

ENZYME FORMULATION AND ACTIVITY STUDIES FOR RAPID COMPOSTING OF VEGETABLE MARKET WASTE TO SYNTHESIZE NUTRIENT-RICH COMPOST.

Submitted in partial fulfilment of the requirements for the award of Bachelor of
Technology degree in Biotechnology

by

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**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **MANITEJA GURENKA (39230024)** who carried out Project Phase-1 entitled "Enzyme formulation and activity studies for rapid composting of vegetable market waste to synthesize nutrient-rich compost." under my supervision from January 2023 to April 2023.

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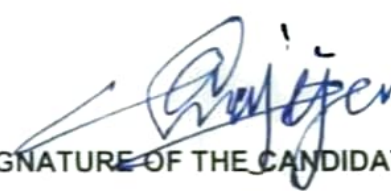
DECLARATION

I, MANITEJA GURENKA, hereby declare that the Project Report entitled **"Enzyme formulation and activity studies for rapid composting of vegetable market waste to synthesize nutrient-rich compost."** done by me under the guidance of Dr. S. Jayashree and Dr. Dawn SS at the Department of Biotechnology, Sathyabama Institute of Science and Technology, Chennai, is submitted in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Biotechnology.

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ABSTRACT

Composting is a natural process that turns organic waste into a beneficial soil additive known as bio-compost. Bio-compost is rich in nutrients and can increase soil health, while lowering the quantity of organic waste transported to landfills. However, composting also produces greenhouse gas emissions, which can have significant environmental implications. This article discusses the factors determining greenhouse gas emissions from composting, as well as measurement methods and their accuracy. It also examines the microbial variety of bio composting, and the role of maturity and stability indicators in assessing the quality of the finished compost. Advancements in composting bins and the role of additives and bulking agents are also studied. The cycling of carbon released from composting via carbon sinks is explored, along with the economics and business strategies involved with composting. The paper finishes by outlining the challenges and future directions of composting as a sustainable waste management option.

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1.INTRODUCTION

Landfill and incineration have until now been the most widely used means of solid waste disposal throughout the world, but in recent years interest has grown in disposal methods which take recycling into consideration. One of the more successful systems used in many countries is the transformation of biodegradable organic material from various sources into humic substances (DEBERTOLDI, VALLINI and PERA, 1983).

Composting is now one of the most popular technologies to recycle nutrients from organic waste, which can significantly shorten the processing cycle and recover the nutrients from organic waste (Walling, Trémier and Vaneeckhaute, 2020). In China, about 76% of the poultry and livestock manure collected by intensive farming was processed through composting in 2015(Liu *et al.*, 2020), which can promote the organic fertilizer production industry and increase the circulation of regional nutrients (Cerdeira *et al.*, 2018).

Although while research on composting has shown productive outcomes, there is still a significant issue when microorganisms transform complicated substrates into eventually usable products in the composting process, in which some by-products, as Ammonia (NH₃), Carbon dioxide (CO₂), Methane (CH₄), Nitrous oxide (N₂O), are made to pollute the environment (Li *et al.*, 2020). By applying compost, the build-up of P in top soil has the potential to transmit P to groundwater, raising environmental concerns (Galvez-Sola *et al.*, 2010). The amount of carbon (C) and nitrogen (N) lost to the atmosphere throughout the composting process varies from 30% to 63%, 19% to 42%, and less than 2%, respectively, due to strong NH₃ volatilizations and runoff, respectively (Eghball *et al.*, 1997). By changing the qualities of the soil, it will also help other fertilisers work more effectively while also providing environmental and agronomic advantages. Because of this, it's important for composting technology to reduce both carbon and nutrient losses to produce stable, high-quality products (Oladele and Adetunji, 2021).

The pH level in bio composting is an important factor that affects the decomposition process. Ideally, the pH range for bio composting should be between 6.0 to 8.0. If the pH level is too low (below 6.0), it can slow down the decomposition process, and if it is too high (above 8.0) it can harm the microorganisms responsible for breaking down the organic matter. Maintaining the appropriate pH level in bio composting is essential for creating a suitable environment for microorganisms to thrive and decompose the organic matter effectively. The pH level can be adjusted using various techniques such as adding alkaline or acidic agents, adjusting the carbon to nitrogen ratio, or adding water to the compost pile (Effect of pH and moisture content on composting of MSW).

Biological degradation during composting and vermicomposting is one of these strategies to transform organic wastes into organic amendments. These amendments can be applied on soils to increase soil carbon stocks and associated ecosystem services (Schott et al., 2016 a) or used as potting media. Compost application leads to improved soil structure, reduced erosion and increased water holding capacity (Diacono: Long-term effects of organic amendments... - Google Scholar). However, compost production is associated with greenhouse gas emissions such as NO₂, CH₄ or CO₂, contributing to global warming (Schott et al., 2016 b). In addition, immature composts have negative effects on plant germination and, more generally, on plant development and might cause environmental problems such as water pollution and odour emissions (Wang, Li, et al., 2016).

Microorganisms found in compost are mostly beneficial. Microorganisms found in compost are mostly beneficial mainly Bacteria and Fungi provide the fastest and most efficient composting by excreting nutrients (Nemet, Perić and Lončarić, 2021a). In composting the bulking agents may affect gas emissions, moisture content (MC), and the stabilization of the material. (Mohajer *et al.*, 2010) observed that the MC is affected by the proportion of the bulking agents and

waste. The bulking agent may alter physical properties, chemical characteristics, microbial activity, composting time, and leachate generation (Gao *et al.*, 2010). A study by (Chang and Chen, 2010) evaluated the composting process of food waste in a lab-scale reactor with different mixtures of structural materials such as rice husk (RH), sawdust and rice bran, concluding that good results may be obtained by using only RH as bulking agent rather than other mixtures that use sawdust or rice bran (Composting using different ratios of bulking agent to food waste. Journal of Environmental Management, 207, 141–150 | 10.1016/j.jenvman.2017.11.031).

In composting the waste compost bin is a common waste collection tool used in households or small residential communities. According to one study of composting in households, aerobic composting has a better performance and generates less odour compared to anaerobic composting. Almost all engineered composting mechanisms are aerobic systems. In Thailand, aerated compost bins have been developed for small communities (CHIEMCHAI SRI *et al.*, 2012). However, studies of compost bins, waste collection execution and source-separation efficiency have rarely been conducted. Appropriately designed compost bins and their deployment at suitable locations will lead to improved source-separated collection. So, composting has many benefits, including reducing greenhouse gas emissions from landfills, reducing the need for chemical fertilizers, and improving soil health. With proper care and attention, anyone can start composting and contribute to a more sustainable future.

2. LITREATURE REVIEW

2.1 BIOCOMPOST

Bio-compost is a type of compost that is produced using organic matter, such as food waste, yard waste, and agricultural waste. Unlike traditional composting methods, bio-composting is usually done in a controlled and optimized environment, such as a compost bin or a commercial composting facility, to

ensure the proper balance of moisture, aeration, and temperature for the microorganisms to thrive (Oliveira and Franca, 2015). This process involves a combination of mesophilic (moderate temperature) and thermophilic (high temperature) stages, which ultimately lead to the conversion of organic waste into stable, agronomic value product (Delgado *et al.*, 2002a).

Composting is a widely accepted and adopted method of waste management around the world, and it can be carried out either at an industrial level or at home. Composting at home is an easy and convenient way to reduce the organic fraction of solid waste and nourish the soil for plant growth. All that is needed is a composting bin, which can be placed in the backyard or balcony of a home. The compost produced at home is best suited for plant growth and has high demand in the market due to the absence of any artificial process. The fertilized compost helps in nourishing the soil by providing enough nutrients, such as nitrogen, phosphorus, and potassium.

To create a nutrient-rich compost, it is important to maintain the carbon to nitrogen (C/N) ratio by combining green and brown waste. Green waste includes fruit and vegetable leftovers, bread, cardboard, while brown waste includes fallen leaves, small wood chips, sawdust, and plant leftovers (Samal *et al.*,). By mixing these two types of waste, the composting process is enhanced, and the nutrients are released gradually over time to the soil. However, it is important to note that certain waste materials should be avoided in the composting process, such as meat and fatty food wastes. These waste materials are the main contributors to bad odour in the composting process and can attract pests and rodents. Therefore, it is best to limit the use of these waste materials and focus on incorporating more green and brown waste in the composting bin (Jouhara *et al.*, 2017).

There are several methods for composting, such as on-site composting, which allows organisations to compost modest amounts of leftover food. Composting can help to cut down on the quantity of food waste that is thrown away. On-site composting is possible for small amounts of food scraps and yard clippings.

Large amounts of food waste and animal products are inappropriate for onsite composting (Types of Composting and Understanding the Process | US EPA). When using vermicompost Compost is produced by red worms in bins as they consume food scraps, yard waste, and other organic material. This substance is broken down by the worms into castings, a superior kind of compost. Worm bins are simple to build and may be bought as well. A mature worm population of one pound (or around 800-1,000 worms) may consume up to half a pound of organic matter every day. The bins may be adjusted in size to accommodate the quantity of food waste that will be used to make castings. Producing acceptable castings normally takes three to four months. You may use the castings as potting soil. Worm tea, another by-product of vermicomposting, is a premium liquid fertiliser for gardens or indoor plants (Types of Composting and Understanding the Process | US EPA).

Composting utilising oxygen-dependent bacteria is known as aerobic composting. The bacteria that cause composting are naturally occurring and dwell in the moisture that organic waste is surrounded by. The air's oxygen diffuses into the wetness, where it is absorbed by the bacteria. Heat, water, and carbon dioxide are the by-products of aerobic digestion (CO_2). Although CO_2 is a greenhouse gas, the evolution it undergoes during the composting process is not included in emissions. Therefore, the environmental impact of CO_2 is just one twentieth that of methane (the main by-product of anaerobic degradation).

As hazardous bacteria and pathogens are not suited to these climatic conditions, the heat created during aerobic composting is adequate to destroy them. Moreover, it aids in the development of beneficial bacterial species, such as thermophilic, mesophilic, and psychrophilic bacteria, which flourish at higher temperatures. The Hot Rot in-vessel aerobic composting procedure only requires 8–10 days to complete from beginning to end. There is no leachate created since any additional moisture is taken as water vapour, which may then be condensed and utilised to hydrate surrounding plants (Aerobic Composting vs Anaerobic | Global Composting Solutions). Composting that takes place

anaerobically uses microorganisms that do not require oxygen to live. The majority of the chemical energy included in the starting material is released as methane in an anaerobic system. The process is characterised by extremely potent odours, and because little heat is produced, decomposition takes a lot longer and doesn't reach temperatures high enough to properly destroy weeds, seeds, and plant diseases.

It is typically necessary to inject external (artificial) heat to get over these restrictions. Anaerobic digestion breaks down the substance, resulting in a sludge-like substance that is much more challenging to digest. The stabilisation of this substance, digestate, often involves aerobic composting (Aerobic Composting vs Anaerobic | Global Composting Solutions). (Nemet, Perić and Lončarić, 2021b) says that the microorganisms play a vital role in the composting process, and bacteria are especially crucial in biodegradation. Bacteria produce carbon dioxide and heat, which are essential for the breakdown of organic matter in composting.

The different types of bacteria present in compost piles, such as psychrophilic, mesophilic, and thermophilic bacteria, each have their role in the composting process. Psychrophilic bacteria are most active at a temperature of 13°C and secrete a small amount of energy. Mesophilic bacteria are most active at a temperature range of 21–32°C and have a similar role to psychrophilic bacteria. When the temperature of the compost pile rises above 45°C, thermophilic bacteria take over and continue to biodegrade in the composting process. *Bacillus* is a genus of bacteria that is optimal at a temperature range of 50–65°C, and at temperatures above 65°C, *Stearothermophilus* dominates. Overall, the role of microorganisms, particularly bacteria, is essential in the composting process to break down organic matter and produce compost that is beneficial for plants and the environment.

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Overall, the role of microorganisms, particularly bacteria, is essential in the composting process to break down organic matter and produce compost that is beneficial for plants and the environment (Abu-Bakar and Ibrahim, 2013). Compost fertilisers have advantages for agriculture from a number of angles, including technological, economical, and environmental. One tonne of agro-biowaste may be composted to create green, safe, and organic fertiliser rather of having to synthesise 8.4 kg of mineral NPK fertilisers, saving money. The composting process also has a 48 kg CO₂ sequestration capacity, which is advantageous for the environment. Overall, switching to compost fertilisers from inorganic fertilisers for agriculture may be a sustainable and ecologically responsible choice (Sarlaki *et al.*, 2021).

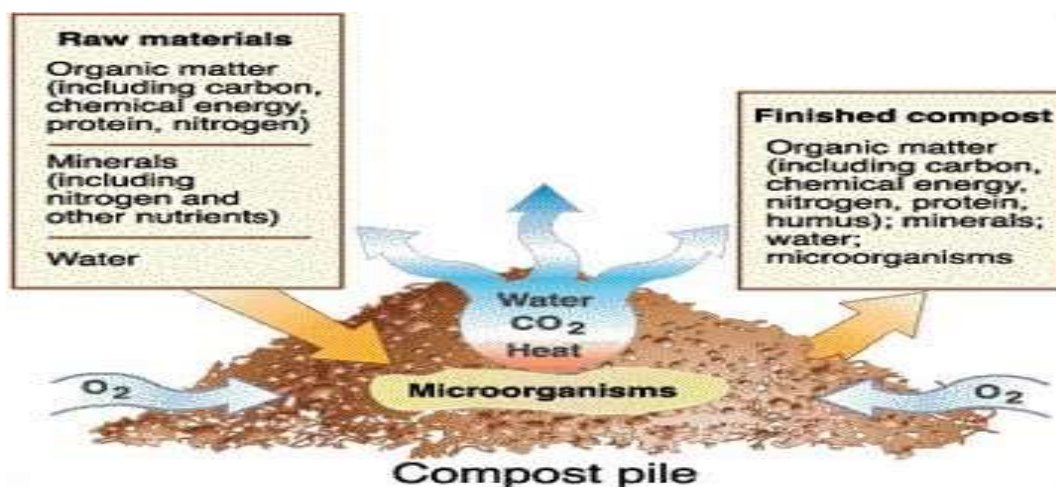


Fig 2.1. Process of Bio-composting (Compost Requirements)

Name	Type/Source of Microbe	Temperature Amount	Concentration	Main Substrate	Research Findings
Pseudomonas fragi, Pseudomonas simiae, Clostridium Pseudomonas and Iodobacter fluvialis	Mix strain	10 °C	1 10 CFU/ mL, 1 % in dry weight	Food waste & maize straw	Contributed to composting up at low temperature
CB1, Flavobacterium glaciei CB23 Aspergillus niger CF5 and Penicillium commune CF8	Psychrotrophic bacteria (isolated from frozen soil) and thermophilic fungi (isolated from compost)	-2-5°C	1 x 10 CFU/ mL, 10 mL/kg	Dairy manure & rice straw	Promotes maturity of dairy manure-rice straw composting under cold climate conditions
Pichia kudriavzevii RB1	Mesophilic yeast	27 °C	1 x 10 CFU/ mL, 10 mL/ kg	Model food waste (commercial rabbit food and cooked rice)	Promote degradation of organic acid and accelerating the composting process
Phanerochaete chrysosporium	White-rot fungi	25-29°C	2 x 10 CFU/ mL, 2 % in wet weight	Rice straw. bran, vegetables and soil	Stabilise in composting of lead-contaminated agricultural waste

Table2. 1. (Application of microorganisms in composting process | Download Scientific Diagram)

2.2. GREENHOUSE GAS EMISSION FROM COMPOSTING:

Compost is typically used to turn organic wastes into nutrients. The composting process creates other harmful gases too, including methane (CH₄), ammonia

(NH₃), hydrogen sulfide (H₂S), methyl sulfur [(CH₃)₃S], methanethiol (CH₃SH), sulfur dioxide (SO₂), and other alkane gases. At present, the most common methods to treat these pollutant gases are absorption, adsorption, thermal destruction, condensation, biological purification, separation membranes, and photooxidation decomposition (Li et al., 2017; Huang et al., 2014; Luengas et al., 2015; Jo and Yang, 2009; Zhang et al., 2017).

