U.P.B. Sci. Bull., Series B, Vol. 88, Iss.1, 2026 ISSN 1454-2331

ECONOMIC AND PRACTICAL WAYS OF MANAGING COMPOSTING OF HOUSEHOLD HAVING VARIOUS PHYSICO-CHEMICAL PARAMETERS

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Home composting is an efficient and sustainable way to utilize biodegradable waste, with significant implications for soil fertility, reducing the volume of household waste and reducing the negative impact on the environment. The present work aims to identify economic ways to manage home compost, based on the analysis of essential physicochemical parameters of the composting process: temperature, pH, humidity, organic matter content and carbon/nitrogen ratio (C/N). By correlating these parameters with various composting practices at the household level, the research highlights efficient possibilities for optimizing the composting process from an economic perspective, without compromising the quality of the compost obtained. The study thus proposes a sustainable model for managing compost at small scale, leveraging traditional knowledge and contemporary scientific data.

Keywords: home composting, waste, crops

1. Introduction

In the current context, marked by the climate crisis, the increase in prices of agri-food products and the pressure on natural resources, home composting is back at the center of concerns related to sustainability and household autonomy. Far from being a simple archaic practice, composting today represents a tool with multiple valences: ecological, economic and educational. The rediscovery of this traditional method of managing biodegradable waste implies, however, an approach adapted to the current context, based on research and the scientific substantiation of the processes involved. The composting process is governed by a series of physicochemical factors that directly influence the quality of the resulting material and the efficiency of the process. Among them, temperature, humidity, pH, chemical composition and carbon/nitrogen ratio play an essential role in transforming organic matter into a valuable soil amendment. A detailed

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understanding of these parameters allows not only to optimize the composting process, but also to identify economical solutions, adaptable to the individual household level, that maximize the benefits and reduce the costs associated with soil maintenance. The main objective of this paper is to analyze, from a physicochemical perspective, the home composting process and to propose economical ways to manage it, in a sustainable and efficient manner. The paper integrates data from the specialized literature, case studies and empirical observations, aiming to develop a practical, scientifically substantiated guide, intended for home users and small agricultural producers. Composting is an aerobic biological process by which organic matter is transformed, through the action of microorganisms, into stable humus, rich in nutrients. This technique, known and used for centuries in traditional households, is today rediscovered and revalued as an integral part of circular economy strategies, organic farming and food waste reduction.

At the household level, composting has a number of undeniable advantages: transforming biodegradable waste into a valuable product, reducing the volume of household waste and reducing fertilizer costs. At the same time, composting contributes to soil regeneration and reducing greenhouse gas emissions.

1.1 Physico-chemical parameters involved in the composting process

In order for the composting process to be efficient and to lead to the production of quality compost, it is necessary to carefully monitor and control some essential physico-chemical parameters. Specialized literature [1-3] identifies the following factors as determinants:

- Temperature - an indicator of microbial activity. Temperatures between 40–60°C favor the active composting phase, contributing to the destruction of pathogens and weed seeds.
- Humidity - influences the availability of water for microorganisms. The optimal level is between 40–60%. Too high humidity inhibits aerobic processes, and too low humidity stops biological activity.
- pH - determines the availability of nutrients and enzymatic activity. Values between 6.0 and 8.0 are considered optimal.
- C/N (carbon/nitrogen) ratio - an initial ratio between 25:1 and 30:1 favors rapid decomposition. Imbalances lead to slow down the process or the appearance of unpleasant odors.
- Physical structure and aeration - air is necessary for aerobic microbial activity. Excessive compaction leads to anaerobiosis and incomplete decomposition. [4-5].

1.2. Compost as an economic resource in the household

Beyond the ecological benefits, compost can be seen as a product with economic value. The direct costs (containers, labor, possible additions) are minimal compared to the value of the fertilizer obtained, which can completely or partially replace chemical fertilizers. In addition, compost improves soil structure, increasing crop yields without additional interventions.

Economic literature [6-7] indicates that the investment in home composting is quickly amortized, and households that practice this method save considerable amounts annually. Integrating composting into a sustainable household vision also leads to increased independence from commercial waste management systems and agricultural inputs.

1.3. Analysis models and best practices

Recent research in the field of home composting highlights the need for small-scale adapted models, with a focus on efficiency and ease of implementation. Composting models proposed by organizations such as EPA [8] or Horizon Europe projects emphasize:

- adaptability to urban and rural spaces,
- use of locally available materials,
- simplified monitoring of essential parameters,
- ecological education of households.

2. Methodology and analysis methods

Measuring pH and electrical conductivity (1:5 soil/water) For each sample were weighed each 10 g of compost was mixed with 50 ml of deionized water on a shaker for 30 min. The compost solutions were then filtered by filter paper. The filtered liquid sample was used to determination pH and electrical conductivity (EC) by a pH meter and electrical conductivity meter (EC meter).

Measuring moisture content Compost samples were analysed for moisture content, by oven drying at 105°C, in accordance with ISO standardized method [9].

