CGIAR
SCIENCE FOR A FOOD-SECURE FUTURE

Training Manual

Composting: A Training Module for Trainers and Practitioners

Noah Adamtey, Tosin Somorin, Dzifa Agbefu and Olufunke Cofie

December 2025

The Authors

Noah Adamtey, Senior Researcher – Resource Recovery and Agri-food System Expert, International Water Management Institute (IWMI), Accra, Ghana
Tosin Somorin, Researcher - Circular Economy Waste Management, IWMI, Accra, Ghana
Dzifa Agbefu, Innovation Hub Coordinator, Circular Economy Waste Management , IWMI, Accra, Ghana
Olufunke Cofie , Africa Director for Research, IWMI, Accra, Ghana

Acknowledgments

This work was carried out under the CGIAR Multifunctional Landscapes Program. We would like to thank all funders who support this research through their contributions to the CGIAR Trust Fund (www.cgiar.org/funders).

CGIAR Multifunctional Landscapes Program

Multifunctional Landscapes is a CGIAR Science Program that aims to enhance the resilience, productivity, and sustainability of agricultural landscapes by integrating diverse land uses, ecosystem services, and livelihood strategies. The initiative supports evidence-based policies and innovations that balance food production with climate adaptation, biodiversity conservation, and social inclusion. By working with local communities, governments, and partners, it promotes landscape-level approaches to managing natural resources for long-term ecological and economic benefits. To learn more about the CGIAR Research Portfolio, please visit www.cgiar.org/cgiar-research-porfolio-2025-2030/

Citation

Adamtey, N.; Somorin, T.; Agbefu, D.; Cofie, O. 2025. *Composting: a training module for trainers and practitioners.* Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Multifunctional Landscapes Program. 42p.

Copyright

Front cover photo credit: Freepik | image by @freepik

Back cover photo credit: Freepik | image by @freepik

Designer: Jonathan Dickson

About the Manual

This training manual was primarily designed to support the training of small-scale farmers and entrepreneurs on how to produce compost from agricultural, food and other organic waste streams. This module is built on verified research and field experience, aligned with global circular bioeconomy policies and strategies. Following the introduction in Section 1, Section 2 introduces key theoretical foundations of composting, covering the process, quality, safety and health implications, and constraints. Further information on selection of suitable materials for composting, compost material preparation, the different methods of composting, ensuring compost quality including guidance on safety and health practices for composting facilities are provided. Section 3 provides a practical guide to composting. The training manual can be adapted as an operational or train-the-trainer manual for training community groups, enterprises, individuals, and organizations working or interested in waste management, circular economy, or composting, particularly women and youth. Technical training may be facilitated with practical demonstrations.

CONTENTS

Chapter 1

The Manual **1**

1. Background, Training Objectives and Scope of the Manual 2

Chapter 2

Classroom Training of Trainers - Science and Technology of Composting **3**

2. Composting Process 4

2.1.1 Why composting? 4

2.1.2 Benefit of compost 5

2.1.3 Tools and equipment for compost production 7

2.1.4 Materials for compost production 7

2.1.5 Selection of suitable composting materials 11

2.1.6 Composting material preparation 13

2.1.7 Composting methods 14

2.1.8 Compost Production 16

2.1.9 Requirement for a successful composting 18

2.1.10 Monitoring and turning of the compost pile 19

2.2 Compost Quality 20

2.2.1 Nutrient value properties of compost 20

2.2.2 Pathogens deactivation during composting 20

2.2.3 Production of compost to control soil borne and plant pathogens 21

2.2.4 Removal of foreign bodies, poisonous substances, high concentration of heavy metals and pesticides sources, and evidence of bad smell 22

2.3 Safety and health principles and practices for composting facilities 23

2.4 Safety and health regulations 24

2.5 Constraints of composting 25

Chapter 3

Guide to Practical Composting **26**

3. How to make compost 27

3.1.1 Selection of a suitable composting site 27

3.1.2 Construction of composting structures 27

3.1.3 Selection of composting materials 28

3.1.4 Material ratio combination 30

3.1.5 Create your compost pile 31

3.1.6 Cover compost heap 32

3.1.7 Maintain your compost pile 32

Bibliography **35**

GLOSSARY

Agricultural waste	Agricultural (crop and animal) and agro-industrial residues.
Aerobic composting	Is the decomposition of organic wastes by microorganisms in the presence of oxygen (air), to produce stabilized organic matter called compost or humus, carbon dioxide, ammonia, water, and heat.
Brown materials	Carbon-rich materials are those that provide a source of energy for the microorganisms that break down organic matter in a compost pile.
Compostable materials	Organic materials that can completely break down into natural elements without leaving toxic residue in a relatively short period of time.
Composting	A process of transforming organic materials of plant and animal origin under controlled conditions into a hygienic, humus and nutrient rich, relatively stable product that conditions soils and nourishes plants.
Compost	Compost is the product resulting from the controlled biological decomposition of organic matter (plant and animal residues) that has been sanitized through the generation of heat and stabilized to the point that it is beneficial for plant growth and to enrich the soil.
Mature compost	Stabilized composts that do not generate heat.
Compost pile	Heap of compost
Feedstock	Composting material
Green Materials	A material higher in nitrogen-to-carbon ratio mostly found in fresh organic materials.
Hazard	Something that has the potential to cause harm, (even if the harm is made unlikely due to the proper controls) such as a machine, electricity, dust, or sunlight.
Health	Refers to physiological injury or illness to a person, usually from continued or repeated exposure to a hazard.
Humus	A dark organic material that forms in the soil when plants and animal decays.
Manure	Manure from non-carnivorous animals only (like horses, goats, cows, chickens, and sheep)
Safety	Physical trauma, such as an equipment accident, a fall, or impact from a projectile.
Risk	The chance or likelihood of somebody being harmed by a hazard, combined with an indication of how serious the harm could be.

Source: Authors own

Chapter 1

The Manual

1. Background, Training Objectives and Scope of the Module

In rural, peri-urban and urban communities worldwide, agriculture is a vital source of livelihood and sustenance. However, it also produces substantial agricultural and market waste, like crop and animal residues (known as organic matter). The improper disposal of such waste not only poses health and environmental challenges, including water pollution but also contributes to greenhouse gas emissions. In response to these concerns, the practice of composting agricultural and market waste has gained significant traction as an effective means of recycling and promoting sustainable agricultural practices. Composting involves the transformation of organic materials of plant and animal origin under controlled conditions into a hygienic, humus and nutrient rich, relatively stable product. This product acts as a natural fertilizer, enriching soil health, enhancing water retention, and promoting plant growth.

This compost module is built on verified research and field experience, aligned with global biocircular economy policies and strategies. The concept of a circular economy aligns with the principles of sustainability, circularity, and environmental stewardship. This approach seeks to close the loop between production, consumption, and disposal by promoting the efficient use of resources and the minimization of waste. The module serves as a reference for training trainees, farmers, and entrepreneurs in compost production and marketing.

It imparts knowledge in:

- Effective organic waste management for farms, markets, and the environment.
- High-quality compost production from agricultural and market waste.
- Understanding composting processes to minimize emissions.
- Promoting local compost marketing.

Our goal is to reduce water pollution and synthetic fertilizer use and cut down on Greenhouse gas emissions through recycling of organic waste to restore soil health, and to create business for rural communities. The specific objectives are to:

a. Explain and optimize aerobic composting in rural communities.
b. Aid in planning composting practices and techniques for various scales.

The module has 3 chapters: Apart from Chapter 1- introduction, Chapter 2 explains the theoretical foundations of composting's, covering the process, quality, safety and health implications, and constraints. Chapter 3 offers a practical guide to composting.

By gathering organic waste and utilizing it for compost production, we anticipate the creation of an environmentally friendly product that eliminates hunger and improves health (SDGs 2 and 3). Also fostering the sustainability of oceans, water, climate, and land through responsible production and consumption (SDGs 6, 12, 13, 14, and 15), while also working towards reducing poverty.

Chapter 2

Classroom Training of Trainers - Science and Technology of Composting

2. Composting Process

Making compost is quite a lengthy and involving process, and timing is of utmost importance to have it ready at the time when it is required. The composting process involves preparation of composting materials or feedstock, decomposition, quality control, product storage,packaging, and preparation for market. Before we go into the composting process, it is important to look at why we do composting and the benefits of composting.

2.1.1 Why composting?

The main reasons for composting plant and animal residues from agriculture, agro-industrial and municipal solid waste are to recycle:

a. Manage the waste to achieve a clean healthy environment: Food waste is the third highest emitter of greenhouse gases (like carbon dioxide). Composting of organic waste help to reduce the quantity of waste transported into sanitary landfill sites by 50 percent thereby prolonging the lifespan of landfills. Composting, if done properly, will ensure clean and healthy environment (Figure 1).

