Enrichment of Organic Kitchen Waste through Microbial Inoculation and its application quality

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BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY
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FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN
HOME SCIENCE
(FOOD AND NUTRITION)

SUPERVISOR

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2019

Dedicated to

My Loving Husband

&

Adorable Daughter

CANDIDATE'S DECLARATION

I, hereby declare that this doctoral work entiled **“Enrichment of Organic Kitchen Waste through Microbial Inoculation and its application quality”** submitted by complete regular basis for the degree of **Doctor of Philosophy** to the School for Home Sciences, Babasaheb Bhimrao Ambedkar University, Lucknow, it is an outcome of my noble and original research work. I also declare that thesis or any part of thesis has not been previously submitted to any other degree or diploma to this or any other university and also undertake that thesis is essentially free from all kind of plagiarism.

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<u>CERTIFICATE</u>

This is to certify that the thesis entitled **“Enrichment of Organic Kitchen Waste through Microbial Inoculation and its application quality”** submitted by Mrs.Shweta Chaudhary is an original research work and has not been previously submitted in part or full for the award of any other degree or diploma to this or any other university.

The thesis submitted to Babasaheb Bhimrao Ambedkar University, Lucknow satisfies all the requirements as stipulated in *Doctor of Philosophy (Ph.D) regulation-1999 as amended in 2008/2010/2013* and it is fit for submission and evaluation for the award of the degree of **Doctor of Philosophy** of the university.

Date: **Supervisor**

Head of the Department

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We dream, we desire, we strive to achieve our dreams, at last it is our perseverance and determination that pays and then only we achieve what we dream. So, today it is my dream and I am at the meridian of achieving my goal. As I begin to write these lines; after completion of my thesis, my heart is filled with deepest sense of gratitude.

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ABSTRACT

Due to rapid population growth and Urbanization the production of Kitchen waste (KW) has increased annually. KW is the most general kind of organic waste. The major chemical components of KW are starch, protein, fat, cellulose and other. The deterioration of KW produces large amount of toxins and foul odours. NH_3 (ammonia) and H_2S (hydrogen sulfide) gases have a strong pungent odour and cause serious burns to the skin, eyes and respiratory tract. These gases cause serious water and air pollution. Therefore, the efficient and environmentally responsible disposal of KW is important. Because of its high organic matter content, comphrehensive nutrient profile and abundant microorganism, compost enables KW to be degrading effectively .Using biological composting technology organic compost can facilitate the safe and non-polluting recycling of nutrient resource.

This present study investigated the composting of KW of four climate season, the evolution of several main parameters during composting of separately collected KW generated from BBAU hostel mess.

Compost from organic waste collected in autumn contained the highest amount of nutrients, showing the rich content of nutrients in plant feedstock followed by spring, summer and winter.

The pH and DOC of seasonal Kitchen waste composting (KWC) frequently showed a close relationship with other parameters. The highest seasonal variation was found in Nitrate Nitrogen which is the reason for the more frequent analysis of this parameter.

The microbiological analysis was done during summer, rainy and autumn season. As previous studies also revealed that pH and temperature effects microbial community. In this study highest number of microbial colonies were found between 30-40 days of KWC in all three seasons.

Actinomycetes were lower in summer season while higher in rainy season. Bacteria (aerobic and anaerobic) were highest in rainy followed autumn and summer. Fungal

growth during composting found maximum in rainy season followed by summer and autumn season.

From the above it is found that that the summer and autumn season favoured the microbial growth by providing suitable environmental condition.Hence, the KW degrades properly in these two seasons than rainy.

The phytotoxicity assessment of KWC reveals that the compost is mature and stable for agriculture purposes. The 20% of KWC extract of every season found to be best because it provides optimum nutrients to seeds (mung bean) where as high concentration 40%-60% of KWC extract may not be favourable for seed germination and agricultural purposes because of high concentration of salt content or over mineralization.

The OKWC of autumn was selected for enrichment. The enrichment of Organic Kitchen waste compost (KWC) with *Trichoderma harzianum* 1373 and to assess its effect on physico-chemical and microbial parameters of KWC with respect to different days was done. The result found that there was minor increment in vital nutrient which required for plant nutrition and healthy development. Statstically , it is also proven that after inoculation or enrichement of OKWC , around 14th day it gave better results and could be utilized in organic farming to secure better yield and nutritious response of crops.

Under green house nursery condition the pot experiment was done.The OKWC inoculated with *Trichoderma harzianum* U2 treatment(40% Enriched compost + 60% soil) gave significant plant growth and significant improvement in nutritional(biochemical and mineral) quality of tomato fruit followed by KWC T3(60%KWC of autumn +40% soil).

This high efficiency of *Trichoderma harzianum-1373* enriched KWC might be the result of its potential of nutrient solubilization and harboring soil microorganisms.

Collectively, enriched KWC increases soil fertility and favoures the growth of microbes in the rhizoshere which ultimately contributed to higher yield and nutritional quality in tomatoes.

Thus, *Trichoderma harzianum* enriched KWC may reduces application of chemical fertilizer and therefore can be considered as a noble practice in sustainable and organic agriculture.

Keywords: *Organic kitchen waste, chemical component, organic compost, kitchen waste composting, seasonal variation, microbiological analysis, phytotoxicity assessment, enrichment, kitchen waste compost (autumn) , Trichoderma harzianum , organic farming, tomato plants , plant growth and nutritional quality*.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abbreviations and symbols

%	Percentage
^0C	Degree Celsius
^0F	Fahrenheit
AAS	Atomic adsorption spectroscopy
AAS	Atomic Absorption Spectrometer
ABC	ATP binding cassette
AOAC	Association of official analytical chemists
APHA	American Public Health Association
Approx.	Approximately
ATP	Adenosine triphosphate
BBAU	Babasaheb Bhimrao Ambedkar University
BIS	Bureau of Indian Standard
BOD	Biological oxygen demand
C/N	Carbon/Nitrogen
C:N	Carbon nitrogen ratio
Ca	Calcium
CAT	Catalase Test
CAT/DPTA	Diethylene triamine pentaacetic acid
CBWTF	Common bio-medical waste treatment facility
CC	Contamination control
CCME	The Canadian Council Of Ministers Of The Environment
CDA	Czapek Dox Agar
CEC	Cation exchange capacity
Cfu/gm	Colony forming unit per gram
CH_4	Methane
Cm	Centimeter
CO_2	Carbon Dioxide
CPCB	Central pollution control board
CQI	Compost Quality Index

Cu	Copper
CUT	Citrate Utilization Test
DDWS	Department of Drinking Water and Sanitation
dm^{-3}	Cubic decimeter
DOC	Dissolved organic carbon
DW	Distilled water
EC	Electrical Conductivity
EFB	Empty fruit bunches
EPA	Environmental protection agency
ET	Ethylene
FCO	Fertilizer control order
Fe	Iron
Fe_2O_3	Ferric oxide
FW	Food waste
FWDM	Food waste disposal machine
FYM	Farmyard manure
GHT	Gelatine Hydrolysis Test
GI	Germination index
Gm	Grams
Gm/l	Gram per litre
GWMO	Global waste management outlook
H ,hrs.	Hour
H_2O	Water
H_2S	Hydrogen Sulphide
HCL	Hydrochloric acid
HF	Hydrogen fluoride
HI	Humification index
HNO3	Nitric acid
IAA	Indole-3-acetic acid
INT	In dole Test
ISWA	International solid waste association

K	Pottasium
KBrO3	Potassium Bromate
Kcal	Kilo Calories
Kg	Kilogram
KOH	Potassium hydroxide
KW	Kitchen waste
KWC	Kitchen waste compost
L	Litre
M	Molar
MAMPs	Microbe-or pathogen-associated molecular patterns
MC	Moisture content
Mg	Magnesium
Mg	Milligram
Min.	Minute
ml	Milliliter
Mm	Millimeter
Mn	Manganese
MnO_2	Manganese dioxide
MoEF	Ministry of environment and forests
MRP	Mussoorie rock phosphate
MRT	Methyl Red Test
mS/cm	Microsiemens per centimeter
MSW	Municipal Solid Waste
MT	Million tonnes
N	Normality
N_2O	Nitrous oxide
NA	Nutrient agar
NaOH	Sodium Hydroxide
NGOs	Non Government Organizations
NH_3	Ammonia
NH_4^+	Ammonium Ions

NH_4^+-N	Ammoniacal Nitrogen
NHþ 4	Dissimilatory nitrate reduction to ammonia
Nm	Nanometer
N-NH_4^+	Ammonium nitrogen
N-NO_3^-	Nitrate nitrogen
NO_2^-	Nitrites
NO_3^-	Nitrates
NPK	Nitrogen Phosporous Potassium
NRT	Nitrate Reduction Test
O_2	Oxygen
OKWC	Organic kitchen waste compost
OM	Organic matter
Org	Organic
OXT	Oxidase Test
P	Phosphorus
P_2O_5	Phosphorus Pentoxide
PAHs	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PCR	Polymerase chain reaction
PDA	Potato dextrose agar
PDB	Potato dextrose broth
pH	Potential of hydrogen ions
Ppm	Parts per million
PSB	Phosphate solubilizing bacteria
PTE	Potentially toxic elements
RE	Root enlongation
Rpm	Rotation per minute
SDGs	Sustainable development goals
SG	Seed germination
SGWC	Smart Garbage and Waste Collection bins
SHT	Starch Hydrolysis Test

SPCB	State pollution control Boards
SWM	Solid waste management
TKN	Total Kjeldohl nitrogen
TOC	Total Organic Carbon
Tot	Total
TSM	Trichoderma harzianum selective medium
TSS	Total soluble solids
UNEP	United nations environment programme
UNICEF	The United Nations Children's Fund
URT	Urease Test
US EPA	United State Environmental Protection Agency
USDA	United states department of agriculture
UV	Ultra Voilet
v/v	Volume /volume
VFAs	Volatile fatty acids
VPT	Voges-Proskauer Test
VS	Volatile solid
W/V	Weight / volume
wt.	Weight
Zn	Zinc

Chapter -01

Introduction

Chapter-1

"Recycling is a good thing to do. It makes people feel good to do it.The thing I want to emphasize is the vast difference between recycling for the purpose of solving the trash problem."- Barry Commoner

1.1 Introduction

Today solid waste management (SWM) is biggest problems in the world. Around 50% of the waste in the world is organic waste. India is 2nd largest populated country in world; it produces more than 100 tons of the solid waste a day. It is the mixture of both organic food waste and inorganic waste. Around 78% is food waste, which can be recycled. Some of them are land filled but it is not segregated properly and it mixes organic and inorganic waste, which produces bad odour, and it will spoil the soil. To manage the solid waste, it should be properly segregated at the source (houses) as shown in fig. 1.1. The organic and inorganic waste needs to be separated, the organic waste can be treated to make compost, and inorganic waste can be segregated and given for garbage collection. There are many companies who take in the waste and segregate and convert the organic waste into compost but as the waste are very high; they are unable to achieve all the targets so it is better to compost at home.

1.1.1 Solid Waste Practices In India

In India, the term municipal solid waste refers to solid waste from houses, streets and public places, shops, offices and hospitals. Management of these types of waste is most often the responsibility of corporate or urban local bodies. Except in the metropolitan cities, solid waste management (SWM) is the responsibility of a health officer who is assisted by the engineering department in the transportation work. The activity is mostly labour intensive and 2-3 workers are provided per 1000 residents served (Zhu et al.,2007). The municipal agencies spend 5-25% of their budget on SWM. A typical waste management system in a low or middle-income country like India includes the following elements:

- Waste generation and storage
- Segregation, reuse, and recycling at the household level
- Primary waste collection and transport to a transfer station or community bin

- Street sweeping and cleansing of public places
- Management of the transfer station or community bin
- Secondary collection and transport to the waste disposal site
- Waste disposal in landfills
- Collections, transport and treatment of recyclables at all points on the solid waste pathway (Collection, storage, transport and disposal)

Compost is the organic type of matter that decomposed as a fertilizer. Compost is vital in the organic form of farming. The process of the composting requires wet organic matter called as waste of green (leaves, food waste) and also waiting so as to break it down into the humus for a certain period. Modern methodical composting is multi step, monitered process with measured inputs of water, carbon, air, and the materials of nitrogen rich. The process of decomposition is carried out by shredding plant matter, addition of right amount of water and also ensuring proper aeration by repeatedly turning mixture. Compost is rich with nutrients. It used in mini gardens, agriculture, and rooftop farming etc. The composting is valuable for land in several ways, like soil conditioner, the fertilizer, and addition of the vital nutrients to soil and as natural pesticide for the soil. In the ecosystems, compost is being valuable for controlling soil erosion reclamation, and stream reclamation, wetland construction and covers the landfill. Compost is commonly known as Black gold by gardeners. Anaerobic compost results in black colour of the soil due to presence of methane. Aerobic composting results in dark brown colour/ chocolate colour of the soil after composting.

Perhaps a more acceptable approach will be to separate organic waste at the source and for it to be transferred directly to end users. However, organic wastes from rural and urban areas will need to be approached differently. Smaller facilities for sorting non-organic recyclable waste might be accommodated throughout the municipality (Guardia et al., 2008).

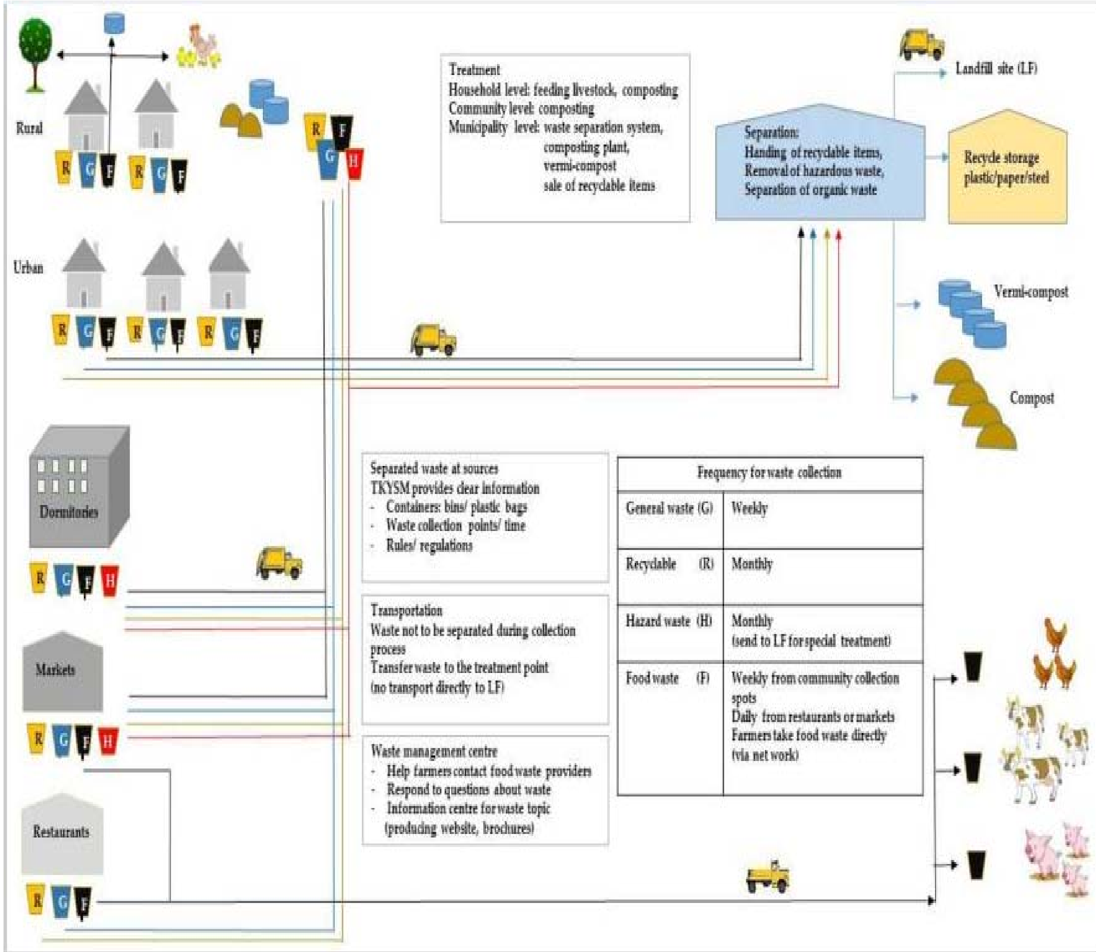


Figure1.1: Waste Separation Components Schematic Approach.

1.2. Solid Waste Management (SWM) System Model

Solid waste management is the one thing just about every city government provides for its residents. While service levels, environmental impacts and costs vary dramatically, solid waste management is arguably the most important municipal service and serves as a prerequisite for other municipal action. As the world hurtles toward its urban future, the amount of municipal solid waste (MSW), one of the most important by-products of an urban lifestyle, is growing even faster than the rate of urbanization. Ten years ago there were 2.9 billion urban residents who generated about 0.64 kg of MSW per person per day (0.68 billion tonnes per year). This report estimates that today these amounts have increased to about 3 billion residents generating 1.2 kg per person per day (1.3 billion tonnes per year). By 2025 this will likely increase to 4.3 billion urban residents generating about 1.42 kg/capita/day of municipal solid waste (2.2 billion tonnes per year).

This model fig 1.2 of the Solid Waste Management system for Housing Societies will integrate composting, segregation as well as the use of sanitary landfills. Idea is Zero garbage.

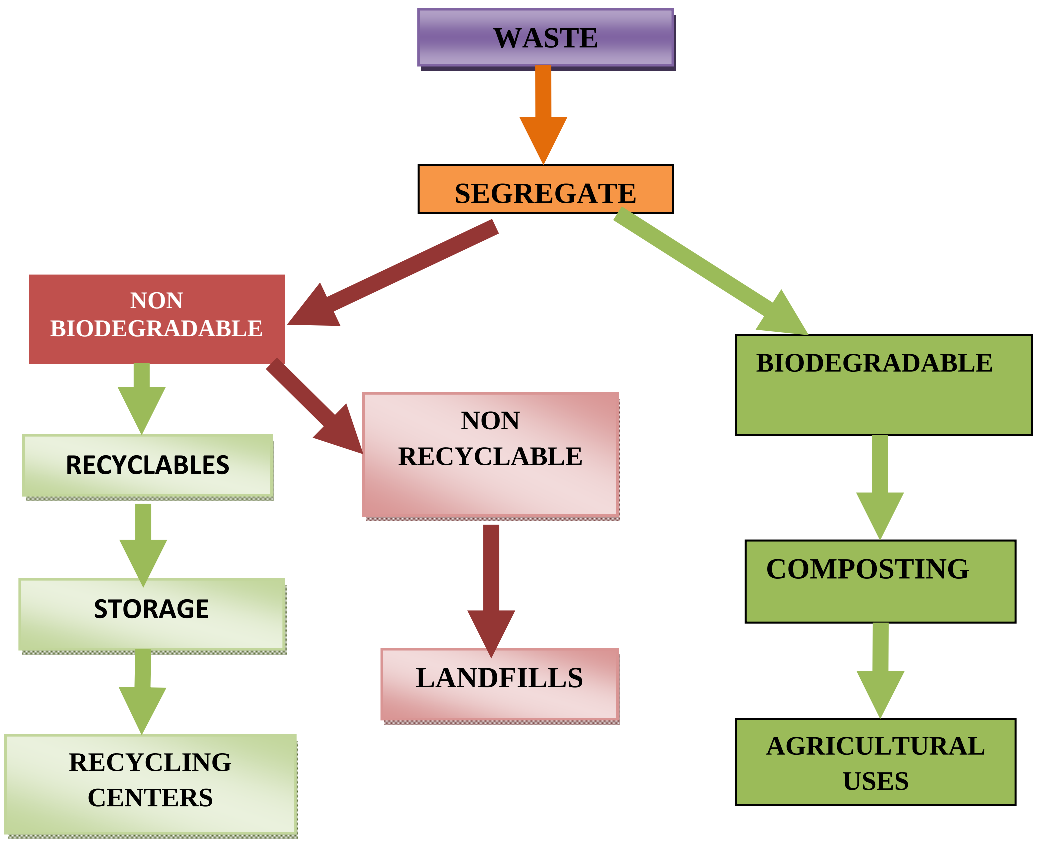


Figure 1.2: Solid Waste Management system for Housing Societies.

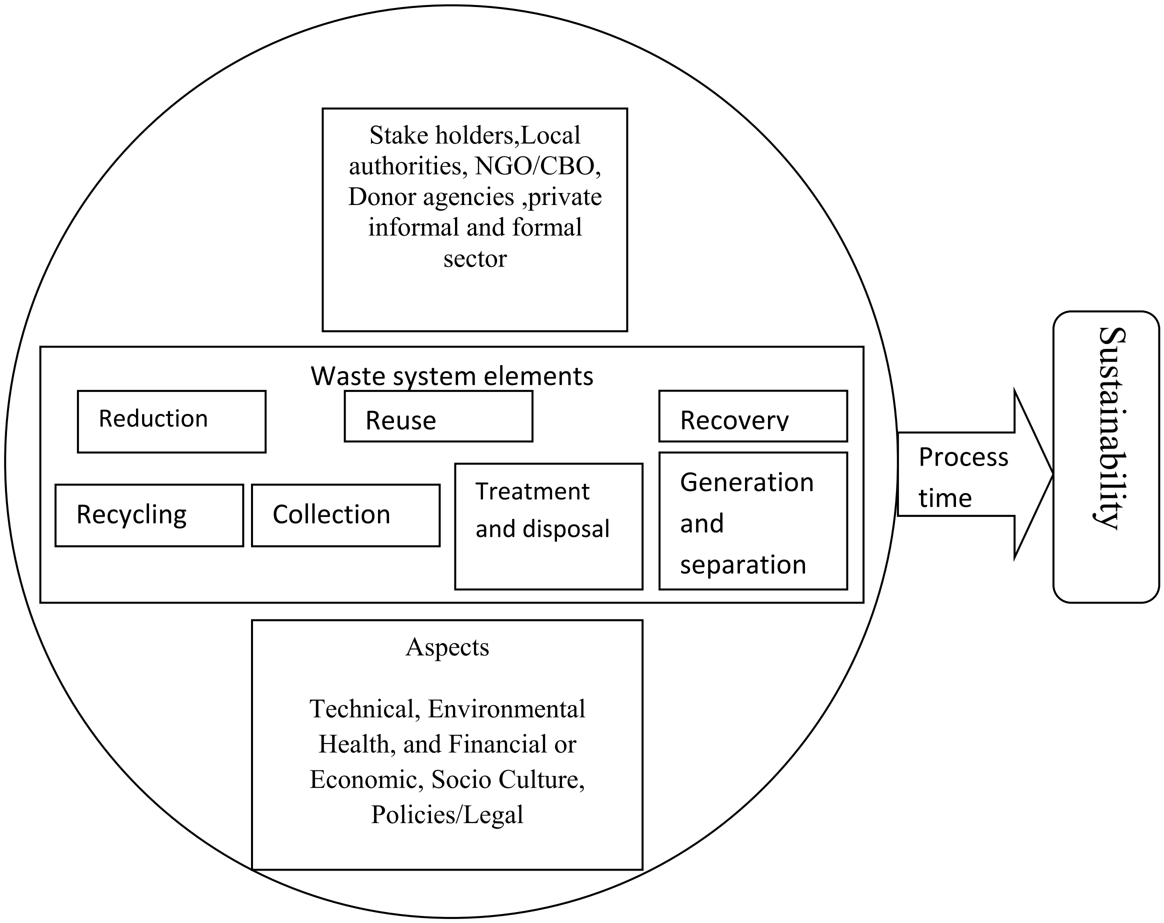


Figure 1.3: Sustainable Waste Management model.

1.3. Waste and its types

Waste(s) are discarded or not viable materials. Waste is any matter which is not needed after key use, or is valueless, substandard and of no use. A by-product by contrast is a joint product of comparatively small economic value. A waste product may be converted into a by-product, joint product or resource through an innovation that raises a waste product's importance above zero.

1.3.1. Household waste (HHW)

With land based houses, organic waste is than also given to the pigs or be hidden in backyard pit while inflammable dead waste is either the piled into heap and then burnt or the buried a pit, yet, a few houses near order of beachfront of people household waste into sea particularly at night-time when tide is inside. With over the-sea houses, organic waste is once more feed to pigs other than left over whatever their is - and all inorganic waste - is tossed into sea.

1.3.2. Human waste

Over-the-sea drop toilets used by 70 percent of people (i.e., approximately 1,000 people). All houses of the sea are situated near to the beach; the method is not practiced, especially if at lower tide, it is dangerous. In addition, most households use over-the-sea drop-toilets in beachfront homes. Yet, most pits are badly designed as well as produced, and due to the unpleasant smell, the bugs are attracted to the disease.

Some villagers are pointed that the disposal of the waste from the homes close to main beach on the surface is quite effective. However, concerns have arisen between the capacity of the bay surface houses and capacity to open the ports.

1.3.3. Hazardous waste

This type of waste contains useless oil and the fuel, old batteries, paint, soft phones, tires, tubs and scrap metal. These waste substances can cause harm to the environment and human health, and has at least one of the hazardous characteristics (explosive, flammable, tendency to oxidation, organic peroxide, acute toxicity, infectivity, tendency to rust in contact with air, releases flammable gases in contact with air or water, releases toxic substances, contains toxic substances with delayed chronic action and eco toxic properties), including the packaging in which hazardous waste is or was packed.

1.3.4. Liquid type waste

Waste can come in non form of solid. A few solid wastes are able to transform to liquid waste form for its disposal. It has point source and non point foundation discharges like used or waste water, liquid used for the clear out in the industries and the detergents waste.

1.3.5. Solid waste

Solid waste primarily, is any sort of garbage that is created in homes and at other places. Such include tires of old car, newspapers, furniture of no use and even food waste.

1.3.6. Organic waste

Organic waste comes from plants sources or animals sources. Normally, they contain food waste, fruit waste and the vegetable peels, flower trimmings of flower etc. which can be classifed as the waste of organic type. They are form of biodegradable (that means they can be broken easily by other form of organisms over the time and curved into the manure). Most of the citizens turn organic waste into manure and then utilize them in their own gardens.

1.3.7. Recyclable Waste

Recycling is the way of processing that is reusing materials (waste) into the new and the useful products. This is needed to decrease the raw materials which would be used. Waste that could potentially recycled is called "Recyclable waste ". For example products of Aluminum (like soda cans, milk cans and tomato cans), the Plastics (are like grocery shopping bags), products of Glass are like wine and beer bottles, and broken glass), the Paper products (used envelopes, the magazines, the cardboard boxes etc.) can be recycled (Nandan et al., 2017).

1.4. Global Waste management and its goals

Waste management is a global, national and regional problem. Sustainable development goals (SDGs) already have global waste management objectives appear or meaningfully.

Table 1.1: Global Waste management and its SDGs

GLOBAL WASTE MANAGEMENT GOALS(GWMG)		RELATED SUSTAINABLE DEVELOPMENT GOALS
certify by 2020	1. Get safe access and solid type waste collection services in affordable amount	. Health for all .Safe cities
	2. Stop uncontrolled dumping, open burning	. Health for all . Clean water and sanitation . Safe cities . Sustainable resources . Marine Terrestrial ecosystems .Consumption production
Ensure by 2030	3. attain sustainable waste management of the entire waste, mainly hazardous waste	. Managing all waste .Access to energy .Climate change
	4. To prevent waste generation, 3R's (reduced, recyclable, and recycling) can be significantly reduced and Green Job creation.	. The 3R's . End poverty .Growth & industry employment . Sustainable development
	5. Halve per capita global food waste at retail levels and consumer levels and decrease losses of food in supply chain	.Food waste security . End of hunger; .security of food

India is the oldest civilizations in world, period spanning of more to 4000 years, and witnessing fusion of more customs as well as traditions, which are meditative of culture which is rich and full of heritage in Country. An area is covered of 3,287,590 sq. km, and extending from snow enclosed heights of Himalayan to forests of tropical rain of south. It is the 7th major country in the world. India is 2nd nation which is largest in the world, with 1.21 billion population (Census 2011) accounting for near about 18% of human population from the world. Population directly related to waste generation as every individual is the contributing factor. Solid Waste Management is both an urban and rural problem, it is a critical difficult not the countries which is developing but for urbanized countries also. Enormous amount of Waste which is being generated all around the world, generally posed question is that how to supervise these wastes effectively and much efficiently to save environment and continuous mankind existence (Agrawal et al., 2015).

1.5. Waste generation scenario

India is undergoing speedy urbanization. In 2001 population of India was 1028 million as compared with 1252 million people live in 2013. The population, economic inflation, and the lifestyle of urban people have changed. “The Use & Throw Concept” of the modern society is adding to the already existing problem of Municipal Solid Waste. Biodiversity is much less than the wastes produced by products like construction of products. World Bank in (1999), 'what is Waste: Solid Waste Management of Asia' is comparatively lower in India's per capita wastage compared to other developed countries. An average Indian produces waste 0.3-0.6 kg per day where as American generates 2kg per day. The municipal SW is poor financial health, lack of training and lack of equipment, unscientific processing and disposing of waste. Collection from door to door is done in the most part of Municipalities, but the enormous population is a major hurdle which results in inefficient waste collection on a daily basis. Various Municipal Corporations are substantially dependent on government funds; the cities do not levy any user charge for Municipal Solid Waste service. Casual specialists e.g., cloth pickers, squander gathering networks, and so on assume an imperative job in the accumulation, transportation and transfer of waste and redress, to some degree, the deficiency of the administrations. Inability to coordinate these labourers in the Municipal Solid Waste Management standard adds to poor administration conveyance. Controversies in the field of scientific and environment related to some waste management tehnologies (aerosol, plasma gasification) lead to more hurdle in SWM

City	*Population (2011)×10^6	#Total Generation of Waste In the Tonnes Per Day	Generation of Waste (Kg *Per Capita* per Day)
Ahmadabad	6.3	2300	0.36
Hyderabad	7.7	4200	0.54
Bangalore	8.4	3700	0.44
Chennai	8.6	4500	0.52
Kolkata	14.1	3670	0.26
Delhi	16.3	5800	0.41
Mumbai	18.4	6500	0.35

Table 1.2 India's major cities and their per capita per day waste generation data year (2010-2011).

*Source: India Census 2011, # CPCB Report 2011 (Nandan et al., 2017).

1.5.1. Regulations and Policies

The Ministry of Environment and Forests (MoEF and CC) and the contamination control sheets: Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs) together structure the administrative and managerial center of the waste administration area in India. At the state level, the administration of solid waste is the responsibility of Urban Local bodies. Enterprises producing perilous squanders must look for authorization from the separate SPCB. A key issue is that civil experts don't have the financial plans enough to take care of the costs related with creating successful waste administration frameworks. The absence of vital plans, just as frameworks for administration (especially squander accumulation/isolation), and guideline are significant obstructions to accomplishing successful Solid Waste Management (SWM) in India

Different bits of enactment covering the administration of dangerous waste exist. The fourty-second revision to the Indian Constitution that was received in 1976, and became effective on 3 January 1977, directed the state to ensure and improve the earth to protect general wellbeing, woodlands, and untamed life. The Directive Principles of State Policy (Article 47) in the Constitution require that the state ensures the earth, yet in addition that it improves dirtied conditions. Until 2016, unsafe waste was imported from nations, for example, Saudi Arabia and Malaysia. In any case, this training was suspended with the institution of the Hazardous and Other Wastes (Management and Trans-limit Movement) Rules 2016 that restricted the import of strong plastic waste, consumable fats, creature oils, and family unit squander. The guidelines additionally require State governments to allot lands for reusing sheds for unsafe waste, guarantee legitimate enrollment, aptitude improvement, hardware supply, and installment for laborers occupied with the gathering of dangerous waste, and the foundation of observing offices to check the creation and reusing of perilous waste from each state. Another key bit of enactment is the Environment Protection Act (EPA) in 1986, which is umbrella enactment to ensure and improve the earth and to direct the administration and treatment of dangerous substances and synthetic concoctions. There are likewise different guidelines under this Act including:

- E-Waste in (Management and the Handling) Rules 2010

- Production, Import and Storage of Dangerous Chemical the Rules in 2001
- Biomedical Waste the (Management and the Handling) Rules 1998
- Hazardous Waste (Management and Handling) Rules, 2008 (This is the main control for controlling dangerous waste in the country)

Figure 1.3 illustrates the responsibilities of the producers of the hazardous waste to ensure that damage to the environment and to public health is minimized. These measures include adequate labelling, containment, transport of the waste, and the provision of an audit trail to follow the waste from generation to treatment.

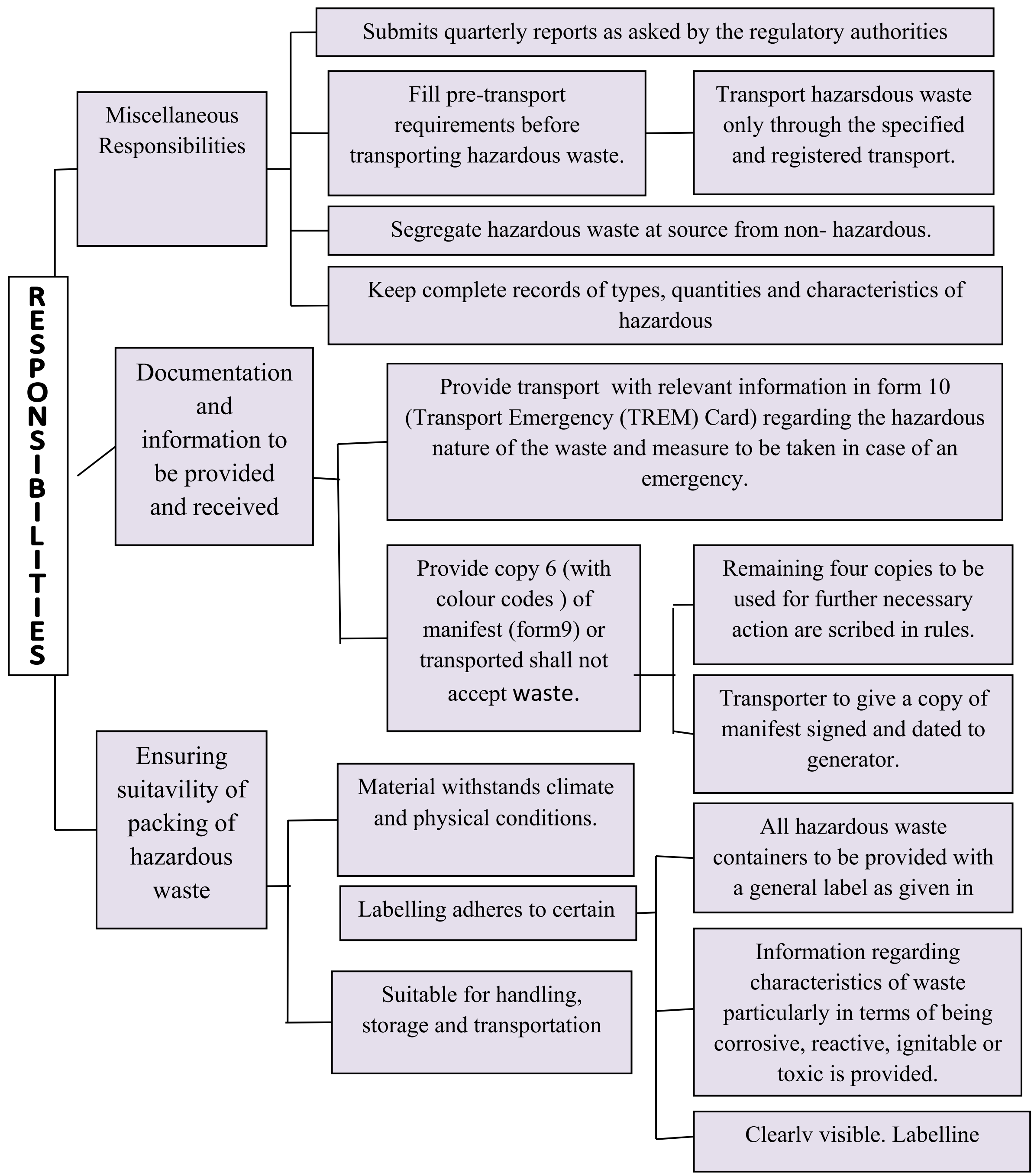


Figure 1.4: The generator responsibilities for the hazardous waste Source.

In any case, regardless of the presence of these enactment and rules, impediment in their authorization is a noteworthy test. Other key difficulties incorporate absence of monetary assets, a deficiency of staff, an absence of institutionalized conventions, and an absence of power. The Hazardous and Other Wastes (Management and Trans-limit Movement) Rules 2016 express that proprietors of dangerous waste transfer offices are at risk to pay monetary punishments if the principles of transportation, stockpiling, and reusing of such waste are not conformed to, and may even be detained because of carelessness. The standards likewise explicitly direct the state governments to recognize areas for the development of perilous waste treatment offices. Be that as it may, no new locales have been worked since the new standards became effective. Numerous states like Karnataka, Kerala, Punjab, and Orissa don't have perilous waste treatment offices.

Waste management board controls in India depend on the standards of "feasible improvement", "safety measure" and "polluter pays". These standards order districts and business foundations to act in a naturally responsible and mindful way—reestablishing harmony, if their activities disturb it. The expansion in waste age as a side-effect of monetary advancement has prompted different subordinate enactments for directing the way of transfer and managing created squander are made under the Umbrella law of Environment Protection Act, 1986 (EPA). Explicit types of waste are the topic of isolated guidelines and require separate compliances, for the most part in the idea of authorisations, upkeep of records and sufficient transfer components (Zhu et al.,2007).

1.6. Urbanization and Waste Generation

Preservation of ecological balance may mean conservation and wise management of the life support systems of land, water, flora, fauna and the atmosphere.The most important of natural resources for economic growth is land; productivity of land is basic to the economic welfare of any country. All the demands of food, energy and other requirements have to be met by land. Hence, land is the most important endowment of nature. The precious land is being polluted constantly by the explosion of human population.

Pollution is the main cause for environmental degradation. Pollution is caused by substances that directly or indirectly harm human health or the environment.Due to increase in human activity, green cover is reducing day by day. Besides overpopulation of certain species, improper disposal of harmful wastes, overuse of natural resources (water, wood, etc.), deforestation, rapid industrialization and urbanization are held responsible for environmental degradation.

Today, waste has become a major environmental and economic issue for consumers and municipalities. There are many ways to reduce and dispose our household waste. Most of our waste is destined for landfillsbut because of public concern about landfill location and stricter disposal regulations in many parts of the world, acceptable landfill space is becoming scarcer and /or more expensive.Hammer,(2012) informs that environmental laws have forced many dumps and incinerators to close or modernise at a cost of millions of dollars. In areas without nearby disposal options, consumers may be paying higher rates to have waste hauled hundreds of miles to be buried or incinerated.

Human activities whether domestic, agricultural or industrial generate huge quantity of waste, due to different human activities, tons and tons of wastes are generated every year. The wastes generated from these activities of more advanced societies produce more complex and heterogeneous wastes because of change in life style and food habits. These activities change the quality of waste and increase quantity per capita in recent years. They also cause local pollution and contribute to global warming. Joshi & Ahmed, (2016), emphasised that the annual waste generation has been observed to increase in proportion to the rise in population and urbanization, and issues related to disposal have become challenging as more land is needed for the ultimate disposal of these solid wastes period. At this time of reduced land availability for human living, in the near future, the waste may also compete for land space.

According to the information given by DDWS-UNICEF (2008) the quantity of waste generated is also increasing in rural areas as a result of increased population, consumerism and commercial activities. Chakraborty,(2011) stated that it is estimated that 15,000 to 18,000 million litres of gray water and 0.3 to 0.4 million metric ton of solid waste are generated each day in rural areas. About 77% of the waste generated in the village was used as domestic fuel, animal fodder and organic fertilizer for crop production. The rest (23%) was left out in open fields for natural decomposition.

Although the quantity of waste generated in rural areas is increasing, it is still relativelylow compared to urban areas. In rural areas, compared to urban, land availability is not often a constraint. Also, there are more options possible in rural areas for reuse of waste, such as composting of biodegradable material, which can be used in kitchen gardens, agricultural fields, etc.

Naveen et al., (2011) state that it is also estimated that about 700 metric tons of agricultural waste is available in the country every year. About 1800 metric tons of animal dung per annum is available, from which 120 million cubic meter of biogas is produced and in addition 440 metric tonnes of manure is generated (which is equivalent to 2.9 metric tons, 2.75 metric tonnes and 1.89 metric tonnes of N,P,and K respectively). Coir pith availability is to an extent of 10 lakh tonnes per annum.

In some urban focuses, individuals working in the casual segment gather solid waste for every doorstep to get an accumulation charge and get extra salary from clearance of recyclables. The casual reusing industry assumes a noteworthy job in waste administration. It likewise guarantees that less waste achieves landfills.

There has been mechanical evolution for handling, treatment and transfer of waste. Vitality from-squander is an essential component of SWM on the grounds that it decreases the volume of waste from transfer additionally helps in changing over the loss into sustainable power source and natural manure.

Establishment of waste-to-compost and bio-methanation plants would diminish the heap of landfill destinations. The biodegradable part of India's solid waste is as of now assessed at a little more than 50 percent. Bio-methanation is an answer for preparing biodegradable waste which is additionally remains underexploited. It is trusted that segregation of biodegradable waste from the rest, decrease the difficulties significantly. E-squander segments contain lethal materials and are non-biodegradable which present both occupational related and natural wellbeing dangers including dangerous smoke from reusing procedures and filtering from e-squander in landfill into nearby water tables.

Bio-medicinal waste (the executives and dealing with) rules, 1998 endorse that there ought to be a Common Biomedical Waste Treatment Facility (CBWTF) at each 150 kms in the nation. CBWTFs have been set up and are working in urban areas and towns. Be that as it may, foundation of practical CBWTF all through the nation must be guaranteed. Coordinated regular dangerous waste administration offices join verified landfill office, hardening/adjustment and cremation to treat perilous squanders created by different modern units. They contribute about

97.8 percent of absolute landfill squander and 88 percent of all out unsafe waste created in the nation, according to a situation service report CPCB (2013).

1.7. Waste management principles

Squander (waste) management is the usage of measures endorsed for the treatment of waste inside the gathering, transport, stockpiling, treatment and transfer of waste, including supervision of such exercises and support of waste administration offices. Squander is created at all dimensions, national and neighborhood, in families, fabricating offices, open organization, retail locations, instructive establishments, the travel industry associations and undertakings, restorative foundations, military foundations, and so forth. Squander generation relies upon the dimension of mechanical improvement, expectations for everyday comforts, ways of life, social condition, vitality and different parameters inside each network. The measure of waste can fluctuate fundamentally between nations, yet additionally inside the pieces of a similar nation. The essential arrangement of waste is the accompanying: According to the place of beginning:

- Municipal waste - household waste, as well as other waste which, based on its nature or composition, is similar to waste from households.
- Commercial waste - waste generated by businesses, institutions and other organizations that are wholly or partially engaged in trade, services, offi ce affairs, sport, recreation or entertainment, except for household and industrial waste.
- Industrial waste - waste from any industry, except for the tailings and associated minerals from mines and quarries.

The key rule of waste administration is the guideline of manageable advancement and it depends on six sub-standards. Supportable waste administration infers progressively effective utilization of assets, squander minimization and treatment of waste so that it adds to the goals of maintainable improvement. Practical advancement is a planned arrangement of specialized innovative, monetary and social exercises in the general improvement in which the standards of cost-adequacy and the sensibility of the utilization of characteristic and man-made qualities are met so as to protect and upgrade the nature of the earth for present and who and what is to come. Waste administration depends on the accompanying standards:

1. The principle of proximity and regional approach to waste management,

2. The precautionary principle,
3. The "polluter pays" principle,
4. Principle of the hierarchy of waste management,
5. Principle of the optimal option for the environment,
6. The principle of accountability.

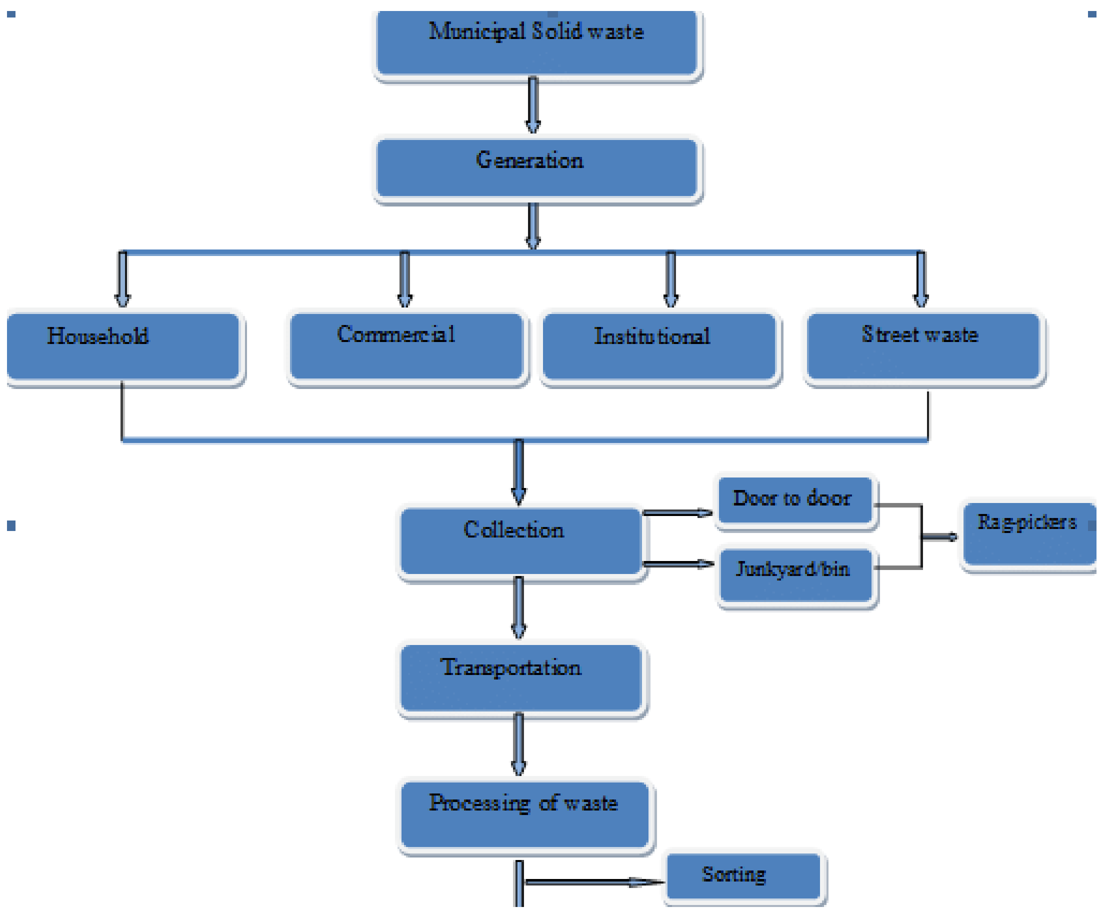


Figure 1.5: The Flow Chart of Waste Management

1.8. Waste recycling

Waste recycling is the process of transferring waste into new products in such a manner that the original matter may lose its identity and in turn become a useful product. It should be realized that waste is a treasure which could be recycled to from "Wealth".

Recycling is a way to manage waste to reclaim the potential waste so that the product can be used. Recycling helps reduce the overall demand for hazardous household products and the amount of waste produced.

Recycling is a solution for accumulative household waste. It is important to practice the four "R"s of recycling and waste management: reduce, reuse , recover and recycle(www.niteshcapecod.co.in).

Recycling of over 80 percent of the household waste promotes a green lifestyle and makes the home more eco-friendly. It also makes people more conscientious of what one should buy and bring into the home.

The 4R’s

- Reduce
- Reuse
- Recycle
- Recover

Figure 1.6: The 4 R’s

1.8.1. The Reduction of Waste

Reduce waste production at the source. This means reducing the quantity of waste during production, distribution, purchasing, use and elimination.

Replace your consumption of disposable objects and products by reusable ones.

- Cloth napkins (washable) instead of paper napkins (disposable);
- Cloth or strainer coffee filters (washable) instead of paper filters (disposable);
- Eliminate throw-away razors, lighters, non-rechargeable batteries, etc.

1. Buy recycled or recyclable products;
2. Buy products that aren't over-packaged;
3. Buy products that contain recycled materials.

1.8.2. Recycling of Waste:

Like reuse, reuse implies recouping an item and allowing it a second life. While reusing an item implies utilizing it without truly changing it or favoring multi-reason articles and items over single-utilize ones, reusing implies taking an item back to a condition of crude material: paper returns to mash, plastics are softened and formed into new items, and so on. With new outlook, an ecologically benevolent cycle and practical advancement are set up, and that decreases utilization and its negative effect. After accumulation, recovered materials head to a reusing focus where paper, cardboard; plastics, glass and metals are simply arranged. Every material is then packed in a cubic ton and sold to organizations that do the genuine reusing of these assets.

- Preserves our increasingly more of our valuable normal assets by limiting backwoods and mining exercises;
- Preserves immense measures of water;
- Reduces vitality requests amid assembling;
- Bypasses air, water and soil sullying amid mining and transfer (dumps, incinerators);
- Favors the preservation and insurance of the earth and biological systems;
- Reduces contamination (every ton of reused materials spares 2.8 tons ozone harming substances).

1.8.2.1. Recycling

It's the Möbius lace, the logo for reusing. It ensures that an item and additionally its bundling are made altogether of reused materials. At the point when the image is white on a dark foundation, the item contains reused materials. Items containing postconsumer reused materials are perfect since they have just been utilized in any event once. The level of reused filaments is now and again written in the focal point of the logo. These logos are accessible for downloads on Industry Canada's site in a wide scope of standard software.

1.8.3. Reuse of Waste

- Provide separate canisters for gathering utilized bundling, string official, envelopes and different materials that can be reused.
- Use re-usable cutlery, dishes, mugs and espresso channels (eg abstain from utilizing paper glasses)
- Reuse gear parts and installations and fix furniture to lessen squander, reuse bundling materials (eg boxes, plastic sacks)

1.8.4. Recovering of Waste

The vast majority of the materials tossed in the refuse can be utilized and prepared in manners other than being demolished. This is called recuperating. Reusing, reusing and composting is the most much of the time utilized techniques for recovery waste. At the point when it's unlikely to reuse or reuse objects, for example, dead batteries, ink cartridges or mobile phones, which all contain lethal components named dangerous household squander—there is one final alternative before discarding them: scrap sellers, reusing specialists and recuperations.

Another option is recouping the vitality put away in remaining material. That implies transforming waste into a fuel for assembling procedures or hardware intended to create vitality. Different mechanical, organic and caloric frameworks and advancements can change over, reprocess or separate squanders into new materials or vitality. For instance, the methane brought about by spoiling materials in dump locales can be reused. This gas is changed over into power, and subsequently disposes of its hurtful consequences for the earth (methane is an ozone depleting substance multiple times more dominant than CO_2) Buenrostro and Bocco (2003).

1.9. Kitchen Waste (KW)

India stands second in the production of Fruits and vegetables in the world. It contributes about 10% as well as 14% of fruits and vegetables in the world production (Gautam and Guleria, 2007 and Chaudhary and Mishra, 2018). Vegetable Wastes are produced during harvesting, transportation, storage, marketing and processing. Due to their nature and composition, they deteriorate easily and cause foul smell production. In recent years, solid waste treatment has become a serious issue worldwide (Park et al., 2008). Material waste is a derivative of almost all human activities and results in stress and pollution in the environment. Waste prevention is the principal goal of the waste management. Solid waste production is increasing gradually with the passage of time due to population explosion and urbanization. Each urban resident produces 0.35–1.0 kg of solid waste every day. (Upadhyay et al., 2005).

Kitchen waste is defined as left-over organic matter from restaurants, hotels and households (Li et al., 2013). Kitchen waste forms a significant part of domestic waste. Food waste is an unwanted raw or cooked food discarded during or after food preparation that is no longer fit for consumption or desirable. Toxic Links at New Delhi conducted a survey in May 2002 and prepared a fact file on solid waste which stated that about 0.1 million ton of municipal solid waste is generated in India every day. So, annual production of solid waste reaches approximately 36.5 million tones (Kaur and Arora, 2012).

Tons of kitchen wastes are produced daily in highly populated areas. An Indian city produces about 0.8 to 1 kg solid wastes per capita per day (Sarkar et al., 2012). These wastes are collected and dumped into the landfills, causing major pollution (Bouallagui et al., 2005). This results in loss of potentially valuable materials that can be processed as fertilizer, fuel and fodder (Baffi et al., 2007). The bulk of organic kit comprises mainly carbohydrates, amino acids, peptides and proteins, volatile acids, fatty acids and their esters are easily biodegradable.

Due to reasonably high moisture content of kitchen waste, bioconversion technologies such as anaerobic digestion are more appropriate as compared to thermo-chemical conversion technologies, viz. combustion and gasification (Zhang et al., 2007).

1.9.1. Kitchen Waste Managment by Composting

As agriculture became progressively more mechanized after World War II, use of synthetic fertilizers replaced the practice of applying manure or compost to soil to sustain soil fertility, and composting fell into disuse. In recent years there has been renaissance in composting initiatives at various levels as urban and rural areas face increasing landfill costs and decreasing landfill space (EPA, 1994).