Measuring total cations and trace minerals The compost samples were digested in a TOP wave microwave sample preparation system from Analytik Jena equipped with closed Teflon vessels. For the acid digestion procedure, a sample was digested, 0.5±0.05 g, placed in the digestion vessel with clean Teflon. Then, 6.0 ml of concentrated nitric acid (65%) and 1.0 ml hydrogen peroxide (30%) were added. The vessel was closed, placed in the rotor, followed by digestion. The vessel was closed, placed into the rotor, followed by digestion using a three step temperature program, namely (*i*) pressure 40 bar, ramp 5 min, temperature 170°C, time 10 min; (*ii*) pressure 40 bar, ramp 1 min, temperature 200°C, time 15 min; and (*iii*) cooling. The dishes were cooled and opened carefully. After the digestion process, each digested sample was quantitatively transferred with ultra-pure water into a 50 ml volumetric flask. The concentration of elements (Ca, Mg, K, Na, Mn, Zn, Cu) was determined by flame atomic absorption spectroscopy method (*NOVAA 300, Analytik Jena, Germany*).

All chemicals and reagents used during the study were of spectroscopic grade; the ICP Multi-Element Standard Solution XVI Certipur, with a certified value of 100.0 ± 0.3 mg·L^{-1} (*Merck KGaA Frankfurter, Darmstadt, Germany)* was used in the quantitative analysis for the calibration curve. Ultrapure water, having a maximum resistivity of 18.2 MΩ·cm^{-1}, was used for sample treatment and dilution. All the investigated calibration curves were characterized by a high correlation coefficient (r>0.995).

3. Analysis and interpretation of the composition of household compost samples – physico-chemical and functional approach

The composting process involves the aerobic transformation of organic matter by the activity of microorganisms, being strongly influenced by the carbon/nitrogen (C/N) ratio, humidity, pH and the composition of the materials introduced. In the four samples analyzed Table 1, a significant variety is observed in terms of the sources of organic matter, which determines notable differences in the dynamics of the composting process.

Table 1

Physico-chemical parameters of the analyzed samples

Physico-Chemical Parameters	Sample 1	Sample 2	Sample 3	Sample 4
pH (aqueous extract 1:5)	9.1	8.4	8.6	8.1
Electrical Conductivity (μS/cm)	2980	2430	4700	3160
Moisture Content (%)	33.68	59.47	67.60	55.81
Calcium (Ca, mg/kg)	18,958.96	20,289.13	27,786.64	26,669.32
Magnesium (Mg, mg/kg)	2,938.94	2,470.59	2,326.02	2,497.51
Sodium (Na, mg/kg)	728.73	638.98	1,031.90	1,059.40
Potassium (K, mg/kg)	6,381.38	5,142.57	10,338.98	7,597.17
Zinc (Zn, mg/kg)	199.50	222.43	106.38	160.06
Manganese (Mn, mg/kg)	205.01	202.09	251.05	237.59
Copper (Cu, mg/kg)	17.57	18.24	8.88	9.57

Table 2

Samples analyzed (Composition of the Four Vermicompost Samples (Input Materials))

Sample	Composition
Sample 1	10 kg quince + 2 kg sawdust + 2 kg sour cherry compost + 2 liters of water
Sample 2	5 kg quince + 4 kg cherry sawdust + 4 kg soil + 4 kg potato peels + 2 liters of water
Sample 3	Household vegetable waste (potato peels, onion skins, banana peels, wilted flowers)
Sample 4	Compost made from vegetable waste + 2.5 kg matured compost

Table 2 presents the samples taken for analysis with the raw materials used in the recipes.

Sample 1: 10 kg quince + 2 kg sawdust + 2 kg sour cherry compost + 2 l water This sample has a high intake of sugars and organic acids from quince, which are easily biodegradable and cause accelerated fermentation. Sawdust, rich in carbon and with a fibrous structure, has the role of balancing the surplus nitrogen in quince, but in small quantities, it fails to reach an optimal C/N ratio.

The presence of mature compost (from sour cherry) acts as a microbiological inoculum, accelerating the degradation process, especially in the first weeks. However, the risk of acid fermentation is increased, in the absence of proper aeration. Interpretation: Sample 1 has high composting potential, but required regular mixing to avoid the accumulation of acidity and anaerobic fermentations. The structure obtained has the potential to generate a medium-quality compost, with a good intake of carbohydrates, but with a slightly prolonged maturation time**.**

Sample 2: 5 kg quince + 4 kg cherry sawdust + 4 kg soil + 4 kg potato peelings + 2 l water

This composition shows a more pronounced physicochemical balance, through a better distribution between carbon-rich materials (sawdust) and nitrogen-rich materials (potato peelings, quince). The addition of soil contributes to stabilizing the pH and maintaining internal humidity, favoring microbial activity. The estimated C/N ratio is close to the optimal value (~25:1), which allows for efficient decomposition and uniform maturation. Humidity is maintained at an appropriate level by the presence of water and hydrated organic matter.Interpretation: Sample 2 is an example of good practice in home composting. A compost that can be matured within 6–8 weeks is expected, with a stable structure, neutral odor and high agronomic value.