The absorption approach utilises water or a chemical reagent solution as the absorbent that immediately meets the gas to remove the pollutant gases and dissolve some harmful components physically and/or chemically. Adsorption, often by activated carbon, is another key physical technique to remove low-concentration organic components in the compost waste gases. Thermal destruction is a way to breakdown organic molecules in the waste gas by thermochemical processes such as oxidation, pyrolysis, and thermal degradation by direct burning, targeted combustion, and catalytic combustion. The condensation technique acts via the underlying mechanism in accordance with the differences in the saturated vapor pressures of various organic components in the compost waste gases.

Biological purification is done by absorption of organic gases in the waste gas with living microorganisms attached to a medium, where the gases may be transformed into harmless inorganic compounds or cellular components such as CO₂ and H₂O through oxidative breakdown processes. To date, biofiltration and bio dropping filter reactors are extensively employed in the biological technique for compost waste gases. The membrane separation method principally exploits a semipermeable polymerized membrane to separate the organic compounds in the waste gas. The waste gas enters a membrane separation module after pressurization for condensation. The semipermeable membrane may cleanse and remove the uncondensed organic gases from air. The cleaned air is then quickly discharged across the semipermeable barrier. A minor amount of the concentrated organic gases is refluxed, recompressed, and then purified. Photooxidative decomposition is a way to degrade gaseous organic materials using light of a particular wavelength and a photocatalyst.

Sl. No	Waste type	Amendment	Duration (Days)	CH4	N2O	CO2
1	Chicken pig and dairy manure	Cornstalk (CS)	28	582.21 - 842.48 mg d ⁻¹	39.5-64.9 gd ⁻¹	62.56-119.22 gd ⁻¹
2	Sewage sludge and straw	Bamboo biochar with bacterial agents	29	128.57 - 235.47 mg.kg ⁻¹	0.127 - 0.163 mg.kg ⁻¹	16.39 - 24.91 mg.kg ⁻¹
3	Stored dairy cattle and swine manure	Raw straw	33	281.4 mg C m ⁻² h ⁻¹	13.4-34.7g C m ⁻² h ⁻¹	0.06 to 7.16 mg N m ⁻² h ⁻¹
4	Sewage sludge	Saw dust	23	273.0 to 363.3 mg CH4-C.kg ⁻¹		320.7 mg CO2C/kg to 529.4 mg CO2-C.kg ⁻¹
5	Cattle manure	Lignite	90	0 - 0.06 g.day ⁻¹ kg ⁻¹ D M	0.01 and 0.008 g.day ⁻¹ kg ⁻¹ DM	5 and 10 g.day ⁻¹ kg ⁻¹ DM
6	Green waste	Wood chips (1:9)	365	0.022–0.254 Kg C m ⁻² day ⁻¹	0.152–0.511 Kg C m ⁻² day ⁻¹	-
7	Dairy manure		42	153 CO2-eq (g.kg ⁻¹ VS deg)	48.0 CO2-eq (g.kg ⁻¹ VS deg)	587.0 CO2-eq (g.kg ⁻¹ VS deg)
8	Cattle slurry	Barly straw	31	748 mgCO2 eq.kg ⁻¹ TS	26 mgCO2 eq.kg ⁻¹ TS	85gCO2 eq.kg ⁻¹ T S
9	Hen manure	Barly straw	31	131mg.kg ⁻¹ TS	28mg.kg ⁻¹ TS	79g.kg ⁻¹ TS
10	Household wastes	Mulches	120	2.2 kg.mg ⁻¹	1.5 kg.mg ⁻¹	882 kg.mg ⁻¹
11	Organic household waste	Garden waste	600	0.4–4.2 kg CH4 Mg ⁻¹ (Wet Waste)	0.30–0.55 kg N2O Mg ⁻¹ (wet Waste)	100–239 kg CO2eq. Mg ⁻¹ (wet Waste)

Table 2.2 (Yasmin et al., 2022a) Table displaying the amount of Greenhouse gas emissions emitted from different composts.

i. METHANE (CH_4):

Researchers have begun to pay attention to the methane emissions produced by composting organic waste as a significant contribution to global warming since this greenhouse gas has a global warming potential 25 times larger than carbon dioxide over a time horizon of 100 years. Lack of oxygen (strictly anaerobic microorganisms), a redox potential below -200 mV, neutral pH, and the availability of nutrients and substrates rich in organic matter are the ideal growth conditions for methanogenic bacteria (Appuhamy, France and Kebreab, 2016).

These circumstances are temporarily present in the early stages of composting, when the pile's oxygen content is reduced by the microbial activity that is sparked by the abundance of nutrients and readily accessible organic molecules. As a result, the majority of CH_4 emissions have been observed in the early stages of the process, at the start of the thermophilic phase (Miguel A. Sánchez-Monedero *et al.*, 2010). As a result of the process's early high temperatures, which make oxygen less soluble, anaerobic areas of the pile can more easily form. A high ammonia content, which may impede methanogen activity at pH levels higher than 9, or the presence of electron acceptors such sulphates, which hinder their activity by competing with sulphate-reducing bacteria. According to (Sánchez-Monedero *et al.*, 2001), the composting of olive mill waste was hampered by the high ammonia levels produced by the hydrolysis of urea, which was utilised as a nitrogen source.

In addition to the biological activity of the pile, additional variables impacting gas transport from anaerobic regions to the pile surface, such as gas diffusion within the pile and the presence of methanotrophic bacteria, also influence the emission of CH_4 from composting heaps. The ability to oxidise between 46 and 98% of the CH_4 produced in the pile is possessed by methanotrophs, aerobic bacteria that colonise the area around anaerobic zones and the pile surface (Aoki *et al.*, 2006). Other significant Greenhouse gases released during

composting, such N_2O and CO , are produced and consumed in large part by methanotrophic bacteria.

In addition to the biological activity of the pile, additional variables impacting gas transport from anaerobic regions to the pile surface, such as gas diffusion within the pile and the presence of methanotrophic bacteria, also influence the emission of CH_4 from composting heaps. The ability to oxidise between 46 and 98% of the CH_4 produced in the pile is possessed by methanotrophs, aerobic bacteria that colonise the area around anaerobic zones and the pile surface (Jäckel, Thummes and Kämpfer, 2005).

Other significant Greenhouse gases released during composting, such N_2O and CO , are produced and consumed in large part by methanotrophic bacteria. (Yasmin *et al.*, 2022b) conducted a four-year interannual review of the GREENHOUSE GAS emissions from an olive mill waste composting facility and discovered a decrease in CH_4 emissions linked to the facility's improved management (watering and turning frequencies). The main factors governing CH_4 emissions during the process are the composting feedstock, the height and shape of the pile, the control of moisture content, and turning frequency because these variables will affect both the oxygen availability and gas diffusion in the composting pile. These factors were reviewed by (Kebreab *et al.*, 2006) in his reviews of the topic of GREENHOUSE GAS emissions from livestock and composting operations. Due to the inclusion of anaerobic bacteria, the introduction of manure can also boost methane emissions, as was found by (Miguel A. Sánchez- Monedero *et al.*, 2010) in composting heaps processing food and olive mill wastes, respectively.

ii. NITROUS OXIDE (N_2O):

Denitrification is a primary source of N_2O emissions from composting and is affected by various factors, such as the properties of the initial materials and amendments used, turning of the pile, solubility in the pile, and oxygen (O_2)

availability at microsites (Ammonia and nitrous oxide interactions: Roles of manure organic matter management; Béline et al., 1999; Hao et al., 2001).

The study found low N₂O emissions in both non-lignite and lignite windrows, with lignite windrows accounting for 76.7% of total Greenhouse gas emission. The cumulative N₂O emission was 1.16 (0.3) g kg⁻¹ DM in the lignite windrow and -0.52 (0.1) g kg⁻¹ DM in the non-lignite windrow, indicating a slow nitrification process. The addition of lignite to manure reduced nitrogen (N) loss as N₂O in composting (Bai *et al.*, 2020). Similarly, the addition of bamboo biochar during poultry manure composting significantly reduced N₂O emissions compared to composting without biochar. Biochar promotes oxygenation and high temperatures, suppressing the nitrification process that produces N₂O by inhibiting the growth of nitrifying microorganisms and enzymes (Cui et al., 2010; Sánchez-García, ... and 2015; Carbon dioxide concentration NASA global climate change). Excessive acidification (pH 6 and pH 5) accelerated the emission of N₂O by 18.6% and 17.6%, respectively. The emission of N₂O during denitrification increased as the pH value decreased from 7 to 5.5 (Russenes et al., 2016). The study found that vermicomposting with agricultural waste resulted in lower N₂O emissions (5.76 kg CO₂-eq t⁻¹ DM) compared to thermophilic composting (12.29 kg CO₂eq t⁻¹ DM) due to the arrangement of the pile, which the earthworms destroyed during vermicomposting, resulting in a 53% lower emission of N₂O. Denitrification occurred in the intestine of earthworms, resulting in lower N₂O emissions (Ma et al., Yang et al., 2017).

iii. CARBON DIOXIDE (CO₂):

One of the main greenhouse gases that traps heat and is mainly responsible for global warming is CO₂ (Riebeek: NASA earth observatory - Google Scholar). The biogenic CO₂ was produced by biological processes like litterfall decomposition or soil respiration (Harris, Milner and Taylor, 2018). As CO₂ released during decomposition is already taken as food by plants and is therefore considered to be biogenic in origin, the Global warming potential

(GWP) of carbon dioxide gas is not analysed for organic waste (Jungbluth, Hartung and Brose, 2001; He, Han and Huang, 2020).

Changes to the factors that contribute to emissions can lower GREENHOUSE GAS emissions. The increase or decrease in Greenhouse gas emission is significantly influenced by the insertion of modifications. (Wang, Awasthi, et al., 2018) revealed that using 10% of the recommended amount of biochar during the composting of pig manure might reduce CO₂ emissions by a proportion equal to 26.06%. The early thermophilic phase and the final maturation, or mesophilic phase, of composting are the two stages of waste stabilisation.

Aerobic and anaerobic thermophiles consume and degrade readily available OM during the thermophilic phase. High temperatures (50–70°C) and increased microbial activity during this phase, which causes OM to volatilize and CO₂ and NH₃ to be released, make this phase distinct. Temperature decreases (40–50°C) during the last maturation phase show full breakdown of degradable OM in the trash and minimal to no Greenhouse gas emissions as a result. (Awasthi et al., 2019) noted that CO₂ emissions were very high in the beginning and subsequently dropped.

According to what many other researchers discovered, the beginning of the composting or vermicomposting process employing substrates such municipal solid waste, green waste, and sewage sludge resulted in the largest CO₂ emissions, which then gradually decreased over the latter stages (Lv et al.,). For the first two weeks of composting food waste, (Hwang et al., 2020) discovered a considerable initial CO₂ emission of around 9.23g kg⁻¹ hr⁻¹, which significantly declined in the following stages. A rise in temperature has been seen by a number of other researchers as well. The temperature can increase up to 55°C in the early stages before dropping throughout the following stages. As a result, it is probable that the early phases' high temperatures are what caused the early phases' increase in CO₂ emissions. CO₂ it is produced by the breakdown of plant matter, the CO₂ emitted during composting is thought to have a neutral Global warming potential.

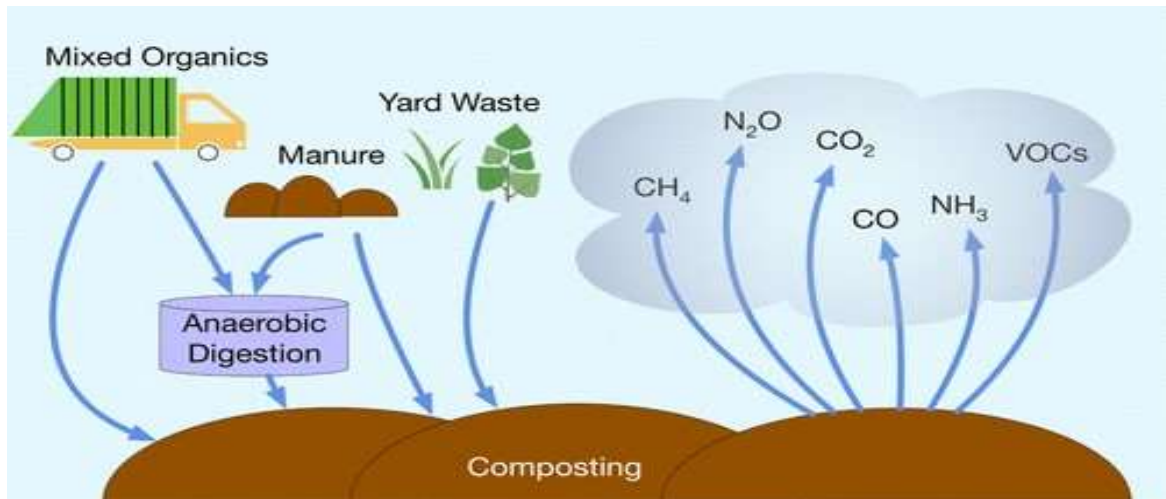


Fig:2.2 Emission of various Greenhouse gases from the composting (Nordahl et al., 2023)

2.2.1 IMPACTS ON THE ENVIRONMENT:

Organic waste may be managed very well by composting without creating any garbage. Greenhouse gases (Greenhouse gases), which are a factor in the greenhouse effect, are nevertheless also released as a result of it. Greenhouse gases are essential to preserving the Earth's habitable climate for all living things. Sadly, the excessive amount of Greenhouse gases poses a threat of substantial changes that might have a negative influence on life on this planet (Nunez et al., 2019).

