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Article

Traditional Composting, Vermicomposting, and Gongocomposting: A Comparative Analysis of Methods and Applications in Agriculture

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ABSTRACT

This study conducted a systematic literature review to critically compare traditional composting, vermicomposting, and gongo composting, highlighting their potential for application in agriculture. The advantages and disadvantages of each method were evaluated based on technical and operational parameters, such as: (i) ease of handling and preparation of the compost; (ii) total processing time; (iii) labor demand; (iv) types of suitable organic waste (animal or vegetable); (v) physical space required; (vi) biological agents involved (earthworms, gongolos, microorganisms); (vii) physical-chemical and biological characteristics of the final compost; and (viii) impacts on plant development (growth, productivity, and health). The results highlight the particularities of each technique, providing support for choosing the most appropriate method according to available resources and agricultural objectives.
Keywords: sustainability; organic waste; recycling; sustainable agriculture.

ABSTRACT

This study conducted a systematic literature review to critically compare traditional composting, vermicomposting, and gongocomposting, emphasizing their potential agricultural applications. The advantages and disadvantages of each method were evaluated based on technical and operational parameters, including: (i) ease of compost preparation and management; (ii) total processing time; (iii) labor requirements; (iv) suitable organic waste types (animal or plant-based); (v) physical space needed; (vi) biological agents involved (earthworms, millipedes, microorganisms); (vii) physicochemical and biological characteristics of the final compost; and (viii) impacts on plant development (growth, yield, and health). The results highlight the unique features of each technique, providing insights for selecting the most appropriate method based on available resources and agricultural goals.
Keywords: sustainability; organic waste; recycling; sustainable agriculture.

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Introduction

Currently, rural properties use various organic materials as ingredients for the composition of different substrates used in agricultural production. However, an in-depth study is needed to assess the feasibility of using these materials in crop production, whether in agricultural or urban environments, as well as to generate knowledge about their chemical and physical composition, stability, and maturity, given that this information is essential for assessing the quality of the material.

The use of organic waste as a source of organic matter (OM) for the soil tends to reduce CO_2 emissions into the atmosphere, help improve soil texture and maintain soil moisture, and may reduce the occurrence of erosion and soil compaction processes . However, Kiehl(2004) states that for the organic matter contained in organic waste applied to the soil to be incorporated, it must undergo adequate stabilization and maturation, i.e., the macro and micronutrients in the waste to be used must be readily available for the plants and microorganisms in the soil to absorb them, and for this to occur, the waste must undergo some process of chemical, physical, and/or biological transformation.

In this sense, traditional composting, vermicomposting, and gongocomposting emerge as important mechanisms for the biological decomposition of organic waste to obtain high-quality organic substrates. However, for these processes to occur with the desired efficiency, the waste must be subjected to environmental conditions considered optimal for the decomposition processes to occur.

Traditional composting is considered a controlled process of microbial decomposition, oxidation, and oxygenation of a heterogeneous mass of OM in a solid and moist state (Kiehl 2004) . According to the same author, composting is not limited to the addition and mixing of organic waste in windrows; it also involves choosing the composting system to be used, the location for setting up the composter, and the choice of materials and their availability so that the process occurs satisfactorily. Vermicomposting, on the other hand, is a decomposition process carried out by the joint action of earthworms and microorganisms, with earthworms considered the determining agents of fragmentation, since the degradation of organic matter occurs through their activity (Martín and Schiedeck 2015) . Gongocomposting is a technique characterized by the use of different species of diplopods, which, in partnership with microorganisms, act in the decomposition of different types of organic vegetable waste generated in urban and rural agricultural properties, considered important sources of nutrients (L .

Therefore, this study aimed to conduct a comparative analysis of the use of traditional composting, vermicomposting, and gongocomposting techniques to obtain quality organic compost produced from the treatment of urban or rural waste, which can be considered an efficient way to significantly reduce costs on properties.

Composting Techniques

Traditional Composting

The use of the composting process as a technique for solving recurring problems related to the final disposal of various types of waste has proven to be a viable and environmentally friendly alternative for treating some organic waste, in addition to being considered economically and ecologically viable because its final product is a compost with good characteristics that can contribute positively to increasing soil fertility (Kiehl 2004).

