CIRAWA Agroecological Solutions for Resilient Farming in West Africa

Composting Technical Manual

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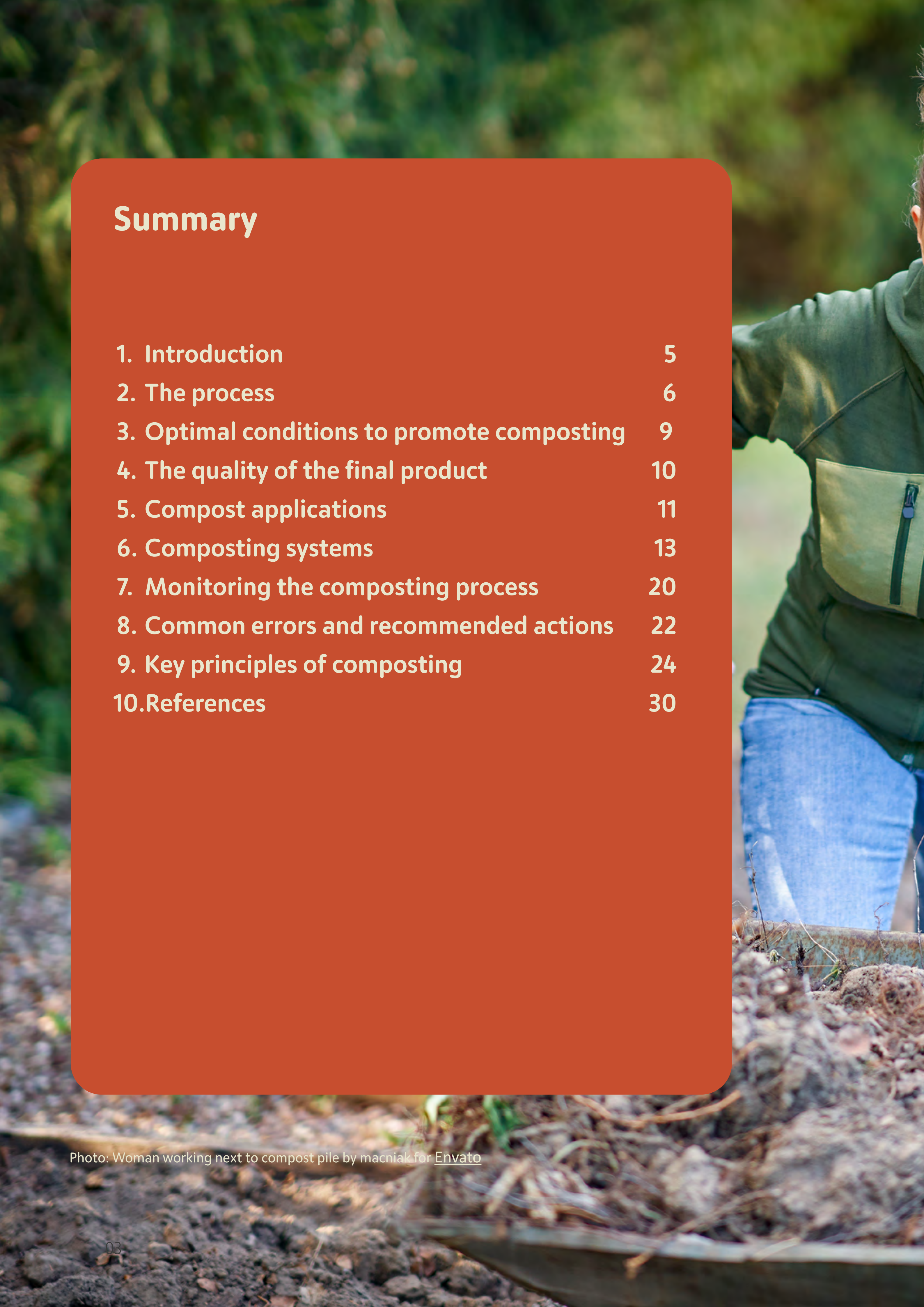


Summary

Photo: Woman working next to compost pile by macniak for Envato

Introduction

Definition

Composting is a biochemical process through which organic residues are transformed into a stable, humified material with complex structure, known as compost. It allows the reintegration of waste—along with its full nutrient content— into agroecosystem, thereby closing nutrient cycles and enhancing resource efficiency.

Adaptability

Owing to its high degree of adaptability, composting can be applied to all type of materials, ranging from crop residues to manure and agro-industrial waste.

