



Physicochemical and microbiological quality of compost from agricultural waste as an indicator of waste management

Calidad físico-química y microbiológica del compost a partir de residuos agropecuarios como indicador de gestión de residuos

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Abstract

The study analyzed the nutritional content of soil amendments derived from the utilization of residual agricultural and livestock biomass. This non-experimental research employed inductive-deductive methods and techniques such as observation. The composting process was carried out at the Organic Fertilizers Unit of the Environmental Engineering program at the Escuela Superior Politécnica Agropecuaria de Manabí Manuel Félix López (ESPAM MFL), using biomass collected from various local sources. Samples of 1 kg per treatment were collected and analyzed at the Research Laboratory of the Universidad de Las Américas (UDLA). The obtained data were subjected to analysis of variance (ANOVA) and compared with the parameters established in the AGROCALIDAD Technical Manual. The results showed that T2 (30% goat manure, 30% chicken manure, 30% peanut shell, and 10% neem leaves) exhibited the highest total nitrogen values, whereas T3 (60% goat manure, 20% chicken manure, and 20% neem leaves) displayed higher concentrations of P, K, Ca, and Ba. Nevertheless, T4 (40% goat manure, 40% chicken manure, and 20% neem seed shells) was the most efficient in terms of essential microelement and metal concentrations such as Cu, Fe, Mn, and Zn. Despite this mineral complexity, the comparative analysis with the AGROCALIDAD Technical Manual revealed that macronutrient levels were below the minimum permissible limits. Additionally, the presence of *Salmonella* spp. and critical levels of *Escherichia coli* were detected. It is concluded that there are structural deficiencies in the composting process, particularly during the sanitization phase; therefore, the obtained amendment is restricted exclusively to non-food system applications.

Palabras clave: nutritional content, concentrations, treatments.

Resumen

En la investigación se analizó el contenido nutricional de la enmienda de suelo a partir del aprovechamiento de la biomasa residual agrícola y pecuaria. La investigación fue de tipo no experimental, empleando los métodos inductivo-deductivo y técnicas como la observación. El proceso de compostaje se llevó a cabo en la Unidad de Abonos Orgánicos de la carrera de Ingeniería Ambiental de la Escuela Superior Politécnica Agropecuaria de Manabí Manuel Félix López (ESPAM MFL), utilizando biomasa recolectada de diversas fuentes locales. Se recolectaron muestras de 1 kg por tratamiento, las cuales fueron analizadas en el Laboratorio de Investigación de la Universidad de Las Américas (UDLA). Los datos obtenidos fueron sometidos al análisis de varianza ANOVA y se compararon con los parámetros establecidos en el Manual Técnico de AGROCALIDAD. Los resultados determinaron que T2 (30% caprinaza, 30% gallinaza, 30% exocarpio de maní (cáscara de maní) y 10% hojas de neem) presentó los valores más alto de nitrógeno total, mientras que, T3 (60% caprinaza, 20% gallinaza y 20% hojas de neem) exhibió mayores concentraciones de P, K, Ca y Ba. No obstante, T4 (40% caprinaza, 40% gallinaza y 20% pericarpio; cáscaras de semillas de neem) fue el más eficiente en concentraciones de microelementos esenciales y metales como Cu, Fe, Mn y Zn. Aun ante esta complejidad mineral, el análisis comparativo con el Manual Técnico de AGROCALIDAD reveló que los macronutrientes se encontraron por debajo de los límites mínimos permitidos. Además, se detectó la presencia de *Salmonella* spp. y niveles críticos de *Escherichia coli*. Se concluye que existen deficiencias estructurales en el proceso de compostaje, principalmente en la fase de higienización; por tanto, la enmienda obtenida queda restringida exclusivamente a usos en sistemas no alimentarios.

Keywords: contenido nutricional, concentraciones, tratamientos.



Introduction

Currently, food production requires an increase in the areas allocated to livestock farming and the expansion of various crops. However, the rapid growth of societies raises concerns regarding environmental sustainability, since both agricultural and livestock production systems generate large volumes of untreated waste that represent a serious threat to human health and environmental components (Hidalgo, 2019; Flor et al., 2022). It is estimated that, worldwide, 2 billion tons of solid waste are generated annually, with up to 53% consisting of organic waste originating from households (Pereira et al., 2020). In turn, livestock production generates approximately 60 million t·year⁻¹ of unused organic matter, which is directly discharged into the environment, causing water and soil degradation (González, 2023). Furthermore, Paccha et al. (2023) stated that agricultural and livestock waste accounted for 18.17% of global greenhouse gas (GHG) emissions.

In Ecuador, in 2022, it was shown that 55% of organic waste originated from the agricultural sector (National Institute of Statistics and Censuses (INEC), 2023). This amount was obtained mainly from pruning residues and certain crops from the agricultural sector; however, due to a lack of information, these residues are not properly treated, and are disposed of by taking them to dumps or burning them (Quishpe, 2023). Corrales et al. (2024) argued that agricultural and livestock activities generated large amounts of organic waste, which became pollutants that can cause damage to the ecosystem; however, these residues can be reused as a source of nutrients for agriculture if they are provided with adequate treatment.

According to the Ministry of Environment and Water of Ecuador [MAATE] (2022), in Ecuador, poor solid waste management constitutes one of the most critical environmental challenges. The inadequate management of this waste has increased considerably, reaching an estimated production of 4.9 million tons per year; of this figure, 58.47% corresponded to organic matter (INEC, 2023). The inadequate final disposal of this waste and the limited recovery process cause serious environmental impacts and epidemiological risks for the population, serving as a source of infection proliferation and ecosystem degradation.

In view of the problem described, the use of agricultural and livestock waste through composting has become consolidated as an efficient alternative that makes it possible to reduce the high volumes of waste and, furthermore, the conversion of this waste into compost offers environmental benefits to the soil, since this amendment provides numerous benefits. Among these, it is worth noting that organic matter improves soil structure, reduces erosion, and contributes to the maintenance of microbial life in

the soil, as it is an invaluable source of carbon (López et al., 2022).

At present, the 2030 Agenda, through the Sustainable Development Goals (SDGs), especially Goal 12 on “Responsible Consumption and Production,” in targets 12.4 and 12.5, highlights the importance of environmentally sound waste management. However, in view of the exponential increase in the demand for goods, the technical approach has evolved from the mere reduction of waste toward the implementation of circular economy models. Likewise, Goal 13, “Climate Action,” emphasizes the importance of adopting sustainable agricultural practices that help reduce greenhouse gas emissions (United Nations [UN], 2018). Based on the foregoing, the present study aims to analyze the nutritional content of the soil amendment (compost) obtained from the use of residual agricultural and livestock biomass collected in collection centers and communities in the cantons of Calceta, Tosagua, and Zapotillo.

Materials and methods

Area of study

The study was conducted in the Environmental Engineering Program of the Escuela Superior Politécnica Agropecuaria de Manabí “Manuel Félix López” - ESPAM MFL, located in the El Limón site of the city of Calceta, Bolívar canton, Manabí province, Ecuador (figure 1).

Tip of research

The research adopted a non-experimental approach, characterized by the observation of variables in their natural state without direct intervention. In addition, the bibliographic method was used to review and obtain technical information on the preparation of organic amendments from agricultural and livestock waste (Guevara et al., 2020). The inductive-deductive method was used to analyze the current situation regarding agricultural and livestock waste generated at ESPAM MFL in the different Teaching, Research, and Community Outreach Units (UDIV), while the statistical method made it possible to interpret the data obtained in the laboratory (Hidalgo, 2019). As a collection technique, direct observation was used to determine the condition of the organic amendments (Escobal and Garro, 2020).

Compost preparation

The compost was prepared from organic and livestock waste collected in different areas. Agricultural waste (16.5 kg) was obtained from a collection center in the city of Calceta; forestry waste (19.5 kg) was collected between the Vargas Torres community in Tosagua canton and Calceta. Finally, livestock waste (54 kg) was obtained in Zapotillo canton, Loja Province.



Figure 1. Location of the ESPAM MFL Environmental Engineering nursery and the study site.

The amendments consisted of residual agricultural biomass (peanut exocarp; peanut shell), forestry biomass (pericarp (husks) and neem leaves), and livestock biomass (poultry manure and goat manure). These materials were selected according to the criteria established by Reyes (2023).

After the waste was weighed on an electronic scale, it was mechanically homogenized to ensure a uniform distribution of the biomass. At this stage, the rapid fermentation technique known as Bokashi was applied, using the ground pile method with dimensions of 1.5 m wide $\times$ 1.5 m long, critical dimensions to ensure heat retention during the thermophilic phase. Moistening was carried out gradually until reaching a moisture content of 60%, an optimal level verified through the field technique known as the fist test. Regarding biological activation, a solution composed of molasses and effective microorganisms of the genus *Bacillus* was used at a dose of 1 L per 5 L of water per pile, according to the criteria established by Álvarez et al. (2021).

Turning and watering were carried out manually on a weekly basis, according to the methodology of Cabrera and Rossi (2016). Temperature and pH control was conducted five days a week throughout the four weeks of the Bokashi fermentation and maturation process. During this 28-day period, the temperature was monitored to ensure that it remained within the optimal ranges for the accelerated degradation of organic matter, thereby ensuring the safety and stability of the final product. Measurements were taken in the morning (9:00 am). For chemical control of nitrogen (N), phosphorus (P), and potassium (K) content, the Rapitest #1601 test kit from Lustr Leaf Products was used, with evaluations performed through the comparison method using standardized color charts (Loaiza, 2020). To ensure scientific rigor, the results obtained in the field

were calibrated through certified laboratory analysis. The degree of statistical correlation between both methods was determined, ensuring that the colorimetric measurements were representative and allowed for a reliable interpretation of the nutritional evolution of the fertilizer.