The effects of greenhouse gas emissions on the environment include:

2.2.1.1 Global warming

Human activities have been proved to make a major contribute to the effect of climate change during the last 200 years (Moumen et al., 2019). The chemical composition of the atmosphere has been modified as a result of these human activity. Besides, the two key reasons contributing to global climate change are Greenhouse gases and the Earth's magnetic field. The quantity of radiation impacting the earth's surface is less likely to be reflected back as greenhouse

gas emissions grow. In order to balance the anomaly and restore the equilibrium between incoming and outgoing radiation, the Earth's climate changes.

More radiation is trapped within the Earth's surface when greenhouse gas emissions grow. These greenhouse gases enhance the temperature of the earth's surface by allowing sunlight to enter and blocking heat from escaping. This creates a rise in air temperature, as well as irreversible implications such as global warming and climate change (Huang et al., 2016). Many researchers and experts worldwide have done countless experiments and have evaluated to uncover several techniques to decrease Greenhouse gases and thus minimise the effect of global warming and maintain the balance of life on Earth. According to several studies, in the last 100 years, the Earth's global temperature risen by 0.5-1°C. Although the rise may look tiny, even a slight gain in global temperatures generates some important impacts such as cloud cover and wind patterns. In its third assessment, the "Intergovernmental Panel on Climate Change" (IPCC) anticipated that global mean temperature would grow from 1.4°C to 5.8°C by the end of 2100, resulting in more catastrophic scenarios rapidly (Yasmin et al., 2022c).

2.2.1.2 Melting of glaciers and ice sheets

Ice is a great indicator of changes in the climate. Glaciers and ice sheets tend to reflect back the radiations of the sun. However, melting of the ice decreases the ice cover, which leads to increased absorption of these radiations instead of reflecting them back. Climate change is most likely to occur as of global warming since it has a significant potential for melting ice masses on our globe, such as ice sheets and mountain glaciers. The melting of glaciers and permafrost has had a considerable influence on their stability. These are often perceived as quicker melting, greater glacier flow, creation of supra-glacial lakes, and a rise in permafrost deterioration. Even in the absence of future temperature changes, some glaciers are projected to retreat, while the number of rising glaciers will expand (Ding et al., 2018).

2.2.1.3 Rise in sea level

According to (Latake et al., 2016), the emission of greenhouse gases is causing a rise in sea level, which is predicted to climb by 0.09 to 0.88 meters between 1990 and 2100. This elevation is connected to two independent processes: thermal expansion and melting of mountain glaciers and ice caps. Thermal expansion occurs due to higher temperatures, culminating in a rise in sea level, while melting Greenland and Antarctica glaciers and ice sheets would add water to the ocean. These two processes are projected to contribute the most major contributions to sea level rise. Additionally, the ocean absorbs roughly 80% of the heat contained by greenhouse gases, causing the water temperature to rise, leading to water expansion. The basic engine of sea level rising over the millennia is thermal expansion, according to many researchers. Since 1990, sea level has risen at a pace of 0.14 inches per year, largely attributable to thermal expansion. As the temperature increases, snow and ice melt more rapidly, leading to a rise in sea level (Latake et al., 2016). According to (H. Riebeek's research studies), this problem is worsened.

2.3 EMISSION FACTORS:

2.3.1 Temperature

The temperature is a strong predictor of microbial activity throughout the composting process and the maturity of the final product collected (Duan et al., 2019). The release rate of greenhouse gases is roughly related to temperature in both open and closed composting systems. The concentrations of CH₄ and NH₃ are greatest when the temperature is between 40°C and 50°C, but N₂O is only generated when the temperature is below 40°C. Due to temperature fluctuations and changes in the microbial population, the composting process is seen as a succession of different sub-processes, such as mesophilic and thermophilic (Vergara et al., 2019). Researchers have noted a rapid spike in

temperature during the first few days of composting. For instance, (Li: Effects of chemical additives on emissions of... - Google Scholar noticed that the temperature climbed greatly for all treatments at the beginning of composting and reached above 55°C during the first two days. To guarantee pathogen clearance, the thermophilic phase (>50°C) was continued for 10-12 days.

Following the thermophilic phase, the temperature progressively decreased to ambient levels in all treatments, suggesting that the mature state had been obtained. (Ren et al., 2020) reported that N₂O-N emissions in the two treatments were lower in the starting stage but peaked throughout the cooling stage, corresponding to Jiang et al.'s (2016) findings during pig manure composting. This pattern was created by high temperatures. Vergara et al. (2019) revealed that as temperatures hit 65°C, methane fluxes surged more rapidly. (Arora, Rajpal and Kazmi, 2016) indicated that as the temperature rose, treatment parameters such as Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) declined. They also observed that the optimal temperature for earthworms fluctuates between 25-27°C.

2.3.2 Aeration

The aeration process plays a vital role in establishing the aerobic state of composting. Studies have demonstrated that continual aeration during composting may reduce greenhouse gas emissions (Keener et al., 2001). Therefore, it is crucial to provide continuous aeration not only after the thermophilic stage but also during the maturation phase to decrease the environmental impact of N₂O emissions (Pereira et al., 2018). The creation of anaerobic pockets is the major source of CH₄ production, which is created by methanogens deoxidizing carbon dioxide/hydrogen and acetic acid under anaerobic settings. The occurrence of these pockets signifies a lack of oxygen supply or aeration in the composter. (Scaglia et al., 2011) suggest that by adding O₂ to the compost pile, the production of these anaerobic pockets may be decreased, as previously observed by (Osada et al., 2000), who displayed a

reduction in CH₄ and N₂O emissions resulting from reduced anaerobic zone growth. (Zeng et al., 2018) have revealed that the amount of GREENHOUSE GAS emissions is largely dependent on the duration of aeration.

GREENHOUSE GAS emissions were lower during the aeration period compared to the aeration interval, i.e., the time without aeration. Therefore, prolonging the duration of the aeration interval may aid effectively lower GREENHOUSE GAS emissions. (Amlinger et al., 2008) advise enhanced air supply and removal of NH₃ during the early stages of thermophilic decomposition to prevent N₂O production. However, it has been found that higher aeration in open compost may modestly augment NH₃ production due to increased material and turning frequency. The equivalent effect may be seen in closed compost, backed by improved NH₃ removal and evaporation. Furthermore, higher aeration may reduce CH₄ emissions. Proper maintenance greatly minimises gas release. Well-managed and operated composters release less methane and N₂O throughout the composting process (Dhamodharan et al., 2019).

2.3.3 Moisture content

In the vermicomposting process, moisture content has a major influence on CH₄ and N₂O emissions. Due to constraints in their dermal respiratory systems, extreme water content (either high or low) may trigger earthworm death in vermicomposting systems. Moreover, it may boost N₂O production by concurrently promoting nitrification and denitrification in mesophilic settings. In addition, waste substrates with a high-water content led to anaerobic conditions in vermibeds, which preferred methanogenic bacteria for CH₄ emission (Swati and Hait, 2018). Several research have revealed that the ideal range for the water content for vermicompost is between 70 to 90% (Amouei, Yousefi and Khosravi, 2017), yet a water level of 25 to 30% in vermicompost resulted in

increased microbial activity. (Velasco-Velasco et al., 2011) reported that a water content of 80% at 15°C created less NH_3 than 70% water content at 22°C in vermicomposting. (Ermolaev et al., 2019 a) observed that elevating the feedstock water content (WC) from 43 to 66% contributed to an increase in CH_4 production by about 1000-fold in composting done in a small-scale reactor with regulated temperature at 55°C, forced aeration, and frequent mixing. Raising WC by 43-59% lowered N_2O emissions by roughly 77%. The greatest CH_4 and N_2O were emitted by oversaturated compost with 66% WC. The significant amount of water in residential composters, as well as the reported temperatures, may result in excessive N_2O emissions. Increasing the water content reduces the diffusion of oxygen, which impacts Greenhouse gas emission.

2.3.4 Carbon and Nitrogen ratio

Insufficient nitrogen availability hampers microbial metabolism when the C/N ratio is extremely high. The composting and end product maturity are determined by the C/N ratio (Chen et al., 2019). Raw material quality generates differences in the C/N ratio, green waste having the largest C/N ratio, followed by cow dung and chicken manure. A C/N ratio of 12 demonstrates compost maturity and stability, and according to (Jjagwe et al., 2019a), the vermicompost reached entire maturity with a C/N ratio of 10 in week 12. The C/N ratio is also significant for determining whether the compost is suitably stabilized. The optimal C/N ratio range is 15 to 30, but composting may occur in a larger range of values. CO_2 emissions are influenced by the total carbon (TC) and total nitrogen (TN) content. Greater carbon and nitrogen levels are more beneficial to microorganism respiration. For microbial metabolism, TC and TN are important to offer a carbon and nitrogen source as well as the energy needed for life. (Qin et al., 2010) discovered that changes in TC concentration were strongly related to CO_2 emissions. CO_2 generation was also demonstrated to be substantially linked with temperature. This may be connected to the rapid breakdown of organic molecules at higher temperatures (Pattey et al., 2005). Moisture content

was inversely related to CO₂ emissions, as demonstrated by component analysis (PCA). Increased moisture content enhances microbial mass metabolism but may also extend the heap's anaerobic region. Less NH₃ production is promoted by high aeration and high heating when the feedstock has a low C/N ratio. A C/N ratio more than 35 will result in incorrect decomposition and humification of the process, but a C/N ratio more than 25 may aid restrict NH₃ and N₂O formation.

2.3.5 Ph

The quickest degradation rates were discovered when CO₂ production reached its peak two days after the initiation of the therapy, and again when the temperature soared. As previously noted in their reactor testing. (Ermolaev et al., 2019 b) showed that the initial peak in CO₂ production corresponded with a fall in pH, indicating the synthesis of organic acids during the fermentation of readily available carbohydrates. The pH is changed by the application of bulking agents. Supplying 12% biochar to treatments with 10%, 15%, and 30% zeolite generated appropriate buffering capacity in the compost matrix to maintain a neutral pH throughout the composting process, which was acceptable for Malt Extract Agar (MEA) degradation and Total Organic Matter (TOM) breakdown. Conversely, the pH of compost treated with Biochar and lime decreased from 8.58 to 6.87 on day 10, and this acidic state continued for a short time before steadily recovering, with a slightly alkaline pH observed near the finish of composting.

Recent pH investigation has proven that it has an effect on the discharge of odours. Additionally, earthworms may modify the original properties of substrates by accelerating the degradation of organic components and causing an acidic pH. It has been shown that higher pH values restrict earthworm generation rates because they facilitate the passage of nano toxin particles to the worm (Vergara, Letters and 2019, 2019). (Mahbub et al., 2017) observed that these toxins decreased the number of harmful chemicals in the earthworm.

N₂O emissions were negatively related to substrate pH, and low pH may restrict NH₄⁺-N conversion to NH₃ while concurrently promoting the nitrification/denitrification process. As a result, the greater N₂O emission reported in vermicomposting may be due to a lower pH than in control treatments (Samal, Engineering and 2020).

2.4 MEASUREMENT METHODS:

2.4.1 Chamber methods

The most popular techniques for observing Greenhouse gas emission from compost heaps are chamber techniques. This method is based on inverted boxes or cylinders of predetermined dimensions, sometimes known as enclosures. They can either cover the entire compost pile or just a portion of it. Instrumental methods are used to measure the Greenhouse gases released by composting material. As detailed below, this strategy may be separated into two categories: closed chamber approaches and open chamber methods.

2.4.2 Closed chamber method

Fixed chambers are frequently used to measure CH₄ and N₂O discharges. Emissions of Greenhouse gases from heaps made with manure, source-separated organic household wastes, lignocellulosic wastes, and olive mill wastes (Miguel A Sánchez-Monedero *et al.*, 2010) have all been successfully assessed using this method. To seal the chamber from external forces, a collar is placed on top of a compost bed and inserted to a depth of approximately 5-10 cm. The collar has an opening that enables gases to enter the chamber. Sealing is carried out properly to prevent gas leakage. The chamber is equipped with a tube and a valve that allow collected gas samples to be drawn into a syringe and injected into a vacuum vial. In a compost pile, several chambers may be positioned in different locations. The chamber only covers a small portion of the bed's surface (usually up to 1 m²). There are two types of closed chamber

methods: static and dynamic. The static chamber method has been effectively used to measure GREENHOUSE GAS emissions in heaps made with cow dung (Jagwe *et al.*, 2019b), using the equations of (Chan, Sinha and Wang, 2011):

$$Er = (C \times MW \times V) / (0.08206 \times T \times Af \times D)$$

$$Efd = [(Er \times 24) / 1000] \times (Av / Mv)$$

$$Ef = \sum Efd \times P$$

Where Er = Emission rate ($\text{mg} \cdot \text{h}^{-1} \text{ m}^{-2}$)

C = Concentration of the gas (ppm)

MW = Molecular Weight of the gas

V = Volume of the air above the waste surface inside the drum (m^3)

0.08206 = Ideal gas constant

T = Temperature (K)

Af = Area of the waste surface inside the drum (m^2)

D = Duration of sampling (h)

Efd = Emission factor per day ($\text{g} \cdot \text{mg}^{-1} \text{ d}^{-1}$)

Av = Total area of the vermicomposting unit (m^2)

Mv = Total mass of the waste in the vermicomposting unit (mg)

Ef = Emission factor ($\text{g} \cdot \text{mg}^{-1}$)

P = Vermicomposting period (d)

Enclosures and bands are frequently crafted from zinc-coated steel, aluminium, durable steel, and polyvinyl chloride (PVC). The height of the enclosure varies from 0.10-0.8 m, depending on the measuring circumstances. The number of

samples and the intervals of sampling ranged from 7 to 40 mL. The frequency of sampling ranges from seconds to a few minutes after the enclosure has been sealed (5, 10, 15, and 20 minutes), 2-4 weeks per year, or once a week for approximately a year, depending on the technique of gas sampling. To stir the air inside the enclosure, a fan is sometimes used, and mixing is necessary to prevent gases from separating within the enclosure.