Sir Albert Howard was maybe the first agricultural scientist to bring a scientific approach to composting, almost 75 years ago in India (Howard,1935).

Green manuring involves the cultivation of leguminous plants that are used due to their symbiotic nitrogen or N fixing capacity. In some areas, non-leguminous plants may also be used due to their local availability, drought tolerance, quick growth and adaptation to adverse conditions. The popularity of organic farming is gradually increasing and now organic agriculture is practiced in most of the countries of the world. Vegetables produce with less chemical residue will be boon for the public health. This is of special importance for vegetables which are consumed either raw or mildly cooked. Enhanced self-life of organically produced vegetables will go a long way in reducing the pre and post-harvest losses of these commodities, which at present is about 25-40% (Doyle and Kelleher, 2008).

1.9.2. The Advantages of Composting

Nowadays, composting is known for its numerous advantages which involve:

- Reducing yard and food waste make up 30% of the waste stream and therefore diverting that waste away from the landfills.
- The plants from well-done compost will look better, will produce better and will have a much greater ability to fight diseases.
- Adding organic matter to the soil improves moisture retention.
- Adding decomposed organic material to the soil feeds the soil's organisms.
- Compost provides a balanced source of nutrients that helps the soil hold nutrients long enough so that the plants can use them.
- Composting saves money.
- Composting improves our diet, the plants will have fair amount of nutrients.

1.9.3. Application of Compost

1.9.3.1. Waste Management

Treating the soil natural waste considers disintegrating the natural materials into an increasingly minimized structure for the executives (Othman and Benson , 1993; Tognetti et al., 2011).

Manure has been utilized at the family or little homestead level for reusing of natural issue and supplements for a huge number of years. Since the late twentieth century, increasingly more vast scale treating the soil offices were set up to oversee and reuse natural waste from urban regions. Especially lately, these urban treating the soil exercises have been seen as promising endeavors to diminish squander streams to landfills and oversee squander in an increasingly manageable way.

1.9.3.2. Nutrient Management

Compost is produced using an assortment of feedstocks, for example, plants materials from rural fields and vegetable greenery enclosures, creature squander (excrement), city strong waste, yard squander (patio nursery and park trimmings), local and business nourishment squander, and civil and mechanical wastewater handling ooze (biosolids). Green waste is natural squanders basically comprising of crisp plant material, however local and business nourishment squander is regularly included under this characterization (Oregon Department of Environmental Quality, 2001). Green waste contains apparent measures of nitrogen, phosphorus, and mineral supplements (Raj and Antil, 2011; Amlinger et al., 2003) and has low C/N proportions. Feedstocks, for example, feed paper, cardboard, and dry plant leaves contain principally carbon, oxygen, and hydrogen (Goyal et al., 2005; Zmora-Nahum et al., 2005; Raj and Antil, 2011) and have high C/N proportions, such waste is called darker waste. Manure produced using green waste as a rule contains a lot of nitrogen and phosphorus. Treating the soil in this manner assumes a critical job in supplement cycling. As of now manure discovers use as supplement sources in farmlands, open and private greenhouses, parks, roadway banks, and finishing (Hanc et al,2011)

1.9.3.3. Pathogen Control & Public Health Issues

Pathogen control and debasement of harmful natural mixes by fertilizing the soil are imperative proportions of general wellbeing. The treating the soil procedure is a key strategy to control pathogenic living beings that are available in public sewage and solid waste. Treating the soil includes oxygen consuming breath by bacterial and parasitic creatures, which separate natural issue. The debasement procedure brings the temperature up in the fertilizer heaps to somewhere in the range of 45◦C and 70◦C. In this temperature extend valuable thermophilic microscopic organisms flourish, while numerous bacterial pathogens and weed seeds are killed. (Turner et al., 2005; Erickson et al., 2009). An ongoing audit by (Wichuk et al., 2011) demonstrates that treating the soil can dispense with generally phytopathogens. Studies have demonstrated that manure and fertilizer removes connected to financially essential harvests (e.g., wheat, peppers, tomato, okra) can smother a few pathogens and weeds (Boulter-Bitzer et al., 2006; Yogev et al., 2010). Comparative valuable elements of fertilizer applications have been accounted for concealment of flurry shape contaminations of Fusarium Patch and Typhula Blight in turf grass. Treating the soil is likewise powerful in inactivating pathogenic infections (Bendfeldt et al., 2001; Benson et al., 2008; Guan et al., 2010).

1.9.3.4. Ecological Issues

Oxygen is essential for bacterial breath that drives the fertilizing the soil procedure. In this manner, fertilizing the soil happens best in outside heaps (called wind-lines), or in compartments and receptacles that have air get to. Normal air circulation is likewise regularly enlarged utilizing vacuum apparatuss. The breath amid the disintegration procedure in fertilizing the soil causes arrival of carbon dioxide. Under oxygen-constrained conditions, the decay procedure additionally delivers a mixture of different gases, similar to methane, nitrogen oxides, unstable natural mixes, and alkali. Feedstock high in nitrogen content will in general discharge extensive measures of nitrogen oxides and smelling salts if anaerobic conditions be successful in the manure heap . In vast fertilizing the soil offices, downpour or snow may fall on fertilizer heaps, and the water permeating through the heap can drain out. There is additionally the likelihood of filtering from the feedstock itself. At the point when manure is connected as a soil modification to agrarian fields, greenhouses, or roadsides, at that point dissolvable and dispersible materials can be filtered from the fertilizer by downpour or water system water. This manure leachate contains solvent minerals, natural issue, and suspended solids, including mineral and natural colloids and possibly pathogens (Boulter-Bitzer et al., 2006; Chen et al., 2010). The accurate creation of the leachate is controlled by the idea of the feedstock, the level of advancement of the treating the soil procedure, and the portion of the fluid that penetrates into the fertilizer. For instance, manure connected to roadsides will be presented to draining by street overflow, which can convey metals and hydrocarbons. These synthetic compounds will associate with the strong and dissolvable segments in manures, and keeping in mind that a few contaminants can progress toward becoming immobilized in the fertilizer, some can drain with fertilizer lactates.

1.9.3.5. Environmental Benefits of Composting

In spite of the fact that the natural advantages of composting are numerous this area of the writing survey will concentrate on four of the most imperative advantages of treating the soil. Landfill redirection and contamination, decrease of engineered manure use, soil enhancement and soil disintegration decrease landfill preoccupation and contamination. Food squander redirection from landfills is vital as sustenance squander is a substantial and essential part of all city squander produced (EPA, 2009). Indeed, in 2007 food scraps spoke to practically 12.7% of the complete metropolitan solid waste created in American families and under three percent was recuperated. Information demonstrates that Americans disposable over 25% of the sustenance we set up, that adds up to around 96 billion pounds of nourishment squander every year (United States Department of Agriculture (USDA, 1997). In addition, sustenance squander dealing with and conveyance into landfills and incinerators is expensive and the amassing of it in landfills can prompt ecological issues and make wellbeing dangers (Means et al., 2005). The decay of sustenance squander in landfills generally happens under anaerobic conditions which delivers and discharges methane. Breaking down refuse in landfills discharge around 10 million metric huge amounts of methane every year in the United States (2004), a gas that as indicated by Wolfson ,(2007) "is multiple times more grounded than CO_2 in its warming impacts" and now landfills are the single biggest human wellspring of methane emanations in the United States and on the planet. Once sustenance squander is dumped in landfill Once nourishment squander is dumped in landfills, it gets compacted and melts and it blends with numerous toxics (for example paints, oils, cleansers) and keeps on leaking down through the ground contaminating underground waters (Crawford, 2003) and from that point streams, lakes and beach front zones. Composting nourishment waste and natural materials lessens the creation of methane from landfills and leachate and their relating impacts on a worldwide temperature alteration and water contamination (University of Colorado Recycling Services, 2002) Reduction of engineered compost use. Another critical advantage of treating the soil is that its utilization disposes of the ozone depleting substance discharges identified with engineered compost fabricating and the horrendous natural harms that its utilization can cause. Engineered manures are for the most part utilized in agrarian terrains and record for the vast majority of the responsive nitrogen (N) delivered by people, and for a critical level of the all out ozone depleting substances emanations. At the point synthetic manure is connected on fields soil microbes break down nitrates and transmit nitrous oxide (N_2O) an amazing ozone harming substance. N_2O is around multiple times more dominant than CO_2, as it were 1 kilogram of N_2O causes as much a worldwide temperature alteration as 310 kilograms of CO_2 the use of manufactured composts represent 5% of the complete a dangerous atmospheric devation.

Plants can just take such an extensive amount the supplements given by manufactured composts and the rest (overabundance) of the supplements go to contaminate streams, lakes and waterfront zones (Dybas, 2005). The open does not understand the harm that the intemperate utilization of engineered manure has on our waters, to give a thought of the effect (Howarth, 2007) recorded the results that abundance supplements from manufactured composts have on waterfront waters and beach front networks as pursues:

- Creation of dead zones.
- Loss of biodiversity.
- Change in ecosystems and detriment of habitat quality.
- Increased cloudiness of water and greater odors from water.
- Loss of sea-grasses and other ecologically valuable submerged aquatic vegetation.
- Decline of coral reefs.
- Decreased production of commercially important fish and shellfish.
- Increased frequency, duration, and extent of harmful algal blooms, with risk to human health and great damage to marine mammals.
- Increased transmittance of some human diseases such as cholera.

Synthetic fertilizer use has severe environmental consequences ranging from global warming to water pollution and soil acidification, but another consequence of synthetic fertilizer use that is not always taken in to consideration is the economic cost that its environmental footprint has. The economic costs of synthetic fertilizer use include the effects of green house gas emissions, water pollution, fisheries' decline, aquatic life's loss of habitat, and soil acidification, thus the importance of reducing its application.

1.9.3.6. Soil enrichment

Through its Extension program site characterizes manure as a natural soil alteration that improves the physical, substance, and organic properties of soils. The compost can expand soils ability to hold and discharge fundamental supplements and furthermore advances the action of night crawlers and microorganisms valuable to plant development. Manure profoundly improves the dampness holding limit of sandy soils, which thus decreases dry season harm to plants. Moreover, when fertilizer is added to substantial dirt soils, it improves waste and air circulation, along these lines decreasing the harm that unreasonable dampness causes to plants. The EPA clarifies in its site for the advantages of manure how its utilization recovers poor soils. They clarify that compo sting procedure of natural waste empowers the generation of valuable small scale creatures (for the most part microorganisms and growths) which thusly separate natural issue to make humus.

1.9.3.7. Soil erosion reduction

Composting revealed a very important and effective effect on soil erosion. It helps to stimulate the soil's organic activities and utilize nutrients for production and improve soil structure. Thus reduces soil erosion.

1.10. The Economics of Composting

For a composting system to have the capacity to turn into a reality it needs to bode well particularly in the current financial circumstance. Unfortunately, the ecological advantages alone won't make the open help a sustenance squander composting system, yet the purposes behind composting nourishment squander are more than natural. Monetary motivating forces, nearby employments creation and the utilization of neighborhood information are an essential part also. Additionally, the making of a compo sting system includes a stage towards the improvement of a naturally manageable economy.

1.10.1. Economic benefits for communities and businesses

A food squander composting system will make the neighborhood economy more grounded on the grounds that it utilizes nearby assets and gives fertilizer to neighborhood clients. As found in their examination, other than explicit kinds of manure for nurseries and fairways 64% of the fertilizer utilized was pulled less than 30 miles. In addition, the availability of manure inside a monetarily achievable separation is vital for the improvement of a business opportunity for fertilizer. The market for a composting system in Menomonie, Wisconsin ought to be essentially established by huge clients, for example, farm region of rural and decorative (ornamental) yields, golf courses and landscaping business and ultimately smaller users made of residents and organizations with a little requirement for compost (Anschutz et al., 2004).

By the use of chemical fertilizers farmers were happy of getting increased yield in agriculture in the beginning. But slowly these chemical fertilizers started displaying their ill effects such as leaching out, and polluting waster basins, destroying microorganisms and beneficial insects, making the crops more susceptible to pests, diseases and also reducing the soil fertility.

Green revolution in India has witnessed a jump in agricultural production with the introduction of high yielding varieties of various crops and by following intensive cultivation practices with the use of fertilizers, pesticides and other synthetic inputs. The intensive use of these inputs has not only polluted the soil, water and the environment causing their slow degradation but also affected the human beings. With the increase in the country's population, compulsion would be not only to mobilize the agricultural production but also increase further in a sustainable manner. The scientists have realized that the green revolution with high input use has reached a plateau and is now sustained with diminishing return and falling dividend.

Organic agriculture is a viable alternative because it enlivens the soil, strengthens the natural resource base and sustains biological production at levels to commensurate the carrying capacity of the managed agro eco- system.In addition to this export market can also be tapped by group initiatives in organic farming. In a country like India, food production has to grow steadily. A sudden switch over to organic farming is not feasible.The stage will be set in due course for a smooth transition to organic farming without causing any decline in production. Products of biological origin can be advantageously blended to replace a part of the enery-intensive inputs.It is in this context, biofertilizers can provide to the small and marginal farmer on economically viable level for realizing the ultimate goal of increasing productivity.

The term biofertilizer refers to the preparation containing primarily active strains of microorganisms.They are ready to use live formulates of such beneficial microorganisms which on application to seed, root or soil fix atmospheric nitrogen or solubilize/ mobilize plant nutrients or otherwise stimulate plant growth substances.These biological activity in particular helps to build up the microflora/ fauna and in turn the soil health in general (Adhikari et al., 2018).

Keeping in view of all facts, my topic of study is enrichment of organic kitchen waste through microbial inoculation and its application quality for achieving waste management sustainable development goals.

The objectives of the study

- To prepare the organic kitchen waste compost from kitchen waste seasonally.
- To analyze and compare the physico-chemical content , microbial content of the prepared compost and also assess their phytotoxicity.
- To develop an enriched compost from the prepared compost.
- To examine the application quality of enriched compost through comparative pot study.

Thesis Organization

The thesis of study has been compiled into following chapters;

- Chapter 1 has introduced the basic information on the topic of thesis. The information related with solid waste management system model, waste and its type, global waste management and its goals, waste generation scenario, regulation and policies, urbanization and waste generation, waste management principles, kitchen waste, advantages of composting, application of compost and economics of composting.
- Chapter 2 of this thesis has described the objectives and need of this study, keeping in view exploring the novel methodology and scientific findings for Kitchen waste composting.
- Chapter 3 of this thesis deals with review of literature which includes comprehensive existing information on composting and its science , composting parameters ,effect of compost enrichments on composting parameters and effect of enriched compost on

various crop as well as promising techniques and need for compost enrichment.

- Chapter 4 has described a brief introduction, detail procedure for feedstock preparation and experiment set up for kitchen waste composting for four different seasons.
- Chapter 5 deals with a brief introduction, flow chart representation of the experiment deatail methodology regarding physico-chemical, microbial and phytotoxicity assessment of seasonally prepared compost with their result discussion and conclusion.
- Chapter 6 has described a brief introduction on microbial inoculation of prepared KWC, method of microbial enrichment of KWC, changes after inoculation on KWC's parameters, flow chart of this experiment, result discussion and conclusion.
- Chapter 7 has described a brief introduction on compost enrichment, a flow chart of the experiment, the application quality of prepared KWC and enriched KWC at different treatment combination on tomatao plants, result, discussion and conclusion.
- Chapter 8 has summarized the findings and conclusion of thesis. This section has mentioned the brief findings of each chapter and recommendation for future work.
- Chapter 9 described the concerned references cited in the whole thesis. The reference section has been written in a standard format and all the important references related with topic have been included.
- Chapter 10 has been annexed with the published and accepted research papers and other scientific output of work.

Chapter-02

Objectives in Detail

Chapter-2

The main objective of the study was to find out the best combination of waste materials for producing nutritionally rich fruit (tomatoes) at which dose of prepared enrich bio-compost gives best result. The purpose was also to find the best season KWC for enrichment. And that particular best season KWC application quality before and after enrichment on tomatoes plant. The objectives of this study were as below :

1. **Preparation of compost from organic kitchen waste (OKW) seasonally.**
    - Feedstock preparation for different season's kitchen waste compost (OKWC).
    - Composting experimental set up for preparation OKW for different seasons.

2. **Investigation and comparision of seasonally prepared organic kitchen waste compost on the basis of physico-chemical, microbial parameters and phytotoxicity evaluation.**
    - Physico- chemical analysis of different season's OKWC.
    - Microbial analysis of different season's OKWC.
    - Phytotoxicity assessment of different season's OKWC using seed germination test.

3. **Development of enriched compost through microbial inoculation.**
    - Microorganisms used in experiment.
    - Inoculumn preparation for composting.
    - Composting experiment set up.
    - Microorganism colony forming unit (cfu) estimation.
    - Physico- chemical variation analysis of OKWC after enrichment.
    - Microbial variation analysis of OKWC after enrichment.

4. **Examination of the application quality of prepared and enriched compost through comparative pot study.**

- Green house experimental details.
- Nursery bed preparation and transplantation.
- Treatment combination details
- Crop details

- Parameter analysis

  a). Physical parameter of tomato plants

  b). Nutritional assessment (biochemical and mineral content) of tomato fruits.

Need of the Study

Composting is an ability of reusing process in which the assets are saved in a progressively accessible structure with the goal that they can be most effectively utilized. Not at all like other chemical and physical not reusable procedure, for example, consuming and landfill, can these natural methods for arranging add much favorable position to the biological community by rationing the plant supplements. Composting of natural (organic) waste will result in supplement rich and stabilized end product. It likewise lessens the ozone harming substances and leachate creation in landfill and open (illicit) dumping, if they are source segregated and composted using Composting bin method in aerobic condition.

Agriculture especially Organic Farming is receiving enormous consideration around the world, as government and non-government specialists perceive that there is a need to build profitability in a progressively quickened path so as to guarantee nourishment security and enhanced sustenance to a developing populace. Agriculturists should create around 1.5% more grain each year, speaking to an expansion of 35% by 2030 and more noteworthy than 70% by 2050 (Hilimire, 2011). Since the compost is fundamentally centered around nitrogen, phosphorous, potassium and different micronutrients, that can be very much utilized as a soil conditioner. Use of compost as a fertilizer has enhanced the physical structure of the soil that incorporates gardening soil mixture. Moreover there was an expanded concealment of plant maladies brought about by soil-borne nematodes, growths and microorganisms because of the expansion of compost to the soil in different cropping pattern (Schonfeld et al., 2003). Kostov et al. (1996) directed a test by treating the soil with compost, mineral composts and manure to study the yield efficiency and quality of vegetables and fruits. Previous studies also revealed that the utilization of fertilizer got from vine branch, rice husks, and flax from in soil fundamentally expanded the yield of tomatoes and nature of organic products when contrasted with other two materials.

Finally, this present study aims to accomplish zero waste targets and diminish ecological pollution. Composting is an affordable, ecological benevolent, wealth creating method. The utilization of chemical manure could prompts ground water tainting or contamination which will cause various hazards to nature and humans where as bio-compost will be a better substitute for chemical fertilizer.

Organic waste management by composting will upgrade the reusing of waste, landfills, helpful in production of organically produced food crop and job-creation.

Chapter-03

Review of Literature

An open dumping is defined as a land discarding site at which solid wastes are disposed of in a manner that does not protect the environment, are susceptible to open burning, and are exposed to the elements, vectors and scavengers. Open dumping can include solid waste disposal facilities or practices that create a reasonable possibility of adverse effects on health or the environment. The health risks associated with illegal dumping are noteworthy. Areas used for open dumping may be easily accessible to people, especially children, who are vulnerable to the physical (protruding nails or sharp edges) and chemical (harmful fluids or dust) hazards posed by wastes. Rodents, insects, and other vermin attracted to open dump sites may also pose health risks. Dump sites with scrap tires provide an ideal breeding ground for mosquitoes, which can multiply100 times faster than normal in the warm stagnant water standing in scrap tire causing several illnesses (EPA, 1994). Poisoning and chemical burns results from contact with small amounts of hazardous, chemical waste mixed with general waste during collection and transportation. Burns and other injuries can occur resulting from occupational accidents and methane gas exposure at waste disposal sites. Dust generation occurs from on-site vehicle movements, during placement of waste and materials. The waste in the dumping ground undergoes various anaerobic reactions and produces offensive greenhouse gases such as CO_2, CH_4 etc. These gases are contributing potentially to global warming and climate change phenomenon.

3.1. Composting

Composting is a sustainable waste management method in developing countries. It is an eco- friendly move toward for bioconversion into value added products which may be utilized as plant nutrients. Composting is an aerobic, thermophilic, and controlled microbial biooxidation process resulting in a product affluent in humus which is used as a fertilizer. The oxidation produces a transient thermophilic phase which is followed by a stage of cooling of degrading organic matter. The consequential material is held at ambient temperatures for maturation purposes which results in stable, volume-reduced, hygienic, humus like material which is useful to soil and plants.

Composting is a microbiological conversion of organic residues of plant and animal origin to manure rich in humus and nutrients by various micro-organisms including bacteria, fungi and actinomycetes in the presence of oxygen. During the process it releases by products such as carbon dioxide, water and heat (Abbasi and Ramasamy, 1999; Bhatia et al., 2013).

Composting is a great recycling process in which the resources are conserved in a more available form so that they can be most efficiently used. Unlike other chemical and physical disposal process such as burning and landfill, this biological means of disposing that is composting can add much advantage to the ecosystem by conserving the plant nutrients. The application of compost can drastically reduce the usage of ammonia-type fertilizers, in which approximately 2% of the natural gas consumed in the United States is used up in the manufacture of these chemical fertilizers . Since the compost is primarily focused on NPK and other micronutrients it can be well used as a fertilizer. Most of the nitrogen can be trapped into the compost if the loss of ammonia is reduced during the process. Application of compost as a fertilizer has improved the physical structure of the soil that includes potting soil mixtures. In addition there was an increased suppression of plant diseases caused by soil-borne nematodes, fungi and bacteria due to the addition of compost to the soil in various cropping systems (Schonfeld et al., 2003).

3.1.1. The principles of composting

Composting is the process by which complex organic materials are changed into a material with environmentally useful applications. The composting can transform huge quantities of organic material into compost in a relatively short period by properly organising moisture, air and nutrients. During composting, the microorganism consumes oxygen and nourish on organic matter. Active composting generates a significant amount of heat and large quantities of carbon dioxide and water vapour are released into the air.

The carbon dioxide and water losses can amount to half the weight of the initial organic materials, so composting reduces both the volume and mass of the raw materials while transforming them into a useful humus-like material.

Organic compounds+O_2 $\rightarrow$ Stabilized organic waste material+CO_2+$2H_2O$+Energy

This conversion is not achieved during a single reaction, but through a series of reactions. These reactions are provide not only to release significant quantities of energy, but also to form a large number of organic intermediates that provide as starting points for other synthetic reactions. The two possible modes of energy yielding metabolism for heterotrophic microorganisms are respiration and fermentation. Respiration can be either aerobic or anarebic.Aerobic respiration is favored over anaerobic respiration and fermentation for composting because it is more resourceful, generates more energy, operates at higher temperatures, and does not produce odorous compounds. Aerobes can also use a greater variety of organic compounds as a source of energy that results in more complete degradation and stabilization of the compost material. In anaerobic respiration, the microorganism use electron acceptors other than O_2, such as nitrates (NO^-_3), sulphates, and carbonates to obtain energy. Their use of these alternate electron acceptors in the energy-yielding metabolism produces odours or undesirable compounds, such as hydrogen sulphide (H_2S) and methane (CH_4).Anaerobic respiration also leads to the formation of organic acid intermediates that tend to accumulate and are detrimental to aerobic microorganisms. Aerobic respiration also forms organic acid intermediates, but these intermediates are readily consumed by subsequent reactions so that they do not pose as a significant a potential for odours as anaerobic respiration. Fermentation is the simplest means of energy generation .It does not require oxygen and is quite inefficient. Most of the carbon decomposed through fermentation is converted to end – products, not cell substituent, while liberating only a small amount of energy.In addition, nitrogenous organic residue is broken down to obtain the nitrogen necessary for the synthesis of cellular material in heterotrophic microorganisms.Nitrogenous organic residues or proteins undergo enzymatic oxidation (digestion) to form complex amino compounds through a process called ammonization. Carbon dioxide (CO_2),energy, and other by-products are also produced.

Protein+O_2 →Complex amino compounds+CO_2+Energy+Other products

The complex amino compounds formed can be synthesized into microorganisms or undergo additional decomposition into simpler products. The products of the digestion of proteins and complex amino acid can only be used in the synthesis of new cellular material if sufficient carbon is available. If not enough carbon or energy is available to incorporate these amino compounds into the cells, unstable nitrogen forms accumulate through the process of ammonification.As the ammonia group is characteristic of amino acids, ammonia(NH_3), or ammonium ions(NH_4^+)accumulates. The ammonium compound that is formed interconverts between the two forms depending on the pH and temperature of the heap.This interconversion between NH_3 and NH_4^+ is described by the reaction shown below.Acidic conditions (pH<7) promote the formation of NH_4^+,while basic conditions promotes the formation of NH_3. Elevated temperature also favors the formation of NH_3 and because of low pressure vapour of NH_3; it generally results in gaseous NH_3 emission from the heap. Another key chemical transformation of the composting process is nitrification, the process by which ammonia or ammonium ions are oxidized to form nitrates. (NO_2^-) through the action of autotrophic bacteria that use the energy produced by this conversion. The nitrites are then rapidly converted to nitrates (NO_3^-) by a different group of microorganisms called nitrifying bacteria.

Nitrification occurs during the curing period. Since (NO_2^-) nitrites are toxic to plants and nitrates (NO_3^-) are the form of nitrogen most usable in plant metabolism, enough time must be allowed for the curing period so nitrates are the final nitrogen product in the compost. In addition, because nitrification requires oxygen, proper aeration of the compost pile must be maintained during curing. Another important nitrogen transformation is denitrification. Denitrification occurs in oxygen-depleted environments. It can be carried out by either aerobic or anaerobic bacteria. If denitrification is carried out by either aerobic or anaerobic bacteria, the reaction is as follows:

$NO^-_3 \rightarrow NO_2^- \rightarrow N_2O \rightarrow$ (gas)

If denitrification is carried out by anaerobic bacteria, the general reaction is

$HNO_3^- \rightarrow +H_2 \rightarrow NH_2^+ \rightarrow N_2O$

As nitrous oxide is an odorous compound and results in the loss of beneficial nitrate-nitrogen, is not desired and can be avoided by maintaining aerobic heap conditions. This is accomplished with proper aeration (Chandra, 2016).

3.1.2. Phases in composting process

The phases in the composting processes can be distinguished according to temperature patterns. In the mesophilic phase, the microorganisms acclimatize and colonize in the new environment in the compost heap. Growth phase is characterized by the rise of biologically produced temperature to mesophilic level. In thermophilic phase, the temperature rises to the highest level with stabilization of waste and pathogen destruction which are more effective. During maturation phase the temperature decreases to mesophilic and consequently ambient levels.

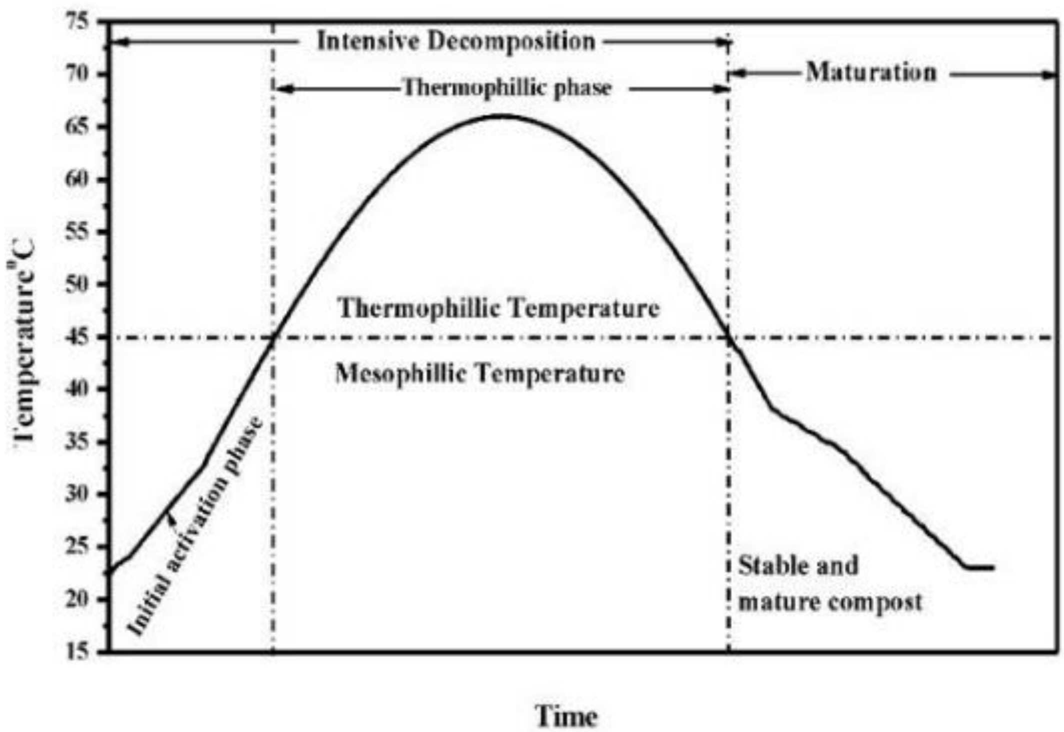


Figure 3.1: The Different Phases of the Composting Process.

3.1.3. History of composting

Even though it is very difficult to attribute the birth of composting, the history of urban waste generation and its management begins with human civilization and urbanization. During the Neolithic period when human beings changed their habitat from essential hunters and gatherers to farmers, they started making pits out of stone for the storage of organic urban waste for the application of agricultural fields (Martin and Gershuny, 1992). However the most accurate and technical descriptions of composting has been conducted by the Knights Templar of thirteenth century. These Templar's were a military order during the time of the crusades.

There are references for the usage of manure in agriculture on clay tablets by the ancient Akkadian Empire in the Mesopotamian Valley, thousand years before Moses was born. There are evidences that Romans, Greeks and the Tribes of Israel knew about compost. Even in tenth and twelfth century Arab writings of both Bible and Talmud, have references for using rotted manure straw and organic materials to compost. Many New England farmers' composted 10 parts of muck to 1 part of boneless fish by periodically turning the compost heaps until the disintegration of fish was achieved (Math, 2013).

Some of the advances made during the twentieth century include the work of Sir Albert Howard in the year 1933 in India. His work was one of the first documented efforts on the application of composting in the management of organic residues in India ever in the history of modern composting (Howard and Wad, 1935; 1938). Sir Howard in collaboration with few researchers developed the "Indore Process". Initially in Indore process only the animal manure was used for composting. But later readily biodegradable materials such as night soil, garbage, straw, leaves, municipal refuse and stable wastes were also composted on open ground. Indore process included two methods; the heap method and the pit method. In heap method the materials were piled up to height of 1.5 m and in pit method the materials were placed in trenches of 0.6-0.9 m deep. The leachate from the compost material was recirculated to maintain the moisture content and the composting process lasted for 6 months or longer.

Later in 1939, the Indian Council of Agricultural Research at Bangalore developed the "Bangalore Process" with some improvements of Indore method. This process overcame many of the disadvantages of Indore process such as heap protection from adverse weather; nutrient losses due to high winds/strong sun rays, frequent turning requirements and fly nuisance etc. An important modification to the Indore method was increasing the turning frequencies in order to maintain aerobic conditions, thus achieved more rapid degradation and shortened the composting period.

Later, a process that was used in a number of countries and heavily marketed throughout the world is the Dano Process. This is one of the widely known in-vessel systems which uses a large, slowly rotating drum with baffles incorporated inside it that carries the material during the digestion. This process was mainly concerned in the segregation and size reduction of the waste; however the output of this process can be composted by any of the procedures that were available at that time. This process was first developed in Denmark. The Dano Corporation later developed a mechanical silotype digester known as the Bio-stabilizer (Golueke, 1992). The materials are fed to the stabilizer and maintained in thermophilic conditions for most of the time. The outputs are passed through a 1 mm mesh screen and further composted using windrows system if necessary. Later, Mr. T. van Maanen had started Vuilafvoer Maatschappij (VAM) Company to compost city refuse in Netherlands. In the process, the refuse was placed in long and high piles. The piles were sprinkled periodically with the recirculated leachate to maintain the moisture content of the system (Diaz et al., 2007). Overhead cranes were used to turn the piles and the decomposed material was shredded, screened and sold as humus. Stovroff and his associates built an aerobic composting facility in Oakland, California, USA using the windrow method, which is also a modified version of the basic Indore method. This composting methodology was designed to compost 300 tons of mixed waste in an 8 h shift per day or 600 tons on a two shift i.e. 16 h/day basis (Stovroff, 1954a; b). Usually the piles were made in the range of 2 to 3 m in length and it was dependent on the site characteristics (Varma, 2015).

3.1.4. Types of Composting

Generally, composting systems are of two types: the open process and reactor process. Open composting process are the first types systems originated and practiced from the evolution of composting times, which also includes windrow systems, static and household systems. Reactor systems include tunnel systems, the rotary drum and the reactor systems of various designs (Gajalakshmi and Abbasi, 2008; Haug, 1980). Furthermore, based on the supply of aeration to the composting system they are classified into two; the agitated and the static system. Normally in agitated system the compost materials are mechanically turned using large machines to supply air and to release inner temperature, which also includes mixing of the materials. Whereas in static systems, the compost heaps are made on a series of perforated tubes connected to a blower which is controlled manually or in timer basis to supply air into the system so the temperature is maintained within the system (Kayhanian et al., 1993). Major composting system is discussed below:

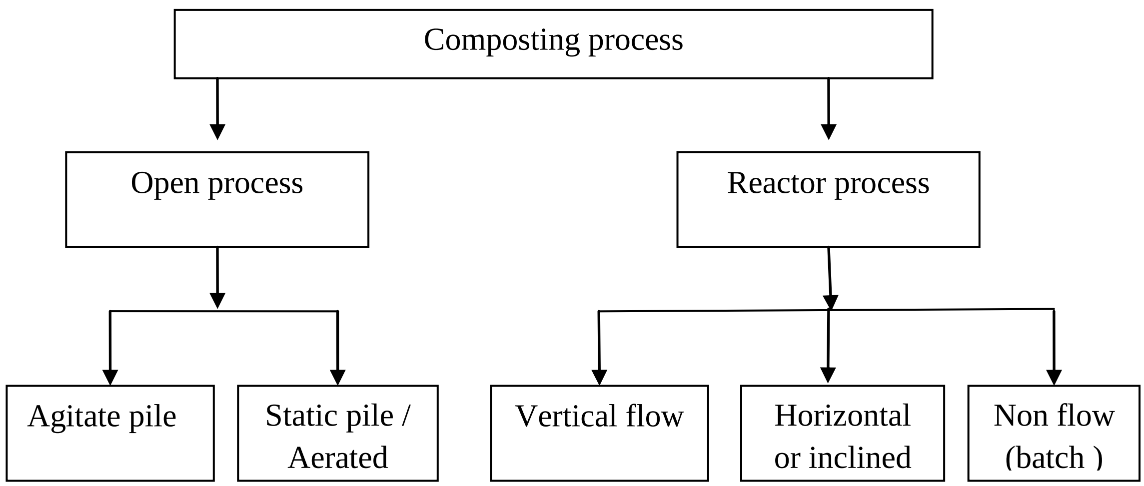


Fig. 3.2.Types of composting methods (Haug, 1980)

3.1.5. In-Vessel Composting

Rotary drum composters are one of the first types of In-vessel composting system design with engineering systems that are completely different from other conventional methods practiced earlier. A common feature of these types of system is that large amount of waste material can be decomposed within an enclosed space in shorter time under controlled process. Therefore, drum composting of vegetable waste is an efficient and promising technique with its decentralized processing of the material, as it provides agitation, aeration and uniform mixing of the compost material to produce a stabilized end product with high quality (Kalamdhad and Kazmi, 2009). In such systems aeration is optimized by various forced aeration and mechanical turning devices. Since the time of the composting is drastically reduced when compared with other composting methods, this methodology can be successfully used. There are many reports on the application of drum composting on vegetable waste in combination with many wastes such as cattle manure, tree leaves and saw dust (Tolvanen et al.,2005; Kalamdhad et al., 2008; Kalamdhad et al., 2009). A maximum of 70% reduction in the volume of the input can be achieved in vessel composting process of household wastes with high quality when compared to other reactors tested. The final compost can also be used as a soil conditioner by improving the quality of the soil and supplying basic nutrients to the plants (Iyengar and Bhave, 2006). Drum provides complete mixing of the material for better degradation organic matter as reported by many authors. There is always a major concern on C/N ratio of the material being added to the compost and this C/N ratio plays crucial part in the compost. Since the composting is fully dependent on microbial activity, if there is any improper supply of carbon and nitrogen sources it will greatly affect the quality of the end product.

Aerated Static Pile	Windrow	In vessel
Highly affected by weather (can be lessened by covering, but at increased cost)	Highly affected by weather (can be lessened by covering, but at increased cost)	Only slightly affected by weather
Extensive operating history both small and large scale	Proven technology on small scale	Relatively short operating history compared to other methods
Large volume of bulking agent required, leading to large volume of material to(including final distribution)	Large volume of bulking required, leading to large volume of material to(including final distribution)	High biosolids to bulking agent ratio so less volume of material to handle at handle
Adaptable to changes in biosolids and bulking agent characteristics	Adaptable to changes in biosolids and bulking agent characteristics	Sensitive to changes in characteristics of biosolids Wide-ranging capital cost
Wide-ranging capital cost	Low capital costs	High capital costs
Moderate labour requirements	Labour intensive	Not labour intensive
Large land area required	Large land area required	Small land area adequate
Large volumes of air to be treated for odour control	High potential for odour generation during turning; difficult to capture/contain air for treatment.	Small volume of process air that is more easily captured for treatment
Moderately dependent on mechanical equipment	Minimally dependent on mechanical equipment	Highly dependent on mechanical equipment
Moderate energy requirement	Low energy requirements	Moderate energy requirement

Table 3.1 Comparison of composting methods

3.1.6. Micro- organism in compost

Within a compost pile a variety of microbial populations develops in response to the different levels of temperature, moisture, oxygen and pH this microbial diversity enables the composting process to continue despite the constantly changing environmental and nutritional conditions within the pile. The microorganism responsible for composting degrades a broad range of compounds from the simplest form of sugars to complex persistent compounds. Temperature levels and available food supply generally have the greatest influence in determining what class and species of organisms make up the microbial population at a particular time.

Decomposition proceeds rapidly in the initial stages of composting because of the abundant supply of readily degraded material.The material are characterized by a low molecular weight and a simple chemical structure. It is water soluble and can metabolize by a broad range of non specialized organisms. As the readily degradable material is consumed and the supply diminishes, more complex, less degradable material begins to be decomposed. This material is characterized by a high molecular weight, and a polymeric (long chain) chemical structure that cannot pass directly into the cells. The material must be broken down into smaller components through the action of extracellular enzymes. Not all of the microorganisms present in the compost pile can produce these enzymes, particularly simple organisms, such as bacteria. Such decomposition requires more specialized organisms, such as fungi. After the polymeric material is hydrolyzed into smaller components by these specialized organisms, the resulting fragments can then be used by the non specialized organisms. Microorganisms that are present in a compost pile are in three major classes: bacteria, fungi and actinomycetes.The microorganisms within a compost pile can be psychrophilic, mesophilic , or thermophilic depending on the temperature range within which they experiences optimal growth rates. The psychrophilic temperature range is defined as being below 50 ^{0}F, mesophilic between 50 ^{0}F and 105 ^{0} F and thermophilic between 105 ^{0} F and 160 ^{0} F.

Bacteria

Bacteria are small, simple organisms present primarily during the early stages of composting period. They are responsible for much of the initial decomposition and include a wide range of organisms that can survive in many different environmental conditions. Although they are small relative to fungi and actinomycetes, they are present in significantly greater numbers. Bacteria are fast decomposers. Bacteria function optimally within a pH range of 6-7.5 and are less tolerant of low moisture conditions than other types of microorganisms. Some bacteria form endospores that enable them to withstand unfavourable environmental conditions, such as high temperature or low moisture. When the environment becomes active again, this feature of certain bacteria helps to continue the composting process during the cooling phase that follows peak thermophilic temperatures. They may also utilize more complex materials, or may exploit substances released from the less degradable materials due to the extracellular enzymes activities of other organisms. Among bacteria that occur commonly in aerobically decomposing substrate are species of *bacillus*, *cellulomonas*, *pseudomonas*, and *klebsiella,* while clostridium occurs substantially in aerobic conditions. Typical bacteria of the thermophilic phase are species of bacillus, for examples, *subtitles , B. licheniformis and B. circulans*.Many thermophilic as high as 65 ^{0} C and even 82 ^{0} C .Nitrosomonas spp.and Nitrobacteria spp. are the ammonium oxidizing and nitrite oxiding bacteria, respectively, present in the compost heap. Establishment of a large population of denitrifying bacteria suggests that some anaerobic microhabitat exists within the compost piles. These microhabitats could have been developed within the piles partially due to the initial high water content (65%) of the piles and partially because of the rich contents of organic matter and nitrogen present in the substrate, which promote microbial activity to the extent of causing depletion in the O_2content in isolated pockets within the piles. Some microbial genera capable of denitrification are *bacillus, flavobacterium* and *pseudomonas*. Mesophilic microorganisms are partially killed or poorly active during the thermogenic stage (40-60^{0} C).The diversity decreased as temperature increased, with a shift from *Pseudomonas*. Mesophilic microorganisms are partially killed or poorly active during the thermogenic stage 40 ^{0} C to 60^{0} C). The diversity increased as temperature increased, with a shift from *Pseudomonas, achromobacter, flavour bacterium, micrococcus* and *bacillus* to being dominated by *Bacillus*. Bacteria related to *B.schlegelii,* Hydrogen bacteria spp. and particularly to the genus *Thermus (Th.thermophilus, Th. Aquaticus)* apper to be the main active microbes in hot compost (65^{0} C-80 ^{0} C). Bacterial survival in high temperature composting material is possible through the formation of microcolonies. Mesophiles are likely to contribute little to compost degradation at these temperatures. Microbial fermentation of carbohydrates generally results in an increase in acidity. *Clostridium* species commonly ferment glucose to yield butyl and ethyl alcohols and certain acids. *Lactobacillus* lactic yields almost entirely lactic acid, while *Lactobacillus bevies* yield lactic acid and acetic acids, ethyl alcohol and carbon dioxide.

Fungi

Fungi are members of a large group of eukaryotic organisms and are larger organisms than bacteria. They form network of individual cells in strands called filaments. Fungi tend to be present in the later stages of composting because of the nature of the material they decompose.

Fungi are less sensitive than bacteria to environments with low moisture and pH, but because most fungi are obligate aerobes (requiring oxygen to grow), they have a lower tolerance for low-oxygen environments than bacteria.Most fungi are eliminated by high temperatures, but they are commonly recover when temperatures are moderate and the remaining substrates are predominantly cellulose or lignin. Considering that fungi cannot survive in temperatures greater than 140^0 C and that they are responsible for much of the decay of resistant material indicates that excessive temperatures are detrimental to the composting process in terms of complete degradation. While, high temperature levels are desirable for pathogen destruction, they must be controlled to reduce the destruction of beneficial organisms and their subsequent effect on the completion of decomposition. The most commonly observed species of celluloytic fungi in composting materials are *Aspergillus, Penicillium, Rhizopus, Fusarium, Chaetomonium, Trichoderma, Alternaria, and Cladiosporium*. Some of the species of *Paecilomyces* and *sporotrichum* have also been identified as efficient degraders of lignocelluloses wastes. White rot fungi are known to be the most efficient legalism with this activity and it is often used as a reference. Among other well – known white rot fungi, *coriolus vesicular* show even higher efficiency and a wider range of lignolytic activity. *Phanerochate flavidoalba* causes preferential loss of lignin rather than of cellulose and it is more efficient than *Ph.chrysosporium* on paper mill effluents. The most important among these are white – rot fungi belonging to basidiomycetes. Species of *Polyporus, Pleurotus,Collybia, Poria, Fomes,Trametes,Sporotrichum,Cyathus* ,and *Coriolus* have also been found to degrade lignin .Other important factors are sources of C and N and the pH. During composting, temperatures above 55^0 C discourage fungal growth .Fungi are excluded during the earlier high temperature stage of the composting process. A moderately high level of nitrogen is needed for fungal growth, although some fungi, mainly wood –rotting fungi, grow at low nitrogen levels. Indeed, a low nutrient nitrogen level is often a prerequisite for lignin degradation. However, low nutrient nitrogen is a rate limiting factor for the degradation of cellulose. Most fungi prefer an acidic environment but tolerate a wide range of pH, with the exception of the basidiomycotina, which donor grows well above pH 7.5. The majority of the fungi are mesophill,which grow between 5^0 C, within optimum temperature of 25-35 ^{0} C.However, in the compost environment the relative temperature means that the small group of thermopile fungi is an important biodegradation agent.Thermophilic fungi that have been found growing in lignocelluloses substrate or compost are *Taloromycetes emersoni, Ta.thermophilus,Thermoascus aurenticus,* and *Thermomyces lanuginosus*.However a few basidiomycotina grow well at elevated temperatures.*Phanerochaete chyrsoporium (sporotrichum pulverulentum)* is a white-rot fungus within optimum temperature of 36 -40 ^{0} C and maximum temperature of 46-49 ^{0}C.

Actinomycetes

Actinomycetes are the third major class of organisms that play a major role in composting.Actinomycetes are technically bacteria because of their structure and size, but are similar to fungi in that they form filaments and are able to use a variety of substrates.Actinomycetes can degrade organic acids, sugars ,starches, hemicelluloses, celluloses, proteins, polypeptides, amino acids, and eve complex compounds such as lignins.They also produce extracellular proteases and can lyses other bacteria. Actinomycetes are more prevalent in the later stages of composting when most of the easily degradable compounds have been degraded, the moisture levels have decreased and the pH has become less acidic.They are primarily strict aerobic saprophytes and are common in many environments. Their ubiquity is a result of their ability to utilize a wide range of carbon sources and to speculate prolifically. Actinomycetes colonize more slowly than bacteria and fungi.

Colonization is minimal in areas that are poorly aerated. They also appear during the thermopile phase as well as during the cooling and maturation phase of composting can occasionally become so numerous that they are visible as a white film on the surface of the compost. The genera of the thermopile actinomycetes isolated from compost include Nocardia, Streptomycin, Thermoactinomyces and Micromonospora. Actinomycetes are able to degrade some cellulose and solubilise lignin and they tolerate higher temperatures and Ph than do fungi, the actinomycetes are thus well placed to exploit the compost environment as the piles in the immediate post peak heat phase. During the cooling stage of composting, actinomycetes actively degrade hemicelluloses in the compost with an optimum growth between 25-30 ^{0}C and pH of 5-9, this microorganism of most significant group of microbes in the degradation of relatively complex, recalcitrant polymers. As actinomycetes develop more slowly than most bacteria or fungi, they are infective competitors when nutrient level are high, but become more competative as nutrient level decreases. Actinomycetes thermopiles, Streptomyces and Micromonaspora spp. are common in compost. Although optimum growth temperatures fall in the mesospheric range, obligate thermopiles such as Thermoactinomycetes and Saccharomonospora spp. have been isolated. Certain species of actinomycetes are more tolerant of high temperatures, becoming increasingly active as temperatures approach to 60 ^{0} C.

Higher Organisms

Higher organisms begin to invade the compost pile once the pile temperatures cool to suitable levels. These organisms include protozoa, rotifers and nematodes. They consume the bacterial and fungal biomass and aid in the degradation of complex compounds. These higher organisms contribute to the disease suppressive qualities of compost.

3.1.7. Pathogens in composting

One of the aspects of composting that makes it an attractive alternative to the direct application of untreated manure is the high degree of pathogen destruction that is possible with a well – managed composting operation The pathogen content of the compost is important because improperly treated compost can be a source of pathogens to the environment and, as such, a threat to humans and animals .This depends on the on the type of pathogen involved. The type and quantity of pathogens in the initial compost mix are dependent on the waste that is being composted. Animal pathogens are in manure and on plant residue that has come into contact with any manure. Plant pathogens are in plant residue. Pathogenic microorganisms that may be in compost include bacteria, viruses, fungi and parasites. Although parasites and viruses cannot reproduce apart from their host, they can often survive for extended periods .If they are not killed during the composting process , they can survive until the compost is land applied. At that time, they may infect a new host. Pathogenic bacteria fungi must be killed in mature compost. Conditions unfavourable to pathogenic growth include a lack of assailable organic matter and a pile with moisture content of less than 30%.As such condition are difficult to achieve in mature compost, as many pathogens as possible should be destroyed during the composting process. Pathogens can be destroyed by heat, competition, destruction of nutrients, antibiosis and time. Antibiosis is the process by which a microorganism releases a substance that, in low concentrations, either interferes with the growth of other microbes or kills it. Most pathogen donot grow at the optimum temperatures for composting. As such, exposure to high temperature kills them. The few exceptions to this are among fungal plant pathogens.Some of these pathogens can withstand.

Most pathogen originating from animal cannot survive above the 130 ^{0}-160 ^{0}F temperature range. Pathogens can also be destroyed as a result of competition with the indigenous microbial population for nutrient and space. Pathogens are at a disadvantage because they are not as well adapted to the environment as the indigenous population and their numbers are insignificant relative to the indigenous population. Pathogens must compete with the indigenous Microorganisms for site of attachment on the waste particles. Nutrient requirements of pathogenic microorganisms are specific. If their key nutrients are used by competing indigenous microbial population, then the pathogens are deprived of nutrients, and they will die. Good pathogen destruction is possible with the various composting methods if the windrows or piles are managed correctly. The two essential elements in achieving good pathogen destruction are:-

: All of the material must be exposed to lethal conditions either simultaneously or successively.

: The exposure must be last for a sufficient amount of time to maximize its effectiveness.

Pathogens are killed through the process of turning .During turning the innermost layers that have highest temperature levels and greatest degree of pathogen destruction is exchanged. The outermost layers that have not been exposed to the lethal conditions are then allowed to reheat so that all material within the pile is exposed to the lethal temperature conditions. In reality, however, the outermost layer is decontaminated with pathogens from the outermost layer. To counteract the effects of recontamination and ensure complete pathogen destruction, either the frequency of turning or the duration of active composting must be increased.

3.1.8. Factor influencing composting process

A given nutrient in waste can be utilized only if it available to active microbes. Availability may be chemical and physical. A nutrient is chemically available to microbes if it is a part of a molecule that is vulnerable to attack by the microbes. Usually, breakdown of compounds or nutrients is accomplished enzymatic ally by microbes that either possess the necessary enzyme or can synthesize it. Physical availability is interpreted in terms of accessibility to microbes. Accessibility is a function of the ratio of mass or volume to surface area of a waste particle, which in turn is determined by particle size. Factors which influencing composting are divided into two major group that is, nutrient factors and environmental factors.

3.1.8.1. Nutrient factors influencing composting process

Macronutrients and Micronutrients- Nutrients can be grouped into the categories “macronutrient” and “micronutrients.” The macronutrients include carbon (C), nitrogen (N), phosphorus (P), calcium (Ca) , potassium(K). However, the required amount of Ca and K are much less than those of C,N and P. As they are required only in trace amounts, hence they are frequently referred to as the “essential trace elements.”If their concentrations are above a trace they become toxic for organisms. Among the essential trace elements are magnesium (Mg), manganese (Mn),cobalt(Co),iron(Fe), and sulphur(S).Most trace elements have a role in cellular metabolism. The substrate is the source of the essential macronutrients and micronutrients. Although an element of uncertainty exists, economic reality dictates that waste constitutes most or all of the substrate in compost practice. Any uncertainty is due to variation in the availability of some nutrients to the microbes. Variation in availability, in turn, arises from differences in the resistance of certain organic molecule to microbial attack. Variations in resistance lead to variations in the rate at which the process advances. Examples of resistant materials are lignin (wood), chitin, several forms of cellulose, chlorinated hydrocarbons, and many other persistent compounds.

Carbon -to-Nitrogen ratio (C: N)

The carbon-to-nitrogen ratio(C:N) is a major nutrient factor. Based on the relative demands for carbon and nitrogen in cellular processes, the theoretical ratio is 25:1. The ratio is weighted in favour of carbon, because the use of carbon outnumbers those for nitrogen in microbial metabolism and the synthesis of cellular materials. Thus, not only is carbon utilized in cell wall or membrane formation, protoplasm and strong products synthesis, an appreciable amount is oxidized to CO_2 in metabolic activities. On the other hand, nitrogen has only one major use as a nutrient, an essential constituent of protoplasm. In compost practice, it is in the order of 20:1 to25:1.The general experience is that the rate of decomposition declines when the C:N exceeds that range. On the other hand, nitrogen probably will be lost at ratios lower than 20:1. The loss could be due to the conversion of the surplus nitrogen into ammonia-N. The high temperatures and Ph levels characteristic of composting during the active stage could include the volatilization of the ammonia. In a developing country, an unfavourably high C:N can be lowered by adding a chemical nitrogenous waste to the compost feedstock. If economics permit, it also can be lowered by adding a chemical nitrogen fertilizer, such as urea or ammonium sulphate. Conversely, a carbonaceous waste can be used to elevate a low C: N.