Sample collection

According to the methodology of Delgado and García (2023), 1 kg samples were taken for each treatment from the four organic amendments prepared. The composition of the treatments was established as follows: T1 consisted of a mixture of 5 kg of goat manure, 1 kg of poultry manure, 2.5 kg of peanut, and 1.5 kg of neem. T2 contained 3 kg of each main component and 1 kg of neem. T3 included 6 kg of goat manure, 2 kg of poultry manure, and 2 kg of neem leaves, while T4 combined 4 kg of goat manure, 4 kg of poultry manure, and 2 kg of neem husk. These samples were placed on aluminum foil and introduced into plastic bags, each duly labeled for shipment to the laboratory, following the protocol established by the Food and Agriculture Organization of the United Nations [FAO] (2013).

Analysis of the nutritional content of the amendment

To determine the nutritional content of the organic amendment, the parameters described in the “Technical Manual for the Registration and Control of Fertilizers, Soil Amendments, and Related Products for Agricultural Use” of the Ecuadorian Agency for Agricultural Quality Assurance “AGROCALIDAD” were used as a reference. Following the methodology of Jara et al. (2020), the chemical parameters were determined through laboratory analysis, as described in table 1. The analyses were conducted at the Research Laboratory of the Universidad de Las

Américas (UDLA). All the parameters described in table 1 were analyzed in the laboratory.

Table 1. Physicochemical and microbiological variables analyzed in the laboratory for residual biomass amendments.

Variables	
Silver (Ag)	Gold (Au)
Aluminum (Al)	Germanium (Ge)
Boron (B)	Hafnium (Hf)
Barium (Ba)	Iridium (Ir)
Beryllium (Be)	Molybdenum (Mo)
Calcium (Ca)	Niobium (Nb)
Cadmium (Cd)	Paladium (Pd)
Cobalt (Co)	Platinum (Pt)
Chromium (Cr)	Rhenium (Re)
Copper (Cu)	Rhodium (Rh)
Iron (Fe)	Ruthenium (Ru)
Gallium (Ga)	Antimony (Sb)
Indium (In)	Tin (Sn)
Potassium (K)	Tantalum (Ta)
Lithium (Li)	Titanium (Ti)
Magnesium (Mg)	Tungsten (W)
Manganese (Mn)	Zirconium (Zr)
Sodium (Na)	Phosphorus (P)
Nickel (Ni)	Mercury (Hg)
Lead (Pb)	% Total nitrogen (N)
Strontium (Sr)	<i>Escherichia coli</i>
Talio (Tl)	<i>Salmonella</i>
Zinc (Zn)	

Statistical analysis

Following the methodology of Delgado and García (2023) and Pérez (2023), the data obtained were subjected to analysis of variance (ANOVA) with a 5% probability of error, and mean separation was performed using Tukey's test at a 5% probability of error, employing the IBM SPSS Statistics software. The treatments analyzed are described in table 2.

Table 2. Composition of the amendment treatments and presence of microorganisms in the composting trials.

Treatment	Treatments (quantities in % for 10 kg)					Microorganisms
	Goat manure	Poultry manure	Peanut shells	Neem leaves	Neem seed husks	
T ₁	50	10	25	15	-	<i>Bacillus</i> spp.
T ₂	30	30	30	10	-	
T ₃	60	20	-	20	-	
T ₄	40	40	-	-	20	

Comparison with Agrocalidad environmental regulations

The laboratory results were compared with AGROCALIDAD standards (Jara et al., 2022) to verify the suitability of the compost as a soil amendment. This technical validation confirmed whether the final product met the stability and nutritional content requirements necessary to reverse edaphic degradation in areas of intensive agriculture (Aguirre, 2023).

Establishment of strategies for the use of amendments

Finally, a proposal of strategies for the use of organic amendments focused on soil bioremediation was developed. The proposal is systematized under the following parameters:

Objective and responsible party: definition of goals and those responsible for implementation.

Application: location and proposed technical measures.

Monitoring and control: indicators, means of verification, and costs.

Results and discussion

Figure 2 shows the results for silver (Ag) content for each treatment, highlighting that T4 obtained the highest value, with 10.16 mg·kg⁻¹, among the other treatments. With respect to aluminum (Al), presented in figure 3, T4 reached values of 15,748.99 mg·kg⁻¹, significantly exceeding the others; meanwhile, T1 and T2 showed values between 13,926.58 mg·kg⁻¹ and 13,860.17 mg·kg⁻¹. The presence of high concentrations of Ag and Al in T4 may come from the poultry manure, since it often contains metals or traces of minerals depending on the birds' diet; or also from the type of soil where the neem was cultivated (Morales, 2020).

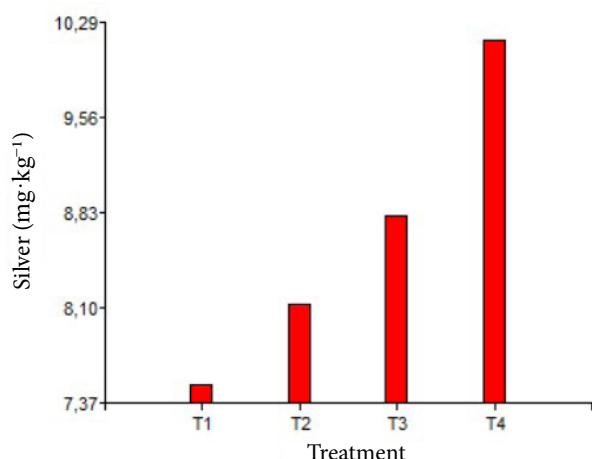


Figure 2. Silver (Ag) concentration in the different amendment treatments.

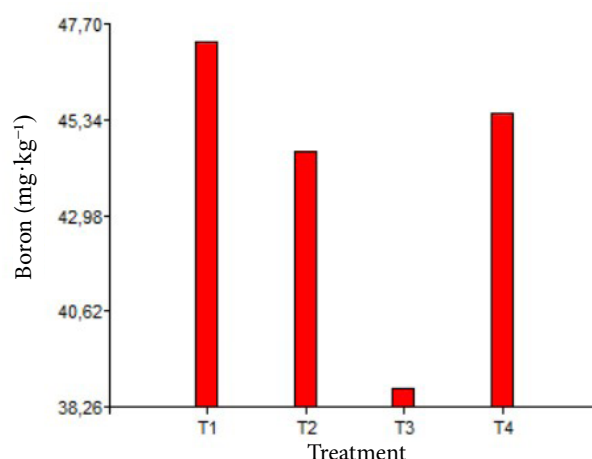


Figure 4. Boron (B) concentration in the different amendment treatments.

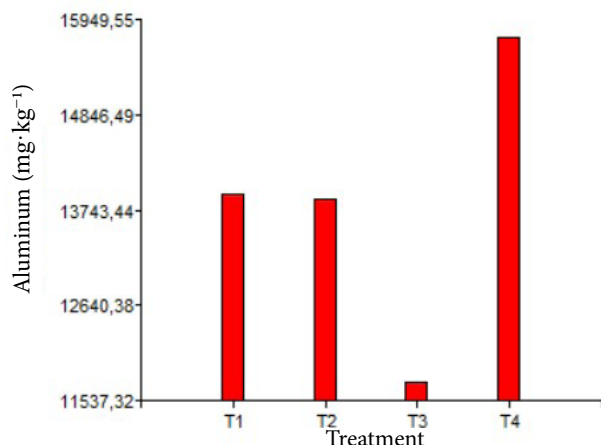


Figure 3. Aluminum (Al) concentration in the different amendment treatments.

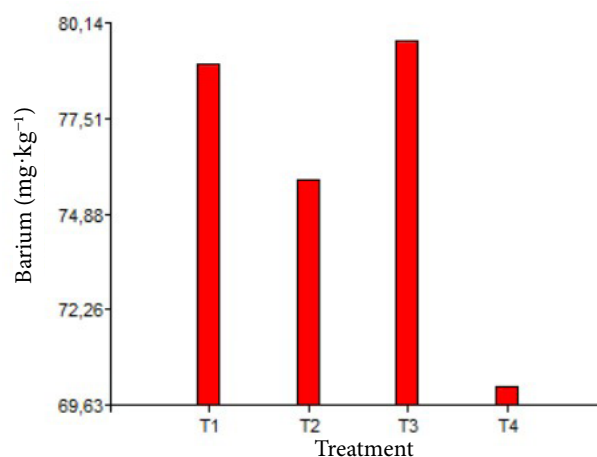


Figure 5. Barium (Ba) concentration in the different amendment treatments.

Regarding boron (B) content, figure 4 shows that T1 obtained the highest concentration, with 47.27 mg·kg⁻¹, followed by T4 (45.49 mg·kg⁻¹), T2 (44.55 mg·kg⁻¹), and T3, with 38.69 mg·kg⁻¹. These data indicated minimal variability among the treatments evaluated. As for barium (Ba), the highest values were recorded in T3 (79.66 mg·kg⁻¹) and T1 (79.02 mg·kg⁻¹), while T4 presented a value of 70.11 mg·kg⁻¹ (figure 5). When comparing these results with the AGROCALIDAD Technical Manual, it is observed that boron is below the minimum nutrient concentration (0.10%); however, this regulation does not specify the limit for barium. In turn, in the study by Delgado and García (2023), conducted at ESPAM MFL, it was observed that the treatment composed of 20% pre-flowering grass, 20% pre-flowering legumes, 20% poultry manure, 20% banana rachis, and 5% biochar reached a higher boron concentration, with a value of 61.50 mg·kg⁻¹, higher than those obtained in this study.

