exhaust manifold on the digestion block, preheated in the fume-hood.
6. Digest for 3 hours or until the digest is white or pale yellow on the block digester pre-heated to 300°C .
7. Allow cooling, and cautiously adding 50 ml of distilled water, and then cool again.
8. Transfer the acid digest quantitatively to the macro-kjeldahl flasks and rinse using distilled water.
9. Measure 20 ml boric acid solution from a dispenser into a receiver Erlenmeyer flask corresponding to the number of samples. Add to it 2 drops of indicator solution and place under the condenser. Take care that the end of the condenser is immersed in the boric acid solution to prevent any loss of ammonia.
10. Pour 75 ml of 40 percent NaOH carefully down the neck of the distillation flask containing the digests and mix gently.
11. Fit the prepared 250 ml kjeldhal distillation flasks containing the digest to the corresponding holder, close it as soon as possible and start the distillation by heating the flasks containing the digests.
12. When the distillation is complete, i.e. when about 80 ml of distillate has been collected, remove the receiver flask. Continue with the next sample.

13. Add a stirrer bar and titrate the receiver flask solution from green to a pink end point with 0.1 N H₂SO₄. Record the reading of the burette. Transfer the magnet by means of a magnetic rod to the next flask to be titrated. Always standardize the acid to obtain the exact normality of the titrant.

Calculation

Let V be the volume of 0.1 N H₂SO₄ used after correcting for the blank.

$N \times V$ = meq of N/g of soil

$N \times V \times 14$ = mg of N per g of soil

$N \times V \times 0.014$ = g of N per g of soil

$$\% N = \frac{(a - b) \times N \times 0.014 \times 100 \times mcf}{S}$$

Where:

a = ml of H₂SO₄ required for titration of sample

b = ml of H₂SO₄ required for titration of blank

s = air –dry sample weight in grams

N = Normality of H₂SO₄ (0.1 N)

0.014 = meq weight of nitrogen in g

mcf = moisture correction factor

The tanning sector

Currently, there are 26 tannery industries in operation. The tanneries have 153,650 sheep and goat skin soaking capacity and 9,725 cowhides soaking capacity per day. Together they also employ 4577 persons. Ethiopia Tannery with 12,000 sheep and goat skin and 1,200 cowhide soaking

capacity and Ethio-Leather - ELICO with 15,500 sheep and goat skin and 1,050 cowhides soaking capacity are the two largest industries. Most tanneries seem to be working below capacity.

No	Name of factory	Location	Soaking capacity per day		Number of employees
			Sheep and goat skin	Cow hides	
1	Ethiopia tannery	Mojo (Oromiya)	12,000	1200	682
2	Kolba tannery	Mojo (Oromiya)	8,000	500	290
3	Gelan tannery	Mojo (Oromiya)	3,000	0	87
4	Mesako Global tannery	Mojo (Oromiya)	3,000	0	40
5	East Africa tannery	Mojo (Oromiya)	8,000	0	92
6	Mojo tannery	Mojo (Oromiya)	8,000	500	360
7	Friendship tannery	Mojo (Oromiya)	10,000	1,000	100
8	Farida tannery	Mojo (Oromiya)	7,000	0	
9	Vasen United tannery	Mojo (Oromiya)	5,000	0	
10	Bale tannery	Debre zeit (Oromiya)	2,000	400	80
11	Hora tannery	Debre zeit	7,000	0	210
12	Ethio leather industry	Addis Ababa	15,500	1050	1128
13	Dire tannery	Addis Ababa	6000	600	425
14	Walia tannery	Addis Ababa	5000	1000	150
15	Batu factory	Addis Ababa	8000	1000	360
16	Addis Ababa tannery	Addis Ababa	2400	1200	190
17	Christal tannery	Addis Ababa	1750	100	80
18	China Africa tannery	Sululata (Oromiya)	10,000	0	450
19	Debreberhan tannery	DebreBerhan (Amhara)	6,000	0	80
20	Hafde tannery	Sebeta (Oromiya)	6,000	250	430
21	Blu Nile tannery	Sebeta (Oromiya)	3,500	0	78
22	Kombolcha tannery	Komoblcha (Amhara)	6,000	0	145
23	Mersa tannery	Mersa (Amhara)	6,500	325	161
24	Sheba tannery	Wukro (Tigray)	6,000	600	373
25	Bahirdar tannery	Bahirdar (Amhara)	4,000	0	125
26	Habesah tannery	Bahirdar (Amhara)	4,000	0	112
	Total		163,650	9725	4577

Source: LIDI, marketing department unpublished

APPENDIX₂

Preparation of samples before vermicomposting



Tannery sample



Cow dung sample



Horse manure sample

Different photo graphs during the experimental period



During Composting Of Tannery Sludge With Cow Dung And Horse Manur



Moister contenet folow up in ervery week to make sweetable environment for vermis



Production of vermicompost in lab scale at addis ababa university addis ababa institute of technology

SOIL AND WATER MANAGEMENT TEAM

SOIL LABORATORY

Sample type: Manure

Submitted by: Girum A

S/N	Lab code	Client's code	pH (1:5)	Ec ds/m(1:5)	OC (%)
1	m01/15	Th73 120A	8.22	16.30	23.18
2	02	Tc73 120B	8.23	13.78	15.85
3	03	Tc73 120A	8.33	10.59	19.22
4	04	Th73 120B	8.31	16.02	22.19
5	05	Tc32 100A	8.20	13.62	16.25
6	06	Tc32 100B	8.38	10.25	18.23
7	07	Th11 100A	8.47	14.20	21.00
8	08	Th11 80	8.78	15.46	26.15
9	09	Th32 100A	8.20	17.74	22.39
10	10	Th3 100B	8.22	20.10	22.59
11	11	Tc11 80A	8.20	11.86	20.01
12	12	Tc11 80B	8.31	11.33	17.63

S/N	Lab code	Client's code	pH (1:10)	Ec ds/m(1:10)	OC (%)	TA (%)
1	01	Cow dung	7.79	2.61	10.21	1.291
2	02	Horse manure	7.86	5.42	48.64	2.176
3	03	Tannery sludge	8.23	10.29	11.14	2.271
4	04	Horse manure	7.90	5.43	28.59	1.879

Prepared by Embet F. Sig [Signature] Date 05/08/15
 Approved by Zelate T. Sig [Signature] Date 05/08/15
 Received by Misgana Amare Sig [Signature] Date 06/08/15



Experimental works are done in Wonji Sugar Factory soil and water Laboratory