Figure 1a: Management of Agricultural Residue through composting

b. The inherent nutrients and organic matter into finished product called the "black gold" (compost): Nutrients present in plant and animal residues are usually in complex organic form. Composting of these residues converts the nutrients from the organic to inorganic forms in compost which are useful for crop uptake. For example:

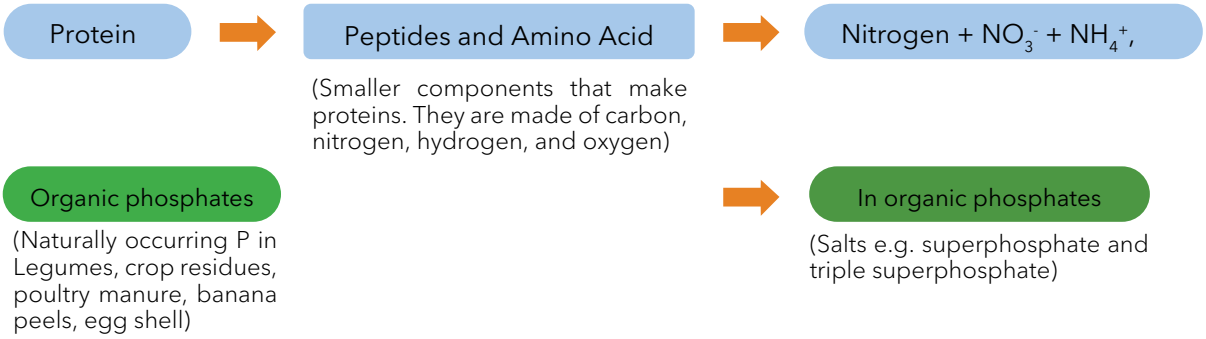


Figure 1b: The conversion of organic materials into inorganic ions through composting

c. Composting inactivates pathogens and prevents temporary ill effects of the soil: Crop and animal residues contain pathogens and eggs of parasites that could pose serious health hazards to human population: During composting process, diseases, pests and weed seeds are destroyed. Even viruses are destroyed, if a high temperature is reached.

2.1.2 Benefit of compost

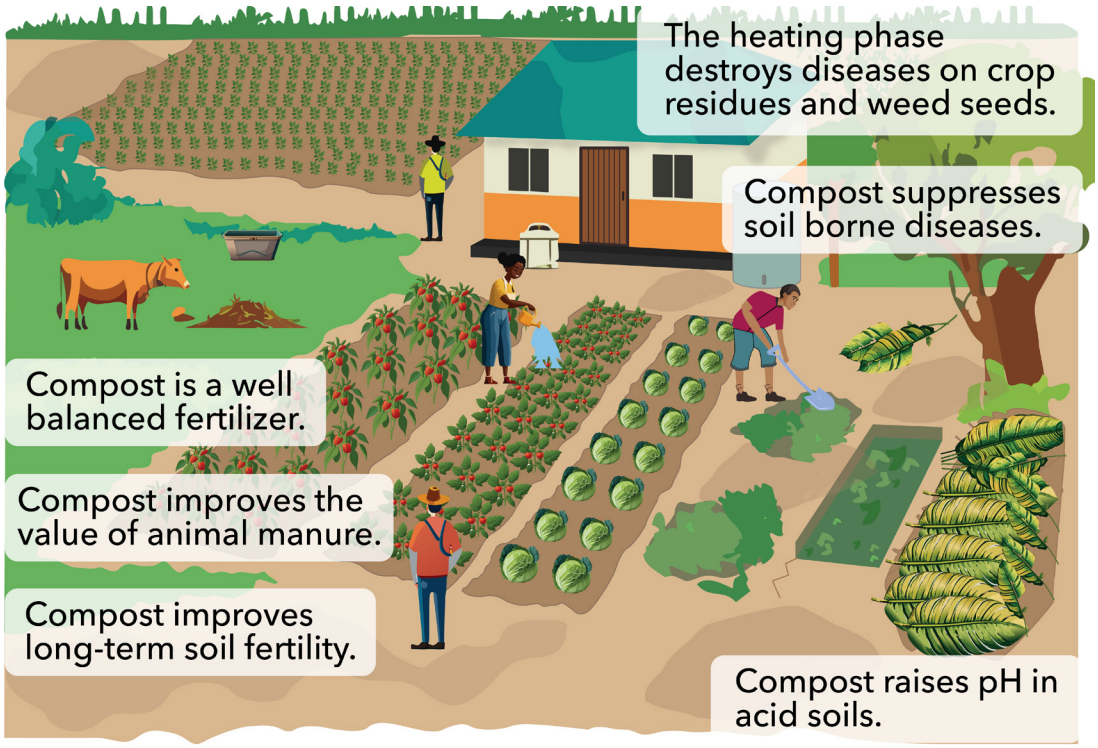


Figure 2: Farmers showing how compost is use on a farm

a. *Compost improves soil fertility on soil low in organic matter and supplies balance nutrients for plant growth and development:* Compost contains a mixture of ingredients (plant nutrients, beneficial soil organisms, biopesticides etc,). Frequent addition of compost to soil increase soil organic matter or carbon (thereby changing the colour of the soil to black) (Figure 3A & B). It also adds nutrients (nitrogen, phosphorus, potassium, magnesium, calcium, iron, copper, boron, etc.) to the soil, and thus it is used as plant fertilizer to improve soil health. It also supplies balance and adequate nutrients for plant growth and development (Figure 3C).

Image source: (Growing Guides 2021)

A B C

Figure 3: Addition of compost increase (A-B) soil organic matter, and C) nutrients

b. Compost increases beneficial organisms and their activity in the soil and their capacity to positively influence biological control of root rot diseases from fungi, bacteria and nematodes. (Figure 4)

Image sources: (Google images)

Figure 4: Addition of compost increase the population of beneficial soil organisms

c. Compost improves soil organic matter content which binds the soil particles into large aggregates (i.e crumbs) to improve soil structure, aeration, infiltration, and to hold water for a longer period. In a well-structured soil, a large aggregate will easily break into smaller aggregates. If it doesn't break apart and remains as a solid clod, then this indicates poor structure. Alternatively, poorly structured soil may collapse into loose dust or powder when you break it up. Poorly structured soils have limited large and medium-sized pores in them. This usually results in low water and air penetration of the soil and it also means roots cannot grow easily into and through these soils.

d. Cuts Methane Emissions from Landfills when organic matter decomposes, it undergoes aerobic decomposition, meaning that it's broken down by microorganisms that require oxygen. When compostable waste goes to a landfill, it gets buried under massive amounts of other trash, cutting off a regular supply of oxygen for the decomposers. The waste then ends up undergoing anaerobic decomposition, being broken down by organisms that can live without free-flowing oxygen. During anaerobic decomposition, biogas is created as a by-product. This biogas is roughly 50 percent methane and 50 percent carbon dioxide, both of which are potent greenhouse gases, with methane being 28 to 36 times more effective than CO2 at trapping heat in the atmosphere over a century. Although most modern landfills have methane capture systems, these do not capture all the gas.

e. It prevents or lessens soil erosion and conserve water, our research has shown that the use of compost reduces runoff water, soil and nutrient loss from arable cropping systems and watershed (*Adamtey et al., under review*). The water-retaining capacities of soil increase with the addition of organic matter such as compost. In each 1 percent increase in soil organic matter helps soil to hold 20,000 gallons more water per acre. By using compost to foster healthy soil, farmers do not have to use as much water and can still have higher yields compared with farming with degraded soil.

f. Enhance crop yields, quality, and shelf life compost use improves the growth and productivity of crops in terms of quantity and enhances the quality, as well as increasing the shelf life of agricultural products. Cabbage and tomatoes grown in compost-enriched media taste better than those cultivated with synthetic fertilizers.

g. Improves and stabilize soil pH

h. Reduces the need for chemical fertilizers but cannot fully replace them, particularly for plants requiring rapid nutrient release

2.1.3 Tools and equipment for compost production

Tools are needed to cut or shred compost materials. Tools needed for small scale composting include a hand hoe, machete (panga), shredder, shovel, spade, hand forked, stick pegs, watering can, wheelbarrow, sharp stick, garden hose of sufficient length, temperature probe (to monitor the temperature changes in the compost heap) and sieve (5 mm mesh sizes). For watering, a watering can should be used rather than a bucket, as this allows the material to better soak up the water. For medium scale composting you will need in addition to the above, a shredder, front end loader or a bucket loader on a tractor, a tractor with watering can for spraying or a sprayer, soil moisture meter, compost stirrer, and an electric rotary sifter or sieve, etc. (see figure 5a-d)

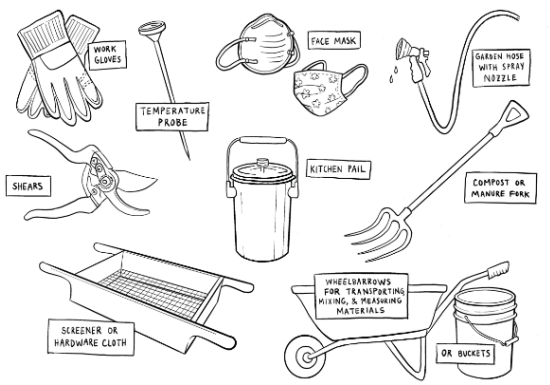


Image source: (Home composting basics), ILSR

Figure 5a: Tools for composting

Figure 5b: Equipment for compost turning and watering (tractor and turner)

Figure 5c: Front wheel loaded useful for windrow compositing

Figure 5d: Compost sieve for seiving finished compost

2.1.4 Materials for compost production

Knowing what materials to put into compost can be a headache at times, in this section of the manual we try to distinguish non-compostable materials from the compostable one and provide a summary in a chart to show what materials can be composted.