Figure 6 shows the results for calcium (Ca) content, where T3 recorded the highest concentration, with 19,243.70 mg·kg⁻¹, followed by T2 with 17,178.42 mg·kg⁻¹. Regarding cobalt (Co), figure 7 indicated that T4 stood out with the highest value, at 11.75 mg·kg⁻¹, while T1, T2, and T3 showed similar concentrations, close to 8.00 mg·kg⁻¹. When these results were compared with the AGROCALIDAD Manual, the calcium concentrations obtained were found to be within the established limit for nutrients (1 to 1.5%), especially T3, which presented a value of 19,243.70 mg·kg⁻¹ (equivalent to 1.92%); this indicated that the amendment reached excellent calcium levels, exceeding the minimum range of the standard. With respect to cobalt, the treatments were below the parameter of 0.002% (20 mg·kg⁻¹) indicated in the regulation for micronutrients. Finally, in the study by Delgado and García (2023), the reported calcium values of 56,850 and 53,600 mg·kg⁻¹ were higher than those obtained in the prepared organic amendment in this research.

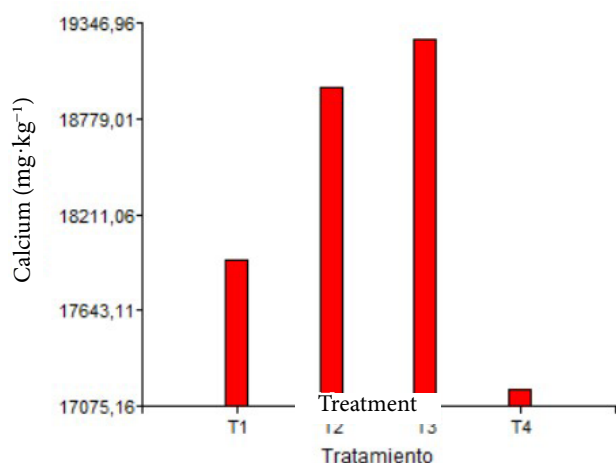


Figure 6. Calcium (Ca) concentration in the different amendment treatments.

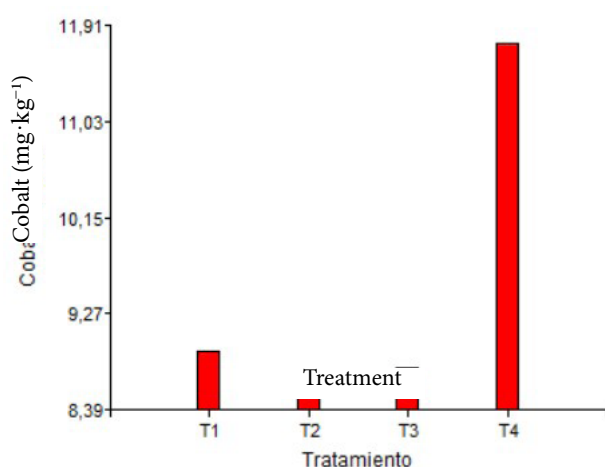


Figure 7. Concentración de cobalto (Co) in the different amendment treatments.

Figure 8 shows the chromium (Cr) values among treatments, evidencing that T4 reached the highest concentration, with 47.04 mg·kg⁻¹, followed by T1 with 38.33 mg·kg⁻¹, while T2 and T3 presented values of 36.32 and 33.81 mg·kg⁻¹, respectively. Regarding copper (Cu), T4 exhibited the highest value (42.09 mg·kg⁻¹), followed by T3 (39.52 mg·kg⁻¹), T1 (37.10 mg·kg⁻¹), and T2 (35.87 mg·kg⁻¹). Compared with the AGROCALIDAD Technical Manual, it was observed that chromium levels significantly exceeded the maximum permissible limit of 2.5

mg·kg⁻¹ for heavy metals. In contrast, copper values satisfactorily met the minimum nutrient concentration established in the regulation, with values of 0.002% (20 mg·kg⁻¹) for macro- and micronutrients, since all treatments presented an average close to 0.004%. This indicated that the amendment had an adequate source of this micronutrient.

In the study by Castro and Daza (2016) on amendments derived from tannery waste, they reported Cr values of 24 mg·kg⁻¹, a relatively low value compared with that recorded in the present study. In contrast, Delgado and García (2023) obtained Cu concentrations of 66 mg·kg⁻¹ in the treatment composed of 20% pre-flowering grass, 15% pre-flowering legumes, 30% poultry manure, 5% mountain soil, 15% banana rachis, and 5% biochar, exceeding the results obtained in the amendment prepared in this study.

The results obtained showed variations in copper (Cu) concentration among the different amendment treatments (figure 9). T2 presented the lowest concentration (35.6 mg·kg⁻¹), while T1 showed an intermediate value (37.2 mg·kg⁻¹). In turn, T3 reached approximately 39 mg·kg⁻¹, and T4 recorded the highest concentration (42.4 mg·kg⁻¹).

These data indicated that, according to the proportions of goat manure, poultry manure, and other components in each treatment, there was an increasing trend in copper concentration as certain wastes were combined in a specific manner. This observation suggested that the composition of the treatments influenced the accumulation of this micronutrient, although statistical analysis is required to formally determine the significance of these differences.

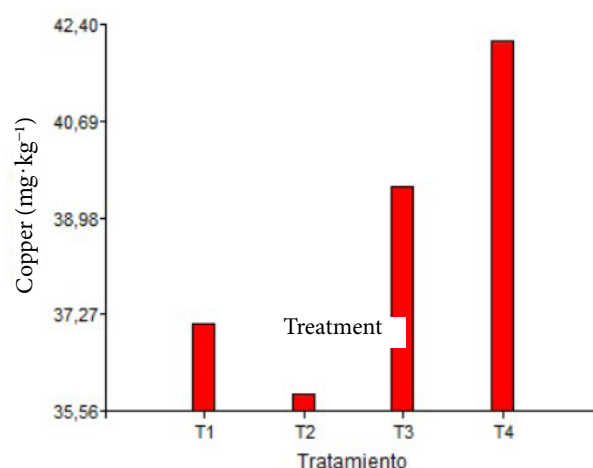


Figure 8. Chromium (Cr) concentration in the different amendment treatments.

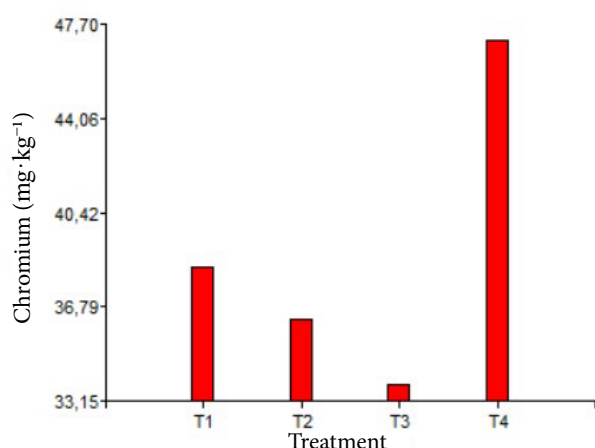


Figure 9. Copper (Cu) concentration in the different amendment treatments.

Regarding iron (Fe) content in the amendment, T4 presented the highest concentration, with a value of 17,100.8 mg·kg⁻¹, followed by T1 (15,579.08 mg·kg⁻¹). In turn, T3 and T2 recorded values of 13,534.09 and 12,474.68 mg·kg⁻¹, respectively (figure 10). According to the AGROCALIDAD Technical Manual, iron exceeded the minimum declarable levels of 0.020% for macro- and micronutrients. The high iron content in T4 indicated that the amendment was of high mineral quality, which may be attributed to the content of poultry manure, neem husk, and goat manure. caprino.

With respect to gallium (Ga), T4 exhibited the highest value, with 7.99 mg·kg⁻¹, followed by T1 (6.52 mg·kg⁻¹), T3 (4.50 mg·kg⁻¹), and T2 (3.98 mg·kg⁻¹) (figure 11). According to Kabata (2010), gallium values in soils can range from 3 to 70 ppm, which indicated that there is no toxicity in the concentrations of this metal in the amendment. In turn, the AGROCALIDAD Technical Manual does not regulate gallium, because it does not represent an environmental risk.

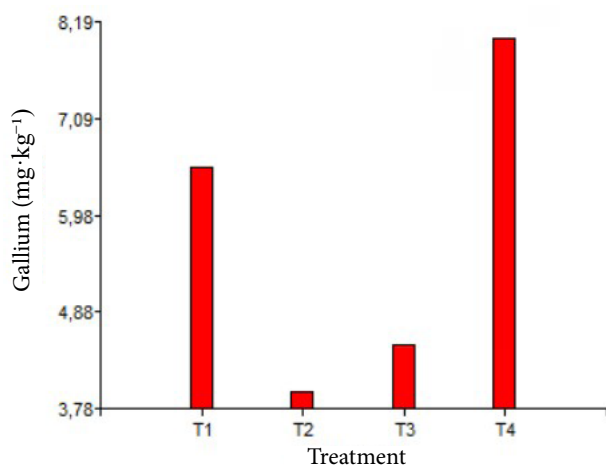


Figure 10. Iron (Fe) concentration in the different amendment treatments.