Photo: Authors' own.

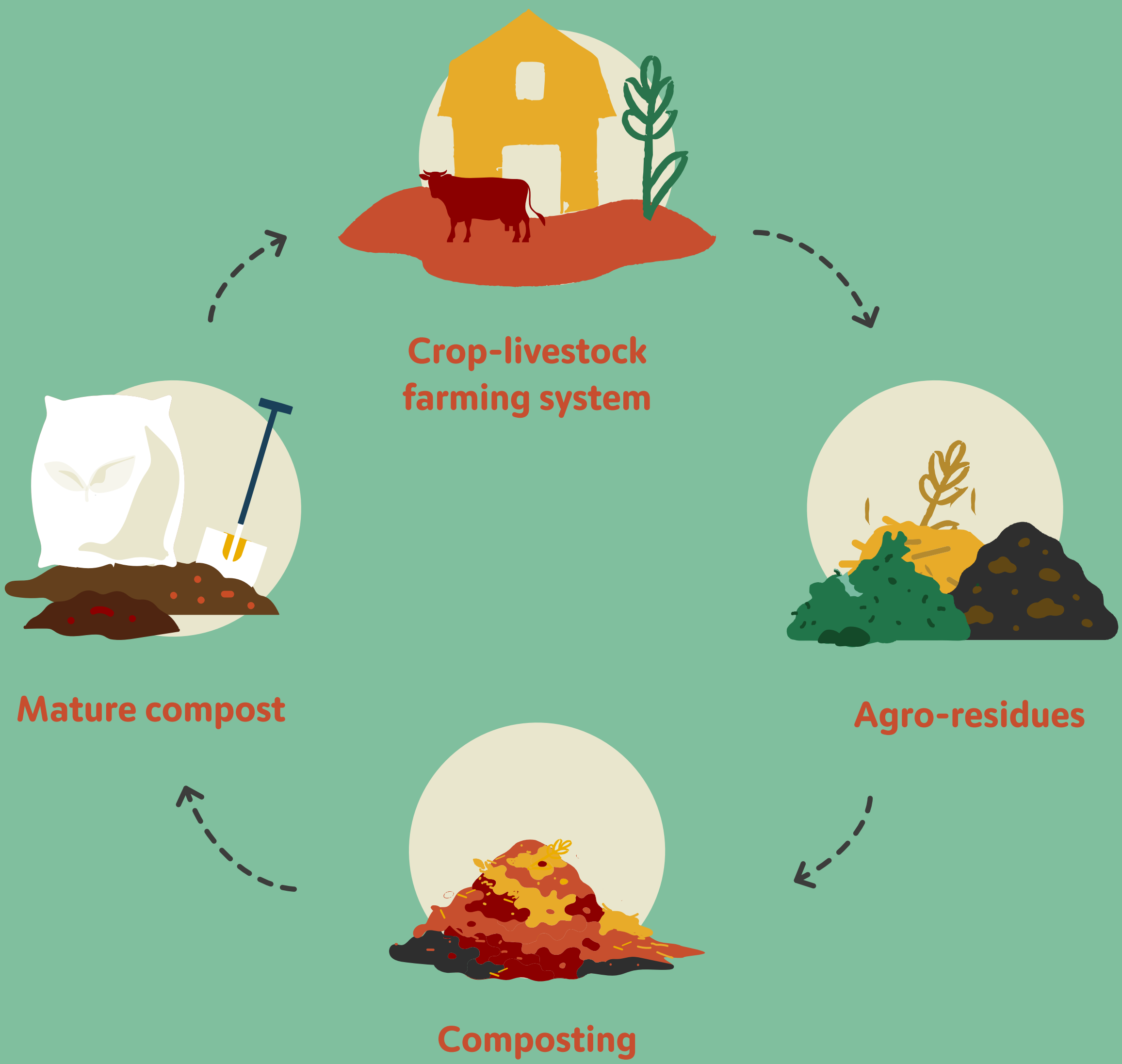


Figure 1. The composting cycle

2. The Process

The composting process may range from 2 to 12 months, depending on the initial characteristics of the input material, the levels of moisture and temperature maintained throughout the process, the management of the decomposing biomass, and the type of final product desired. While fresh compost can be obtained within 2 to 3 months, the production of mature compost typically requires between 4 and 12 months. To ensure the quality of the final product, it is essential that the composting process undergoes a series of distinct phases (Figure 1).

a. Material decomposition

Mesophilic phase. At the beginning of the composting process, temperature rises from ambient levels to approximately 40–45°C. During this phase, mesophilic fungi and bacteria initiate the decomposition of organic matter. This stage typically lasts between one and three days and may be accompanied by a decrease in pH.