Sample 3: Household vegetable waste (potatoes, onions, bananas, wilted flowers)

This sample presents a heterogeneous composition, with a predominance of soft, moist waste, rich in nitrogen, carbohydrates and water. The lack of mention of a dry material (carbon-rich structurant, e.g. sawdust or straw) generates a major imbalance in the C/N ratio, which can lead to anaerobic composting, the development of unpleasant odors and the presence of mold. Onions and bananas, although nutritious for the soil, can slow down the composting process due to their high content of volatile compounds and tannins.

Interpretation: Sample 3 required immediate adjustments: addition of fibrous materials and constant aeration. Without interventions, it would have had a slow decomposition, with a risk of pathogenic microbial development. The quality of the final compost could have been compromised due to the lack of correct balancing.

Sample 4: Plant residues + 2.5 kg mature compost

This sample has the major advantage of inoculation with mature compost, which causes a visible acceleration of the thermophilic phase. The presence of plant residues provides an active source of nitrogen, but no carbon-rich materials are mentioned, which again suggests an unbalanced C/N ratio.Interpretation: The sample has the potential for rapid maturation, but requires the supplementation of structured materials (e.g. dry leaves, sawdust, cardboard) to ensure an appropriate C/N ratio. If well aerated, the final compost can have a very good quality, with high nutritional value.

Sample 2 is the most balanced from a physico-chemical point of view and presents the highest agronomic potential.Sample 1 requires careful monitoring of acidity and aeration.

Samples 3 and 4, although promising by the contribution of fresh matter and mature compost, must be supplemented with carbon-rich structuring materials to avoid biological imbalances. In all cases, the C/N ratio remains the key parameter that determines the quality of the resulting compost, in interdependence with humidity and the presence of oxygen. Interpretation of the physicochemical results Sample 1, after 3 months from the start of the composting process, focuses on the values of the main important parameters of the compost:pH aqueous extract 1:5 = 9.1 which highlights a strongly alkaline value, above the optimal range (6.5 – 8.0). A high pH can inhibit microbial activity in the soil and reduce the bioavailability of some microelements (e.g. iron, manganese). Possible causes high content of untreated sawdust or excess of basic salts (Na, Ca). The compost is too alkaline for neutral or alkaline soils. It is recommended to use in acidic soils or in a mixture with acidic composts for neutralization. [10].

Electrical conductivity is (EC) = 2980 μS/cm and the recommended threshold for compost is below 4000 μS/cm, ideally below 3000 μS/cm. This value is at the upper limit of acceptable, indicating medium salinity. The possible accumulation of soluble salts (K, Na, Ca) can affect the germination of sensitive plants. The compost is usable for salt-tolerant crops (e.g. tomatoes, cabbage), but should be avoided in seedlings or soils already poor in drainage. Humidity = 33.68%, and the optimal value for mature compost, below 40%. This humidity indicated advanced stabilization of the compost, without risk of anaerobic fermentation. The compost is well matured or almost mature, with an aerated structure and good preservation.

Calcium (Ca^{2+}) = 18,958.96 mg/kg highlights a very high level, which contributes to increased alkalinity. It can be beneficial for acidic or sandy soils, but excess can lead to magnesium blockage and cation imbalance. The compost is excellent for correcting soil acidity, but must be dosed carefully.

Magnesium (Mg^{2+}) = 2,938.94 mg/kg is a good value, but can be antagonized by excess Ca. For chlorophyll synthesis, Mg is essential, and the intake is beneficial, especially in sandy soils. The compost provides sufficient Mg, but the Ca/Mg ratio is probably unbalanced (>5:1).

Sodium (Na^{+}) = 728.73 mg/kg indicates a slightly high level, but below the critical threshold (2000 mg/kg).

It can contribute to increasing salinity and reducing soil structure in the long term. Compost is acceptable, but excessive use is not recommended in arid areas or areas with salinization problems. Potassium (K) = 6,381.38 mg/kg indicates a very good level, indicating an excellent supply for plants. Potassium promotes fruiting, disease resistance and crop quality. Compost is valuable for vegetable and fruit crops, especially for the fruiting phases [10].

Zinc (Zn) = 199.50 mg/kg; Manganese (Mn) = 205.01 mg/kg; Copper (Cu) = 17.57 mg/kg these microelements are in good agronomic ranges. They are not phytotoxic and can improve plant nutrition in deficient soils. The compost has a very good microelement profile, favorable for plants with high requirements in Zn and Mn (corn, beet, grapevine).

The concentration of elements (Ca, Mg, K, Na, Mn, Zn, Cu) was determined by flame atomic absorption spectroscopy method (*NOVAA 300, Analytik Jena, Germany*).All chemicals and reagents used during the study were of spectroscopic grade; the ICP Multi-Element Standard Solution XVI Certipur, with a certified value of 100.0 ± 0.3 mg·L^{-1} (*Merck KGaA Frankfurter, Darmstadt, Germany)* was used in the quantitative analysis for the calibration curve [9].

In Table 3, Sample 1 recommends a use in mixture with acidic composts or acidic soils, avoiding direct use in young crops (seedlings), dilution or additional composting to stabilize pH.