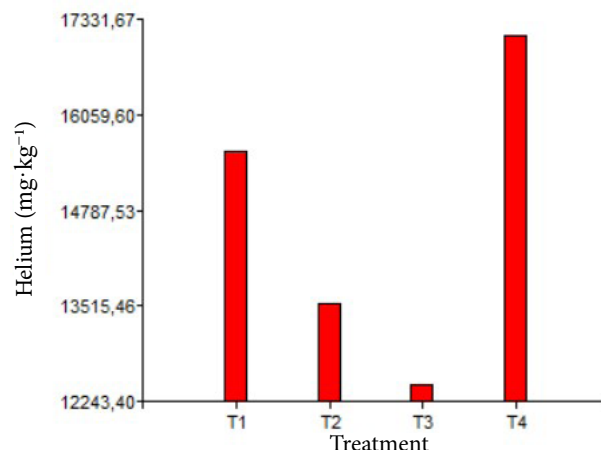


Figure 11. Gallium (Ga) in the different amendment treatments

Regarding indium (In) content, T4 recorded the highest concentration, with 8.76 mg·kg⁻¹, followed by T3 with 7.95 mg·kg⁻¹, T2 with 7.10 mg·kg⁻¹, and T1 with 6.98 mg·kg⁻¹ (figure 12). As for potassium (K), T1 showed the highest value, with 7,841.23 mg·kg⁻¹, while T4 showed the lowest value, with 5,245.41 mg·kg⁻¹ (figure 13). It should be noted that the AGROCALIDAD Technical Manual does not establish values for indium; however, for potassium, the regulation requires a minimum concentration of 3%. It is observed that none of the treatments studied reached the minimum level required for potassium; nevertheless, the amendment was rich in iron and calcium..

According to FAO guidelines, quality compost should present potassium concentrations within a range of 3,000 to 10,000 mg·kg⁻¹ (FAO, 2013). When these values were compared with those obtained in the study, it was observed that all treatments complied with the international standard.

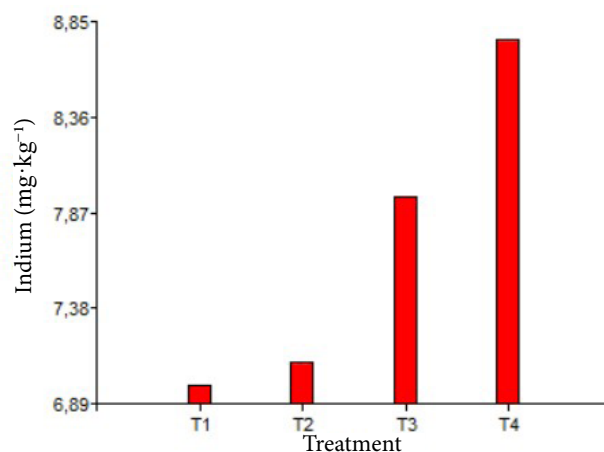
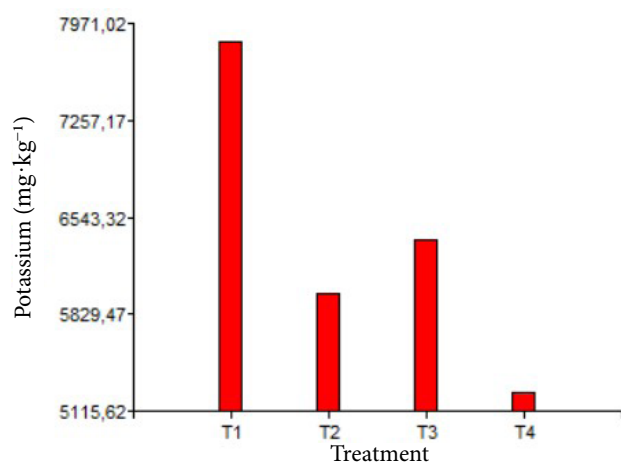


Figure 12. Indium (In) concentration in the different amendment treatments.



Figur 13. Potassium (K) concentration in the different amendment treatments

Regarding lithium (Li) content, T4 recorded the highest value, with 140.73 mg·kg⁻¹, followed by T1 with 111.05 mg·kg⁻¹, while T2 and T3 obtained values of 101.00 and 99.36 mg·kg⁻¹, respectively (figure 14). With respect to magnesium (Mg), T1 presented the highest concentration, with 5,163.27 mg·kg⁻¹, whereas T4 reached lower values, with 4,859.46 mg·kg⁻¹ (figure 15). According to the AGROCALIDAD Technical Manual, magnesium must meet a minimum concentration of 1%. In the study, Mg values were below the range established in the regulation, as in the study by Delgado and García (2023), who obtained values below 1,500 mg·kg⁻¹; this indicated that the mixture of goat manure and neem favored the retention of this macronutrient. Regarding lithium, no minimum ranges are reported in the AGROCALIDAD Manual, since its content in compost was variable and depended largely on the organic materials used for its preparation (Naeem et al., 2021).

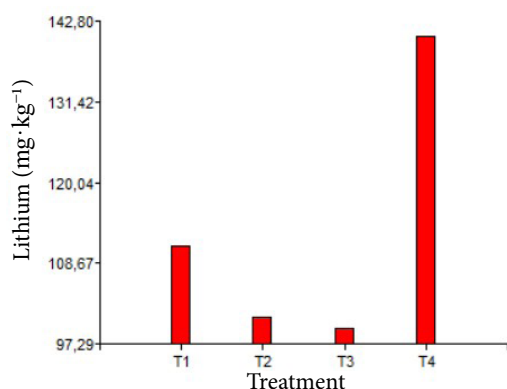


Figura 14. Lithium (Li) concentration in the different amendment treatments.

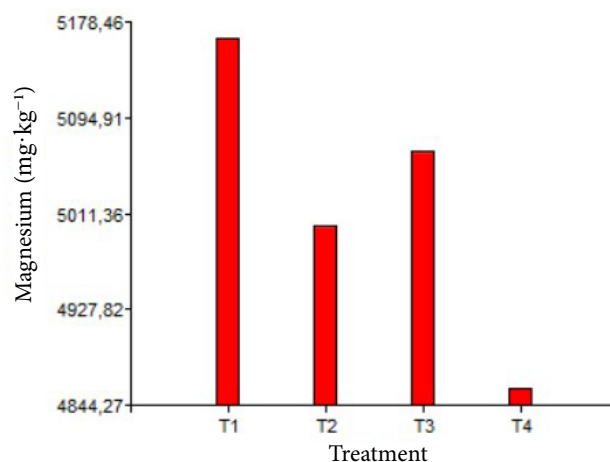


Figure 15. Magnesium (Mg) in the different amendment treatments.

Regarding manganese (Mn) concentrations, T4 obtained the highest value, with 344.28 mg·kg⁻¹, exceeding T3 (296.45 mg·kg⁻¹), T2 (287.08 mg·kg⁻¹), and T1 (283.07 mg·kg⁻¹) (figure 16). According to the AGROCALIDAD Technical Manual, manganese must meet a minimum concentration of 0.010%. In this regard, all Mn treatments exceeded that value. In turn, Álvarez et al. (2021) reported manganese concentrations of 388 mg·kg⁻¹, a value higher than that obtained in this study. However, both studies agreed that the increase in this macronutrient may be related to the interaction between manure and plant residues.

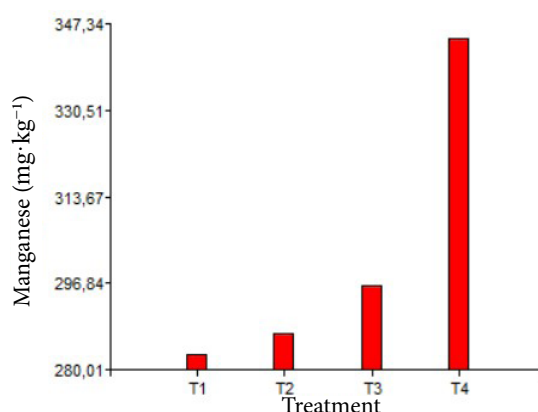


Figure 16. Manganese (Mn) concentration in the different amendment treatments.

Regarding sodium (Na) (figure 17), the highest levels were recorded in T2 (1,348.78 mg·kg⁻¹) and T1 (1,281.43 mg·kg⁻¹). It is important to note that the AGROCALIDAD Technical Manual does not establish specific parameters for sodium content in organic amendments. However, the concentrations found in the amendment were considered moderate and, therefore, did not represent a risk of phytotoxicity due to salinity (Torres et al., 2016).

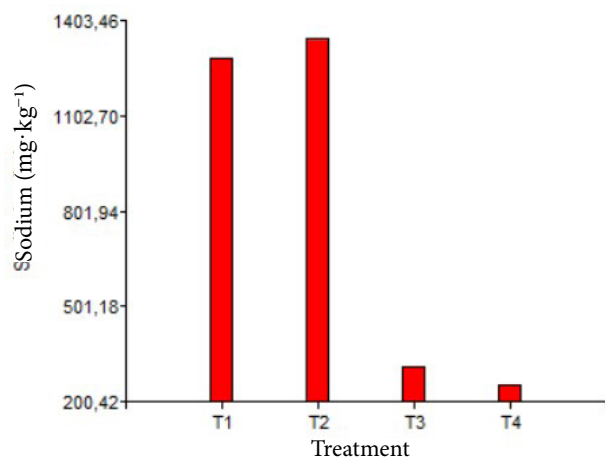


Figure 17. Sodium (Na) concentration in the different amendment treatments.