Several authors state that the compost produced during this process is characterized by being a stabilized, mature product, rich in organic matter and humic substances, free of pathogens, phytotoxins, and weed seeds

(Bernal et al. 1998; Kiehl 2004; Pereira-Neto 2007; Morales et al. 2016). However, for a compost to have the desired characteristics mentioned above, it must be considered stable and mature, and for this, the process must last approximately 90 to 120 days after the waste is mixed (Kiehl 2004).

Organisms

Organisms play an essential role in the decomposition of organic matter, nutrient cycling, and soil fertility. According to Kiehl (2004), the transformation of raw organic matter into humus occurs through the action of different communities of microorganisms, the main organisms being bacteria, fungi, and actinomycetes, also occurring in conjunction with macro- and mesofauna, such as protozoa, nematodes, worms, insects, and their larvae. These organisms are usually observed at different stages of the composting process, as they survive at different temperature levels, i.e., they depend on favorable conditions for their survival and performance of their functions in the decomposition process.

Uncomposted organic material may contain various types of waste in its composition and, consequently, due to its origin, may present a potential risk to human and animal health, as this waste may contain pathogenic organisms (Onwosi et al. 2017). In this sense, the composting process emerges as an efficient mechanism for eliminating and reducing these pathogens, since in this process there are several mechanisms that can cause pathogenic inactivation, such as thermal inactivation, competition between microorganisms, toxicity (ammonia, sulfites, organic acids, and phenolic compounds), and enzymatic breakdown (Wichuk, Tewari, and McCartney 2011). This reduction occurs very efficiently, as the population level of pathogens present in the compost falls below the limit considered capable of causing disease transmission (Zittel et al. 2018).

Total coliforms, Salmonella spp, and viable helminth eggs are commonly found in this waste and are considered examples of pathogenic microorganisms that can be a source of contamination. When present, these microorganisms are considered indicators of microbiological contamination. Therefore, some regulations establish maximum limits for these possible contaminants to be present in the material without posing a risk to human and animal health (Table 1) (CUNHA 2018). In this regard, MAPA Normative Instruction No. 64 of 2008 establishes technical regulations for organic animal and plant production systems and determines that the use of animal excrement is permitted as long as it is composted and biostabilized (Annex VI) (MAPA 2008).

Table 1 - Maximum pathogen limits established by regulations.

Regulations	Thermotolerant coliforms (NMP/g)	Salmonella (10g of dry matter)	Viable helminth eggs
MAPA (2014)	<1000	Absent	1/4g of DM
CCME (2005)	<1000	<3 MPN/4g	---
EPA (2003)	<1000	< 3 MPN/4g	1/g of ST

Ministry of Agriculture and Livestock (Mapa); Guidelines for Compost Quality (CCME); United States Environmental Protection Agency (EPA). Source: Cunha(2018) .

Heck et al. (2013) conducted a study on the influence of temperature on the reduction of Escherichia coli, Salmonella sp., helminth eggs, and enteric viruses during the composting process and observed a fluctuation in the counts of E. coli and heterotrophic bacteria, even after the thermophilic phase. In contrast, no Salmonella sp., enteric viruses, or viable helminth eggs were detected at the end of the process. Souza et al. (2019) evaluated the microbiological characteristics of animal waste composting by measuring microbiological and parasitological variables, such as thermotolerant coliforms, *Salmonella* sp. and viable helminth eggs, and observed that the composting process promoted the elimination of the pathogens evaluated, indicating that the compost does not pose a risk of transmission and can be used safely.

The traditional composting process

Composting is considered a controlled process of microbial decomposition, oxidation, and oxygenation of a heterogeneous mass of OM in a solid and moist state, comprising a rapid mesophilic initial phase (Phase I), which is characterized by microbial cells that exhibit intense metabolic activity. Phase II is a biostabilization phase characterized by a gradual decrease in temperature with the continued decomposition of slow-degrading substances such as cellulose, hemicellulose, and lignin, which is the main source of the aromatic rings that form humic substances, and Phase III, which is where humification or maturation of the compost occurs, accompanied by the mineralization of certain OM components, such as nitrogen, phosphorus, calcium, and magnesium. At this point, these elements become available to plants, as they change from organic to inorganic form (Kiehl 2004).

In the composting process, temperature acts as a form of control for some pathogens. Thus, at the beginning of decomposition, during the mesophilic phase (40 to 50°C), it is possible to observe the predominance of bacteria and fungi that produce organic acids and small amounts of inorganic acids. Actinomycetes, on the other hand, usually act in this process when the organic matter is in a more advanced stage of decomposition (Kiehl 2004).