Finally, gas samples are gathered and analysed using gas chromatography or other methods. (Maeda *et al.*, 2013a) utilised the dynamic enclosure method to measure Greenhouse gas emission during dairy manure composting, and they used dried orchard grass as a bulking agent. The enclosure was constructed of PVC and had dimensions of 4m x 6m x 4m. It also included an air-blowing ventilator and a gas collection outlet at the end of the ventilation blower. With two replications, the gas concentration at the exhaust outlet was monitored every 30 minutes. The following equation was employed to calculate the emission rate (E):

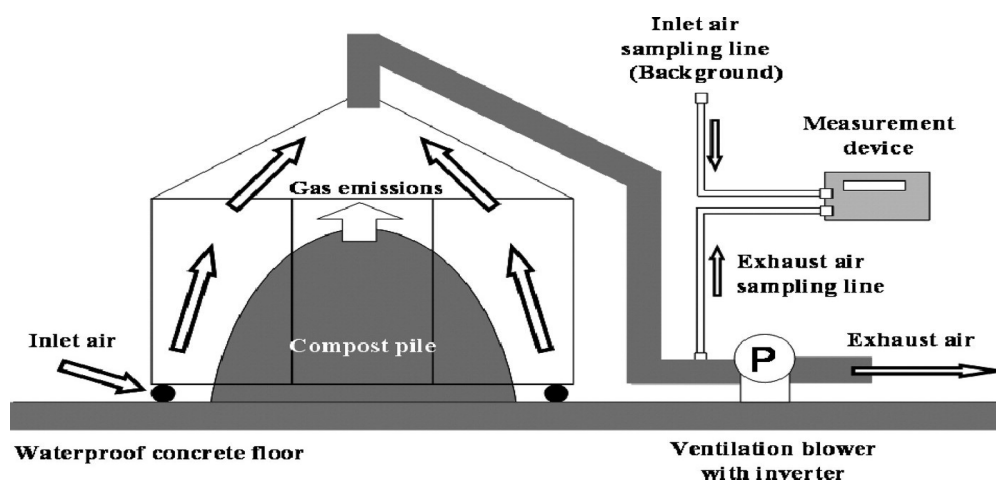


Fig: 2.3 (Maeda *et al.*, 2013b) closed Chamber system for monitoring compost gas emissions continuously

2.4.3 Open chamber method

Contrary to what its name indicates, the open chamber technique does not really use an open chamber. Instead, it is made up of a structure that resembles a closed chamber. The main distinction between procedures using closed and

open chambers is that the latter requires a constant flow of outside air through the chamber (Ahn *et al.*, 2011a). Open chamber systems are commonly used on a large scale, perhaps because they can be combined with portable automated gas analysers, which allows for on-site assessment of emissions. Additionally, the constant flow of outside air in open chambers permits rapid adjustments in the sampling approach, resulting in an increase in gas flux capture due to changes in ambient conditions and management activities.

Several studies have used the open chamber approach to evaluate greenhouse gas emissions (Ahn *et al.*, 2011b). (Arriaga *et al.*, 2017) used the open chamber technique to assess Greenhouse gas emission during cattle dung composting. During the measurement, a compressor (ABAC FC2/24, Torino, Italy) created an airflow that then flowed through orthophosphoric acid and distilled water before being introduced into each chamber via Poly Tetra Fluoro Ethylene (PTFE) tubes. The flow rate during the procedure was maintained at 2 to 3 L.min⁻¹, which was determined using a flow meter.

2.4.4 Gradient technique

The gradient method is a speedy technique for computing Greenhouse gas emission. A perforated pipe is placed horizontally beneath the compost level in this process. The pipes are sealed at both ends and have a valve that permits gas samples to be obtained. To obtain clean samples in the next step, it is crucial to eliminate the initial samples. The samples may be assessed in the same way as chamber samples. (Maljanen *et al.*, 2003) The gradient method has the advantage of being usable in winter. It is based on Fick's law of diffusion, and the flow of N₂O gas between snow and the atmosphere can be computed.

2.5 MICROBIAL DIVERSITY IN BIO-COMPOSTING

Microorganisms degrade organic material during the composting process, creating carbon dioxide, water, heat, and humus, a highly stable organic product. Under ideal circumstances, composting happens in three phases. the mesophilic phase, also known as the moderate-temperature phase, which lasts a few days. Finally, there is a cooling and maturation phase that lasts for several months after the thermophilic, or high-temperature phase, which may last anywhere from a few days to many months. Several microorganism populations are dominant at various stages of the composting process (CORNELL Composting - Compost Microorganisms).

Mesophilic bacteria perform the first breakdown, breaking down the soluble, easily degradable chemicals rapidly. The temperature of the compost rapidly increases thanks to the heat they generate. The mesophilic bacteria lose their competitive advantage above around 40°C and are replaced by thermophilic, or heat-loving, microorganisms. Many microorganisms that generate plant or human ailments are eliminated at temperatures of 55°C and higher. Compost managers utilise aeration and mixing to maintain temperatures below 65°C, which kills many types of bacteria and slows the pace of decomposition. High temperatures hasten up the breakdown of proteins, lipids, and complex carbohydrates like cellulose and hemicellulose, which are the primary structural components in plants, during the thermophilic phase. The temperature of the compost steadily falls as the supply of these high-energy molecules runs out, and mesophilic microbes once again take over for the last process of "curing" or maturation of the residual organic matter

2.5.1 BACTERIA

Bacteria are the smallest living creatures and are the most numerous in compost; they make up around 80 to 90% of the billions of microorganisms that are normally present in a gramme of compost. Bacteria are often responsible for

the majority of compost's decomposition and heat generation. They are the category of compost organisms with the biggest diversity of nutrients because they employ a wide range of enzymes to chemically break down a variety of organic components.

Single-celled creatures known as bacteria may take the shape of a rod, a sphere, or a spiral spirilla. Many can migrate independently of other species because they are motile. In the early stages of composting (0–40°C), mesophilic bacteria predominate. Most of them may be found in topsoil in various forms. After the compost reaches a temperature of more than 40 °C, thermophilic bacteria begin to proliferate. Members of the genus *Bacillus* dominated in the microbial communities during this era. The diversity of bacilli species is still quite robust between 50 and 55°C, but it begins to drop dramatically around 60°C or above.

Bacilli create endospores, which have thick walls and are extremely resistant to heat, cold, dryness, and a lack of food, to live in harsh circumstances. They emerge everywhere in nature and jump into action whenever the surrounding conditions are adequate. Bacteria belonging to the genus *Thermus* have been proven to exist at the higher composting temperatures.

Composters occasionally debate how microorganisms that can endure the high temperatures found in active compost developed in nature. Hot springs in Yellowstone National Park are where *Thermus* bacteria were originally detected and may have evolved. Deep marine thermal vents, animal faeces, and clusters of decaying plants that are in the optimum circumstances to heat up like a compost pile are some more natural sites where thermophilic conditions may be found. Once the compost has cooled, mesophilic bacteria have taken control once again. The spores and organisms present in the compost as well as in the neighbouring environment impact the amount and kind of mesophilic bacteria that recolonize it as it develops. Generally speaking, the microbial population that is perpetuated by a longer curing or maturation phase is more diversified (CORNELL Composting - Compost Microorganisms).

2.5.2 ACTINOMYCETES

The filamentous bacteria known as actinomycetes are what give soil its characteristic earthy fragrance. Actinomycetes are a class of bacteria even though they resemble fungus due to their absence of nuclei. They contribute considerably to the composting process by dissolving complex organic molecules including cellulose, lignin, chitin, and proteins. They can chemically decompose refractory detritus, such as woody stems, bark, and paper, due to their capacity to create enzymes. At the thermophilic stage of composting, some actinomycete species are more active, whereas others are dominant at the colder curing stage, when only the most resistant compounds are left. Actinomycetes may be discovered in the outer layers of the compost pile, typically in the last 10 to 15 cm, where they grow long, thread-like branching filaments that resemble grey spider webs.

Actinomycetes may create circular colonies that increase slowly over time. Overall, these bacteria are a significant aspect of the composting process since they aid in the breakdown of complex organic waste and the creation of humus that is rich in nutrients (CORNELL Composting - Compost Microorganisms).

2.5.3 FUNGUS

Molds and yeasts, two kinds of fungus, are significant decomposers in the environment. They turn complex plant polymers into less complicated chemicals that may be exploited by bacteria and other organisms. This stage is particularly crucial in compost because it allows bacteria to take over the breakdown process once cellulose has been totally eaten. Fungi break down the tough waste in compost. Fungi are renowned for their quick development, which is done through the production of a great number of cells and filaments. They may eat organic garbage that is hard for bacteria to break down, such as dry, acidic,

or low-nitrogen rubbish. Because of this, they are categorised as saprophytes, meaning they obtain their energy from decaying and dead organic components in plants and animals. Both the mesophilic (moderate temperature) and thermophilic (high temperature) stages of composting are characterised by an abundance of fungal species. When temperatures are high, most fungus prefer to stay on the compost's top layer. A sort of fungus that thrives in aerobic conditions are compost moulds. On the compost surface, they may develop as invisible threads or as grey or white fuzzy colonies. These moulds are particularly vital for composting since they simplify complex organic components and speed up the breakdown process (CORNELL Composting - Compost Microorganisms).

2.6. MATURITY AND STABILITY OF BIO-COMPOST:

The maturity and stability indexes are primarily used to evaluate the quality of compost. It can be useful to use certain physical, chemical, or biological characteristics as standards to assess the calibre of compost. Maturity is a measure of how far along a composting process it has progressed (Bernal *et al.*, 2017 a). As compost is "aged" and "cured," or after reaching maturity, it improves in quality and may be used for a variety of applications. It is impossible to determine a compost's maturity by evaluating only one attribute; at least two other factors must be considered. One indicator of the compost's stability and maturity might be its phytotoxicity or capacity for plant development (Iannotti *et al.*, 1993a).

Phytotoxicity, temperature (Ponsá *et al.*, 2008), colour, odour, and moisture are a few on-site factors that aid in determining a compost's maturity and stability. The Germination Index (GI), volatile solids (VS), C/N ratio, OM, Bc/Bn ratio, microbial respiration (Iannotti *et al.*, 1993b), and biological assays are laboratory measures that aid in evaluating the maturity and stability of a compost. Every compost product can only be applied if it is sufficiently old and free of

components that can be phytotoxic. Use of mature compost depends largely on how it affects seed germination or plant development (Teshome, 2021).

Compost's maturity and stability varies from one another. Although stability refers to a certain OM condition or stage of compost decomposition, maturity describes the extent to which the composting process is complete. Stability refers to the rate of oxygen absorption by a compost sample. Compost's stability index provides information on the state of OM during the composting process. It defines a particular phase or process of compost decomposition (Kranz et al., 2020). The microbial activity of the compost affects its stability, which essentially implies that stability is a measurement of the biological breakdown brought about by composting feed supplies (Bernal et al., 2017 b). An indication of stability may be found in the type of organic molecules that are still present and the subsequent biological activity in a

substance. Composts that are unstable are useless because when they are unstable, microbes create phytotoxic chemicals. If the compost is not sufficiently stabilised, toxic chemicals are produced during the breakdown process (Delgado *et al.*, 2002b).

2.7 MATURITY AND STABILITY INDICES:

Mesophilic, thermophilic, and cooling phases are the three primary temperature fluctuations that take place throughout the composting process. During the first several days of composting, when the temperature tends to rise, is the mesophilic phase. This mostly occurs as a result of the biodegradation of organic molecules by an increase in mesophilic microbial growth. According to (Resources, Recycling and 2013 a), the composting process took 25 days, and during that time the temperature progressively rose to 25–45°C.

When an organism is in the thermophilic phase, the temperature rises over the tolerance threshold for mesophilic germs ($> 45^{\circ}\text{C}$). The majority of the time the temperature increased beyond 40°C in 30 to 130 days. Mesophilic bacteria were displaced by thermophilic microorganisms as a result of the rise in temperature. When a large number of local microorganisms begin to assault the soluble and easily degradable chemicals, this phase is achieved (Jimenez *et al.*, 1991a). When easily degradable elements are present in the compost, the thermophilic phase quickly forms. By their investigation, A peak temperature of 70°C could be reached in 15 to 20 days after the procedure began. It demonstrated the quick emergence of the thermophilic phase as soon as the composting process got going and how every turning event causes a slight rise in temperature.

A second explanation for the reduced temperature rise is humidification, which may indicate that certain under-composed elements are still present in the pile even after the thermophilic phase (Oviedo-Ocaña *et al.*, 2015a). The C/N ratio tends to stabilise throughout the cooling phase as the OM start to deplete and the temperature also starts to drop. According to (Oviedo-Ocaña *et al.*, 2015b), the temperature started to drop quickly after the 19th week to an average value of 33°C , and by the conclusion of the 5th month of composting, there was no additional change in temperature despite rotating or adding water. The depletion of the available substrate is the primary cause of the temperature drop during the cooling or maturity phase. Moreover, a mesophilic microbiota replaces the thermophilic one as a result. The mesophilic microflora continues to partially degrade bio-resistant substances, namely cellulose and to a lesser extent lignin (Resources, Recycling and 2013 b). After the cooling phase is complete, the maturity is mostly attained.

Several maturity and stability parameters are shown in Fig. 4. (Mahapatra, Ali and Samal, 2022; Zhou *et al.*, 2022)

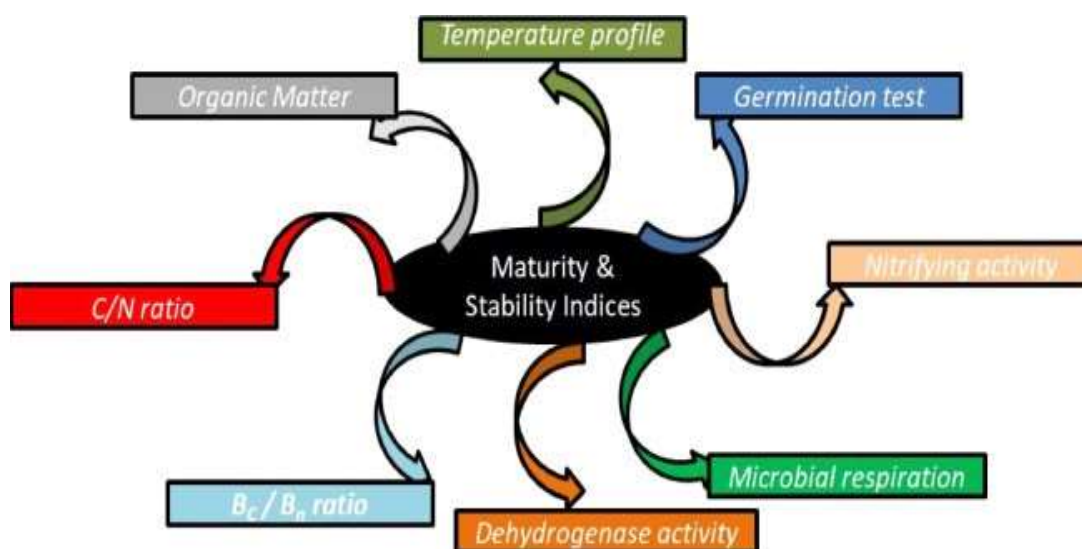


Fig 2.4. Maturity and Stability indices

2.7.1 ORGANIC SUBSTANCES(OM):

The level of humification of an OM can be used to gauge the maturity of compost (ElHousseini, ... and 2002; Rivers et al., 2002). Microorganisms biochemically change the OM during the composting process, and the presence of any degradable component indicates incomplete composting. When a plant reaches maturity, humification, or the creation of humic-like compounds, occurs. Thus, the level of OM humification is a very helpful predictor of the compost's maturity (Roy Antonin Azai *et al.*, 2018).