What not to compost: To harvest the benefits of composting, we need to keep a few things out of our compost to avoid inefficient biodegradation or, worse, contamination of the whole heap. These include materials from diseased or pest infested plants, plants that have died because of diseases/fungi infection, insect infestation, or plants that have been sprayed with pesticides or herbicides, chemically treated sawdust, materials with hard prickles or thorns, which may hurt the persons handling the compost. Persistent perennial weeds and invasive plants should not be composted either: Dandelions, ivy, and striga for example, are

persistent weeds that will simply sprout in your compost pile and spread to wherever you use the compost (Figure 6a - d). Instead, they should be destroyed by spreading them out in the sun to dry, or even burning. The dried material or ashes can then be added to the compost heap.

a. Pest infested plant b. Plants with thorns c. Dandelions d. Striga

Figure 6a-d: Plant samples that should not be composted

Citrus fruit peels: Can citrus be composted? Aside from taking a long time to break down, putting acidic citrus peels in compost risks throwing off the pH of your compost media and slowing the overall decomposition process. Composting citrus is especially forbidden if you have a vermicomposter, because it can kill your hardworking worms.

Onions and garlic scraps: If you're wondering, "Can I compost onions?", or "Can you compost garlic?", the answer is: it depends. As with citrus food scraps, putting garlic and onion in compost can kill worms and other beneficial composting organisms essential for breaking down organic matter. While they are not recommended for vermicomposters, they should be fine, in small amounts, in your regular compost pile, provided they're balanced with other items.

Non-organic materials: such as metal or plastic, rubber, leather, and textile materials cannot be composted. Graphic papers magazines, glossy paper and coated cardboard packages and paper cartons should also not be composted since they contain toxic metals like lead and cadmium and may affect the quality of the compost. Meats, bones, and dairy products may degrade over time, but will also invite pathogens and unwanted insects into the compost heap. Butter, cooking oil, animal fat, and grease: Oil and water just don't mix. Since moisture is a key component of the composting process, these non-compostable food waste items won't break down. Instead, they'll shift the moisture balance of your pile and attract pests.

Figure 7: Non compostable materials

Synthetic fertilizer: Don't dump remnants of fertilizer into the compost pile. Synthetic fertilizers may do a few things to compost: kill microorganisms (slowing down the pile's decomposition rate), alter the pH and nutrient levels, and eventually leach into the ground.

Materials to compost: Feedstocks, the raw ingredients for composting, are organic materials, usually solid, and usually in an active state of decomposition. Many organic materials can be composted ranging in diversity from garden plant debris to food processing residuals.

"Compostable materials": Anything that can completely break down into natural elements without leaving toxic residue in a relatively short period of time.

The secret to healthy compost production

The secret to compost heap is something called the Carbon to Nitrogen ratio (C/N), all the organic material that we add to the compost heap is made up of carbon and nitrogen. Maintaining an optimal C:N ratio is essential for effective composting, as it fosters the activity of microorganisms responsible for decomposing organic matter. The ideal C:N ratio is approximately 30:1, meaning 30 parts carbon to 1 part nitrogen. We refer to materials C:N ratio greater than 30:1 (e.g., 40:1) as "carbons". Materials with C:N ratio less than 30:1 (e.g. 15:1) are referred to as "nitrogen's". If you have too much carbon to nitrogen in your compost heap, decomposition slows down. On the other hand, if you have too much nitrogen to carbon in your compost heap, you'll end up with a stinky compost heap. This is why organic matter added to your compost heap is classified into browns and greens, browns are high in carbon, greens have high amounts of nitrogen. Monitoring and adjusting the C/N ratio by mixing appropriate amounts of browns and greens is therefore crucial for an efficient composting.

Browns

Carbon acts as a food source for decomposers, helping to keep them alive while they break down the waste. Higher proportions of carbon can be found in brown plant materials. These include dead plant matter, sticks and twigs, crop residues, hay, straw and other yard scraps (Figure 8a - 8e). These materials provide aeration and structure to the compost. However, they break down slowly, so it's best to chop/cut them into small pieces. Other available carbon-rich materials that can be used include maize stover and rice straw or husks, sugar cane waste, wood shavings, saw dust and biochar.

a. Maize stover

b. Maize cobs

c. Rice straw

d. Saw dust

e. Biochar from rice husks

Figure 8a-e: Carbon rich compostable materials

Greens

Nitrogen is another basic building blocks of life, and it is an essential element for growth and reproduction in both plants and animals. A higher nitrogen-to-carbon ratio is most found in fresh organic material (often referred to as greens). Providing sufficient green in your compost pile helps decomposers to grow and reproduce quickly and increase their activities. Some green sources include prunings from leguminous trees or shrubs e.g tithonia, gliricidia, leucaena, sesbania, crotalaria and lantana leaves. Nitrogen-rich materials like grass clippings, spent coffee grounds, fruit and vegetable scraps can also be added.

a. Tithonia

b. Gliricidia

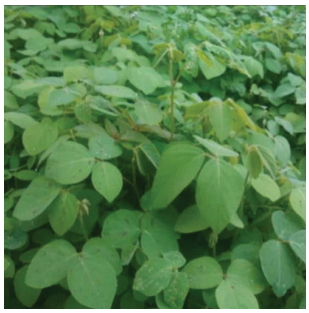
c. Leucaena

d. Sesbania

e. Crotalaria

f. Lantana leaves

g. Mucuna



h. Desmodium

i. Coffee ground

j. Coffee pulp

k. Coffee husks

Figure 9a-k: Greens (nitrogen) rich compostable materials

Burned wood ashes

A great alkaline substance to balance the pH of your pile if you've been adding a lot of acidic items (i.e. citrus fruits and peels)

Manure

Manure from non-carnivorous animals only (like horses, goats, cows, chickens, and sheep). Whenever possible, plant materials should be composted together with animal manure. Addition of animal manure accelerates the composting process and results in compost with higher fertilizer value. Dung can be dissolved in or mixed with water and poured over the compost heap when preparing the compost. Urine and slurry, both rich in nitrogen, can encourage decomposition of dry material when poured over it.

Image source: (Freepik)

a. Poultry manure b. Cattle manure

Figure 10: Poultry and Cattle manure

2.1.5 Selection of suitable composting materials

Selection of composting materials should be based on the **end use of the compost** (whether as ***soil conditioner***, ***fertilizer*** or to ***control soil*** and ***plant pathogens***), ***availability of the materials*** and their ***nutrient content*** (see Table 1 below). The materials you put into your compost pile also have a major impact on how well the composting process works and the quality of the final compost. One important key to good composting is to have a variety of materials and balance carbon to nitrogen ratio.

Rule of thumb

It is advisable to select materials with high carbon, nitrogen, phosphorous and potassium content for most field and horticultural crops. To use as fertilizer for the cultivation of tree crops e.g oil palm, mango, macadamia, etc. you may in addition need feedstock that is also rich in magnesium, zinc, copper and boron. Mucuna spp and Lantana camara are high with these trace elements, so they should be used in large proportion during composting (see above images under the greens for the plant samples).

Table 1: Nutrient content (dry weight) of some composting materials (%)

	N	P	K	B	Zn	Cu	C/N
Poultry Manure	2 -4	1-3	1-3				
Cattle Manure	1.5-2.5	0.3-0.5	1.9-2.2	6.5	23.6	4.5	15
Maize Stover	0.7-0.8	0.9-1.3	1-1.3				60
Ash	0.4-0.5	1.2-1.3	8.8-9.0				
Mucuna Pruriens	2-2.3	2.6-3.6	1.3-1.5	1.8	2.9		13
Tithonia Diversifolia	2.6-3.3	3.6-4.9	3.5-3.7	5.9	7.3		
Lantana Camara	1.6-2.0	2.1-3.1	1.8-2.0	2.3	4.1	4.0	
Leucaena Trichandra	4.15	0.23	1.7				
Moringa Spp	4.8	0.5	1.9		0.54-0.89	0.03-0.04	
Rice Husks							
Coffee Ground	1.45-2	0.06	0.06				
Coffee Husks	1.27	0.67	2.46				

Source: Authors own

2.1.6 Composting material preparation

Sorting of crop residues: Market organic waste contains several crop residues, and it is important to separate them into the different waste stream before air drying for composting.

Figure 10a: Unsorted waste

Figure 10b: Sorted waste

Dewatering and Air drying: Fruit waste contains a lot of water, and there is the need to dewater it before composting. The excess water should be collected, stored, and used for composting. The vegetable and any other fresh crop residues should be air dried under shade and thereafter cut into pieces before use for composting. This is to reduce the high-moisture content of the residues, to ensure accurate measurements for the different waste combinations and to avoid fermentation of the compost heap. Drying under shade helps to reduce nitrogen loss from materials.

Figure 11a: Dewatering fruit waste

Figure 11b: Drying of fresh crop residues for composting

Shredding of materials: To aid faster decomposition, before using materials to your compost, you have to shred or chop off the composting materials especially those with high carbon content such as maize and sorghum stalks, the twigs (that are more than 2.5 to 5 cm in size) into smaller pieces. You don't need to shred nitrogen's based materials because they will decompost quickly.
Cutlass can be used for small scale composting, while we recommend shredder for medium to large scale composting.