With respect to heavy metals, nickel (Ni) concentrations showed that T4 presented the highest value, with 18.34 mg·kg⁻¹, while T3 exhibited the minimum content, with 12.47 mg·kg⁻¹ (figure 18). Regarding lead (Pb), the treatments showed similar behavior, with values ranging from 3.13 mg·kg⁻¹ for T4 to 2.14 mg·kg⁻¹ for T2 (figure 19). When these results were compared with the AGROCALIDAD Technical Manual, it was confirmed that both elements were within the maximum permissible range. In the case of nickel, the limit was 50 mg·kg⁻¹; in turn, lead levels were relatively low, representing less than 3% of the established maximum, which is 120 mg·kg⁻¹. The findings guarantee that the organic amendment is a safe product for agricultural use, since it is free of risk due to heavy metal contamination.

In contrast, Dueñas and Intriago (2021), in their study, reported nickel concentrations ranging from 1.4691 mg·kg⁻¹ in poultry manure, 3.5757 mg·kg⁻¹ in cattle manure, and 8.1100 mg·kg⁻¹ in compost; while for lead, the values were significantly lower: 0.24, 0.27, and 0.26 mg·kg⁻¹, respectively. Although the levels found in this study were higher than those cited, both studies were below the limits permitted by the regulation.

According to Kennou et al. (2015), the presence of these metals in organic fertilizers usually derives from the presence of primary and secondary minerals found in the soil.

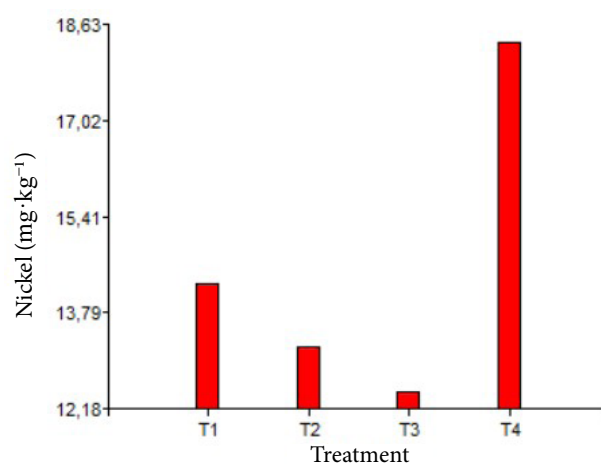


Figure 18. Nickel (Ni) concentration in the different amendment treatments.

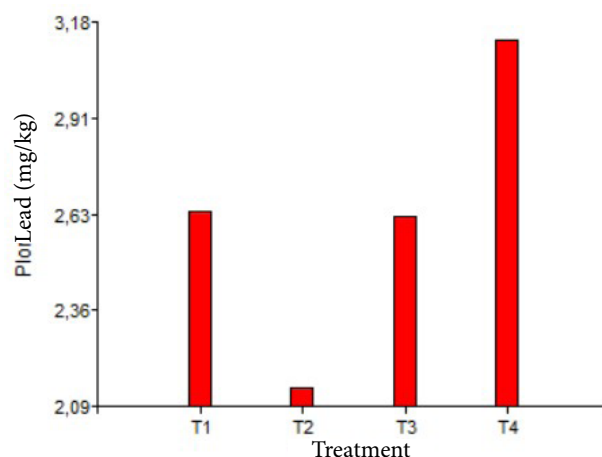


Figure 19. Lead (Pb) concentration in the different amendment treatments.

Regarding strontium (Sr), T3 recorded the highest concentration, with 103.93 mg·kg⁻¹, followed by T2 (99.52 mg·kg⁻¹), T1 (96.17 mg·kg⁻¹), and T4 (92.14 mg·kg⁻¹) (figure 20). With respect to zinc (Zn), T4 showed the highest concentration, with 155.87 mg·kg⁻¹, while the other treatments presented minimal variation, with values of 144.24 mg·kg⁻¹ (T1), 143.08 mg·kg⁻¹ (T2), and 141.46 mg·kg⁻¹ (T3) (figure 21). According to the AGROCALIDAD Technical Manual, zinc must meet a minimum declarable concentration of 0.020% for macro- and micronutrients. In this regard, even though the findings presented approached the limit established in the regulation, the amendment provided a significant amount of this micronutrient, which is essential for plant metabolism.

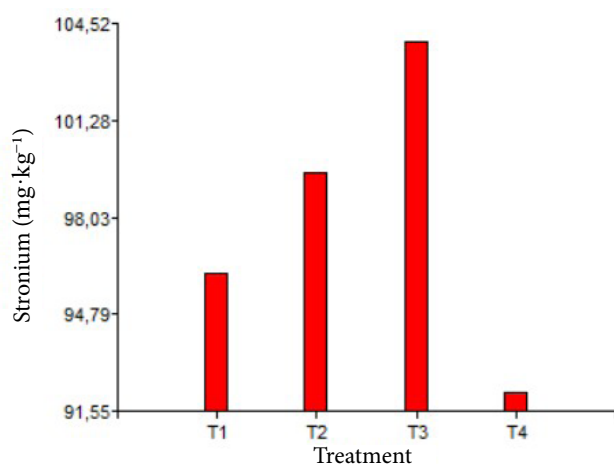


Figure 20. Strontium (Sr) in the different amendment treatments.

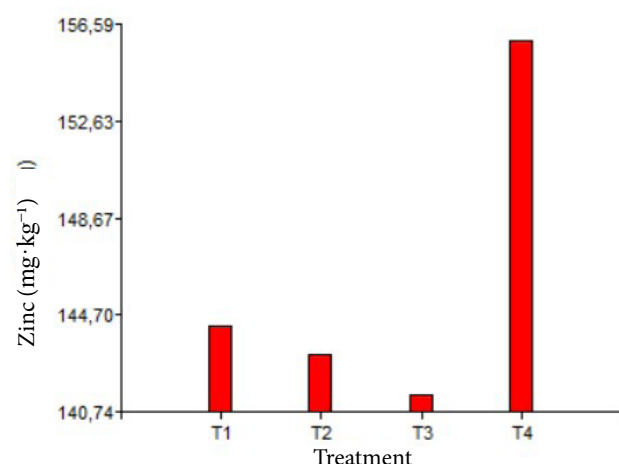


Figure 21. Zinc (Zn) concentration in the different amendment treatments.

The presence of zinc in the amendment constitutes an essential contribution to soil fertility. Guarino et al. (2020) stated that zinc is a component of many proteins, is also an enzymatic cofactor, and is fundamental for optimal plant growth and development. Therefore, the application of this amendment in agricultural soils in the province of Manabí will not only help improve physical structure, but will also stimulate root and foliar development in crops. In turn, strontium content was an indicator of the mineral richness of the goat manure used (Briceño et al., 2020).

Regarding germanium (Ge), T4 presented the highest concentration, with 11.49 mg·kg⁻¹, followed by T1 with 10 mg·kg⁻¹, while T2 and T3 exhibited values of 8.68 and 8.25

mg·kg⁻¹ (figure 22). In turn, iridium (Ir) revealed a similar trend, where T4 showed the highest concentration, with 5.68 mg·kg⁻¹, followed by T3 (5.24 mg·kg⁻¹), T1 (4.52 mg·kg⁻¹), and T2 (4.08 mg·kg⁻¹) (figure 23). It is important to mention that the AGROCALIDAD Technical Manual does not establish reference parameters for germanium or iridium. However, the detection of these elements in low concentrations confirmed that the composition of these amendments came from the soils where the raw material for compost production was obtained. del compost.

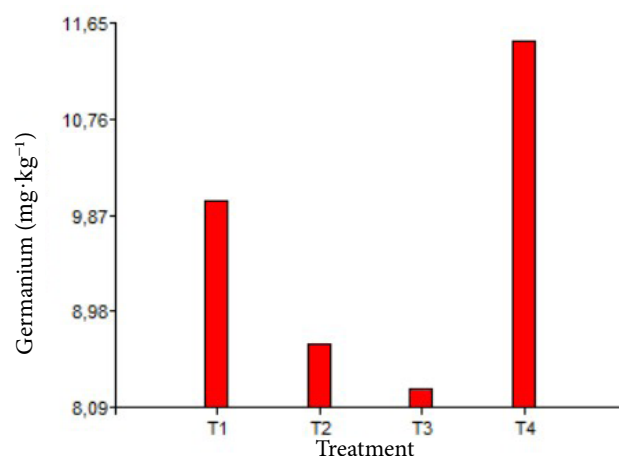


Figure 22. Germanium (Ge) concentration in the different amendment treatments.

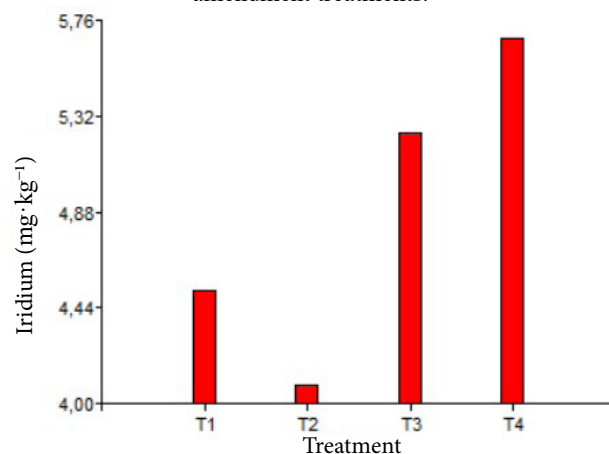


Figure 23. Iridium (Ir) concentration in the different amendment treatments.