Humic acid production is responsible for the OM's humification revelation. Humic acid production results in a rise in the quantities of O and N, molecular weight, aromatic properties, and functional groups. During the humification of OM, the generated functional groups offer cation exchange capacity (CEC) (Bernal et al., 2017 c). As a result, the CEC and CEC/Organic carbon may be utilised as a gauge for the compost's maturity.

most biodegradable carbon component in any compost, dissolved organic carbon (DOC), may be used to gauge the compost's maturity. By their research, (Technology and 2011) shown that the ratios between organic carbon and

organic nitrogen as well as between organic carbon and total nitrogen may be utilised to gauge the compost's stability and maturity. As the composting process advances, the C/N ratio steadily falls. The C/N ratio for chicken manure containing the bulking agents rice bran and rice straw steadily fell from a value of 30 to 18 (Bernal et al., 2017 d). Similar to the previous experiment, it was shown that the breakdown of organic components caused the C/N ratio to progressively decline from 29 to 16 in a composting process helped by biochar. Degradation of organic molecules results in the emission of CO₂, which ultimately leads to an increase in total nitrogen.

An important parallel for the stability and maturity examination of compost is the percentage increase in total nitrogen or the decrease in carbon content during the course of composting. When the composting process continues, the C/N ratio eventually drops from 70:1 to 10-15:1, and this represents the compost's maturity. While two-thirds of the carbon is released as CO₂, the declining C/N ratio is caused by bacteria consuming organic molecules. The degree of organic matter breakdown or consumption by microbes is a good indicator of a compost's stability. As a result, the C/N ratio also provides insight into the stability of compost.

2.7.2 C/N RATIO

Nitrogen is necessary for biological decomposition; hence C/N serves as a measure of the overall amount of nitrogen available (Li et al.,). The microbes that break down trash require a constant supply of nutrients, primarily composed of carbon and nitrogen. The primary source of these nutrients is waste itself, but for the process to be effective, it needs to be present in the right proportions. A reduction in the C/N is seen as the composting process continues. Similar to (Tiquia et al., 1996), who reported that the C/N was 53.57 on the 25th day, before falling to 34.73 on the 50th and finally to 16.6 on the 100th day after the composting process began. This decrease in C/N is mostly caused by CO₂ emissions as composting progresses.

For the composting process to be as effective as possible, a C/N ratio between 20 and 25 is ideal. If there is an excess of either carbon or nitrogen, the surplus will be transformed to CO₂ and ammonia, respectively, until the proper balance is restored. The rate of composting slows down when the ratio is out of equilibrium. The C/N ratio rises throughout the thermophilic stage and subsequently progressively drops, according to a pattern noted by (Alidadi *et al.*, 2016).

The degree of disintegration has a significant impact on the C/N ratio; a lower degree of disintegration results in a greater C/N ratio number. On the 126th day, a C/N ratio value of 31.5 to 35.7 was noted, and this higher value was brought about by a lesser degree of disintegration. The presence of aromatic carbon in biochar, which affects the composting process, was the cause of the increased C/N ratio result. In a two-window system (devoid of sludge), (Khan *et al.*, 2014) reported an initial C/N ratio of 32 and 28.5, respectively, and at the conclusion of the process, the net C/N ratio was seen to be 18.6 and 14.6, respectively. Although a C/N value close to 12 is typically recognised as a sign of high degree of compost maturity, several writers contend that the indication of appropriate maturity is below 20 (Jimenez *et al.*, 1991b).

During fermentation, the first group of bacteria builds up nitrogen, which is used by the subsequent microbial groups. The proteolysis of proteins results in the creation of amino acids, which are then utilised to create new proteins. Because of this, monosaccharides breakdown quickly and nitrogen loss is often minimal. The breakdown of monosaccharides causes an increase in temperature, which leads to a net reduction in carbon concentration over time. Although a general pattern is largely visible, the total nitrogen content during the composting process is still rather unknown. Early on in the composting process, a mixture of sewage and municipal solid waste exhibits high total nitrogen content. As the composting process continues, NH₄-N levels typically decrease while NO₃-N levels rise (Resources, Recycling and 2013).

2.7.3 Bc/Bn RATIO

The ratio of microbial carbon biomass to microbial nitrogen biomass, or Bc/Bn, essentially captures the biological activity balance of the compost. A high Bc/Bn ratio mostly results from a high level of microbial diversity and heterogeneity and is a sign of a significant biological activity (Belete *et al.*, 2001). In the thermophilic phase, this ratio rises. Most often, a minimal value is seen at the start of the cooling phase, which increases again throughout the maturation period, or almost towards the conclusion of the cooling phase.

2.7.4 Dehydrogenase ACTIVITY

At the mesophilic and thermophilic stages of the composting process, biological activity is characterised by dehydrogenase enzymatic activity. The biological oxidation of diverse organic compounds by various enzymes is the dehydrogenation process. The dehydrogenase enzyme, which is an essential component of the microorganism, contributes significantly to the oxidation of organic molecules by shifting pH from substrates to acceptors. Values are often given as mg of triphenyl formazan (TPF) released per grams dry matter¹ h¹. Since a quick rise is noted at the beginning of the thermophilic phase and the maximum value is mostly recorded towards the conclusion of this phase (0.54 mg TPF g dry matter¹ h¹), an increasing trend in this activity is often observed across the thermophilic phase of the composting process (Barrena *et al.*, 2008).

Over the mesophilic and cooling stages, activity is weak. According to (Resources, Recycling and 2013), the dehydrogenase activity was found to be less than 4 mg TPF/g dry matter/d¹ for the mesophilic and cooling phases, and was on average 8 and 7 mg TPF/g dry matter/d¹ across 50 to 140 days during the thermophilic phase. The presence of sludge also affects the biological activity. (Resources, Recycling and 2013 e) conducted study and discovered that a windrow free of sludge had higher dehydrogenase activity than one that had.

A solid waste compost that had been mature for three months was the subject of research by (Serra-Wittling, Houot and Barriuso, 1995), who discovered a value of 2.3 mg TPF/g dry matter/1 d1. The dehydrogenation process threshold value is 0.83 mg TPF/g dry matter/1 d1. A net reduction in dehydrogenase activity suggests high stability of biodegradable materials and is a very strong measure of compost maturity. Both foreign carbon supplies and overall microbial respiration have a direct impact on the dehydrogenase activity. Volatile substances including trichloromethane, benzene, and toluene, which are typically present in solid wastes, have a detrimental impact on the dehydrogenase activity in composts.

2.8 COMPOSTING BINS:

Open composting, tunnel composting, or controlled composting are the most prominent kinds of composting technology used for solid waste management. In cities or towns, open or tunnel composting is difficult to achieve due to quick growth and a lack of space.

The only realistic solution is to do restricted composting and deploy compost containers. Not only do compost containers take up less land, but they are also cost-effective. of some expertise of the composting process, it is pretty straightforward to utilise. If the bin has an odour control feature, it may be viable to place a composting bin inside if desired, such as on a balcony or in a garden.

Composting containers that are offered commercially are lightweight and simple to install. In addition to saving time and money, adopting these containers fosters sustainable rubbish reduction. Also, it stops flies and rats from eating on residential garbage in gardens. Bins give a cleaner, safer way to manage solid waste with just little upkeep required from a human.

For a composting bin to perform correctly and deliver the finest results, there are a few components that are required. Mesophilic phase, thermophilic phase, and mature phase should all have space in a compost bin. To generate a mature,

nutrient-rich compost, it has to be appropriately aerated, mixed, and should include a chamber for collecting excess water (leachate). According to the needs of a family or community, it should be portable and accessible in a variety of sizes (Lleó et al.,).

The optimal place for a composting bin to function is in a shady or partially shaded zone. Very few of the commercially available bins detailed in the book have all of these properties. Realistically, a composting bin may be constructed from materials like plastic, wood, or bamboo, but owing to its lightweight nature and durability, plastic is most typically utilised to manufacture bins (Samal, Dash, chemical, et al., 2017). Compost that has gained maturity may be used in gardens to feed nutrients to the soil, prevent plant diseases, and promote soil moisture retention. Compost that has gained maturity may be sold commercially for use in agriculture.

2.8.1.1 ECO BIN

An eco bin composting container is developed in Bengaluru, India. It is constructed of food-grade, UV-stabilized, LDPE-impregnated plastic and is suited for composting indoors. The bin is around 35.5 cm tall, with a top width of 22 cm, and a 20-liter capacity. The eco bin is sometimes referred to as an all-season composter due to its potential to generate compost in any season. With the use of this container, all sorts of junk, including kitchen waste, green waste, food waste, vegetable and animal waste, dairy products, citrus fruits, bread, etc., may be changed into organic compost (Oktiawan, Conferences and 2018).

Either an aerobic (with air) or anaerobic (without air) mechanism may be deployed to compost material in the bin. Fundamentally, the Bokashi bran for anaerobic use and the Coco magic block for aerobic utilisation are included in the Eco bin package (Veen et al., 2019).

The breakdown of organic waste starts as soon as the container is filled with kitchen rubbish and the bacteria are freed. These ingested bacteria quicken the

composting process, get rid of smells, and keep pests away. The Bokashi bran strainer and drain tap work together to remove the moisture that the food waste, which is utilised as fertiliser, releases. When aerobic composting is applied, the bacteria are found in the coco magic block, and the liquid that is expelled throughout the procedure streams into the washbasin. It is not essential to mix or stir this bin or to add brown leaves, sawdust, cow manure, etc. Its benefits as a trashcan are further strengthened by the fact that it does not attract any form of flies, insects, or rodents. Table 3 includes numerous composting bin types.

Sl No.	Bin	Type of Bin	Description of the Bin
1	Eco Stack	Outside use	Material - UV Stabilized polyethylene made of thick plastic. Capacity - 260 kg
			<i>Distinct feature</i> - Rain catching vent is provided at the bottom with additional aeration vents. No turning required
2	Smart Pot Compost Sak	Outside use	Material - Polypropylene Fabric
			Dimension - 76.2 cm wide and 96.52 cm height
			<i>Distinct feature</i> - Permeable fabric accelerates microbial activity The fabric allows the air and water through. This allows the compost to cook faster.
3	Tumble Weed	Outside, Garden use	Material - 100 % UV protected recycled plastic.
			<i>Distinct feature</i> - Consists of air vents on both sides and also contains a big hinged door. Attached with a stainless-steel breaker bar and powder coated frame. Wheels are attached for mobility. Spinner is provided for the purpose of mixing.
4	Thermo-King, Plastic Omnium	Outside - Garden use	Material - High-density Polyethylene
			<i>Distinct feature</i> - It is available in variable different sizes. Consists of lateral system

	Caraibes		with natural ventilation. Bottom panel is provided for compost extraction.
5	Hungry Bin	Outside - Garden use	Material - Food grade polypropylene
			Capacity - 0.6 kg
			<i>Distinct feature</i> - Unique design and simple to harvest castings. The hungry bin is a continuous flow system. The unique shape of the bin creates a large surface area allowing all the worms living in the bin an easy access to the food scraps at the top. It has a fertilizer producing tray at the bottom. It consists of wheels for ease in transportation.
6	Home Compost Bin- SCB100	Outside - Garden use	Material - UV stabilized polyethylene with rust proof insulated foam
			Dimension - It consists of a composting compartment of 70 ltr and compost collecting compartment 30 ltr.
7	Eco Bin	Terrace, Balcony use	Material – Plastic
			Dimension - Top Width - 22 cm and Height - 35.5 cm
			<i>Distinct feature</i> - Composting mechanism can take place both in aerobic and anaerobic conditions. The composter kit comes along with complete user instructions and a pack of magic microbes bokashi bran (for anaerobic) and coco magic block (for aerobic).
8	Humus Composting	Plastic Bin for Outside use	Material - Recycled Polyethylene Polypropylene.
			Dimension - 48 and 105 cm top and bottom diameter with 95 cm height.
			<i>Distinct feature</i> - It consists of a base plate and a fly net made up of welded hot-dip galvanized steel mesh and nylon. Holes are provided at the bottom for aeration.

9	Envirocycle Composter	Rotary Drum type for Outside use	Material - Recycled plastic and Aluminum
			Dimension- 64.5 cm × 54.6 cm x 70.36 cm
			<i>Distinct feature</i> - The drum, door and compost tea collecting base are made up of food safe, BPA free, UV and antioxidant protected materials. It consists of 8 drain plugs to collect the liquid fertilizer. It has an easy to turn drum body which allows regular mixing. Vents are also provided to increase airflow into the drum.
10	Bokashi Compost Bin	Inside use	Material – Plastic
			Dimension – 30 cm x 30 cm x 42 cm
			<i>Distinct feature</i> - Clean and Odorless. Kit consists of bokashi bran. The bin is provided with easily twistable tap, drainage tray, bokashi masher and a scoop. A simple conversion process is involved.