The relative proportion of carbon and nitrogen is a major controlling factor in composting process. Carbon serves primarily as an energy source for the microorganisms, while a small fraction of the carbon is incorporated to the microbial cell. Nitrogen is critical for microbial population growth, as it is a constituent of protein that forms over 50% dry bacterial cell massif nitrogen is limited, microbial populations will remain small and it will take longer to decompose the available carbon . Excess nitrogen, beyond the microbial requirements, is often lost from the system as ammonia gas .In the composting process , the substrate should achieve a C:N ratio of 30:1 for stimulating degradation and immobilization of nitrogen. A balanced carbon to nitrogen (C:N) ratio of 25:1-30:1is ideal for an active compost pile.C:N ratios of as low as 20:1 or as high as 40:1 also produce good quality finished compost.

If C:N<20:1

Excess nitrogen will let off gas into the atmosphere as NH_3 or N_2O, resulting in an undesirable odour

If C:N>40:1

Nitrogen mineralization generally occurs in two phases, a rapid exponential immobilization or mineralization phase, followed by a slow linear mineralization phase. Nitrogen mineralization is the process by which organic nitrogen is converted to the plant available inorganic form such as ammonium and nitrate. The C:N ratio of the substrate determines whether immobilization or mineralization will dominate in the early stages of composting. The rate of inorganic N release to the soil from composted manure depends on the rate of decomposition of the organic matter and on subsequent turnover of the decomposed C and N in the soil. Release of plant available N from manure in the soil is controlled by the balance of N immobilization and mineralization, which in turn is controlled, to a large extent, by the C:N ratio of the decomposing organic material. The decomposition rate (i.e., composting process) slows down.

3.1.8.2 Environmental Factors Influencing Composting

The principal environmental factors that affect the compost process are temperature, pH, moisture, and aeration .The rate and the extent of decomposition are proportional to the degree that each nutritional and environmental factor approaches optimum. A deficiency in any one factor would limit the rate and extent of composting, in other words, the deficient factor is a limiting factor.

Moisture

Moisture is one of the composting variables that affect microbial activities, as it provides a medium for the transport of dissolved nutrients required for the metabolic and physiological activities of microorganisms. It is essential for the decomposition process, as most of the decomposition occurs in the thin liquid films on the surfaces of the surfaces of particles. Moisture content of 60%-70% is generally considered ideal to start with. At later stages of decomposition, the ideal moisture content may be 50%-60%.Moisture management requires a balance between microbial activity and oxygen supply. Very low(<30%) or high moisture content (>75%) inhibits microbial activities due to early dehydration or anaerobiosis .Excess moisture will fill many of the pores between particles with water, thereby limiting oxygen transport. This in turn creates anaerobic conditions and brings about putrefaction, resulting in a disagreeable odour and undesirable products. On the other hand, if the composting substrate is supplied with insufficient water, the growth and proliferation of microbial microorganisms as well as the rate of decomposition of the organic material will slow down or even stop. It is important, therefore, to ensure adequate moisture in each layer of the compost heap.

Oxygen and Temperature

The decay process of pollutants present in industrial waste is also affected by oxygen and temperature. The temperature within the composting mask determines the rate at which many of the biological process takes place and plays a selective role in the development and the succession of the microbiological communities. Temperature and oxygen fluctuate in response to microbial activity, which consumes oxygen and generates heat. Both are linked by a common mechanism of control: aeration. Inadequate oxygen may lead to the growth of anaerobic microorganisms, which can produce odorous compounds. Usually , in an aerobic system, the temperature rises to50 ^{0}-60 ^{0}Celsius in just a few days and can even go up to 80 degree Celsius in some cases. If done correctly, a compost pile will heat to high temperature with in 24-48h. If it does not, the pile is too wet or too dry or there is not enough green material (or nitrogen) present. The high temperature rise in the compost pile destroys weed seeds, pathogenic microorganisms and worms and prevents fly breeding. This and the generation of antibiotics during composting drastically reduce pathogens in the final compost. A temperature in the range of 55^0-65^0 Celsius ensures destruction of pathogenic organisms. A temperature of 65 degree Celsius for at least 30 minutes is considered a critical threshold for plant pathogens. Human pathogens are also inactivated at high temperatures. The heat resistance of human pathogens increases markedly under dry conditions. Therefore, wet condition must prevail in the compost pile. The maximum temperature of the composting process reaches $60\ ^0$-$80\ ^0$Celsius , the temperature level where many microorganisms become less active. At the top of the pile, the temperature is slightly lower due to conductive heat loss from the top to the surrounding. Overtime, the temperature gradually drops as the degradation rate of organic matter becomes less . This course in composting will result in adequate stabilization of organic matter, drying of the compost, and killing of pathogens and weeds. Low temperature typically indicates low aerobic activity in the composting pile. Temperature alone is not a fool proof indicators of aerobic activity, as it is a result of heat production and heat removal. Lack of aerobic activity can only be confirmed by measuring the oxygen content within the compost bed. To attain temperatures high enough for heat activation throughout in compost, the vessel has to be insulated to retain the heat produced. High temperature combined with high exchange rates of the air will increase the ammonia losses. In a composting pile, however, the rate of degradation is a result of metabolic activity of a mixed microbial population that may originally include microorganisms with different temperature optima. These microorganisms adapt to the environmental temperature during composting and have a collective temperature optimum at which respiration from the microbial community is highest. Not only is microbial metabolism highly temperature dependent, but it also dramatically influences the population dynamics (e.g., composition and density) of microbes. Temperature increase with in composting materials is a function of initial temperature, metabolic heat evolution, and heat conservation. Indeed, temperatures of composting material below 20^0 Celsius have been demonstrated to significantly slow or even stop the composting process. Temperature in excess of $60\ ^0$ Celsius has also been shown to reduce the activity of the microbial community and above this temperature, microbial activity declines as the thermophilic optimum of microorganisms is surpassed. If the temperatures reach $82\ ^0$ Celsius, the microbial community is severely impeded.

Aeration

Aerobic organisms survive only in presence of air or O_2. Aeration is necessary in high temperature aerobic composting for rapid odour- free decomposition. Aeration is also useful in reducing high initial moisture content in composting materials. Several different aeration techniques can be used. Turning material is the most common method of aeration when composting is done in piles. Hand turning of the compost piles is most commonly used for small garden operations. Mechanical turning or static piles with a forced air system are most economical in large municipal or commercial operations. The most important consideration in turning compost, apart from aeration is to ensure that material on the outside of the pile is turned into the center where it will be subject to high temperatures. In hand turning with forks, this can be easily accomplished. For piles or windrows on top of the ground, material from the outer layers can be placed on the inside of the inside of the new pile . For static piles with a forced air system finished compost or a physical "cover" can be placed on the composting material, ensuring it reaches high temperatures uniformly. Volume reduces during the compost process.

pH

pH is another parameter that greatly affects the composting process. The range of pH values suitable for bacterial development is 6.0-7.5, while fungi prefer an environment in the range of pH 5.5-8.0. An intial phase characterized by a low pH is often observed during the composting of organic wastes and perhaps especially in the case of easily degradable energy – rich materials. This is due to the formation of carbon dioxide and Volatile Fatty Acids (VFAs).With the subsequent evolution of CO2 and utilization of VFAs, the pH begins to rise and may even reach values exceeding 8.0. Organic acids are produced during the decomposition of organic matter, but their existence is only transitory. Problems may arise if the material obtained undergoes putrefaction, as appreciable amounts of troublesome organic acids are produced during anaerobic decomposition and may produce malodor.However, a rise in pH beyond 7.5 could make the environment alkaline which may cause loss of nitrogen as ammonia. The growth of active microorganisms is inhibited by a temperature of above about 40 degree Celsius if short chain fatty acids and low pH are present. Microbial tolerance to thermophilic temperature is reduced by the combination of low pH and increasing concentrations of fatty acids. The optimum pH range for decomposition is between 6.5 and 8.5. The pH affects the potential for beneficial bacteria to colonize composts, below pH 5.0, bacterial biocontrol agents are inhibited. To curtail excessive ammonia loss, Hoitink and Kuter (1986) suggest that the pH should be below 7.4 in aerated composting systems. pH is an indicator of aeration levels within a composting pile . Well – aerated compost pile generally have a high pH, whereas pile with anaerobic conditions have decreased pH values. The decrease in pH during the initial period of composting is expected because of the acids formed during the metabolism of readily available carbohydrates.

Electrical conductivity

Generally, it is found that electrical conductivity (EC) increases during composting as VSs are degraded and the amount of water – soluble salts increases on a total solids (TS) basis. At lower pH values, negatively charged surface sites of organic matter are occupied by protons, which thus lowers action exchange capacity (CEC). A decrease in CEC results in a lower adsorption of actions to organic matter and thus an increase in EC (Chandra, 2016).

3.1.9. Compost stability/ maturity

The stability of compost can be defined as the degree to which the organic fractions in compost have been stabilized during the process. Compost is considered unstable if it contains a high proportion of biodegradable matter that may sustain high microbial activity. If the material contains mainly recalcitrant or humus-like matter, it is not able to sustain microbial activity and therefore, it is considered stable. Stability is an important aspect of composting in relation to its field application, potential of odour generation and pathogen regrowth (Zucconi et al.1985). Stability prevents nutrient mineralization in rapid microbial growth, allowing them to be available for plant needs. Unstable compost can show phototoxic behaviour and therefore affect crops. This is due to the occurrence of toxic substances produced due to an insufficient biodegradation of organic compounds. Additionally, the degree of stability attained within a certain time can be used for process performance monitoring and comparative evaluation of different composting systems (Lasaridi and Stentiford, 1998; Gomez et al.2006). Therefore, it is essential to prove the stability of compost to ensure about the technology and operational performance. Different methods for measuring stability based on physical (temperature, aeration demand, odor and color, optical density of water extracts), chemical (volatile solids, C/N ratio, COD, polysaccharides, humic substances, etc.) and biological (respiration measured either as O_2 consumption, CO_2 production or heat generation, enzyme activities, ATP content, seed germination and plant growth, etc.) characteristics of composts have been proposed, but none has found universal acceptance (Lasaridi and Stentiford, 1998). Respirometric techniques are well suited for compost stability measurement. Respiration tests include both CO_2 production (Naganawa et al., 1990) and OUR (Palestki and Young, 1995). These are the most accepted methods for the determination of the biological activity of a material (Adani et al., 2001; and Iannotti et al., 1993). Respirometric techniques provide accurate information about the activity of a compost sample. A large number of methods are also available for determination of CO_2 evolution (Fibre-Optic Fluoro-Sensors, Amperometric, Conduct metric, Potentiometric sensors, NaOH and KOH absorption). Their main disadvantage is that they need more specific instrumentation and more skilled labour. Furthermore, the equipment needs constant maintenance and frequent calibration. Generally, a composted product should contain a low organic content that will not undergo further fermentation when discharge on land and the pathogens should be inactivated. Some of the approaches to measure the degree of compost stabilization are:

- Temperature decline at the end of the composting.
- Decrease in organic content of the compost as measured by the volatile solids content, chemical oxygen demand, percentage carbon or ash content and C/N ratio.
- Presence of particular constituents i.e. nitrate and the absence of ammonia.
- Lack of attraction of insects or development of insects larvae in the final product.
- Absence of obnoxious odor.

- Presence of white or grey color due to the growth of actinomycetes.
- In cases where the composted products are to be applied to crops and where public health aspects are of concern, the time required for pathogen die-offs during composting is another important criterion to be considered.

3.1.10. Organic matter transformation during composting

The use of compost in agriculture as soil amendment is one of the practices for the sustainable management of soils and it also contributes to recycling organic residues. Composting of biological material generally means a full or a partial mineralization of organic compounds by producing CO_2, H_2O, NH_3, or NO_3, sulphates and carbonates of Ca, Mg and K, oxides of Fe and Mn, and phosphates. Some of these mineralization products get lost from the composting biomass as gaseous compounds (CO_2, H_2O, NH_3), some as solutes with the drainage water and some remain as precipitated or adsorbed compounds in the final compost product (Saad, 2002). A small metabolic sideway of all composting processes, even under strongly oxidative conditions allow the decaying of biological masses to the formation of fulvic and humic substances. These are able either to mummify decaying organic tissues or to become strongly precipitated as hamates on the surface of clay particles (mull-formation). In both cases these relatively stable or even inert by-products create the dark, blackish grey color of all composts.

Approximately 50% of the added organic matter becomes fully mineralized, mostly due to the degradation of easily degradable compounds such as proteins, cellulose and hemi-cellulose, which are utilized by microorganisms as C and N sources. The residual organic matter contains newly formed macromolecules along with nondegradable organic matter jointly forming the humic-like substance, the most stable fraction of the mature compost (Chefetz et al., 2010). Organic matter is decomposed for the most part of the soil micro-flora, although slight decomposition occurs even under biotic or photochemical conditions . In aerobic condition, there is a great diversity of decomposers, consisting of fungi, actinomycetes and a wide range of bacteria, which degrade the readily available organic components or transform them into stable humic components. It is reasonable to expect that the humification and transformation process might differ depending upon raw materials used for composting. Humic substances constitute the most important fraction of organic matter because of their effect on soil ecology, structure, fertility and plant growth. Many tests have been proposed to assess the biodegradation and humification of organic matter resulting in compost maturity and stability.

Changes in compost stability or the degree to which the composts have been decomposed can be predicted with C/N ratio in the solid phase soluble organic carbon content in water extract (Inbar et al., 1994), humification indices (Chefetz et al., 2010), oxygen and CO_2 respirometry, plant growth bioassay, NMR and IR spectroscopy (Chen et al., 2010). Several studies have investigated organic matter transformation during composting of municipal solid waste, municipal sewage sludge and separated cattle manure using chemical, spectroscopic and microbiological methods (Adani et al., 2001; Jouraiphy et al., 2005).

Lignocelluloses degradation during composting of agricultural waste (Vegetable waste, cow dung, saw dust and dry leaves) plays an important role during the process as it contributes to the major organic matter (Tuomela et al., 2000; Zeng et al., 2010; Feng et al., 2011). Lignin is considered as the most abundant renewable source on earth and it is very difficult to degrade, as it slows down the degradation of cellulose and hemicelluloses (Huang et al., 2010). Huang et al. (2010) had reported that lignin as the most abundant renewable source on earth and its difficulties during degradation process. It has been estimated that there is $2.5\text{-}4\times10^{11}$ tonnes of cellulose and $2\text{-}3\times10^{11}$ tonnes of lignin in the earth, representing 40 and 30% of organic matter carbon respectively (Fengel and Wegener, 1989; Argyropoulos and Menachem, 1997). The balance of the global carbon cycle is maintained by the photosynthesis and degradation of these lignocellulosic fractions. Temperature, moisture content and type of lignocellulose majorly govern the degradation rate (Rayner and Boddy, 1988). During composting, transformation and mineralization of organic matter is carried out by many microbial communities such as bacteria, fungi and actinomycetes (Zucconi et al., 1987). However, these microbial communities are greatly affected by the varying temperature during the process and physical properties of initial waste material.

3.2. Changes in compost parameters during composting process

Shyamala and Belagali (2014) studied the effects to investigate the prevailing seasonal changes of physico-chemical and microbial community for mesophilic bacteria and fungi at different degradations stages of municipal solid wastes. The samples were collected from Excel plant (Vidyaranyapuram, Mysore) in different depths of pile during summer, rainy and autumn seasons in the year of 2011 to 2012 at once in 10 days intervals up to 60 days. Temperature and pH were measured by using standard method. The microbial analysis was done by serial dilution method and bacterial growth Nutrient agar (NA) and Czapek Dox Agar (CDA) for fungi enumeration. The pure cultures of the bacterial isolates were subjected to various morphological and biochemical characterization tests like, Catalase Test (CAT), Oxidase Test (OXT), In dole Test (INT), Methyl Red Test (MRT), Voges-Proskauer Test (VPT), Citrate Utilization Test (CUT), Urease Test (URT), Nitrate Reduction Test (NRT), Hydrogen Sulphide Production (H_2S), Starch Hydrolysis Test (SHT) and Gelatine Hydrolysis Test (GHT) to determine the identity of the bacteria isolates. The results reveal that, the temperature of the windrows in all seasons reached maximum after 4 weeks of composting and then decreased by the end of the composting period (60 days). Marked changes in pH values of the composts in all seasons during degradation stages were found, but final stages shows the pH was at neutral except rainy season (60 days old compost sample with 8.7).The microbial populations were significant increase during initial stages of composting process and final stages pathogenic microbes was reduced, for all the three seasons. The *Bacillus* Sp., *Pseudomonas* and *Asprigillus* Sp., was dominate species during composting process. From the present investigation, it can be concluded that, the summer and autumn season’s microbial activities faster because the favorable environmental conditions for supporting the proper wastes degradation, therefore, these two seasons for obtained better quality of compost than rainy season.

Indumathi (2017) studied the effect to carried out to screen the soil borne bacteria from decomposing vegetables and fruits. The collected samples were subjected to total microbial count, Standard plate count, Coliform count and Biochemical tests to identify the bacteria present in it. Bacillus sp. and Pseudomonas sp. dominantly found in the sample were identified and confirmed by their morphological and biochemical characters. The isolates were sub cultured and involved in composting process. The physical and biochemical activities occurred during 50 days of composting period were analyzed. The moisture content, pH, Electrical conductivity, energy sources such as Carbon, Nitrogen, Phosphorous, Potassium content and C: N of the compost prepared using bacterial cultures were compared with that of the control. An experimental study was also conducted to find out the effect of compost on germination, root length and shoot length of green gram plant. Towards the end the positive outcome substantiated that microbial biotechnology was a powerful tool for the decomposition of kitchen waste into a value added material.

Nandan et al. (2017) studied the effect to current status of municipal solid waste management in different regions of India. It further summarizes a collective, systematic effort which improves implementation of legal frameworks, institutional arrangements, financial provisions, technology, operations management, human resource development, and public participation and awareness of Integrated SWM systems .

Islam et al. (2016) studied to determine the performance of vermicompost and conventional aerobic compost produced from municipal organic solid waste used in *Amaranthus viridis* production during the period from October 2014 to June 2015 at the Horticulture Research Centre of the Bangladesh Agriculture Research Institute, Gazipur, Bangladesh. In this study, three compost varieties (vermicompost, conventional aerobic compost, combination of vermicompost and conventional compost) and three levels of compost treatments (0, 100 and 150 g/m^2) with three replications were applied. The plots were arranged in randomized complete block design. Vermicompost was prepared by using *Eisenia fetida*. Different composts (vermicompost and conventional aerobic compost) and plant sample were taken first for chemical and physical analysis to find out the effect of these composts on the growth of amaranth. The result of the study showed that different compost varieties significantly affected the chlorophyll content, dry matter content, height per plant, numbers of leaves, weight per plant, nitrogen, calcium, magnesium, potassium, total phosphorus positively in favour of vermicompost application and sulphur content, sodium, moisture content in conventional aerobic compost application. Vermicompost application showed higher result for growth and yield indices and nutrient content compared with conventional aerobic compost.

Agarwal et al. (2015) studied the effect to the current practices related to the various waste management initiatives taken in India for human wellbeing. The other purpose was to provide some suggestions and recommendations to improve the waste management practices in Indian towns. This study was based on secondary research. Existing reports related to waste management and recommendations of planners/NGOs/consultants/government accountability agencies/key industry experts/ for improving the system are studied. It offers deep knowledge about the various waste management initiatives in India and find out the scope for improvement in the management of waste for the welfare of the society.

Pathak et al. (2012) studied the effects of four consecutive years to assess the potential and possibilities of MSW (Viz. KW) composting generated from Jhansi city, Uttar Pradesh. In the present study, they studied physico-chemical parameters and succession of microbial populations during composting process of MSW (Viz. KW) and found that the pH ranged between 7.1-7.9, Temperature 14-65.2°C, Organic Carbon 20-26 %, moisture content 22-66.7 %, nutrients N – 1.16 %, P – 0.04 %, K – 0.34%, Na – 2.89 % and microbial colonies like Bacteria, fungi, and Actinomycetes were also present in large numbers. Temperature plays an important role in the growth of microbial colonies during composting of Municipal Solid waste (Viz. Kitchen Waste).

Nath et al., (2009) did a study on the effects of India million tons of livestock excreta, agro and kitchen wastes are produced every year which are serious problems for society. This work to evaluate the potential of an epigeic earthworm Eisenia foetida to convert the different combination of variety of wastes in to rich nutrient vermicomposts/vermiwash and pre and post chemical analysis of feed mixtures. Vermicomposting results in significant decreased in pH, Total organic carbon (TOC), electrical conductivity (EC) and C:N ratio while significant increase in Total Kjeldohl nitrogen (TKN) available phosphorus, exchangeable potassium and calcium in vermicomposts/vermiwash. The increased level of plant nutrients in final products in different organic resources demonstrated that the vermicompost/vermiwash of these wastes will be a valuable biofertilizer for sustainable land restoration practices. This study clearly indicates that vermicomposting of animal, agro/kitchen wastes not only produced a valuable vermicompost/vermiwash but also increased level of plant growth supplements in final vermicompost.

Ryckeboer et al. (2003) studied the effects to determine the microbial succession of the dominating taxonomic and functional groups of microorganisms and the total microbial activity during the composting of biowaste in a monitored process. For this process, Biowaste (vegetable, fruit and garden waste) was composted in a monitored composting bin system. During the process, taxonomic and functional subpopulations of microorganisms were enumerated, and dominating colonies were isolated and identified. All counts decreased during the thermophilic phase of the composting, but increased again when the temperature declined. Total microbial activity, measured with an enzyme activity assay, decreased during the thermophilic phase, increased substantially thereafter, and decreased again during maturation. Bacteria dominated during the thermophilic phase while fungi, streptomycetes and yeasts were below the detection limit. Different bacterial populations were found in the thermophilic and mesophilic phases. In fresh wastes and during the peak-heating phase, all bacterial isolates were bacilli. During the cooling and maturation phase the bacterial diversity increased, including also other Gram-positive and Gram-negative bacteria. Among the fungi, Aspergillus spp. and Mucor spp. were predominant after the thermophilic phase.

Nilay et al. (2014) studied to assess the quality of the vermicompost and farmyard manure in terms of total nutrient content and microbial population count following inoculation of various microbial cultures. *Azotobacter, Azospirillum* and phosphate solubilizing bacteria (PSB) culture @ 0.2 % each was inoculated in different consortia to farmyard manure (FYM) or vermicompost and incubated for thirty days in a completely randomized design laboratory experiment maintaining moisture content at about 25±1 % (w/w). The population of *Azotobacter, Azospirillum and PSB* significantly increased in the composts by about 35 to 133% during the 30 days incubation period with different consortia. The C: N ratio reduced significantly in FYM and vermicompost after 30 days incubation due to significant decrease in total carbon content. The content of total N, P and K was not affected in vermicompost at 30 days after inoculation of microbial culture, but the same in FYM decreased significantly barring few occasions.

Bera et al. (2013) studied about Maud tea estate (Maud T.E.) in Assam, India was aimed at comparative evaluation of different available and practiced composting methods viz. Vermi, Indigenous, biodynamic and Novcom composting in terms of their end product/ compost quality as well as respective cost. Study revealed that comparable values were obtained for all types of compost in terms of physical properties, organic carbon, C: N ratio, stability, maturity and phytotoxicity status. However, compost produced under Novcom composting method showed better results in terms of total NPK content (i.e. nutritional content) and microbial population was significantly higher than the values obtained for rest other types of studied compost. Compost Quality Index (CQI) was formulated (using four specific compost quality parameters viz. total nutrient content, C/N ratio, microbial potential and germination percent) to classify the quality of different types of compost as good, moderate, poor etc. for easy understanding at the users' level. Study of convenience factor and cost of production also indicated comparatively higher potential of Novcom composting method.

He et al. (2011) studied to make good experiment effect, kitchen waste temperature rising rate should be at least 20°C / min.Taking in account experiment effect and experiment energy consumption, a pyrolysising technology is designed to change the kitchen waste's temperature rising rate in phases. At last, a set of mechanical equipment is designed to solve kitchen waste problem efficiently as well as produce bio-oil and other chemical raw materials. The result of prototype experiment shows the feasibility of the kitchen waste disposal equipment and technology.

Dexun et al. (2010) studied and found that the emissions rate of CO_2 at the beginning of compost was relatively stable, and then two peaks appeared, after that emissions rate decreased. The emission of NH_3increased along with compost process, reached its peak in the middle and later period of compost, and then declined in the end. In addition, compared with the stalks, spent mushroom could be regarded as a better conditioner for kitchen waste compost in controlling the emission of NH $_3$. In this paper, NH $_3$ and CO_2 release during Kitchen waste composting in controlled temperature condition were analyzed and the following conclusion was drawn. The CO_2 release in the initial phase of composting for these two treatments were gentler, the first release peak appeared in 6day, then gradually reduced. The second peak appeared in 12day, this might be caused by the degradation of different organic matters. The NH $_3$ emission during the composting for these two treatments was almost the same: the NH_3release was comparatively little in the initial stage of composting, and then increased gradually to the peak with the time prolonged, after that the trends began to decline. The NH $_3$release in this experiment for both treatments was mainly on 7-12day, this phase was the release peak for NH $_3$ and could be regarded as the critical period for controlling NH $_3$ release.

Li et al. (2013) studied about the Composting has been used as a method to dispose food waste (FW) and recycle organic matter to improve soil structure and fertility. Considering the significance of composting in FW treatment, many researchers have paid their attention on how to improve FW composting efficiency, reduce operating cost, and mitigate the associated environmental damage. This review focuses on the overall studies of FW composting, not only various parameters significantly affecting the processes and final results, but also a number of simulation approaches that are greatly instrumental in well understanding the process mechanism and/or results prediction. Implications of many key ingredients on FW composting performance also discussed. Perspects of effective laboratory experiments and computer-based simulation are finally investigated, demonstrating many demanding areas for enhanced research efforts, which include the screening of multi-functional additives, volatile organiccompound emission control, necessity of modeling and post-modeling analysis, and usefulness of developing more conjunctive .

Warman et al. (1999) studied the effects of Experiments involved the comparison of three procedures used to determine compost maturity I phytotoxicity. The three tests evaluated were the CCME germination test , a modified Zucconi et al. (1981) extract and a direct seed procedure. Three different plant species and seven types of 'composts' were used.

The species were cress *(Lepidium sativum)*, radish *(Raphanus sativus)*, and chinese cabbage *(Brassica chinensis).* Germination and growth experiments were performed on three types of mature composts: 1) racetrack manure-food waste; 2) two different samples of municipal solid waste; and 3) racetrack manure-sewage sludge), two types of immature composts (farmyard manure-food waste and farmyard manure-yard waste-food waste], and a control (soil or water). Four replicates for each species, 'compost' and test procedure were evaluated. The study concluded that the commonly used compost extract test and the compost-soil germination and growth tests were not sensitive enough to detect differences between mature and immature 'composts', that other test(s) must be used to evaluate compost maturity.

Krogmann et al. (1999) studied on the effects of a German federal law, enacted in 1993, requires that biogenic wastes be source-separated for re-use in most circumstances. This has resulted in the collection of over 4 million metric tons of biogenic waste per year, most of which is composted. The purpose of this study was to examine the potential to control and to optimize the chemical and physical properties of biogenic waste composts from suburban and urban communities during different seasons. Therefore, the composition of the biogenic waste stream in the City of Hamburg, Germany was determined and the chemical and physical properties of the resulting composts were analysed. The most dramatic differences were found for trace metals, especially in urban areas. Although some trace metals cannot be avoided, careful analysis of typical waste stream fractions can permit moderation of end-product contamination levels.

Tiquia et al. (1996) Studied the effects of the phytotoxicity of spent pig-manure sawdust litter (spent litter) was evaluated during cornposting. Aqueous extracts of the spent litter were prepared by shaking the sample with water (1:10 w/v), and the toxicity of these extracts was determined on relative seed germination, relative root elongation and germination index (GI, a factor of relative seed germination and relative root elongation). The sensitivity of six plant species, namely *Brassica parachinensis* (Chinese cabbage), *Brassica albogalera* (Chinese kale), *Allium sativum* (onion), *Cucumis sativus* (cucumber), *Amaranthus espinosus* (Chinese spinach), and *Lycopersicon esculentum* (tomato) were compared. The effect of defferernt moisture levels during camposting on the phytotoxicity of the spent litter was also examined. Phytotoxicity of the spent litter was only evident during the earlier stage of cornposting (first 14 days) and, that seed germination and root elongation reached 100% (same as the control) towards the end of the cornposting. The concentrations of the major inhibitors, water-extractable Cu and Zn, and ammonia of the spent litter, declined during cornposting, indicating that these inhibitors were gradually eliminated as cornposting proceeded. Multiple regression analysis showed that the ammonia content of the spent litter was the most important chemical factor affecting phytotoxicity of the plant species selected for this study. Relative root elongation and GI were more sensitive indicators of phytotoxicity than seed germination. In the present study, the Gl's of all plant species were > 80% at day 60, indicating that the spent litter had reached its maturation by day 60. The responses of different plant species to the water-extracts of the spent litter were direrent. Among the six species, Chinese cabbage and Chinese spinach were the most sensitive species, and tomato and cucumber were the least sensitive species to indicate phytotoxicity of the spent litter. Moisture adjustment during the composting process did not affect the results of the phytotoxicity test.

Tam and Tiquia (1994) studied about the phytotoxicity of spent litter collected from pig pens employing the 'pig-on-litter'system at various times was evaluated using seed germination and root elongation techniques. The percentage seed germination of four plant species (lettuce, Chinese cabbage, tomato and green beans) was not affected by the water extracts of spent litter samples collected in the first 30 weeks of production. Seed germination was significantly retarded by litter extracts from 34 weeks onwards. The percentages of seed germination at the end of the 45 weeks study were 1% for lettuce, 16% for cabbage, 21% for tomato, and 44% for green beans. Compared with seed germination, root elongation was more sensitive to the toxicity of the spent litter. The root lengths of all seedlings except green beans were less than 50% of the control (deionized water) throughout the experiment. The inhibitory effects of spent litter on root elongation increased with the age of the litter. The final root lengths of lettuce, Chinese cabbage and tomato seedlings were 14%, 24% and 28% of the control, respectively. Green beans behaved very differently from the other species; spent litter extracts stimulated root growth throughout the study, except the last week. The elevated concentrations of heavy metals (in particular extractable Cu) and nutrients present in spent litter were the main factors responsible for the phytotoxicity of the spent litter. The aged spent litter had accumulated more salts, nutrients and heavy metals and imposed more toxic effects on seed germination than did the young spent litter.

Nakasaki et al. (1985) studied the effects of degree of inactivation by UV irradiation was different between vegetative cells and spores of bacteria isolated from sewage sludge composting at 60 ^{0} C. By using this property, a method to estimate the spore ratio of a mixture of vegetative cells and spores was presented. This UV irradiation method was applied to the estimation of the spore ratio of sewage sludge compost samples collected at several stages of composting. The spore ratio of mesophilic bacteria in the samples obtained at the thermophilic stage of 60 degrees C was 40% at most. The vegetative form of mesophilic bacteria showed a thermotolerance property at 60 degrees C by forming colonies but showed no respiratory activity at that temperature.

Jiang et al. (2011) studied the effects to Gaseous emission (N_2O, CH_4 and NH_4) from composting could be an important source of anthropogenic greenhouse gas and air pollution. A laboratory scale orthogonal experiment was conducted to estimate the effects of C/N ratio, aeration rate and initial moisture content on gaseous emission during the composting of pig faeces from Chinese Ganqinfen system. The results showed that about 23.9% to 45.6% of total organic carbon (TOC) was lost in the form of CO_2 and 0.8% to 7.5% of TOC emitted as CH_4. Most of the nitrogen was lost in the form of NH_3, which account for 9.6% to 32.4% of initial nitrogen. N_2O was also an important way of nitrogen losses and 1.5% to 7.3% of initial total nitrogen was lost as it. Statistic analysis showed that the aeration rate is the most important factor which could affect the NH_3 ($p = 0.0189$), CH_4 ($p = 0.0113$) and N_2O ($p = 0.0493$) emissions significantly. Higher aeration rates reduce the CH_4 emission but increase the NH_3 and N_2O losses. C/N ratio could affect the NH_3 ($p = 0.0442$) and CH_4 ($p = 0.0246$) emissions significantly, but not the N_2O. Lower C/N ratio caused higher NH_3 and CH_4emissions. The initial moisture content can not influence the gaseous emission significantly. Most treatments were matured after 37 days, except a trial with high moisture content and a low C/N ratio.

Francou et al. (2008) studied the effects on the influence of green waste, biowaste and paper–cardboard proportions in initial mixtures on organic matter (OM) evolution during composting in pilot-scale reactors was studied using respirometric procedure, humic substance extraction, crude fiber analysis and Fourier transform infrared spectroscopy. The stabilisation of OM during composting resulted from the degradation of easily biodegradable organic fraction as cellulose and hemicellulose, the relative increase of resistant compounds as lignin, the microbial synthesis of resistant biomolecules, and from humification processes. Little stabilisation of green waste OM during composting was observed, in relation with their large lignin content. With moderate contents of paper–cardboard in initial mixtures (20–40%), cellulose proportion remained favorable to fast OM stabilisation. Larger proportions of paper–cardboard (more than 50%) affected OM stabilisation, probably due to a lack of nitrogen. The influence of biowastes only appeared at the very beginning of composting, because of their large proportions of easily biodegradable OM.

Tiquia et al.(2008) did a study on the effects to Characterization of soil-applied organic material is necessary in order to clarify the nature of the organic matter and nutrients in it In this study, the organic matter and nutrient contents of the spent pig litter (a mixture of partially decomposed pig manure and sawdust was characterized before and after windrow composting to: (1) determine their changes during composting, and (2) assess the suitability of the composted spent litter as a soil amendment Results demonstrated mat the time required to teach maturity, and the composition of composted spent litter, depended on the chemical properties of the initial compost feedstock as well as the compost strategies used during composting. Total N, P, and K concentrations of the composted litter depended on chemical properties of the initial material. On the other hand, CN ratio, humic and fulvic add and cation-exchange capacity was influenced by differences in composition of the initial spent litter and composting strategy. If moisture content was maintained weekly at 60% with a four-day turning frequency, the litter reached maturity in 56 days. Maturation of spent litter was accompanied by a decline in total C, water-extractable metals, $NH_4{}^+$-N, increase in ash, ($NO_3{}^-$+$NO_2{}^-$)-N, humic acid, humic acid fulvic add ratio, and cation exchange capacity, and elimination of phytotoxicity. The stability of nutrient and organic matter, acceptable pH and electrical conductivity values, and low levels of undesirable components such as heavy metals and phytotoxic compounds of the spent litter provided substantial evidence that agronomically suitable compost can be obtained after composting in windrows.[84]

Sundberg et al. (2011) studied the effects of composting of source separated municipal biowaste has at several plants in Scandinavia been hampered by low pH. In this study the hypothesis that increased aeration would improve the process was tested in full-scale experiments at two large composting plants. The O_2 concentrations were high (>15%) even at the low aeration rates, so the prevailing low pH was not due to an anaerobic process environment. In spite of this, increased aeration rates at the start of the process resulted in higher microbial activity, increased pH and a more stable compost product. At one plant the decomposition rate varied in proportion to the aeration rate, to the extent that the temperatures and O_2 concentrations were similar during the early processes even though aeration rates varied between 10 and 50 m3 per (h, m3 compost). However, increased aeration caused severe drying of the compost, but at one plant the addition of water was adequate to prevent drying. In conclusion, by increasing the aeration rates and adding water to compensate for drying, it was possible to shorten the time needed to produce a stable compost product and thus to increase the efficiency of the composting plants.

De Guardia et al. (2008) studied the effects to the influence of aeration rate on nitrogen dynamics during composting of wastewater sludge with wood chips. Wastewater sludge was sampled at a pig slaughterhouse 24 h before each composting experiment, and mixtures were made at the same mass ratio. Six composting experiments were performed in a lab reactor (300 L) under forced aeration. Aeration flow was constant throughout the experiment and aeration rates applied ranged between 1.69 and 16.63 L/h/kg de-mineralisation of mixture. Material temperature and oxygen consumption were monitored continuously. Nitrogen losses in leachates as organic and total ammoniacal nitrogen, nitrite and nitrate, and losses in exhaust gases as ammonia were measured daily. Concentrations of total carbon and nitrogen i.e., organic nitrogen, total ammoniacal nitrogen, and nitrite and nitrate were measured in the initial substrates and in the composted materials. The results showed that organic nitrogen, which was released as

NHþ $_4$ =NH_3 by ammonification, was closely correlated to the ratio of carbon removed from the material to Total C/N organic of the initial substrates. The increase of aeration was responsible for the increase in ammonia emissions and for the decrease in nitrogen losses through leaching. At high aeration rates, losses of nitrogen in leachates and as ammonia in exhaust gases accounted for 90–99% of the nitrogen removed from the material. At low aeration rates, those accounted for 47–85% of the nitrogen removed from the material. The highest concentrations of total ammoniacal nitrogen in composts occurred at the lowest aeration rate. Due to the correlation of ammonification with biodegradation and to the measurements of losses in leachates and in exhaust gases, the pool NHþ $_4$ =NH_3 in the composting material was calculated as a function of time. The nitrification rate was found to be proportional to the mean content of NHþ $_4$ =NH_3 in the material, i.e., initial NHþ $_4$ =NH_3 plus NHþ $_4$ =NH_3 released by ammonification minus losses in leachates and in exhaust gases. The aeration rate was shown to be a main parameter affecting nitrogen dynamics during composting since it controlled the ammonification, the ammonia emission and the nitrification processes.

Hanc et al. (2011) Studied the effects on the composition of bio-waste collected in urban settlement through four seasons was almost invariable. Fruit and vegetable waste prevailed. Bio-waste collected from family houses was affected by seasonal garden activity. Chemical parameters were influenced by the proportions of components in bio-waste. The amount of variation among seasons in both type of bio-waste increased in sequence: basic parameters < macro-elements < potentially toxic elements (PTE). It would indicate that there is need to analyze for PTE frequently than others parameters. On the other hand, the total content of PTE in four seasons complied with regulations. Majority of bio-waste was dry and addition of water would be suitable before biological processing. According to composition and parameters, U-bio-waste is preferable for anaerobic digestion and F-bio-waste for composting. It is possible to modify and combine the two processes, to get a high biogas yield and agronomically available fertilizer. In the case of composting of U-bio-waste with low pH, the addition of a bulking agent is a prerequisite. Added reason for addition of a bulking agent is requirement to achieve a more porous structure that promotes aeration. Wood chips made of wood and branches from winter F-bio-waste collection would be suitable. The problem of high C:N could be solved by this way. The analyses of dry matter content and volatile solids showed that F-bio-waste from winter period is more suitable for eventual waste to energy compared to other seasons. This suggestion could be supported by low content of recoverable N, P and K nutrients in F-bio-waste during winter. Low compost consumption and high demand for energy in winter is added reason for the use of this conception. Characterization of bio-waste originated in other neighborhoods should be realized to compare results presented in this study.

Raj and Antil (2011) studied and evaluated the changes in physical, chemical and biological parameters to assess the maturity and stability of composts prepared from mixture of different farm and agro-industrial wastes over a period of 150 days. All the composts appeared granular, dark grey in color without foul odor and attained an ambient temperature at 120 days of composting indicating the stable nature of composts. Correlation analysis showed that the optimal values of the selected parameters for this experimental conditions are as follows: organic matter loss >42%, C:N ratio 1.9, humification index (HI) >30%, cation exchange capacity (CEC):total organic carbon (TOC) ratio >1.7 and germination index (GI) >70%. Compost enriched with sewage sludge, pressmud and poultry waste matured earlier compared to composts either enriched with distillery effluent or un-enriched.

Pagans et al. (2006) did a study on the effects of the Ammonia emissions were quantified for the laboratory-scale composting of three typical organic wastes with medium nitrogen content: organic fraction of municipal solid wastes, raw sludge and anaerobically digested sludge; and the composting of two wastes with high nitrogen content: animal by-products from slaughterhouses and partially hydrolysed hair from the leather industry. All the wastes were mixed with the proper amount of bulking agent. Ammonia emitted in the composting of the five wastes investigated revealed a strong dependence on temperature, with a distinct pattern found in ammonia emissions for each waste in the thermophilic first stage of composting (exponential increase of ammonia emitted when increasing temperature) than that of the mesophilic final stage (linear increase of ammonia emissions when increasing temperature). As composting needs high temperatures to ensure the sanitisation of compost and ammonia emissions are one of the main environmental impacts associated to composting and responsible for obtaining compost with a low agronomical quality, it is proposed that sanitisation is conducted after the first stage in large-scale composting facilities by a proper temperature control.

Zmora-Nahum et al. (2005) studied about the collected on composts prepared in different types of processes with diverse source materials. Of the parameters tested on these composts, the DOC stood-out in its consistent behavior and its correlation to plant experiments.They suggested that the DOC concentration, which was a simple measure, might be a sufficient parameter of compost maturity for composts of different source materials and different composting processes, since it reached a level of less than 4 g kgK1 regardless of source materials and process. They also suggested that the absorbance at 465 nm might be used as a cheap and simple substitute for organic carbon determination, which could also serve as a tool used by compost producers after calibration.

Emino et al. (2004) studied about the plant biological assay or bioassay for determining compost quality and maturity has received attention over the past two decades. However, no universal acceptance for compost quality was evident and cress, which was first reported to be used as a plant bioassay, was still the most commonly used. Furthermore, there was evidence indicated that cress was not sensitive enough to distinguish between mature and immature composts. Fourteen seed propagated species were surveyed to see if one or more would be useful as a bioassay for compost quality. The study confirmed that cress is a less sensitive indicator than several species, for example, lettuce, carrot or Chinese cabbage. Amaranthus tricolor was identified as a potential sensitive indicator species since it did not germinate in an immature compost extract. When the compost extract was diluted, the germination index was linear with extract concentration. While cress responded by differences in root growth, amaranthus responded by reduced germination and root growth which gave it a more definitive response. The study concluded that most of the species, including the commonly used cress, are not sensitive enough to detect differences between mature and immature composts. However, Chinese cabbage appears to be the best of the commonly used assay plants. Amaranthus' potential as a sensitive compost maturity indicator was discovered and more studies were needed to confirm this finding.

Cambardella et al. (2003) studied about the impact of composting process conditions and the extent of compost decomposition on soil C and N mineralization after compost incorporation was poorly understood. This study evaluated post-incorporation effects, using composts from experiments that examined the effects of moisture, C/N ratio, and two alternative strategies on N conservation during the composting process. This work revealed the major conclusions that Organic substrates that did not degrade because of sub-optimal conditions during the composting process might readily mineralize after compost incorporation in soil, where moisture or C/N ratio constraints be reduced. Therefore, cumulative carbon mineralization in compost-amended soils can be increased relative to similar-aged composts following sub-optimal compost conditions. Compost produced after several weeks of intensive composting under near-optimum conditions may not result in net N mineralization after soil incorporation. The dynamics of mineralization, nitrification, denitrification, ammonia volatilization and N cycling through the microbial biomass are complex in soil systems, and can be affected by compost feedstock, processing conditions, and time. Denitrification could severely limit N availability from compost when the compost was applied to agricultural soils. The composts used in this study were significantly altered through drying and grinding relative to moist heterogeneous composts typically used in agronomic settings. These alterations were necessary to allow homogeneous application in small quantities for laboratory incubations, providing better relative understanding of the differences related to compost feedstock and processing, but doubtless also affecting the magnitude of the results.

Kalamdhad et al.(2009) studied the effects of Long term monitoring (150 days) suggested that institutional organic waste, i.e. vegetable wastes and tree leaves, etc., were composted successfully within 7 days period in a rotary drum composter by maintaining aerobic conditions through passive air supply by exhaust fan. About 60^0–70^0 C temperature was maintained even in cold weather conditions (ambient temperature – 6 ^{0}C). A steep temperature gradient existed horizontally in inlet, middle and outlet zone of the drum. Sustained higher temperature at inlet zone had transformed the quality of waste material immediately after feeding into the drum. Two rotations caused 60–70% previously added waste material at inlet to move forward in the drum while remaining material was mixed with the incoming new waste material. This remaining material could possibly serve as an inoculum for the incoming material resulted in higher degradation. Instead of classical mesophilic phase, the incoming material directly enters into thermophilic phase, resulted in rapid decrease in organic matter.

3.3 Recent method for Solid waste handling and its uses

Haydar et al. (2016) studied to find a technique for reducing the amount of solid waste being collected and dumped. For this purpose kitchen waste composting was studied. Windrow composting was carried out from the kitchen waste in three different windrows with varying amounts of kitchen waste. One out of the three windrows was supplemented with sewage and animal manure to observe change in quality and reduction in composting period. The prepared composts and a compost sample from existing Municipal Solid Waste Composting facility, Lahore Compost were analyzed in the laboratory for quality. The results of the study demonstrated that the compost prepared from kitchen waste was better in terms of organic content (44.25% as compared to 26.24%) and C/N ratio (10.67:1 as compared to 6.77:1). Moreover, it was also concluded that the composting period is reduced from 3 months to 1 month by the use of sewage. If composting of kitchen waste was carried out in backyards of homes then the amount of solid waste entering the system in Lahore can be reduced by 30%, which was a substantial reduction.

Brandli et al. (2007) studied the effects of composting and digestion are important waste management strategies. However, the resulting products can contain significant amounts of organic pollutants such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). In this study, the concentration changes of PCBs and PAHs during composting and digestion on field-scale for the first time. Concentrations of low-chlorinated PCBs increased during composting (about 30%), whereas a slight decrease was observed for the higher chlorinated congeners (about 10%). Enantiomeric fractions of atropisomeric PCBs were essentially racemic and stable over time. Levels of low-molecular-weight PAHs declined during composting (50e90% reduction), whereas high-molecular-weight compounds were stable. The PCBs and PAHs concentrations did not seem to vary during digestion. Source apportionment by applying characteristic PAH ratios and molecular markers in input material did not give any clear results. Some of these parameters changed considerably during composting.

Sadi et al. (2012) conducted a study to determine the use of waste minimisation technique in creating sustainable waste management in order to identify the technique which has the most capabilities to reduce on-site waste. The objective of this study was to assess the waste minimization techniques taken from the 4R concept (which includes reduce, reuse, recycle and recovery techniques) in minimizing the waste in construction waste management. The most used waste minimization technique found in the 4R concept would be waste reduction. This shows that the local construction industry had the knowledge necessary to plan out the waste management processes but the implementation was still far from satisfying. Additionally, the findings revealed that because the industry was profit-driven, construction practitioners are motivated by profit to adapt to this techniques.

Jayalakshmi et al. (2017) found that the food and as well our "natural resources" and the "limited available agricultural land" will be used up which could be handled in a much better and sustainable way. Additionally, waste has a strong financial impact and affects the environment including the overall greenhouse gas emission. To avoid all such situations they implemented Smart Garbage and Waste Collection bins (SGWC). The idea was based on creating a social awareness to reduce food wastage through measuring and displaying the amount of food wasted and recycling the wasted food using embedded systems. The Food waste disposal machine (FWDM) used here recycles the wasted food to make fertilizer at planting.

Christiana et al. (2014) did a study based on the design, and fabrication of an effective composting machine for small-scale agricultural processes was achievable using local content materials and indigenous technology. The efficiency of the machine was at a value above average, further research can be carried out to improve the existing design. Furthermore, the design aim and objectives were achieved. The machine can thus be said to have appropriate technology for efficiency in output, and if further research was carried out on the study, the quantity of output and time of operation could be improved upon. With the machine, composting time and cost of purchasing manure will be saved on a long term basis, while agricultural practices and machine fabrications using indigenous technology will be encouraged.

Seal et al. (2012) studied the need for scientific composting methods for effective utilization of organic waste is increasing day by day. In this respect, a new process called the Novcom composting method is being increasingly adopted by the organic tea planters of Assam and Darjeeling (India) for large-scale composting. Study of the biodegradation process under this method and quality evaluation of the end product was carried out at Maud tea estate (Assam) during 2008–2009 and 2009– 2010. Generation of high temperatures (4658C) within the compost heap during the biodegradation process provided an indication regarding the destruction of pathogens and weed seeds in the composted material. Samples collected on day 0, 7, 14, 21 and 30 day of composting, were analyzed for physicochemical properties, nutrient status, microbial population, and stability and phytotoxicity parameters. The most significant finding was the high microbial population in the final product, which was generated naturally during biodegradation. Assessment of the maturity and stability parameters of the compost indicated that biodegradation was complete in 3 weeks. The study provided an indication of the potential of the Novcom composting method for the production of good quality, stable and mature compost, within a short period.

Jayaprakash et al. (2018) studied for designing a compost bin for Indian household kitchen, which was easy to use, odour free, ergonomic in nature and visually appealing. Designed Compost bin consists of a separate chamber for compost starter, composting chamber consisting of a mixing blade (runs with help of a direct current motor and rechargeable batteries), air filter setup and a compost collection tray. Rechargeable batteries used in the product makes it portable. The air filter contains pellets made out of *Azadirachta Indica* (neem) and Gomaya (Cow dung) which were used to keep away bad odor and acts as a disinfectant. Simple mechanism allows the user to maintain cleanliness. A video was made of the working of the compost bin for user feedback.

Users appreciated the product for its colour, aesthetics, easy mechanism, odour free, easy handling, easy maintenance etc.

Trichoderma effect on seed germination, plant morphology and physiology leads to better field stand and it also accelerate the vegetative and reproductive growth of plants. It enhances number of branches, spikes, flowers and fruits per plant. In many cases average weight of individual fruit is also comparatively higher. Higher yield by the application of Trichoderma species in mustard, wheat, corn, tuberose, sugarcane, tomato, okra etc. has been found (Haque et al., 2012; Srivastava et al., 2006, Tucci et al., 2011, Idowu et al., 2016). There are many more examples about effective application of competition for the biocontrol of pathogens such as B. cinerea . These reports suggest that the molecular and proteomic assembly of Trichoderma is more efficient to mobilize and take soil nutrients as compared to many other pathogens and other organisms.

Iyengar and Bhave (2006) studied the process of composting has been studied using five different types of reactors, each simulating a different condition for the formation of compost; one of which was designed as a dynamic complete-mix type household compost reactor. A lab-scale study was conducted first using the compost accelerators culture *(Trichoderma viridae, Trichoderma harzianum, Trichorus spirallis, Aspergillus sp., Paecilomyces fusisporus, Chaetomium globosum)* grown on jowar *(Sorghum vulgare)* grains as the inoculum mixed with cow-dung slurry, and then by using the mulch/compost formed in the respective reactors as the inoculum. The reactors were loaded with raw as well as cooked vegetable waste for a period of 4 weeks and then the mulch formed was allowed to maturate. The mulch was analysed at various stages for the compost and other environmental parameters. The compost from the designed aerobic reactor provides good humus to build up a poor physical soil and some basic plant nutrients. This proves to be an efficient, eco-friendly, cost-effective, and nuisance-free solution for the management of household solid wastes.

The results also suggested that it might be advisable to add potassium from an external source to improve the quality of the mulch. Leachate produced might be recirculated into the reactor to improve the efficiency and quality of the compost. Cooked food wastes may be washed before loading into the reactor to remove the undesirable sodium content and to increase the overall quality of the mulch produced in the reactors. The anaerobic reactor failed to qualify as a household reactor because of the poor quality of the mulch produced, and low level of volume reduction.

3.4 Enrichment of compost using various types of inoculants and their effects on the crop's quality and quantity

Increased use of agro-chemicals in intensive cultivation has disturbed the harmony that existed among soil, plant, bio-life, animals and human beings. In this context, a keen awareness has to be created on the adoption of organic farming as a remedy to maneuver the ill effects of chemical farming. In organic farming, the first and foremost priority was to protect the fertility status and integrity of soil. The organic farming promotes replacement of chemical fertilizers by microbial sources of nutrients like bacteria, fungi, algae, mycorrhiza and other sources such as compost, green manures, vermicompost. The sustainable agriculture practices can effectively prevent the entry of pesticides and toxicants in the food chain and prevent soil and water pollution. Hence it is adopted with a blend of ecologically safe modern technologies.

The role of organic manures and other nutrient management practices are important to achieve a sustainable soil fertility and crop productivity. Organic manure includes all nutrient sources derived from both plant and animal origin. Organic manures are very different from chemical or mineral fertilizers. The basic difference is that they contain organic matter. The sustainable agriculture practices can effectively prevent the entry of pesticides and toxicants in the food chain and prevent soil and water pollution. It is adopted with a blend of ecologically safe modern technologies. The organic agriculture, though not in its orthodox version, has the potential to be accepted by the farmers (Pathak and Ram, 2007). In organic manures, although majority of plant nutrients are available nutrient status, however, is less. Hence enrichment of organic manures is being carried out using rock phosphate, free living nitrogen fixers, P-solubilizers *etc*. The organic farming promotes replacement of chemical fertilizers by microbial sources of nutrients like bacteria, fungi, algae, mycorrhiza and other sources such as compost, green manures etc. Pest and disease management is achieved through physical, mechanical and biological methods such as trap crops, resistant varities and biocontrol agents.