The energy produced by microorganisms during the composting process tends to promote an increase in compost temperatures. Research shows that there is a relationship between temperature and time, and this relationship is used as a parameter in the elimination of these species of pathogenic microorganisms. In a study conducted by Zittel et al. (2018), the combination of temperature and time throughout the thermophilic phase in a temperature range between 40-65°C proved to be effective in eliminating these pathogens. However, according to the same authors, in the mesophilic phase, temperature should not be considered the condition that determines the inactivation of these microorganisms, as factors such as competition, variation in pH values, chemical reactions, and ammonia concentration can also act, favorably interfering in the reduction of pathogens harmful to human health.

When the compost reaches temperatures above 65 °C, the vast majority of microorganisms in the sample will be eliminated, including the beneficial organisms that are responsible for the decomposition of materials. From this, it can be observed that it is necessary to maintain moisture and aeration values in temperature control so that it is kept at levels where these microorganisms are not eliminated. At the end of the composting process, when the temperature of the compost is close to room temperature, mesophilic organisms predominate in the decomposing mass, and protozoa, nematodes, ants, myriapods, and insects can be found in the compost (Kiehl 2004).

In summary, at the beginning of the composting process, organisms attack the most easily degradable compounds, such as starches, sugars, amino acids, etc. Subsequently, they act on the degradation of certain hemicelluloses and proteins, while substances that are more difficult to decompose, such as some hemicelluloses, fats, oils, etc., are decomposed more slowly. The final product of the degradation of lignin, mineralized products, and dead microorganism cells will produce humus, which is considered the most stable product of the transformation of organic substances (Pereira-Neto 2007).

Use and application of traditional compost

Currently, different studies are being conducted with a view to using composting as a technique for obtaining organic substrates, which will be used in the production of seedlings. These substrates can be evaluated in their original composition or in combination. In this sense, Faria et al. (2020) evaluated the use of carbonized coffee husk compost as a way to promote the production of ingá seedlings. They observed that composting significantly improved the quality of *Inga vera* subsp. *affinis* seedlings, resulting in good results for survival and for most of the quality parameters evaluated. In a study on the production of melon seedlings in substrate obtained from the composting of cassava branches, it was observed that the 120-day composting period for shredded cassava branches (substrate) was the most suitable for the best development of melon seedlings of the Gaúcho Casca de Carvalho and Melão Amarelo cultivars (Pelloso, Farias, and Paiva 2020).

The use of coffee grounds compost as a substrate in the production of jiló seedlings was evaluated in a study, which concluded that the use of a combination of composted substrates and soil can replace commercial substrates and is as efficient or better in the production of jiló seedlings (Carmo et al. 2018). Araujo et al. (2018) evaluated the process of composting murumuru in nylon bags and its quality as a substrate for tomato seedling formation and observed that the use of nylon bags proved to be very effective for this process, facilitating compost management. It was also observed that composting a combination of murumuru and chicken litter was the most suitable for use as a substrate for tomato seedling production ( ).

Vermicomposting

Vermicomposting is considered an eco-technology that has no negative environmental impacts and low investment, energy, and maintenance costs (Martín and Schiedeck 2015). In this sense, Aquino et al. (1992) state that vermicomposting consists of the transformation of organic matter resulting from the combined action of earthworms and the microflora that lives in their digestive tract.

This technique is considered a controlled process, which is carried out by the joint action of earthworms and microorganisms under aerobic conditions. The purpose of these organisms is to promote the stabilization and maturation of organic matter, reducing the pathogenicity of waste and making nutrients available to plants (Kiehl 1985). According to Martín and Schiedeck (2015), worms act as a "biological mill," increasing the contact surface through transformations of organic matter, modifying its physical, chemical, and biological characteristics. After the vermicomposting process, the waste used in the process is transformed into compounds rich in nitrogen, phosphorus, potassium, and humic substances.

The final product obtained from this technique is called vermicompost, which consists of a humus-like material with a low C/N ratio, high porosity, high water retention capacity, and high nutrient content in a form that is easily assimilated by plants (Martín and Schiedeck 2015).

Earthworms

Earthworms are segmented invertebrates belonging to the phylum Annelida and the class Oligochaeta. Their bodies have divisions called metameres, which are similar to rings, hence the name annelid (Dal Bosco et al. 2017).