Mesophilic Phase

~20°C to 40 - 45°C
TEMPERATURE RANGE

Mesophilic fungi and bacteria
DOMINANT ORGANISMS

1 - 3 days
DURATION

This phase marks the **initial decomposition** of easily degradable compounds. A slight drop in pH may occur due to organic acid formation.

Thermophilic phase. Once the temperature exceeds 45°C, mesophilic microorganisms are replaced by thermophilic bacteria and actinomycetes. Temperatures can reach up to 70°C or even higher. This phase is characterized by the degradation of waxes, proteins, polymers, and complex sugars. Sustained high temperatures—ideally maintained for at least four weeks—are critical for sanitization, as they eliminate pathogens and undesirable organisms, thereby improving the quality of the final product. The duration of this stage is closely related to the cellulose content of the decomposing material.

Thermophilic Phase

Above 45°C (Up to 70°C or more)

TEMPERATURE RANGE

Thermophilic bacteria and actionomycetes

DOMINANT ORGANISMS

4 weeks (recommended)

MINIMUN DURATION

Key processes:

- Decomposition of waxes, proteins, and complex carbohydrates
- Sanitazation: High temperatures eliminate pathigens, weed seeds, and parasites

The **duration of this phase** is directly influenced by the **cellulose content** of the biomass

Cooling phase. Following the thermophilic stage, temperatures begin to decline, eventually returning to ambient levels. Once the temperature drops below 45°C, mesophilic fungi recolonize the material, completing the breakdown of cellulose. If the compost is turned—manually or mechanically—and undecomposed materials remain, the temperature may rise again, re-entering the thermophilic phase. This process can be repeated one to three times, until subsequent turnings no longer produce a temperature increase.

b. Maturation

During this stage, the simple molecules generated in the preceding phases undergo recombination, leading to the formation of large, complex, and stable organic compounds that constitute mature compost. The duration of this phase may range from one to six months, depending on the characteristics desired in the final product. The most reliable indicator that maturation is complete is the absence of any temperature increase following material turning. At this point, the compost is considered fully stabilized and ready for application.