Singh et al.(2018) Trichoderma spp. possess many qualities and attributes, they have great potential use in agriculture such as plant growth development by improving germination, morphological features and physiological alteration by alleviating uptake of nutrients in plants, enhancing nitrogen-use efficiency in different crops, and assisting to improve photosynthetic efficiency. Several strategies have been applied to identify the main genes and compounds involved in this complex, three-way cross-talk between the fungal antagonist, the plant, and microbial pathogens. They also stimulate defence in response of biotic and abiotic stress and antagonism including mycoparasitism, antibiosis and competition against pathogens. Trichoderma elicits ISR by JA/ET-dependent pathways and triggers priming responses in the plant. On the other hand, the Trichoderma–plant interaction is dynamic and the expression of defence-related genes of the JA/ET and/or SA pathways may overlap, depending on the Trichoderma strains and their concentration, the plant material, the developmental stage of the plant, and the timing of the interaction. Trichoderma also produces the phytohormones ET and IAA, which play roles in interconnecting plant development and defense responses. The genome of Trichoderma spp. has been extensively investigated and has proven to contain many useful genes, along with the ability to produce a great variety of expression patterns, which allows these fungi to adapt to many different environments (soil, water, dead tissues, inside the plants, etc.). The metabolomics of Trichoderma spp. are incredibly complex, especially in terms of antibiotics and secondary metabolites production but with the help of advanced genomic and proteomic approaches, it is possible to explore new pathways, novel functions of compounds produced by this genus. The expression of Trichoderma genes in plants has beneficial results, mainly in the control of plant diseases and resistance to adverse environmental conditions. The experimental evidence indicates that Trichoderma–plant interactions have features in common with other beneficial microbe associations but that they also display their own characteristics due to Trichoderma’s particular lifestyle. Nevertheless, there is a need for more studies aimed at gaining insight into the signalling transduction pathways, related to defense and development, resulting from Trichod.erma–plant interactions in the presence of pathogens and/or different types of abiotic stress(figure 3.3). Trichoderma spp. are the most successful biocontrol agents as more than 60% of the registered bio-fungicides used in today's agriculture belongs to Trichoderma-based formulation. Plant-Trichoderma-pathogen is a complex network of multiple mechanisms. Presently many labs tried to dissecting the networking of three way cross talk in PlantTrichoderma-Pathogen interaction. Proteome and genome analysis have greatly enhanced the ability to conduct holistic and genome-based functional studies as they have identified and determined the role of a variety of novel genes and gene-products, including ABC transporters, enzymes and other proteins that produce or act as novel elicitors of induced resistance, proteins responsible for a gene-for-gene avirulent interaction between Trichoderma spp. and plants, antagonism related gene, plant proteins specifically induced by Trichoderma, etc. but there is still much more left than what has been searched. Understanding these mechanisms at the molecular level would help in designing the strains with superior biocontrol properties. Here we review our current understanding of the genetics of interactions of Trichoderma with plants and phytopathogens and their role in mode of action (table 3.2 and 3.3).These factors are expected to enhance not only the rapid identification of effective strains and their applications but also indicate the potentials for improvement of natural strains of Trichoderma.

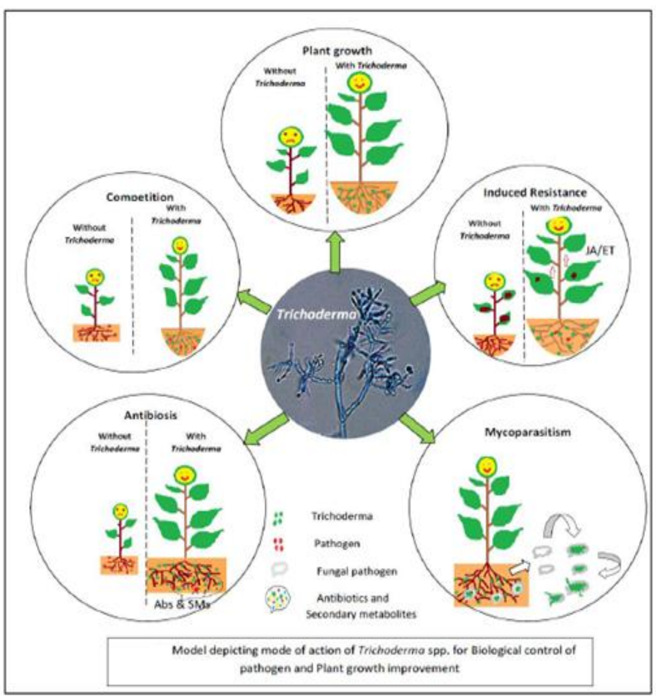


Figure.3.3: Model depicting mode of action of trichoderma sp. for biological control of pathogen and plant improvement. (Benitez et al., 2004)

The recent findings on the genetics of three way interactions of Trichoderma with plants and pathogens and their mode of actionis shown in below tables:

MAMP/effector	Trichoderma Spp.	Activity	Reference
Proteins			
Xylanase Xyn2/Eix	T. viride	A xylanase that elicits ET biosynthesis and hypersensitive response in tobacco leaf tissues	Rotblat et al., (2002)
Cellulases	T. longibrachiatum	Activated and heat-denatured cellulases elicit melon defences through the activation of the SA and ET signalling pathways,	Martınez et al., (2001)
Cerato-platanins Sm1/Epl1	T.virens/T.atroviride	Hydrophobin-like SSCP orthologues that can induce expression of defence responses in cotton and maize	Djonovic et al., (2006),
Swollenin TasSwo	T. asperelloides	Expansin-like protein with a cellulose-binding domain capable of stimulating local defence in cucumber roots and leaves and affording local protection against B. cinerea.	Brotman et al., (2008)
Endopolygalacturonase ThPG1	T. harzianum	Involved in active colonization of tomato root and ISR-like defence in Arabidopsis	Moran-Diez et al., (2009)
Secondary metabolites			
Alamethicin	T. viride	Elicitation of JA and SA biosynthesis in lima bean	Engelberth et al., (2001)
Trichokonin (20mer peptaibol)	T. pseudokoningii	production of ROS, the accumulation of phenolic compounds at the application site and virus resistance in tobacco plants through multiple defence signalling pathways	Luo et al., (2010)
6-Pentyl-a-pyrone, harzianolide harzianopyridone	Various	Low-concentration metabolite activating plant defence and regulating plant growth in pea, tomato and canola	Vinale et al., (2008)

Table.3.2 Trichoderma associated MAMPs

Trichoderma spp.	Mode of application	Biotic Abiotic stress	Crops	Effects	References
Trichoderma harzianum	Soil and seed treatment	Pseudomonas syringae Pvr phaseolicola	Bean	Defensive enzymes Peroxidase, (PO) and Polyphenoloxidase (PPO)	Gailiti 2005
T. virens Gv29-8	Seedling treatment	Colletotrichum graminicola	Maize	AOS, OPR7, OPR8, HPL and LOX10 Gene expression	Djonovic et al., 2007
Trichoderma Harzianum &	Soil treatment	Xanthomonas campestris vesicatoria	Tomato	Chitinase and β1,3-Glucanase	Saksirirat et al., 2009
Asperallum Harzianum	Seed biopriming	Salt stress	Rice	Proline, Malondialdehyde content, total phenol	Rawat et al., 2012
T. harzianum	Soil treatment and soil drenching	Fusarium oxysporum f. sp. radicis cucumerinum Botrytis cinerea	Cucumber, Arabidopsis thaliana	PAL1, CHIT1, β1,3-Glucanase, PR-1, LOX 1 gene expression	Alizadeh, et al., 2013
T. harzianum	Seed biopriming	Pythium aphanidermatum	Cucumber	Phenyl Ammonia Lyase (PAL), PO and PPO	Devi and Shivprakash 2013
T. harzianum	Seed biopriming	Drought	Wheat	Osmotic potential, Phenolics, Proline, lipid peroxidation and PAL	Shukla et al., 2012
T. viridae	Seed biopriming	Fusarium oxysporium and Alternaria alternate	Pigeon pea, Moong bean	PO, PPO, PAL, Catalase, Total phenols and antioxidants	Rao, et al., 2015
T. harzianum	Seed treatment	Phytophthora melonis	Cucumber	PAL, Lipoxygenase and Galactinol synthase and Cucumber pathogen induced 4 gene expression	Sabbagh et al., 2017
T. harzianum	Seed biopriming	Drought	Rice	Proline, SOD, lipid peroxidation and DHN/AQU transcript level	Pandey et. al., 2016
T. harzianum	Soil and seedling treatment	Sclerotinia sclerotiarum	Oilseed rape	AOC3,PDF1.2 and ERF2 genes expression	Alkooranee et al., 2017
T. harzianum	Seed biopriming	Drought	Tomato	Flavonides, phenols, IAA, IBA, Gibberellin, Proline,	Mona et al., 2017

Table.3.3. Mode of action of Trichoderma spp.

Feng et al.(2013) Studied about the understanding of the effect of natural products on plant growth and protection will strengthen new product development for plant production. The isolation and characterization of a known secondary metabolite named harzianolide from *Trichoderma harzianum* strain SQR-T037 were described, and the bioactivity of the purified compound as well as the crude metabolite extract in plant growth promotion and systemic resistance induction was investigated in this study. The results showed that harzianolide significantly promoted tomato seedling growth by up to 2.5-fold (dry weight) at a concentration of 0.1 ppm compared with the control. The result of root scan suggested that Trichoderma secondary metabolites may influence the early stages of plant growth through better root development for the enhancement of root length and tips. Both of the purified harzianolide and crude metabolite extract increased the activity of some defense-related enzymes to response to oxidative stress. Examination of six defense-related gene expression by real-time reverse transcription-PCR analysis revealed that harzianolide induces the expression of genes involved in the salicylic acid (PR1 and GLU) and jasmonate/ ethylene (JERF3) signaling pathways while crude metabolite extract inhibited some gene expression (CHI-II and PGIP) related to basal defense in tomato plants. Further experiment showed that a subsequent challenge of harzianolide-pretreated plants with the pathogen Sclerotinia sclerotiorum resulted in higher systemic resistance by the reduction of lesion size. These results indicate that secondary metabolites of Trichoderma spp., like harzianolide, may play a novel role in both plant growth regulation and plant defense responses.

Molla et al. (2012) Studied about Trichoderma-enriched biofertilizer played significant role in both yield and quality improvement of tomato. Combined application of biofertilizer and chemical fertilizer (especially 50 % BioF +50 % N:P:K) enhanced vegetative and reproductive growth, yield and nutritional quality of tomato by slow and steady release of nutrients to the plants than the sole application of N:P:K fertilizer. The present findings, i.e., Trichoderma-enriched biofertilizer application could save at least 50 % N:P:K, i.e., urea:TSP:MOP can reduce cultivation cost of tomato while minimizing pollution by excessive use of N fertilizer. The impact of Trichoderma-enriched biofertilizer (BioF), i.e., BioF/compost (household/kitchen wastes composted by *Trichoderma harzianum* T22) and BioF/liquid (*T. harzianum* T22 grown in liquid media, i.e., broth culture) were evaluated to recognize their roles in growth, yield and nutritional quality of tomato (Lycopersicon esculentum Mill.) in field studies. Encouraging responses were monitored in all respects. Above 200 and 336.5 % yield increase were recorded over control by BioF/compost alone (T3) and its combination with N:P:K (Nitrogen: Phosphorus: Potassium) application (T4), respectively. Application of 50 % BioF/compost and 50 % BioF/liquid with 50 % N:P:K, provided statistically similar and significant (P B 0.05) performance over control but not significant with standard dose of N:P:K. Total soluble solids, sugar, ascorbic acid, b-carotene, lycopene, phosphorus and manganese content in tomato were significantly higher when fertilized with BioF/compost. In addition, protein content and some essential minerals were increased in 50 % BioF/compost + 50 % N:P:K treatment. Trichoderma composted kitchen wastes can serve as prospective biofertilizer for improvement in yield and quality of tomato cultivation.

Vinale et al. (2009) studied about the secondary metabolites analysed , this study showed different levels of antibiotic activity. Their production in vitro varied in relation to: (i) the specific compound; (ii) the phytopathogen used for the elicitation; (iii) the viability of the elicitor; and (iv) the balance between elicited biosynthesis and biotransformation rates. Production of secondary metabolites in fungi is a complex process associated with morphological development. Secondary metabolites are of tremendous importance in biotechnological applications, but in some cases seem not to have clear function for the producing microbe. In a previous work, we analysed the major secondary metabolites produced by two commercial strains (T22 and T39) of T. harzianum (Vinale et al. 2006). Six compounds obtained from fungal culture filtrates were isolated and characterized. These metabolites showed different levels of antibiotic activity against the fungal pathogens *G. graminis var. tritici, R. solani and P. ultimum* . In this study, their antifungal activity against other important phytopathogens such as *L. maculans* (causal agent of the blackleg disease on crucifers), *P. cinnamomi* (causal agent of the forest dieback disease), *B. cinerea* (causal agent of various grey mould diseases) is reported. Both T22 azaphilone and harzianopyridone produced by T. harzianum strain T22 showed a broad spectrum of activity even if applied at low concentrations (approx. 1–10 kg per plug in a standard plate assay), while T39 butenolide and harzianolide secreted by strain

T39 significantly inhibited pathogens growth only when used at higher concentrations . These results confirmed and contributed to the spectrum of antifungal activity of these secondary metabolites.

Sarwar et al. (2008) did an experiment to analyse the nutrient supplementation efficiency of various organic residues in rice-wheat production along with chemical fertilizers. The results revealed that crop yields significantly increased with the use of compost in combination with chemical fertilizer (3.94 t ha-1 for rice and 5.73 t ha-1 for wheat), FYM (3.36 t ha-1 for rice and 4.38 t ha- 1 for wheat) and Sesbania green manure (2.86 t ha-1 for rice and 3.50 t ha-1 for wheat). However, compost proved superior to farmyard manure as well as Sesbania green manure.

Mahanta et al. (2012) Vermicomposts prepared from rice straw, Eichhornia crassipes, Ipomoea carnea, and their mixed biomass, were enriched with microbial inoculants and evaluated for their effect on growth and yield of rice, and nutrient availability and microbial population in soil. Irrespective of the vermicompost sources, significant increases in nitrogen (N) content and microbial population in vermicomposts were recorded after eight weeks of incubation with inoculation of *Azotobacter chroococcum*, *Azospirillum brasilense*, and *Pseudomonas fluorescens*, either alone or in consortia, and the highest increase was observed with *A. chroococcum* followed by *A. brasilense*. Among different vermicomposts, *Ipomoea* vermicompost was found superior in N content and microbial population. Vermicompost enriched with *A. chroococcum* resulted in the highest improvement in plant growth, grain yield, leaf chlorophyll content and nitrate reductase activity of rice, followed by enrichment with *A. brasilense*. Nutrient content in plant and organic C, available N, P, K, and CEC in post-harvest soil were also significantly improved by the application of enriched vermicomposts, with the best result obtained with *Azotobact*er-enriched vermicompost. Overall, the results suggest that the locally available plant biomasses, particularly *Ipomoea carnea*, a weed abundantly available in northeast India, can be easily converted into an environment-friendly nutrient source by vermicomposting, using plantgrowth-promoting microorganisms such as *A. chroococcum* and *A. brasilense*.Overall, the results suggest that the locally available plant biomasses, particularly *I. carnea*, a weed abundantly available in northeast India, can be easily converted into an environment-friendly nutrient source by vermicomposting, using the plant-growthpromoting microorganisms such as *A. chroococcum* and *A. brasilense*. The application of the enriched vermicompost can help increase the nutrient availability in soil and improve the growth and yield of rice in nutrient-poor acidic soils of northeast India.

Ibrahim et al. (2008) Studied about the impact of organic manure and compost on productivity of wheat (*Triticum aestivum* L.). The amount of various organic manures to supplement the inorganic fertilizers must be optimized to increase crop yield. The results revealed that the organic amendments had positive but variable effects. The organic manures application increased the wheat yield by 11.13 (105%) to 13.53 (128%) g pot–1 compared to the control. Findings of the experiment suggested that instead of using inorganic chemical fertilizer alone, the integrated use could be more effective and sustainable for environment and agriculture.

Harman et al. (2004) studied about the choderma spp. are free-living fungi that are common in soil and root ecosystems. Recent discoveries show that they are opportunistic, avirulent plant symbionts, as well as being parasites of other fungi. At least some strains establish robust and long-lasting colonizations of root surfaces and penetrate into the epidermis and a few cells below this level. They produce or release a variety of compounds that induce localized or systemic resistance responses, and this explains their lack of pathogenicity to plants. These root–microorganism associations cause substantial changes to the plant proteome and metabolism. Plants are protected from numerous classes of plant pathogen by responses that are similar to systemic acquired resistance and rhizobacteria-induced systemic resistance. Root colonization by Trichoderma spp. also frequently enhances root growth and development, crop productivity, resistance to abiotic stresses and the uptake and use of nutrients.

Vinale et al. (2008) studied here about the first part of this work they isolated the major secondary metabolites produced by three *T. harzianum* strains (T22, T39 and A6) and one *T. viride* strain (P1). Seven known compounds obtained from fungal culture filtrates were extracted and characterized. These compounds, with the exception of 6PP, showed different levels of antibiotic activity against the pathogens belonging to taxonomically unrelated groups, *G. graminis var. tritici (Ascomycete), R. solani (Basidiomycete), P. ultimum (Oomycete)* thus, suggesting that each compound exhibits specific antibiotic activity and may play different roles in the direct antagonism of Trichoderma against diverse microbial pathogens. Secondary metabolites play a pivotal role in the antagonistic activities of some biocontrol species of Trichoderma resulting in the suppression of plant pathogens, but their involvement in complex interactions with plants has not been specifically studied. In this work the major secondary metabolites produced by biocontrol strains of Trichoderma (*T. harzianum* strains T22, T39 and A6, and *T. viride* strain P1) have been investigated for their effect on plant growth promotion. An auxin-like activity was observed on etiolated pea *(Pisum sativum)* stems treated with harzianolide and 6-n-pentyl-6H-pyran-2-one (6PP), which also affected the growth of tomato *(Lycopersicum esculentum)* and canola *(Brassica napus)* seedlings. The ability of these molecules to induce systemic defence responses in planta was also investigated. Tomato and oilseed rape seedlings were treated with the metabolites and then inoculated with a spore suspension of *Botrytis cinerea* or Leptosphaeria maculans, respectively. In both cases, a reduction of disease symptoms was observed, particularly on 6PP-treated plants. Moreover an over-expression of pathogenesis-related (PR) proteins was also detected in treated plants. These results clearly indicate that secondary metabolites of Trichoderma spp. may have a role in both plant growth regulation and activation of plant defence response.

Benítez et al. (2004) studied about the genus Trichoderma comprises a great number of fungal strains that act as biological control agents, the antagonistic properties of which are based on the activation of multiple mechanisms. Trichoderma strains exert biocontrol against fungal phytopathogens either indirectly, by competing for nutrients and space, modifying the environmental conditions, or promoting plant growth and plant defensive mechanisms and antibiosis, or directly, by mechanisms such as mycoparasitism. These indirect and direct mechanisms may act coordinately and their importance in the biocontrol process depends on the Trichoderma strain, the antagonized fungus, the crop plant, and the environmental conditions, including nutrient availability, pH, temperature, and iron concentration. Activation of each mechanism implies the production of specific compounds and metabolites, such as plant growth factors, hydrolytic enzymes, siderophores, antibiotics, and carbon and nitrogen permeases. These metabolites can be either overproduced or combined with appropriate biocontrol strains in order to obtain new formulations for use in more efficient control of plant diseases and postharvest applications.

Yedidia et al. (2001) studied about the potential of the biocontrol agent Trichoderma harzianum strain T-203 to induce a growth response in cucumber plants was studied in soil and under axenic hydroponic growth conditions. When soil was amended with T. harzianum propagules, a 30% increase in seedling emergence was observed up to 8 days after sowing. On day 28, these plants exhibited a 95 and 75% increase in root area and cumulative root length, respectively, and a significant increase in dry weight (80%), shoot length (45%) and leaf area (80%). Similarly, an increase of 90 and 30% in P and Fe concentration respectively, was observed in *T. harzianum* inoculated plants. To better characterize the effect of *T. harzianum* during the early stages of root colonization, experiments were carried out in a gnotobiotic hydroponic system. An increased growth response was apparent as early as 5 days post-inoculation with *T. harzianum*, resulting in an increase of 25 and 40% in the dry weight of roots and shoots, respectively. Similarly a significant increase in the concentration of Cu, P, Fe, Zn, Mn and Na was observed in inoculated roots. In the shoots of these plants, the concentration of Zn, P and Mn increased by 25, 30 and 70%, respectively. Using the axenic hydroponic system, we showed that the improvement of plant nutritional level may be directly related to a general beneficial growth effect of the root system following *T. harzianum* inoculation. This phenomenon was evident from 5 days post-inoculation.

Worthington et al. (2001) studied about Organic crops contained significantly more vitamin C, iron, magnesium, and phosphorus and significantly less nitrates than conventional crops. There were nonsignificant trends showing less protein but of a better quality and a higher content of nutritionally significant minerals with lower amounts of some heavy metals in organic crops compared to conventional ones.his analysis found more iron, magnesium, phosphorus, and vitamin C and less nitrates in organic crops as compared to conventional crops. In addition, there were several trends showing less protein but of a better quality, more nutritionally significant minerals, and lower amounts of some heavy metals in organic crops compared to conventional ones. More research is needed both to verify these findings and to discover relevant mechanisms in both plants and soil. As with all real-world data, there was considerable variability in agricultural measurements, making it necessary to collect and consider a lot of data in order to identify underlying patterns. Consequently, for most nutrients, there was a need for additional data collection before any further analysis is warranted. Finally, because the data collected to date suggest that there are real differences in nutrient content between organic and conventional crops, more research into the relative health effects is certainly in order.

Kumar and Singh (2001) assessed the effect of inoculation of vermicompost with nitrogen fixing, *Azospirillum lipoferum, Azotobacter chroococcum* strains and the phosphate solubilizing *Pseudomonas striata* on N and P contents of the vermicompost. Inoculation of N2 fixing bacteria into vermicompost increased contents of N and P. Enriching vermicompost with rock phosphate improved significantly the available P when inoculated with *Pseudomonas striata*. During the incubation period, the inoculated bacterial strains proliferated rapidly, fixed N and solubilized added and native phosphate and made them available to the plants.

Altomare et al.(1999) did study indicated that the biocontrol and plant-growth-promoting fungus *T. harzianum* T-22 has the ability to solubilize many plant nutrients from their solid-phase compounds (e.g., rock phosphate, MnO_2, Fe_2O_3, and metallic zinc), at least in vitro. To the best of our knowledge, this is the first report of the ability of a *Trichoderma* strain to solubilize insoluble or sparingly soluble minerals. A wide range of mechanisms and chemical entities may be involved in the solubilization of different materials. For example, the fungus produced substances that chelated Fe but not Mn. Furthermore, Fe^{3+} and Cu^{2+} were reduced to Fe^{2+} and Cu^{+} but these reductions were due to different substances. In addition, the substances that chelate Fe are unlikely to be the same materials that reduce Fe^{3+} to Fe^{2+}; the fungal metabolites known to chelate iron are not also known to have reducing ability. In preliminary further studies, there appear to be several substances that chelate iron, based on thin-layer chromatography separations. Finally, the mechanism for the nonreductive solubilization of metallic zinc is not known but probably is dissimilar to those already cited, as is the mechanism for solubilization of rock phosphate. Chelation and/or redox activity are known to play a role in biocontrol of plant pathogens and might be part of a multiple-component action exerted by T-22 to achieve effective biocontrol under a variety of environmental conditions.

Kleifeld and Chet (1992) studied about Germination: of seedlings. Seeds of five kinds of vegetables were sown in soil. *T. harzianum* was applied as a bran/peat preparation (5 x 106 cfu/g soil), conidial suspension (5 x 10^6 cfu/gsoil) or seed coating (104-105 conidia/seed). The effect of T-203, applied to petri-dishes and wet filter paper as seed coating (106 conidia/ seed), l mL conidial suspension (106conidia/ mL) or both on germination percentages and final germination rates were recorded. Significant increases were induced, in all vegetable seedlings tested, by the bran-peat preparation in soil, and in beans, radishes and cucumbers at final emergence by the conidial suspension; and only in tomato by seed coating. The polysaccharide 'Pelgel', used for coating, had a very small effect . The fungus Trichoderma harzianum which was applied to pathogen-free soil, induced an increase in emergence of seedlings, plant height, leaf area and dry weight. The fungus was applied to the soil by three different methods: conidial suspension, wheat-bran/peat preparation and seed coating. The most prominent effect was observed in the wheat-bran/peat preparation. Responses occurred in different plant growth substrates such as sandy loam soil, autoclaved soil, vermiculite, peat and a mixture of vermiculite and peat (1 : 1, v/v). *T. harzianum* was also found in roots of plants growing in soil treated with the fungus.

The effectiveness of the inoculum addition to the compost has been studied by adding ligno-cellulolytic bacteria at mesophilic stage followed by ligno-cellulolytic fungi at thermophilic stage and vice versa. From the studies it was reported that addition of bacteria followed by fungal species had a greater effect in increasing the efficiency of the compost material (Feng et al., 2011). It was stated that the bacteria added at the initial stage were thermophilic and they significantly survived at the thermophilic stage with increased population. Furthermore they also showed increased retention time of thermophilic stage leading to a maximum sanitation and biodegradation rate.

Addition of ligninolytic enzymes as the pretreatment for lignin degradation had an enhanced improvement in the process and also the carbon utilization ability of the microbes (Feng et al., 2011). However, the addition of ligno-cellulolytic fungal or bacterial inoculation instead of enzymes in thermo composting had no effect in small scale composting process. In addition, the composting performed equally as the mature compost when it is used in the premix even with the addition of inoculum. Moreover, it was also suggested to know the suitability of different inoculums to the specific substrates in the compost process for its efficient degradation (Nair and Okamitsu, 2010).

Phalke, (2 0 1 6) studied the effects of crop residues which are not fed to animals or are in excess on the farm, if utilized effectively in the form of compost, may improve their quality in the shortest possible time, which, in turn, provides balanced nutrition to plants, improves biological activity of soils and ultimately sustains crop production. The study further suggests that to boost the total pro- ductivity of crops as well as in the system as a whole and to improve soil quality, application of enriched wheat straw compost to soybean may be supple- mented with some quantity of inorganic fertilizers. In other words, to raise wheat crop on residual fertility of soybean, an integrated nutrient supply to soybean is a must the present study it is clear that crop residues which are not fed to animals or are in excess on the farm, if utilized effectively in the form of compost, may improve their quality in the shortest possible time, which, in turn, provides balanced nutrition to plants, improves biological activity of soils and ultimately sustains crop production. The study further suggests that to boost the total pr oductivity of crops as well as in the system as a whole and to improve soil quality, application of enriched wheat straw compost to soybean may be supple- mented with some quantity of inorganic fertilizers. In other words, to raise wheat crop on residual fertility of soybean, an integrated nutrient supply to soybean is a must the present study it is clear that crop residues which are not fed to animals or are in excess on the farm, if utilized effectively in the form of compost, may improve their quality in the shortest possible time, which, in turn, provides balanced nutrition to plants, improves biological activity of soils and ultimately sustains crop production. The study further suggests that to boost the total pro- ductivity of crops as well as in the system as a whole and to improve soil quality, application of enriched wheat straw compost to soybean may be supplemented with some quantity of inorganic fertilizers. In other words, to raise wheat crop on residual fertility of soybean, an integrated nutrient supply to soybean is a must the present study it is clear that crop residues which are not fed to animals or are in excess on the farm, if utilized effectively in the form of compost, may improve their quality in the shortest possible time, which, in turn, provides balanced nutrition to plants, improves biological activity of soils and ultimately sustains crop production. The study further suggests that to boost the total pro- ductivity of crops as well as in the system as a whole and to improve soil quality, application of enriched wheat straw compost to soybean may be supple- mented with some quantity of inorganic fertilizers. In other words, to raise wheat crop on residual fertility of soybean, an integrated nutrient supply to soybean is a must the present study it is clear that crop residues which are not fed to animals or are in excess on the farm, if utilized effectively in the form of compost, may improve their quality in the shortest possible time, which, in turn, provides balanced nutrition to plants, improves biological activity of soils and ultimately sustains crop production. The study further suggests that to boost the total pro- ductivity of crops as well as in the system as a whole and to improve soil quality, application of enriched wheat straw compost to soybean may be supplemented with some quantity of inorganic fertilizers. In other words, to raise wheat crop on residual fertility of soybean, an integrated nutrient supply to soybean is a must the present study it is clear that crop residues which are not fed to animals or are in excess on the farm, if utilized effectively in the form of compost, may improve their quality in the shortest possible time, which, in turn, provides balanced nutrition to plants, improves biological activity of soils and ultimately sustains crop production. The study further suggests that to boost the total pro- ductivity of crops as well as in the system as a whole and to improve soil quality, application of enriched wheat straw compost to soybean may be supplemented with some quantity of inorganic fertilizers.

Eklind and Kirchmann (2000) studied on the effects of composting of N-rich wastes can be associated with substantial gaseous N losses, which mean loss of an essential plant nutrient but may also lead to environmental pollution. We investigated nitrogen dynamics and losses in household waste mixtures with di�erent litter additives during composting, maturation and storage. Standardized, organic household waste was composted mixed with six litter amendments; straw, leaves, hardwood, softwood, paper and sphagnum peat.

Samples were analysed for total and inorganic N and pH. Both the addition and the type of litter amendment greatly pH changes and formation of nitrate during composting. Net N losses after 590 days were 43±62% in mixtures with litter additions, being lowest in the peat and the straw mixtures and highest in the paper mixture, and 70% in the control without litter. A conclusion of the study was that there is no obvious way to efficiently decrease N losses during composting through addition of litter materials.

Awasthi et al. (2018) conducted a field experiment to develop a good initial composting mix using a bacterial *consortium* and 2 % lime for effective co-composting of food waste in a 60-litre in-vessel composter. In the experiment that lasted for 42 days, the food waste was first mixed with sawdust and 2 % lime (by dry mass), then one of the reactors was inoculated with an enriched bacterial consortium, while the other served as control. The results showed that inoculation of the enriched natural bacterial *consortium* effectively overcame the oil-laden co-composting mass in the composter and increased the rate of mineralization. In addition, CO2 evolution rate of (0.81±0.2) g/ (kg·day), seed germination index of (105±3) %, extractable ammonium mass fraction of 305.78 mg/kg, C/N ratio of 16.18, pH=7.6 and electrical conductivity of 3.12 mS/cm clearly indicate that the compost was well matured and met the composting standard requirements. In contrast, control treatment exhibited a delayed thermopile phase and did not mature after 42 days, as evidenced by the maturity parameters. Therefore, a good composting mix and potential bacterial inoculum to degrade the oil are essential for food waste co-composting systems .

Himanen and Hanninen (2009) studied the effectiveness of two commercial additives meant to improve the composting process was studied in a laboratory-scale experiment. Improver A. (sulphates and oxides of iron, magnesium, manganese, and zinc mixed with clay) and B. (mixture of calcium hydroxide, peroxide, and oxide) were added to source-separated biowaste: peat mixture (1:1, v/v) in proportions recommended by the producers. The composting process (T, emissions of CO_2, NH_3, and CH_4) and the quality of the compost (pH, conductivity, C/N ratio, water-soluble NH_4–N and NO_3–N, water- and NaOH-soluble low-weight carboxylic acids, nutrients, heavy metals and phytotoxicity to Lepidium sativum) were monitored during one year. Compared with the control, the addition of improver B increased pH by two units, led to an earlier elimination of water-soluble ammonia, an increase in nitrates, a 10-fold increase in concentrations of acetic acid, and shortened phytotoxicity period by half; as negative aspect it led to volatilization of ammonia. The addition of improver A led to a longer thermophilic stage by one week and lower concentrations of lowweight carboxylic acids (both water- and NaOH-extractable) with formic and acetic of similar amounts, however, most of the aspects claimed by the improver's producer were not confirmed in this trial.

Rajasekar et al. (2012) conducted an experiment to explore the possibility of enrichment of Vermicompost with microbial inoculants such as *Azospirillum brasilense* and *Rhizobium leguminosarum*. They also tried optimization of inoculum level and time of inoculation during vermicomposting and concluded that the inoculation of these two organisms into vermibed on the 30th day resulting in increased survival rate. They also optimized inoculation of 35 ml of inoculum per 175 g substrate on the 30th day of vermicomposting and found to be helpful for the maintenance of sufficient viable population for more than five months in the enriched vermicompost.

Molla et al. (2012) studied about the impact of *Trichoderma*-enriched biofertilizer (BioF), *i.e.*, BioF/compost and BioF/liquid was evaluated to recognize their roles in growth, yield and nutritional quality of tomato in field experiment. The results revealed that above 200 and 336.5% yield increase were recorded over control by BioF/compost alone and its combination with N:P:K. They also observed significantly higher total soluble solids, sugar, ascorbic acid, b-carotene, lycopene, phosphorus and manganese content in tomato when fertilized with BioF/compost.

Biswas (2014) conducted a study and the study was carried out to evaluate the response of microbial bioinoculants along with different organic manures (vermicompost and greencompost) on growth, yield and nutrient uptake of Rumex. Field experiments were carried out in 2010-2011 in randomized replicated block designs consisting of four replicates of each treatment. The experiment consisted of five different microbial bioinoculants combined with two organic manures. Various treatments given to Rumex were *Frateuria aurentia* (potassium mobilizer) *Trichoderma viride* (biocontrol agent), *Azospirillium brasilense* (Nitrogen source) and *Pseudomonas fluorescens* (plant growth promoting bacteria) significantly increased plant biomass, yield and nutrient content of Rumex. Results revealed that among the two organic manures vermi compost combined with bioinoculants significantly influenced the growth and nutrient uptake. Plants inoculated with vermicompost and *Frateuria aurentia* has recorded maximum growth .

Uddin et al. (2011) studied the influence of soil applications with poultry refuse, cocodust, vermicompost, ash, sawdust, khudepana, cowdung, solarized sand, *Trichoderma sp.*and/or with seed treatment by *T. harzianum* against damping off disease complex of potato and chilli. Among the different soil amendments, poultry refuse and vermicompost had promising impact on seed germination, reduction of per cent damping off and growth of potato and chilli seedlings when applied along with *T. harzianum*.

Mazhabi et al. (2011) studied the effects of *Trichoderma spp.* on qualitative and quantitative traits of polianthes. Enriched coco peat with 100% concentration significantly increased stem length and diameter, floret number and leaf length in both main and lateral bulbs compared to control. The results obtained from the experiment showed that *Trichoderma* enhanced qualitative and quantitative traits of polianthes cut flowers.

Espiritu (2011) studied the effects of an experiment to determine the effect of compost with microbial inoculation on the growth of mungbean and pechay. The results showed that the mungbean and pechay supplied with uninoculated compost had the lowest fresh biomass and lowest number of nodules as compared to compost which was combinely inoculated with *Trichoderma sp.*and *Azotobacter* sp. with a highest fresh biomass and higher number of nodules.

Shafawati and Siddiquee (2013) studied about Malaysian oil palm industry was getting bigger; expecting higher the waste produce by the industry. As a solution, composting is an alternative way to reduce the wastes. However, composting process is much dependent on the soil texture and the microbial organisms, control parameters such as pH, temperature C: N ratio and total oxygen dissolve. Using specific Trichoderma species in compost is broaden; not only use as the soil enhancer but also used as the accelerator for rapid composting, control plant disease, higher the production yield, biocontrol, biopesticides, bioherbicides, enzymes producer, toxin producer against phyto- pathogenic species, exert strong competitive effect for space and nutrients and able to degrade woody materials. Thus, there is no doubt in application of Trichoderma specific-species isolate is used for rapid composting of oil palm fibres. The aim of this review is to summarize composting process of oil palm fibres especially empty fruit bunches (EFB) and in application of Trichoderma sp. as the bio- logical control agents. However, more research and review on the information regarding oil palm fibres compost and Trichoderma sp. application as the biocontrol agents in oil palm fibres compost needed to exploit their actual potential.

Godhani et al. (2011) did an experiment to evaluate the efficacy of *Trichoderma sp.*and *Pseudomonas fluorescens* antagonists in the management of wilt disease of chickpea. Results concluded that wilt disease in chickpea crop suppressed effectively with seed treatment of *T. harzianum* @ 8 g per kg seed + application of FYM (5 ton/ha) colonized with *T. harzianum* (2 x 10^{12} spores /ha) there by the yield also get increased.

Kumar and Singh (2001) conducted a study on vermicompost enrichment by using nitrogen fixing and phosphate solubilizing bacteria, which show that there was a significant increase in the inoculated bacterial populations in vermicompost by the second week. Maximum numbers were found between 45±60 days. After the 60th day there was a decline in count of microbes, an increase in N and available P contents during the incubation period. Initially at day 0 vermicompost contained only 1.40 (g/100g) of N which was increased to 2.72 (g/100 g) at the 60th day after inoculation with *A. chrooccocum* (Mac27). Similarly, with inoculation of other strains of *Azotobacter*, N content increased up to 2.53 and 2.50 (g/100 g). *Azospirillum lipoferum* also increased N content up to 2.18 (g/100 g) but this bacterium was less efficient than *Azotobacter* strains. The inoculated phosphate-solubilizing bacterium *P. striata*, caused a significant effect on the available P content in vermicompost when inoculated alone or with 1% MRP(Mussorie rock phosphate), but available P content was greater with MRP and P. striata combination (1.97) at 60th day. Without addition of MRP the available P content was 1.51 (g/100 g). At 75th day N and P contents were more or less similar to those of the 60th day. Addition of rock phosphate inoculated with P. striata led to more availability of

P, most likely due to the production of organic acids by the bacteria which solubilized the rock phosphate (Premono et al., 1996). The P content in other treatments was higher at 45th and 60th day than at day 0, which was due to release of P present in the agricultural wastes. It is evident from this experiment that Azotobacter, Azospirillum and Pseudomonas inoculation helped to increase the N and P contents of vermicompost, and rock phosphate was solubilized during composting. The effect of inoculation of vermicompost with nitrogen-fixing *Azotobacter chroococcum strains, Azospirillum lipoferum* and the phosphate solubilizing *Pseudomonas striata* on N and P contents of the vermicompost was assessed. Inoculation of Nitrogen fixing bacteria into vermicompost increased contents of N and P. Enriching vermicompost with rock phosphate improved significantly the available P when inoculated with *P. striata*.

Gajalakshmi and Abbasi, (2002) studied the effect of compost/vermicompost obtained from a pernicious weed like water hyacinth on kitchen gardens with lady's finger (*Hibiscus esculentus*), brinjal (*Solanum melongena*), cluster bean (*Cyamopsis tetragonoloba*), chilli (*Capsicum annum*) and tomato (*Lycopersicon esculentum*). They reported that there was total absence of any harmful effect by the use of such compost material and moreover the quality of vegetables was better than normal conditions. Authors have also studied the effects of same water hyacinth compost on the growth and yield of a flowering plant, *Crossandra undulaefoila*. The results stated that the plants in pots amended with water hyacinth compost showed significantly better height, larger number of leaves, more favorable shoot: root ratio, greater biomass per unit time and larger length of inflorescence.

Pointcelot (1974) reported that C:N ratio of around 30 was desirable for composting, when it exceeds 35, the process becomes inefficient and took more time for complete decomposition. Further, he reported that, if oxygen concentration is low, aerobes are replaced by anaerobes, which do not decompose organic matter rapidly and they produce foul smell. And also opined that without sufficient moisture, the microbial activity ceased. Below 40% moisture, the organic matter did not decompose properly and above 60% moisture, the compost tend to become anaerobic according to him the optimum moisture for composting was 57-60%. Microorganisms require carbon for growth and nitrogen for protein synthesis. On an average they utilize 30 parts of carbon per one part of nitrogen. So C:N ratio of 30 is desirable for composting. If it is above 35, the process becomes inefficient and the compost requires more time for completion. If it is below 26, the excess nitrogen is converted to ammonia and wasted into atmosphere (Pointcelot, 1974).

Gaur and Sadasivam (1982) studied the effect of mesospheric cellulolytic fungi on composting and reported that due to inoculation, the period of composting was reduced by one month and the quality of compost improved. Total nitrogen, phosphorous and humus contents increased in composted material and inoculation with *Aspergillus niger* and *Penicillium sp.* showed maximum effect. Composting is the process of conversion of organic substances by a mixed population of microorganisms. With the course of time, various groups of microorganisms such as bacteria, fungi, and actionomycetes become established performing a specific role in the process. Contents of macro and micronutrients are found to increase during the process of composting due to volume reduction and due to loss of organic carbon as CO_2 (Gaur, 1982). The C:N ratio of the substrate is an important factor in the decomposition. The materials with wide C:N ratio are degraded slowly and narrowed C:N ratio is preferred for ready attack by the microorganisms. For decomposing, the C:N ratio of the organic substances should be balanced. The C/N ratio is an important factor to be considered when mixing different kinds of materials for composting, wider C/N rations of more then 40:1 promote the immobilization of available nitrogen in the compost (Gaur, 1982 and Zibiliske, 1999). A C:N ratio of 30:1 to 40:1 was reported to be desirable.

Hegarty and Curran (1986) showed that different fungi used in their study produced greater weight loss of wood in 5 to 8 pH range. Inbar found that organic matter with a wide range of pH (3.0 to 11.0) can be composted. The optimum pH levels were between 6 and 8 for composting and between 4 and 7 for end products.

Nagarajan et al.(1988) reported that there was drastic reduction in lignin and cellulose content and four fold increases in potassium content, five fold increase in phosphorous content and two fold increased in micronutrient contents during the composting. Composting is mainly a degradative process where in complex organic molecules are broken down to simpler components. So there will be drastic reduction of complex molecules such as lignin, cellulose hemicellulose, lipids etc, during composting.

Gaur (1982) reported that moisture content of 50-60% was favorable for composting and this moisture per cent enhance the bio degradation of the substrate. The periodic turning was good for enhancing the composting process, since composting was mainly an aerobic process requiring oxygen for oxidation of organic carbon in substrates.

Bertoldi (1985), reported that bacteria and fungi might reproduce and gain in number with the passage of time and in turn could provide conditions during composting process. Pathogenic microorganisms only were reduced and were also unable to grow and multiple in mature compost.

Chapter-04

Preparation of compost from organic kitchen waste (OKW) seasonally.

Chapter 4

4.1 Introduction

The entire waste being generated in India is in Lakh about 1.54 tonnes / day. 50 % of total waste is biodegradable. In the current worldwide situation and future prospects, the recycling of natural matter from waste from different sources becomes necessary for the quest for maintainability and conservation of natural resources. (Hottle et al.2015). Definition of Kitchen waste (KW) is left over organic material from the restaurants, the hotels & the households (Liu , 2012). Tons of wastes from kitchen sector are produced daily in form of highly dense areas. Because of its high organic matter content, comphrehensive nutrient profile and abundant microorganisms, compost enables KW to be degraded effectively.

There is an alternative method of aerobic treatment of KW, known as composting, which converts organics in KW into a hygienic, humus-rich, relatively stable product that conditions soils and nourishes plants. KWcontains a high amount of organic matter and is a very suitable raw material for composting.

In order to produce a good composting product from KW, the carbon to nitrogen ratio needs to be adjusted to around 30 by the addition of carbon-enriched materials such as sawdust, straw etc. With the addition of oxygen and water, a good biodegradation process can be achieved.

The compost derived from KWcontains a good balance of nutrients for plant growth and the high organic content can improve the physical properties, especially for degradedagricultural soils under the continuous application of inorganic fertiliser.Composting also leads to reduction in odour and removal of pathogens. The application of composts from KW could improve the physical properties of the soil and the yields of crops. The optimal conditions for composting of KWare: moisture content of the composting material must be at least 65%; pH near neutral; the C/N ratio of the material must be between 25 : 1 and 35 : 1. Additional aeration can improve the process; a temperature of 60 ^{0}C must be kept for optimal thermophilic composting(Zhang, 2013)

Composting is the biological decomposition predominant process which is spontaneous of organic materials in environment of aerobic. During the process bacteria, other microorganisms and fungi, as well as micro arthropods, split down materials which is organic to stable, utilizable organic substances called compost Bernal et al. (1998). Thus, compost known as the stabilized and the sanitized end product of composting that has undergone to first stage of rapid decomposition. The compost have definite characteristics of humid and is useful to plant enlargement thus creation of the composting of MSW issue for agriculture which is suitable and to manage resource.

Composting reduce waste volume generated and provide nutrients for the plants, also helps in waste segregation at source. In term of factor affecting composting process, pH contents, moisture contents, temperature, and ratio of carbon nitrogen are main factors so as to contribute to effectiveness of process of composting (Hanc et al. 2011)

Therefore the present study was conducted to prepare the different season's KW compost for different seasons.

4.2 Material and Methods

4.2.1 Description of kitchen waste composting seasons

Composting of kitchen waste for 4 different seasons which were taken for this study described as

1. Kitchen waste compost (KWC) for summer month June, July and August year 2016.
2. Kitchen waste compost (KWC) for autumn month September, October and November year 2016.
3. Kitchen waste compost (KWC) for winter month December year 2016, January and February year 2017.
4. Kitchen waste compost (KWC) for spring month March, April and May year 2017. (https://www.timeanddate.com/calendar/aboutseasons.html)

According to previous study Hanc et al.,(2017), three months(84 days approx) were enrolled for each season . The various analysis would be done for 12 weeks like at 0 week as starting day, 4 week, 6 week and 12 week in next objective.

For all four seasons separate bin method and aerobic condition were used for composting. All the experiment was done in triplicates.

4.2.2. Feedstock preparation

KW was collected from the main hostel mess of the Babasaheb Bhimrao Ambedkar University campus continuously for one week in order to get a homogenous feedstock mixture.

The collected KW was expressed as specimen sample of the waste generated in hostel's mess of those particular seasons .The total no. of people may includes approximately 300 per day.

The moisture content of of the gathered sample was between 82.6%-85.8% for all the four season's kitchen waste(KW) and in KW composting process the utilization of such high moisture content(MC) waste mixture can create anaerobic (waterlogged) conditions(Brinton,2000). Therefore sample must be sun dried for 24 hours to attain the required MC (less than or equal to 70%) for KWC process, as per recommended guidelines of Brinton (2000) and EPA (2014).

The fractional description of the KW sample took place gravimetrically and the fraction percentage of each material such as seasonal fruits and vegetables and different grain, rice, meat and bakery was classified as general solid waste (EPA, 2014).
The sample was mixed well and grounded into small pieces, not more than 5 cm in order to enhance degradation process in KWC; because grounded or cutting into small pieces of sample also increases the surface area provided to the microbes (Rawat et al.,2005).

4.2.3 Experimental Setup

A laboratory scale –in-vessel compost bioreactor made up of plastic with a complete working capability of 10 kg was accredited and used. Dimensions of the reactor were thickness 15mm, diameter 63.5 cm and height 68.6cm. The vessel was safeguarded with aluminum foil and Styrofoam to prevent warmness losses. The reactor was filled upto

70% with grounded feedstock mixtures, whereas 30% of the area was kept as a top spaces or head spaces. The volume and type of bioreactor was used in this study was based on earlierreported work on laboratory scale setups for KWCprocess.

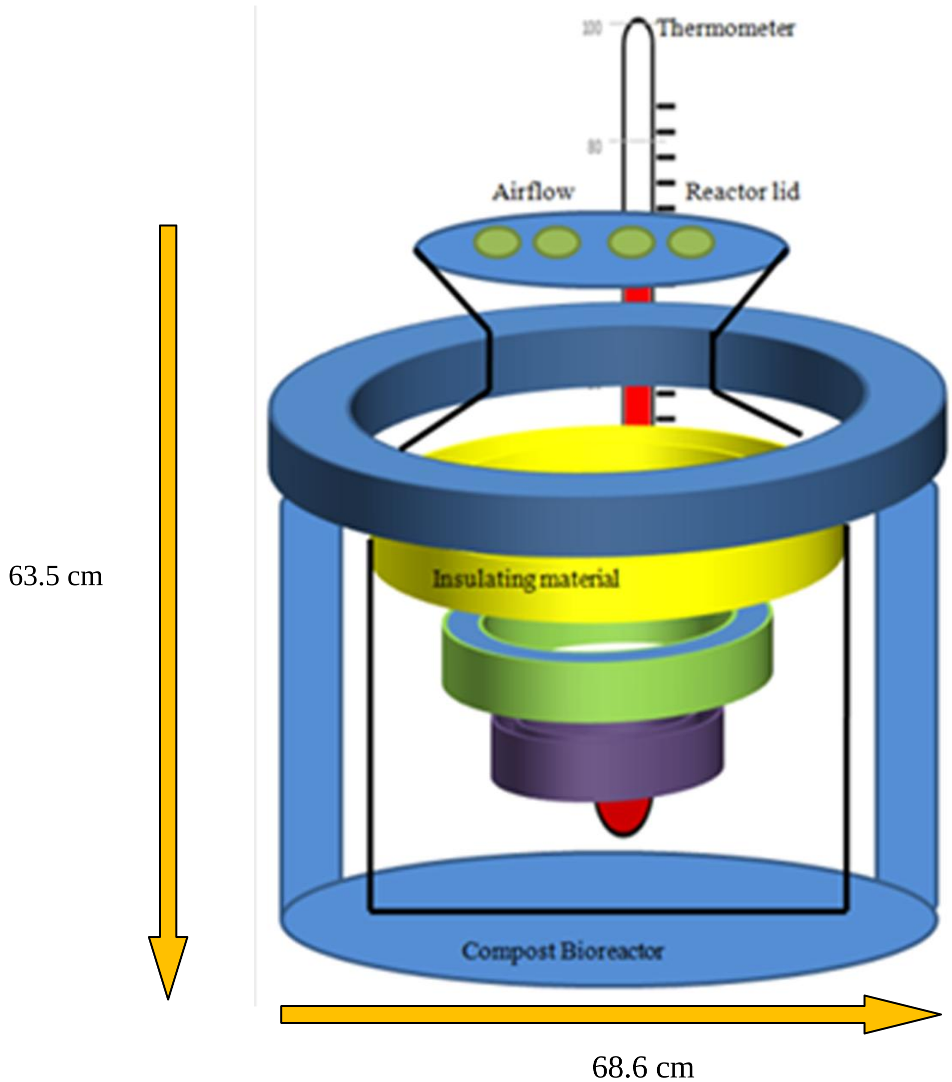


Figure 4.1. Schematic representation of compost bioreactor

Changes during the process were monitored by the thermometer, which was placed in the middle of the compost bioreactor. After filling the feedstock mixture the cover of the bioreactor was closed properly. Aeration took placed through holes located at the bioreactor. Shredding of the compost feedstock mixture was done mechanically for attaining homogeneous mixing and oxygen(O_2) supply during the experiment as recommended by An et al,(2012). The method of aerating the compost feedstock material through mixing and turning was take up according to the methods discussed by Singh and Kalamdhad (2014).

The duration for each season experiment was as per Hanc et al. (2017) refer 4.2.1 of this chapter. The above discussed process was repeated for each season. During each season the microbial and physicochemical analysis were done.

Figure 4.2 A general view of kitchen waste of different seasons

Chapter-05

Investigation and comparison of seasonally prepared organic kitchen waste compost on the basis of physico-chemical, microbial parameters and phytotoxicity evaluation

Chapter 5

5.1 Introduction

The characteristics (composition and quality) of the raw materials entering a composting plant are influenced by both geographic region and seasonal change (Boldrin et al., 2010). In varied geographical regions social, economic, environmental, and geological factors affect the properties of the biogenic wastes that are collected, including variations in nutrients. Once waste enters a composting plant the effect of the above mentioned factors decrease over time as the initial bio-waste is converted to compost. The amount and availability of nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) are important in determining the quality of the final compost product, because they are essential nutrients for plant growth (Krogmann ,1999). For example, Ward et al., 2005 examined the characteristics of composts produced from nine different green waste feedstocks composted at eight composting sites spread across the United Kingdom over a period of 12 months. There were few parameters that showed any degree of seasonal variation between the samples taken at different times of the year from individual sites. The exception was K, which varied both in feedstocks, and in composts made from those feedstocks. In general, pH, electrical conductivity, total carbon (C), total P, and the carbon to nitrogen (C:N) ratio did not vary significantly within or between sites over the course of the year. Hogarh et al., (2008) investigated some physicochemical properties and macro-nutrient values in three types of municipal solid waste composts including household compost, and one type of agricultural waste compost. They reported that agricultural waste compost appeared richer in plant macro-nutrients, especially N, K, and organic C, compared to compost from municipal solid waste sources. This effect was explained by differences in the types of materials that were used as the feedstock to produce the compost. Hamoda et al., 1998 examined process kinetics through experimentation with bench-scale reactors under controlled composting conditions to show the interdependence between biological, chemical, and physical factors. The results obtained revealed that temperature, moisture content, waste particle size, and the C:N ratio should be carefully controlled in order to achieve optimum composting process performance.