The results for molybdenum (Mo) content indicated that the highest concentration occurred in T2, with 4.94 mg·kg⁻¹,

followed by T1 ($4.47 \text{ mg}\cdot\text{kg}^{-1}$), T3 ($2.00 \text{ mg}\cdot\text{kg}^{-1}$), and T4 ($1.30 \text{ mg}\cdot\text{kg}^{-1}$) (figure 24). Based on the AGROCALIDAD Technical Manual, the minimum declarable content for this micronutrient is 0.002% (equivalent to $20 \text{ mg}\cdot\text{kg}^{-1}$). In this regard, Mo values were below the established limit. Regarding niobium (Nb), shown in figure 25, the treatments exhibited homogeneous behavior, with T4 recording the highest value, at $3.91 \text{ mg}\cdot\text{kg}^{-1}$, followed by T2 ($3.55 \text{ mg}\cdot\text{kg}^{-1}$), T3 ($3.34 \text{ mg}\cdot\text{kg}^{-1}$), and T1 ($3.02 \text{ mg}\cdot\text{kg}^{-1}$). It should be noted that the AGROCALIDAD Technical Manual does not include the maximum permissible limits for this parameter.

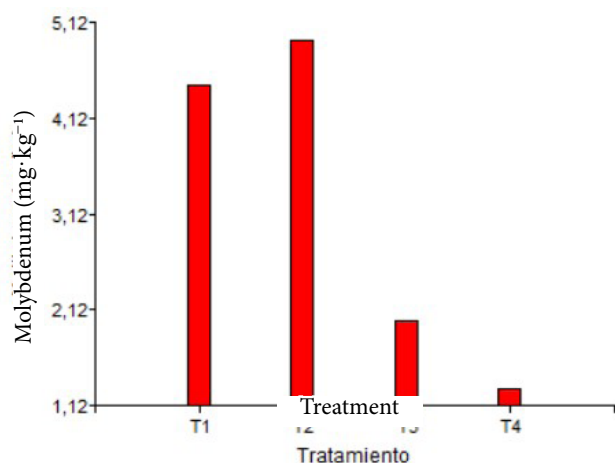


Figure 24. Molybdenum (Mo) in the different amendment treatments.

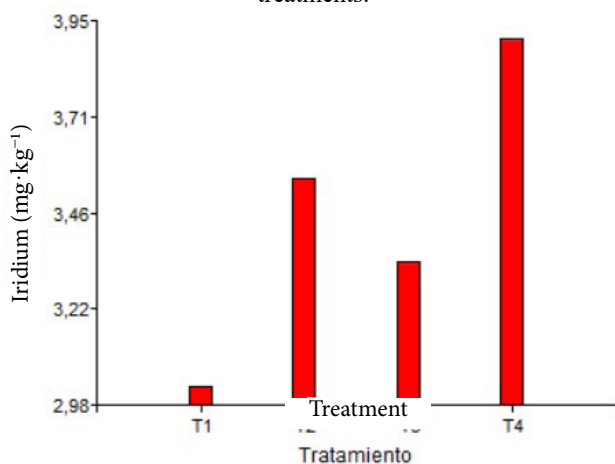


Figure 25. Niobium (Nb) in the different amendment treatments.

Regarding ruthenium (Ru) concentrations in the amendment, T4 recorded the highest value, with $4.38 \text{ mg}\cdot\text{kg}^{-1}$, followed by T1 with $4.38 \text{ mg}\cdot\text{kg}^{-1}$, while T2 and T3 presented values of $3.96 \text{ mg}\cdot\text{kg}^{-1}$ and $3.61 \text{ mg}\cdot\text{kg}^{-1}$, respectively (figure 26). In turn, tin (Sn) exhibited minimal concentrations among the treatments, ranging from $0.24 \text{ mg}\cdot\text{kg}^{-1}$ (T1 and T3) to $0.30 \text{ mg}\cdot\text{kg}^{-1}$ (T4) (figure 27). It should

be noted that the AGROCALIDAD Technical Manual does not establish reference limits for these elements.

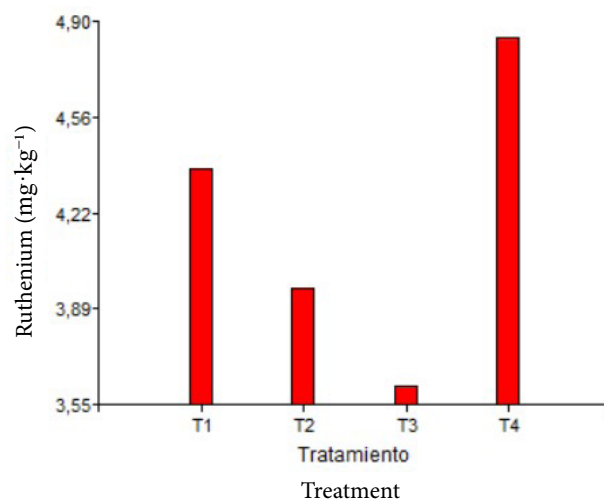


Figure 26. Ruthenium (Ru) concentration in the different amendment treatments.

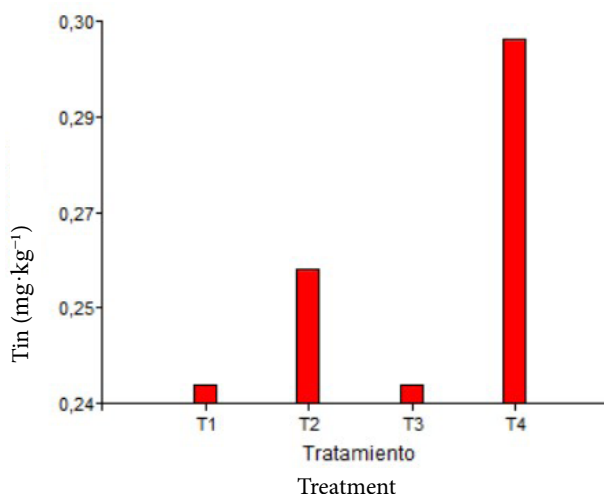


Figure 27. Tin (Sn) concentration in the different amendment treatments.

Regarding zirconium (Zr), the analyses indicated low variability among treatments, with concentrations ranging from $1.16 \text{ mg}\cdot\text{kg}^{-1}$ (T3) to $1.84 \text{ mg}\cdot\text{kg}^{-1}$ (T4) (figure 28). As for phosphorus (P), T3 recorded values of $7,124.45 \text{ mg}\cdot\text{kg}^{-1}$, followed by T4 ($6,744.46 \text{ mg}\cdot\text{kg}^{-1}$), T1 ($5,948.97 \text{ mg}\cdot\text{kg}^{-1}$), and T4 ($5,686.21 \text{ mg}\cdot\text{kg}^{-1}$) (figure 29). When these results were compared with the AGROCALIDAD Technical Manual, which establishes a minimum concentration of 3% for phosphorus, it was observed that the values obtained were below the indicated limit. Nevertheless, Wei et al. (2015) stated that waste of animal and plant origin has high potential for supplying P to arable land, which favors soil fertility through organic sources.

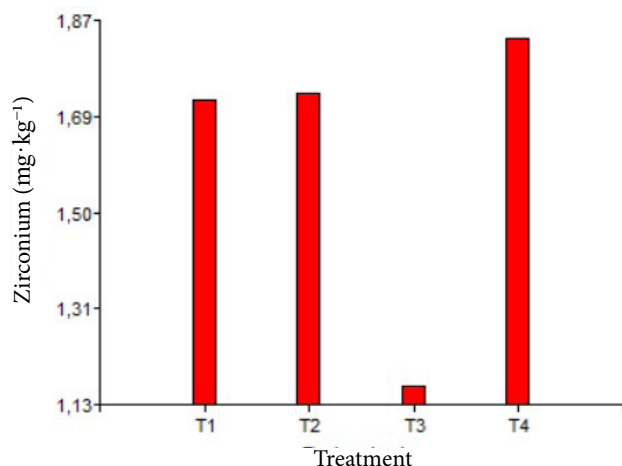


Figure 28. Zirconium (Zr) concentration in the different amendment treatments.

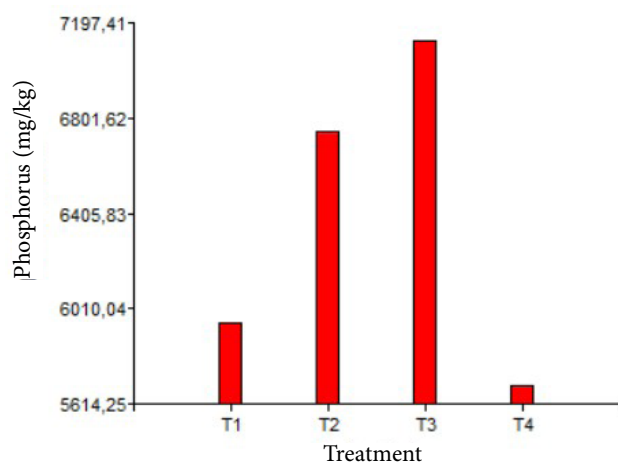


Figure 29. Phosphorus (P) concentration in the different amendment treatments

Regarding total nitrogen (N), T2 exhibited the highest concentration, with 1.59%, followed by T1 (1.51%), T3 (1.43%), and T4 (1.30%) (Figure 30). When these results were compared with the AGROCALIDAD Technical Manual, it was observed that none of the treatments analyzed reached the minimum required level of 3%. In this regard, when contrasting total nitrogen content with the literature, it was observed that the values

obtained in this study (1.30 to 1.59%) were below those reported by Pasqualotto (2022), who reported average concentrations of 2.13%. In turn, Ortiz (2020) determined a higher range, which varied between 1.79% (T3) and 2.25% (T2). Monsalve et al. (2017) stated that nitrogen from organic sources was essential for plant growth.