Table 3

Evaluation of Sample 3 according to indicators

Indicator	Evaluation	Practical Implication
pH 9.1	Too alkaline	Not recommended for neutral or alkaline soils
EC 2980 µS/cm	Upper acceptable limit	Potential salt stress; avoid use on seedlings
Ca, K, Mg	High values	High nutritional value, especially in acidic soils
Na	Moderate	Avoid repeated application on the same plot
Micronutrients	Optimal	Support healthy plant development

In Table 3, the vermicompost samples exhibit a pH of 9.1, which is considered too alkaline for most agricultural soils, especially those that are neutral or alkaline. Such alkalinity can potentially lead to phytotoxicity, impairing nutrient uptake by plants and limiting microbial activity crucial for soil health. Therefore, application of this vermicompost should be carefully managed, preferably avoided on soils already trending toward alkalinity. Dilution or blending with more acidic organic amendments might be necessary to balance pH levels.

The electrical conductivity (EC) value of 2980 µS/cm is at the upper acceptable limit for composts used in horticulture. While nutrient-rich, elevated salinity poses a risk of osmotic stress, particularly for sensitive seedlings and young plants. This suggests that vermicompost application should be judicious, avoiding direct use on delicate transplants or in excessive quantities that could lead to salt accumulation in the soil [11].

High concentrations of macronutrients calcium (Ca), potassium (K), and magnesium (Mg) underscore the vermicompost's strong nutritional potential, making it a valuable soil amendment, especially in acidic soils where these elements may be deficient or less available. The elevated levels can significantly enhance soil fertility and promote robust plant growth, assuming other soil conditions are favorable. Moderate sodium (Na) content warrants caution. Although not excessive, repeated application of vermicompost with moderate Na can lead to sodicity problems, negatively affecting soil structure and permeability over time. Rotation with other organic amendments or periodic soil testing is recommended to prevent long-term soil degradation.Finally, the micronutrient levels are within the optimal range to support plant development, contributing essential trace elements such as zinc (Zn), manganese (Mn), and copper (Cu) that are critical cofactors in enzymatic processes and overall plant metabolism. [11].

In summary, while the vermicompost analyzed shows promising fertilizing qualities, its alkaline pH and relatively high salinity require careful management to avoid adverse effects on soil and plants. These findings highlight the importance of context-specific application strategies and reinforce the need for continuous monitoring to maximize benefits while minimizing risks.

4. Results and comparative interpretation of physico-chemical parameters for the four household compost samples

According to international soil and agronomic standards[11],[12],[13],[14]. the pH of a soil or aqueous extract (1:5) is a key indicator of chemical balance, nutrient availability, and overall suitability for plant growth.

A pH below 4.5 indicates a strongly acidic environment, typically associated with aluminum and manganese toxicity, which inhibits root growth and reduces microbial activity. In the range of 4.6 to 5.5, the medium is still acidic, leading to reduced availability of essential base nutrients such as calcium, magnesium, and potassium; under these conditions, liming is usually recommended to raise the pH.Values between 5.6 and 6.5 are considered slightly acidic, representing the optimal range for most agricultural crops, where nutrient solubility and microbial processes are at their best. A pH from 6.6 to 7.5 is classified as neutral to slightly alkaline, which remains acceptable for most plants, although mild deficiencies in iron or zinc may occasionally occur[15].

When the pH rises to 7.6–8.0, the medium becomes moderately alkaline, and the availability of micronutrients—particularly iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu)—starts to decline. Sensitive species may develop chlorosis under these conditions. The 8.1–8.5 range is described as alkaline, where nutrient uptake efficiency decreases significantly, and corrective measures such as acidification or dilution of the extract are advisable. Finally, pH values above 8.6 are deemed strongly alkaline, representing a severe chemical imbalance with possible phytotoxic effects; such conditions require immediate remediation using acidic amendments, organic matter,or mature compost to restore pH to agronomically acceptable levels.Comparing the results obtained after analyzing the samples, it was found that all samples are alkaline, but Sample 4 has the pH closest to the comfort zone for plants (6.5–8.0). Sample 1 is the most unbalanced.

Table 4

pH values of the aqueous extract (1:5)

Sample	pH Value	Interpretation
1	9.1	Too alkaline, potentially phytotoxic
2	8.4	Slightly alkaline, still usable
3	8.6	Moderate alkalinity, requires dilution
4	8.1	Closest to the optimal agronomic range

The pH values measured in the Table 4 ,vermicompost samples range from 8.1 to 9.1, indicating a general trend toward alkalinity.

Sample 1, with a pH of 9.1, is notably too alkaline, raising concerns about potential phytotoxic effects. Such high alkalinity can disrupt nutrient availability, particularly of micronutrients like iron and manganese, which become less soluble at elevated pH levels. This condition might inhibit seedling growth and microbial activity in the soil, making this vermicompost less suitable for direct application on neutral or alkaline soils without prior adjustment.

Samples 2 and 3, presenting pH values of 8.4 and 8.6 respectively, fall into the slightly to moderately alkaline range. While still usable, these samples might require dilution or blending with more acidic amendments to mitigate any adverse effects on plant development and maintain balanced soil chemistry. The moderate alkalinity suggests these vermicomposts could be applied safely in acidic soils where they may help buffer pH and supply essential nutrients [11].