Within a compost pile a variety of microbial populations develops in response to the different levels of temperature, moisture, oxygen and pH this microbial diversity enables the composting process to continue despite the constantly changing environmental and nutritional conditions within the pile. The microorganism responsible for composting degrades a broad range of compounds from the simplest form of sugars to complex persistent compounds. Temperature levels and available food supply generally have the greatest influence in determining what class and species of organisms make up the microbial population at a particular time.

Microorganisms that are present in a compost pile are in three major classes: bacteria, fungi and actinomycetes.The microorganisms within a compost pile can be psychrophilic, mesophilic , or thermophilic depending on the temperature range within which they experiences optimal growth rates. The psychrophilic temperature range is defined as being below 50 ^{0}F, mesophilic between 50 ^{0}F and 105 ^{0} F and thermophilic between 105 ^{0} F and 160 ^{0} F.

Phytotoxicity is the most essential criteria for assessing the reasonableness of compost for farming purposes and to maintain a strategic distance from ecological dangers before these fertilizers can be reused back to agricultural land (Tiquia et al., 1996; Brewer and Sullivan, 2003 and Cooperband et al., 2003). Past research work has shown that utilization of immature manure onto the soil causes negative impacts on seed germination, plant development and improvement. These impacts occur because of the fact that a immature compost instigates high microbial action (which lessen oxygen level in the soil), obstructs the current soil available nitrogen (Zucconi et al., 1981a) .Immature compost additionally present phytotoxic mixes, for example, substantial metals (Tam and Tiquia, 1994).

Phytotoxicity is frequently best assessed by leading germination or development tests (Gariglio et al., 2002 and Brewer and Sullivan, 2003), yet the test plants must be chosen with consideration (Emino and Warman, 2004).

Germination Index (GI) is the most ideal approach to test the phytotoxicity of manure to plant development because the results of it are quite accurate and reliable.
Germination bioassays are broadly used to test for saltiness, soil pathogens, lethal substances and some other chemical properties of compost (Zucconi et al., 1985and Gajdos 1997), which could be the significant potential reasons of phytotoxicity. A few specialists detailed that phytotoxic compounds are progressively eliminated of amid the composting procedure, which could clarify the GI increments with composting time.

The Germination Index (GI), which combines of relative seed germination (G%) and relative root lengthening (L%), has been utilized to assess the harmfulness of manure (Tam and Tiquia, 1994 ;Tiquia et al., 1996 and Wong et al., 2001). It has been noticed that a GI value of 80% showed the vanishing of phytotoxins in compost (Zucconi et al., 1981b). Tiquia et al. (1996) utilized this value not just as sign of the vanishing of phytotoxicity but also as a sign of the maturity of compost.

The germination index is a maturity test based on seed germination and starting plant growth utilizing an aqueous concentrate from the compost (Zucconi, et al., 1981b). It shows the phytotoxicity of the manure extricates at diverse phases of composting. The compost is considered mature when the germination index is higher than 60 %, contrasted with the control with distilled water (Zucconi and De Bertoldi, 1987).

5.2 Material and Method

5.2.1 .a. Sampling and analysis

A total of 600gm sample was collected from composting bin for complete analysis. By taking representative samples from 3 different points means from top , middle and bottom of the experimental bin the sample was prepared after mixing of the experimental bin's materials in order to get homogenized sample. These samples were collected at 0 week, 4^{th} week, 6 week and 12 week for analysis.Lastly, the collected samples were mixed thoroughly to make a homogenized sample. Triplicate samples were collected and air dried immediately, ground to pass through 0.2 mm sieve and stored for physico-chemical analysis. The sub-samples were either used or stored at 4^oC for microbial analysis of the wet sample within 2 days.

a) Cutting of Kitchen

b) Kitchen Waste compost bin

c) Kitchen Waste in compost

d) Finished product (compost)

Figure 5.1 A general view of various steps involved for composting process

5.2.2 Parameters analysis

Different experimental methods were used in the study to accomplish the stipulated objectives. Physico-chemical, microbial analysis and phytotoxicity assessment of the kitchen waste samples were carried out in Environmental sciences laboratory (Department of microbiology). Experimental procedures of the physico-chemical, microbiological parameters and phytotoxicity evaluation were explained below.

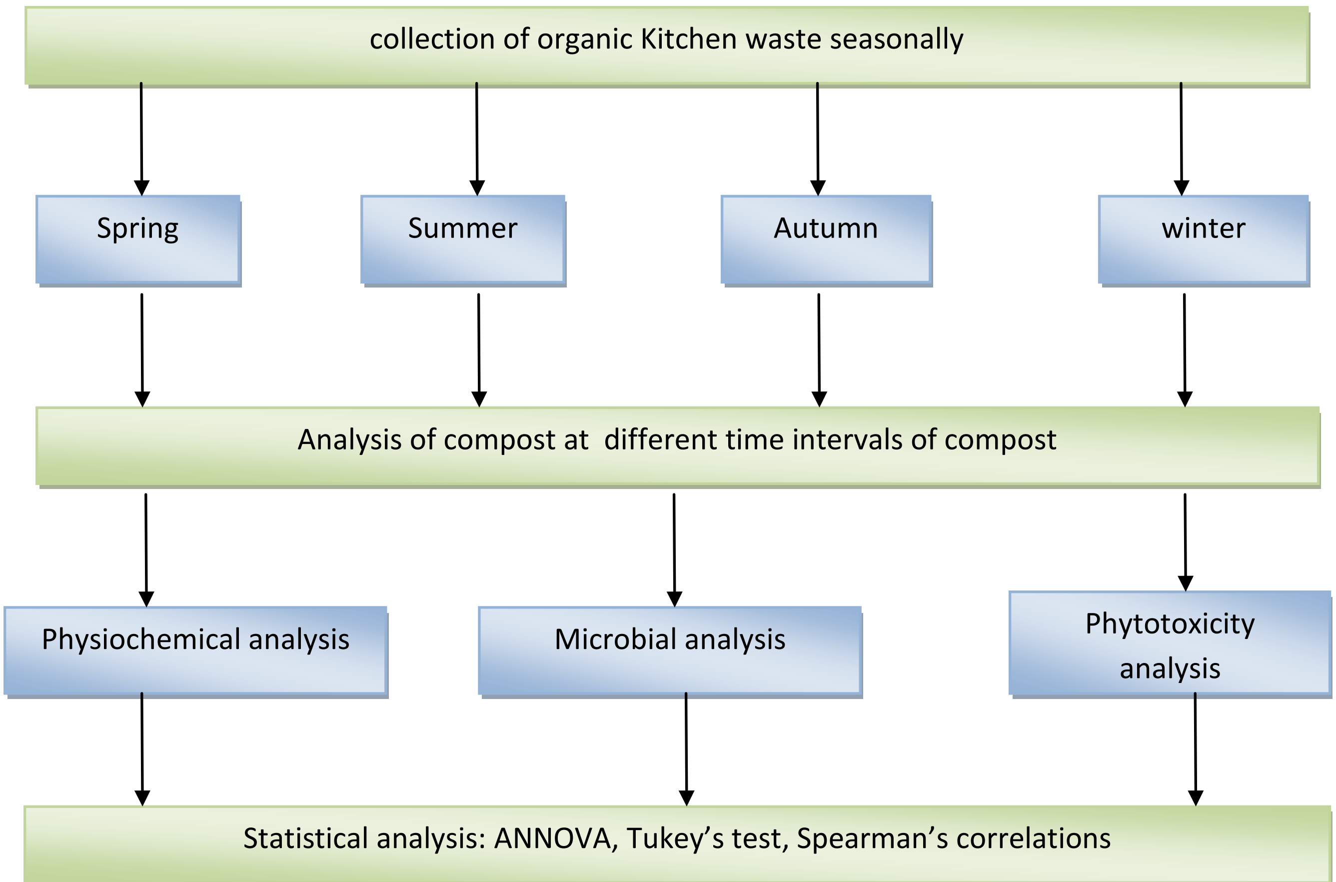


Figure 5.2 Flow chart representation for Analysis of physico-chemical , microbial content and phytotoxicity assessment of seasonally prepared KWC.

5.2.2.1 Physico-chemical assessment

Estimation of pH

- Take 25 g of compost into a suspension in 50 ml of distilled water and shake on a rotary shaker for 2 hours.
- Filter through Whatman No. 1 or equivalent filter paper under vacuum using a Buchner funnel.

Determine pH of the filtrate by pH meter. **(Biofertilizers and Organic Fertilizers in Fertilizer (Control) Order, 1985)**

Estimation of moisture

Weigh to the nearest mg about 5 gm of the prepared sample in a weighed clean, dry Petri Dish. Heat it in an oven for about 5 hours at 65oC ±1 ^{0}C to constant weight. Cool in a dessicator and weigh. Report percentage loss in weight as moisture content (MC) (Biofertilizers and Organic Fertilizers in Fertilizer (Control) Order, 1985)

a.) Calculation:

Moisture percent by weight = 100(B-C)/ B-A

A = Weight of the Petri Dish

B = Weight of the Petri dish plus material before drying

C = Weight of the Petri Dish plus material after drying

Estimation of conductivity

a.) Requirements

- 250 ml flask, Funnel [OD-75mm]
- 100ml Beaker, Analytic Balance
- Potassium Chloride [AR grade] , Filter paper
- Conductivity meter [With temperature compensation system]

b.) Method

- Pass fresh sample of organic fertilizer through a 2-4mm sieve.

- Take 20 gm of the sample and add 100 ml of distilled water to it to give a ratio of 1:5
- Stir for about an hour at regular intervals.
- Calibrate the conductivity meter by using 0.01 M potassium chloride solution.
- Measure the conductivity of the unfiltered organic fertilizer suspension.

c.) Calculation

Express the results as millimho's or dsm-1 at 25^{o}C specifying the dilution of the organic fertilizer suspension viz, 1:5 organic fertilizer suspensions. (Biofertilizers and Organic Fertilizers in Fertilizer (Control) Order, 1985)

<u>Estimation of total Nitrogen</u>

a.) Apparatus

1. Suitable Kjeldahl assembly consisting of 500-800 ml round bottom, digestion flask and Kjeldahl distillation assembly consisting of 500-800 ml distillation flask, splash head tube and condenser, all with appropriate glass joints. The length of the condenser's delivery tube should be long enough to keep immersed in a flask for ammonia absorption.

2. Kjeldahl digestion unit with heating control, suitable for 500-800 ml flasks.

b.) Reagents

a. Sulphuric acid – 93-98% H_2SO_4, N-free
b. Salicylic acid, reagent grade, N-free
c. Sodium thiosulphate ($Na_2S_2O_3$ $5H_2O$), reagent grade
d. Zinc dust- impalpable powder
e. Copper sulphate
f. Potassium or sodium sulphate
g. 45% NaOH solution. Dissolve 450 gm of Sodium hydroxide pellets in distilled water and make up the volume to 1000ml
h. Methyl red indicator – Dissolve 1gm methyl red in 200 ml alcohol
i. Hydrochloric or sulphuric acid standard solution – 0.1N or as per requirement

j. Sodium hydroxide standard solution 0.1N or as per requirement.

c.) Procedure

- Place weighed sample (0.7-2.2gm) in digestion flask.
- Add 40 ml H_2SO_4 containing 2 grams salicylic acid. Shake until thoroughly mixed and let stand, with occasional shaking, 30 minutes or more.
- Then add (i) 5 grams Na_2S_2O 3.5 H_2O or (ii) 2 grams zinc dust (as impalpable powder not granulated zinc or filing).
- Shake the flask and let it stand for five minutes then heat over low flame until frothing ceases.
- Turn off heat, add 0.7 grams copper sulphate, 15 gm powdered K_2SO_4 (or anhydrous Na_2SO_4), and boil briskly until solution clears, continue boiling for another at least 2 hours.
- Remove from burner and cool, add 200 ml of water and swirl the flask to dissolve all the contents.
- Transfer to 500 ml volumetric flask, giving several washings with water to the digestion flask. Make up the volume to 500 ml.
- Take 25 ml aliquot in the distillation flask, add 300 ml water and a pinch of zinc dust
- Take 20 ml of standard acid solution in the receiving conical flask, add 4 drops of methyl red indicator and keep the flask at the lower end of the condenser in such a way that the lower tip of the condenser is fully immersed in acid solution.
- Add 30 ml of 45% NaOH to the distillation flask, gently so that the contents do not mix.
- Immediately connect the flask to distillation assembly and swirl to mix the contents. Heat until all the ammonia is distilled (at least 150 ml distillate).
- Remove from receiving flask. Rinse outlet tube into receiving flask with a small amount of distilled water.
- Titrate the contents in the receiver conical flask with standard NaOH solution.
- Determine blank on reagents using same quantity of standard acid in receiving conical flask.

d.) Calculation

$$\text{Nitrogen \% by weight} = \frac{1.401(V1N1-V2N2)-(V3N1-V4N2) \times df}{W}$$

where

V1 = Volume in ml of standard acid taken in receiver flask for sample

V2 = Volume in ml of standard NaOH used in titrating standard acid in receiver flask after distillation of test sample

V3 = Volume in ml of standard acid taken in receiver flask for blank

V4 = Volume in ml of standard NaOH used in titrating standard acid in receiver flask after distillation in blank

N1 = Normality of standard acid

N2 = Normality of standard NaOH

W = Weight in gm of sample taken

df = Dilution factor of sample (Biofertilizers and Organic Fertilizers in Fertilizer (Control) Order, 1985)

Estimation of C: N Ratio

a.) Method

Calculate the C:N ratio by dividing the organic carbon value with the total nitrogen value.

Estimation of phosphate

a.) Preparation of sample - Accurately weigh 10 gm oven dried sample in 50 g cap. silica crucible and ignite it to 650^o – 700^oC for 6-8 hrs to obtain ash. Cool and keep in a Dessicator. Transfer the contents to a 100 ml beaker. Add 30 ml 25% HCl. Wash the crucible with 10 ml 25% HCl twice and transfer the contents to Beaker. Heat over hot plate for 10-15 min. Keep for 4 hrs. Filter through Whatman No.1 filter paper.

Wash with distilled water 4-5 times (till acid free). Make up the volume of filtrate to 250 ml in a volumetric flask. Estimate total P by gravimetric quinoline molybdate method as described under (Biofertilizers and Organic Fertilizers in Fertilizer (Control) Order, 1985)

Gravimetric quinoline molybdate method for determination of total phosphorus

b.) Reagents

a.) **Citric molybdic acid reagent** – Dissolve 54 gm, 100% molybdic anhydride $(Mo)_3)$ and 12 gm NaOH with stirring in 400 ml hot water and cool. Dissolve 60 gm citric acid in mixture of 140 ml HCl and 300 ml water and cool. Gradually add molybdic solution to citric acid solution with stirring. Cool, filter and dilute to 1 lit. (solution may be green or blue colour depending on exposure to light) If necessary add 0.5% $KBrO_3$ solution drop by drop until green colour becomes pale. Store in dark in polyethylene bottle.

b.) **Quinoline solution** – Dissolve 50 ml synthetic quinoline with stirring in mixture of 60 ml HCl and 300 ml water. Cool dilute to 1 lit and filter. Store in polyethylene bottle.

c.) **Quimociac reagent** – Dissolve 70 gm of sodium molybdate dehydrate in 150 ml water. Dissolve 60 gm citric acid in mixture of 85 ml HNO_3 and 150 ml water and cool. Gradually add molybdate solution to citric acid-nitric acid mixture with stirring. Dissolve 5 ml synthetic quinoline in mixture of 35 ml HNO_3 and 100 ml water. Gradually add this solution to molybdate –citric-nitric acid solution mix and let it stand for 24 hr. Filter, add 280 ml acetone, dilute to 1 lit with water and mix well. Store in polyethylene bottle.

Procedure

1. Digest 1 gm sample as described above and dilute to 200 ml.

2. In 500 ml Erlenmeyer flask pipette aliquot containing not more than 25mg P_2O_5 dilute to approximately 100 ml with water. Proceed with one of the following method.

a. Add 30 ml citric-molybdic acid reagent and boil gently for 3 min (solution must be precipitate free at this stage). Remove from heat and swirl carefully. Immediately add from burette 10 ml quinoline solution with continuous swirling (add first 3-4 ml drop wise and remainder in steady stream) or

b. Add 50 ml quimociac reagent, cover with watch glass place on hot plate in well ventilated hood and boil for 1 min. After treatment with a or b cool to room temperature, swirl carefully 3-4 time during cooling, filter through sintered glass Gooch crucible Grade 4 (30 ml capacity), previously dried at 250 ^{0}C and weighed, and wash 5 times with 25ml portion of water. Dry crucible and contents for 30 min at 250^{0}C. Cool in dessiccator to constant weight as $(C_9H_7N)_3H_3PO4.12MoO_3$. Subtract blank weight. Multiply by 0.03207 to obtain weight of P_2O_5. Report as percent P_2O_5.

Estimation of Potassium

a.) Flame photometry method

Total Potassium are usually determined by dry ashing at 650-700 Degree Centigrade and dissolving in concentrated hydrochloric acid.

b.) Reagent and Standard curve

(1) Potassium chloride standard solution: Make a stock solution of 1000 ppm K by dissolving 1.909 g. of AR grade potassium chloride (dried at 60oC for 1 h) in distilled water 1 ; and diluting up to 1 litre. Prepare 100 ppm standard by diluting 100 ml of 1000 ppm stock solution to 1 litre with extracting solution.

(2) Standard curve: Pipette 0, 5, 10,15 and 20 ml of 100 ppm solution into 100 ml volumetric flasks and make up the volume upto the mark. The solution contains 0, 5, 15 & 20 ppm K respectively.

c.) Procedure

- Take 5g sample in a porcelain crucible and ignite the material to ash at 650-700 C in a muffle furnace.
- Cool it and dissolve in 5 ml concentrated hydrochloric acid, transfer in a 250 ml beaker with several washing of distilled water and heat it.
- Again transfer it to a 100 ml volumetric flask and make up the volume.
- Filter the solution and dilute the filtrate with distilled water so that the

concentration of K in the working solution remains in the range of 0 to 20 ppm, if required.

- Determine K by flame photometer using the K- filter after necessary setting and calibration of the instrument.
- Read similarly the different concentration of K of the standard solution in flame photometer and prepare the standard curve by plotting the reading against the different concentration of the K.

d.) Calculation

Potash (K) %by weight = R x 20 x diluting factor, where R= ppm of K in the sample solution (obtained by extra plotting from standard curve). (Biofertilizers and Organic Fertilizers in Fertilizer (Control) Order, 1985)

Temperature

Temperature was monitored using a digital thermometer throughout the composting period. **(BIS: 10158-1982).**

Estimation Volatile Solid

Volatile solid (VS) and ash content were also measured according to **BIS, 10158-1982.** Initial weight of the crucible was taken as W_1 g. Weighed (10 ± 0.1g) ground sample (screened through 0.22 mm sieve) in crucible and kept it in a muffle furnace operating at a temperature of 550-600^{o}C for 2 h. After 2 h crucible was taken out of the muffle furnace and kept in desiccator for ½ h for cooling and then final weight of crucible with sample was taken as W_2 g. Volatile solids content of the sample was calculated as

$$VS(\%) = \frac{(5-(W_2-W_1))}{5} \times 1000$$

Total organic carbon (TOC) was calculated from VS with a factor of 1.8. NH_4-N using KCl extraction (Tiquia and Tam, 2000).

Mg concentration was measured by atomic absorption spectrometer (AAS) (Varian Spectra 55B) after the digestion of 0.2 g sample with 10 mL of H_2SO_4 and $HClO_4$ (5:1) mixture in block digestion system (Pelican equipments, Chennai, India) for 2 h at 300^{o}C.

Ambient air temperatures, the temperatures in individual fermenters, as well as the emission of oxygen (GMH 3691 digital oxymeter, Greisinger electronic, Germany) in exhaust air were measured daily during the entire composting process.

The $N\text{-}NH_4^+$, $N\text{-}NO_3^-$ dissolved organic carbon (DOC) and the available portion of $P_{(CAT)}$, $K_{(CAT)}$ and $Mg_{(CAT)}$ was estimated in CAT solution (0.01 mol L^{-1} $CaCl_2$ and 0.002L diethylene triamine penta acetic acid) at the rate of 1:10(w/v) according to the International BSI Standard EN 13651, 2001. The contents of N − NH+4, N− NO_3^- , and DOC in extracts were measured colorimetrically using the SKALAR SANPLUS SYSTEM. Total element contents were determined in the digests obtained by pressurized wetashing (HNO_3 + HCl + HF) with microwave heating using an Ethos 1 (MLS GmbH, Germany) **(EN 13 651 Soil improvers and growing media – extraction of calcium chloride/DTPA (CAT) soluble nutrients; 2001)**

5.2.2.2 Microbial analysis

The decrease was higher in case of summer season than other two seasons which could be attributed to the decrease in moisture content in summer season, where it was unsuitable to mesophilic microbial growth. In case of rainy season, for the final stage compost sample, few more bacteria will be present which may have adverse environmental conditions (due to high moisture content). Autumn seasons are considered to be suitable but not the optimum for composting. The nearest conditions to the optimum were found in autumn season. Therefore in this study the microbial assessment is done in summer, rainy and autumn season only according to (Shyamala and Belagali, 2014, 2012)

5.2.b.Sampling for microbial analysis

Microbial count was done by adding 10 g of composting specimen into 90 mL of sterile distilled water containing 0.85% (w/v) sterile sodium chloride solution in 250 mL

Erlenmeyer flasks. The solution is mixed mechanically at 150 rpm for 2 h at 25^{o}C. Finally, the waste suspensions were diluted serially and used for microbial counts on appropriate media

Culture media and conditions

For bacterial growth nutrient agar medium was used, total count of the prokaryotes was examined .Petriplates were poored with the nutrient agar medium and kept in the BOD incubator for 24-48 h at 25^{0}C for mesophilic bacteria and for 24 h at 55^{0}C for the spores of bacteria.Cycloheximide was added in concentration of 0.2gm/L in order to restrict the growth of fungi.

For actinomycetes growth, Actinomycete isolation agar was supplemented with 2 g sodium caesinate, 0.1 g/L-Asparagine, 4 g sodium propionate, 0.5 g K_2PO_4, 0.1 $MgSO_4$,0.001 g $FeSO_4$ and 5 mL glycerol per liter and cycloheximide (0.2 g/L) (for fungal growth inhibition). Final petri plates poured with this medium were incubated in the BOD incubator at 25°C for 4-5 days.

Fungal count was done in the Sabouraud 4% dextrose agar with 5 g peptone from casein, 5 g peptone from meat, 40 g D(+)Glucose per liter. Prepared plates were incubated at 25°C for 3-4 days. (Ryckeboer et al.,2003 and Varma, V.S., 2015)

Isolation of microbial cultures from compost

The compost sample (10 g) was diluted in 90 mL of buffer solution (0.06M Na2HPO4/NaH2PO4) (1/9 v/v), pH 7.6. Decimal serials dilutions (10-1 to 10-10) were made and inoculated aseptically in Petri dishes (10 μL for plate) with different culture media: Potato Dextrose Agar (PDA), Nutrient Agar (NA) and Starch Ammoniacal Agar (SAA); in order to facilitate the growth of fungi, bacteria and actinomycetes respectively. Petri dishes were incubated at 30°C(mesophilic microorganisms) and 50°C (termophilies) for 72h (PDA), 37°C or 50°C for 24h (NA) and 37°C or 55°C for 120 h (SAA), according to the phase were the isolation was carried out. After incubation isolated colonies of bacteria, fungi and actinomycetes were selected. The evaluation of cellular concentration in a compost samples was determined by plate counting of serials dilutions according to the givn equation :

CFU/g = Colonies Numbers • dilution •100 (Shyamala and Belagali, 2014)

5.2.2.3 Phytotoxicity assessment

Compost water extracts preperation:

Based on the above method, the water extract of different season's compost was prepared by shaking the samples with distilled water at different concentration level(ratio) 2:10w/v as 20%(C2) , 4:10w/v as 40%(C3) and 6:10w/v as 60%(C4) respectively for one hours and then filtered (Zucconi *et al*., 1981b).

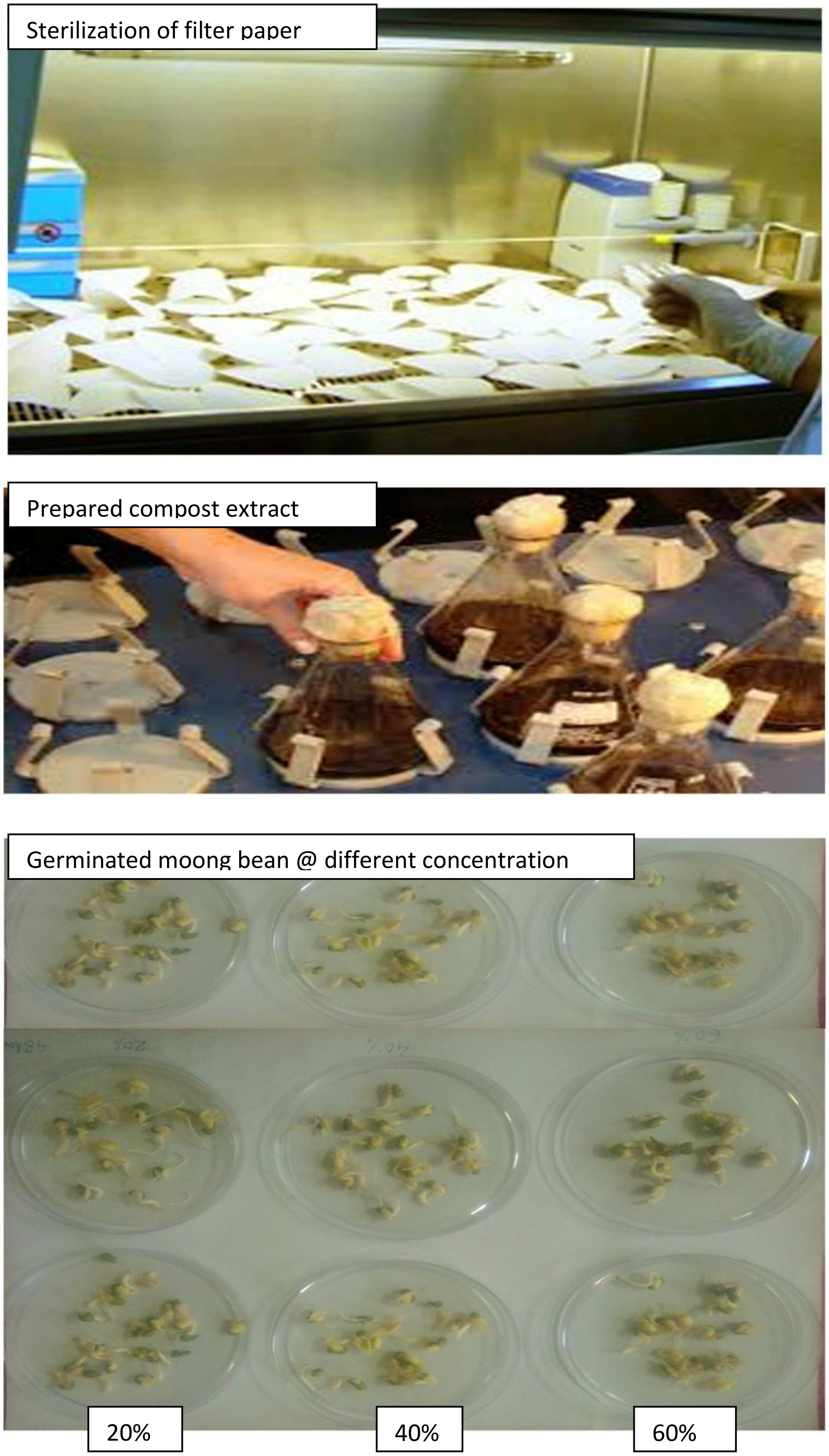


Figure 5.3 A general view of KWC extracct used for phytotoxicity evaluation

Phytotoxicity evaluation:

The phytotoxicity of compost extracts was assessed by the seed germination technique (Zucconi *et al.*1981b, Tam and Tiquia, 1994 and Tiquia *et al*., 1996).Mung seeds (*Vigna radiata L.*) surface were sterilized by immersion in 75% alcohol for three minutes followed by transferring in 0.001 HgCl2 solution for two minutes with periodical agitation and then thoroughly washed with sterilized distilled water to get rid of toxic chemicals [Rovira, 1956]. Subsequently, 10 seeds of *Vigana Radiata(L.)* were placed in sterilized petriplates of uniform size lined with two filter paper of Whatman No. 1. These filter paper were then moistened with 10 ml of prepared water compost extract of different seasons at different ratio was applied in a Petriplate. All experiments were run in triplicate. The Petri dishes were sealed with tape to reduce water loss while allowing air penetration and then were incubated in the dark for 24, 48 & 72 hours at room temperature, the seeds that germinated were counted and removed from petri plate at the time of initial count on each day for 3 days that is for 72 hours. The criteria of germination which we have taken was the visible protrusion of radical from seed coat and it was expressed in percentage. The germination index was estimated for seeds kept at ambient temperature at every 24 hours of time interval of incubation duration up to 72 hours. The germinated seeds were counted to the initial appearance of the radical by continuous visual observation for 72 hours. The seed germinated in distilled water was used as control(C1). The percentage of seed germination, root elongation and germination index (GI) was calculated according to **(**Zucconi *et al*., 1981b) as follows:

Seed germination (%)

$$= \frac{\text{No of seeds germinated in compost extract}}{\text{No of seeds germinated in control}} \times 100$$

Root Elongation (%)

$$= \frac{\text{Mean root length in compost extract}}{\text{Mean rootlength in control}} \times 100$$

Germination Index (%)

$$= \frac{\text{Seed Germination (\%)} \times \text{Root elongation (\%)}}{100}$$

5.3 Statistical analysis

Continuous variables were expressed as means ±standard deviation (SD). One way analysis of variance (ANOVA) has been calculated using a 95% confidence level, followed by Tukey's test determined differences among the seasons. Spearman's correlations were computed between the physiochemical parameters in the final compost at probability levels of .05 and .01. All statistical analyses were performed using the SPSS V.20

5.4 Results and Discussion

Changes in the parameters during composting

Biological composting has been carried out mostly by microorganisms, but several confounding factors regulate growth and reproduction of these microorganisms which also accounts for proper composting process. These factors include temperature, pH, moisture content, aeration level, and C:N ratio.

Composting process varies with environmental conditions, method used for composting, also on raw materials and other elements used in compost. Some of the important factors are listed below:

Oxygen content in the outlet and temperature

Composting is an aerobic process and adequate ventilation should be maintained to allow respiration of microorganism, Initially the oxygen concentration between 5% to 10% and temperature <35°C is considered as optimal for growth. Most optimal results were found in winter season where initial oxygen concentration was 9.8% and temperature was 22°C. The O2 content in off-gas was also found inversely related in spring, summer and autumn seasons with nearly optimal conditions. After 2 weeks of composting, aeration level was reduced in all four seasons equally which strengthen usefulness for composting. This composting material might be more useful for composting companies with their cheaper values.

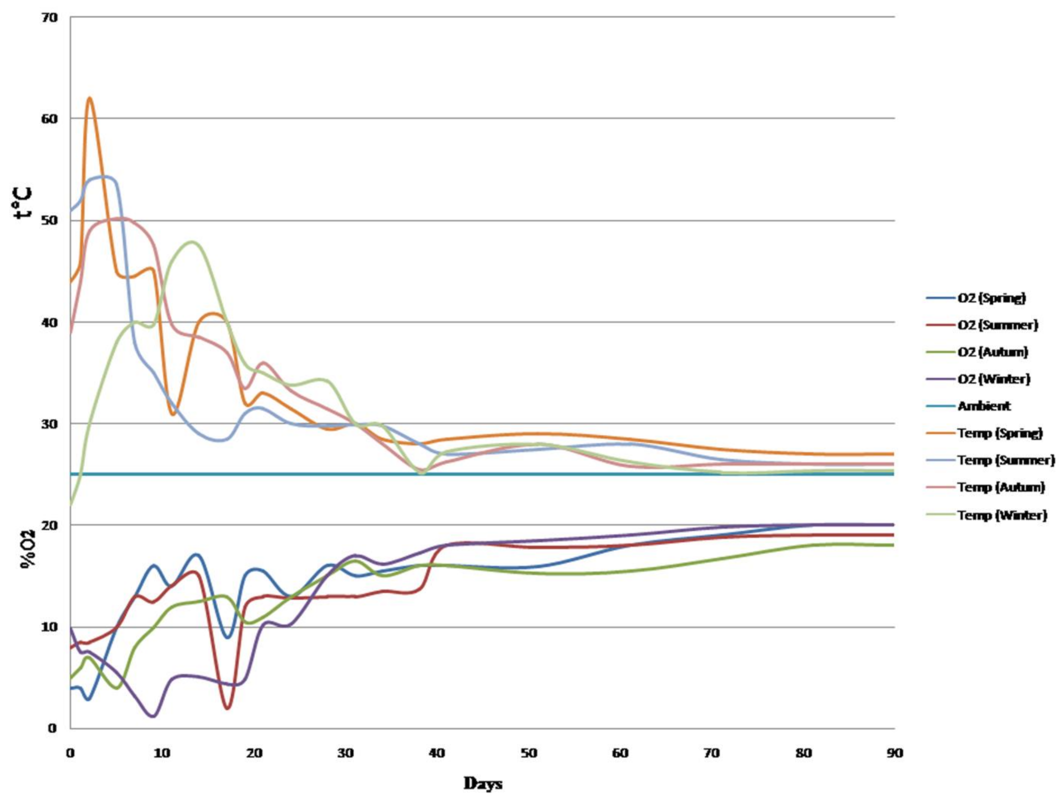


Figure 5.4. The course of temperature (°C) and O2 content in off-gas (%) during the composting of KW collected in spring, summer, autumn and winter

Simultaneously there was increase in temperature was recorded with maximum 62°C during spring, 54°C during summer on the 3rd day, 50°C on 5th day during Autumn and 48 during winters on 14th day of composting, after this temperature tend to decline rapidly. Lowest temperature was 26°C during autumn at the end of composting. In the beginning of 3rd week of composting, higher aeration rates were observed, with increase in oxygen content in outlet , jiang et al also reported higher aeration rate (Jiang et al., 2011). Miller, reported that optimal O2 concentration is between 15 to 20% (Miller, 1993) .

In this study oxygen content reached above 15% after 9 days in spring, 14 days in summer and 28 days in Autumn and winter, while rise in temperature (>45°C) was found within 10days in all four seasons thus it represents quick transition of composting from mesophillic to thermophiilic stage (Fig.5.4) (Hanc et al., 2009). This initial increase and rapid decline in temperature is reported in other studies also (Brandli et al., 2007; Pagans et al., 2006). They found that in laboratory prepared compost, temperature evolves initially and then remain higher than the ambient temperature.

Total mass

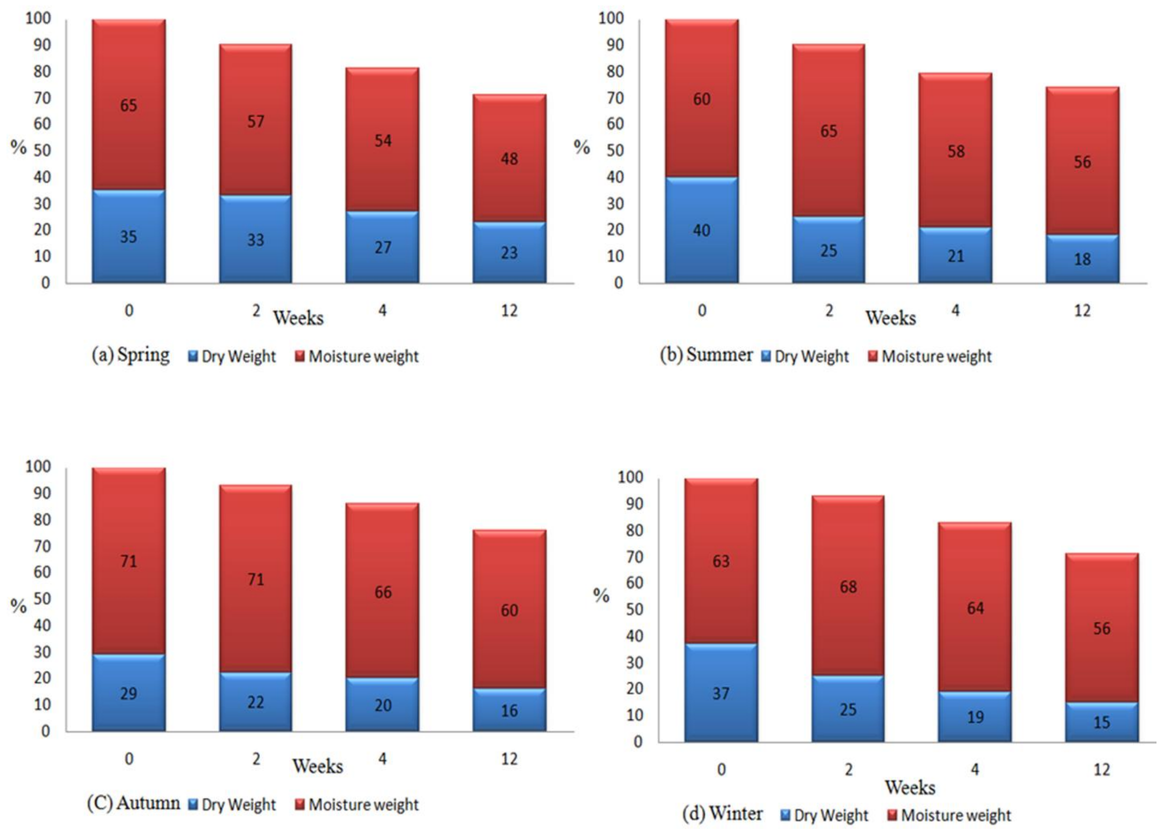


Figure 5.5. The relative weight of the total mass in % during the composting of KW collected in a.spring, b.summer,c. autumn and d. winter

Decline in the total mass during composting was found, which mainly caused by the volatization loss of CO_2 generated during the decomposition of organic matter and vaporization of moisture content (Fig.5.5). The highest loss of total mass was recorded in winter season which was approximately 38% followed by summer with 35%. Lowest reduced in total mass was 28% in autumn season. This was the slightly highest loss rate in comparison with one of the reported study (Hanc et al., 2017), while Francou et al., found 32% of total mass loss, which is nearly equal with our studies (Francou et al., 2008). Maximum moisture content was observed in autumn season while dry weight was highest during summers. The dry matter content gradually decreased in every season over the course of the experiment. Decrease in dry weight was maximum 15% in summer and winter season, while decrease in moisture content was observed only in spring season about 14%, while it increases during Autumn and winter season with 6% to 19% respectively). This increase in moisture content is probably due to relatively low temperature (nearly equal to ambient temperature) during completion of composting process. Increase in moisture content in final compost is also reported by hanc et al (Hanc et al., 2017).

pH

Discrimination of various physiological parameters of compost over four seasons is mentioned in table 5. 1.pH value considerably effects composting process throughout by discriminates its acidic or alkaline nature. In our study, compost was initially acidic with pH value 4.90 during spring, 4.50 during summer, 5.77 during autumn and 6.10 in winter season. These results were concordant with Kim et al who also found low initial pH value for compost. Acidic nature of compost results due to presence of higher amount of organic matters. During post composting days this organic matter degrades, thus releases various acids which are used later on as substrate by other microorganisms (Table 5.1) .

Table 5.1: Physicochemical parameters with week (at starting as 0 and after 4, 6, 12 week) of kitchen waste over four seasons.

	Spring	Summer	Autumn	Winter	Mean	MIN	MAX	CV (%)
pH	Mean(±SD)	Mean(±SD)	Mean(±SD)	Mean(±SD)				
0	4.90(±0.10)	4.50(±0.61)	5.77(±0.15)	6.10(±0.10)	5.32	4.5	6.1	14
4	7.23(±0.31)	6.90(±0.26)	7.23(±0.21)	7.60(±0.10)	7.24	6.9	7.6	4
6	7.57(±0.06)	7.60(±0.20)	7.43(±0.21)	8.33(±0.15)	7.73	7.43	8.33	5
12	8.13(±0.15)	7.22(±0.11)	7.57(±0.21)	7.77(±0.15)	7.67	7.22	8.13	5
VS(%)								
0	79(±1.53)	81(±2.00)	87(±1.00)	91(±1.53)	84.5	79	91	7
4	71(±1.53)	78(±2.08)	83(±2.08)	85(±2.08)	79.25	71	85	8
6	69(±1.00)	78(±2.52)	78(±2.08)	79(±2.52)	76	69	79	6
12	61(±2.00)	72(±2.00)	78(±1.53)	71(±1.53)	70.5	61	78	10
Nitrogen(%)								
0	1.54(±0.03)	1.33(±0.03)	0.98(±0.03)	0.89(±0.04)	1.19	0.89	1.54	26
4	1.66(±0.06)	1.45(±0.02)	1.26(±0.04)	1.07(±0.03)	1.36	1.07	1.66	19
6	1.89(±0.16)	1.65(±0.04)	1.60(±0.20)	1.42(±0.08)	1.64	1.42	1.89	12
12	2.26(±0.15)	1.85(±0.05)	1.77(±0.13)	1.57(±0.02)	1.86	1.57	2.26	16
C:N								
0	26(±2.52)	34(±3.61)	36(±0.58)	22(±1.53)	29.5	22	36	22
4	24(±3.21)	29(±1.00)	34(±1.00)	21(±1.53)	27	21	34	21
6	23(±2.08)	27(±3.06)	33(±2.08)	20(±1.00)	25.75	20	33	22
12	21(±1.53)	26(±1.53)	27(±2.08)	20(±1.53)	23.5	20	27	15
DOC(%)								
0	1.57(±0.03)	1.74(±0.11)	3.07(±0.14)	3.25(±0.28)	2.41	1.57	3.25	36
4	1.04(±0.03)	0.95(±0.04)	2.64(±0.11)	1.81(±0.10)	1.61	0.95	2.64	49
6	0.84(±0.14)	0.76(±0.02)	1.75(±0.09)	0.86(±0.11)	1.05	0.76	1.75	44
12	0.74(±0.05)	0.66(±0.05)	0.82(±0.12)	0.67(±0.02)	0.72	0.66	0.82	10
N-NH_4^+(ppm)								
0	419.87(±25.44)	400.30(±1.84)	403.25(±2.63)	370.44(±17.82)	398.47	370.44	419.87	5
4	76.17(±13.84)	62.09(±4.91)	54.37(±2.84)	42.40(±2.21)	58.76	42.4	76.17	24
6	33.23(±0.92)	28.76(±1.11)	32.66(±2.49)	31.46(±1.25)	31.53	28.76	33.23	6
12	25.77(±4.55)	22.00(±0.42)	26.92(±1.66)	24.28(±2.47)	24.74	22	26.92	9
N-NO_3^-(ppm)								
0	311.63(±1.50)	374.06(±12.44)	400.57(±1.60)	339.85(±6.27)	356.53	311.63	400.57	11
4	13.90(±4.26)	56.93(±8.94)	52.78(±4.42)	72.99(±3.87)	49.15	13.9	72.99	51
6	54.87(±2.58)	11.13(±1.11)	5.43(±1.01)	15.89(±1.91)	21.83	5.43	54.87	103
12	73.53(±1.22)	13.66(±1.81)	6.40(±0.16)	19.38(±1.00)	28.24	6.4	73.53	109

	Spring	Summer	Autumn	Winter	Mean	MIN	MAX	CV (%)
PCAT								
0	692(±11.59)	1227(±16.50)	737(±24.02)	787(±19.05)	860.75	692	1227	29
4	669(±16.62)	668(±12.29)	615(±25.48)	570(±37.75)	630.5	570	669	8
6	437(±25.17)	456(±18.77)	496(±7.37)	493(±7.57)	470.5	437	496	6
12	296(±4.93)	419(±22.74)	440(±34.78)	399(±1.53)	388.5	296	440	16
KCAT								
0	8788(±12.58)	1147(±44.50)	7674(±99.67)	5994(±6.43)	5900.75	1147	8788	57
4	10376(±544.16)	6845(±135.96)	8443(±40.51)	6913(±22.54)	8144.25	6845	10376	20
6	11335(±233.12)	7337(±15.72)	8876(±203.59)	8726(±54.37)	9068.5	7337	11335	18
12	13424(±310.40)	9943(±48.99)	11504(±204.16)	8982(±11.53)	10963.25	8982	13424	18
MgCAT								
0	1040(±26.41)	1393(±6.81)	996(±6.08)	687(±10.54)	1029	687	1393	28
4	626(±24.58)	686(±7.23)	693(±6.66)	618(±23.03)	655.75	618	693	6
6	584(±3.51)	548(±34.59)	614(±15.28)	572(±4.16)	579.5	548	614	5
12	497(±5.13)	550(±11.72)	601(±1.53)	552(±11.24)	550	497	601	8

Legend: Various physiochemical parameters were compared in several intervals , coefficient of variation(CV) has been calculated by comparing mean and standard deviation of four seasons. MC =moisture content EC (ds/m)=EC Electrical Conductivity, C:N =Carbon Nitrogen ratio, DOC= Dissolved organic carbon,P =potassium, K =sodium, Mg=magnesium

This degradation tends to increase pH value rapidly in all four seasons. During 2nd week of composting, highest mean pH value was observed in winter season while lowest was in summer, this may be due to increase in atmospheric temperature decreases pH rapidly. Increase in pH during degradation of organic matter is also reported in previous reports (Sundberg and Jonsson, 2008). After 2 weeks, pH value tends to increase with slightly lowered rate due to drop in serration intensity the volatilization of ammoniacal N, and H+ releases. This is occurred mainly because degradation of several proteins during nitrification, Kalemelawa et al. also reported slower rate of pH elevation after 2 weeks of composting (Kalemelawa et al., 2012). During 6th week of composting, pH value fall near to the Neutral value. Neutral pH phenomenon is explained during maturation of composting material in published study (Chefetz et al., 2010) . While two other studies reported that change in pH value during composting process is a specific indicator of decomposition and stabilization (Benito et al., 2006; Miller, 1993). During maturation compost turns to alkaline in nature with pH 8.13 in spring season which was maximum in our study, while 7.22 was minimum in summer season, 7.57 and 7.77 were the final pH values during Autumn and winter seasons respectively

Volatile Solid(VS) content

VS content is the most efficient parameter used for the estimation of age and physical properties as well as maturity of compost. Initial mineral content of the compost defines efficiency of composting process. Composting maturation begins with the initiation of mineralization reactions, and if composting process operates properly, VS content tend to decrease which was observed in all four seasons in this study (Table 5.1).

Initially VS content was minimum in spring season, while it was maximum in winter season. which decreases gradually in all four seasons. Mineralization process was higher autumn season and lowered in Spring season. This results was slightly differ from other studies, they found seasonal sequence of spring and summer < autumn and winter (Hanc et al., 2011). The initial VS content in Spring was 79%, in Summer was 81%, in Autumn was 87% and highest in winter was 91%, these contents were quite higher that reported studies (Krogmann, 1999) . At the end of composting process, Minimum VS content was 61% during spring season, 72% was found during summer, maximum was found in Autumn 78% and during winters it was 71%.

Electrical Conductivity content

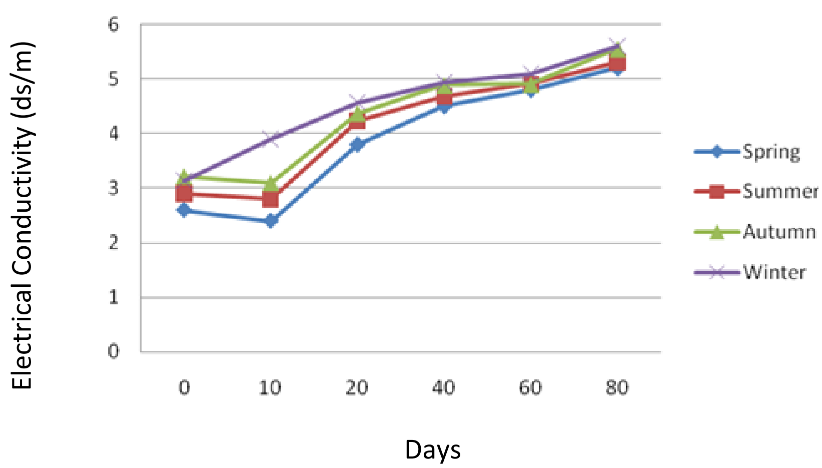


Figure 5.6 Electrical conductivity variation of four season with no. of days (0, 10, 20, 40, 60 and 80)

Electrical conductivity of compost is depend on the ions concentration including, chloride, potassium, nitrate, sulphate and ammonia salts , carries electrical charges and maintain the ability of electrical conductivity of compost (Brinton, 1998). In this study composting material, initial EC was minimum in Spring (2.6) and maximum in winter season 3.1, which increased during post composting process in a consecutive manner (Fig. 5.6). At 6 weeks of composting, electro conductivity during all four season was almost equal, but at the final stage highest EC was achieved in winters (5.6). The sequential sequence of EC was Winter <Autumn<Summer<Spring. Campbell et al., 1997 reported that degradation of organic matter tend to increase EC of compost to high values. Decrease in EC could also be explained as increase in concentration of nutrients such as nitrites and nitrates .

Nitrogen content

During composting, ideal nitrogen concentration is required which is around 0.3 to 1.5% for the absorption of other nutrient? Initial nitrogen concentration of our compost was higher 1.54% during spring season and lowest was in winter season. As mineralization process proceed, there was gradual increase in nitrogen concentration was observed in all four seasons. Multiple studies reported increasing trend of nitrogen composition in post composting days (de Guardia et al., 2008; Hanc et al., 2017; Himanen and Hanninen, 2009), but the increasing amount (1.2) was low in comparison with hanc (1.4) and Himanen and Hänninen (1.5) during spring, summer and winter while it was higher (1.9) during Autumn season (Table 5.1).

C:N(Carbon nitrogen ratio) ratio

Efficient and effective composting is largely depends on its C:N ratio and it changes according to the parent material. Higher concentration of C tend to cool and slow down the composting process while nitrogen rich compost tend to overheat the process, also generates odors from the ammonia released, thus it makes continuous monitoring of C:N necessary for effective and efficient composting. During mineralization of organic matter, absolute nitrogen tend to decrease while relative remaining mass of nitrogen tend to increase due to accumulation of biomass of nitrifying bacteria and some other microorganisms. One the study reported increase in nitrogen content (Nitrogen and Ammonia) directly increase pH of the compost which turn to adequate for microbial growth and reproduction, while Simultaneously another study reported decrease in VS and increase in Nitrogen content led to decrease in C;N ratio which was observed in our study also in all four seasons (Table 5.1) (Hanc et al., 2017; Kalamdhad et al., 2009).

Initially adequate amount of Nitrogen was found in compost of autumn and summer season, while it was low in Spring and winter. Francou et al. found low amount of C;N ratio and tend to decrease slightly from 17 to 16. However decrease in C;N ratio from 6 to 10% in all four season was reported by Hanc et al, which was observed in this study also. At the end of composting process, compost material was effectively matured in all four seasons in comparison with standard value which should be greater than 20 but not higher than 30 (tend to reduce growth) with an average value of 23

Total organic carbon (TOC) and Dissolved organic content (DOC)

During composting, decrease in the total organic carbon and dissolved organic carbon content has been reported in several studies (Fares et al., 2005; Zmora-Nahum et al., 2005). Microbial population in compost tends to be responsible for decomposition of waste which decreases percentage of carbon content of compost. In our study initial dissolved carbon content was minimum in spring (1.5), while it was slightly higher in summer (1.74) and much higher in autumn (3.07) and maximum in winter (3.25). At 2 weeks of composting decrease in DOC was observed in all four seasons. After 6 weeks of composting, after that time, the DOC values leveled off, reaching a concentration below 1%. Previous study on predicting compost stability, suggested a value of 10 g kg−1 as a threshold for compost maturity (Table 5.1). At end of composting maximum decrease was observed in winter season (Hue and Liu, 1995).

N-NH_4^+ Transition

The ratio of N-NH_4^+ has been used as maturity index of compost, also this transition during composting process affects compost quality. Highest concentrations of N-NH_4^+ are produced in the first few weeks of composting in all four seasons. Ammonia volatization occurs with increase in pH in conjugation with increase in temperature during spring and summer, which results due to increase nitrogen loss. Increase in moisture content mainly during Autumn and winter season decreases nitrogen volatization, as dissolved ammonia is directly utilized by microorganisms (Li et al., 2013). During initial stage, $N\text{-}NH_4^+$ composition was maximum approx 420 ppm in spring, 400 ppm in summers, 403 ppm during Autumn and lowest was in summer 370ppm which falls rapidly during second and sixth week of composting. These decrease in $N\text{-}NH_4^+$ results were in agreement with earlier reports (Eklind et al., 2004; Hanc et al., 2017). Hanc et al reported that rapid decline in $N\text{-}NH_4^+$ content is an efficient indicator of good quality composting process. The final compost contains lowest $N\text{-}NH_4^+$ transition during summer season which was 22ppm while it was highest in Autumn (approx 27ppm) and intermediate in Spring and winters with approx 25ppm (Table5. 1).