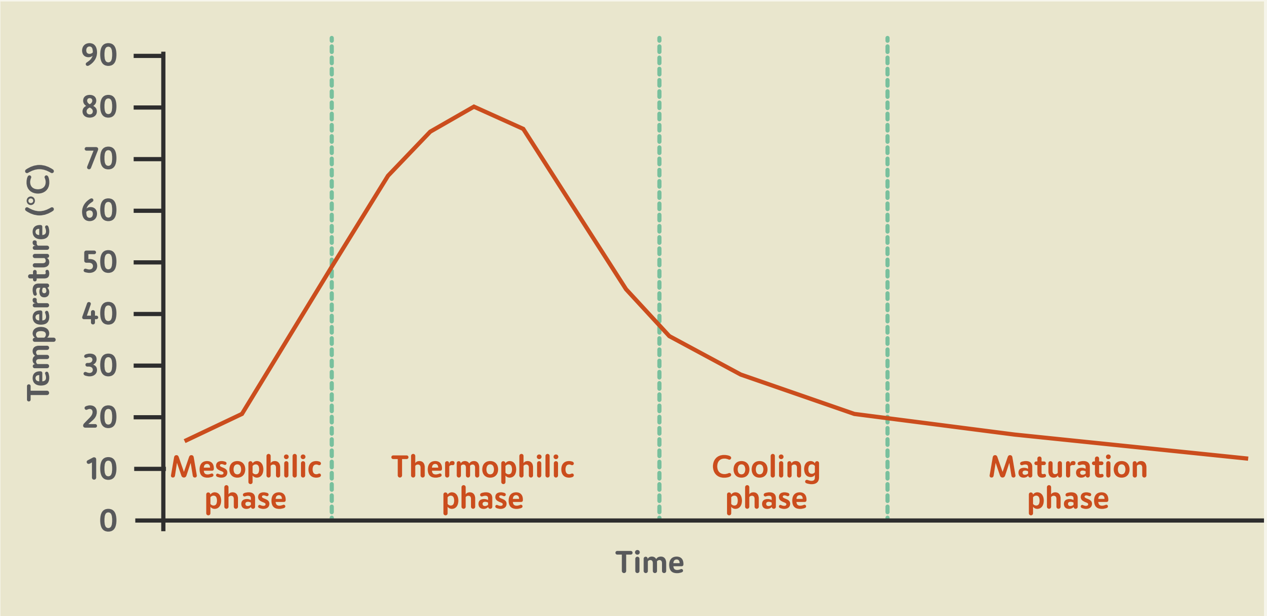


Figure 2. Phases of the composting process based on temperature dynamics

A composting process that does not proceed through the phases described above may result in a compost whose application can lead to several agronomic issues, such as:

- nitrogen immobilization in crops following soil amendment,
- The dissemination of unwanted plant seeds,
- and increased soil salinity, among other potential problems.

Furthermore, it is critical to assess the heavy metal content in the initial materials to prevent their incorporation into the composting process.

Important !

Organic production standards include specific regulations regarding this matter, which must be followed.

3. Optimal Conditions to Promote Composting

To ensure an effective composting process, it is essential to understand the environmental and nutritional requirements of the microorganisms responsible for each stage. Failure to meet these conditions may still result in compost formation, but the process will take longer and yield a product of inferior quality. A summary of the key recommendations is provided in Table 1.

Table 1. Guidelines for ensuring an effective composting process

	Parameter	Recommended Values
Material characteristics	Particle size	Aiming to maximize contact between organic matter and decomposer microorganisms while ensuring adequate aeration. A particle size of 1–5 cm is recommended.
	Composition	The mixture should maintain a balanced carbon-to-nitrogen ratio. An optimal C/N ratio is approximately 30–35 and should not exceed 50.
	Microbial presence	Typically high in unsterilized crop residues, which naturally contain decomposer microorganisms.
Pile characteristics	Moisture content	An average of around 50% is optimal. Below 10-12%, the process is completely stopped.
	Aeration	Oxygen levels should be maintained at 10–15%.
	Orientation	Not critical under mild climate conditions; in other cases, orient the pile along a north–south axis.
	Volume	Dependent on various factors; however, a minimum of 4 m^3 is recommended to achieve thermophilic conditions.
About the process conditions	Pile coverage	Not generally necessary unless under very cold or heavy rain conditions. Avoid covering during light rainfall, as it may help to maintain adequate moisture levels

4. The Quality of Final Product

The quality of the final product must be assessed once the composting process is completed, as the properties of the material remain variable during the intermediate phases. Table 2 presents several parameters commonly used to indicate that the compost is mature and of high quality.

Table 2. Key indicators of compost quality and maturity

Nature	Parameter	Characteristics/Values
Physical	Odor	Mature compost emits an earthy smell, like that of a damp forest floor.
	Temperature	The temperature remains stable even after turning the material and is comparable to ambient conditions
	Color	The color progressively darkens throughout the process, reaching a dark brown to black hue.
Chemical	pH	Following an initial decline and subsequent increase, pH stabilizes between 7.0 and 8.0
	C/N ratio	Regardless of the initial ratio, the final product should have a C/N ratio below 20; the ideal value is around 15.
	Ammonium concentration	The amount of NH_4^+ should not exceed 0.04%
Biological	Germination tests	Conducted by comparing compost extracts with a control. A germination index above 50% indicates maturity; ideally, 100% seed germination should be observed.

5. Compost Applications

Compost is primarily applied as a **solid soil amendment**, not only to meet the nutritional requirements of crops but also to improve soil structure and overall quality.

Additionally, it can be processed into a **liquid extract**—commonly referred to as **compost tea**—for use as a **soil or foliar fertilizer**.

Application to soil as a fertilizer

Depending on the characteristics of the final compost, various applications are possible:

- When compost is intended to serve as the sole source of soil fertilization—as is often the case in organic production systems—it is preferable to use mature compost, as its mineralization and nutrient release occur more efficiently.
- In contrast, fresh compost is more commonly utilized for its biofumigant properties rather than as a nutrient source.

Table 3 outlines general recommendations regarding application rates, which should be interpreted as **indicative guidelines**. It is important to note that the appropriate quantity to apply depends on several factors, including whether compost is the sole source of fertilization, its intended use as a soil amendment, the existence of legal limitations on its application, and, most importantly, the specific composition of the compost, requirements of the plants and characteristics of the soil.