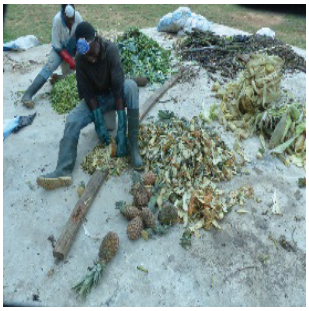


Figure 12a: Manual shredding of composting materials into smaller pieces

Figure 12b: Compost shredder cutting large materials into smaller pieces

2.1.7 Composting methods

a. *Pit or trench composting:* Composting can be done in a pit under a shade (see Figure 13). In that case, the floor is not with concrete. Dig the hole for your compost pit. Measure out an area 1.5 meters wide and of any convenient length. The width should enable you to work with the compost without having to walk on it. Your compost hole should be about 30.5 cm deep. In the more arid climate region, the deeper the pit, the better. Compost pits should, however, not be deeper than 50 cm to ensure aeration. The area of the hole will be determined by the amount of organic matter you want to add. At most, the compost material should reach a depth of 10 cm in the pit.

Building and assembling your compost heap: Before you build a batch of compost, wet the ground first. This will help prevent the ground from soaking up the moisture from the pile. It will also encourage earthworms to visit your heap. Chop your compost materials high in carbon (such as twigs). Lay a 10cm layer of twigs or other coarse carbons on the bottom of the pile to allow air to circulate at the base. Lay the rest of your organic materials, alternating carbon and nitrogen layers (such as greens and manure) followed by wood ash and soil. Add water as you go, remembering that 45 – 50% of the heap by weight should be water. Repeat the process again until you get to the top surface of the soil. Improve decomposition by watering the compost area.

Underground compost decomposes more slowly than above ground piles. Speed up this process by ensuring the area stays wet with a garden hose. During dry weather, soak the ground above the compost pit with a hose. Dryness will make it more difficult for microbes to break down your scrap. If you live in an area that is excessively dry or excessively wet, cover the pile with a black plastic sheet to prevent the compost heap from rainfall or excessive sunshine. Turning of the compost is from pit 1 to pit 2. The next turning will be from pit 2 to pit 1 and vice vesa. The process then repeats itself whenever you want to turn the compost.

Figure 13: Pit or trench composting

b. *The heap composting method under shade (in a shed or under a tree):* Well-drained and levelled ground under a shade should be used (a cemented floor will be ideal). The level ground minimizes the risk of being sieved out of nutrients by runoff rainwater. The natural shade such as a tree or a built shade reduces evaporation and leaching of nutrients out of the compost heaps. Mark out the space for your heap or pile and build up the pile as described above under the pit composting.

Credit to: FiBL Syscom

A

Credit to: NRC Malawi

B

Figure 14: Heap Composting under shed and tree

c. *Windrow composting on an open field:* Windrow composting on an open field is normally done with tractors. The compost windows is formed as shown in Figure 15. The windrow-composting method consists of linear rows of compost materials (brown material such as rice straw and cow manure), which are placed layer by layer and mechanically turned periodically. The piles can range from 90 cm (dense raw materials such as manures) to 360 cm height (light raw materials such as leaves). The piles can vary from 3 to 6m width. Pile dimensions are determined to a large extent by the equipment machinery available for turning. Examples of the machinery include front end loader or a bucket loader on a tractor. The piles of raw materials need to be turned regularly to mix the materials and enhance aeration for good decomposition. Thus, the turning process helps improve aeration and mixing of compost constituents. The windrow composting method relies on mechanical aeration, typically with a compost windrow turner, to optimize the composting process. The window need to be covered with plastic sheet when there is rain or in the night to prevent water logging.

Figure 15: Windrow composting on an open field at Kasisi training center, Zambia

c. *Windrow composting under a shed:* Windrow composting can also be done under a constructed shed (Figure 16a-b). In that case, the flour must be cemented with concrete and the shed partitioned into windrows (W1-W4). The partitioning of the windrows should be with temporal structures such as wooding material. They are removed whenever you want to turn the compost. The compost is prepared in W2 and W4. Turning of the compost is from W2 to W1, and the other from W3 to 4.

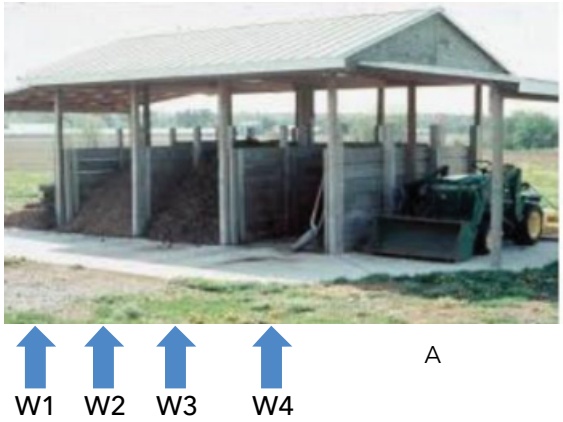


Image Source: Mortality Composting Basics for Poultry Producers, University of Georgia Extension, 2023

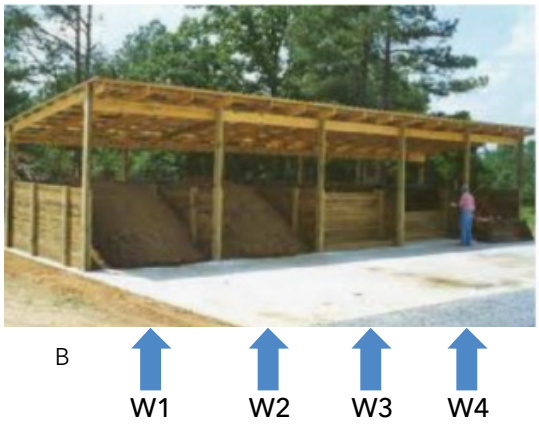


Image Source: USDA Compost and Food Waste Reduction Applications are Due Friday, 2021

Figure 16: Windrow composting under a shed

a. *Box and bin composting:* Compost Bins are available made from various materials, each with their own benefits and or drawbacks.

- *Wood* - Looks nice, may rot if untreated (Figure 17a).
- *Plastic bin* - It is not UV tolerant (Figure 17b).
- *Metal wire* - Allows air flow but cannot stop pests from getting to your pile.

Figure 17a: Wooden box composting

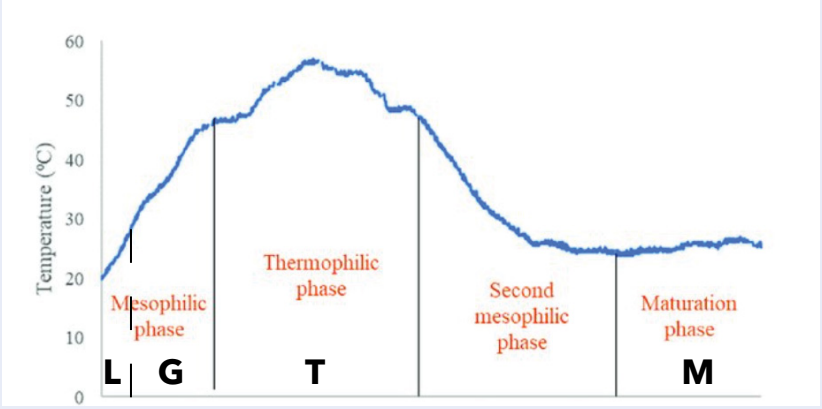
Figure 17b: Plastic bin composting

2.1.8 Compost Production

Compost is produced through the decomposition (breakdown) of organic materials (plant and animal residues) by the activity of aerobic (oxygen requiring) microorganisms. These microorganisms require oxygen, moisture, and food (nutrients) to grow and multiply. When these factors are maintained at optimum levels, the natural decomposition process of the organic materials is greatly accelerated. Microorganisms (microbes) generate heat, water vapour, carbon dioxide and Sulphur dioxide as they transform the residues into a stable substance called compost for use as soil conditioner or organic fertilizer (see Equation 1).

Organic matter + Oxygen + Nutrients —(Microorganisms)→ New cells + Stabilized organic matter (Compost) + Carbon dioxide + Water vapour + ammonia + Sulphur dioxide ... + Heat energy

Properly made compost goes through four phases: the 1st mesophilic (heating) phase (which can be divided into latent and growth phase), thermophilic (the high temperature phase) phase, the 2nd mesophilic (cooling) phase, and the maturation phase (see figure 18 below).



Latent phase (L): Corresponds to the time necessary for the microorganisms to acclimatize and colonize in the new environment in the compost heap. At this stage the raw materials have not yet undergone any decomposition.

Growth phase(G): Which is characterized by the rise of biologically, produced temperature to 1st mesophilic level (25-40°C).

Thermophilic phase(T): Temperature rises to the highest level (50-65°C). This is the phase where waste stabilization and pathogen destruction are most effective.

Maturation phase(M): Which is a lengthy period of stabilization intended to produce a highly stabilized and humified mature compost where the temperature decreases to 2nd mesophilic level (25-40°C) and, subsequently to ambient levels (A).