$N\text{-}NO_3^-$ Transition

Compost testing and analysis service provided standard nitrate-nitrogen concentration during composting. It is reported that $N\text{-}NO_3^-$ releases during the maturation stage of composting process, thus it is favorable that sufficient amount of Nitrogen content should be present in compost of all seasons (na Mona, 2003) . $N\text{-}NO_3^-$ concentration higher than $N\text{-}NH_4^+$ denotes proper maturation and efficient compost material. Unfortunately initial concentration of N- NO_3^- was quite low in comparison with N-NH4 concentration in this study. N- NH_4^+ and N- NO_3^- ratio depends on dry mass and moisture mass of the compost. It is reported that compost with high dry mass tend to have high $N\text{-}NH_4^+$: N-NO_3^- ratio, while compost having high moisture content tend to have low $N\text{-}NH_4^+$: N-NO_3^- ratio thus it determines maturity of the compost.

At the 2 weeks of composting, rapid decrease in $N\text{-}NO_3^-$ concentration was observed in all four seasons, maximum fall was observed during spring and summer season while it was minimum in winters, which may be due to increase in temperature and high $N\text{-}NH_4^+$ content. At 6th week of composting there were subsequent increase in N- NO_3^- content was observed in spring season which indicates faster maturity of compost, while $N\text{-}NO_3^-$ were continuously tend to decrease in summer, winter and Autumn seasons (Table 5.1). Himanen and Hänninen also found increase in $N\text{-}NO_3^-$ concentration during post composting days, while hanc et al and krogman et al reported that the concentration of

$N\text{-}NO_3^-$ varied considerably during the year, with coefficients of variance found between 100% to 110% on average founds similar with our study with 109% coefficient variation. Inverse correlation between decreasing amounts of $N\text{-}NH_4^+$ with increases in the concentration of N − $N\text{-}NO_3^-$ towards the end of composting suggest that intensive biological decomposition has been completed (Pare, 1998). High $N\text{-}NH_4^+$: $N\text{-}NO_3^-$ ratio was observed during spring season, intermediate during summer and winter while lowest was observed during Autumn season in this study.

Macro- Nutrients

Kitchen compost structure constitute of various minerals and ions including potassium, magnesium and phosphorus. In kitchen waste compost, Vegetables gets decomposed and releases highly soluble potassium during composting process This type of compost absorbs significant amount of water, thus maintain structural integrity and porosity, while phosphorus is one the most essential nutrient component of growth and Calcium and Magnesium are considered as bases for maintaining cells structure. CAT solutions were used in this study to estimate the amount of useful nutrients (Table 5.2).

Table5. 2. The total content (in %) of the main macro-nutrient in the beginning of composition of KW for four seasons.

Parameter	Spring	Summer	Autumn	Winter
P_{tot} (%)	0.38	0.22	0.29	0.18
K_{tot}(%)	1.80	1.29	1.91	1.68
Mg_{tot}(%)	0.17	0.13	0.29	0.33

Phosphorus (P)

Total phosphorus is one the most essential nutrient component of growth. In kitchen compost, the total phosphorous concentration varied from 18% to 38% which was slightly higher in comparison with recommended standards (na Mona, 2003).

Initially Higher amount of P_{cat} was observed during summer season followed by winter than autumn and spring seasons. In our study, there were slightly decrease in P_{cat} was observed during all four seasons with significant amount of water absorption. Iyengar and Bhave et al also found decrease in water soluble P_{cat} during post composting days. Initially P_{cat} showed 29% coefficient variability among four seasons (Iyengar and Bhave, 2006). While P^{tot} was higher in spring season followed by Autumn and summer, while winter had lowest amount of Ptot (18%). this proportion of P_{tot} and P_{cat} ranges were in agreement with results reported by hanc et al who found Ptot concentration about 33% and krogman et al found P^{tot} around 45% (Table 5.2).

Potassium (K)

In this type of compost, composition process releases highly soluble potassium, thus absorbs significant amount of water, and maintain structural integrity and porosity which inversely decrease the loss of potassium during composting. in present study, initial concentration of potassium was noted maximum during spring season followed by Autumn, while lowest was noted during summer season, which was exponentially increased during post composting day. Potassium is considered as essential growth nutritional element, so it helps plants in better growth, also its higher concentration has fewer or now toxic effects on human growth. There was 57% coefficient variability among values of four season of K_{cat} (Table 2). Unlike P_{cat}, the content of K_{cat} increased during composting. while K_{tot} was higher in Autumn season 19% followed by spring season 18%, than winter 16% and least Ktot was observed during summer season 12% (Table5. 2).. These results were found concordant with other reported study (Hanc et al., 2017)

Magnesium (Mg)

In kitchen waste compost, food and vegetables, fine earth, pulses and various spices are the principal source of magnesium. This tends to varies magnesium content drastically from region to region. in our compost, magnesium higher in summer season and lower in winter seasons, these concentrations were higher than standard magnesium concentration recommended by ASC Symposium series (Barker, 1997). The coefficient variation was 28% initially and decreases to 8% while comparing Mg_{cat} in four seasons. Mgcat tend to decrease rapidly and higher percentage of decrease was noted in spring season. However Mgtot ranges from 13% to 0.33% over four seasons higher was observed during winters and lower was recorded in summer season. The average Mg_{tot} (total Mg) in compost was 0.23%, which corresponds with the range from 0.18% to 0.44% shown in selected study

(Table 5.2) (He et al., 1995). Generally, composts produced from kitchen waste contained higher amounts of nutrients extracted from vegetables, fruits oils and by implication exhibit superior agronomic value.

Spearman correlation between parameters

All the parameters included are either directly or indirectly related with each other, also showed dependence on each other in various ways, thus mutual relationship between these parameters may always influence final compost product. So analyzing degree of dependence of this parameters would reveal masked role of each parameter in compost product.

Table5. 3: Spearman correlation between physioco-chemical parameters of four season

	pH	**VS**	**Nitrogen**	**C:N**	**DOC**	**$N\text{-}NH_4^+$**	**$N\text{-}NO_3^-$**	**P_{CAT}**	**K_{CAT}**	**Mg_{CAT}**
pH	-	-0.46023	0.397938	-.655**	-.520*	-.749**	-0.48932	-.781**	0.456891	-.818**
VS		-	-.926**	0.337309	.818**	.616*	0.467378	.742**	-.775**	.683**
Nitrogen			-	-0.21402	-.809**	-.629**	-.544*	-.741**	.832**	-.685**
CN				-	0.398527	0.428047	0.066421	0.484136	-0.31292	.551*
DOC					-	.800**	0.491176	.826**	-.603*	.803**
$N\text{-}NH_4^+$						-	.662**	.932**	-.559*	.918**
$N\text{-}NO_3^-$							-	.553*	-0.46765	.582*
P_{CAT}								-	-.715**	.915**
K_{CAT}									-	-.565*
Mg_{CAT}										-

Legend: Physiochemical parameters were compared to identify linear correlation among them and impact of that correlation in various seasons, significant levels were measured using P <0.05 (Denoted by *) and P< 0.001 (Denoted by **). Maximum Significant positive correlation was found in VS content followed by $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$

The pH values were negatively correlated with DOC with a probability of 0.05 and with C:N, NH4, P_{cat} and Mg_{cat} with 0.001 probability, which may are favorable properties of this compost. These results were discordant with earlier studies, Hanc, Raj and Antil found positive correlation of pH with DOC , P_{cat} and Mg_{cat}. VS presented high negative correlations with N and K_{cat}, and positive correlations with the DOC, NH4 and Mg_{cat}. These findings corresponded somewhat strongly with correlation coefficients determined recent studies (Hanc et al., 2017). Nitrogen was also found in negative correlation with DOC, N-NH4, N-NO3, P_{cat}, Mg_{cat} and positive correlation with K_{cat}. Earlier studies, reported the correlation between maturity of compost and its stability parameters with different characteristics at different stages of composting (Raj and Antil, 2011). They reported that C:N ratios and the N − NO3 and N-NH4 may be useful assets for determining the maturity of compost, in our study N-NH4 was found to be highly correlated with several parameters, thus these parameters may be useful for determining the maturity kitchen compost with respect to time. Hanc et al found positive relation of C:N with VS and DOC, while negative N, we also found similar results, but statistically they were insignificant. However, correlation coefficients between the C:N ratio and DOC comparatively were lower than earlier reports (Zmora-Nahum et al., 2005). These outcomes attributed to the different concentration and composition of the compost as well as use of more solvents to determine exact DOC level of the compost. Compost with minimum DOC levels at initial stage contained high concentration of N-NO_3^-. There was extremely positive correlation was found between decrease in DOC and P_{cat} with a significant level of 0.001. Apart from other studies Hanc, Raj and Antil, we found significant correlation between N-NH4 and N-NO3, were opposite from their findings. N-NO3 shown significant positive correlation with P_{cat} and Mg_{cat}, as soon as N-NO3 of compost increase, P_{cat} also tend to increase. While P_{cat} is positively correlated with Mg_{cat} only. Hanc et al also found positive correlation of P_{cat} with Mg_{cat} but in different type of compost. Of the parameters examined, pH, VS content and Nitrogen composition of compost were most frequently showed close relationships with other parameters(table 5.3)

Focusing on these parameters would be beneficial in comparing and analyzing several parameters in any compost, also they may be assets for determining maturity time of the compost as well as make compost economically acceptable.

Microbial analysis

Bacterial growth

Most efficient management of composting process is the monitoring of microbial succession as microbes play crucial role in process of composting, Also presence of some bacterial and fungal organisms reflects the quality and maturity of compost (Ryckeboer *et. al.*, 2003). In our study, total aerobic bacteria per gram of compost ranged from 1.9 X 10^9 to 5.4 X 10 ^{9}CFU in summer, while it was higher in rainy season 2.1 X 10^9 to 10.4 X 10^9 CFU in rainy season, and lowest in 1.8X 10^9 to 5.5X 10^9 CFU in Autumn. Similar findings were reported by Shyamala and Belagali, 2014.

During summer season, decrease in bacterial colony numbers was higher in comparison with two other seasons, which could be attributed to the decrease in moisture content, where it was unsuitable to mesophillic microbial growth. While during rainy season, few other species of bacteria would be expected to be found due to adverse environmental conditions (due to high moisture content). Previous studies provided a justified explanation to analyze microbial growth in three seasons instead of four. Of these, Autumn season is considered as adequate season for bacterial growth, but not optimum or nearest conditions to the optimum requirements (Fig. 5.7a).

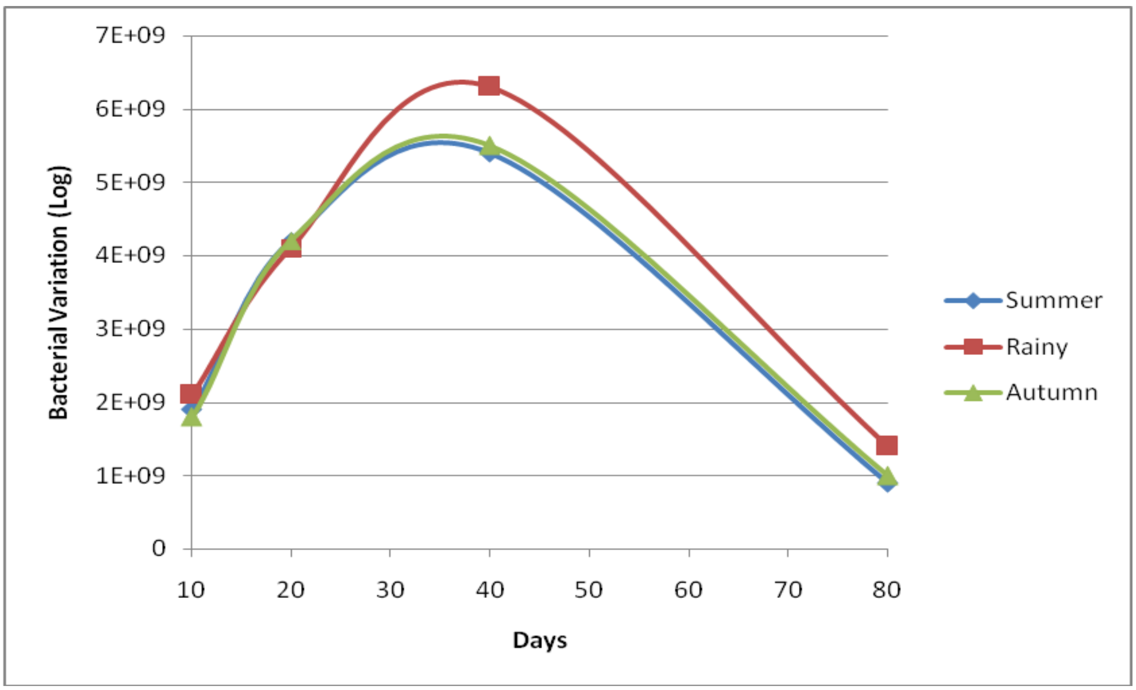


Fig. 5.7a

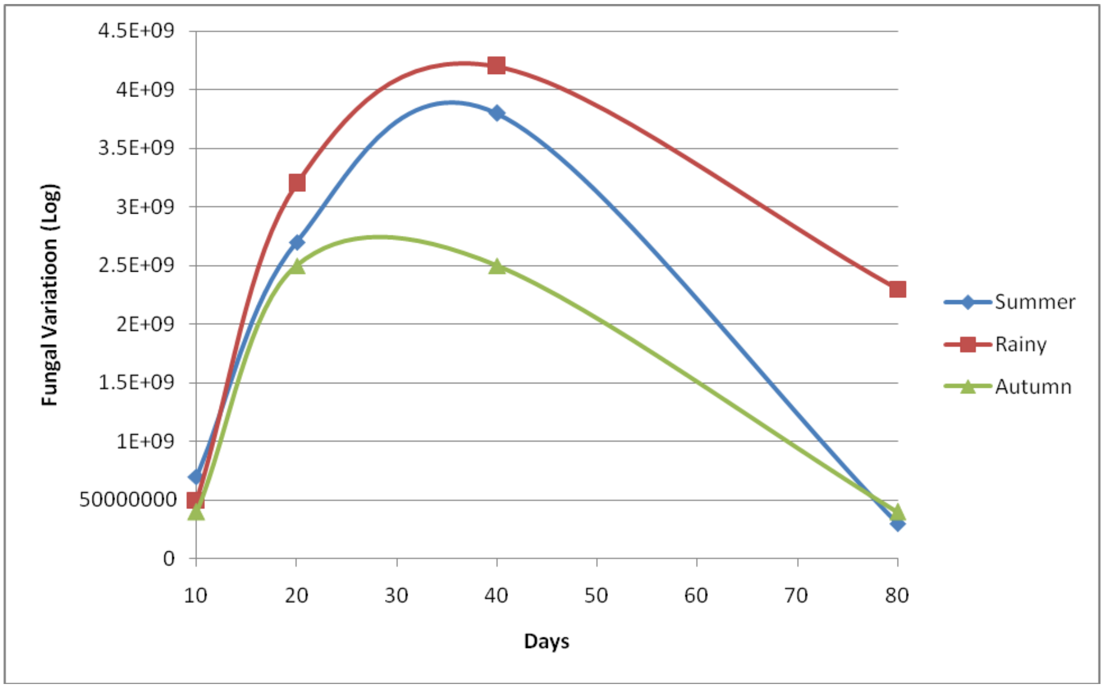


Fig. 5.7b

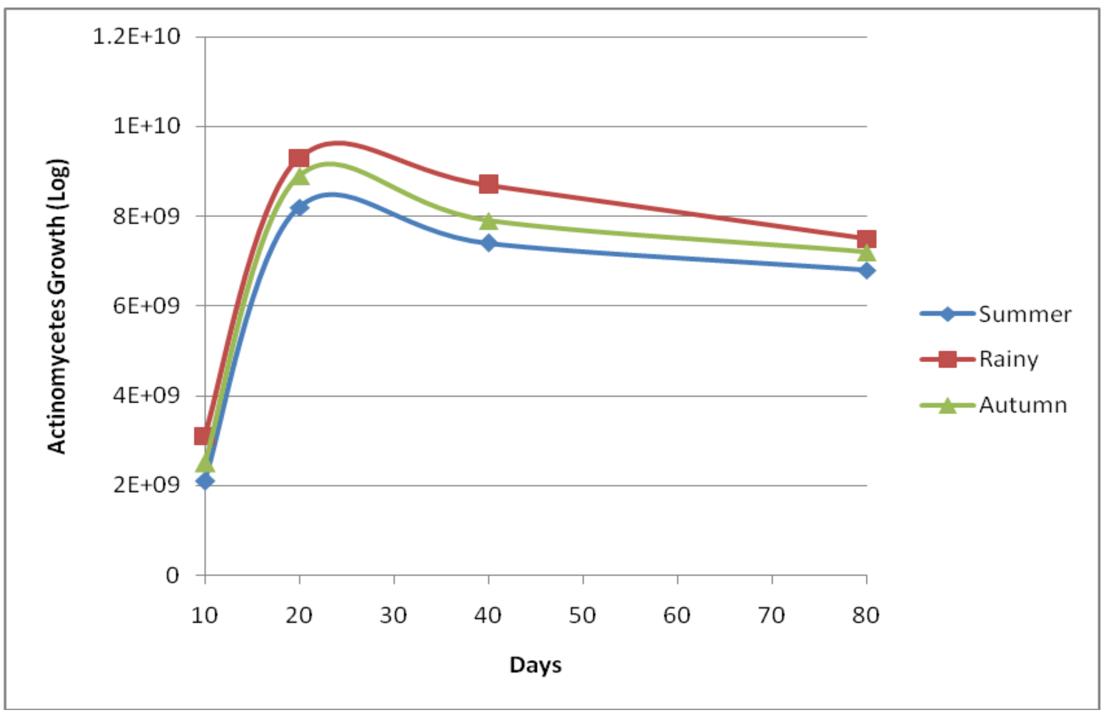


Fig. 5.7c

Figure 5.7 Succession in microbial population (a=Bacteria, b=Fungi, c=Actinomycetes) during composting process of KW of four season

Study on thermophiilic bacteria reported that number of microbial colonies in inversely proportional to temperature, as the temperature rises, there is decrease in microbes. Similar results were found in our study, higher the temperature during summer lesser the number of viable microbes, followed by Autumn and rainy. Highest number of microbial colonies were noted in between 30 to 40 days of composting in all three seasons (Fang and Wong, 1999).

Fungal study on compost

The total viable fungi per gram of compost ranged from 0.7 X $10^9$to 3.8 X 10^9 CFU in summer, 0.6 X 10^9 to 4,2 X 10^9 CFU in rainy, 0.4 X 10^9 to 2.5X 10^9CFU in autumn seasons and number of mesophillic fungi disappeared within 10 days of composting, on the other hand, the thermophiilic fungi increased and reached the maximum number after 30days of composting and then gradually decreased (Fig. 5.7b). These findings were in conformity with other reported studies (Singh et al., 2012). However this decrease was maximum in summer season, and lately at the final stage of composting, fungal colonies were higher in rainy season followed by Autumn and lowest were in summer, this may be dues to adverse temperature and pH during summers. Earlier studies by reported that, microbial population fluctuates mainly by physical parameters (temperature and pH) (Ryckeboer et al., 2003).

Actinomycetes composition in compost

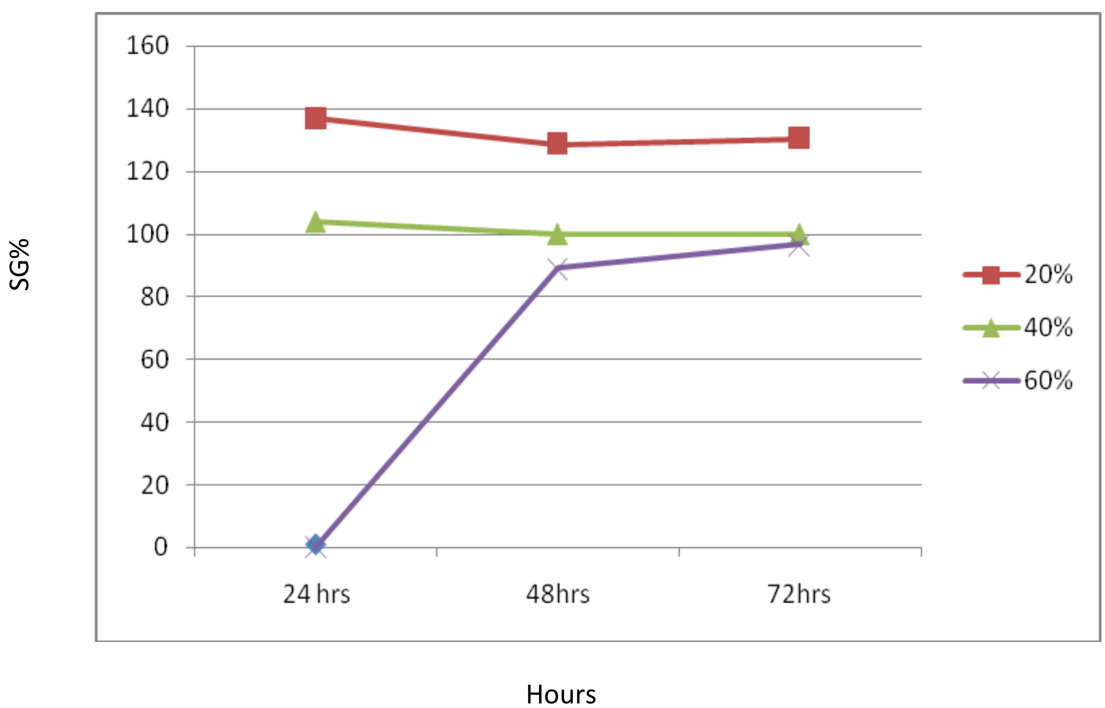
Actinomycetes were the highest microorganism in comparison with bacterial and fungal colonies. Initially Actinomycetes counts were higher in rainy season, than in autumn season and were less in summer. Gradually increase in the Actinomycetes count during composting was observed in all three seasons, and almost nearly equal around 40 days of composting In this study, the decline of temperature indicated that the compost had gone through the thermophiilic stage and approached maturity, the biomass of Actinomycetes also decreased with composting age, At final stage of composting Actinomycetes were lower in summer season while higher in rainy (Fig. 5.7c).

The most common microorganisms were bacteria, then Actinomycetes and lastly fungi. During lagging phase mesophillic bacteria and lately thermophiilic bacterial composition were higher in comparison with mesophillic fungal colonies, this may be due to mesophillic fungi had shorter half life period than mesophillic bacteria. Bacterial flourished more rapidly due to their ability to grow rapidly on soluble proteins. Bacteria grow more rapidly in available substrates due to their tolerance strength for high temperatures.

Initial decomposition of organic materials and generation of thermophiilic bacteria and increase in composting temperature is mostly depends on mesophillic micro-organisms viable during composting. Several studies reported that, there was maximum increase in microbial composition of the compost under favorable environmental conditions (Fogarty and Tuovinen, 1991; Nakasaki et al., 1985; Singh et al., 2012).

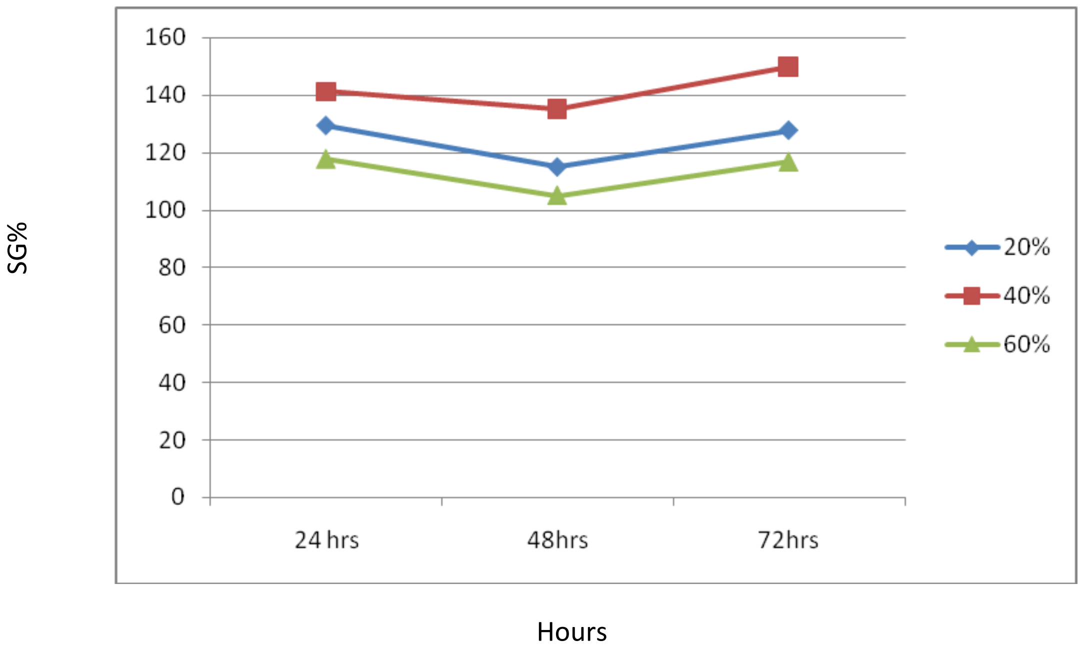
Phytotoxicity assessment

Seed germination: The toxicity and maturity of compost has been estimated in all four seasons in three different composting concentrations by using seed germination and relative root elongation percentages.



Fiure 5.8a : Seed Germination% Spring Kitchen waste compost at different level of concentration.

During spring season, there was 86% and 90% seed germination in C2 and C3 compost composition respectivelyas shown in figure 5.8a, which was selectively higher than control compost (63%). The percentage of seed germination was gradually increased in all four compositions, but reaches maximum in C2 and C3 compost after 72hrs of composting. Initially C4 of compost shown no growth, which reveals presence of toxic elements or higher amount of minerals than required for minimal growth. After 72hrs, C2 and C3 compost was found appropriate concentration of matured compost as shown in figure 5.8a



Fiure 5.8b : Seed Germination% Summer Kitchen waste compost at different level of concentration.

During Summer, according to figure 5.8b C3 compost shown maximum growth rate (90%) in all four types of compost. Interestingly C4 composition of compost also shown seed growth equivalent to control compost which is may be due to temperature gradient during summers, which enhances activity of thermophiilic bacteria, thus provide minimal growth even at higher mineral concentration. The N- NO_3^- , $P_{(CAT)}$, $K_{(CAT)}$ and $Mg_{(CAT)}$ found maximum in summer.

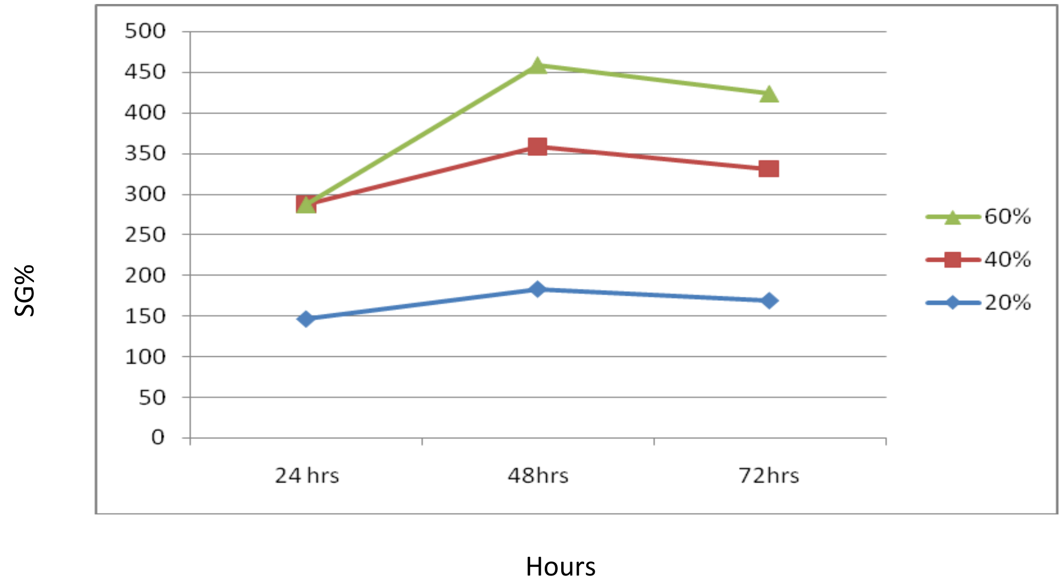
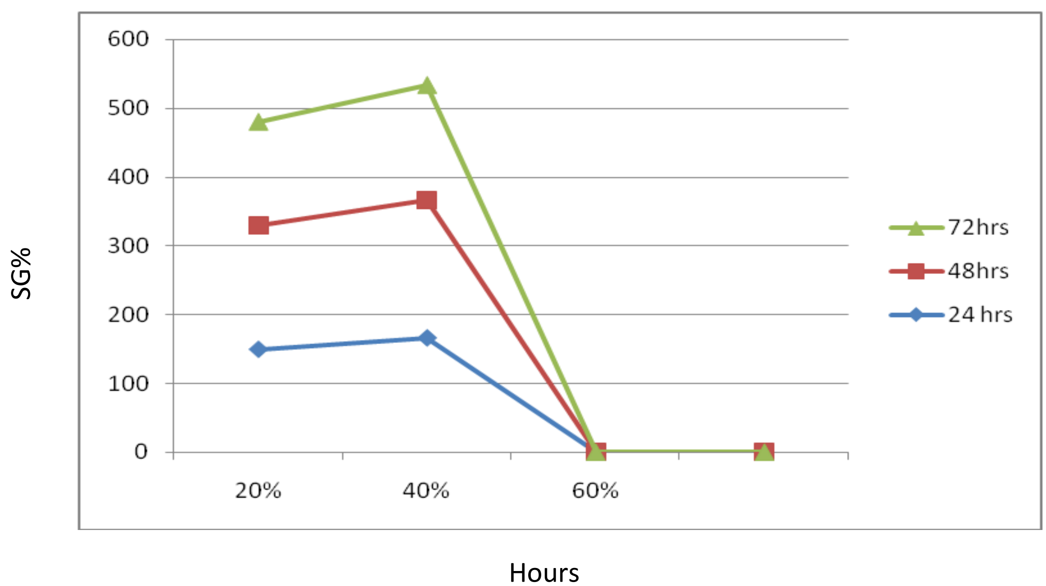


Figure 5.8c : Seed Germination% Autumn Kitchen waste compost at different level of concentration.

In Autumn, figure 5.8c reveled, C2 compost provides maximum nutrients for growth, almost 23% higher in comparison with control compost, while C3 compost also found almost similar results as per C2. C4 compost shows no growth initially and minor growth after 72 hours.

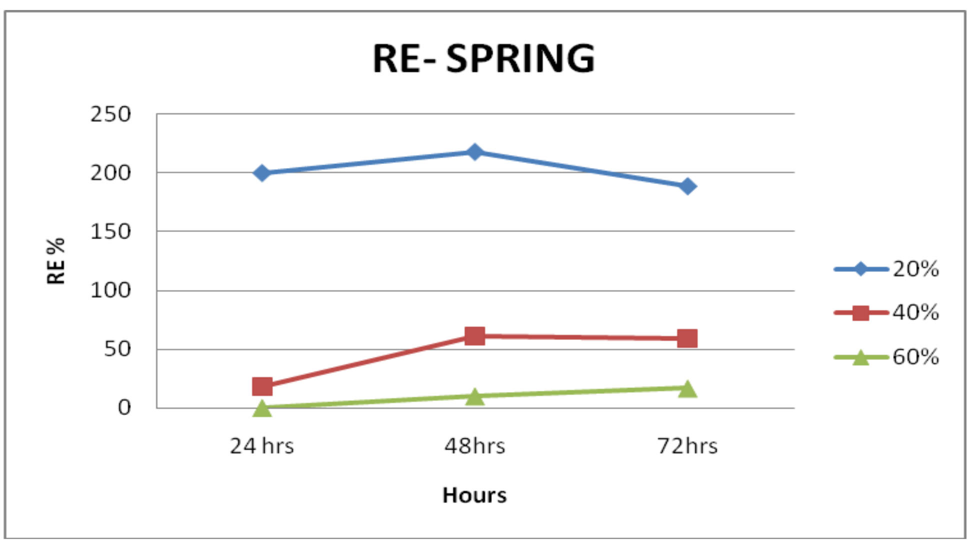


Fiure 5.8d : Seed Germination% Winter Kitchen waste compost at different level of concentration.

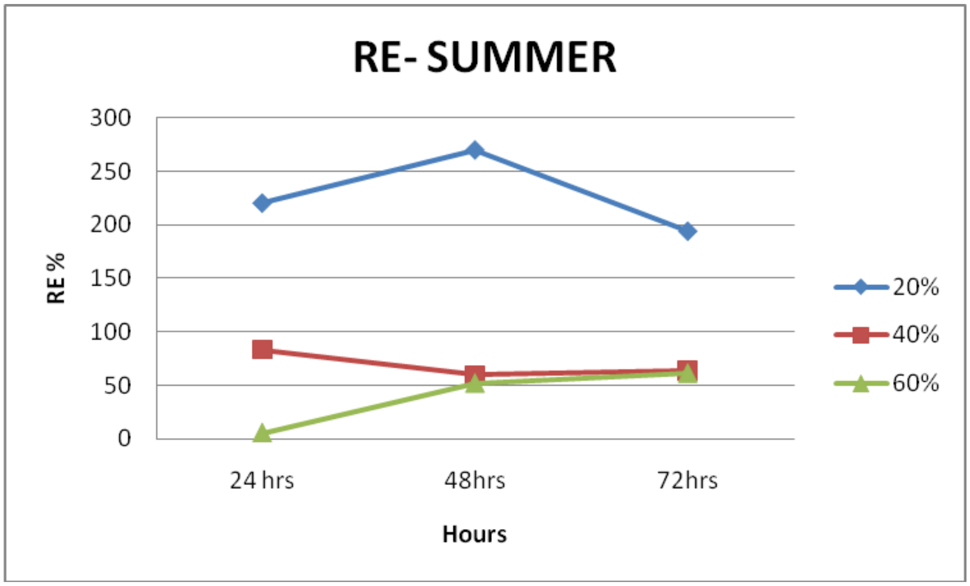
In winter's when moisture content increases, C3 compost was the best composting concentration as it shows 26% greater than growth provided by control compost, again C2 provide growth concordant to C3 compost and C4 provides no growth throughout the 72hours as shown in figure 5.8d. Thus, C2 and C3 were found for maximal growth in all four seasons.

Root Elongation:

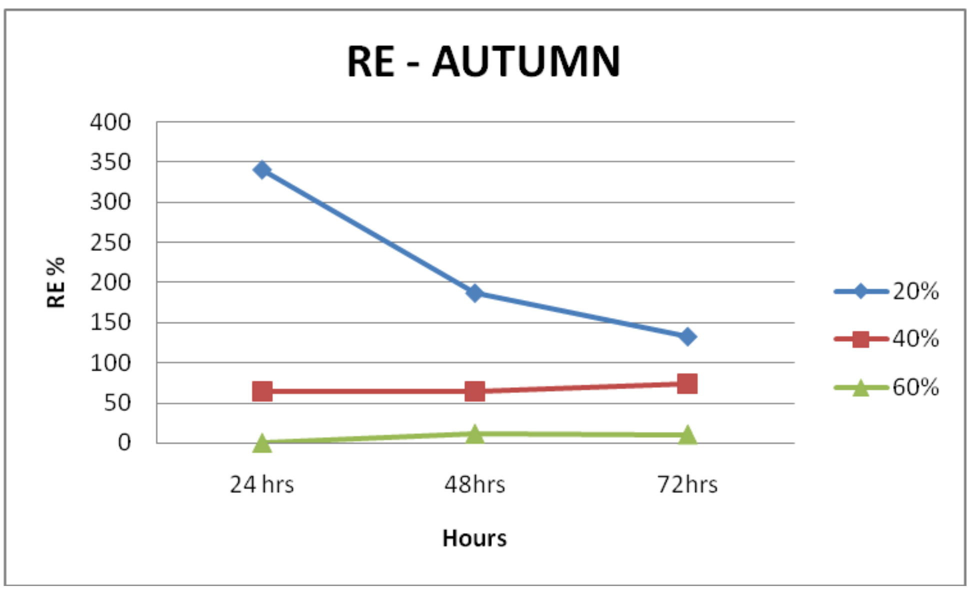
As there were maximum percentage of seed germination was observed in C2 and C3, favorable results were found in their root elongations also. During spring season root length in C2 treated compost was double in comparison with control which was gradually increased with time and remained double as shown in figure 5.9a in comparison with control. similar results was obtained in summer season (figure 5.9b.) also, were root length was maximum in C2 composition throughout the time . In C2 maximum root length reached in 48hours of composting. C3 also showed significant root length in 48hours and 72hours. While there was no to minimal growth in C4 compost water extract. Similarly Autumn and winter seasons according to figure 5.9c,d, shown maximum root length in C2 composition, in autumn season C2 shown 77% greater root length in comparison with control while in winters its 63% greater root length.



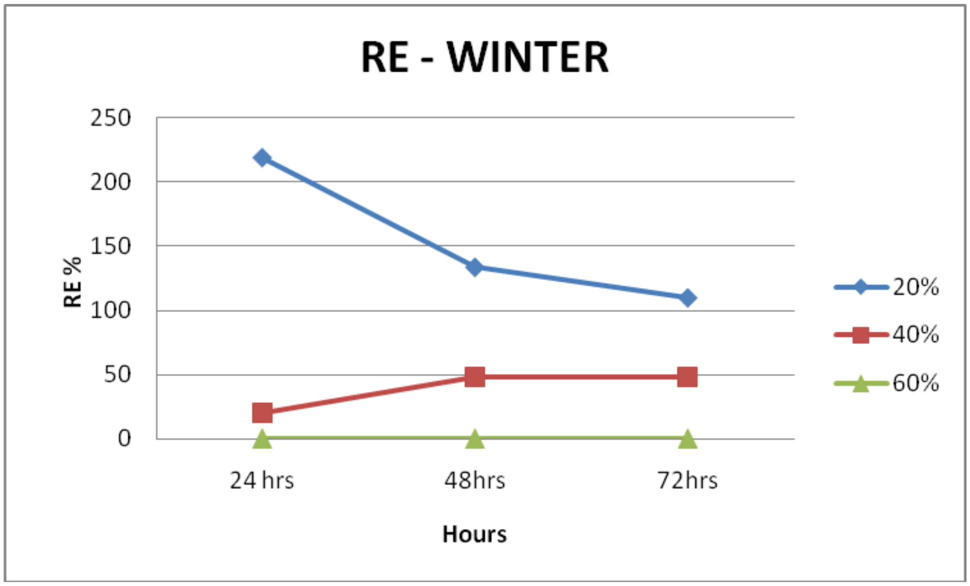
Fiure 5.9a : Root Elongation (RE)% Spring Kitchen waste compost at different concentration with hours



Fiure 5.9b.: Root Elongation (RE)% Summer Kitchen waste compost at different concentration with hours



Fiure 5.9c : Root Elongation (RE)% Autumn Kitchen waste compost at different concentration with hours.



Fiure 5.9d : Root Elongation (RE)% Winter Kitchen waste compost at different concentration with hours.

Germination Index (GI)

Consistent with the results of seed germination and root elongation in all four seasons , C2 compost shows maximum germination index in all four season as shown in figure5.10a,b,c and d. In the 24 hours GI was around 27% in C2 which was maximum in all four types of compost, this was gradually increased and reaches maximum in 48hours. But after that, GI in all four types of season's compost extract was tend to decrease. In summer there was 4% decrease in C2 compost, in summer (figure 5.10b) its 6% decreased in GI, while in autumn(figure 5.10c) GI falls almost 12% in 72hours, and in winter there was 8% decrease in GI was noted. Above results revealed that C2 compost is the most prominent for seed germination and root elongation in at 48hrs of time, thus it is considered as best concentration for seed germination which is significant in comparison with control compost. Thus, it would be beneficial to use C2 compost composition of every season and autumn season compost extract found to be more beneficial for provide better agricultural applications.The elimination of phytotoxicity has also been widely used as a measure of compost maturity (Wei *et al.*, 2000 ; Butler *et al.*, 2001 Cambaradella *et al.*, 2003 and Menunchang *et al.* 2005).

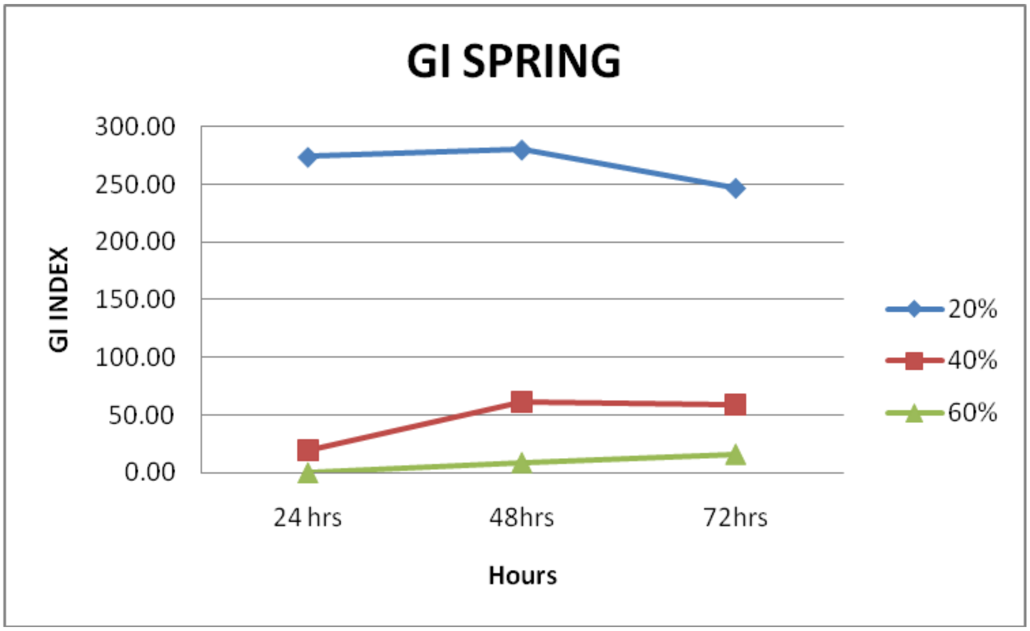


Figure 5.10a : Germination Index Spring

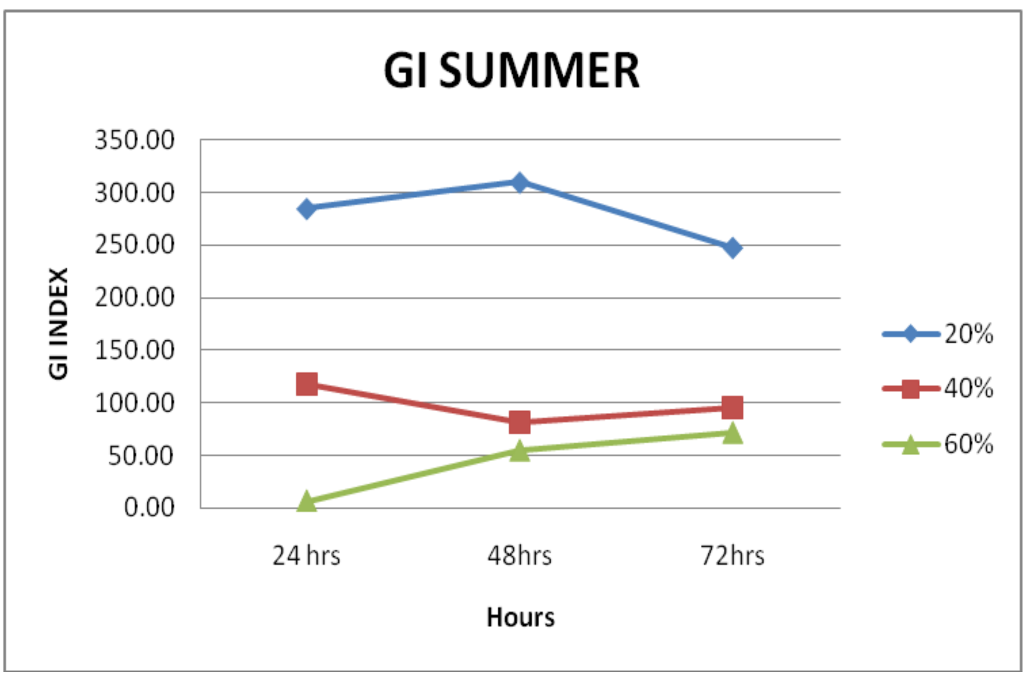


Figure 5.10b : Germination Index Summer

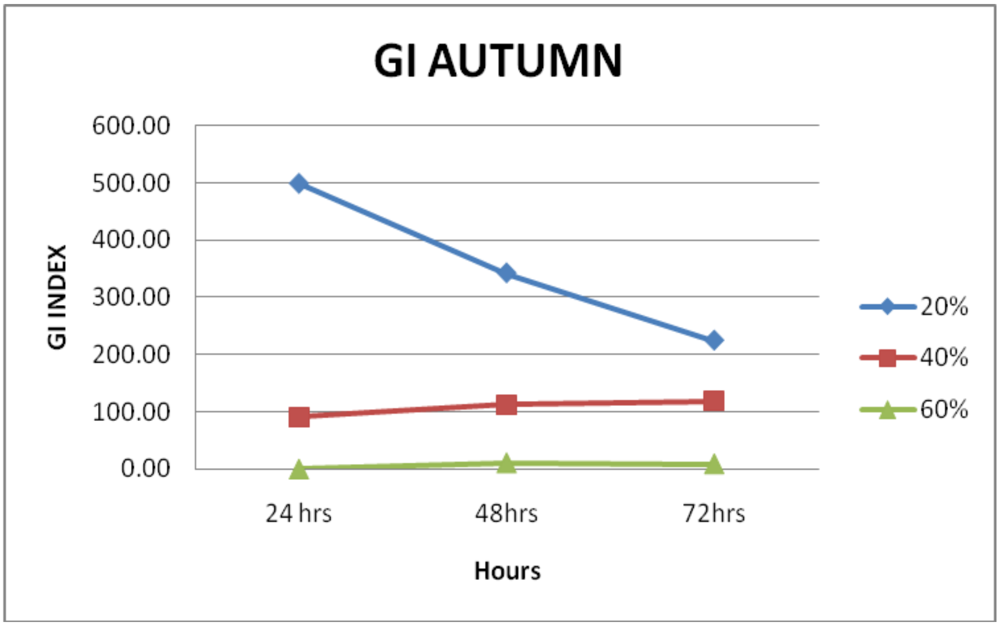


Figure 5.10c : Germination Index Autumn

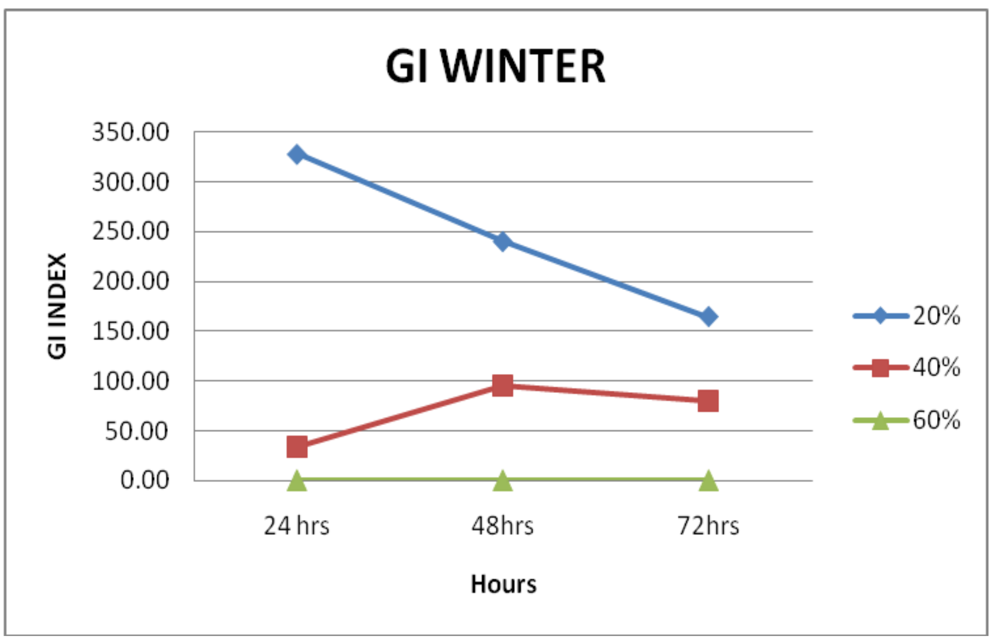


Figure 5.10d : Germination Index Winter

Conclusion

This study revealed that kw has good potential for recycling . KWC compostion varied according to season and the seasonal feedstock (raw material used in composting).The various parameters proved autumn season's KWC as the best compost reflecting the high content of nutrients in plant feedstock and the highest mineralization rate KWC of autumn season provide best plant nutrition. The toxicity and maturity assessment of Kitchen waste compost of different seasons at different level of concentration directly proportional to seed germination , root elongation and germination index ,unmature Kitchen waste compost (high concentration of $N\text{-}NH_4^+$ to $N\text{-}NO_3^{-)}$ inhibiting seed germination and root elongation.Kitchen waste composting by using aerobic vessel method may be considered as an eco- friendly and also job orienting method at large scale

Chapter-06

Development of enriched compost through microbial inoculation

Chapter 6

6.1 Introduction

Benefits of organic fertilizers for soil fertility & agricultural production have been known for decades, but they are inadequate in terms of nutritional content &nutrient supply. Total nutrients reproduced from the surface of the biomass are much less than the number of crops used. The composition of composts is essential in the production of micro-organisms such as free living with nitrogen fixers; phosphate solubilises and many. To recover nutritional grade of the compost. Therefore, there is a need for fortification of compost.

Trichoderma species are non-pathogenic fungi often found in soil as well as in association with plants. These green coloured fungi are well known for their anti-fungal and/or plant-growth-stimulating effects. Some Trichoderma strains may also be able to colonize root surfaces and cause substantial changes in plant metabolism. Furthermore, Trichoderma may produce organic acids that decrease soil pH and permit the solubilisation of phosphates, micronutrients and mineral cations like iron, manganese, and magnesium that are useful for plant metabolism. Molecular study revealed that Trichoderma metabolites or roots colonization by Trichoderma, changes the proteome and transcriptome of plants. The effect of Trichoderma on plant growth and productivity has been studied for a large number of plant species mainly in greenhouse or in pot experiments

For these reasons, several strains of Trichoderma have been developed into biological control products which are used all over the world to combat fungal plant diseases on various crops. Most of these biological control products are from the species *Trichoderma harzianum, T. viride* and *T. atroviride.*

Trichoderma strains can directly or indirectly exert biological control activity against fungal pathogens (Benitez et al., 2004).Trichoderma can attack fungal pathogens directly by producing toxins and/or enzymes that cause shrivelling, hyphal disintegration and ultimately death of pathogen hyphae, a phenomenon called antibiosis . Trichoderma are also parasites of other fungi (mycoparasites) in which case they attach to, coil around and penetrate the hyphae of the host fungi .Indirectly Trichoderma compete with pathogens for space and nutrients and may also induce plant resistance to pathogens either by making the plant synthesise defence compounds or by priming the plant, making it respond quickly to stop infection. Trichoderma species have a tremendous ability to establish in numerous environments, grow rapidly and successfully compete with other microorganisms. It has also been found that Trichoderma promotes growth by stimulating root proliferation (Fourie et al., 2001) and hence their application as biofertilisers and not biological control agents.

The two Trichoderma species, *Trichoderma harzianum and Trichoderma virens* has been found for growth promotional activity which was correlated with productive configuration of tangential heredity (Contreras-Cornejo et al., 2009).

6.2 Material and Methods

As the chapter 5, statistical analysis result reveals that kitchen waste compost of autumn season found to be best content in microbial, physicochemical analysis and best seed germination index. Therefore KWC of autumn season selected for microbial enrichment.