Table 3. Indicative compost doses for agricultural soil application

Crop/Use	Quantity	Characteristics
High-demand vegetables (e.g., artichoke, spinach, cabbage, potato)	20–30 t/ha	Preferably mature compost
Moderate-demand vegetables (e.g., asparagus, lettuce, beet, carrot)	20–30 t/ha	
Low-demand vegetables (e.g., legumes, onion, turnip)	<10 t/ha	
Tree crops (maintenance fertilization)	<10 t/ha	
Cereals and extensive crops	1–5 t/ha	
Soil disinfection	20–30 t/ha	Use a fresh, undecomposed compost.

Source: Own elaboration based on personal experience and data from GENCAT, 2015.

Other applications

When applying a product such as compost—organic in nature and rich in agronomic benefits—the objective may extend beyond simple fertilization to include a variety of soil-enhancing functions:

Mulching

Fresh compost in the process of decomposition, or screened compost residues, can be applied as a surface cover to reduce soil water evaporation and conserve moisture levels.

Soil protection against erosion

This benefit is derived from the enhanced structural stability of soils with elevated organic matter content. Compost used for this purpose should be in an advanced stage of maturation, prior to the beginning of mineralization.

Biofumigation

In soil disinfection practices, fresh organic material—typically manure at the early stages of composting—can be applied at rates exceeding 20 t/ha. Proper management of this technique is essential, as poor execution may lead to adverse outcomes such as the spread of weed seeds or the incorporation of materials with unsuitable compositions. To increase soil temperature to at least 45°C, the treated area must be covered with plastic during warm periods.

6. Composting Systems

Composting is an exceptionally adaptable technique, suitable for implementation in both low-cost, small-scale setups and in highly advanced, technology-intensive systems capable of processing large volumes of organic waste. Table 4 provides a classification of these systems.

Table 4. Composting systems types based on mechanization level and site conditions

	Mechanization	Location	Systems
Small scale	Manual	Outdoor	Bins, commercial composters, layered piles, boxes, any household container
Medium scale	Mechanized	Outdoor	Windrows
	Manual	Outdoor	Pile with or without layers
Large scale	Mechanized	Outdoor	Windrows with or without forced aeration
		Confined	Digesters

Small-Scale Systems

These systems are primarily intended for household/small gardening composting. A wide range of methods can be employed, and successful composting is achievable as long as appropriate moisture levels and material mix composition are maintained. In some cases, thermophilic conditions are not reached due to the small volume of material, which may result in a final product that is not fully sanitized.

Medium-Scale Systems

Composting facilities of intermediate size are suitable for managing domestic organic waste generated by neighbourhood communities or small municipalities. The most basic and cost-effective method, which also allows for continuous waste input, is windrow, described in the following section. These structures can be managed either manually or with mechanical equipment, depending on their size and technological capacity of producers.

Large-Scale Systems

These systems are designed for the recycling of organic waste originated from large agricultural operations, medium-sized municipalities, or the agri-food industry. Operations are fully mechanized. In some cases, composting is conducted in enclosed environments, such as digesters.

The final compost can be marketed in its raw form, directly as obtained from the composting process, or it may be subjected to a sieving step to produce more homogeneous products with greater commercial value.

Materials that do not pass through the screen can be reincorporated into a new composting cycle, thereby contributing to the establishment of zero-waste circular economy systems.

Photo: Authors' own.

a)

b)

c)

d)

e)

f)

Image 1. Different composting systems. a) Domestic composting in wooden boxes. b) Composting in a small digester. c) Composting in a pile. d) Composting in a long windrow. e) Large-scale outdoor composting facility. f) Digesters for large-scale composting.

Example: Construction of a compost windrow/pile

This is one of the **simplest**, **most universal**, and **manageable** methods for implementing composting processes. It involves stacking organic residues according to specific guidelines that facilitate the initiation and progression of all necessary phases to obtain high-quality compost. This system is **highly adaptable** to both small- and large-scale operations and offers a wide range of mechanization possibilities—from fully manual execution to highly mechanized procedures.

The i**nput materials** should be **stored separately** to allow for the formulation of optimal mixtures. It is recommended that materials be **pre-shredded** (into particles ranging from 1 to 5 cm) and adequately moistened prior to their incorporation. The compost pile can be constructed either by simultaneously mixing all materials before stacking or by layering them within the pile. The level of mechanization available for pile construction can significantly influence the design of the process: when high mechanization is available, simultaneous mixing is often preferred; for manual processes, layered pile construction tends to be more practical.