Figure 18: The main phases during the composting process

The high temperature phase is a result of the energy that is released during the decomposition of easily digestible materials by the microorganisms (bacteria). Due to the rapid development of their population, the oxygen demand of the bacteria is very high during this phase of the composting process. High temperatures in the heap indicate that oxygen supply is adequate. If temperature stays low or the compost develops an unpleasant odour, this can be an indication that the heap is compacted, and oxygen supply is low.

The fairly high temperature is typical and important for the composting process. The heat destroys diseases, pests, weed-roots and seeds and thus prevents their further propagation. The high temperature phase allows a high rate of decomposition. Bacteria not only depend on oxygen, but also on humidity for their development. Due to the high biological activity and high evaporation, the humidity requirements are highest during the 1st Thermophilic phase of composting. After decomposition of the residues by the bacteria, the temperature in the compost heap declines slowly to 25 to 45°C. When temperature declines, fungi settle and start the decomposition of straw, fibres and wooden material.

As this decomposition process is slower, the temperature of the heap does not rise. The low temperature phase allows the compost product to stabilize while still decomposing at a lower rate. During the maturing phase, red compost worms and other soil organisms start to inhabit the compost heap. Nutrients are mineralized and humic acids and antibiotics are built up. At the end of this phase the compost has lost about half of its original volume, has taken on a dark colour and the smell of fertile soil and is ready to use. Water requirement during this phase is low.

WHAT IS COMPOSTING?

Composting holds different meanings for different groups, all of which are valid: for waste managers, it is a waste volume reduction strategy; for public health professionals, it is an organic waste sterilization process; and for gardeners, it is a method of transforming organic materials of plant and animal origin under controlled conditions into a sanitized, humus-rich, nutrient-dense, and relatively stable product that conditions soils and nourishes plants.

WHAT IS COMPOST?

Compost is the product resulting from the controlled biological decomposition of organic matter (plant and animal residues) that has been sanitized through the generation of heat and stabilized to the point that it is beneficial for plant growth and to enrich the soil.

2.1.9 Requirement for a successful composting

The effectiveness of a composting process is dependent upon several factors including the groups of decomposing organisms that inhabit and stabilize organic wastes. Also, on the proportion of composting materials (browns and greens) (carbon and nitrogen) and their particle sizes, the moisture or water content of the compost heap, air circulation, warmth (temperature) and the composting period (time).

The proportion of browns, greens, and water can affect the microorganisms that decompose organic matter. Cutting composting materials into smaller pieces provide wider surface area for the microorganisms or decomposers to digest or break down, multiply faster and generate more heat. Similarly, if the amount of oxygen (air), nitrogen, carbon, moisture, and temperature in the heaps are in the right proportion, it provides good environment for the microorganisms to thrive and decompose the organic waste. During the growth phase of composting (see figure 18), sufficient air is needed to allow a good start for microbial transformation, and to promote the appropriate temperature rise, needed to inactivate pathogens.

Absence of air (anaerobic conditions) will lead to different types of micro-organisms developing, causing either acidic preservation or putrefaction which lead to bad odour generation from the heap. Optimal air flow can be achieved by layering materials, making sure your materials are in small pieces (ideally no thicker than a finger), and turning piles regularly. Hot composting is achieved when the balance of greens, browns, air, and water creates ideal conditions for aerobic organisms to thrive.

The moisture content of the composting materials affects the availability of oxygen for microbial processes. Water is essential for the decomposition process and water stress is among the most common limitations on microbial activity on solid substrates. However, when moisture levels exceed 65%, air in the pore spaces of the composting materials is displaced by water, which leads to anaerobic conditions, odors, and slower decomposition. Moisture content of the mixture should be maintained at 60%, which is the optimum level for microbial activity. To maintain the moisture content at an optimal range of 50–65% (wet basic), water is added to the compost during turning periods. After the turning process, a plastic sheet is used to cover the windrow to retain the moisture content and prevent excessive loss of heat. At the end of the composting process, the moisture content of the compost should be about 30% to prevent any further biological activity in the stabilized material.

2.1.10 Monitoring and turning of the compost pile

A Properly built compost pile (heap) temperature will continue to rise if optimum water and air are present in the heap. The temperature is desirable to vary from 60C° to 70C° in the first 25 days of composting. Temperatures of 65.5°C are good because they will kill pathogens and weed seeds. If your compost heap does not reach 48°C to 71°C, you probably do not have enough nitrogen in your pile. Add more nitrogen materials, mix, and monitor again.

The minimum temperature should be 46°C. Also monitor the moisture content of your heap. It should be 50% water by weight. One of the ways to check the moisture content is to squeeze a handful of the compost with your hands: If it has an adequate concentration of water, we will be able to feel the moisture and the aggregation of the material, which will form a "scone", without the water slip through your fingers. The initial moisture should be between 55 and 60%, with a minimum of 40%. The optimal moisture of the pile is 55%. If the moisture is greater than 60% then you should turn over the pile. If the moisture is less than 40% then more moisture can be added to the pile. Temperature can be measured with a Thermometer (Figure 19) or a stick or bamboo inserted into the middle of the pile after a few minutes, from top to bottom (Figure 20). The stick or the bar must be withdrawn from the pile, after a few minutes (from two to three). While removed and touched, observe if:

Image Source: Compost pile temperature after first turning, Steve Masley

Figure 19: Thermometer for testing the temperature of the compost heap

Figure 20: Stick for testing the compost heap

- It's hot and wet. In this case, there's no need to wet the compost pile until the next turning;
- If it is dry, it will probably be cold too and then the pile must be wetted again until the water is at the base of the pile. Be careful not to drain it abundantly.

But as air and water are consumed, the supplies will become too depleted to sustain the aerobic bacteria population your heap needs. Your heaps temperature will drop as excess bacteria begin to die. Turning your compost heap at this point introduces air and water into the heap, reviving the bacteria population. Temperature rises again as aerobic bacteria reproduce more rapidly. Turn the heap regularly to provide air to the microorganisms which speeds up the composting process. To do so, use a shovel or pitchfork to turn and rotate the materials, which helps distribute air and moisture evenly. How often you need to turn your compost depends on many factors, including the size of the pile, amount of moisture, and ratio of brown to green materials.

RULE OF THUMB

You should start by turning your pile every 4–7 days. As your compost starts to mature, you may need to turn it less often.

2.2 Compost Quality

Compost quality addresses the nutrient value properties of the compost such as essential plant nutrients (nitrogen, phosphorus, potassium, calcium, magnesium, iron, copper, manganese, boron, zinc, molybdenum, and nickel), pathogens, absence of seeds, perceivable foreign bodies, poisonous substances, high concentration of heavy metals and pesticides, and bad smell. Compost should be easy to apply, homogeneous in quality, and not dusty.

2.2.1 Nutrient value properties of compost

Quality and marketing of compost are the most crucial issues.' Good quality compost should ensure a high crop yield on a sustainable basis. Quality depends on the desired properties of the compost such as essential plant nutrients (N, P, K, Ca, Mg, and trace elements), absence of seeds, pathogens, perceivable foreign bodies, poisonous substances, concentration of heavy metals and pesticide, and odour. Compost should be easy to apply, homogeneous in quality, and not dusty.

- Compost for crop production needs to be high in nutrient content especially nitrogen (N), phosphorus (P), potassium (K) and other micronutrients. Based on our findings, any compost with at least the following nutrient contents can increase productivity:
  N content ≥ 2.5 %
  P content ≥ 2 %
  K content ≥ 2%
  To get the above nutrient levels, there is the need to analyze and know the nutrient content of the composting materials (see section 2.1.5, Table 1, page 15). Also, to guide the types and the proportion (dry weight by dry weight) of materials to be used.

- Compost for soil amendments to improve soil physical, chemical, and biological properties need to be high in carbon and nitrogen content. Compost pile needs a proper ratio of carbon-rich materials, or "browns," and nitrogen-rich materials, or "greens."

- Compost to control soil erosion and reduce soil compaction need to be high in coarse texture.

- Compost to control soil born and plant pathogens need to be high in bio pesticides-based plants.

2.2.2 Pathogen deactivation during composting

Organic residues contain pathogens and eggs of parasites that could pose serious health hazards to human population. They also contain germination inhibiting substances i.e., phytotoxic organic metabolites which might affect crop production. Some phytotoxic metabolites are acted upon by microbes during composting thereby inactivating them or reducing their concentration. Salmonella spp., Hepatitis viruses, and Ascaris lumbricoides (common roundworm) can persist if compost temperatures do not reach at least 55°C for three or more days, or if there is uneven heat distribution or a failure to maintain aerobic conditions. Similarly, Fusarium or tomato wilt can survive in compost at temperatures as high as 62°C. Effective pathogen reduction requires maintaining temperatures between 55°C to 65°C for a minimum of three days in a well-managed composting process. During composting the biological heat produced at a temperature of about 65°C is sufficient to inactivate most of the pathogenic bacteria, viruses and helminthic ova which otherwise could infect the workers. Addition of minimal amount of ammonium phosphate or urea fertilizer to the compost heap also help to sanitize the compost. Therefore, composted products can be safely disposed of on land, or used as fertilizers for plant growth.