The earthworm species most commonly used for this process is *Eisenia foetida*, commonly known as the California redworm or manure worm. This species has a great ability to convert poorly decomposed organic waste into stabilized material (Aquino, Almeida, and Silva 1992), in addition to living in organic waste with different degrees of moisture and being quite resistant to handling (Cotta et al. 2015). Ricci (2016) states that, in addition to the California redworm (*Eisenia foetida* or *Eisenia andrei)*, worms known as Night Crawlers (*Eisenia hortensis)* are also widely used. The choice of these species for use in the process is related to their high detritivorous capacity, rapid reproduction, and great resistance, which make them ideal for use in domestic worm farms as they optimize the composting process (Pusceddu and Bassini 2020). In addition to being ubiquitous species, widely distributed throughout the world, spontaneously colonizing many organic wastes, they are resistant to a wide range of temperatures and live in wastes with different moisture levels (Martín and Schiedeck 2015).

The vermicomposting process

Worms for vermicompost production can be raised in different structures, such as wooden boxes, cement blocks, concrete rings, brick beds, or piles (Ricci 1996). The choice of structure will depend on the reality of the location where it will be installed, as well as the availability of these materials.

The waste that will be used as a food source for the worms can consist of one or more types of organic waste, such as sawdust, legume scraps, straw, and manure, provided that such waste undergoes pre-composting before being made available to the worms to prevent fermentation, which is harmful to worms because during this process, toxic gases are produced and the temperature rises, which can cause the death of the worms (Ricci 1996). It is recommended to use a mixture of waste with different C/N ratios (Kiehl 1985; Pereira-Neto 2007).

It is recommended that the compost be turned once a week during the vermicomposting process to maintain aeration of the piles. Temperature is also an important indicator. During the pre-composting process, temperatures can vary between 50 and 70 °C, which can lead to nitrogen loss and the death of beneficial microorganisms. The worms should be spread over the windrows. It is recommended that 1,000 to 1,500 individuals per m² be introduced. It is worth remembering that for this introduction to be carried out, the windrow must have a temperature of approximately 28 °C. After the worms are inserted, the windrows should be covered with some type of porous material. Humidity should be checked periodically, as the ideal humidity level varies between 50 and 70%. Very dry piles facilitate the escape of worms, and piles with humidity above 70% can generate anaerobic zones. The compost should be collected when 80% of the waste initially placed in the pile is decomposed and stable ( ), when it has a black grease-like appearance. This occurs approximately 50 to 60 days after the piles are assembled (Ricci 1996).

According to Dal Bosco et al. (2017), the vermicomposting process can be divided into three stages: in the first stage, called the initial or degradation stage, microorganisms carry out the initial "attack" on the waste, and the first mineralization processes occur. In the second stage, called the colonization stage, organic molecules are transformed into simpler constituents through the action of microorganisms and the digestion process of earthworms. All organic compounds are colonizable by earthworms to a lesser or greater degree. In the third stage, called the maturation stage, the compounds undergo mineralization and humification, thus producing a compost with highly stable substances.

Use and application of vermicompost

Currently, different studies are being conducted with a view to using vermicomposting as a technique for obtaining organic substrates, which will be used in the production of seedlings. These substrates can be evaluated in their original composition or in combination. In this sense, Pereira et al. (2020) evaluated the use of rabbit manure-based substrate in the production of lettuce seedlings. After undergoing vermicomposting, processing using Cetoniinae larvae, and natural composting, it was observed that processing using vermicomposting with *Eisenia foetida* or Cetoniinae larvae proved to be the most efficient for obtaining a substrate of adequate quality for the production of lettuce seedlings. In a study that aimed to evaluate the use of vermicompost and coconut fiber as sustainable substrates in the production of *Corymbia citriodora* seedlings, it was concluded that the proposed alternative substrates with coconut fiber and vermicompost proved to be an efficient alternative for the production of *Corymbia citriodora* seedlings, especially when associated with fertilization (Ferreira et al. 2020).

The use of vermicompost in the substrate composition for the production of *Schinus terebinthifolius* seedlings was evaluated in a study developed by Franceschi et al. (2018), and it was concluded that the mixture of different proportions of vermicompost and commercial substrate proved to be efficient in seedling production, with proportions of 50% and 75% vermicompost proving to be the most suitable for the production of S. *terebinthifolius* seedlings, as they increased the morphometric characteristics in relation to the treatment without the addition of vermicompost and provided the production of higher quality seedlings. Lima et al. (2019) evaluated the use of vermicompost as substrates in the performance of lettuce and arugula seedlings and concluded that substrates produced from vermicomposting with sawdust and rice husks as conditioning agents can replace commercial substrate during the production of lettuce and arugula seedlings.