Sample 4, at pH 8.1, is closest to the optimal agronomic range for most crops, offering a better balance between nutrient availability and microbial activity. This makes it the most versatile option among the four, suitable for a broader range of soil types and crop species without significant risk of phytotoxicity.In traditional agricultural practice, maintaining soil pH within an optimal range (generally 6.0-7.5) is crucial for maximizing nutrient uptake and crop yield. Although vermicompost with slightly alkaline pH values can provide benefits, care must be taken to monitor and manage these levels to avoid long-term soil imbalances[12].

Looking ahead, the pH characteristics of vermicompost should guide application strategies highlighting the importance of site-specific soil testing and amendment customization, rather than one-size-fits-all approaches.This cautious, tailored method respects the proven wisdom of balanced soil management while embracing innovative organic fertilization techniques [13]. According to international standards and guidelines including [16], [17], [18], [19], electrical conductivity (EC) is a key indicator of soluble salt content in composts and substrates. EC values are expressed in microsiemens per centimeter (µS/cm) or decisiemens per meter (dS/m, where 1 dS/m = 1000 µS/cm).

For horticultural use, the following interpretive ranges are commonly accepted:

- Below 1000 µS/cm (≤ 1.0 dS/m):Very low salinity. Safe for all plants, including salt-sensitive seedlings.
- 1000–2500 µS/cm (1.0–2.5 dS/m):Low to moderate salinity. Suitable for most crops and seedlings.
- 2500–4000 µS/cm (2.5–4.0 dS/m):Moderately high salinity. Tolerated by mature or salt-tolerant plants, but may stress sensitive species.
- Above 4000 µS/cm (> 4.0 dS/m):High salinity. Unsuitable for seedling production; risk of osmotic stress and soil salinization. Compost should be diluted or mixed before use.

For vermicomposts, FAO and EC guidelines recommend that EC should ideally remain below 3000 µS/cm (3.0 dS/m) to avoid osmotic stress during germination and early growth.

Table 5

Electrical Conductivity (EC) – Indicator of Soluble Salt Levels

Sample	EC (µS/cm)	Observation
1	2980	At the limit, tolerable
2	2430	Safest for seedlings
3	4700	Too high – risk of salinization
4	3160	Slightly above the recommended limit (3000)

Electrical conductivity (EC) is a crucial parameter indicating the concentration of soluble salts in vermicompost, which directly influences its suitability for agricultural use. Elevated EC levels may cause osmotic stress to plants, particularly affecting sensitive seedlings [16]

Sample 1, with an EC of 2980 µS/cm, lies at the upper boundary of the acceptable range. While still tolerable, its use requires caution to avoid potential salt accumulation in the soil, especially with repeated applications.

Sample 2, exhibiting the lowest EC value of 2430 µS/cm, is the safest option for seedling production. The lower salt concentration minimizes the risk of osmotic stress, promoting healthy germination and early growth stages [17].

In contrast, Sample 3 has a markedly high EC value of 4700 µS/cm, well above the recommended thresholds. Such elevated salinity poses a significant risk of soil salinization and phytotoxicity, which can severely hinder plant development. Its application should be avoided or significantly diluted[18].

Sample 4, with an EC of 3160 µS/cm, slightly exceeds the recommended maximum of 3000 µS/cm. This indicates a moderate risk, suggesting that while it may be used, care must be taken regarding application rates and frequency to prevent salt buildup [19].

In traditional agronomy, maintaining EC within safe limits is vital to preserving soil health and ensuring sustainable crop production. These findings underscore the importance of regular monitoring of vermicompost salinity and highlight that not all organic amendments are equally suitable for all growth stages or soil types. According to international compost quality [14], [16], [17], [18], [19] moisture content is a crucial parameter that governs microbial activity, aeration, and compost stability.Standardized ranges for moisture content:

- Below 30%- Too dry: microbial activity slows down sharply;decomposition becomes inefficient due to insufficient water for enzymatic reactions.
- 40–60% -Optimal range: supports aerobic microbial metabolism and stable composting dynamics; oxygen diffusion and water balance are ideal.
- 60–70% -Excess moisture: risk of anaerobic pockets, unpleasant odors, and reduced oxygen availability; may require aeration or drying.
- Above 70% -Overly wet: predominantly anaerobic conditions, possible methane or ammonia release, and nutrient loss.

For vermicomposting systems, most studies [1], [16], [19], [21], emphasize that moisture should be maintained between 50% and 60%, ensuring sufficient hydration for earthworms and aerobic microbes without causing anaerobiosis.

Table 6

Variation of Moisture Content in the Analyzed Samples

Sample	Moisture Content	Observation
1	33.68%	Too dry for active microbial activity
2	59.47%	Optimal for active composting
3	67.60%	Too wet – risk of anaerobic conditions
4	55.81%	Good, within the optimal range (50–60%)

Moisture content presented in Table 6 is a critical factor influencing the microbial activity and overall quality of vermicompost. Optimal moisture levels facilitate aerobic microbial processes, essential for efficient organic matter decomposition and nutrient cycling.