2.2.3 Production of compost to control soil borne and plant pathogens

Several soil-borne diseases are challenging to control due to their persistence in the soil, resistance to various treatments, and ability to spread easily. Some of the most difficult soil-borne diseases to manage include Fusarium wilt (caused by Fusarium oxysporum, a fungus), Verticillium wilt (caused by Verticillium dahliae and Verticillium alboatrum, fungi), clubroot (caused by Plasmodiophora brassicae, a fungus), root knot nematodes (caused by various species of Meloidogyne), and bacterial wilt (caused by Ralstonia solanacearum, a bacterium). These pathogens can survive in the soil for long periods and spread easily. Aside from chemical treatments, these pathogens can be managed through crop rotation, the use of resistant plant varieties, and the application of compost—particularly compost that contains medicinal plants as part of the materials used. The plants that can enhance the effectiveness of compost in managing soil borne pathogens are listed below.

Plants commonly from Sub Saharan Africa

Neem cake: Neem cake is a by-product of neem oil production and is rich in nutrients and compounds that can help protect plants from pests and diseases. Neem cake is being used as a natural pesticide, a soil amendment, or even a fertilizer. The addition of neem cake and leaves to compost heaps increase the nutrient content of the compost, boost compost effectiveness in managing diseases in the soils and enhance the resilience of the farming systems.

The nutritional composition of neem cake could arrange from 2-5% N, 0.5-1.2% P, 1-2.0% K, 0.5-3% Ca, 0.3-1.0% Mg, 0.2-0.3% S, along with 4-20 ppm copper, 500-1200ppm iron, 20-60 ppm manganese, and 15-60 ppm zinc.

How to prepare neem cake:

1. Neem cake can be prepared from dry leaves, bark and seed or from the seed alone after extraction of oil.
2. Take dried neem seed and remove the seed coat with the help of mortar and pastel or any mechanical means.
3. Clean the neem kernel and seed coat mixture by winnowing or sieving the seed coat.
4. Weigh 1 kg of clean neem kernel, add it to the dry leaves and make powder of grain size like fine tea powder. It should be pounded in such a way that no oil comes out.
5. Alternative, an oil is extracted from the seed using a mechanical presser (if it is from the seeds), the residue is the neem cake.

Lantana camera (Sleeper weed): Extracts from the leaves of sleeper weed have been proven to exhibit antimicrobial, fungicidal, insecticidal and nematicide activities. The addition of the freshy parts of the plant and its leaves boost the effectiveness of compost in managing diseases that affects the soil and crops.

a. Neem Cake

b. Neem leaves

c. Lantana Camara (Sleeper Weed)

Figure 21: Common plants to treat pathogens

Plants mainly from Southeast Asia and Latin America

Acorus calamus (Sweet flag): Acorus calamus is commonly referred as Sweet flag and use in traditional Bhutanese medicines. The rhizomes of this plant contain insecticidal properties, and its dried powdered can be added to compost piles.

Nicotiana tabacum L. (Tobacco): It is a fast-acting insecticide. Tobacco leaves are highly effective against a variety of pests that are challenging to manage. The leaves or residues can be dried, and a small proportion of the powder can be incorporated into compost. Tobacco residue also enhances soil health by improving soil microbial diversity, community composition, network structure, keystone microorganisms, and ecosystem functions. However, it's crucial to acknowledge that farms adhering to certified organic production standards are prohibited from its use due to certain regulatory constraints.

Tagetes sp (Marigold): The extract of marigold flowers has been known for its use against insect pests and nematodes. The flowers can be crushed into a powder sprinkled on compost or to a paste and diluted with water to spray the compost before use.

a. Sweet flag

b. Tobacco

c. Marigold

Figure 22: Plant materials to use with compost to suppress or control nematode, bacterial wilt, and other soil pests

2.2.4 Removal of foreign bodies, poisonous substances, high concentration of heavy metals and pesticides sources, and evidence of bad smell

When compost is mature there is the need to sieve it through wire mesh to remove all foreign bodies (stones, broken bottles, pieces of wood, plastics, etc.). Heavy metals are poisonous substances that can contaminate the compost. They normally get into the compost when the composting material includes graphics or newspapers, batteries, glue, etc. Hence it is important to sort out and remove such materials.

Figure 23: Un-sieved compost heap

Figure 24a: Sieving of compost

Figure 24b: Sieved

2.3 Safety and health principles and practices for composting facilities

Composting is rugged work, facilities vary in scale, the feedstocks handled, composting methods, types of equipment, climate, worker skills and training, hours of operation, and level of management. The feedstocks handled, methods employed, the equipment used, and the work practices followed strongly affect the specific safety and health hazards encountered and the associated levels of risk. In addition, foreign objects delivered with some composting feedstocks are damaging to machinery and potentially hazardous to human operators. Examples include gas cylinders, batteries, containers with chemicals, cables, chains, rope, metal strapping, and large or sharp metal items.

By its nature, composting exposes operators to assorted microorganisms (e.g., molds and bacteria), dust, gases, vapors, noise, sharp objects, heavy objects, sunlight, heat, extreme cold, strain, fatigue, and mechanical and electrical machinery. Thus, composting inherently entails safety and health hazards. Even when composting facilities employ sound practices, there are always risks associated with day-to-day operations, and occasional accidents. However, awareness of the hazards, prevention, and preparedness keep the risks from becoming safety incidents and health problems.

Before considering the details of composting safety, health hazards, and risks, it is necessary to be clear about what these terms mean.

Safety is associated with physical trauma, such as an equipment accident, a fall, or impact from a projectile.

Health refers to physiological injury or illness to a person, usually from continued or repeated exposure to a hazard.

A hazard is something that has the potential to cause harm, (even if the harm is made unlikely due to the proper controls) such as a machine, electricity, dust, or sunlight.

Risk is the chance or likelihood of somebody being harmed by a hazard, combined with an indication of how serious the harm could be.

Tables 2 and 3 provide an overview of the general hazards that composters may encounter in different facets of an operation.

Table 2: Relative risk from safety and health hazards during compost production

Hazard	Harm that may result	Receiving & Sorting	Grinding	Mixing & Pile Forming	Turning	Screening	Bagging	Materials handling	Site Management & Monitoring
Machinery	Physical injury	✓✓✓	✓✓✓	✓✓	✓✓	✓	✓✓	✓✓	
Vehicles	Accidental collisions	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓	✓	✓✓✓	✓
Bacteria, viruses, and other pathogens	Infection and allergic reaction	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓
Dust and bioaerosols	Infection or respiratory illness; allergy	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓
Volatile chemicals	Respiratory illness	✓	✓	✓	✓✓	✓✓	✓	✓	✓
Weather (ambient temperature, sunlight)	Heat stress, cold stress, extended sun exposure, dehydration	✓	✓	✓	✓	✓	✓	✓✓	✓✓
Heavy items	Physical overexertion (sprains, strains)	✓✓	✓	✓	✓	✓	✓✓	✓✓	✓

✓ Relatively no to little risk; ✓✓ Relatively no to little risk; ✓✓✓ Moderate to high risk.

Source: Adapted from Nellie et.al., 2016

Table 3a: The potential hazards associated with composting

Potential Harzard	Harm that may result	Comments	Relevant operations and activities
Machinery	Physical injury	Accidents ranging from pinches, cuts, and scratches to loss of fingers and limbs	All operations involving rotating and moving parts, such as conveyors, grinders, chippers, power take off drives, bagging lines, motors and engines, etc.
Vehicles	Accidental collisions	Between vehicles or between vehicles and individuals. Vehicle operators' vision can be obscured by piles. Also, loaders or other materials handling equipment can inadvertently entrain unseen workers	Any activity that includes moving equipment; simply walking the site.
Bacteria, viruses and other pathogen	Infection and allergic reaction	Infection can occur through inhalation, skin contact, hand-to-mouth contact, and especially through open wounds. Each type and source of feedstock brings its own mixed population of bacteria and fungi. Risks are greater prior to high temperature composting. The risk presented is dependent on an individual's susceptibility (e.g.,allergies, immune)	All operations involving materials handling, including receiving (feedstocks and bulking agents), grinding, mixing, pile windrow formation, turning, screening, compost handling and application, sampling and monitoring.
Dust and bioaerosols (also note above information on bacteria, viruses, and other pathogens)	Infection or respiratory illness	The primary pathway is via inhalation of particles. A constant factor, especially with dry materials and under dry conditions. Applying moisture with mists or sprays suppresses dust.	Vehicle movement on the site. All operations involving handling dry materials, including turning, screening, compost handling and application, bagging.
Volatile Chemicals	Acute or chronic injury to body's target organs	The primary pathway is via inhalation of gases. Ammonia from the composting process is the primary risk.	Turning; receiving and handling of raw feedstock from storage; handling, pumping, transferring leachate.
Weather (air temperature/ sunlight)	Heat stress (Including dehydration), cold stress, extended sun exposure	Includes fatigue, extreme cold or heat, extended sun exposure, dehydration.	All operations, especially those occurring outdoors.
Heavy Items	Physical overexertion (sprains, strains)	Includes heavy lifting, repetitive movement, general overexertion, sprains, strains.	All operations, including materials handling and maintenance tasks.