Table 2.3. Different Types of Composting Bins

2.8.1.2 BOKASHI

The square Bokashi composting container is produced in the UK and is known as "fermenting organic matter" in Japanese. Throughout the previous several decades, the phrase has attained its current definition and use in North America and Great Britain. Food scraps and other organic waste are transformed into a soil additive known as bokashi that enhances soil texture and supplies nutrients. It varies from standard composting procedures in a number of ways. The manufacturers of Bokashi bin may have adopted this phrase and its connotation as a result. Some 40 units were positioned around the buildings on the Charles Sturt University's Wagga Campus as part of the deployment of this in 2007. Essentially, it transforms food waste into high-quality liquid fertiliser and odourless organic compost (Delgado et al., 2002c; Colón et al., 2010). It is made

of plastic, measures 30 cm by 30 cm by 42 cm, and has a 23-liter capacity. A 23L Bokashi bin, a lid, 2 kg of Bokashi bran, an easy twist integrated tap, a drainage tray, a Bokashi scoop, and a Bokashi masher make up the whole set. Bokashi bran is

a bran-based product that has been activated using molasses and powerful bacteria. When put to the bin, the fragrant chemical known as bokashi encourages the fermentation of organic materials. Effective bacteria have been introduced to the Bokashi bran to hasten decomposition. Adding food waste to the Bokashi bucket and then filling it up with Bokashi bran until the bucket is full is all that is required to fill the bin. The fermentation process is then allowed to run its course for two to three weeks. Regular draws of the liquid fertiliser are done to eradicate any leftover moisture. Once the procedure is accomplished, the waste is prepared for planting and can be buried in the garden, put to a compost pile, or placed in a wormery to be "finished off." Now that the meal has entirely fermented and been neutralised by odour, bokashi should no longer attract rodents when placed in the composter. This composting container also has the virtue of not attracting fruit flies as the process doesn't require air. Meat, fish, fruit, and vegetables may all be composted appropriately, which also assists in re-establishing the soil in the garden.

2.8.1.3 ECO STACK BIN

The Gardener's Supply Company produces the Eco Stack composting container in the United States. To prevent corrosion, it is comprised wholly of UV-stabilized polyethylene and has no metal components. Its base is roughly 70 cm in width and 100 cm in height, and it can store up to 254 litres of material (food waste + yard debris). Worms help Eco Stack in breaking down the materials inside the bin in a method similar to a typical compost bin. There are side vents that aid in circulating the oxygen inside the bin, which is vital for the contents to break down. Due to the vents, the bin automatically turns the items into compost without rotating. The top of the bin has a cover, but the bottom of the bin is open,

allowing the worms to quickly enter. Rodents and other pests might enter the bin through the aeration holes that are offered at the bottom. Thus, it is preferable to use fabric or plastic sheets to cover the foundation. When the composting process is complete and the bin is full, all the pieces may be easily pulled off, compost extracted, composter restacked, and unfinished wastes poured back into it.

2.8.1.4 ENVIROCYCLE COMPOST BIN

A composting container dubbed as Envirocycle is comprised of recycled plastic and aluminium. High-quality, BPA-free, UV and antioxidant-protected materials are employed to build the drum, the barrel's door, and the base for collecting compost tea. The bin has measurements of 64.5 cm x 54.6 cm x 70.36 cm, a drum volume of 132.5 litres, and a base capacity of 9.5 litres. The bin is filled with biodegradable food waste through a door and snap lock on the drum. Its snap lock and door are also deployed to remove the mature compost. Every three days, the drum is totally rotated or spun three times. The bin yields mature, fresh, earthy-smelling, and garden-ready compost after 4 to 8 weeks. Worms may speed up the composting process and provide vermicast that is rich in nutrients. It contains vents that permit more air to enter the drum, aerating and oxygenating it as a result. In the bottom of the bin, there are eight drain plugs for collecting liquid fertiliser (compost tea). This bin has the

property that its drum may be transferred to any place where it is necessary. The rotation may still be decreased during the snowy winters by continuing with this method.

2.8.1.5 AUSTRIAN EXACO JUWEL COMPOST BIN

JUWEL is the producer of the Exaco Juwel Austrian Compost bin. High-grade polypropylene copolymer resin with up to 40% recycled material makes up its composition. Due to the bin's UV resilience, colour fading is less possible. It is

available in a range of sizes and capacities, the most effective of which has a capacity of roughly 292 litres. Active aeration is applied in four walls, and there is no demand for mixing as the air ducts are incorporated. It features a foundation that is resistant to rodents, openings on two sides for compost disposal, and a hinged top to keep the bin from being blown away by heavy winds.

2.8.1.6 SCB 100: RESIDENTIAL COMPOST BIN

The UV-stabilized polyethylene and insulated foam that make up the SCB 100 compost bin are produced in India by Spintech. Its thick covering offers the drum structural strength and aids in retaining the heat released during composting, speeding up the process. The bin is 28" x 21" x 18" and can hold 30" of compost in the collecting section and 70" of compost in the composting chamber. Green and brown trash can total up to 1-1.5 kilogramme each day. It has air holes all throughout to provide the microorganisms an appropriate quantity of oxygen. As a result, the number of bacteria will rise, speeding up the composting process. Leachate may be drained away using the tap at the bottom. Moreover, it has a door at the bottom for compost collection. This bin is believed to have a continuous treatment mechanism since compost is extracted through the bottom door and rubbish is put to the top of the bin.

2.8.1.7 COMPOSTER FOR HUMUS

The cone-shaped, 22 kilogramme, recycled PE (Polyethylene) and PP (Polypropylene) humus compost container is manufactured in Denmark. The bin is 95 cm in height, 48 cm at the top and 105 cm at the bottom, with a volume of 320 litres. The compost bin has a cover, a side door through which the compost may be emptied, a fine-meshed steel net at the bottom to keep rats out, and a net (to prevent flies from entering). Aeration is aided by bottom holes and a stove-like design where air is drawn in at the bottom and released at the top.

The flux chamber, which is installed below the lid and used to measure the emissions, is supported by a plastic rim. The bin is topped off once a month with dolomite/garden lime and is fed about twice a week with organic household garbage and a small bit of garden waste. Depending on the temperature, fresh compost can be retrieved in a period of 4 to 12 months.

2.8.1.8 THERMO KING

A 400-liter compost container named Thermo-King from Plastic Omnium Caraibes, France, is produced of high-density polyethylene. To guarantee aerobic conditions, it incorporates a lateral

system with natural ventilation. The initial investigation was conducted in Guadeloupe (one of the French Overseas Departments in the Caribbean). The composter's top was used to insert the organic waste, and its two bottom lateral panels were used to remove the mature compost. The bins were fed twice or three times a week and kept in a level, shaded area. Domestic kitchen wastes (such as vegetable matter, cooked meals, coffee grounds, fruit scraps, eggshells, and bread) and garden wastes are among the organic materials utilised for composting (e.g., grass clippings, rotten fruits, dead leaves, branches and twigs). To avoid unpleasant odours and the presence of flies, rodents, and parasites, meat, fish bones, and animal waste were not used. Every week, a compost mixing tool was used to mix the composter's upper layers. The organic material was composted for around 12 weeks after the moisture level of the material was gently adjusted by adding 5 litres of tap water. Around 1 kg of compost was removed from each lower panel at the conclusion of the composting process, and both subsamples were then combined and taken to the lab for testing. The outcomes matched the safety requirements.

2.8.1.9 COMPOST TUMBLER FOR TUMBLEWEED

Australia-based Tumbleweed is the business that makes the compost tumbler. This bin measures 36.2" (H) x 31" (L) x 27.5" and is comprised wholly of UV-protected recycled plastic. It has a 140-liter capacity (W). 50%-yard debris, 50% kitchen waste, and a pinch of soil are placed into the bin. Avoid ingesting fish, meat, dairy products, and animal waste. The bin has two air vents on each side, and it has two wheels for rapid compost transfer from one area to another. Moreover, it boasts a powder-coated frame and a breaker bar made of stainless steel. The container also features a single door that has a latch and can be secured. Both putting compost in the bin and extracting finished compost come out the door. For optimal results, rotation must be undertaken every two days. The container is prepared to deliver the readily accessible compost in 4 to 6 weeks after composting begins.

2.8.1.10 THE HUNGRY BIN

New Zealanders created and built the trashcan. It exploits composting worms as part of an effective and efficient technique for transforming residential garbage into nutrient-rich organic compost. Composting worms weighing up to 3 kg (6.5 lbs) may be detected in a properly operating bin. They are great for dissolving food particles and assisting in the manufacturing of quality natural fertiliser. Overfilling the garbage can with food may cause it to decay, which makes it unpleasant and sticky. This may result in poor worm growth circumstances, which would limit their output and establish an anaerobic environment inside the bin.

The feeding process of the bin should be gradually enhanced over time as the worm population expands since these worms reproduce more quickly in favourable settings. The bedding materials (compost, soil, potting mix, coconut fibre, decaying leaves, or shredded paper) may be added to the bin first and

then the worms (initially with 500 grammes which after 6 to 8 months grows into full population by breeding). The food waste has covered it, and for the bin to perform more well, castings must fill at least 3/4 of the capacity.

When the castings in the bottom part (floor) have clumped together and are worm-free, they are suitable for use. The optimal site for the bin is in a shaded zone where the temperature is between 15 and 25°C.

Castings weigh around 125 kg when they are in a bin, so transporting the bin from one place to another demands wisdom. For easier transporting of the bin from one region to another, a set of wheels are offered at the bottom. The waste disposal device consists of a tap via which excess water (leachate) is drained and collected in the base pan.

2.8.1.11 COMPOSTING SMART POT SAK

The smart pot compost sak is made in the United States, and its developers have spent 30 years refining it in practical use. The sak's porous geo-textile construction offers for natural airflow, improving the composting process. The sak has a 350-liter capacity and is 76.2 cm broad by 96.52 cm tall. It must be kept in a place that gets some sunlight and a little moisture. It is necessary to feed the sak with leaves, yard garbage and home waste.

2.8.2. COMPOSTING'S USE OF ADDITIVES AND BULKING AGENTS:



Fig. 2.5. Bulking agents in Bio-composting (Zhang et al., 2019)

It's crucial to employ bulking agents and additives to make sure the composting process runs smoothly and effectively. Bulking agents are substances that are added to the compost pile to strengthen it and make it more porous. Better ventilation and water retention are made possible as a result, both of which are crucial for preserving the compost's ideal moisture content.

The composting process might sluggish or even halt if there is insufficient moisture and ventilation. The carbon-to-nitrogen (C: N) ratio, which is critical for the development of the microbes that break down the organic matter, can also be balanced with the use of bulking agents.

The ratio of carbon to nitrogen in composting material is known as the C:N ratio. Bulking agents can aid in achieving the necessary C:N ratio for composting, which ranges from 25:1 to 30:1. Straw, sawdust, chopped leaves, and other coarse materials are examples of bulking agents. These materials have a balanced C:N ratio due to their high carbon content and low nitrogen content. Moreover, bulking agents aid in forming air pockets inside the compost pile, allowing oxygen to permeate the pile. The aerobic microbes that degrade the organic matter must have access to this oxygen in order to develop (Ren *et al.*, 2023).

Contrarily, additives are substances that are added to the compost pile in order to increase the nitrogen and other vital nutrients for the microorganisms. This might hasten the composting process and produce compost of higher calibre. Nonetheless, it's crucial to utilise additives sparingly to prevent throwing the C:N ratio out of equilibrium. Manure, blood meal, bone meal, and other nitrogen-rich substances are examples of additives. By giving the microorganisms in the compost the nitrogen they require to flourish, these elements can aid in accelerating the composting process. By adding vital nutrients that plants can utilise, additives can also enhance the quality of the compost.

Bulking Agent	Functions
Sugarcane trash	Control carbon content, pH, moisture
Sawdust	Control moisture, pH, aeration, bulk density, temperature
Poultry waste	Control carbon content, bulk density
Cow dung	Control carbon content, bulk density, Ph
Rice husk	Control moisture, temperature

Table 2.4. Different types of bulking agents and their functions (Batham et al., 2013)

It is essential to remember that not all materials can be composted. Meat, dairy, and fatty meals are examples of ingredients that might draw pests and hinder the composting process. These substances ought to be avoided or used sparingly. Bulking substances and additives play a crucial role in the composting process. Although additives offer vital nutrients that can hasten the composting process and enhance the quality of the compost, bulking agents help the compost pile's structure and porosity. Composting may be a very effective and efficient approach to transform organic waste into a useful resource for plants and gardens by utilising the correct blend of bulking agents and additions (Ren *et al.*, 2023).

2.9. USING CARBON SINKS TO CYCLE THE CARBON EMITTED DURING COMPOSTING:

An essential mechanism that aids in reducing the effects of climate change is the cycling of carbon released from composting through various carbon sinks. Systems that naturally or artificially capture and store atmospheric carbon are known as carbon sinks. The carbon cycle, which describes how carbon moves

through the atmosphere, seas, and terrestrial ecosystems, depends critically on carbon sinks. Decomposing organic materials into a nutrient-rich soil amendment known as compost is a technique that may be used to nourish gardens and plants. Carbon dioxide and other greenhouse gases are released into the environment during the composting process. This carbon may, however, be recycled through a variety of carbon sinks, which can lessen the effects of climate change.

The forest ecosystem serves as one of the most significant carbon sinks. By the process of photosynthesis, trees take up carbon dioxide and store it in their biomass. Since they can hold a lot of carbon, forests are crucial in the battle against climate change. Using compostable organic material as fertiliser for trees or other forms of flora can help these ecosystems store more carbon and produce more biomass. By offering a sustainable source of organic waste that can be utilised as fertiliser, composting can also aid in reducing deforestation.

The ocean is another significant carbon sink. As carbon dioxide from the atmosphere is absorbed by the ocean, it helps to lessen the effects of climate change. When compost is utilised as agricultural fertiliser, some of the carbon may ultimately find its way into the ocean through runoff or groundwater. This may increase the ocean's ability to absorb carbon. Yet, it's crucial to keep in mind that too much nutrients from fertilisers can also contribute to the acidification of the ocean, which can harm marine ecosystems.

Another significant carbon sink is soil. The quantity of carbon stored in soil may be increased by adding composted organic matter to the soil. By lowering the quantity of carbon in the atmosphere, this can increase soil fertility and aid in minimising the effects of climate change. Also, as landfills are a big source of the powerful greenhouse gas methane, composting can also help to lessen the quantity of greenhouse gases generated from these sources.

Last but not least, carbon may be stored in additional man-made carbon sinks like carbon capture and storage (CCS) methods. Carbon dioxide from industrial activities is captured by CCS, and it is then stored underground in geological

formations. CCS has the potential to be a crucial weapon in the battle against climate change, although not being extensively used yet.

Carbon released by composting is cycled through carbon sinks, which is a crucial step in reducing the effects of climate change. Composting can aid in enhancing the ability of carbon sinks like forests, seas, and soil to store more carbon, which is crucial in the battle against climate change. We can assist lower the amount of carbon in the atmosphere and lessen the effects of climate change by using compost as a sustainable supply of organic matter and minimising the greenhouse gas emissions from landfills.

2.10 ECONOMICS AND BUSINESS MODELS:

The old linear economy, which depends on the extraction of raw materials, the manufacture of commodities, and the disposal of trash, is being replaced by the circular economy as a viable and environmentally benign alternative in recent years. Contrarily, the circular economy emphasises recycling and reuse of materials and trash in order to reduce resource loss and establish a closed-loop system.