Sample 1, with a moisture content of 33.68%, is notably too dry to support active microbial populations. Low moisture limits microbial metabolism and slows down composting, potentially leading to incomplete organic matter breakdown and reduced nutrient availability [16].

Sample 2 presents an ideal moisture level of 59.47%, which falls within the optimal range for active composting (generally 50–60%). At this moisture content, microbial activity is maximized, promoting efficient decomposition and humification processes that enhance vermicompost quality [17].

Sample 3 shows excessive moisture at 67.60%, increasing the risk of anaerobic conditions. High moisture content can create oxygen-limited environments, favoring anaerobic microbes that produce undesirable by-products such as methane and hydrogen sulfide, negatively affecting compost quality and potentially causing phytotoxicity [18].

Sample 4, with a moisture content of 55.81%, also lies within the optimal range, supporting robust microbial activity and maintaining favorable aerobic conditions. This balance is crucial for producing stable, nutrient-rich vermicompost suitable for agricultural applications.

Traditional composting wisdom emphasizes maintaining moisture within a moderate range to ensure microbial efficiency while preventing detrimental anaerobic states. These findings highlight the importance of regular moisture monitoring and adjustment during vermicomposting to optimize product quality and agronomic value [19].

Beneficial Ca^{2+} supply in acidic soils, but in calcareous soils excess can block essential microelements. Samples 3 and 4 risk creating cationic imbalances. All samples have very high calcium content, with values that can be observed in Fig 1. Sample 1: 18,958 mg/kg ; Sample 2: 20,289 mg/kg; Sample 3: 27,786 mg/kg; Sample 4: 26,669 mg/kg

Regarding $Mg^{2+,}$ good values were obtained in all samples, but: Sample 1 has the best Ca^{2+}/Mg^{2+} ratio and Sample 3 has the lowest Mg^{2+} with a possible nutritional imbalance It is recommended to monitor the Ca/Mg ratio, ideally between 3:1 and 5:1.

As for Na^{+} Sample 3 and 4 has more than 1000 mg/kg which shows an increased level and Sample 1 and 2: below 750 mg/kg shows a moderate level, Sample 3 and 4 can contribute to the accumulation of salts in the soil, reducing permeability and affecting the long-term soil structure. K^{+} is an essential element for fruiting and stress resistance and the variation of values can be observed in Fig 2. Considering the results obtained. Sample 3: 10,338 mg/kg very rich ;Sample 4: 7,597 mg/kg good ; Sample 1: 6,381 mg/kg sufficient ; Sample 2: 5,142 mg/kg modest Sample 3 is ideal for crops demanding potassium (tomatoes, grapevines), but also has high saline risks. According to international standards and reference works [1], [22], [23], [24], [25], micronutrient levels in composts should be sufficient to enrich the soil without reaching toxicity thresholds,Table 7.Typical concentrations are expressed in milligrams per kilogram of dry matter (mg/kg DM).

Table 7

Standards for Zn, Mn, and Cu Parameters

[1], [22], [23], [24], [25]

Element	Adequate Range in Compost	Agronomic Role	Toxicity Threshold (approx.)
Zinc (Zn)	100–300 mg/kg	Enzyme cofactor; regulates auxin metabolism and membrane integrity	>1000 mg/kg may inhibit root elongation

Manganese (Mn)	150–500 mg/kg	Photosynthesis, chlorophyll synthesis, oxidative stress control	>1500 mg/kg can cause leaf necrosis
Copper (Cu)	50–200 mg/kg	Enzyme activation, lignin synthesis, pathogen resistance	>400 mg/kg can cause phytotoxicity

From a microelemental point of view, micronutrients: Zn, Mn, Cu, Sample 2 is the most balanced, Sample 3 is deficient in Cu and Zn. Recommendations for the three parameters can be identified in Table 8.

Table 8

Recommendations for Zn, Mn, and Cu Parameters

Parameter	Observations
Zinc (Zn)	Sample 2 has the highest concentration (222 mg/kg) – beneficial for maize and cereals. Sample 3 shows a low level.
Manganese (Mn)	All samples have excellent levels (>200 mg/kg), with the highest concentration in Sample 3.
Copper (Cu)	Acceptable in all samples. Samples 1 and 2 are the richest in copper, while Sample 3 has a low copper content.

From a microelemental perspective, the concentrations of zinc (Zn), manganese (Mn), and copper (Cu) in the analyzed vermicompost samples provide valuable insights into their agronomic potential and balance. Micronutrients play indispensable roles in plant physiology, functioning as enzyme activators, cofactors in redox reactions, and regulators of photosynthesis and stress response [22], [25]. Their presence in adequate amounts is essential to sustain plant growth and soil fertility.

Among the analyzed materials, Sample 2 exhibits the most balanced micronutrient composition, with concentrations of Zn, Mn, and Cu falling within the optimal agronomic ranges established by international compost quality standards [1],[23]. The zinc content of 222 mg/kg is particularly beneficial for maize and cereal crops, which require elevated Zn levels for enzyme activation and pollen viability. Manganese concentrations are excellent across all samples, exceeding 200 mg/kg a level generally associated with adequate support for chlorophyll synthesis and oxidative stress control [22], [23].