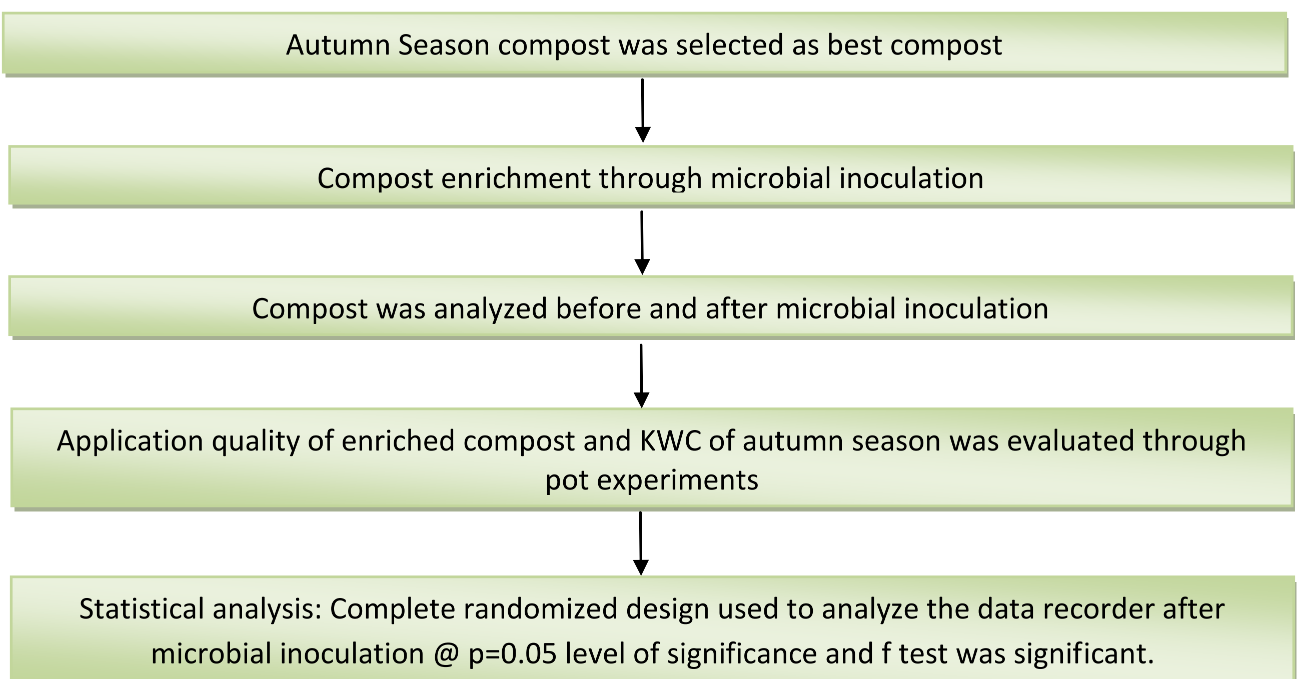


Fig 6.1 Flow chart representing Enrichment of organic kitchen waste compost(OKWC)

6.2.1.a Microorganism used in experiment

For mictobial analysis (bacteria and fungi) methodology of chapter 5 (5.2.2.2) is used. For inoculum, the growth *Trichoderma harzianum* strain 1373 was obtained from National Chemical Laboratory, Pune, Maharashtra, India. This fungus strain was accounted for as plant development promoting and potential bio-control agent against a wide scope of bacterial and fungal pathogens causing economically imperative issues in agriculture. They were kept frozen in glycerol at −80 °C temperature until use.

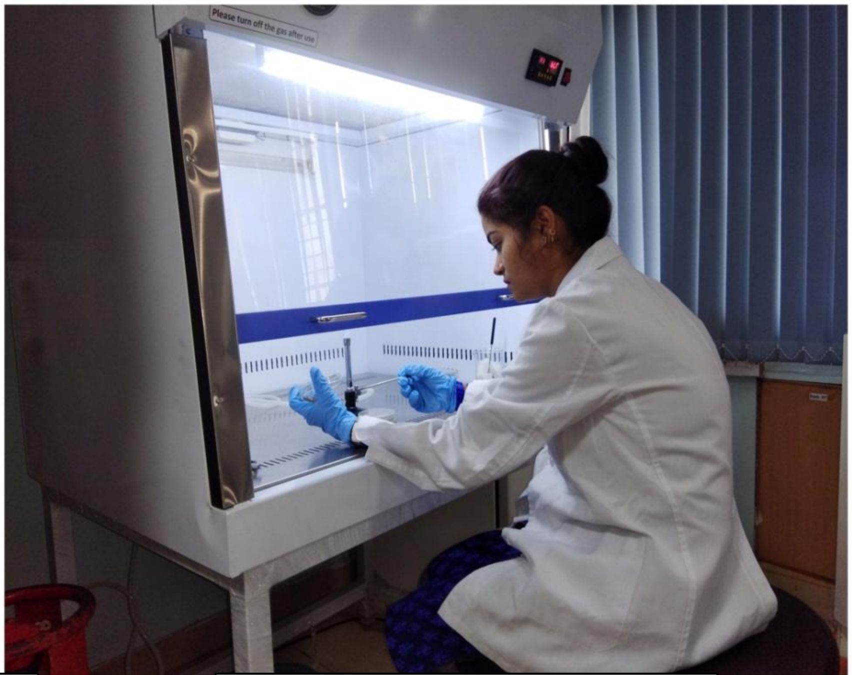
6.2.1.b Physicochemical analysis

All the given physicochemical parameters were analysed as per methodology 5.2.2.1 of chapter 5.

6.2.2 Inoculum preparation for OKWC enrichment

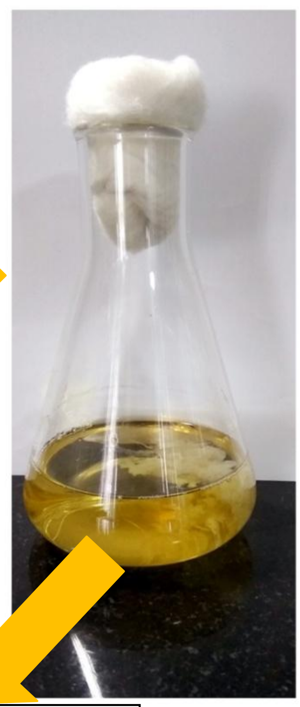
A single fungal colony growing on potato dextrose agar (PDA). Petri dishes equivalent to the picked strains were used as the basis for the creation of inoculum for the experiment. The inoculum of *Trichoderma harzianum* was grown on synthetic PDA medium (SRL, India) for 7-8 days and incubated at 28±2 ^{0}C for 7-10 days. The inoculum was kept in B.O.D. incubator for 10–12 days for maximum growth and sporulation. Usually, *Trichoderma harzianum* development was assessed by estimating its growth diameter from an attachment with 5 mm diameter in 10-day-old mycelium developed on agar situated at the focal point of each petri dish. The shape and colour of the colony were studied on the 7th day and the sporulation rate was checked in the meantime as the colony develops. Mycelium with spores from one Petri plate was scratched from the surface of medium and transferred to 500-mL flasks containing PDB, and developed aerobically in flasks on an orbital shaker (150 rpm) at 28±2 ^{0}C for 7-10 days. The fungal suspension was then diluted in sterile distilled water to a final concentration of *Trichoderma harzianum* spores (5 ml·1 dm^{-3}; 10^{8}cfu/ml) and the subsequent suspensions were utilized to compost enrichment.

Trichoderma harzianum 1373 culture



Culturing *Trichoderma harzianum* in Laminar flow cabinet

Prepared *Trichoderma harzianum* culture



A close view of Prepared *Trichoderma harzianum inoculum*

Fig 6.2 A general view of preparation of *Trichoderma harzianum* culture

6.2.3 Composting Experiment Setup

This experiment was directed in the green house of Department of Human Development and Family Studies during july to august month of 2017year. The prepared manure utilized in this investigation was prepared in our research center. The compost had following values of physico-chemical parameters pH (8.10), Nitrogen (2.43%), C:N ratio (21.33%), DOC (0.74%), N-NH_4^+(25.77ppm), N-NO_3^-(73.54ppm), P_{CAT} (290 ppm), K_{CAT}(13210 ppm) and Mg_{CAT}(501ppm), respectively before enrichment at 0 day.

The KWC containers were turned twice, this being sufficient to accomplish temperature adjustment, and were completely treated the soil in three months. The KWC sample (1.5 kg) was exchanged to every plastic pot (12 cm breadth × 13 cm height). The organic compost was inoculated with the prepared suspension of *T. harzianum* spores (5 ml•1 dm^{-3}; 10^8 cfu/ml) in each container. After this, *T. harzianum* were blended with the manure in the KWC container and incubated at 60% of water-holding limit in dark at 25°C for 45 days (Bernal-Vicente et al., 2012).

6.2.4. Trichoderma colony forming unit (CFU) estimation

KWC (autumn) samples were taken before and after applying *Trichoderma harzianum* to the composting containers, and then blended homogenously. Five grams of compost test was weighed out and 50 mL sanitized distilled water was included before shaking with the orbital shaker at 210 rpm for 30 minutes. Then, 1 mL of the compost solution was added to 9 mL saline water for the first (10^{-1}) dilution. The serial dilutions of 10^{-3} and 10^{-5} were used for Colony Forming Unit (CFU) measurements. Around 1 mL of compost solution was pipetted out and seeded into each Petri dish followed by pouring 9 mL of sterilized *Trichoderma harzianum* Selective Medium (TSM) [0.20 g of $MgSO_4.7H_2O$, 0.90 g of K_2HPO_4, 0.15 g of KCl, 1.0 g of NH_4NO_3, 3.0 g of glucose, 0.15 g of Rose Bengal, 20.0 g of agar and 1000 mL of distilled water] as detailed earlier (Elad et al.1981). Manually each Petri dish was swirled before being allowed to solidify and then incubated at 28±2 ^{0}C for 7 days. Fungal colonies could be seen as small whitish spots developed. Each single colony appearance was scored as a Colony Forming Unit (CFU), assessed and re-isolated onto Potato Dextrose Agar (PDA) (Oxoid, UK).

6.2.5 Statistical analysis

According to Gomez and Gomez (1976), complete randomized design was used to analyze the data recorded after microbial inoculation. The level of significance used was p = 0.05. The critical difference (CD) and coeeficient of variation values were calculated wherever the 'F' test was significant. All statistical analyses were performed using the SPSS V.20

Result and Discussion

Table 6.1 Changes in physico-chemical parameters in kitchen waste compost (Autumn) after microbial inoculation.

Parameters	0 Day	7th Days	14th Days	21st Days	28th Days	Mean	MIN	MAX	CV(%)
pH	8.10	8.13	8.27	7.10	6.13	7.55	0.92	6.13	12
VS(%)	63.00	61.33	61.00	60.00	58.33	60.73	1.72	58.33	3
Nitrogen(%)	2.43	2.81	3.13	2.13	2.00	2.50	0.47	2.00	19
C:N	21.33	20.95	21.00	20.50	21.01	19.69	2.82	14.68	14
DOC(%)	0.74	0.75	0.75	0.77	0.74	0.75	0.01	0.74	2
N-NH_4^+(ppm)	25.77	25.77	25.78	25.70	25.75	25.75	0.03	25.70	0
N-NO_3^-(ppm)	73.53	73.53	73.53	73.55	73.52	73.53	0.01	73.52	0
P_{CAT}(ppm)	290.00	309.43	336.73	324.77	205.33	293.25	52.17	205.33	18
K_{CAT}(ppm)	13210.00	13876.67	15456.00	12125.67	11168.33	13167.33	1645.00	11168.33	12
Mg_{CAT}(ppm)	501.00	511.22	524.34	420.67	327.67	456.98	82.85	327.67	18

6.3.1 Changes in the physiochemical parameters after microbial inoculation

Kitchen waste compost enrichment with microbial inoculants results in significant change and high decrease in pH, total organic carbon (TOC), electrical conductivity (EC) and C:N ratio and inversely significant increase in total content of available nitrogen, available phosphorus, exchangeable potassium (Nath et al 2009). The changes in some of the important factors are listed below.

pH

Discrimination of various physiological parameters of compost after microbial inoculation is mentioned in table 6.1 pH effects composting process throughout by discriminates its acidic or alkaline nature. In this study, pH before enrichment was higher around 8.10, after enrichment with *Trichoderma harzianum* , pH value initially increased to a minor degree, then it decreases and almost become neutral in 21 days. At 14th day, compost achieved maximum maturity. Statistical analysis revealed 12% of coefficient of variation in comparison of before and after enrichment.

VS content

The most specific parameter for estimation of age, physical parameters and maturity of compost is VS content. Composting maturation begins with the initiation of mineralization reactions, and if composting process operates properly, VS content tend to decrease which was observed before and even after microbial enrichment. Gradual decrease in VS content after microbial enrichment represent beneficial applications of *Trichoderma* in maturity of compost.

EC of compost

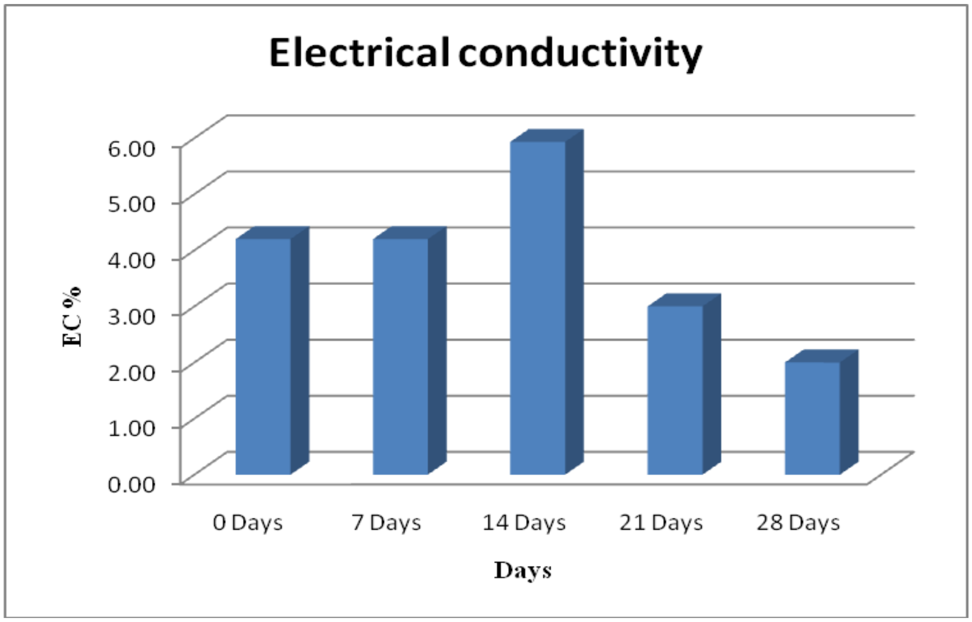


Figure 6.3: Change in EC% after microbial inoculation.

Electrical conductivity of compost is depend on the ions concentration including, chloride, potassium, nitrate, sulphate and ammonia salts (Brinton, 2003), carries electrical charges and maintain the ability of electrical conductivity of compost.

Total ions concentration including, chloride, potassium, nitrate, sulphate and ammonia salts manage EC content of compost. Initial increase in EC content was observed after microbial inoculation, which reaches to maximum at 14th day after inoculation (6%), then tend to decrease in post following days and become normal in 28th day. Decrease in EC could also be explained as increase in concentration of nutrients such as nitrites and nitrates, figure 6.3.

Nitrogen content

Microbial inoculation increases nitrogen concentration of compost gradually in 14 days and peaks at 14^{th} day. Before enrichment, nitrogen was low (1.2 - 1.5 %) but it becomes almost double in 14^{th} days after enrichment with *Trichoderma* with coefficient of variation of 19%. Increase in nitrogen content has many agricultural applications. Microbial inoculation with N2 fixing bacteria into compost increased contents of N and P (Kumar and Singh 2001).

Mahanta *et al.* (2012) also reported that microbial enriched compost showed significant increases in N content. Most of the organic manures are very low in nutrient contents, which are not sufficient to meet the nutritional requirement of the crops, especially when inorganic fertilizers are not applied (Manna *et al.*, 2001). Under such circumstances, fortification of organic manures and composts with permitted additives like beneficial microbial cultures is a feasible option for nutrient supplementation in organic food production.

The enrichment of the organic manures with beneficial microbial cultures will further contribute to the enhancement of N and P contents through nitrogen fixation and phosphate solubiliztion.

C:N ratio

Change in parent composition of compost changes its C;N ration which in turn changes efficiency and effectiveness of compost. C:N ratio remains unaffected after microbial inoculation, thus maintain equilibrium between cooling and heating process of compost.

Total organic carbon and Dissolved organic content

Microbial population in compost tend to be responsible for decomposition of waste which decreases percentage of carbon content of compost. Enrichment of compost with microbes enhances DOC with negligible range over 28days with coefficient of variation only 2%. Hue and Liu suggested a value of 10 g kg^{-1} as a threshold for compost maturity.

Nitrogen transition

According to Mahanta *et al.* (2012), Nitrogen concentration of compost increases after microbial inoculation, but as soon as compost gains the maturity, nitrogen transition to N-NH4 and N-NO3 becomes constant, which was clearly evident in our study. Even after inoculation, N-NH4 and N-NO3 remained constant. indicating a no more dynamic N transformation during composting. It has been noted that the absence or decrease in NH4

+-N is an indication both for good composting and maturation process (Riffaldi *et al*., 1986 and Tiquia *et al*. 1996).

Other essential elements

various minerals and ions including potassium, magnesium and phosphorus constitute structure of compost. In kitchen waste compost(autumn season), CAT solutions were used(as mentioned in 5 material and method) in this study to estimate the amount of useful nutrients before and after microbial inoculation. The data recorded on the nutrient status of enriched compost revealed highest P, K and Mg content on 14th day of inoculation. Rapid growth in all three nutrient has been evident, P and Mg has 18% of coefficient variation while K increased around 12% .

Microbial Population

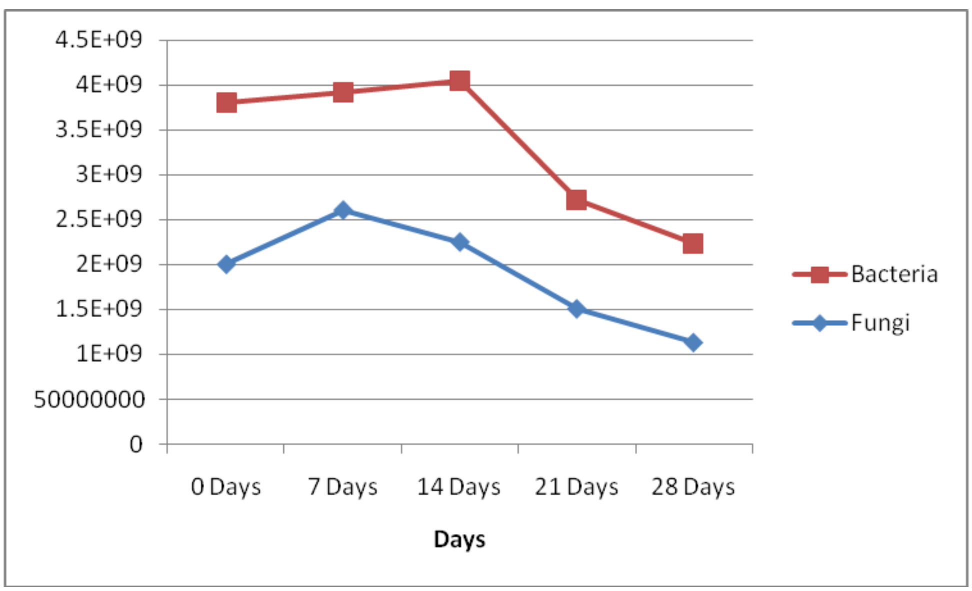


Figure 6.4: Change in Microbial growth after inoculation.

Both bacterial and fungal population of compost shown rapid increment just after inoculation for next seven days, on 14th day, microbial species becomes equivalent to before enrichment stage, and then gradually decreases as compost becomes more mature with basic nutrients. Thus enrichment of kitchen compost with *Trichoderma* results in 14th days of inoculation, thus 14th day inoculated compost would be beneficial for agricultural applications, figure 6.4.

Conclusion

From the above study it is concluded that *Trichoderma* is not only an effective bio-control agent, used an activator in composting and used in seed treatment but can also be used as better source of plant nutrition because the present result and discussion reveals that after enrichment of KWC with *Trichoderma harzianum* there were found some enhancement in nutrient composition of compost.This may be due to some enzyme secretion as it is also used as plant growth promoter. It may be posses support to mineralization process of KWC of autumn season. Enrichment of kitchen compost with *Trichoderma harzinum* results best on 14th days of inoculation, 14th day inoculated compost would be beneficial for agricultural applications.

Thus, microbial inoculation to prepared KWC of autumn season with potential of *Trichoderma harzianum* strain might be beneficial in enhancement in nutritive value of KWC of autumn season.

Chapter-07

Examination of the application quality of prepared and enriched compost through comparative pot study

Chapter 7

Tomato (*Lycopersicum esculentum Mill.*) is one of the most popular vegetables worldwide, and contains carbohydrates, amino acids, minerals, and vitamins. Yield and nutrient content of tomato are dramatically affected by the application of inorganic fertilizer. In fact, non-judicious use of inorganic fertilizer may lead to environmental pollution including contamination of groundwater, and soil acidification as well as increase gentrification resulting in higher the emission of nitrous oxide (N_2O) to the atmosphere which is responsible for global warming. Currents efforts include exploring the possibility of substitution of inorganic fertilizer with organic ones which are eco-friendly and cost effective. Some previous researches suggested that organic fertilizer can be combined with inorganic fertilizer at rates below those recommended for sustainable tomato production. Yield of tomato are significantly lower in organically fertilized plants than the plants that receiving inorganic fertilizer . In recent years, bio fertilizer, products containing living cells of different types of microorganisms have emerged as an important component in integrated nutrient supply system and hold a great promise to improve yield and quality of crop through better nutrient supplies.

Figure 7.1 : A general view of experimental plants in green house

Tomato plants are affected by several diseases, including Fusarium wilt caused by *Fusarium oxysporum f. sp. lycopersici (sacc.)*. This is a destructive disease of tomato worldwide. Methods used to control vascular wilt are either not very efficient or are difficult to apply. The best way to control the disease is by selecting resistant varieties of tomatoes. Although commercial varieties of tomato resistant to *F. oxysporum f. sp.lycopersici* races 1 and 2 are available, additional pathogenic strains and race 3 of the pathogen has been reported in several countries. For this reason, alternative methods of controlling the disease have to be explored inclusive of biological control methods.

7.2 Material and method

A pot culture experiment was conducted at Babasaheb Bhimrao Ambedkar University (BBAU) using KWC(Autumn) and with enriched KWC (KWC of autumn season with *trichoderma harzianum*) during *Kharif* 2018 to study the effect of the prepared KWC(Autumn) and enriched KWC on growth of tomato (*Lycopersicon esculentum* Mill) plant and their influence on nutritional assessment of tomatoes. The detailed information on the material used and experimental techniques adopted during the study period are presented in this section. For this study KWC of Autumn season was selected because compost of this season reveals best content of nutrients and microbial properties from 5th chapter's result.

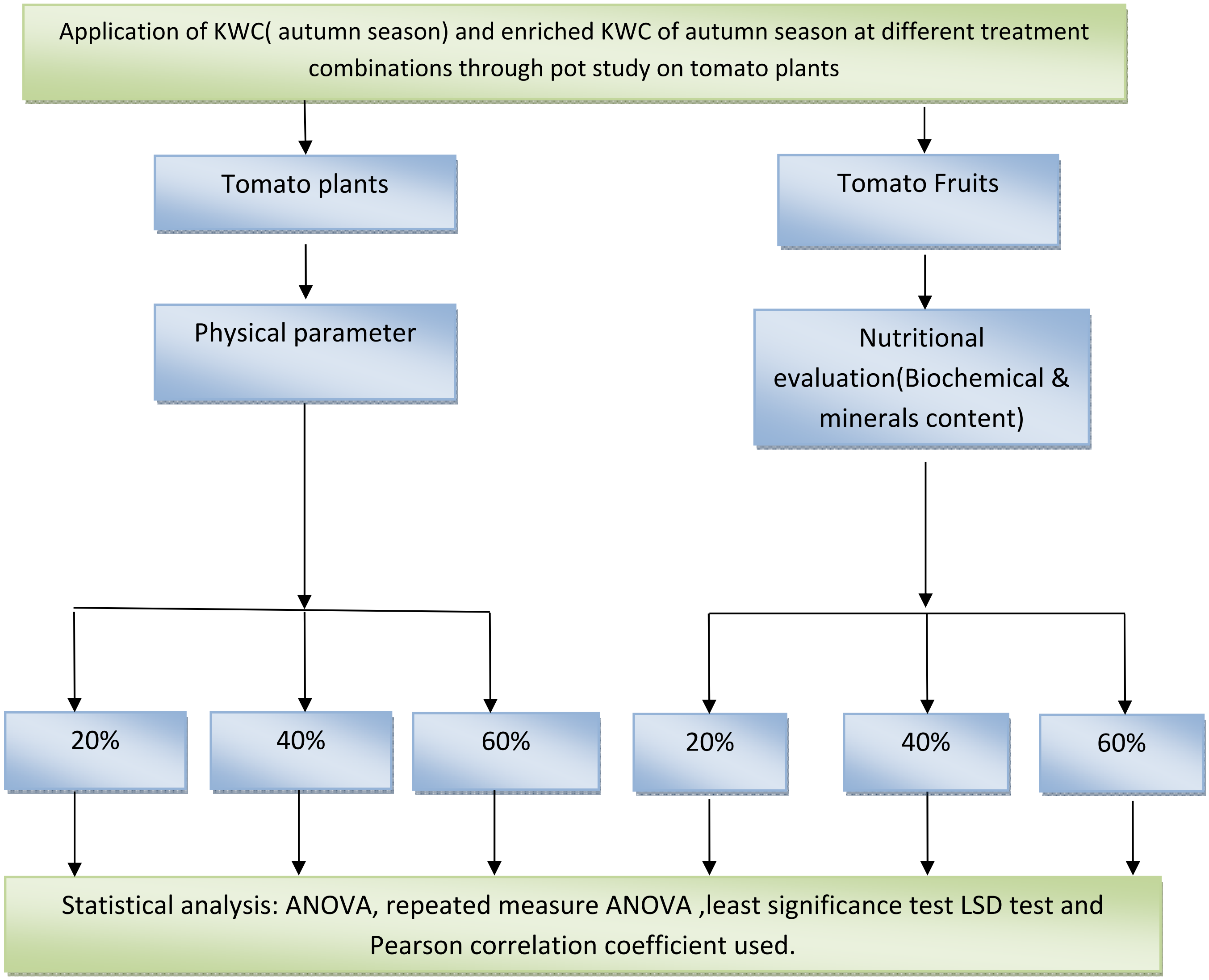


Fig 7.2 : Flow chart representation of steps involved in application quality of prepared compost through pot study

7.2.1 Greenhouse experimental details

- **Soil**

Soil Sample Collection Soil samples was collected from the horticultural farm of BBAU,Lucknow district. Soil sample was collected with the help of auger, and stored in polythene bags. Collected soil samples were air dried in shade, crushed gently with a pestle mortar and then pass through 2.0 mm sieve to obtain a uniform representative sample. Sample was properly labelled with tag and stored in polythene bags for analysis. The soil samples was processed and stored in the lab at suitable room temperature, and analysed for pH and Electrical Conductivityby using standard methods as per details given below:

a) Soil Reaction (pH) was determined by using 1:2.5 soils: water suspension with the calibrated pH meter (Hanna instruments H198129) by following the method given by Jackson (1973).

b) Soil Salinity (Electrical Conductivity) was determined by using 1:2.5 soil: water suspension with the calibrated conductivity meter (Hanna instruments H198129) by following the method given by Jackson (1973).

The microbial and physicochemical load in the KWC before and after their enrichment was enumerated at weekly intervals (0, 7th, 14th, 21st and 28th day) to determine the period on which maximum attainment of microbial population can be achieved. Analysis result of chapter 6 had clearly indicated highest microbial load (inoculated microorganisms) and nutrient content on 14th day after inoculation. Hence the KWC were enriched for 14 days based on the results of preliminary studies (by using chapter 6 methodology) and were used for pot culture experiment. The pot capacity was 10kg.

Figure 7.3 : A general view of preparation of seedling tray

- **Nursery bed preparation and transplantation**

For this coconut husk 250 gm (soaked overnight in water) used to germinate of tomato seed into baby plant .The soaked coconut husk was partially filled in the seed germination tray with 2-3 tomato seed in each provided area and again covered the sown seed by sprinkling soaked coconut husk .The 24 days old seedlings were uprooted and transplanted @ one baby plant per pot. Here , the coconut husk is used for seedling preparation because it have several best feature which support seedling growth such as water retention and drainage, low compaction, requires low maintenance, eco- friendly, disease –resistance and nutrient balance property.

- **Treatment combination details**

The experiment consisted of six treatments (with control, with KWC autumn and with enriched KWC). The total 21 no. of pots was used, as the experiment was done in triplicates.

Treatments Combination-

1.	**Control (C1)**	100% soil
2.	**T1**	20% KWC(Autumn)+80% soil
3.	**T2**	40% KWC (Autumn)+60%soil
4.	**T3**	60% KWC (Autumn)+40%soil
5.	**U1**	20% enriched KWC(Autumn)+80% soil
6.	**U2**	40% enriched KWC (Autumn)+60%soil
7.	**U3**	60% enrichedKWC (Autumn)+40%soil

Table 7.1 : Treatment combination for experiment

- **Crop details**

Location : Greenhouse, BBAU, Lucknow
Crop : Tomato

Variety : S-22

Season : *Kharif*

Design : Completely Randomized Design

Treatments : 07

Replications : 03@ (each) treatment

Prepared *Trichoderma harzianum* culture

Preparation of enriched compost

Distribution of enriched compost

Prepared experimental pots

Figure 7.4 : A general view of preparation of pot mixtures for pot experiments

- **Harvesting**

The matured red coloured tomato fruits were harvested and stored separately as per the treatments in the polythene bags to assess their nutritional content.

- **Collection of the experimental data**

The observations on various parameters were recorded at 25, 50 , 75.110 and 135 days after transplantation.

7.2.2. Prameters analysis

a.) Physical parameters of plants

Plant height-The plant height was measured in centimeters from the lower end of the stem to the tip of main shoot. The mean height was recorded and expressed as plant height in centimeters.

Numbers of leaves- The no. of leaves were done by counting from bottom at fix point to the top (last leaf of plant) it was started from 25^{th} day after transplantation.

Days to flowering- The data of flower initiation on each tagged plant was recorded again no. of days from date of transplanting were counted and recorded.

Numbers of fruits- The data of flower initiation on each tagged plant was recorded .The no. of days from date of flower initiation to fruit setting was counted and recorded.

Measurement of plant height

Floral counting in plants

Plants at fruiting stage

Figure 7.5 : A general view of plants growth at different stages

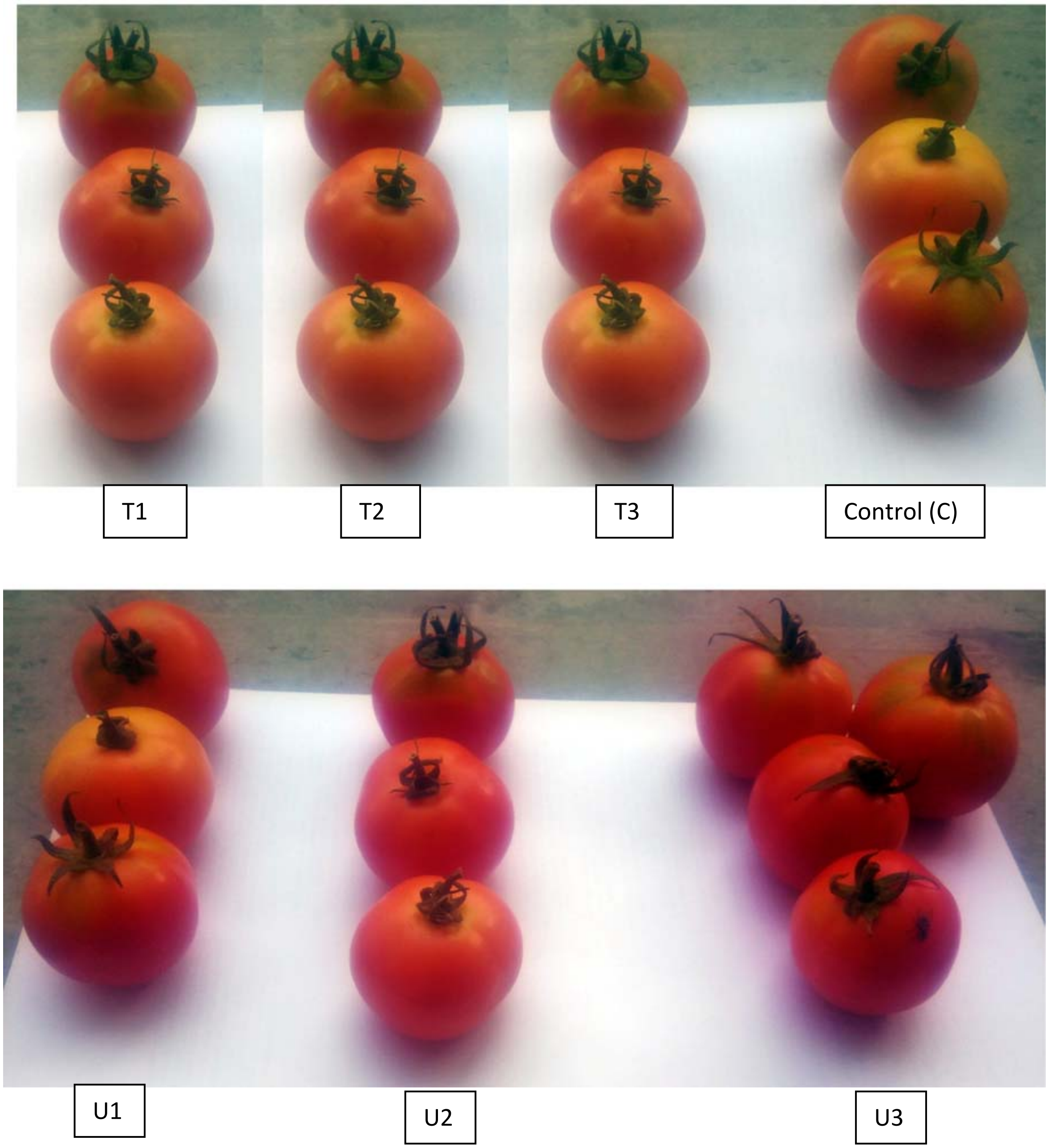


Figure 7.6 : A general view of experimental tomato fruits before treatments(T) and after treatments(U)

7.2.3 Nutritional assessment of fruits-

a.) Biochemical assessment

Estimation of Lycopene

Five grams of tomato pulp was taken in pestle and mortar and extracted repeatedly with acetone until the residue was colorless. The acetone extracts were pooled and transferred in to a separating funnel containing 20 ml of petroleum ether and mixed gently. The sodium sulphate (5%) solution was added at 20 ml and again petroleum ether was added. Two layers were separated into two beakers. The petroleum ether extract was poured into brown bottle containing about 10 gm anhydrous sodium sulphate and kept for incubation for 30 min. the colour developed was read in a spectrophotometer at 503 nm using petroleum ether as blank.

The lycopene (mg/100 g) content was calculated by using the formula given by Ranganna (1976).

$$\text{Lycopene (mg/ 100 g sample)} = \frac{31.206 \times \text{OD of sample}}{\text{Weight of the sample (g)}}$$

Estimation of Total soluble solid (TSS)

TSS was determined using hand refractometer immediately after harvesting the ripe fruits. The percentage of TSS in sample was recorded by using Erma made hand refractometer (lower range of 0 to 32 o Brix). The juice was extracted through cheese cloth and place on refractometer prism and reading were recorded and expressed in term of percentage total soluble solids (Ranganna ,1976).

Estimation of Total sugar (%)

For the estimation of total sugars the titrate obtained in the estimation of reducing sugars was used. An aliquot from the filtrate was taken 10 ml of hydrochloric acid was added and the inversion was carried out at room temperature for 24 hr. Subsequently contents were cooled and neutralized with 40 per cent sodium hydroxide using phenolphthalein as indicator and the final volume was made. The solution was filtrated through what man No.1 filter paper and titration was carried out using filtrate as detailed for reducing sugars. The total sugar content was expressed as percentage in terms of invert sugars according to the formula (Ranganna 1976). :

$$\text{Total sugar (\%)} = \frac{\text{Glucose equivalent of Fehling's solution} \times \text{Total volume Madeup} \times \text{Volume made up made up for inversion}}{\text{Titre} \times \text{weight of sample} \times \text{Aliquote taken for inversion}} \times 100$$

Estimation of Ascorbic acid (mg/100g)

The titrimetric method described by Ranganna (1976) was adopted. For this a known weight of the homogenized sample was taken and transferred to a 100 ml volumetric flask. Volume was made up with 3 per cent metaphosphoric acid solution. After 30 minutes the solution was filtered through what man No. 1 filter paper. The known volume of aliquote was used for titration. The dye (2.6 Dichlorophenol indophenol dye) was standardized by titrating against standard ascorbic acid and the dye factor was calculated. The known volume of aliquote was taken in a 100 ml conical flask and titrated against standard dye solution through a burette. Titration was continued till the light pink colour persisted for more than 15 seconds. The ascorbic acid content was calculated by using following formula :

$$\text{Ascorbic acid (mg/ 100g)} = \frac{\text{Titre x Dye factor x volume made up}}{\text{Aliquot of extract taken for estimation} \times \text{Weight of volume of sample taken for estimation}} \times 100$$

Estimation of Protein - Microkjheldal Method (AOAC, 2005)

Principle

The nitrogenous compounds convert into ammonium sulphate in food when it boiled with concentrated sulphuric acid. It is subsequently composed by addition of excess alkali and the liberated ammonia is absorbed by a boric acid solution containing bromocresol green indicator by steam distillation. Ammonia forms a loose compound, ammonium borate with boric acid, which is titrated directly against the standard sulphuric acid.

Reagents

• 40% NaOH in distilled water

• 2% Boric acid (20g of reagent grade boric acid dissolved in about 500ml of hot distilled water) is added in 2ml of 0.1% bromocresol green in alcohol (or aqueous solution of the sodium salt) and finally the volume was made up to 1 litre by adding distilled water to prepare 0.01N H2SO4 solution (standardized).

Procedure

Protein content of tomato was estimated for which 0.3g sample was transferred into a 50 ml of long necked micro- Kjeldahl flask and thereafter the sides of the flask was properly washed with the distilled water. After this 2ml of concentrated sulphuric acid was added and digested in the micro digestion unit. When charring began and white fumes started appearing in the flask, digestion was stopped for a while to allow the flask to cool down before adding a few drops of hydrogen peroxide. The digestion was continued till the solution became clear. Wherever necessary, addition of hydrogen peroxide and digestion were repeated to hasten the process. After this, distilled water was added, and was boiled for a few more minutes and then the flask was allowed to cool. After this, 10ml of the solution of boric acid was taken in a 100 ml conical flask and place it in such a way that the tip of the condenser outlet of the steam distillation apparatus dips below the surface of solution. If colour of the boric acid solution has faded, 2 or 3 drops of bromocresol green indicator may be added. Transfer the digested sample completely by means of repeated rinsing to the chamber of the steam distillation apparatus. The chamber should be previously cleared off against contaminating ammonia by repeated washings. Add about 8ml of 40% NaOH and distilled it till about 30 ml distillate is collected into flask. Lower the receiving flask and stop the steam generation. Wash the condenser outlet tube into the receiving flask with distilled water. The solution in receiving flask colored blue at this stage. Titrate the contents against 0.1 N H_2SO_4 till the original green color is obtained.

Run the blank preparation through all the steps by taking distilled water in place of the sample.

Calculations

1 ml of 0.01 N H_2SO_4 = 0.00014 g nitrogen.

$$\text{Nitrogen g/100g} = 0.00014 \times \frac{\text{Titre value-Blank value} \times 100}{\text{Sample wt.} \times 100}$$

Conversion factor = 6.25

Protein g/100g = Nitrogen × 6.25*Reagents*

Estimation of Beta-Carotene

Samples extracted in acetone and transferred to petroleum ether phase. Total carotene is read colorimetrically using petroleum ether for baseline correction. β-carotene was separated by column chromatography and read colorimetrically (Ranganna, 1986).

Weigh 0.5 - 1.0 g sample, grind in a pestle and mortar with acetone. Use pure sand if necessary to assist grinding. Filter through a wad of cotton into a conical flask. Continue extraction and filtration. Transfer the residue to a separating funnel. Add 10 -15 ml of petroleum ether (60-80ºC), transfer pigments into the ether phase by diluting the acetone with water. Repeat the extraction of the acetone phase with small volumes of petroleum ether if necessary until no more color is extracted. Filter the petroleum ether extract through anhydrous Na_2SO_4 and note the volume. Plug the adsorption tube with non-absorbent cotton, add the adsorbent (Aluminium oxide, neutral) and pack it tight till column is approximately 10 cm length. Place 1 cm Na_2SO_4 over the top of the column. Wet the column with 25 - 50 ml of the petroleum ether. While the last ml of petroleum ether is still above the Na_2SO_4, pipette out an aliquot (5 - 10 ml) of the extract to be chromatographed into the column. Add successive portions of the eluent (3% Acetone in petroleum ether), when the preceding one is just barely visible above Na_2SO_4. β-carotene, which moves down the column prior to all the pigments, is collected. Continue washing, till the desired pigments have moved off the column and the eluent is colorless. Eluent is made up to a known volume and the intensity of color is measured at 452 nm using 3% acetone in petroleum ether as blank.

Read the concentration of β-carotene in per ml of the solution from the standard curve. To measure total carotene, pipette an aliquot of the petroleum ether extract of the sample (unadsorbed) to a 100 ml volumetric flask containing 3 ml of acetone and dilute to 100 ml with petroleum ether. Measure the color at 452 nm.

Preparation of standard curve:

Weigh accurately 25 mg of beta -carotene, dissolve in 2.5 ml of chloroform and make up to 250 ml with petroleum ether (1 ml = 0.1 mg or 100 µg). Dilute this solution to 100 ml with petroleum ether (1 ml = 10 µg). Pipette 5, 10, 15, 25, and 30 ml of this solution to separate 100 ml volumetric flasks, each containing 3 ml of acetone. Dilute to mark with petroleum ether. The concentration will be 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 µg per ml. Measure the color at 450 nm using 3% acetone in petroleum ether as blank. Plot absorbance against concentration.

Calculation

$$\text{mg of total carotene/100 g} = \frac{3.857 \times \text{Absorbance} \times \text{Dilution} \times 100}{\text{Weight of sample}}$$

$$\mu\text{g of } \beta\text{ - carotene/100 g} = \frac{\text{Conc. of carotene} \times \text{Final volume} \times \text{Dilution} \times 100}{\text{Weight of the sample}}$$

b.) Mineral assessment

Estimation of Potassium - Flame Photometric Method (Rangana, 2010)

Principle

Potassium solution was atomized into an oxyhydrogen or oxyacetylene flame. The flame excited atoms of potassium caused emitted radiations at specific wavelength. The amount of radiation emitted is measured on a spectrophotometer.

Reagents

- Potassium chloride (KCl) stock solution: 1.909 g of potassium chloride was dissolved in distilled water and make up it upto 1 litre (1.0 mg K per ml or 1000 ppm).
- Standard solution: Measure 150 ml stock standard solution (containing 150 ppm of potassium) and 5 ml HCl into a flask and make solution upto 1 litre.

In order to compensate for minute interference produced by other ions in the flame photometric determination of potassium, it is recommended that the standard solution be augmented with approximately equivalent concentrations of those ions that occur in highest proportions in the sample being analyzed. Dilute aliquots of the standard solution from 0 to 150 ml made each aliquot to a volume of 150 ml with 0.5% HCl.

Procedure

Sample was used for estimation of potassium content by taking readings in triplicate. Dilute an aliquot of ash solution containing less than 150 ppm potassium. Add sufficient amount of HCl so that the concentration of acid was same as that in the standard solution. Atomized the diluted extract in a calibrated flame photometer with the wavelength dial set at 768 nm. And the transmittance set at 100% for the top standard solution of potassium. Check the instrument periodically with the top standard solution. From the standard curve note the concentration.

Calculation

$$\text{Potassium mg/100g} = \frac{\text{ppm found from standard Curve} \times \text{Volume madeup} \times \text{Dilution if any}}{\text{Wt. of Sample} \times 100} \times 100$$

- Estimation of Phosphorus content

Estimation of minerals viz**. P, Na, Ca** was estimated as per standard methods by **A.O.A.C. (1984).** Phosphorus content was estimated by calorimetric method.

Reagents and materials

*Molybdate Solution***:** 25 g of ammonium molybdate was dissolved in 400 ml of distilled water. 500 ml of 10 N H2SO4 was added and the volume was made up to 1 liter with distilled water. *Amino naphtholsulphonic acid solution:* 0.5 g of l-amino- 2-naphthol-4-sulphonic acid, 30 g sodium bisulphate and 6 g sodium sulphate were dissolved in 100 ml distilled water in a 250 ml beaker, transferred to a measuring flask and the volume was made up to the mark with water. It was allowed to stand overnight and filtered. *Standard Phosphate Solution:* 0.4389 g of potassium dihydrogen phosphate was dissolved in distilled water containing 10 ml of 10N H2SO4 and volume was made up to 1 liter with distilled water (1 ml = 0.1 mg P) and 1 ml of chloroform was added as preservative. *Standard curve:* 100 ml of standard potassium dehydrogenate phosphate solution was diluted to 500 ml with distilled water (1 ml=0.02mg P). 5 mol aliquots of this solution were taken in 50 ml measuring flask and 4 ml of molybdate reagent and 2.0 ml of amino naphtholsulphonic acid were added. The volume was made up to the mark. The colour intensity was measured at 650 nm. Absorbance was plotted against the concentration and concentration of the sample was read from the curve.

Procedure

5.0 ml of ash (minerals) solution was taken in 50 ml measuring flask and 5 ml of molybdate reagent and 2 ml of amino naphtholsulphonic acid solution were added and finally the volume was made up to the mark. Similarly a blank wasprepared using distilled water in place of the sample. It was allowed to stand for 10 minutes and the colour was measured at 650 nm.

-Estimation of Iron content

The iron was estimated by calorimetric method as per A.O.A.C. (1984).

Reagents and materials

Concentrated H2SO4 (Iron free), saturated potassium sulphate solution, 3N Potassium thiocyanate solution and *Standard iron solution:* 0.702 g of crystalline ferrous ammonium sulphate was dissolved in 100 ml distilled water. Then 5 ml concentrated H2SO4 was added. The mixture was warmed slightly and concentrated potassium permanganate solution was added drop by drop until one drop produced a permanent colour. The solution was then transferred to 1 liter volumetric flask and volume made up to mark with distilled water. This solution contained 0.1 mg of ferric iron per ml.

Calibration curve was constructed by taking 0.0, 0.5, 1.0, 1.5, 2.0 and 2.5 ml of standard iron solution. The absorbance 480 nm was plotted against the concentration. The amount of iron in the sample was read directly from the calibration curve.

Procedure

0.5 ml of concentrated sulphonic acid was added to 5 ml of ash (minerals) solution in 15 ml stopper measuring cylinder, 1.0 ml of potassium persulphate solution, 2.0 ml potassium thiocyanate solution were then added. The volume was made up to 15.0 ml with water. The colour intensity was measured at 480 nm using Spectrophotometer.

Determination of Sodium and Calcium content

Sodium and calcium were determined using Corning EEL-100 Flame Photometer method as per A.O.A.C. (1984).

Sodium Standard Solution

Sodium chloride reagent grade was dried at 110°C over night and 2.5418 g of it was dissolved in 1 litre water. This solution contained 1 mg sodium per ml or 1000 ppm of sodium. 10 ml of this solution was further diluted to 100 ml for 100 ppm solution. Similarly stock solution was further diluted to give solutions containing 5, 2.5 and 1 ppm of sodium ions.

Calcium Standard Solutions

Calcium carbonate (A.R. grade) was dried at 110°C over night and cooled in desiccators. 2.4973 g of it was dissolved in about 50 ml dilute hydrochloric acid and diluted to 1 liter with distilled water. This stock solution contained the equivalent of 1.00 mg of Ca++ per liter. This solution was then diluted to get concentration of 100, 50, 25 and 10 ppm of Ca++.

Procedure

The solution of the samples were filtered and sprayed in the flame and the percent transmittance was noted. In case of higher concentration of the metal ions, the solutions were diluted so that the galvanometer deflection was within the scale.

Percent variation:

The percent variation was calculated as follows:

$$\text{Percentage of variation} = \frac{\text{Improved cultivar-Local cultivar}}{\text{Local cultivar}} \times 100$$

Trace mineral Zinc, Copper and Manganese estimation

Zinc, copper and manganese were analyzed by atomic absorption spectrophotometer (AAS). In AAS, a light radiation from a specific wavelength from a hollow cathode lamp (HCL-cathode made of specific metal to be assayed) passes through the flame to the detector. The ash solution is aspirated into the flame (Temperature = 2400^0 C). The sample is atomized in the flame, where the atoms of the element which are in the ground state, absorb energy from the hollow cathode lamp radiation and go to the excited state. The amount of radiation energy absorbed by the element is proportional to its concentration of metal under assay.

Instrument parameters such as resonant wavelength, slit width and air-acetylene flow rate that are appropriate for each element were selected (AOAC, 2000). The instrument was set up and calibrated as per the guidelines in the manual provided by the manufacturer. A calibration curve (Concentration Versus absorbance) for each mineral to be determined was prepared using a range of working standards. The flame parameters were optimized in accordance with the instrument manufacturer's instructions.

The standard solutions were read before and after each group of 6 - 12 samples. The burner was flushed with water between samples and zero was reestablished each time. Suitable dilutions of the ash solutions were made to read the content of the minerals in the ash solution. In case of sodium and potassium assay, the ash solutions as well as standard sodium and potassium should have a cesium content of 0.5% (w/v). Lanthanum chloride solution was added to the final dilution of each standard and test dilution to make 0.1% (w/v) lanthanum for determination of magnesium only. The concentration of metals in ash solutions of samples as well as in blank solutions were read from the calibration curve and the concentration in the test sample calculated taking into account the dilutions and the weight of the sample taken.

Calculation

Concenteration of metal in sample(μg metal per g sample)=(CS-CB)xVxD/W_

Where: CS = Conc. of metal in ash solution of sample (μg/ml)

CB = Conc. of metal in blank solution (μg/ml)

V = Volume of ash solution made up (ml)

D = Dilution volume (ml)/aliquot taken for dilution (ml), if original solution is diluted

W = Sample weight (g)

7.3 Statistical evaluation

Continuous variables were expressed as means± standard deviation (SD). Before enrichment of OKWC four treatment dilutions has been given in which C1 (control means 100% soil), T1 (20% KWC autumn+ 80% soil), T2 (40% KWC autumn+ 60% Soil) and T3 (60% KWC autumn+ 40% Soil)values were documented on 25 days, 50 days, 75 days, 110 days, 135 days . And U1(20%Enriched KWC autumn +80%soil) , U2(40%Enriched KWC autumn +60%soil) and U3 (60%Enriched KWC autumn +40%soil) after enrichment three treatment were applied to plant and also evaluated for the same days as above. One way analysis of variance (ANOVA) and comparison of means were calculated separately using at 95% confidence level. The means were compared by using the least significance difference (LSD) test. The significance of difference between the pairs of treatment means was evaluated by repeated measure ANOVA Furthermore, a pair wise correlation analysis based on the Pearson correlation coefficient was done with SPSS Version 20 to relate availability of nutrients analysis and physical parameters.

Result and Discussion

Characteristics of soil Soil reaction (pH) Soil samples collected from surface and subsurface of BBAU horticultural farm Lucknow district was mostly found neutral with approximate pH 7.0 in reaction.

Electrical conductivity (EC) The electrical conductivity of the soils varied from to 0.17 to 0.88 and 0.22 to 1.29(dSm-1) at surface and subsurface of soil with textured silty clay loam to clay loam (Upadhyay and Sharma, 2016) reported the similar .

Plant growth

Treatment comprising KWC and organic content of soil showed significant effects on vegetative growth such as Plant height, Number of leaves, flowers and fruits and tomato yield. In comparing plant height of treated plants with control as C1, all three treatments T1, T2, and T3 offered statistically significantly higher plant height on 1st and 2nd interval (i.e, 25th day and 50th day), but only T3 remained significant till last interval (135th Day) of this study (Mention in Table7.1) Number of leaves were significantly higher in T2 and T3 ($P<0.001$). 20% KWC shows no enhanced growth in terms of leaves, while treating plants with 60% KWC induces growth in plants efficiently.

Table 7.1 : Impact of Kitchen waste compost (Autumn) before enrichment on tomato plant growth parameters.