To construct a compost pile that rapidly enters the mesophilic phase it is essential that the carbon-to-nitrogen (C/N) ratio of the constituent materials does not exceed 30–35.

Piles with a C/N ratio greater than 50 and/or lower than 25 tend to experience delays in reaching the thermophilic phase.

An approximate estimation of the overall C/N ratio of a planned compost pile can be made using the formula proposed by Trautmann and Richard (1996):

$$R = \frac{Q1 \times C1 \times (100-M1) + Q2 \times C2 \times (100-M2) + Q3 \times C3 \times (100-M3)}{Q1 \times N1 \times (100-M1) + Q2 \times N2 \times (100-M2) + Q3 \times N3 \times (100-M3)}$$

Where:

R = resulting C/N ratio of the pile

Qn = weight of each material

Mn = moisture content of each material (percentage by weight)

Cn = carbon content (percentage by weight)

Nn = nitrogen content (percentage by weight)

Representative C/N ratios for various compostable materials, sourced from the literature, are presented in Table 5. In addition, there are online composting calculators that suggest mixing ratios based on the composition of the selected materials. One of the most user-friendly tools is provided by Cornell University and is available at: https://compost.css.cornell.edu/calc/2.html

Table 5. Typical C/N ratios in common organic waste materials

Material	C/N Ratio	Material	C/N Ratio	Material	C/N Ratio
Cattle manure[1]	25	Dried corn stalks[2]	100–150	Green manures[2]	10–20
Poultry manure[1]	7	Rice straw[1]	77	Banana leaves[3]	32–35
Horse manure[2]	20–60	Legume residues[2]	10–15	Leaf litter[3]	47
Cow slurry[2]	5–8	Fresh grass clippings[2]	10–20	Pruning residues[4]	80–115
Pig slurry[2]	4–7	Garden waste[1]	37	Pig slurry[4]	5

Source: [1]Martinez et al., 2003. Lombricultura. Manual práctico. [2]GENCAT, 2015. El compostaje en agricultura ecológica.[3] FAO, 2013. [4]Own data.

Compost piles should have a minimum volume of 4 m^3, although a volume of no less than 6 m^3 is recommended. Smaller piles often fail to reach temperatures above 50°C during the thermophilic phase, which may compromise the sanitization of the final compost product. The cross-sectional shape of the pile can be adjusted according to the level of mechanization available on each farm; however, recommended dimensions are provided in Figure 2.