In contrast, Sample 3 shows a deficiency in Zn and Cu, suggesting a reduced capacity to promote enzymatic processes and disease resistance in sensitive plants. Although its manganese level is high, this alone cannot compensate for the lack of other micronutrients, as plant nutrition relies on balanced interactions between trace elements [1].The relative depletion of Zn and Cu may therefore limit metabolic efficiency, particularly in crops grown under stress conditions or on sandy soils where micronutrient retention is low.

Overall, the results indicate that Sample 2 is the most nutritionally balanced and agronomically valuable, while Sample 3 would benefit from supplementation or blending with Zn- and Cu-enriched organic materials. These findings are consistent with the recommendations of [23], [25] which emphasize maintaining Zn concentrations between 100–300 mg/kg, Mn between 150–500 mg/kg, and Cu between 50–200 mg/kg in compost to ensure both nutritional adequacy and environmental safety.

Overall, these vermicompost samples present a promising nutrient profile, but site-specific soil testing and targeted amendments remain indispensable for optimizing fertilization strategies and ensuring sustainable agricultural practices. Therefore, maintaining micronutrient concentrations within these limits is essential to achieve a **balanced fertilizing effect** while avoiding potential accumulation of heavy metals in the soil. Proper monitoring and quality control of compost composition help ensure that these trace elements contribute positively to **plant growth, soil fertility,** and **sustainable agricultural management** without causing ecological risk [23]. These vermicompost samples present a promising nutrient profile, but **site-specific soil testing** and **targeted amendments** remain indispensable for optimizing fertilization strategies and ensuring sustainable agricultural practices [25]. In practical terms, several management approaches can be adopted to maximize agronomic benefits:

1. **Blending with locally available organic materials** (such as peat, composted manure, or biochar) to balance electrical conductivity and improve moisture retention, especially for alkaline or saline soils.
2. **Adjusting application rates according to soil test results**, applying lower doses in nutrient-rich soils and higher rates in degraded or sandy soils to avoid nutrient imbalance or salt accumulation. [26].
3. **Periodic micronutrient supplementation** (e.g., zinc sulfate or chelated copper) when analysis reveals specific deficiencies, particularly for sensitive crops like legumes or leafy vegetables [25].
4. **Integrating vermicompost into crop rotation and soil conservation systems,** combining it with green manures or cover crops to enhance long-term soil structure, microbial diversity, and nutrient cycling.

In Fig.1 are compared the relative proportions of Ca^{2+}, Mg^{+}, and K^{+} , in the four compost samples. From the interpretation of the dates presented in the Fig.1 it appears that Sample 3 has a high percent in Ca^{2+} and K^{+} content, but has relatively low $Mg^{2+.}$ Sample 2 is the most balanced of all, without extreme values. Sample 1 has a very good ratio between Ca^{2+} and Mg^{2+}, but K^{+} is lower. Sample 4 is between Sample 1 and 3, with high values of Ca^{2+} and K^{+}, but ab equilibrium balance [1].

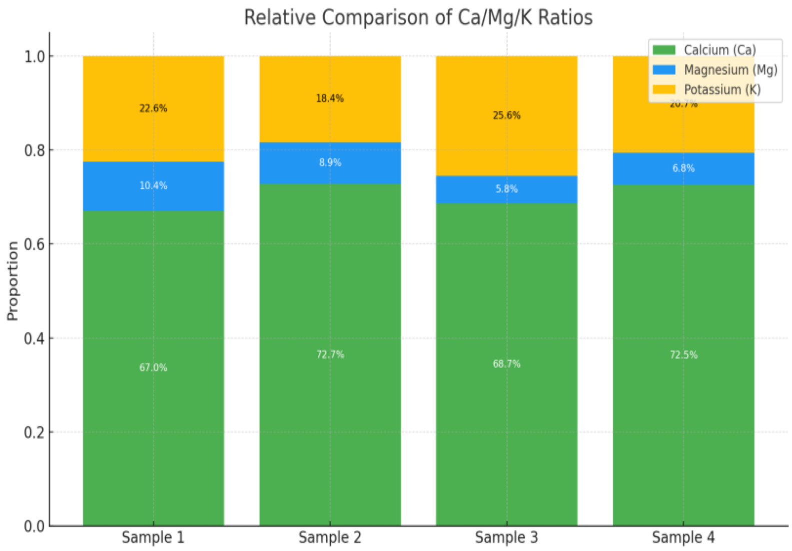

Fig 1. Graphical representation of the Ca/Mg/K ratio comparison.