Gongocomposting

Gongocomposting is considered an environmentally friendly technique that is still little known in Brazil. This technique is characterized by the use of different species of diplopods in the decomposition of different types of plant residues rich in nutrients that are still unavailable to plants (Antunes et al. 2016) after decomposition has occurred. This process occurs through the joint action of the gongolo and the microorganisms present in the soil and waste. The gongolos act to shred the plant materials, reducing their size and consequently increasing their specific surface area, which facilitates their decomposition by microorganisms.

The final product obtained in the development of this technique is called gongocompost and is characterized as a 100% organic substrate. In a study developed by Antunes et al. (2016), this compost was generated from the activity of diplopods of the species *Trigoniulus corallinus,* popularly known as gongolos, which are large consumers of leaf litter and ensure the cycling of nutrients into the soil.

Gongolos

Diplopods are a class belonging to the subphylum Myriapoda, commonly known as snake lice, with an elongated, cylindrical or slightly flattened body (Garcia and Campos 2001). They are considered an important group of macrofauna individuals and usually live in humid environments with low light and a high amount of organic material available for food. They are commonly found in the surface horizons of the soil, where they influence its physical characteristics and existing litter, contributing to its decomposition, as well as altering its moisture, porosity, and the transport of substances (Dangerfield and Telford 1991).

Some studies indicate that these individuals are capable of processing plants thanks to their chewing apparatus, which allows them to grind waste while feeding. In this process, they produce fecal pellets with physical and chemical characteristics different from those found in plant material decomposed in other ways (Karthigeyan and Alagesan 2011; Thakur, Apurva, and Sinha 2011; Ramanathan and Alagesan 2012).

The species of gongolo most commonly used for this process is *Trigoniulus corallinus*. These individuals can be collected manually in areas where they are abundant or by setting traps in areas with ideal characteristics for their development. In his study, Antunes (2017) observed that these individuals are capable of ingesting large amounts of senescent and nutrient-poor plant debris, such as leaves and twigs.

The decomposition carried out by the activity of the gongolos leads to a significant reduction in the mass and volume of the composted plant materials. This decrease occurs mainly due to respiration and the consequent emission of CO_2 , provides the concentration of mineral substances and the obtaining of coprolites with significantly higher nutrient contents than those observed in plant materials before undergoing the composting process (Bugni et al. 2020).

The gongocomposting process

Gongocompost production should be developed following the methodology proposed by Antunes et al. (2016), which indicates the use of concrete rings, 0.5 m high and 1 m wide, with a capacity to receive 500 liters of waste. First, the waste must be quantified and deposited inside the rings, at a height of approximately 40 centimeters.

Gongocomposting is developed from a mixture of different types of plant waste, in proportions where the materials to be used must be related to their nutrient content. In a second stage, approximately 2.2 liters of gongolos must be introduced, which is equivalent to a population of approximately 3,960 adult individuals in each of the concrete rings. The individuals are collected manually from worm farms, compost bins, and lawns containing recent clippings. These rings must remain covered with shade cloth, which serves to prevent the gongolos from escaping by climbing up the wall of the ring or to prevent unwanted items from entering the rings during the gongocomposting process. The moisture content of the waste d in the rings must be monitored throughout the composting process, and when necessary, this moisture must be maintained by adding water with a watering can (L. F. de S. Antunes et al. 2016).

The final compost can be obtained 90, 120, and 180 days after starting the entire process described above, with the 120-day compost being considered the most viable for use. When the gongocomposting process is complete, the waste should be sieved through a 2 mm mesh and stored in plastic bags, which are kept frozen in order to halt biological activity, and only thawed at the specific time for use in the production of vegetable seedlings, as a substrate (L. F. de S. Antunes et al. 2016).

Use and application of gongocompost

There are several studies that evaluate the use of the composting technique based on the action of diplopods for the decomposition of different types of waste. In this sense, Karthigeyan & Alagesanum (2011) evaluated a compost obtained from the action of diplopods as a new method for recycling organic waste and concluded that the compost prepared from different Alagesanum (2011) evaluated a compost obtained through the action of diplopods as a new method for recycling organic waste and concluded that the compost prepared from different organic wastes processed by the diplopod *Xenobolus carnifex* has greater potential than compost produced by other methods in terms of nutritional quality and the development of the plant species evaluated.