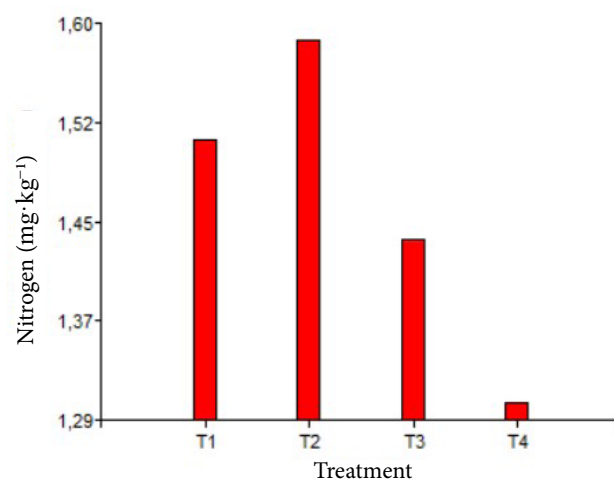


Figure 30. Total Nitrogen (Nt) concentration in the different amendment treatments.

Regarding the microbiological analysis (figure 31), T2 recorded the highest *Escherichia coli* load, with 9.70×10^4 MPN·g⁻¹. Likewise, the presence of *Salmonella* spp. in 25 g was evidenced in all the treatments evaluated. When these results were compared with Chilean Standard NCh 2880, which establishes a maximum limit of 1,000 MPN·g⁻¹ to ensure safety in Class A and B compost, it was evidenced that the amendment did not comply with the standard, since it exceeded the permitted safety limit by 97 times.

De according to Hayany et al. (2021), the application of inadequately composted organic fertilizers or compost on farms can lead to the spread and dispersion of pathogenic bacteria, essentially *E. coli* and *Salmonella* spp. In this regard, FAO (2013) stated that the presence of high concentrations of these microorganisms in compost or organic material was the result of a deficient

thermal process. This occurs when the compost does not reach adequate temperatures during the thermophilic phase, or when such temperatures are maintained for very short periods to achieve biological inactivation. Likewise, it may occur due to subsequent contamination with water during the cooling stages or through contact with external vectors at the site

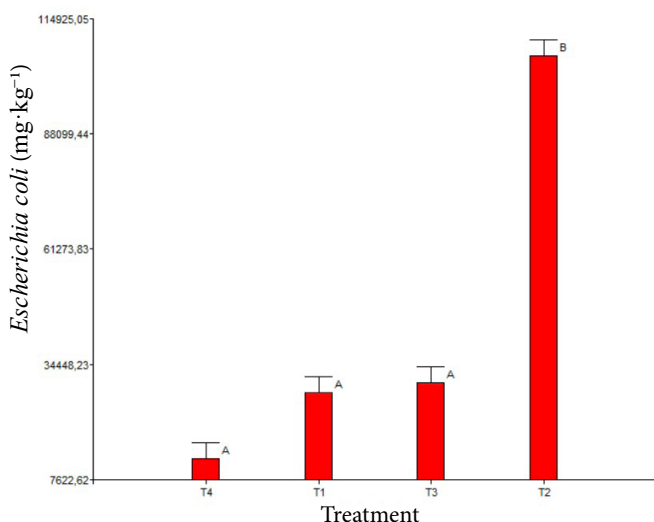


Figure 31. *Escherichia coli* concentration in the different amendment treatments.

In summary, the high concentration of *E. coli* and the presence of *Salmonella* spp. in all treatments determined that the stabilization process did not guarantee the sanitization of the material; therefore, this product is not suitable for agricultural use in crops intended for human consumption. Hence, its use should be limited exclusively to the recovery of eroded soils or forest systems.

The ANOVA analysis of variance reported highly significant differences among the treatments ($P > 0.0001$). This result demonstrated that the specific composition of each biomass mixture had a determining influence on the transformation of organic matter, rejecting the idea that quality was uniform or persistent across all variants. Table 3 presents the analysis of variance table.

Table 3. Analysis of variance.

F.V.	SC	gl	CM	F	p-valor
Model	16051395833,33	5	3210279266,67	77,56	<0,0001
Replicas	60666666,67	2	30333333,33	0,73	0,5191
Treatments	15990729166,67	3	5330243055,56	128,78	<0,0001
Error	248333333,33	6	41388888,89		
Total	16299729166,67	11			

Table 4 shows that T2, with a mean of 106,333.33, was significantly higher than the other treatments, since being alone in group B indicated that, with 95% confidence, this treatment produced a greater impact on the measured variable. In turn, the treatments that share the letter A demonstrated statistical homogeneity among themselves. Even with the numerical variations observed among these three groups, the differences were not significant under the model's margin of error, which indicated similar performance behavior.

Table 4. Tukey's multiple comparison test.

Treatments	Medias	n	E.E.	
T4	12500,00	3	3714,34	A
T1	27833,33	3	3714,34	A
T3	30166,67	3	3714,34	A
T2	106333,33	3	3714,34	B

Means sharing a common letter are not significantly different ($P > 0.05$).

In summary, the organic amendment produced at ESPAM MFL through the valorization of residual agricultural biomass (peanut shells and neem seed husks) and livestock biomass (goat manure and poultry manure) demonstrated notable mineral richness. The findings evidenced that T4 was positioned as the most efficient treatment in terms of microelements, presenting the highest concentrations of Ag, Al, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn. In turn, T3 stood out for its high concentrations of Ba, Ca, K, and P, while T2 obtained the highest total nitrogen content.

Table 5. Strategies for the use of amendments

Strategies for the use of amendments					
Objective:	To propose strategies for the use of high-quality organic amendments at ESPAM MFL for the recovery of soils degraded by intensive agricultural activities.				
Responsible party:	ESPAM MFL authorities				
Place of application:	Environmental Engineering Program – ESPAM MFL				
Proposed measure	Indicator	Means of verification	Cost	Relationship of the strategies	
				Circular Economy White Paper	SDG targets
Implement a composting or vermicomposting system for harvest waste and manure for the production of organic amendments	Number of composting systems implemented	Photographic record of the implemented composting system	\$500	Promote zero-waste models. Identify various alternatives for the management of organic solid waste.	SDG 12.5: Substantially reduce waste generation through prevention, reduction, recycling, and reuse.
Conduct a soil diagnosis for the application of organic amendments.	Soil diagnosis	Soil diagnosis report	\$1000	Effective management of materials at the end of their useful life	SDG 2.4: Ensure the sustainability of food production systems. SDG 12.4: Environmentally sound management of chemicals and waste.
Use organic amendments as basal fertilization to improve soil fertility..	Cultivated area	Photographic record of the application of the amendments	\$500	Sustainable supply	SDG 2.4: Sustainable systems. SDG 12.4: Waste management. SDG 12.2: Efficient use of resources.
			\$2000		

Conclusion

The use of compost prepared from residual agricultural and livestock biomass is an essential strategy for transforming a waste management problem into an environmental solution with high economic value. The study determined that the valorization of residual agricultural and livestock biomass generates an organic amendment of high mineral complexity. However, despite the multielemental complexity detected in treatment T4, the final

product does not comply with the standards established by the AGROCALIDAD manual regarding macronutrients (N, P, K) or biological safety parameters, due to the presence of *Salmonella* spp. and non-compliant levels of *Escherichia coli*. The results show that there were structural deficiencies in the composting process, mainly in the sanitization phase; therefore, it is concluded that the pile volume and thermal management were insufficient to sustain an adequate thermophilic stage, allowing

the persistence of pathogens. Therefore, the amendment obtained is restricted exclusively to use in non-food systems. In this regard, it is essential that future studies optimize the selection of the source material and the C/N ratio, and that more rigorous control of moisture, pH, and temperature be implemented.

Conflict of interest

The authors declare that they have no conflicts of interest in any phase of the present publication.