Source: Adapted from Nellie et.al., 2016

2.4 Safety and health regulations

1. Some composting equipment screeners, grinders, chippers, windrow turners can throw objects. Once these objects become airborne, they can affect the eyes.

   Operators and workers should wear either safety glasses with side shields or goggles to protect the eyes from flying objects, as well as a hardhat. A face shield could be added as face protection (but not as an alternative to safety glasses or goggles; or a face shield/goggle combination could be used).

Figure 25a: Goggles

Image Source: Composting safety & health, (Cornell waste management institute)

Figure 25b: Hazmat suit and Face sheild

2. A composting site can be an active place with several vehicles (trucks, loaders,turners) moving amid each other and amid people on foot. Furthermore, the vehicle operator's view is occasionally obstructed by steam rising from windrows, fog, and piles of material.

   To prevent an accident occurring, operators must make sure that co-workers and visitors are clearly out of the way. Each day an operator should start with an understanding of the general whereabouts of coworkers and visitors on that day and presume that they will remain there. Similarly, pedestrians walking in the vicinity of mobile equipment must make their presence known to the operators, and that they can be seen by the operators. Brightly colored clothing (e.g., reflective vests) is highly recommended.

RULE OF THUMB

a. *As a rule, do not approach an operating vehicle until you first make eye contact with the operator.*
b. *All large mobile equipment (e.g., loaders and trucks) should have an audible back up (reversing) alarm.*
c. *If a tractor or front-end loader needs to travel on public roads it should be fitted with a slow-moving vehicle sign, flashing lights, or similar warning device.*
d. *Vehicle operators should wear seatbelts.*
e. *When working on the site, notify equipment operators and wear reflective clothing.*

3. Foreign objects delivered with some composting feedstocks are damaging to machinery and potentially hazardous to human operators. Examples include gas cylinders, batteries, containers with chemicals, cables, chains, rope, metal strapping, and large or sharp metal items.

   Procedures should be in place for sorting and discarding unwanted items before they come into contact with equipment, especially shredders, grinders, mixers, turners, and screens.

4. Wet and oily feedstocks, wet weather, or leachate can create slippery conditions at a composting facility.

   Nonskid shoes or boots should be worn to reduce this problem, in addition to good site management practices to keep the site as clean and tidy as possible. Workers should also be appropriately protected from dust.

5. In large scale composting sites it is possible for workers walking on windrows, piles, or bins to drop down into the material and be engulfed, trapped or buried alive.

   It is advisable not to walk on lagoons, or climb onto windrows, piles, vessels, or bins. If there is no alternative, workers should not work alone but with a co-worker observing from a safe stable point (i.e., not also on top of the windrow).

Universal rules for reducing safety and health hazards at composting operations.

- Have an educated workforce: trained on process control, process hazards, hygiene practices, signs and symptoms of overexposure or overexertion, and emergency response.
- Exercise good process control, recognize the beginnings of trends that lead to process failures, and take prompt corrective action. Better process control will produce more consistent and predictable exposures and hazards and probably overall lower risks.
- Meet occupational safety and health regulations where they exist; follow well-respected recommendations even where there are no regulations.
- Practice good personal hygiene to protect the worker and his/her family.
- Provide proper protective equipment to match the hazards of the specific site.

2.5 Constraints of composting

Even though the production and use of compost has several benefits, it is an undeniable fact that the process of compost production does involve substantial labor and demanding consistent attention. Tasks such as gathering and pretreatment of composting materials, establishing the heap, providing regular moisture, and frequently turning the pile necessitate a significant labor commitment.

However, these tasks can be scheduled during periods of the farm's labor availability, as composting is not bound by specific seasons. Moreover, the involvement of livestock can greatly facilitate the transportation of plant materials to the composting area, both during material collection and when applying compost to the fields. To further optimize labor efficiency, the adoption of composting technology and the integration of semi-mechanized tools like compost turners can effectively mitigate labor expenses associated with turning the compost pile.

Chapter 3

Guide to Practical Composting

3. How to make compost

Activity 3.1

Produce and demonstrate to farmers and stakeholders how compost is made by following steps 1 to 6 below. During the compost making, explain to the farmers the main points to be considered.

3.1.1 Selection of a suitable composting site

The compost production site should be a place:

a. That is levelled ground and well drained to minimize the risk of losing nutrients especially during rainfall.

b. With natural shade such as a tree or a built shade to (i) reduce leaching of nutrients out of the compost heaps during rainfall; and (ii) reduce and prevent evaporation and drying of the compost during high sunshine.

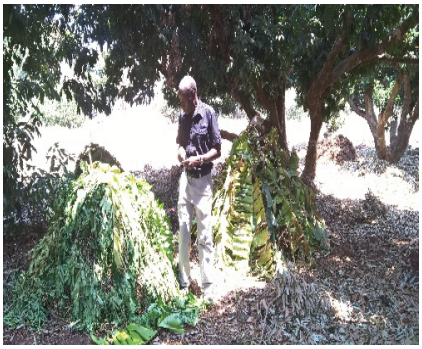
c. That is next to a water source.

d. That is easy to access for easy transport of materials to the composting site.

e. That is close to the fields where the compost is to be used after production.

3.1.2 Construction of composting structures

On-farm composting can be done under shade trees without construction of structures (Figure 26a). Permanent shades of different types and sizes can also be erected (Figure 26b).
For commercial production it is necessary to construct a compost plant with storage facility (Figure 26c). Shade is to prevent direct impact of rainwater from washing away nutrients, and to prevent the compost from excessive drying. It is also use to store the compost when not in use.



Credit to: NRC Malawi

a. Composting under tree

b. Composting under temporal shade

c. Composting in a plant with storage facility

Figure 26: Different composting structures

3.1.3 Selection of composting materials

Activity 3.2

Using Table 4a-c, carefully let farmers and stakeholders discuss the materials that can be composted and those that cannot. Discuss the reason why certain materials cannot be composted.

Table 4a: Composting material chart

Compost Material	Can I compost this?	Green or Brown	Notes
Brown leaves	Yes	Brown	An excellent and abundant source of carbon. Collect them in the fall. Shred before composting for better results.
Green plants	Yes	Green	Adds plenty of bulk. A good source of nitrogen.
Twigs & Branches	Yes	Brown	Harder to decompose but can add structure for aeration. Cut twigs and branches into pieces before use.
Cornstalks/husks	Yes	Brown	Very hard to break down, so chop them up before composting.
Weeds	Yes	Green	Bury them in the center of the pile to thermally kill the seeds – add some extra nitrogen material to help them cook.
Flowers	Yes	Green	Source of nitrogen when fresh.
Grass clippings	Yes	Green	A high-nitrogen source. Mix them with browns such as dried leaves to avoid matting and improve air supply.
Straw & Hay	Yes	Brown	Good source of carbon, and adds structure. Should be mixed with greens to help decomposition.
Straw bedding	Careful	Brown	Straw bedding from animals can be used if they are herbivores. If the animal eats meat it can contain pathogens.
Sawdust	Yes	Brown	A good source of carbon that breaks down quickly. Avoid plywood chips – the glue is potentially toxic to microbes.
Diseased plants	No	Green	You risk spreading the disease further in your garden if your compost isn't hot enough.
Plants with pesticides	No	Green	Avoid any chemically treated material. The chemicals could also kill off the composting microorganisms.

Table 4b: Composting material chart

Compost Material	Can I compost this?	Green or Brown	Notes
Spent grains/beer hops	Yes	Green	The leftover sugars are great food for composting microbes. Spread them thinly and mix them with browns to avoid anaerobic conditions.
Fruit & vegetable scraps	Yes	Green	Fruit and vegetables are a good source of nitrogen and moisture.
Cooked food	No	Green	Avoid cooked food waste which is cooked with fats. This is slow to decompose and can attract pests.
Coffee grounds & filters	Yes	Green	An excellent source of nitrogen. Can also discourage pests due to its odor.
Peanut hulls	Yes	Green	Contributes nitrogen and breaks down quite quickly.
Eggshells	Yes	-	Contains about 95% calcium, which could be a useful amendment for plants. Grind them up before composting.
Fish	No	Green	Attracts pests and is generally full of fats, which slow down composting. Produces bad smells. Can contain bacteria which is a safety issue.
Wood ash	Yes	Brown	A good source of potash (potassium-nitrate). Best added in layers because it washes away easily.
Seaweed	Yes	Green	Kelp is low in nitrogen but contains potassium and many other minerals.
Manure from herbivores	Yes	Green	A good source of nitrogen. Often mixed with bedding like straw or wood shavings, which also adds carbon.
Soil	Yes	-	Soil is good to add to compost when you have a large amount of fresh material. It contributes useful microbes & helps inoculate the pile.

Table 4c: The classification of materials based on C:N ratio

BROWNS (High in carbon)	C:N Ratio	GREENS (High in nitrogen)	C:N Ratio
Dried Leaves	60:1	Goat dung	12:1
Maize straw	60:1	Grass clippings	15:1
Rice straw	70:1	Sheep dung	19:1
Dry straw	75:1	Coffee grounds	20:1
Sawdust	200:1	Food scraps	20:1
Wood chips, shredded cardboard	300:1	Cattle dung	24:1
		Water hyacinth	25:1
		Coffee grounds	40:1

Activity 3.3

Obtain from your area different compostable materials required to produce a high-quality compost for (i) vegetable and food crop production, and

(ii) tree crop production. Let farmers and stakeholders classify the composting materials into brown, green, manure and others using the Table 6.0 below and discuss the benefits that each group of material will provide to the compost quality.