Composting is a crucial part of the circular economy since it provides a way to deal with organic waste while recovering priceless nutrients. Composting is the process of breaking down organic material into a nutrient-rich soil amendment that may be used as fertiliser, such as food scraps, yard trash, and agricultural leftovers.

This procedure generates a useful resource that may be utilised to boost plant development in addition to assisting in the reduction of pollution brought on by organic waste. Interest in the economic analysis and business models of composting for a circular economy has grown in recent years. If the process is well planned and effectively run, composting may be a lucrative enterprise. The availability of a market for compost, the cost of supplies, labour, and

transportation, as well as the kind and volume of organic waste, all affect how economically viable composting is.

There are several business models for composting in a circular economy. The community composting model is one example. It entails cooperation between a number of parties, including the local government, community groups, and commercial firms, in order to collect and handle organic waste. This concept may lower the price of organic waste transportation while boosting community involvement in garbage disposal.

Another option is on-site composting, which entails turning organic waste into compost right where it was produced, like a farm or a restaurant. By enabling more control over the composting process, this technique can assist to save transportation costs and enhance the quality of the compost. Another economic model is centralised composting, which entails the construction of sizable composting facilities capable of handling a sizable volume of organic waste. This concept enables economies of scale and centralised administration of the composting process, making it potentially more cost-effective than on-site composting.

A number of economic evaluation methodologies may be used in addition to these business models to determine if composting is feasible in a circular economy. A method called life cycle assessment (LCA) may be used to estimate how composting would affect the environment in terms of greenhouse gas emissions, water usage, and energy use. Another approach for evaluating the economic sustainability of composting is cost-benefit analysis (CBA), which compares the costs and advantages of the procedure.

As a sustainable method of handling organic waste and reclaiming valuable resources, composting is an essential part of the circular economy. Composting's economic analysis and business models are crucial factors in assuring the process's viability and profitability. Composting will surely be a key component of our effort to move towards a more sustainable and circular

economy as we work to cut waste, protect resources, and strengthen ecological resilience.

2.11. CHALLENGES AND FUTURE DIRECTIONS:

Over 2.01 billion tonnes of garbage are produced globally each year, and by 2050, that number is projected to increase to 3.4 billion. Lack of application of effective and efficient waste management technologies worldwide is mostly due to a lack of understanding regarding SWM.

In the modern world, a new approach to manufacturing, consuming, reusing, recycling, and waste minimization is required. The use and advantages of composting as a sustainable tool for SWM and the use of compost manure and leachate for a circular economy should be made known to government institutions, the state, and the general public. One way to address the issues with SWM is to create a stringent and appropriate legislative framework to support the new economic pattern (Bernal et al., 2017 e).

The finished product (matured compost) needs to be of sufficient quality for soil usage without polluting the environment. There is not a lot of international consensus on the permanence of organic pollutants in compost. Several countries are still in need of implementing an organised waste management system, where everyone must be aware of their role in SWM.

Food waste must be composted at home in a compost container to enable a decentralised solid waste management system. This will assist in collecting high-quality manure and fertiliser in addition to closing the material loop. Only when the compost is grown and stable are the manure and nutrients produced following the composting process beneficial. So, further research and testing should be done to determine the maturity of the compost in order to increase its implications and uses. It is important to create new laboratory assays and indices that may be used to measure the compost's development and stability.

It is laborious to assess stability and maturity at home. Only if specific tests that can be performed at home to gauge the stability and maturity of compost are investigated and established will home composting be effective. For instance, it is impossible to assess the quality of manure and fertiliser made at home without doing experiments on seed germination and plant development. So, it will be useful to create specific tests or metrics to assess the quality and efficacy of the manure and fertiliser (made after home composting), in order for the compost and leachate generated to be utilised for farming and agricultural purposes. There is also a lot of study done on the drawbacks of composting, such as the generation of greenhouse gases. To reduce these drawbacks while maintaining the quality of the compost, more effort should be put forward.

The total composting process may be improved by integrating several methods and machinery, such as a mechanical aerator, temperature control equipment, moisture control equipment, etc. within the compost bin. This will eventually produce high-quality manure and fertiliser. Such cutting-edge bins should be developed with time and money invested without sacrificing cost.

3. MATERIALS AND METHODS

3.1 CONVENTIONAL / TRADITIONAL METHOD OF DECOMPOSITION.

Decomposition is the process of breaking down of the biodegradable nutrient waste into simpler substance by microorganisms and enzymes in-order to be absorbed by the plants.

In the conventional method of decomposition where the vegetable waste is mixed up with soil, ash stones etc. and is waited for 35 to 40 days to be completely decomposed.

The procedure for the Traditional Decomposition is as follows.

- Take 1:1 ratio of soil and vegetable waste (here we have taken vegetable waste as cabbage. It shows similar results for most of the leafy vegetables like lettuce, spinach etc.)
- Cut down the vegetable waste into small pieces of size 1.5 cm each and then keep it in a tray
- Weight and keep equal weight of soil and keep it another soil
- Mix the soil and vegetable waste (vegetable waste taken = 3KG, soil taken = 3KG)
- Once mixed add very little amount of water and make sure not to make a swamp
- Keep the sample for 35-40 days for the decomposition to happen
- Keep mixing the sample in every 3 days for aeration
- Note down your observations based on the weight change, odour and appearance of the sample
- Tabulate your observation and keep it for comparing with enzymatic decomposition and yeast decomposition



Fig3.1. Conventional Compost using 1:1 Ratio of Soil and Vegetable Waste

3.2 YEAST DECOMPOSITION

Yeast are Eukaryotic single celled microorganisms classified as members of Fungus Kingdom. Yeast plays different role in the decomposition of Plant Materials, actively participating as producers of hydrolytic enzymes or as Transient fungi that use product released during decomposition by other organisms such as fungi and bacteria.

Studies have proved that Yeast have increased the rate of decomposition. A study of decomposition of Municipal Market Waste by Yeast the decomposition was done in 7-8 days.

The materials Required Include Commercial Yeast, Vegetable Waste (cabbage, about 3 KG), Tray, Tap-water, Sterile pipettes and test tubes, Autoclave or sterilization device

PREPARATION OF YEAST CULTURE

Prepare the growth medium by dissolving the yeast extract or nutrient broth in distilled water according to the manufacturer's instructions. The growth medium should be sterilized before using. To the Growth medium add the yeast culture or dried yeast. Keep the Yeast culture in a warm place or an incubator until the culture reaches the desired density. Small amount of the Yeast can be stored in a Sterile test tube for any future uses.

. PROCEDURE

- Take vegetable waste (here we have taken vegetable waste as cabbage. It shows similar results for most of the leafy vegetables like lettuce, spinach etc.)
- Cut down the vegetable waste into small pieces of size 1.5 cm each and then keep it in a tray
- Measure about 4.739 grams of yeast and keep it aside
- Sprinkle the measured amount of yeast or yeast culture the vegetable waste evenly
- Moisten the mixture with water until it is damp, but not soaking wet. Yeast needs moisture to grow and ferment the organic matter.
- Cover the pile with a tarp or plastic sheet to retain moisture and maintain a warm temperature (ideally between 60-70°F). Turn the pile every few days to ensure adequate aeration and continue to add water if needed. From day 3 onwards mix the compost setup for aeration.
- Keep mixing the sample for every day for aeration

- Note down your observations based on the weight change, odour and appearance of the sample. Tabulate your observations for comparing.



Fig 3.2. Yeast Compost after 10 days

3.3 ENZYME DECOMPOSITION

Enzymes are Proteins that help speed up chemical reaction. Enzymes play major role in digestion, liver function and much more.

Here Enzymes play a major role in, metabolism of the taken vegetable waste samples. The enzymes act as agents that speed up the decomposition process.

We have seen that the conventional method takes up to 35-40 days for completely decomposing the feed sample whereas with the help of enzymes we can complete the decomposition in 10 days.

The major advantage of using enzymatic decomposition over conventional method is the increase in decomposition rate and the absence of soil.

MATERIALS REQUIRED

Jaggery, Curd, Water, Weighing Balance, Spatula, Beaker, Incubator

THE PROCEDURE FOR PREPARATION OF THE INITIAL ENZYME INOCULATION FOR A SAMPLE OF 3KG OF VEGETABLE WASTE IS GIVEN BELOW

Weight about 50 grams of Jaggery and 3 grams of curd and mix it with 250 ml of water and keep the mixture in a cool place for the enzyme inoculation. The enzymes will be ready to be used in 9-11 days.

For the enzymatic decomposition the Materials required and the Procedure is as follows A plastic tray, 3KG of vegetable market waste, Weighing Scale, Prepared Enzyme sample, Water

PROCEDURE

- Take vegetable waste (here we have taken vegetable waste as cabbage. It shows similar results for most of the leafy vegetables like lettuce, spinach etc.)
- Cut down the vegetable waste into small pieces of size 1.5 cm each and then keep it in a tray
- To the tray add 250 ml of the enzyme sample eventually
- Mix the vegetable waste with the enzyme thoroughly and keep it for the decomposition process.
- DAY 2: Sprinkle water to the compost setup
- From day 3 onwards mix the compost setup for aeration.
- Keep mixing the sample for every day for aeration
- Note down your observations based on the weight change, odour and appearance of the sample and tabulate your observations.



Fig 3.3. Enzyme Compost from day 1 to 10



Fig 3.4. Enzyme Preparation Using 50g Jaggery and 3g Curd in 250 ml of water

3.4 ENZYME COMPOSTING WITH VARIOUS COMPOSITION

3.4.1 40grams Jaggery and 2 grams curd in 200ml

Here the composition of Jaggery (40 grams) and Curd (2 grams) is varied along with the volume of water (200 ml) used in order to compare the rate of decomposition by varying the composition of Jaggery and Curd.

The Materials required and enzyme Preparation are similar to that of the previous enzyme composting.

PROCEDURE

- Take vegetable waste (here we have taken vegetable waste as cabbage. It shows similar results for most of the leafy vegetables like lettuce, spinach etc.)
- Cut down the vegetable waste into small pieces of size 1.5 cm each and then keep it in a tray
- To the tray add 200 ml of the enzyme sample eventually
- Mix the vegetable waste with the enzyme thoroughly and keep it for the decomposition process.
- DAY 2: Sprinkle water to the compost setup
- From day 3 onwards mix the compost setup for aeration.
- Keep mixing the sample for every day for aeration
- Note down your observations based on the weight change, odour and appearance of the sample

- Tabulate your observation and keep it for comparing with enzymatic decomposition and yeast decomposition

OBSERVATION:

- The decomposition was observed to happen in 10-11 days
- It was confirmed by the reduction in weight of the sample.
- The change in odour was also recorded.

All the recordings are given below.



Fig 3.5. Enzyme Compost 2 from day 1 to

3.4.2 60grams Jaggery and 4 grams curd in 300ml

Here the composition of Jaggery (60 grams) and Curd (4 grams) is varied along with the volume of water (300 ml) used in order to compare the rate of decomposition by varying the composition of Jaggery and Curd.

The Materials required and enzyme Preparation are similar to that of the previous enzyme composting.

PROCEDURE

- Take vegetable waste (here we have taken vegetable waste as cabbage. It shows similar results for most of the leafy vegetables like lettuce, spinach etc.)

- Cut down the vegetable waste into small pieces of size 1.5 cm each and then keep it in a tray
- To the tray add 300 ml of the enzyme sample eventually
- Mix the vegetable waste with the enzyme thoroughly and keep it for the decomposition process.
- DAY 2: Sprinkle water to the compost setup
- From day 3 onwards mix the compost setup for aeration.
- Keep mixing the sample for every day for aeration
- Note down your observations based on the weight change, odour and appearance of the sample
- Tabulate your observation and keep it for comparing with enzymatic decomposition and yeast decomposition



Fig 3.6. Enzyme Compost 3 DAY 1 and DAY 10

3.5 MICROBIOLOGICAL STUDIES

Microbiology is the study of biology of microscopic organisms like viruses, bacteria, algae, fungi and protozoa.

Here we will be studying about the biological load of the compost samples to find out the presence of bacteria and fungi. Further identification can be done in the future if required.

In order to find the biological load of the sample we will be doing the colony counting.

MATERIALS REQUIRED:

Compost Sample, Sterile Containers, Autoclave, Test tubes, Conical flasks, Petri dishes, Laminar air flow, Growth Media, Disinfectants, Micro Pipettes, Cotton, Spirit Lamb, Marker, Incubator, Aluminium foil, Agar-Agar, Potato Dextrose Agar, Nutrient Agar etc.

PROCEDURE FOR MAKING GROWTH MEDIA

1.NUTRIENT AGAR (250 ml)

Prepare 1 litre Saline by Mixing 8.5 grams of NaCl to 1 litre of distilled water. Add 7 grams of Nutrient agar in 250 ml of saline (For 1 litre of nutrient medium we need 28 grams of Nutrient agar)

Add 3.35 gram of Agar – Agar to the Nutrient agar Mixture for solidification. Stir and Heat the Mixture.

Using Autoclave Sterilize the medium to avoid contamination and the medium is ready to be used.

Transfer 25 ml of the prepared Nutrient Agar Growth medium to Petri dish and allow it to cool.

After completely cooled the Petri dishes can be used to transfer samples for microbiological study.

2.POTATO DEXTROSE AGAR (250 ml)

Prepare 1 litre Saline by Mixing 8.5 grams of NaCl to 1 litre of distilled water. Add 6 grams of Potato Dextrose agar in 250 ml of saline (For 1 litre of nutrient medium we need 24 grams of Nutrient agar)

Add 7 gram of Agar – Agar to the Potato Dextrose agar Mixture for solidification. Stir and Heat the Mixture.

Using Autoclave Sterilize the medium to avoid contamination and the medium is ready to be used.

Transfer 25 ml of the prepared Potato Dextrose Agar Growth medium to Petri dish and allow it to cool.

After completely cooled the Petri dishes can be used to transfer samples for microbiological study.

PROCEDURE FOR MICROBIAL STUDY

Prepare 1 Litre of Saline by adding 8.5 grams of NaCl to 1 Litre of distilled water and keep it aside.

Sterilize all the apparatus with the help of an autoclave and allow them to cool

Take 1 gram of our compost sample and transfer it to 100ml distilled and mix well.

Proceed for serial dilution by taking 1ml of the compost sample and transfer it to a test tube to which 9 ml of distilled water is added.

Continue Serial dilution for 7-8 times and keep it ready to be transferred to a Petri dish

From the 5th test tube of serial dilution take 0.1 ml of sample and transfer it to a Petri dish with Nutrient Agar for finding the Presence of bacteria.