References

- Agencia Ecuatoriana de Aseguramiento de la Calidad del Agro [AGROCALIDAD]. (2018). Manual técnico para el registro y control de fertilizantes, enmiendas de suelo y productos afines de uso agrícola. https://www.gob.ec/sites/default/files/regulations/2018-10/DOCUMENTO_MANUAL%20TECNICO%20PARA%20EL%20REGISTRO%20Y%20CONTROL%20DE%20FERTILIZANTES%20ENMIENDAS%20DE%20SUELO%20Y%20PRODUCTOS%20AFINES%20DE%20USO%20AGRICOLA.pdf
- Aguirre, J. (2023). *Calidad de compost de residuos orgánicos urbanos producidos en la planta de valorización de la municipalidad provincial de Leoncio Prado*. Universidad Nacional Agraria de La Selva. <https://repositorio.unas.edu.pe/server/api/core/bitstreams/7275110d-9119-4571-86fb-268f8ece1fcd/content>
- Álvarez, A., Llerena, L. y Reyes, J. (2021). Efecto de sustancias azucaradas en la descomposición de sustratos orgánicos para la elaboración de compost. *Terra Latinoamericana*, 38. <https://doi.org/10.28940/terra.v39i0.916>
- Briceño, J., Tonato, E., Silva, M., Paredes, M. y Armando, A. (2020). Evaluación del contenido de metales en suelos y tejidos comestibles de *Allium fistulosum* L. cultivado en zonas cercanas al volcán Tungurahua. *La Granja. Revista de Ciencias de la Vida*, 32(2), 114-126. <https://www.redalyc.org/journal/4760/476064168009/html/>
- Cabrera, V. y Rossi, M. (2016). *Propuesta para la elaboración de compost a partir de los residuos vegetales provenientes del mantenimiento de las áreas verdes públicas del distrito de Miraflores*. Universidad Nacional Agraria La Molina: <https://repositorio.lamolina.edu.pe/items/46032920-1e8a-495d-832c-643b0fa65d47>
- Castro, G. y Daza, M. (2016). Evaluación de enmiendas en el proceso de compostaje de residuos de curtiembres. *Producción + Limpia*, 11(1), 53-65. <http://www.scielo.org.co/pdf/pml/v11n1/v11n1a06.pdf>
- Corrales, E., Luna, R., Carrión, C., Quinatoa, E. y Espinoza, A. (2024). Comparación de producción de compost con diferentes formulaciones de residuos de origen vegetal y pecuario. *Revista Ciencia y Tecnología*, 17(2), 64-72. <https://doi.org/10.18779/cyt.v17i2.803>
- Delgado, M. y García, C. (2023). *Contenido nutricional del compost a partir de residuos agropecuarios en la ESPAM MFL*. Repositorio ESPAM MFL. https://repositorio.espam.edu.ec/bitstream/42000/2086/1/TIC_IA40D.pdf
- Dueñas, J. y Intriago, F. (2021). Contenido de metales pesados (Cu, Pb, Ni, Cd) en abonos orgánicos y las materias primas para su elaboración. *La Técnica: Revista de las Agrociencias*, 27, 26-35. https://doi.org/10.33936/la_tecnica.v0i27.3674
- Escobal, F. y Garro, K. (2020). *Efecto del porcentaje de Saccharomyces Cerevisiae en la calidad y tiempo del compost obtenido con biomasa residual del Mercado Corralón*. Universidad César Vallejo. https://repositorio.ucv.edu.pe/bitstream/handle/20.500.12692/47882/Escobal_CFR-Garro_CKM-SD.pdf?sequence=1&isAllowed=y
- Flor, L., Camacho, R., Grass, J. y Cerón, Y. (2023). *Análisis de las potencialidades de los residuos agrícolas, pecuarios y agroindustriales como sustratos de cultivo, como alternativa a nuevos sistemas de producción de alimentos*. Colombia. Primera Edición Sello Editorial Uniautónoma del Cauca.
- González, J. (2023). *Valorización de la biomasa generada por el sector porcino en la provincia de Santa Cruz para la producción de compost*. Universidad Católica Santo Toribio de Mogroviejo. https://tesis.usat.edu.pe/bitstream/20.500.12423/6558/1/TL_GonzalesDiazJorge.pdf
- Guarino, F., Improta, G., Triassi, M., Cicatelli, A. y Castiglione, S. (2020). Effects of Zinc Pollution and Compost Amendment on the Root Microbiome of a Metal Tolerant Poplar Clone. *Frontiers in Microbiology*, 11. <https://doi.org/10.3389/fmicb.2020.01677>
- Hayany, B., Fels, L., Ouhdouch, Y. y Hafidi, M. (2021). Fate of pathogenic microorganisms during lagooning sludge composting and exploration of bacteriophages as indicator of hygienization. *Environmental Technology & Innovation*, 21. <https://doi.org/10.1016/j.eti.2020.101268>
- Hidalgo, K. (2019). *Contenido nutricional del compost elaborado a partir de residuos de soca de maíz (Zea mays L.)*. Repositorio ESPAM MFL.
- Jara, J., Gallegos, J. y Pullopaxi, A. (2020). Biotransformación de residuos orgánicos generados en la escuela superior politécnica de Chimborazo-Ecuador mediante compostaje. *InterSedes*, XXI(44), 202-221. <https://doi.org/10.15517/isucr.v21i44.43944>
- Kabata, A. (2010). *Trace Elements in Soils and Plants* (4th ed.). CRC Press. <https://doi.org/10.1201/b10158>
- Kennou, B., Meray, M. y Arjouni, Y. (2015). Assessment of heavy metal availability (Pb, Cu, Cr, Cd, Zn) and speciation



- in contaminated soils and sediment of discharge by sequential extraction. *Environmental Earth Sciences*, 74, 5849-5858.
- Loaiza, F. (2020). *Disposición y reciclaje de residuos sólidos orgánicos en la Escuela Profesional de Ingeniería Agropecuaria sede Santo Tomás*. Universidad Nacional de San Antonio Abad del Cusco. <https://repositorio.unsaac.edu.pe/handle/20.500.12918/5072>
- López, A., Miguel, N., Jojoa, S., Fernández, J., Gómez, J. y Ormad, M. (2022). Physico-chemical and microbiological control of the composting process of the organic fraction of municipal solid waste: A pilot-scale experience. *International Journal of Environmental Research and Public Health*, 19(23). <https://doi.org/10.3390/ijerph192315449>
- Lorenzo, M., López, A., Saucedo, C., Cortés, J., Jaén, D. y Suárez, J. (2016). Composición nutrimental del nopal verdura producido con fertilización mineral y orgánica. *Revista Fitotecnica Mexicana*, 39(4). https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0187-73802016000400403
- Monsalve, Ó., Gutiérrez, J. y Cardona, W. (2017). Factores que intervienen en el proceso de mineralización de nitrógeno cuando son aplicadas enmiendas orgánicas al suelo. Una revisión. *Revista Colombiana de Ciencias Hortícolas*, 11(1). <https://doi.org/10.17584/rcch.2017v11i1.5663>
- Morales, J. (2020). *Calidad de compost a partir de estiércol de gallinas con aplicación de biochar*. Universidad Católica de Cuenca. <https://dspace.ucacue.edu.ec/items/26c03c1b-b4f8-43ed-852f-964729b45ab3>
- Naeem, A., Aslam, M. y Mühling, K. (2021). Lithium: Perspectives of nutritional beneficence, dietary intake, biogeochemistry, and biofortification of vegetables and mushrooms. *Science of The Total Environment*, 798. <https://doi.org/10.1016/j.scitotenv.2021.149249>
- Norma Chilena NCh 2880. (2020). *Compost-Clasificación y requisitos*. https://miros.cl/wp-content/uploads/2020/01/NCh_2880_Compost_Clasificaci%C3%B3n.pdf
- Organización de las Naciones Unidas [ONU]. (2018). *La Agenda 2030 y los Objetivos de Desarrollo Sostenible: una oportunidad para América Latina y el Caribe*. CEPAL: <https://repositorio.cepal.org/server/api/core/bitstreams/cb30a4de-7d87-4e79-8e7a-ad5279038718/content>
- Organización de las Naciones Unidas para la Alimentación y la Agricultura [FAO]. (2013). *Manual de compostaje del agricultor. Experiencias en América Latina*. FAO: <https://www.fao.org/4/i3388s/i3388s.pdf>
- Ortiz, L. (2020). *Efecto del tipo de estiércol y frecuencia de aireación (volteo) en el comportamiento del proceso de compostaje*. Universidad Nacional Agraria La Molina. <https://repositorio.lamolina.edu.pe/server/api/core/bitstreams/e2e75687-9e0d-419c-a575-eac15755c8ad/content>
- Paccha, M., Alvarado, V., Heidinger, H. y Ramos, L. (2023). Medición de gases de efecto invernadero en suelos agrícolas y ganaderos mediante cámaras estáticas cerradas en el sector Zalapa, ciudad de Loja. *Bosques Latitud Cero*, 14(1), 137-149. <https://doi.org/10.54753/blc.v14i1.2129>
- Pasqualotto, N. (2022). *Caracterización y aprovechamiento de residuos orgánicos de bodega: compostaje y obtención de enmienda para uso agrícola*. Universidad Nacional de Cuyo. https://bdigital.uncu.edu.ar/objetos_digitales/17531/pasqualotto-noelia-tesis-de-grado-irnr.pdf
- Pereira, J., Contrera, R., Maintinguer, S. and Avezum, M. (2020). Effects of temperature, proportion and organic loading rate on the performance of anaerobic digestion of food waste. *Biotechnology Reports*, 27. <https://doi.org/10.1016/j.btre.2020.e00503>
- Pérez, G. (2023). *Calidad y grupos funcionales microbianos del compost de residuos agropecuarios por efecto de dos biofermentos (montaña y bambusal)*. Repositorio Universidad Nacional Agraria de la Selva. <https://repositorio.unas.edu.pe/server/api/core/bitstreams/68bb8325-43ff-41bf-8ac3-653d0a38ffb5/content>
- Quishpe, E. (2023). *Estudio del proceso de compostaje de estiércol con restos vegetales provenientes de la comunidad de Pisambilla*. <https://repositorio.puce.edu.ec/server/api/core/bitstreams/597f1a52-696a-4794-90db-6d17d9962487/content>
- Reyes, Y. (2023). *Influencia de los sistemas de compostaje en las características físico-químicas del compost elaborado a partir de residuos agrícolas*. Universidad Técnica de Machala. https://repositorio.utmachala.edu.ec/bitstream/48000/22849/1/Trabajo_Titulacion_2941.pdf

- Torres, D., Mendoza, B., Meru, M. y Gómez, C. (2016). Riesgos de salinización y sodificación por el uso de abonos orgánicos en la depresión de Quíbor - Venezuela. *Multiciencias*, 16(2), 133-142. <https://www.redalyc.org/pdf/904/90452745003.pdf>
- Vásquez, J., Alvarez, M., Iglesias, S. y Castillo, J. (2020). La incorporación de enmiendas orgánicas en forma de compost y vermicompost reduce los efectos negativos del monocultivo en suelos. *Scientia Agropecuaria*, 11(1). <http://dx.doi.org/10.17268/sci.agropecu.2020.01.12>
- Wei, Y., Zhao, Y., Xi, B., Wei, Z., Li, X. y Cao, Z. (2015). Changes in phosphorus fractions during organic wastes composting from different sources. *Bioresource Technology*, 189, 349-356. <https://doi.org/10.1016/j.biortech.2015.04.031>

Author contribution statement according to CRediT

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