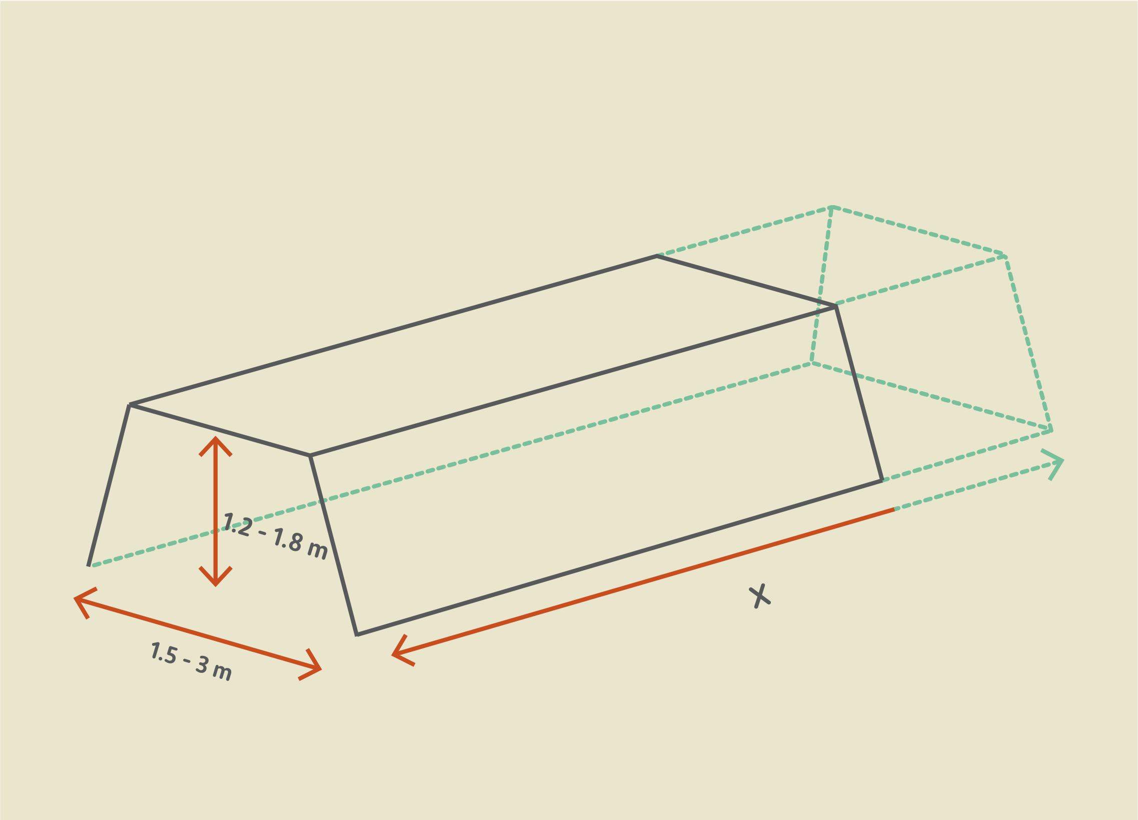


Figure 3. Suggested geometric section for compost pile design

Important !

Excessively tall piles may create anaerobic conditions in the lower layers due to the weight of the materials, which slows down the composting process and reduces the quality of the final product. Piles wider than 3 meters can also present challenges for mechanized handling.

The most common compost pile construction systems

- **Pile construction with simultaneously mixed materials.**

This method is best suited to large-scale composting operations and accommodates any **level of mechanization**—from the use of tractor-mounted loaders to specialized windrow turners. It is the system **most commonly employed in medium- and large-scale facilities** due to its capacity to process large volumes of organic waste.

In this approach, **materials are pre-mixed outside the pile and then stacked** while maintaining the recommended pile dimensions. Alternatively, unmixed materials can be added directly to the pile and then blended using the tractor's loader.

- **Layered pile construction**

This system is **more appropriate for small-scale operations**, such as individual farms or manual community-based initiatives, where smaller volumes of material are handled.

In this case, **materials are pre-mixed and added to the pile in successive layers**. Each layer does not necessarily have to meet the recommended parameters of the overall pile composition, as long as subsequent layers are designed to compensate for any imbalances. For instance, if one layer has a high C/N ratio (>50), the following layer should have a low C/N ratio (<30). **This layering approach is maintained until the first turning, after which the materials become uniformly distributed throughout the pile**. A significant temperature increase is typically observed following this initial turning.

It is recommended to begin pile construction with a layer or addition of mature compost, as it facilitates a rapid transition into the thermophilic phase by introducing active decomposer microorganisms.

7. Monitoring the composting process

During the composting process, it is essential to monitor at least two parameters: **temperature** and **moisture content**.

- **Temperature** can be easily measured using a thermometer with a metal probe, although a simple metal rod inserted into the center of the pile may also suffice—if the temperature exceeds 50°C, the rod will be too hot to touch.
- As for **moisture**, maintaining it around **50%** is advisable.

A simple method for assessing moisture is the "**fist test**": a sample taken from the center of the pile is compressed in the hand (Figure 3). Optimal moisture is indicated when a few drops of water are released during compression. Excessive dripping suggests overly high moisture content, while the absence of water and inability to compact the sample indicates that the decomposing pile is too dry.

Figure 4. Practical Field Test for Evaluating Compost Moisture

Photo: Authors' own.

During a composting process using piles, it is generally advisable to perform **one or two turnings**, continuing until the temperature stabilizes after a turning. The primary objective of turning is to aerate the materials and increase the porosity of the pile; however, this operation is also commonly used as an opportunity to adjust moisture levels by adding water.

It is important during the turning process to **reposition the materials**: the outer layers—typically less decomposed—should be moved to the center of the new pile, while the more decomposed inner materials should be relocated to the outer layers. This redistribution helps to homogenize the decomposition process, resulting in a more uniform and higher-quality final product.

8. Common errors and recommended actions

Given the inherent versatility of composting, it is essential to understand the process in order to evaluate whether it is proceeding within recommended parameters. Many of the most common issues encountered can be easily resolved. The most frequent problems and suggested corrective measures are presented in Table 6.

Photo: Authors' own.