From the 7th test tube of serial dilution take 0.1 ml of sample and transfer it to a Petri dish with Potato Dextrose Agar for finding the Presence of Fungi.

After the transfer of samples to petri dish allow them to form colonies by keeping the samples in the Incubator at 40°C for 24 hrs.

Make Observations and count the number of bacterial and Fungal Growth.

Bacterial growth can be counted by the total number of colonies present in the Petri dish

Fungal growth can be observed and noted down.

Note down Your observations

Repeat for all the compost samples.

3.6 CHEMICAL COMPOSITION OF THE COMPOST:

The Ultimate aim of the Final Product is to be used as an Organic Compost with good Nutritional Value which other plants can easily absorb and be used.

The total solid content of vegetable waste is typically 8 to 18%, with volatile solids accounting for roughly 87% of the total solid content. Organic matter is made up of 75% sugar and hemicellulose, 9% cellulose, and 5% lignin. N, P, K, and other nutrient elements are abundant and essentially non-toxic.

The most important Nutrients that determine the quality of the Compost are N,P,K (Nitrogen, Phosphorous, and Potassium) and it is important to determine the NPK value of the final compost.

In order to find the N,P,K value of the sample there are many Laboratorial Techniques like

1.Kjeldahl method: This method is used for the determination of nitrogen content in a sample. In this method, the sample is digested with sulfuric acid and heated

with a catalyst to convert the nitrogen into ammonium sulphate. The ammonium sulphate is then titrated with a standard solution of sodium hydroxide to determine the amount of nitrogen present in the sample.

2.Gravimetric method: This method is used for the determination of phosphorus content in a sample. In this method, the sample is digested with a mixture of nitric and sulfuric acid to convert the phosphorus into soluble phosphates. The soluble phosphates are then precipitated with ammonium molybdate and ammonium metavanadate, and the resulting precipitate is weighed to determine the amount of phosphorus present in the sample.

3.Colorimetric method: This method is used for the determination of potassium content in a sample. In this method, the sample is digested with hydrochloric acid and heated to convert the potassium into soluble potassium chloride. The soluble potassium chloride is then reacted with a reagent that produces a coloured complex, the intensity of which is proportional to the amount of potassium present in the sample. The colour is measured using a spectrophotometer or a colorimeter.

Here we used an N, P, K testing kit that was bought from online to find the N,P,K value of the samples.

The Procedure is given below.

MATERIALS REQUIRED

Containers, Test tubes, Pipettes, Stirrer, Filter Paper, N, P, K test kit (*AGRINEX CORPORATION RAPID NPK & pH SOIL TESTING KIT*)

In the box itself we will find 4 capsules each for Nitrogen test, Potassium test, Phosphorous test and pH test.

Here these capsule chemicals react with soil extracted nutrients and appear colour of different intensity.

PROCEDURE

Mix soil with water with 1:2 ratio in volume and mix thoroughly

Wait for 10-30 min for the soil to settle at the bottom, and clear water separation using a filter paper.

NITROGEN

Open the Capsule marked N and transfer the chemical in it to the test tube and transfer 4 ml of clear soil extract using a pipette

Cap it and mix gently until the chemical is dissolved. Wait for 20 mins and observe the colour developed.

Compare the developed Colour with the Nitrogen Colour Chart.

PHOSPHOROUS

Open the Capsule marked P and transfer the chemical in it to the test tube and transfer 4 ml of clear soil extract using a pipette.

Add 4 ml of TCA reagent carefully.

Cap it and mix gently until the chemical is dissolved. Wait for 20 mins and observe the colour developed.

Compare the developed Colour with the Phosphorous Colour Chart

POTASSIUM

Open the Capsule marked K and transfer the chemical in it to the test tube and transfer 4 ml of clear soil extract using a pipette

Cap it and mix gently until the chemical is dissolved. Wait for 20 mins and observe the colour developed.

Compare the developed Colour with the Potassium Colour Chart.

pH

Open the Capsule marked pH and transfer the chemical in it to the test tube and transfer 4 ml of clear soil extract using a pipette

Cap it and mix gently until the chemical is dissolved. Wait for 5 mins and observe the colour developed. Compare the developed Colour with the pH Colour Chart

4.RESULTS AND DISCUSSION

4.1CONVENTIONAL COMPOSTING

WEIGHT ANALYSIS

DAY	WEIGHT
1	6 KG
10	4.7 KG
20	3.115 KG
35	3.04 KG

Table 3.1. Weight Analysis of Conventional Composting

ODOUR ANALYSIS

DAY	ODOR
1	NO ODOUR
3	SLIGHT SMELL IN CLOSE RANGE
10	COMPRATIVELY LESS SMELL THAN DAY 3
15	NO ODOUR
20	NO ODOUR
25	NO ODOUR
35	NO ODOUR

Table 3.2. Odour Analysis for Conventional Compost

The Decomposition was observed in about 31 to 35 days and it was confirmed by the reduction of weight of the feed. There was no trouble due to smell. The appearance of soil turned to be darker as days goes on.

4.2 YEAST COMPOST

WEIGHT ANALYSIS

DAY	WEIGHT
1	3.1 KG
3	2.7 KG
5	2.1 KG
7	1.5 KG
10	0.3 KG

Table 3.3. Weight Analysis for Yeast Culture

ODOUR ANALYSIS

DAY	ODOR
1	NO ODOUR
3	NO ODOUR
5	STRONG ODOUR
7	SLIGHT SMELL
10	SLIGHT SMELL

Table 3.4. Odour Analysis for Yeast Compost

The Decomposition was observed in about 10-12 days and it was confirmed by the reduction of weight of the feed. There was no trouble due to smell for the first 3 days but as it started to decompose completely the smell also increased and it was very less when the compost was completely dried. The appearance of soil turned to be darker and a fungal growth was observed in the first few days later they were not found and the final compost is a dark dried sample.

4.3 ENZYME COMPOST 1 WEIGHT ANALYSIS

DAY	WEIGHT
1	3.13 KG
3	2.86 KG
5	1.1 KG
7	0.52KG
10	0.14 KG

*Table 3.5. Weight Analysis
for Enzyme 1 Compost*

ODOUR ANALYSIS

DAY	ODOR
1	NO ODOUR
3	NO ODOUR
5	SLIGHT SMELL
7	COMPARATIVELY LESS SMELL
10	SMELL CAN'T BE IDENTIFIED UNTIL KEPT IN A VERY CLOSE RANGE FROM THE NOSE

*Table 3.6. Odour Analysis
for Enzyme 1 Compost*

The Decomposition was observed in about 8-10 days and it was confirmed by the reduction of weight of the feed. There was no trouble due to smell, there was very less smell when the compost was completely dried. The appearance of soil turned to be greyish day by day into a dries sample.

4.4 ENZYME COMPOST 2

WEIGHT ANALYSIS

DAY	WEIGHT
1	3.05KG
3	2.7KG
5	1.8 KG
7	0.7 KG
10	0.46 KG

*Table 3.7. Weight Analysis
for Enzyme 2 Compost*

ODOR ANALYSIS

5 DAY	ODOR
1	NO ODOUR
3	SLIGHT SMELL
5	SMELLING
7	STRONG IRRITATING SMELL
10	COMPARATIVELY LESS SMELL THAN DAY 7

*Table 3.8. Odour Analysis
for Enzyme 2 Compost*

The Decomposition was observed in about 10-11 days and it was confirmed by the reduction of weight of the feed. The odour of the sample was so bad from day 4 to 8 that we were not able to stand nearby. The irritating smell was reduced from day 9. The appearance of soil turned to be greyish slurry by day 6. It was completely dried by day 11. Some larvae were also observed on the enzyme by day 7.

4.5. ENZYME COMPOST 3

WEIGHT ANALYSIS

DAY	WEIGHT
1	3.18KG
3	2.7KG
5	1.6 KG
7	0.6 KG
10	0.34 KG

Table 3.9. Weight Analysis for Enzyme 3 Compost

ODOR ANALYSIS

DAY	ODOR
1	NO ODOUR
3	SLIGHT SMELL
5	SMELLING
7	STRONG IRRITATING SMELL
10	SMELLING BUT COMPARATIVELY LESS THAN DAY 6-7

Table 3.10. Odour Analysis for Enzyme 3 Compost

The Decomposition was observed in about 10-11 days and it was confirmed by the reduction of weight of the feed. The odour of the sample was so bad from day 4 to 8 that we were not able to stand nearby. The irritating smell was reduced from day 9. The appearance of soil turned to be greyish slurry by day 6. It was completely dried by day 11. Some larvae were also observed on the enzyme by day 7.

4.6 MICROBIOLOGICAL STUDY

SL.NO	COMPOST	BACTERIAL GROWTH	FUNGAL GROWTH
1	VEGETABLE SAMPLE	2 COLONIES OBSERVED	NO FUNGAL GROWTH
2	TRADITIONAL DAY 10	10-11 COLONIES OBSERVED	NO FUNGAL GROWTH
3	TRADITIONAL DAY 20	5-6 COLONIES OBSERVED	FUNGAL GROWTH OBSERVED
4	TRADITIONAL DAY 35	10-11 COLONIES OBSERVED	FUNGAL GROWTH OBSERVED
5	YEAST COMPOST	3-5 BACTERIAS OBSERVED	FUNGAL GROWTH OBSERVED
6	ENZYMATIC COMPOST	BACTERIA GROWTH WAS OBSERVED	FUNGAL GROWTH OBSERVED

Table 3.11. Microbiological Load of Different Samples

For all the samples were able to find the presence of Bacterial growth and except for traditional day 10 sample and vegetable sample we were not able to observe fungal growth. The maximum number of colonies of bacteria was observed on traditional compost sample.



Fig 3.7. Microbiological Study of Various Composts

4.7 NPK TEST

SL NO	COMPOST TYPE (KG/Acre)	NITROGEN (KG/Acre)	PHOSPHOROUS (KG/Acre)	POTASSIUM (KG/Acre)	pH
1	TRADITIONAL COMPOST	20	0-5	100	4.5
2	YEAST COMPOST	20	0-5	100	10
3	ENZYME COMPOST 1	50	0-5	20	4.5
4	ENZYME COMPOST 2	20	0-5	25	8
5	ENZYME COMPOST 3	30	0-5	25	9

Table 3.12. Chemical Composition of Different Compost

The NPK test was carried out and the results are shown in the above table



Fig 3.8. NPK and pH test results for Yeast Compost

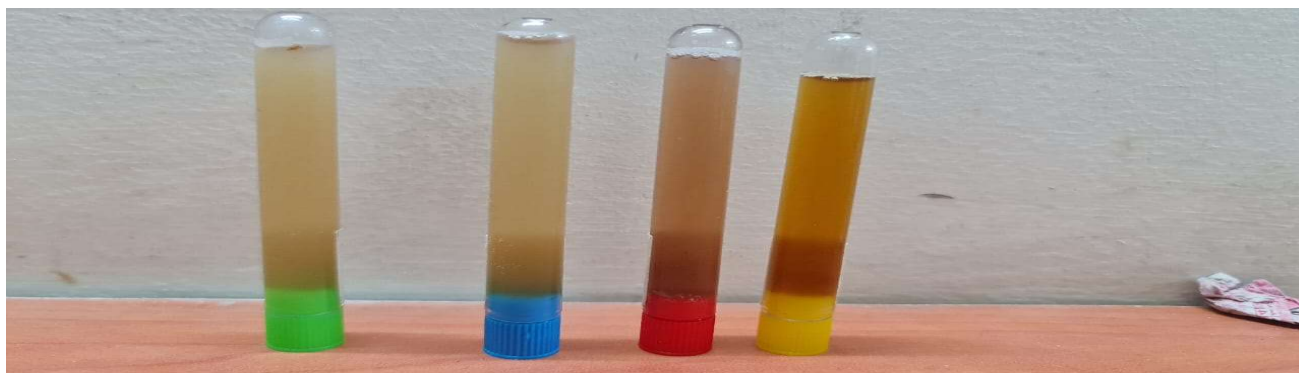


Fig 3.9. NPK and pH test results for Enzyme 1 Compost



Fig 3.10 NPK and pH test results for Enzyme 2 Compost

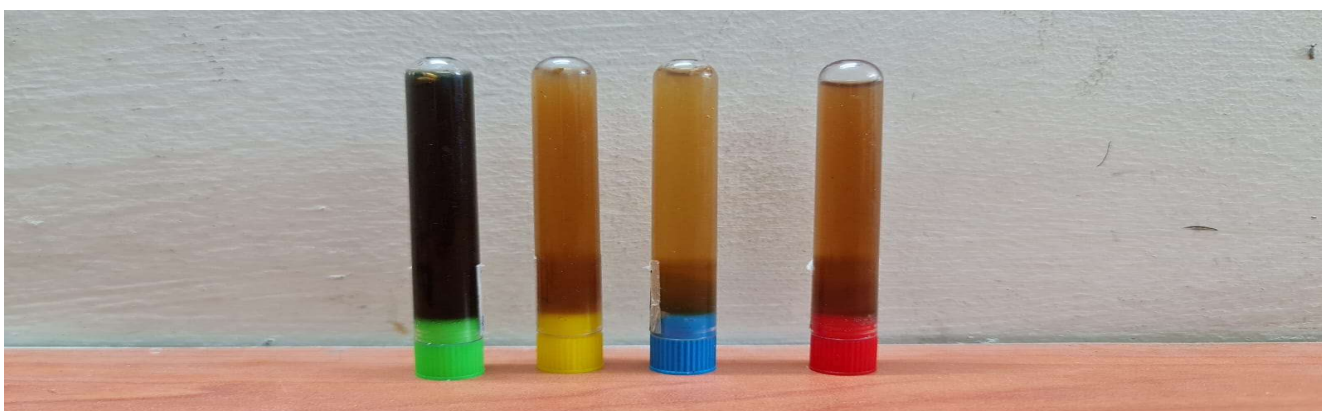


Fig 3.11. NPK and pH test results for Enzyme 3 Compost

5.CONCLUSION

Composting is a natural process that can turn organic waste into a nutrient-rich soil amendment known as bio-compost. However, composting can also produce greenhouse gas emissions that contribute to climate change. Therefore, it is necessary to understand the environmental implications of composting and to develop methods for reliably quantifying greenhouse gas emissions. Microbial diversity plays a critical role in the composting process, and the maturity and stability of bio-compost are important markers of the quality of the final product. Advances in composting bins and the use of additives and bulking agents can improve the efficiency and effectiveness of composting. Additionally, the cycling of carbon released from composting via carbon sinks can help alleviate the negative environmental implications of composting. The economics and business models involved with composting are also essential factors, as are the challenges and future prospects of composting as a sustainable waste management option.

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