Ramanathan and Alagesan (2012) evaluated the efficiency of using diplopods in converting organic waste into useful fertilizers and compared the compost obtained with the compost obtained by the action of earthworms. It was observed that the physicochemical parameters and the promotion of plant growth were significantly higher in the compost produced by diplopods than in vermicompost. Antunes et al. (2016) evaluated the production and efficiency of organic compost generated by the activity of millipedes and concluded that the compost has physical and chemical characteristics similar to vermicompost, both equally efficient when used as a substrate for the production of lettuce seedlings.

When evaluating the use of composting by diplopods as a technique for obtaining an alternative biocompost for forest seedling production, Senthilkumar et al. (2018) observed that the physicochemical parameters were significantly higher in the compost produced by diplopods than in common compost. In addition, it had a positive effect on the germination and growth of the forest species evaluated. Bugni et al. (2021) evaluated the efficiency of organic substrates obtained by gongocomposting from the degradation of urban pruning waste, mediated by the millipede *Trigoniulus corallinus,* in the production of curly lettuce seedlings, and concluded that the substrates produced were suitable for use as substrates for the production of organic arugula seedlings.

The advantages and disadvantages of composting, vermicomposting, and gongocomposting processes

The use of traditional composting, vermicomposting, and gongocomposting processes in the treatment of agricultural and urban waste has proven to be an environmentally viable alternative. However, like any technique, they have advantages and disadvantages in their development, some of which are described below (Table 2).

Table 2. Characteristics, advantages, and disadvantages of traditional composting, vermicomposting, and gongocomposting processes.

Parameter	Traditional Composting	Vermicomposting	Gongocomposting	References
Nutrient absorption by plants	Increases the capacity of plants to absorb nutrients	Increases the nutrient absorption capacity of plants	Increases the nutrient absorption capacity of plants	(Corrêa and Santos 2015; Antunes 2017)
Monitoring the process	Requires regular monitoring and maintenance of the compost pile	No need to turn the material, requiring less work in its preparation	No need to turn the material, requiring less work in its preparation	(Kiehl 2004; Souza et al. 2015; Antunes 2017)
Aeration	Facilitates soil aeration	Facilitates soil aeration	Facilitates soil aeration	(Corrêa and Santos 2015; Antunes 2017)
Area for process development	Greater need for area to carry out the process, but it can also be carried out in smaller areas	Can be carried out in small and large areas	Can be carried out in small and large areas	(Fernandes and Silva 1996; Souza et al. 2015; Antunes 2017)
Selective collection	Requires selective collection of organic waste	Requires selective collection of organic waste	Requires selective collection of organic waste	(Kiehl 2004; Corrêa and Santos 2015; Antunes 2017)
Complexity of process operation	Simple	Simple	Simple	(Fernandes and Silva 1996; Kiehl 2004; Cotta et al. 2015; Antunes 2017)
Density	Medium	Low	Low	(Kiehl 2004; Souza et al. 2015; Antunes 2017)
Climate dependence	Highly dependent on climate	Not very dependent on climate	Not very dependent on climate	(Fernandes and Silva 1996; Kiehl 2004; Antunes 2017; Bergi 2018)
Efficiency in pathogen elimination	High	Relatively high	No studies have been conducted on this subject yet	(Kiehl 2004; Cotta et al. 2015; Bergi 2018)

Characteristics, advantages, and disadvantages of traditional composting, vermicomposting, and gongocomposting processes (continued)