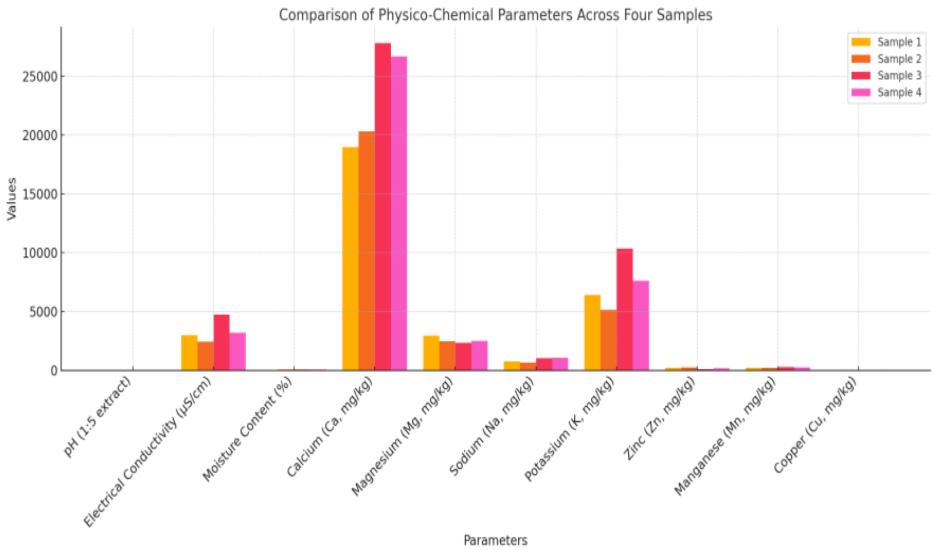

Fig 2. The comparasion values of the physicochemical parameters, pH, conductivity, moisture, Ca^{2+}, K^{+} and Zn,Mg,Cu

Scientific interpretation of the comparative dates (pH, EC, Moisture, Ca, K, Na) Fig 2 gives us information on the need for possible restrictions on use. The pH (hydrogen ion potential) indicates that Sample 1 reaches a clear peak (pH 9.1), highlighting a strongly alkaline reaction, possibly phytotoxic to some crops. Samples 2–4 fall between 8.1 and 8.6, still alkaline, but closer to the upper accepted agronomic limit. All samples are alkaline, but Sample 1 requires neutralization (e.g. by adding acidic materials or older compost). Electrical Conductivity (EC – indicator of salinity) for Sample 3 has the highest EC value (~4700 µS/cm), which signals a significant risk of salinization. Sample 2 has the lowest level (~2430 µS/cm), suggesting a safe compost for sensitive crops (e.g. seedlings, leafy vegetables). Samples 1 and 4 are borderline, but still acceptable. Sample 2 is the only one that can be used without restrictions in most soil types. Sample 3 must be diluted or limited in quantity [22].

Moisture (%) for Sample 1 is very low (~33%) which is a clear signal that it is an almost dry compost with low microbial activity. Samples 2 and 4 have optimal moisture (55–59%), favorable for fermentation and maturation. Sample 3 has excessive moisture (~67%) which poses a risk of anaerobic composting and unpleasant odors. Moisture is critical. Sample 3 requires aeration, and Sample 1 must be reactivated by re-humidification [23].

Ca^{2+} for Sample 3 has the highest value (>27,000 mg/kg), followed by Sample 4. High Ca values can be beneficial for acidic soils but can unbalance already calcareous soils. Compounds with a high Ca content (Sample 3 and 4) are excellent for improving acidic soils but should be avoided on neutral or alkaline soils. K^+ for Sample 3 stands out again with an exceptional content (>10,000 mg/kg), which makes it valuable for crops with high potassium requirements (e.g. tomatoes, grapevines, potatoes). Sample 2 has the lowest level (~5,100 mg/kg), but still adequate [23, 24]. Sample 3 is very nutritious, but should be applied in moderate amounts, preferably during the fruiting phases. Na^+ for Samples 3 and 4 have the highest sodium values (over 1000 mg/kg), which can lead to long-term soil salinization, especially in areas with poor drainage. Sample 2 has the lowest content, making it the safest for repeated applications. The sodium level is critical in assessing the durability of the compost. Sample 2 is ideal from this point of view. Sample 3 has the highest values for calcium, potassium and sodium but also the highest risks of salinization. Sample 2 maintains all values in an ideal balance zone. Sample 1 has the highest pH and the lowest humidity. Sample 4 offers a good balance between nutrients, but with slightly higher Na^+ and K^+ values.

For all the samples studied the recommendations can be seen in Table 9, advantages, risks and use.

Table 9

Conclusion ans recomandations

Sample	Advantages	Risks	Recommended Use
1	Good structure, advanced maturity	High alkalinity, excessive drying	Corrector for acidic soils
2	Excellent balance, safe for all crops	No major risks	Universal compost

3	Very nutritious (Ca, K)	Salinization, excessive moisture	Acidic soils, controlled application
4	Well-balanced values	High sodium, potential accumulation	Perennial crops, mature gardens

5.Conclusion

Home composting is an efficient way to utilize organic waste, contributing to soil improvement and reducing environmental impact. This report comparatively analyzes four compost samples obtained from different sources of organic matter, based on the physicochemical parameters relevant for evaluating compost quality: pH, electrical conductivity (EC), moisture, macroelement content ($Ca^{2+,}$ $Mg^{2+,}$ Na^{+}, K^{+}) and microelement content (Zn, Mn, Cu). The pH for all four samples shows alkaline pH values (8.1 - 9.1).

The presented for all samples studied offers a concise yet insightful perspective on the balance between the benefits and risks associated with soil amendments. From a traditional agronomic standpoint, each sample reveals characteristics that merit careful consideration before application.

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