Plant Height	**Control**	**T1**	**p value**	**T2**	**p value**	**T3**	**p value**	**CV %**
25 days	4.40±0.20	4.63±0.06	0.03	4.87±0.06	<0.001	5.13±0.06	<0.001	7
50 days	11.20±0.20	11.73±0.12	0.02	12.57±0.35	<0.001	13.40±0.17	<0.001	8
75 days	16.60±0.20	16.73±0.06	0.18	17.17±0.06	<0.001	18.17±0.06	<0.001	4
110 days	26.67±1.53	26.30±0.10	0.58	26.77±0.15	0.88	28.67±0.06	0.01	4
135 days	32.33±2.52	31.33±0.23	0.36	33.53±0.32	0.28	35.13±0.06	0.03	5
No. of Leaf's								
25 days	4.00±1.00	5.33±0.58	0.05	7.33±0.58	<0.001	8.67±0.58	<0.001	33
50 days	8.33±1.53	9.00±1.00	0.44	12.33±0.58	<0.001	14.67±0.58	<0.001	27
75 days	18.00±2.00	18.67±0.58	0.49	20.67±0.58	0.02	22.33±0.58	<0.001	10
110 days	24.67±3.06	25.00±1.00	0.82	27.00±1.00	0.13	28.67±0.58	0.02	7
135 days	31.00±1.00	30.33±0.58	0.52	31.67±1.53	0.52	34.33±1.53	0.01	6
No. of Flowers								
50 days	7.00±2.00	8.00±0	0.27	11.00±0.01	<0.001	13.67±0.58	<0.001	30
75 days	8.00±2.00	8.67±0.58	0.49	12.33±0.58	<0.001	13.67±0.58	<0.001	26
110 days	9.00±0	9.67±0.58	0.14	10.33±0.58	0.01	12.67±0.58	<0.001	15
No. of Fruits								
135 days	24±4	84±1	0.05	32±1	<0.001	38.33±0.58	<0.001	20

Legend : Various physiochemical parameters were compared in several intervals, coefficient of variation has been calculated by comparing mean and standard deviation of control with respective treated group before enrichment T1, T2 and T3. Least significant distance (LSD test) has been used to identify significant difference between groups.P <0.05 was considered significant value. Where T1=20% KWC (Autumn)+80% soil, T2=40% KWC (Autumn)+60% soil, T3=60% KWC (Autumn)+40% soil

On the 3rd interval of this study (50 thday), number of flowers were significantly higher in T2 (P<0.001) and T3 (P<0.001), while number of fruits were greater in all three treatments. After enrichment of Treatments with *Trichoderma harzianum* U1, U2 and U3offered significantly (P <0.001) higher plant height and number of leaves per plant. Higher variation in plant height and number of leaves were recorded in U2, however, moderate plant height was recorded in treatments U1 and U3. The maximum number of leaves per plant achieved by the treated dose of kWC (T2 and T3) followed by the enrichment U2 (Table 7.1 and 7.2)

Table 7.2 : Impact of Kitchen waste compost (Autumn) after enrichment on tomato plant growth parameters

Plant Height	**Control**	**U1**	**p value**	**U2**	**p value**	**U3**	**p value**	**CV%**
25 days	4.23±0.06	5.40±0.20	<0.001	8.83±0.06	<0.001	5.80±0.10	<0.001	47
50 days	11.40±0.20	14.40±0.17	<0.001	16.23±0.06	<0.001	16.07±0.12	<0.001	40
75 days	16.37±0.25	22.17±0.84	<0.001	25.80±0.10	<0.001	22.40±0.35	<0.001	25
110 days	25.07±0.06	25.97±0.32	<0.001	32.87±0.06	<0.001	28.37±0.21	<0.001	18
135 days	31.00±1.00	32.93±1.29	0.39	40.53±0.70	<0.001	37.47±1.63	0.02	14
No .of Leaf's								
25 days	4.33±1.53	8.67±1.15	<0.001	15.33±1.15	<0.001	11.67±0.58	<0.001	32
50 days	8.33±1.53	17.00±1.00	<0.001	25.33±0.58	<0.001	20.67±1.15	<0.001	15
75 days	17.67±0.58	26.00±2.00	<0.001	33.33±1.15	<0.001	28.67±0.58	<0.001	18
110 days	24.33±1.53	30.67±1.15	<0.001	38.00±<0.001	<0.001	30.67±1.15	<0.001	12
135 days	32.67±2.08	34.00±2.00	0.08	44.00±1.73	<0.001	36.67±1.15	<0.001	12
No. of Flowers								
50 days	7.00±1.00	10.67±0.58	<0.001	15.67±0.58	<0.001	10.67±0.58	<0.001	32
75 days	7.67±1.53	11.67±0.58	<0.001	17.67±0.58	<0.001	11.33±1.15	<0.001	34
110 days	9.67±1.15	10.33±0.58	0.37	18.33±0.58	<0.001	10±1.00	0.65	35
No. of Fruits								
135 days	25.00±1.00	31.33±1.53	<0.001	55.33±1.53	<0.001	3<0.001±1.00	<0.001	38

Legend: Various physiochemical parameters were compared in several intervals, coefficient of variation has been calculated by comparing mean and standard deviation of control with respective treated group after enrichment U1, U2 and U3. Least significant distance (LSD test) has been used to identify significant difference between groups. P <0.05 was considered significant value. Where U1=20% enriched KWC (Autumn)+80% soil, U2=40% enriched KWC (Autumn)+60% soil, U3=60% enriched KWC (Autumn)+40% soil

Furthermore, application of 40 % KWC combined with *Trichoderma* (i.e., T2 and U2) enhanced number of flowers and fruits The lowest plant height, number of leaves, flowers and fruits per plant were recorded in enriched treatments U1. The increased vegetation growth by Trichoderma may be due to secreation of secondary metabolites which may act as an auxin-like compound (Vinale et al., 2008). According to previous studies (Harman et al., 2004), Trichoderma enhances nutrient uptake thrught root growth by increasing root biomass thus plant enables to absorb greater volume of soil for nutrient acquisition thus promoted availability of necessary nutrients which ultimately provides growth to the plants. Moreover, Trichoderma reduced the concentrations of substances in soil that are inhibitory to plant growth (Kleifeld O, Chet I (1992); Wang et al.,2000 ; Windham et al., 1986). It has also been reported that Trichoderma could improve nitrogen use efficiency and could solubilize a number of poorly soluble nutrients, such as Mn4, Fe3, and Cu2, etc., leading to better plant growth and development (Altomare et al., 1999). Thus, one or several mechanisms may be involved in regulation of growth of tomato by Trichoderma enriched biofertilizer alone or in combination with KWC.

Yield Attributes

Yield contributing characters of tomato was also significantly enhanced by Trichoderma-enriched biofertilizer and KWC (Table 3). Number of flowers per plant (13.67) was significantly ($P<0.001$) higher in treatment T3 which was followed by the treatments T2 (12.33) and T1 (8.67). After enrichment, U2 produced higher number of flowers per plant (18.33), followed by the treatments U1 (10.33) and U3 (10). Both number of fruits per cluster and number of fruits per plant were maximum in treatments T3 and enriched treatment U2, there by indicating positive correlation between the two parameters. However, the lower number of clusters per plant, number of flowers and fruits per cluster, and number of fruits per plant was recorded in control and (T1) treatment that was statistically similar with treatment T2 and T3. Thus, in combination with KWC with Trichoderma enriched may play an important role in the expression of yield-related traits of tomato. Vinale et al. (2008) have also been reported that dramatic increase in the number of fruits per plant by application of Trichoderma than the control (Table 7.1 and 7.2).

Biochemical parameters of tomato fruits before and after treatment

Table 7.3 : Effect of Kitchen waste compost before and after enrichment on biochemical parameters of tomato fruits (per 100 g of tomato)

Parameters	Control	T1	U1	p value	CV%	T2	u2	p value	CV%	T3	u3	p value	CV%
T.S.S	6.26±0.04	6.60±0.46	7.61±0.05	0.001	49	6.76±0.11	7.17±0.03	<0.001	49	6.95±0.05	7.85±0.05	<0.001	48
Protein content	0.65±0.05	0.77±0.06	0.63±0.06	0.624	48	0.74±0.02	0.74±0.03	0.02	48	1.02±0.07	0.53±0.02	0.027	51
Total sugar	2.72±0.04	2.80±0.01	5.80±0.01	<0.001	49	2.86±0.05	5.33±0.26	<0.001	49	3.06±0.06	5.60±0.10	<0.001	48
Ascorbic acid	6.16±0.28	6.90±0.12	17.75±0.36	<0.001	48	7.96±0.06	18.06±0.04	<0.001	48	12.36±0.05	18.09±0.01	<0.001	57
Beta-Carotene	0.08±0.00	0.08±0.01	0.10±0.00	<0.001	46	0.09±0.00	0.11±0.00	<0.001	48	0.09±0.00	0.11±0.01	<0.001	48
Lycopene	0.03±0.00	0.04±0.00	0.09±0.00	<0.001	57	0.05±0.01	0.39±0.51	0.184	46	0.06±0.00	0.08±0.01	<0.001	57

Tables 7.3 show the nutritional quality of tomato before and after enrichment with Trichoderma. Significantly the highest value of total soluble solids (TSS) was found in all three treatment T1, T2 and T3 and U1, U2 and U3. Highest content was observed U3 enriched treatment (7.85) followed by U1 (7.61) and U2 (7.17). While calculating correlation of coefficient between control, treated group and enriched group 49% variation was observed in T1-U1 and T2-U2, while T3-U3 showed 48%.

The protein content was significantly ($P \leq 0.05$) higher in U2 treatment with 48 % variation , followed by T3 with 51% variation, Table 7.3. There was no significant difference between control and treatment T1-U1 protein content. . Total sugar content was highest in T1-U1 treatments , while it decreased in T2-U2 treatmentcompared to the T3-U3 treatment. Ascorbic acid content was significantly ($P \leq 0.001$) higher in ripe tomato fruits fertilized with 60% KWC and 40% KWC, followed by plants received 20% KWC and enriched KWC. the recommended doses of NPK. β-Carotene, a precursor of vitamin A, was also found significantly ($P \leq 0.05$) higher in T2-U2 treatment, but there was only marginal difference in all three groups of treatment . The lycopene content is not only antioxidant but also the main factor on which the red color of tomatoes depends on. It was significantly ($P \leq 0.05$) higher in treatment T2-U2 (0.39 mg kg–1), followed by the treatments T1 (0.09 mg kg–1) and T3 (0.08 mg kg–1). These results are indicative of the fact that KWC and trichoderma enriched KWC compost increases the quality and the functionality of tomatoes.

Mineral content of Tomato fruits before and after treatment

Table 7.4 : Effect of Kitchen waste compost before and after enrichment on mineral parameters of tomato fruits (per 100 g of tomato)

Parameter	Control	T1	U1	p value	CV%	T2	u2	p value	CV%	T3	u3	p value	CV%
Ca	21.23±0.22	22.24±0.05	25.24±0.05	<0.001	14	24.27±0.07	28.95±0.07	<0.001	16	26.75±0.04	27.62±0.36	<0.001	14
Na	5.65±0.03	5.83±0.05	5.99±0.11	0.001	7	5.18±0.06	6.93±0.10	<0.001	15	5.96±0.06	6.50±0.51	0.013	7
Mg	12.66±0.05	13.44±0.03	14.12±0.12	<0.001	9	13.68±0.03	15.95±0.06	<0.001	12	14.76±0.06	15.14±0.17	<0.001	9
K	70.84±0.04	72.15±0.03	73.02±0.04	<0.001	5	75.80±0.10	79.86±0.12	<0.001	6	76.81±0.81	77.88±0.11	<0.001	5
Fe	0.68±0.02	0.73±0.04	0.84±0.04	0.001	15	0.77±0.03	0.96±0.06	<0.001	18	0.81±0.20	0.93±0.16	0.082	15
Zn	0.22±0.03	0.23±0.02	0.39±0.08	0.005	21	0.27±0.06	0.45±0.04	0.001	39	0.29±0.01	0.34±0.06	0.009	21
Cu	0.13±0.04	0.15±0.04	0.19±0.02	0.054	44	0.15±0.03	0.36±0.05	<0.001	60	0.26±0.03	0.34±0.05	0.001	44
Mn	0.07±0.02	0.08±0.01	0.13±0.05	0.054	45	0.11±0.01	0.24±0.06	0.001	63	0.15±0.05	0.19±0.04	0.007	45
P	7.83±0.03	7.96±0.04	10.82±0.08	<0.001	12	8.14±0.06	11.07±0.11	<0.001	20	8.45±0.04	9.93±0.06	<0.001	12

Ca:Calcium, Na: Sodium, Mg: Magnesium, K: Potassium, Fe: Iron, Zn: Zinc,Cu: Copper, Mn: Manganese

Table 7.4 showed that the sole application of BioF/compostKWC or in combination with *Trichoderma* reduced rates of N, alltought all three group showed significant difference, but there was only 5-6% coefficient of variation has been noted for treatments. Available P (11.077.61 mg kg–1) was detected to be higher significantly (P≤0.0015) in treatment T2-U23, followed by the treatments T1-U14 (6.6910.82 mg kg–1) and then T3-U32 (6.689,93 mg kg–1). Zinc content (0.451.34 mg kg–1) was also found to be significantly higher (P≤0.001) in T3 T2-U2 treatment. These results suggested that Trichoderma-enriched biofertilizer might be efficient in solubilizing and increasing the availability of P and Zn in soils.

On the other hand, several other minerals such as Na and Ca, were found significantly higher in fruits fertilized with 40% enriched compost. Coeffcient of variation for Ca and Na was 14% and 7% in T1-U1 and T3-U3 while it was 16% and 15% in T2-U2, However, for Mg, the treatments T2-U2 and T3-U3 were found equally efficient in transferring nutrients from soil to tomato plants and fruits which ultimately attributed to higher nutrient concentrations in tomato fruits.

Essential heavy metals such as Cu), Fe and Zn and Mn were found significantly ($P \leq 0.001$) higher in T2U2 treatment and was least in T1-U1 compared to the other treatments. It is evident from the results that higher minerals and essential heavy metals were detected in plants fertilized with 40% KWC with trichoderma (Table 7.4). Consequently, the maximum accumulation of these elements in fruits were observed in the treatments of KWC compost alone or in combination with Trichoderma Application of KWC was found to have increased not only the antioxidant compounds but also the mineral contents of fruits.

Conclusion

In this experiment, special use of *Trichoderma*-enriched biofertilizer (U2) increased not only the plant growth and yield but also increased the antioxidant compounds (e.g., ascorbic acid, β-carotene and lycopene) and minerals in fruits as compared to control and before enrichment treatments (only Kwc). Enriched compost required less in quantity and gives better result for plant's growth and fruiting whereas application of only KWC of autumn season for horticultural purposes uses required more in quality and gives not better result as compared to enriched KWC Moreover, enriched KWC increased soil fertility and stimulated microbial growth in the rhizosphere. Thus, enriched KW compost may reduce application of chemical fertilizers and therefore can be considered as a noble practice in sustainable agriculture.

Chapter-08

Summary and Conclusion

Chapter 8

Summary and Conclusion

Waste management is a key utility service and a critical element of the infrastructure underpinning society, but it is often not recognized as an useful and enriched product.Today solid waste management is one of the biggest problems in the world. Around 50% of the waste in the world is organic waste. India is second largest populated country in the world; it produces more than 100 tons of solid waste a day. It is the mixture of both organic food waste and inorganic waste. Around 78% is food waste, which can be recycled. Some of them is land filled but it is not segregated properly and it mixes organic and inorganic waste, which produces bad odor, and it will spoil the soil. To manage the solid waste, it should be properly segregated at the source (houses). The organic and inorganic waste needs to be separated, the organic waste can be treated to make compost, and inorganic waste can be segregated and given for garbage collection. There are many companies who take in the waste and segregate and convert the organic waste into compost but as the waste is very high; they are unable to achieve all the targets so it is better to compost at home. Compost is organic matter decomposed as fertilizer. Compost is the key in organic farming.

Organic waste comes from plants or animals sources. Commonly, they include food waste, fruit and vegetable peels, flower trimmings and even dog poop can be classified as organic waste. They are biodegradable (this means they are easily broken down by other organisms over time and turned into manure). Many people turn their organic waste into compost and use them in their gardens.

India is experiencing rapid urbanization while remaining a country with physical, climatic, geographical, ecological, social, cultural and linguistic diversity. The population of India was 1252 million in 2013, compared with 1028 million in 2001. Population growth is a major contributor to increasing MSW in India.

Kitchen waste is defined as left-over organic matter from restaurants, hotels and households . Tons of kitchen wastes are produced daily in highly populated areas. Kitchen wastes entering the mixed-municipal waste system are difficult to process by standard means, such as incineration, due to the high moisture content. Furthermore, organic matter can be transformed into useful fertilizer and bio fuel. New disposal methods that are both environmentally and economically efficient are being developed which rely on various forms of microbial decomposition

Composting is one of the applicable technologies to recycle organic waste into a value-added product. It allows the transformation and stabilisation of the organic waste into bio-fertiliser that can be applied to land and crops safely. The composting systems come in different modes but the three commonly used are windrow, aerated static pile and in-vessel composting.

Recent research is focused on kitchen waste management by using eco- friendly technique and low cost method, job creation activities like composting.

Several researches reveal various method for waste management like biofuel generation, composting, household items (carry bag, plate, paper etc.) from waste. But still scientists continue their research on composting techniques to bring good composting bin in highly scientific manner so that this techniques give more help in order to achieve zero waste target of waste management in less time, its enrichments to increase compost nutrient content .

Based on the above scientific data current literature research are scientifically not yet documented with respect to seasonal KWC , the season which have best KWC and enrichment of organic KW using *Trichoderma harzianum-1373* and its application on tomato plants using pot experiment and with different treatments .

Therefore, the present study was aimed to investigate the preparation of compost from organic kitchen waste seasonally,analysis and comparison of the microbial , physico-chemical content and phytotoxicity test of prepared compost seasonally ,development of an enriched compost through microbial inoculation and lastly examination of the application quality of enriched compost through comparative pot study and nutritional assessment of vegetable.

The above information and thesis organization has been systematically elaborated in the first chapter of thesis as introduction. Subsequently, second chapter has mentioned objectives and need of this study. Further,

Chapter 3 dealt with review of literature of the study. This chapter focused on science of composting, factors (physico-chemical, microbial and phytotoxicity assessment) affecting composting process, method of composting, enrichment of compost through microbial inoculation and application quality of enriched compost on crop.

Chapter 4 dealt with the feedstock preparation for different season's kitchen waste compost (OKWC). Composting experimental set up for preparation OKW and various scientific steps involved for different seasons.

Chapter 5 dealt with the physico- chemical, microbial analysis and phytotoxicity assessment of different season's OKWC.For statistical analysis, continuous variables were expressed as means± standard deviation (SD). One way analysis of variance (ANOVA) has been calculated using a 95% confidence level, followed by Tukey's test determined differences among the seasons. Spearman's correlations were computed between the physio-chemical parameters in the final compost at probability levels of .05 and .01. All statistical analyses were performed using the SPSS V.20. The result revealed that there was significant difference among 4 seasons .On the basis of observation there were statistically significant difference was observed for 4 seasons.

Chapter 6 dealt with development of enriched compost through microbial inoculation using selected KWC. Methodolgy for this study was discussed with respect to microorganisms used in experiment, inoculumn preparation for composting, composting experiment set up.Microorganism colony forming unit (cfu) estimation, physico-chemical and microbial variation analysis of OKWC after enrichment. For the statistical analysis, the level of significance used was p = 0.05. The critical difference (CD) and coeeficient of variation values were calculated wherever the 'F' test was significant. All statistical analyses were performed using the SPSS V.20. Statstically, data reveals that after inoculation on 14^{th} day KWC would be used for agricultural purposes.

Chapter 7 dealt with the application quality of prepared and enriched compost through comparative pot study. The methodology for this chapter was dicussed under , green house experimental detail, nursery bed preparation and transplantation ,treatment combination details , crop details . Lastly Parameter analysis was based on physical parameter of tomato plants and nutritional assessment (biochemical and mineral content) of tomato fruits. Data analysis continuous variables were expressed as means± standard deviation (SD). Before enrichment of okwc four treatment dilutions has been given in which C1 (control means 100% soil), T1 (20% KWC autumn+ 80% soil), T2 (40% KWC autumn+ 60% Soil) and T3 (60% KWC autumn+ 40% Soil)values were documented on 25 days, 50 days, 75 days, 110 days, 135 days . And U1(20%Enriched KWC autumn +80%soil) , U2(40%Enriched KWC autumn +60%soil) and U3 (60%Enriched KWC autumn +40%soil) after enrichment three treatment were applied to plant and also evaluated for the same days as above. One way analysis of variance (ANOVA) and comparison of means were calculated separately using at 95% confidence level, the means were compared by using the least significance difference (LSD) test. The significance of difference between the pairs of treatment means was evaluated by repeated measure ANOVA Furthermore, a pair wise correlation analysis based on the Pearson correlation coefficient was done with SPSS V. 20 to relate availability of nutrients analysis and physical parameters. Result reveals that use of *Trichoderma*-enriched biofertilizer (U2) increased not only the plant growth and yield but also increased the antioxidant compounds (e.g., ascorbic acid, β-carotene and lycopene) and minerals in fruits as compared to control and before enrichment treatments (only Kwc). Enriched compost required less in quantity and gives better result for plant's growth and fruiting whereas application of only KWC of autumn season for horticultural purposes uses required more in quality and gives not better result as compared to enriched KWC

8.1 Testing of Hypothesis

H01- There exist no association of KWC between four seasons

It was observed that there were significant difference between 4 seasons hence null hypothesis was rejected, alternate hypothesis was accepted and proven.

H02- The physico-chemical, microbiological and phytotoxicity assessment variables establish no difference in them over 4 seasons.

On the basis of observation there were statistically significant difference was observed for 4 seasons, thus null hypothesis was rejected and alternate hypothesis was accepted.

H03- There exist no association in KWC before and after microbial inoculation.

As there was significance differences found during comparison of before and after enrichment of compost, null hypothesis was rejected.

H04- There exist no association in physical parameters of plants and nutritional content of tomato with respect to control and treatment combinations.

There was a significant association in physical parameters of plants and nutritional content of tomato with respect to control and treatment combinations, hence alternative hypothesis was accepted and simultaneously proven.

8.2 Conclusion

This chapter dealt with conclusion achieved from the all phases conducted with different season KW composting in order to gain information that in which season composting was best, effects of enrichment of KWC with fungal inoculation , effect of KWC(Autumn season) and enriched KWC on tomato plants , tomato fruit and finally the recommendations for the future scope.

From all the above chapter's result and discussion of this study it is concluded that-

- At 12th week of KWC process get completed almost all 4 seasons.
- Composting of OKW had potential as a beneficial recycling tool.
- The physico-chemical parameter varies with season and raw material used in compost feedstock preparation.
- Compost from organic waste collected in autumn contained the highest amount of nutrient in plant feedstock and highest minralization rate as well.More ash

less organic matter meant that the share of NPK nutrient was greater. The higher availability of P and Mg leads to higher yield of crop production and faster stability in KWC.

- The autumn season KWC found to be best season compost because it contain significant amount of nutrient for plant growth and development followed by spring, summer and winter season.
- The decrease in microbial counts at the end stage of composting period and at the same time adjustment of composting conditions such as aeration, temperature, MC, climatic conditions .This would allow the microbial community and their enzymatic activities ti increase and therefore the increase of OM decomposition as a reduction in C:N ratio , the composting time reduces. The best quality of compost obtain in Autumn>summer>rainy season.
- The phytotoxicity assessment reveals significant seed germination rate at low compost extract concentration(20%) followed by 40% and 60%. Seed germination and growth at low compost extract concentration found significant might be due to the presence of optimum level of primary and secondary nutrients essential for plant growth. While the inhibitory effect at high concentration(40% and 60%) could be because of high salt load. Overall the nutrients present in KWC in all four season is safe and played a significant role in seed germination .
- As per scientific data and analysis, the autumn season KWC selected for enrichment through microbial inoculation and found improvement in the microbial population and nutrient concentration (N, P,Mg and K) of KWC(autumn) on the 14th day after enrichment. Therefore, the enriched (KWC+ *Trichoderma Harzianum-1373)* compost used for agricultural purposes on the 14th day after microbial inoculation.
- There was significant improvement in the growth and nutrient content of tomato with combined application of KWC autumn + enriched KWC (U)and KWC of autumn season(T) were compared to control(C). The application of Trich

h+KWC at U2 (after treatment) gave best result as compared to U1, U3, T1, T2, T3 ,C whereas T3 (before treatment) gave good result in comparison with C, T1 andT2.

- At low quantity of doses of enriched KWC(U2) gave best result whereas T3 (only KWC autumn) also gave good result but the quantity of KWC required more.

8.3 Recommendations For Future Work

- Advancement of composting dynamics by adding up other bulking agents, agricultural and industrial waste materials could be carried out.
- Studies could be carried out on availability and speciation of heavy metals during vegetable waste composting.
- Determined organic compounds degradation through composting.
- The seaweed and biochar may also be added to enhance the quality of KWC.

Chapter-09

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Annexure

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NATIONAL COLLECTION OF INDUSTRIAL MICROORGANISMS

NCIM

NATIONAL CHEMICAL LABORATORY
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Proforma invoice No.2017/NCIM-1106 Dated: December 2017

Dear Sir,

Received your Draft of Rs.1180/- (D.D. No.657142/ Dt.5.1.2018) for the supply of cultures. Following cultures are sent to you along with the details of media for maintenance. Kindly acknowledge the receipt. All cultures are pure and authentic and obtained from standard culture collections. We shall appreciate it if you could kindly let us have the **report on their performance / activity.** ***Kindly note that we do not give any guarantee about the biochemical performance /activity of the cultures.***

Sr. No.	*Name of Organism*	*NCIM No.*	*ATCC No.*	*Passage*	*Qty.*	*Maintenance Medium*	*Temp. ^0C*
1	*Trichoderma harzianum*	1373		*1*	*1 AS Jan 2018*	*Potato Dextrose Agar*	*28*

Dr. Mahesh Dharne
Scientist In-Charge, NCIM

****

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State:Maharashtra	Code 27	Reverse Charge (Y/N):No	

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Babasaheb Bhimrao Ambedkar University
(A Central university) Vidya Vihar Raebareli Road Lucknow -226025

GSTIN: 09BDCPS5341E1ZK

State: UttarPradesh code 09

Sr. No	Description	SAC	Qty	UOM	Rate	Taxable Value	CGST Rate %	CGST Amount	SGST Rate %	SGST Amount	IGST Rate %	IGST Amount	Total
1	Services related to microbial strains	998393	1		1000	1000	0	0	0	0	18	180	1180
Total						1000		0		0		180	1180

Total Invoice amount in words		
Rupees One Thousand One Hundred and Eighty Only	Total Amount before Tax	1000
	Add:CGST	0
Bank Details	Add:SGST	0
	Add: IGST	180
Bank Name :	Total Tax Amount	180
Bank IFSC :	Total Amount after tax	1180
Bank AccNo :	GST on Reverse Charge	0

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Influence of using kitchen waste compost (KWC) on tomato (*Lycopersicon esculentum* Mill.) physical growth parameters

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Abstract
Present study deals with the Influence of using kitchen waste compost (KWC) on tomato (*Lycopersicon esculentum* Mill.) physical growth parameters**.** Result showed that KWC has good potential to improve the physical growth of tomato plants. KWC 60% (T3) showed positive result followed by T(1), T(2) and C(1) may be due to the presence of optimum level of primary and secondary level of plant's vital nutrients.

Keywords: Tomato, physical growth and kitchen waste compost

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most accepted vegetables worldwide, and contains carbohydrates, amino acids, minerals, and vitamins. Yield and nutrient content of tomato are noticeably exaggerated by the application of inorganic fertilizer [2]. In fact, non-judicious use of inorganic fertilizer may lead to environmental pollution including contamination of groundwater, and soil acidification as well as increase denitrification resulting in higher the emission of nitrous oxide (N2O) to the atmosphere which is accountable for global warming. Currents efforts include exploring the possibility of substitution of inorganic fertilizer with organic ones which are eco-friendly and cost effective. Taiwo *et al.* [4]. recommended that organic fertilizer can be combined with inorganic fertilizer at rates below those recommended for sustainable tomato production.

Compost used to enhance soil bodily and organic matter, water retention capability, drainage, pH, better availability of soil micro-organism and decreasing the negative impact of chemical based totally insecticides and fertilizers within the ecosystems [1].

The compost is fundamentally centered a-round nitrogen, phosphorous, potassium and different micronutrients that can be very much utilized as a soil conditioner.

Composting is the process by which complex organic materials are changed into a material with environmentally useful applications. The composting can transform huge quantities of organic material into compost in a relatively short period by properly organising moisture, air and nutrients. During composting, the microorganism consumes oxygen and nourish on organic matter. Active composting generates a significant amount of heat and large quantities of carbon dioxide and water vapour are released into the air.

Material and Method

A pot culture experiment was conducted at Babasaheb Bhimrao Ambedkar University (BBAU) using KWC with soil at different level of combination during *Kharif* 2018 to study the effect of the prepared KWC on growth of tomato (*Lycopersicon esculentum* Mill) plant

Greenhouse experimental details

- **Soil Condition**

The alluvial soil was collected from the horticultural farm. The collected soil having pH 7.1, electrical conductivity more than 4.0 and textured silty clay loam to clay loam.

- **Nursery bed preparation and transplantation**

For this coconut husk 250gm (soaked overnight in water) used to germinate of tomato seed into baby plant. The soaked coconut husk was partially filled in the seed germination tray with

2-3 tomato seed in each provided area and again covered the sown seed by sprinkling soaked Coconut husk. The 24 days old seedlings were uprooted and transplanted @ one baby plant per pot. Here, the coconut husk is used for seedling preparation because it have several best feature which support seedling growth such as water retention and drainage, low compaction, requires low maintenance, eco- friendly, disease –resistance and nutrient balance property.

- **Treatment combination details**

The experiment consisted of three treatments (with control and with KWC). The total 9 no. of pots was used, as the experiment was done in triplicates.

Treatments Combination

1.	**Control (C1)**	100% soil
2.	T1	20% KWC +80% soil
3.	T2	40% KWC +60%soil
4.	T3	60% KWC +40%soil

Crop details

Location	:	Greenhouse, BBAU, Lucknow
Crop	:	Tomato
Variety	:	S-22
Season	:	*Kharif*
Design	:	Completely Randomized Design
Treatments	:	03
Replications	:	03@ each treatment

- **Harvesting**

The matured red colored tomato fruits were harvested and stored separately as per the treatments in the polythene bags to assess their nutritional content.

- **Collection of the experimental data**

The observations on various parameters were recorded at 25, 50, 75.110 and 135 days after transplantation.

7.2.2. Prameters analysis

a.) Physical parameters of plants

Plant height: The plant height was measured in centimeters from the lower end of the stem to the tip of main shoot. The mean height was recorded and expressed as plant height in centimeters.

Numbers of leaves: The no. of leaves were done by counting from bottom at fix point to the top (last leaf of plant) it was started from 25th day after transplantation.

Days to flowering: The data of flower initiation on each tagged plant was recorded again no. of days from date of transplanting were counted and recorded.

Numbers of fruits: The data of flower initiation on each tagged plant was recorded. The no. of days from date of flower initiation to fruit setting was counted and recorded.

Statistical evaluation

Continuous variables were expressed as means± standard deviation (SD) for KWC 3 treatment dilutions has been given in which C1 (control means 100% soil), T1 (20% KWC + 80% soil), T2 (40% KWC+ 60% Soil) and T3 (60% KWC + 40% Soil) values were documented on 25 days, 50 days, 75 days, 110 days, 135 days. The statistical evaluation was done with SPSS ver. 20.0 to relate physical parameters of T1, T2, T3 with control (C1).

Result and Discussion

Plant growth

Treatment comprising KWC and organic content of soil showed significant effects on vegetative growth such as Plant height, Number of leaf's, flowers and fruits and tomato yield. In comparing plant height of treated plants with control, all three treatments T1, T2, and T3 offered statistically significantly higher plant height on 1st and 2nd interval (i. e, 25th day and 50th day), but only T3 remained significant till last interval (135th Day) of this study (Mention in Table.1) Number of leaves were significantly higher in T2 and T3 ($P<0.001$). 20% KWC shows no enhanced growth in terms of leaves, while treating plants with 60% KWC induces growth in plants efficiently. On the 3rd interval of this study (50Th day), number of flowers were significantly higher in T2 ($P<0.001$) and T3 ($P<0.001$), while number of fruits were greater in all three treatments. The maximum number of leaves per plant achieved by the treated dose of KWC (T2 and T3) Use of compost as a fertilizer has enhanced the physical structure of the soil that incorporates gardening soil mixture. Moreover there was an expanded concealment of plant maladies brought about by soil-borne nematodes, growths and microorganisms because of the expansion of compost to the soil in different cropping pattern. Kostov *et al.* [3]. Directed a test by treating the soil with compost, mineral composts and manure to study the yield efficiency and quality of vegetables and fruits. From the above study, it is concluded that KWC has good potential to enhance the physical parameters of plants.

Table 1: Changes in growth parameters using KWC on tomato plants.

Plant Height	Control	T1	p value	T2	p value	T3	p value	CV%
25 days	4.40+0.20	4.63+0.06	0.03	4.87+0.06	<0.001	5.13+0.06	<0.001	7
50 days	11.20+0.20	11.73+0.12	0.02	12.57+0.35	<0.001	13.40+0.17	<0.001	8
75 days	16.60+0.20	16.73+0.06	0.18	17.17+0.06	<0.001	18.17+0.06	<0.001	4
110 days	26.67+1.53	26.30+0.10	0.58	26.77+0.15	0.88	28.67+0.06	0.01	4
135 days	32.33+2.52	31.33+0.23	0.36	33.53+0.32	0.28	35.13+0.06	0.03	5
No. of Leaf's								
25 days	4.00+1.00	5.33+0.58	0.05	7.33+0.58	<0.001	8.67+0.58	<0.001	33
50 days	8.33+1.53	9.00+1.00	0.44	12.33+0.58	<0.001	14.67+0.58	<0.001	27
75 days	18.00+2.00	18.67+0.58	0.49	20.67+0.58	0.02	22.33+0.58	<0.001	10
110 days	24.67+3.06	25.00+1.00	0.82	27.00+1.00	0.13	28.67+0.58	0.02	7
135 days	31.00+1.00	30.33+0.58	0.52	31.67+1.53	0.52	34.33+1.53	0.01	6
No. of Flowers								
50 days	7.00+2.00	8.00+0	0.27	11.00+0.01	<0.001	13.67+0.58	<0.001	30
75 days	8.00+2.00	8.67+0.58	0.49	12.33+0.58	<0.001	13.67+0.58	<0.001	26
110 days	9.00+0	9.67+0.58	0.14	10.33+0.58	0.01	12.67+0.58	<0.001	15
No. of Fruits								
135 days	24+4	84+1	0.05	32+1	<0.001	38.33+0.58	<0.001	20

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Assessment on variations in physico-chemical characteristics at different maturity phages of organic kitchen waste composting at Lucknow City U.P. (India)

Shweta Chaudhary and Sunita Mishra

Abstract
The present reserch papers deals with the evaluation of the changes happening at various stage in the decomposition of Organic kitchen waste, via the estimation of some important physico-chemical and heavy metals concentrations. Changes inside the composition characteristics of the compost over-time, included elevated electric conductivity, bulk density, water retaining capability and so forth, all through the decomposition system, wherein because the moisture content material were given reduced closer to the give up of composting. From the physico-chemical point of view, evaluation of compost's moisture content material, pH, organic matter, calcium, magnesium, total phosphorus, sodium and potassium agreed with advocated requirements and higher heavy metals concentrations became detected at all the decomposition degrees of composting and were found to be inside the permissible limits of Ohai- EPA requirements. From the results, it may be concluded that, composting by using vessel method in aerobic condition ought to produce proper acceptable quality of compost, which may be used as organic manure or soil conditioner.

Keywords: Physico-chemical characteristics, Heavy metals, Organic kitchen waste, Compost, Aerobic condition.

1. Introduction

Kitchen waste is described as left-over organic rely from eating places, lodges and families. Kitchen waste paperwork a considerable a part of domestic waste. Food waste is an undesirable uncooked or cooked food discarded all through or after food coaching that is now not healthy for intake or proper. Toxic Links at New Delhi performed a survey in May 2002 and prepared a fact document on solid waste which stated that about 0.1 million ton of municipal solid waste is generated in India daily. So, annual production of solid waste reaches about 36.5 million tones [4].

Food waste is a global problem of state. It include leftover (cooked food), spoilt greens, peeling and trimming of culmination skins and so forth. Due to excessive moisture content material and natural content within the meals wastes can be utilized inside the land-filling, composting, anaerobic digestion and so on. Therefore it's important critical to enhance food waste management on the way to reduce capability human and environment risks [28].

Composting is a natural process of rotting or decomposition of natural count number by microorganisms beneath controlled situations. Composting allows lessening the quantity of waste this is being directed into landfills. This manner a discount of concentrated, poisonous leachates and methane gas this is being released into the atmosphere, which equates to a decrease in usual pollutants. Composting also cuts down on the usage of chemical fertilizers, which damages water supply.

Compost used to enhance soil bodily and organic matter, water retention capability, drainage, pH, better availability of soil micro-organism and decreasing the negative impact of chemical based totally insecticides and fertilizers within the ecosystems.

Besides population boom, two important elements will affect the earth's surroundings within the upcoming many years: financial increase particularly for international locations with a huge populace, like India and China; and greater monetary disparity between rural and urban regions, driving the agricultural population into towns. While the primary thing leads to an extra demand for sources, along with fossil fuels, metals, water and meals, the second component leads to a greater luxurious waste control burden on huge towns. Cities international extensive are already experiencing waste coping with problems and smog problems [15].

From 20 to 80% of the mass of municipal solid waste (MSW) is made from Kitchen waste. The Food Waste percentage was observed to be inversely correlated to the monetary reputation of the community, even as the mass of food waste produced per capita was without delay correlated [1] In many nations around the globe, the landfill exercise isn't always even possible, ensuing in land and water dumping [20].

Because of its biodegradability, Food Waste attracts sickness vectors which include parasites, pathogens, bugs and vermin [20] and its right disposal can enhance the surroundings and reduce health risks.

Composting is a biochemical method wherein natural materials are biologically degraded ensuing inside the manufacturing of organic or inorganic via merchandise and electricity inside the form of warmth [10]. Heat is trapped inside the composting mass, main to the phenomenon of self-heating this is traits of the composting manner [25].

Composting is a microbiological process, little is understood about microorganisms involved and their activities during unique stages of the composting method. Defining the variety and structure of microbial communities of compost via their constituent populations has been of tremendous interest to compost researchers so as to deal with primary ecological questions along with how comparable are microbial communities in mature compost that have been performed from extraordinary feedstocks and the use of one-of-a-kind composting strategies [29]. Composting is a spontaneous organic decomposition technique of organic materials in a predominantly aerobic environment.

A sustainable technique requires containment, accumulation, delivery, processing, and disposal of Municipal Solid Waste (kitchen waste) with an objective to load reduction on landfills along with fabric healing/recycling [30, 27]. There are numerous techniques in use worldwide for waste processing into value-added products within the form of compost (natural fertilizer), biogas, animals feed and chemical compounds [3]. Composting is an ecofriendly biochemical technique and a viable alternative for a sustainable MSW control [11].

1.1 Study location

Lucknow is the capital and largest town of the Indian nation of Uttar Pradesh and is also the executive headquarters of the eponymous District and Division. It is the 11th maximum populous metropolis and the twelfth most populous urban agglomeration of India. The city stands at an elevation of about 123 metres (404 feet) above sea level. Lucknow district covers an area of 2,528 rectangular kilometres (976 sq.Mi). According to the provisional file of 2011 Census of India, Lucknow town had a population of 2,815,601 [17, 18, 19, 32].

Due to industrialization and urbanization inside the Lucknow metropolis, populace and municipal solid waste has improved concurrently So, the study was undertaken to assess physico-chemical, traits and heavy steel concentrations at different stage in distinct maturity stages of composting procedure of Organic kitchen waste composting. This observe could help to recognize the degradation of kitchen wastes composting at diverse ranges.

The era of municipal waste, both garbage and sewage has been on the rise. Anthropogenic activities in society generate massive portions of wastes, posing a trouble for their disposal. Improper disposal ends in spreading of sicknesses and unhygienic conditions, besides spoiling the aesthetics. Therefore, waste management is crucial element of Lucknow town.

2. Materials and Method

2.1. Feedstock preparation

Kitchen waste become gathered from the main hostel mess of Baba Saheb Bhim Rao Ambedkar University Campus Lucknow, India often for one week in order to get a homogenous aggregate of feedstock. The collective meals waste changed into considered as a representative sample of the waste produced in hostel mess due to all styles of meals waste. The total wide variety of people input into mess for breakfast is round 150 according to day, whereas during the lunch time the entire variety exceeds 300 in step with day. The moisture content material (MC) of the accrued sample become 82.6%, and the use of such moisture wealthy waste aggregate in the composting manner can create waterlogged or anaerobic situations [5]. Therefore, the sample was solar-dried for 24 h to attain the preferred MC (70%) for composting process, as consistent with popular suggestions of Brinton (2000) [5] and EPA (2014).

2.2. Experimental setup

A laboratory scale in-vessel compost bioreactor made of plastic with a complete running potential of 10 kg become commissioned and used. Dimensions of the reactor have been: top 63.5, diameter 66.6 cm and thickness 10 mm. The vessel turned into blanketed with aluminum foil and styrofoam to prevent warmness losses. The reactor became filled with combined and ground feedstock as much as 70%, while 30% of the place was saved as a head area. The thermometer was fixed in the center of the compost bioreactor to display the temperature changes during the method. After loading the feedstock, the bioreactor lid became closed. Air flow changed into done through pores located at the lid of the bioreactor. Shredding of the compost combination was performed robotically through an agitator for attaining uniform mixing and oxygen (O2) supply in the course of the experiment as encouraged by way of [2]. The method of aerating the compost materials via turning and combining become followed consistent with the system defined by Singh and Kalamd had (2014), [26, 13]. The samples have been then transported in sealed aluminum foil to the laboratory, wherein stones, plastic and metals have been removed, oven dried at 700degree Celsius and the compost is homogenized via a 2 mm sieve. The compost samples were saved within the dark bottles until similarly analysis.

2.3. Analysis of compost samples

2.3.1. Physico-chemical evaluation

All experiments had been completed in triplicates. The accrued degraded compost samples had been analysed for numerous physico-chemical traits along with Moisture content material (drying at 105 0C to regular weight by gravimetric technique); Particle densities (Pycnometric method); pH (1:5 water extract by means of pH meter); Electrical conductivity (1:5 water extract, conductivity meter); Calcium and Magnesium (1N ammonium acetate, EDTA approach); Organic matter (ashing); Ammonia nitrogen (1:5 sodium acetate extract, Nesseler's reagent approach); Phosphorus (tri acid combination with a aqua digestion); potassium and sodium (1N ammonium acetate extract the use of flame photometer approach) wellknown approaches for evaluation [12, 23, 21].

2.3.2. Heavy metal analysis

The 1g of oven dried sample turned into transferred to one hundred ml beaker. A tri acid aggregate (10 ml) such as

HNO3, H2SO4 and HClO4 inside the ratio nine:2:1 became introduced to every of the flasks with a hundred ml of distilled water and digested on hot plate till the dense fumes of HClO4 stop, to get a clean extract. The beakers were then allowed to cool and the extracts had been filtered with Whatman No.42 filter out paper. The filtrates have been diluted to 100 ml in general flasks to have an adequate quantity of solution for evaluation. The dilution component turned into noted. The water soluble and acid digested extracts were analyzed for quantitative estimation of heavy metals (copper, lead and mercury) the usage of atomic absorption spectrophotometer [21].

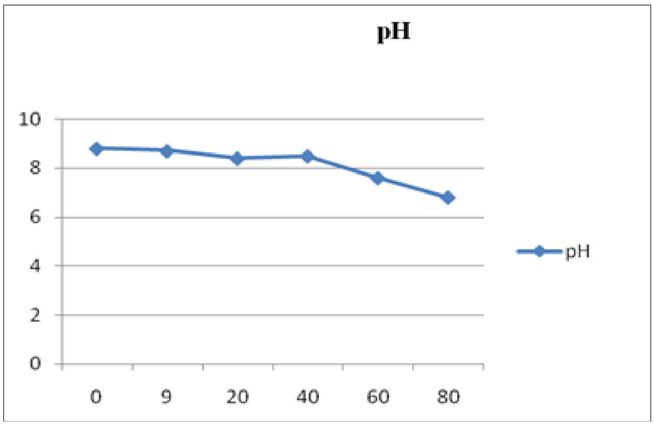
3. Result and Discussion

The physico-chemical characteristics at different stages are presented given in Table.1

Table 1: Physico-chemical characteristics of collected kitchen waste compost samples during different maturity phages of composting process (February 2017 to April 2017)

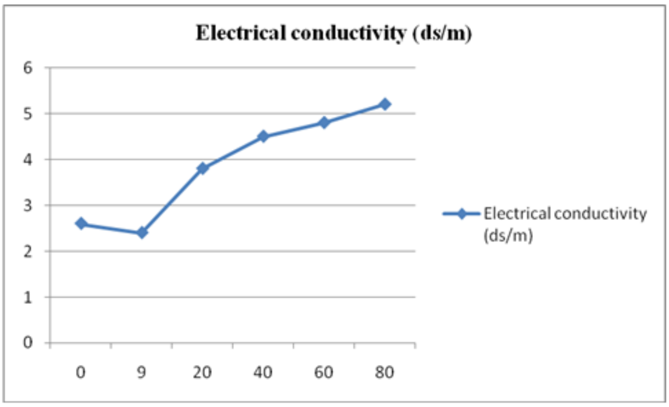
Parameters	Days				
	9	20	40	60	80
1. Moisture Content (%)	86.22	85.12	86.28	81.14	61.28
2.pH	8.7	8.4	8.49	7.6	6.8
3. Particle Density (mg/m3)	2.5	2.3	2	1.64	0.64
4. Electrical conductivity (ds/m)	2.4	3.8	4.5	4.8	5.2
5. Water holding capacity (%)	18.22	30.9	51.6	60.12	75
6. Organic matter (%)	29.32	28.35	23.82	14.6	17.36
7. Total Organic carbon (%)	16.62	15.11	13.82	12	11
8. Sodium (%)	0.036	0.02	0.040	0.06	0.08
9. Potassium (%)	0.07	0.07	0.08	0.12	0.13
10. Total phosphorus (%)	1.44	4.12	6.23	6.26	12.47
11. Calcium (%)	9.55	10.61	16.63	30.49	61.4
12. Magnesium (%)	0.87	3.11	4.78	9.03	11.52
13. Ammonia nitrogen (%)	1.68	2.63	4.2	2.26	1.61
Heavy Metals					
14.Copper (mg/kg)	242	154.1	218.1	212.1	202.1
15.Lead (mg/kg)	7	8	5	3	1
16.Mercury (mg/kg)	3	1	1	0	0

Based on above findings the result and discussion are as follows:-

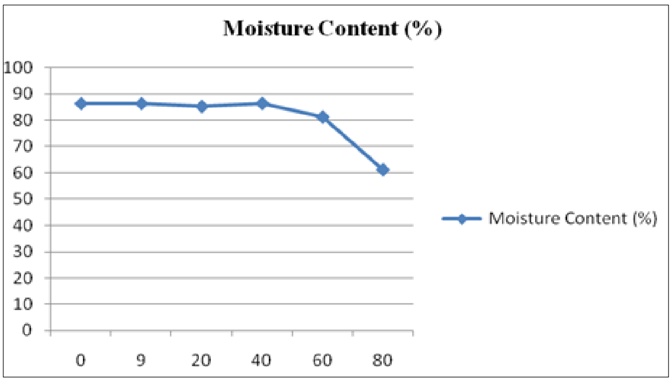


Ph value of compost discriminates its acidic or alkaline nature during composting. in our study, pH was initially very high 8.8, represents its alkaline nature in comparison with recommended value (Neutral pH 7) [4]. As days of composting progressed there was slightly decrease in pH of composting material as shown in Figure1. pH of compost was alkaline around 45 days of composting, and became almost neutral (pH=7.6) on around 60 days of composting. on 80Th day pH compost material becomes acidic. Highest pH in initial days of composting is due to may be presence of high amount of ammonia produced due to proteolitic process. Decrease in pH can be explained as the production off several organic acids results from the fermentation process of fats and carbohydrates.

Due to organic matter degradation in post composting days, pH tend to decrease, and the degraded organic matter is consumed as substrate by small microbes. Neutral pH phenomenon is found during maturation of composting material around 60 days of composting. The change in pH value during composting process is a specific indicator of decomposition and stabilization.



Salt component in composting material including, chloride, potassium, nitrate, sulphate and ammonia salts [5] carries electrical charges and maintain the ability of electrical conductivity of compost. In our composting material, initial EC was less 2.6 which increased in a consecutive manner and were highest around 60 days of composting as expected and recommended [6]. reported that degradation of organic matter tend to increase EC of compost to high values. Decrease in EC could also be explained as increase in concentration of nutrients such as nitrites and nitrates.



Total biomass of compost can be characterized between moisture content and dry mass as the percentage of initial weight. Activities of microorganism is directly propositional to the moisture content of the compost as moisture component of compost provides medium for their transport. Moisture content is concordantly varies with temperature and envoi mental conditions [7]. In this study moisture content ranges from 86.23% to 61.28%. Since from the first day moisture content was high, and it decreased during thermophilic stages to slight ranges only. The result on 50 and 60 days were concordant to the recommended ranges [16]. also found decrease in the moisture content of compost during high evaporating rates due to high temperature. Moisture content of compost between 50 to 60% represents favorable

Conditions for microorganism to grow and multiply as well as their optimal transport medium.

Increased in water holding capacity of compost indicates that compost has been utilized in growth of media.This shows that water content in the pores increases with days of composting.

At a specific time, after complete gravitational loss of water from compost, the amount of water remains in pores is termed as water holding capacity of compost. initial water holding capacity of the compost was 18% while it increased rapidly in post follow up days and reached maximum to 75% on the 80th day of composting.

Particle density varied from 2.5-0.64 mg/m3 which shows that as composting progresses the particle density decreases [4].

Organic matter is a key constituent of soil structure. It provides soil structure, nutrient availability and water holding capacity. In this study the Organic matter found between 29.32%- 17.36%. There is a some decrease in the percentage.

As the composting progresses the total organic carbon percentages decreases from 16.62 to 11 percent. This decrease in percentage indicates that the degradation of waste is by the action microbes [22].

Sodium and Potassium in composting stages varied at different stages of compost maturity. Both are highly soluble and gets easily leached. In the starting days of composting, Sodium found (0.036% -0.08%)to be high and after that it goes on decreasing and it is good because more sodium content in compost leads to damage in soil structure and increase permeability resulting in alkaline salt and which is harmful to plants.

Potassium is a important plant nutrition. It helps plant's growth and it increases as the composting progresses. It ranged between 0.07% -0.13%.

Total phosphorus ranged between 1.44% - 12.47% which shows that it increasing along with the composting maturity stages. Total phosphorous content slowly increased during composting process and water solubility of phosphorous decreased with humification, therefore phosphorous solubility during the decomposition was subjected to further immobilization factor [7]. It is also a plant growth promoting element.

Calcium and Magnesium are the main plant nutrients. In this study Calcium ranges from 9.55% - 61.4% and Magnesium ranges from 0.87% - 11.52%. Both elements found to be increasing in various degradation stages of Kitchen waste composting. Since kitchen waste is organic and biodegradable in nature it is also rich in calcium and magnesium content.

In this study, ammonia nitrogen ranged from 1.68% to 1.61 %. In comparison with recommended requirements [4] the ammonia nitrogen have been determined better in all of the pattern. Highest concentrations of NH4-N are produced in the first few weeks of composting. In fact, the ratio of organic and inorganic varieties of nitrogen has been used as a maturity index. In the final stage concentration of NO3-N is more than the concentration of NH4-N which would imply that the process happened below optimum conditions of aeration and that mature compost was produced [24].

Copper, Lead and Mercury varied in permissible amount prescribed by Ohai EPA [8] standard As kitchen waste is an organic and biodegradable in nature therefore there are no high amount of heavy metals detected. There are traces of some heavy metal found in the composting stages due to the chemical fertilizer and pesticide content in the kitchen waste material used for composting. In this study the variation of Copper, Lead and Mercury was 242-202.1mg/kg, 7-1mg/kg and 3-1mg/kg respectively.

4. Conclusion

Based on the above study it is concluded that due to urbanization of Lucknow and also being a densely populated metropolitan city it results in high rate of waste generation. And due to this Lucknow city is at great risk of environment pollution and health hazards. As this research paper focuses that composting is a sustainable approach to waste management, Kitchen waste composting by using aerobic vessel method may be considered as an eco- friendly and also job orienting method at large scale. The municipal solid waste committee also adopts this method as job and wealth creating approach. Kitchen waste composting is safe for using as natural organic manure and also as soil conditioner.

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- "**Assessment on variations in physico-chemical characteristics at different maturity phages of organic kitchen waste composting at Lucknow City U.P. (India)"**, ***Journal of Pharmacognosy and Phytochemistry*** **2018**; 7(5): **2943-2947.** . By Shweta Chaudhary & Prof. Sunita Mishra

- **“Role of microorganisms in environment management and plant nutrition.”, International Journal of Research and Analytical Reviews,** [VOLUME 5 I ISSUE 3 I JULY– SEPT 2018] E ISSN 2348 –1269, PRINT ISSN 2349-5138 352z IJRAR. . By Shweta Chaudhary & Prof. Sunita Mishra

ACCEPTANCE OF PAPER

- Research paper on **“**Phytotoxicity **assessment of four different seasons kitchen waste compost at different level of concentration on mung beans(** ***Vigna radiata(L.))”*** By Shweta Chaudhary & Prof. Sunita Mishra in **Plant Archives’ Journal.**
- Resarch paper on **“Effect on physico- chemical and microbial properties of kitchen waste compost- using potential fungal inoculant.”** in **ARCC Journal ,Indian journal of Agricultural Research.** By Shweta Chaudhary & Prof. Sunita Mishra.

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