Table 6: Classify the materials provided by the instructor in (i) above into the columns provided below

Compostable materials	Brown	Greens

3.1.4 Material ratio combination

Aside, the carbon and nitrogen ratio which slows decomposition process, and affects the quality and period of composting, the composition and the mixing ratio of the raw materials used for composting also influence the quality of the compost. For an optimal composting process, a C/N ratio in the range of 20–30 is generally recommended. This can be achieved through the following raw material combinations:

a. Crop residues high in carbon to nitrogen ratios such as maize and rice husks should be mixed with vegetables, fruits, uncooked food waste at a ratio of 1:3:4:1 (dry weight by dry weight).
b. Other waste materials high in C/N ratio should be mixed with poultry manure, cocoa pod husk and Mucuna at a ratio of 4:4:4:1 (dry weight by dry weight). More Mucuna or any other greens as captured in the above can be used depending on its availability.
c. Rice straw should be mixed with animal manure, and leguminous at a ratio of 3:1:1 proportion.
d. Coffee husks should be mixed with banana leaves and brown materials at a ratio of 1:1:1
e. Brown materials can be mixed with molasses and coffee ground at a ratio of 1:1:1/3.

Activity 3.4

Obtain from your area different compostable materials required to produce a high-quality compost. Carefully let farmers and stakeholders discuss the waste materials that can be mixed for composting. Let them discuss the ratio of mixing giving reasons.

RULE OF THUMB

To achieve the best carbon-to-nitrogen ratio in your home compost, put in two to four parts brown materials for every one-part green material.

3.1.5 Create your compost pile

It is important to consider the size of compost pile to manage it properly. A compost pile of width less or equal to 4 feet (121 cm) is preferable with height which is a manageable size for most gardeners and ensures that it can retain heat. The length may depend on space availability but there should be space to allow effective turning of the pile.

a. It is advisable to always start the compost pile on a bare earth - This allows worms and other beneficial organisms to aerate the compost and be transported to your farm.

Activity 3.5

Using the composting materials from Activity 3.5 and use them to guide farmers and stakeholders (following steps "a" to "j" below) to develop a compost pile.

a. Lay twigs first on the floor. This aid drainage and helps aerate the pile.
b. Straw should be chopped and placed after the twigs. This improves the carbon content of the final compost product.
c. Add animal manure to the straw. The manure contains microbes which speed up the composting process. It also increases the nitrogen content of the finished compost.
d. Sprinkle a little amount of earth unto the materials. This provides microbial organisms that will speed the composting process.
e. Water the pile
f. Add green manure such as Tithonia and leguminous plants.
g. Where the soil is acidic, a little wood ash can be sprinkled to the pile. The wood ash helps to increase the pH of the final compost. The wood ash also increases the K content of the final compost product.
h. Add water
i. This layer should be about 25 cm thick.
j. Repeat the process 'a" to "h" again until you get six layers of the composting materials.

RULE OF THUMB

It's generally recommended to alternate brown and green materials in layers.

Credit to: FiBL Syscom

a. Spreading of twigs

Credit to: FiBL Syscom

b. Spreading of brown materials on twigs

Credit to: FiBL Syscom

c. Covering browns with greens and soil

Credit to: FiBL Syscom

d. Complete pile with stick to measure warmness of the heap

Figure 27: Building compost pile

3.1.6 Cover compost heap

Cover the pile with any material that can prevent water seepage into the pile. These include plastic sheets, used sacks, banana plantain leaves, coconut or palm branches to trap the heat, increase temperature and prevent too much water into the compost heap which could leach the nutrients.

3.1.7 Maintain your compost pile

You should turn your pile regularly to ensure efficient composting. To do so, use a shovel or pitchfork to turn and rotate the materials, which helps distribute air and moisture evenly. Aeration encourages an aerobic environment, which helps to speed up the composting process and reduce odors. How often you need to turn your compost depends on many factors, including the size of the pile, amount of moisture, and ratio of brown to green materials.

GENERAL RULE OF THUMB

You should start by turning your pile every 4–7 days. As your compost starts to mature, you may need to turn it less often.

3.2 Mature compost ready for use

Compost needs to entirely stabilize and mature before it can be used. Depending on a variety of factors, such as the size of your pile, type of materials used, moisture levels, climate and turning frequency, compost can take a few weeks to over four months to fully decompose and stabilized (mature). At this stage the temperature of the pile remains constant. At this stage, the compost should appear dark brown and crumbly, similar to soil. It should also have a rich, earthy smell and be free of any large chunks of material.

Activity 3.6

Using the compost heap developed from activity 3.5. Assist the farmers and stakeholders to identify mature compost by looking for these characteristics:

a. *Texture:* Crumbly and smooth, without recognizable scraps.
b. *Smell:* Like a forest on a rainy day, or rich earth. Traces of ammonia or sour odors means the compost needs more time to mature.
c. *Color:* Dark and rich.
d. *Size:* The original size of your pile reduced to half or one-third / (depending on the composting material).
e. *Temperature:* Within 25 to 30 °C of the temperature in the middle of the pile.

A compost pile with an internal temperature of 25 to 30°C at the end of composting typically indicates that the active composting process has concluded, and the material has entered the maturation phase or is ready for use. Here's what it means:

- Most of the easily degradable organic matter has been broken down by microorganisms, and the compost is now relatively stable.
- The high temperatures of the thermophilic phase (55–65°C) are no longer sustained because microbial activity has slowed down due to the depletion of readily available nutrients.
- The compost has finished its active phase and may need a curing period where slow microbial activity continues to further stabilize the compost. This phase ensures the compost is safe and mature for application.
- A stable temperature close to ambient (around 25–30°C) often suggests that the compost has cooled down and is safe to use in soil without the risk of harming plants or introducing pathogens.
- To confirm the compost is fully mature, additional tests can be performed, such as checking the carbon-to-nitrogen (C/N) ratio (ideally below 20:1), pH, or conducting a germination test

Bibliography

- *Ants, https://www.scientificamerican.com/article/ants-and-the-art-of-war/*
- *Bacteria, https://www.southlandorganics.com/blogs/news/17989348-microorganisms-that-enrich-your-soil-part-i*
- *Beetle, https://www.istockphoto.com/photo/coleoptera-carabidae-ground-beetle-isolated-on-white-background-gm969328014-264204357*
- *Compost pile temperature after first turning, https://www.grow-it-organically.com/hot-composting.html*
- *Composting safety & health,(Cornell waste management institute), https://cwmi.css.cornell.edu/CompostingSafety.pdf*
- *Earthworm, https://grabngrowsoil.com/blog/real-importance-earthworms/*
- *Fungus, https://www.orchardofflavours.com/mycorrhizae*
- *Growing Guides 2021, https://safergro.com/es/blogs/growing-for-the-future/basic-nutrients-for-growing-your-best-plants*
- *Home composting basics, https://ilsr.org/home-composting-basics/*
- *Isopod, https://isopod.site/isopod/armadillidae-cubaris-sp-lemon-blue/*
- *Mushrooms Produced by Fungal infection In Tree Limb, https://www.lawn-care-academy.com/images/diseased-tree.jpg*
- *Mortality Composting Basics for Poultry Producers, University of Georgia Extension, 2023, https://extension.uga.edu/publications/detail.html?number=B1408&title=mortality-composting-basics-for-poultry-producers*
- *Nellie J. Brown, Jane Gilbert, Ginny Black, Robert Rynk 2016. Safety and health principles and practices for composting facilities, chapter 13, 627-683. In: Rynk, R (ed) 2022.The Composting Handbook, A how-to and why manual for farm, municipal, institutional and commercial composters*
- *Termites, https://www.go-forth.com/blog/post/how-to-spot-early-signs-of-termites-on-your-greensboro-property*
- *USDA Compost and Food Waste Reduction Applications are Due Friday, 2021, https://southeastagnet.com/2021/07/14/usda-compost-food-waste-reduction-applications-due-friday/*
- *White potato cyst nematode, Globodera pallida (Stone) Behrens, on plant roots, https://www.ipmimages.org/browse/detail.cfm?imgnum=2131077*

Credit: © Freepik

CGIAR is a global research partnership for a food-secure future. CGIAR science is dedicated to transforming food, land, and water systems in a climate crisis. Its research is carried out by 13 CGIAR Centers/Alliances in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations and the private sector. www.cgiar.org

Multifunctional Landscapes is a CGIAR Science Program that aims to enhance the resilience, productivity, and sustainability of agricultural landscapes by integrating diverse land uses, ecosystem services, and livelihood strategies. The initiative supports evidence-based policies and innovations that balance food production with climate adaptation, biodiversity conservation, and social inclusion.

To learn more about this and other Science Programs in the CGIAR Research Portfolio, please visit www.cgiar.org/cgiar-research-portfolio-2025-2030/

CGIAR MULTIFUNCTIONAL LANDSCAPES

IWMI International Water Management Institute