Table 6. Operational challenges in composting and corrective measures

Problem	Possible Cause	Recommended Action
Pile does not heat up initially	Inappropriate materials with high C/N	Turn the pile and add low C/N materials
	Pile is dry	Add water until recommended moisture level is reached
	Low ambient temperature	Moisten and turn the pile
	Low volume	Add more materials
	Low porosity	Turn the pile and add coarser materials
Compaction	Very fine materials	Turn the pile and add bulkier materials
Bad odor	Lack of oxygen	Turn the pile
	Excess of low C/N materials	Turn the pile and add carbon-rich materials
	Excessive moisture	Turn the pile
Compost too hot (T > 70°C)	Excess of low C/N materials	Turn the pile to cool it down
Compost is dry	Excessive aeration	Cover the pile
	Lack of water	Moisten until appropriate content is reached
		Turn while adding moist materials
Presence of cockroaches, mice, or rats	Suitable nesting conditions and materials	Turn and moisten more frequently to create unfavorable conditions. Consider allowing cats nearby
Presence of ants	Suitable nesting conditions and materials	Add water and maintain adequate moisture levels
Presence of flies	Excessive moisture	Turn the pile and cover it with dry materials
White fungal layer on materials	Lack of moisture	Not a problem, but an indicator. Moisten the pile
Bluish-green fungal layer on materials	Excessive moisture	Not a problem, but an indicator. Turn only if associated with foul odors; otherwise, no action needed

Source: Own elaboration based on personal experience and data from GENCAT, 2015.

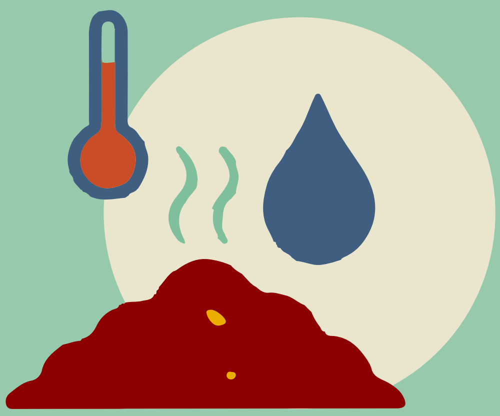
9. Key principles of composting

Composting is a biochemical process primarily driven by bacteria AND fungi which facilitates the reintegration of organic waste—and its full nutrient content—into agroecosystems.

Virtually all organic residues can be composted, provided that suitable environmental conditions are maintained.

Composting is a highly adaptable technique, suitable for a wide range of contexts—from small-scale, manual operations to large-scale, mechanized systems.

The resulting compost is typically used as a solid soil amendment and can partially or entirely meet the nutritional requirements of crops.



Temperature and moisture are the key parameters that must be monitored throughout the composting process to maintain microbial activity and decomposition rates.

An optimal carbon-to-nitrogen (C/N) ratio of approximately 25–30 in the initial mix is crucial to ensure an efficient composting process.

Your notes ...

10. References

Generalitat de Catalunya - GENCAT (2015) Ficha técnica PAE 20: *El compostaje en agricultura ecológica*. Departament d'Agricultura, Ramaderia, Pesca i Alimentació. Generalitat de Catalunya.

FAO (2003) On farm composting methods. Land and water discussion paper Nº2. Rome.

FAO (2015) *Farmer´s Compost Handbook. Experiences in Latin America*. Santiago de Chile. Regional Office for Latin America and the Caribbean. English version. https://openknowledge.fao.org/server/api/core/bitstreams/0658b4e0-53e3-4ed7-89d0-ff351bec1dff/content

FAO (2013) *Manual del compostaje del agricultor: experiencias en América Latina*. Santiago de Chile: FAO, Oficina Regional para América Latina y el Caribe. http://www.fao.org/3/i3388s/i3388s.pdf

Martínez Rodríguez F., Calero Martín B.J., Nogales Vargas-Machuca R. (2003) Lombricultura. Manual Práctico.

Richard, T., & Trautmann, N. (1996). C/N ratio. Cornell Waste Management Institute. http://compost.css.cornell.edu/calc/cn_ratio.html

Rynk R.; van de Kamp M.; Willson G.B.; Singley M.E.; Richard T.L.; Kolega J.J.; Gouin F.R.; Laliberty L.; Kay D.; D.W.; Hoitink H.A.J.; Brinton W.F.(1992) On-farm composting handbook. Northeast Regional Agricultural Engineering Service. New York.

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