Parameter	Traditional composting	Vermicomposting	Gongo Composting	References
Erosion	Reduces soil erosion	Reduces soil erosion	Reduces soil erosion	(Cotta et al. 2015; L. F. de S. Antunes 2017)
Stabilization of organic matter	Good	Good	No studies have been conducted on this subject yet	(Fernandes and Silva 1996; Kiehl 2004; Cotta et al. 2015)
Ease of use of the compost	Easy to use	Easy to use	Easy to use	(Kiehl 2004; L. F. de S. Antunes 2017)
Fertility	Increased nutrient availability	Increased availability of mineral nutrients (N, P, and K)	Increased availability of mineral nutrients (N, P, and K), in addition to high Ca levels	(Cotta et al. 2015; L. F. de S. Antunes 2017)
Homogeneity of the Compost	Production of homogeneous compost	Production of homogeneous compost	Production of homogeneous compost	(Kiehl 2004; Cotta et al. 2015; L. F. de S. Antunes 2017)
Humification	Stabilization and accelerated humification	Stabilization and accelerated humification	There are still no studies on this subject	(Kiehl 2004; Cotta et al. 2015)
Initial investment in the process	Low capital and operating costs	Low capital and operating costs	Low capital and operating costs	(Fernandes and Silva 1996; Kiehl 2004; Corrêa and Santos 2015; Cotta et al. 2015; L. F. de S. Antunes 2017; Bergi 2018)
Labor	High demand for labor or specialized machinery	Low labor demand	Low labor demand	(Kiehl 2004; Cotta et al. 2015; L. F. de S. Antunes 2017)
Environmental pollution	Decrease in environmental pollution	Decrease in environmental pollution	Decrease in environmental pollution	(Kiehl 2004; Corrêa and Santos 2015; Cotta et al. 2015; L. F. de S. Antunes 2017)
Odor problems	The process of transforming waste into humus can generate odors	The process of transforming waste into humus does not generate any type of odors	The process of transforming waste does not generate any type of odors	(Fernandes and Silva 1996; L. F. de S. Antunes 2017)

Characteristics, advantages, and disadvantages of traditional composting, vermicomposting, and gongocomposting processes (conclusion).

Parameter	Traditional Composting	Vermicomposting	Gongocomposting	References
Seedling production	Great potential to benefit the growth of agricultural seedlings	Great potential to benefit the growth of agricultural seedlings	Great potential to benefit the growth of agricultural seedlings	(Corrêa and Santos 2015; Cotta et al. 2015; L. F. de S. Antunes 2017)
Compost quality	Production of good quality humus	Humus produced by earthworms is 70% richer in nutrients than humus obtained through traditional composting.	The compost produced by gongolos is as rich in nutrients as the humus produced by earthworms.	(Kiehl 2004; Corrêa and Santos 2015; L. F. de S. Antunes 2017)
Reduction in initial waste volume	High	High	High	(Kiehl 2004; Cotta et al. 2015; Antunes 2017)
Water retention	Good water retention	Good water retention	Good water retention	(Corrêa and Santos 2015; Antunes 2017)
Reuse of domestic waste	Possible	Possible, must be sorted before undergoing the process	There are no studies on this subject yet	(Kiehl 1985; Cotta et al. 2015; Bergi 2018)
Senescence of invasive seeds	Causes seed senescence	Does not cause seed senescence in pre-composting	There are still no studies on this subject	(Kiehl 2004)
Temperature	Initially, there is an increase in temperature, but high temperatures cause the death of beneficial microorganisms	Occurs at low temperatures; high temperatures cause the death of earthworms	Occurs at low temperatures; high temperatures cause the death of the gongolo.	(Kiehl 2004; Cotta et al. 2015; Antunes 2017)
Composting process speed	Faster composting process	Faster composting process	Slower composting process	(Kiehl 2004; L. F. de S. Antunes 2017)

Source: Authors, 2025

Final considerations

During the development of traditional composting, vermicomposting, and gongocomposting processes, complex interactions occur between microorganisms, earthworms, gongolos, and other fauna, resulting in the bio-oxidation and stabilization of waste, except for gongocompost, giving the product (when used as fertilizer) some advantages, such as contributing to a pH more favorable to plant development, preventing plant nutrients from being lost through volatilization or leaching, promoting drainage and preventing waterlogging, controlling erosion, leaching, and compaction, facilitating nitrogen fixation due to the microbial population, and not polluting the environment. However, the product obtained by traditional composting, vermicomposting, and gongocomposting should not be seen as a substitute for mineral fertilizer, but as a soil conditioner whose use improves its overall conditions in the long term.

During the traditional composting and vermicomposting processes, it is possible to notice significant differences in the chemical and physical characteristics of the compounds obtained, with a decrease in organic carbon content and an increase in humic acid content, which is related to the humification and mineralization process. The stabilization of OM through composting and vermicomposting processes contributes to a nutrient-rich product with high fertilizer potential for the soil. Gongocompost also has this potential use as a fertilizer, although there are no studies on its stabilization and maturation process.

Traditional composting, vermicomposting, and gongocomposting are noteworthy alternatives, as they allow for the enrichment of OM, increasing the availability of nutrients in an economically viable and environmentally sustainable way. It is also possible to observe a significant increase in CTC values in the composts produced using the three techniques.

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