# *Evaluación de propiedades fisicoquímicas de composta como producto de un dispositivo inteligente de degradación biológica*
## *Evaluation of physicochemical properties of compost as a product of an intelligent device for biological degradation*
## *Avaliação das propriedades físico-químicas do composto como produto de um dispositivo inteligente de degradação biológica*

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## Resumen

Uno de los desafíos que debe enfrentar la sociedad actual tiene que ver con la acumulación, gestión, tratamiento y disposición final de desechos orgánicos e inorgánicos. Por eso, en el panorama contemporáneo se requiere de la implementación de técnicas destinadas a mitigar esta problemática con el fin de promover la mejora del entorno ambiental. En cuanto al tratamiento de residuos de origen orgánico, se pueden mencionar estrategias como el proceso de compostaje, un método que propicia la transformación de la materia orgánica mediante la descomposición aeróbica, lo cual genera un producto final estabilizado. Este producto, al ser integrado al suelo, enriquece sus propiedades físicas y químicas, las cuales pueden haberse visto mermadas debido a actividades agrícolas. Explicado lo anterior, el objetivo del presente estudio fue evaluar la calidad de los productos resultantes del compostaje (composta y lixiviados) obtenidos en el seno de un prototipo de compostero, el cual se nutre de desechos orgánicos provenientes de la cocina, así como de componentes orgánicos ligeros. Además, se vale de un coadyuvante microbiano y procesos mecánicos para reducir el tiempo de compostaje hasta en 600 % en comparación con los métodos convencionales, sin menoscabo de la calidad del producto final, según los parámetros de calidad vigentes. En conclusión, los resultados evidencian que el abono orgánico obtenido mediante este procedimiento presenta una humedad del 73 %, ligeramente superior a la estipulada, y carece de una concentración elevada de metales pesados que supere los límites permitidos. Además, se confirma que la relación C/N alcanza un valor de 6.5, lo cual lo convierte en un aditivo orgánico idóneo para mejorar las condiciones de los suelos agrícolas.

**Palabras clave**: composta, compostero *smart*, indicadores de calidad, parámetros bioquímicos.


## Abstract

One of the problems of human activity is the continuous accumulation of garbage, both inorganic and organic, its management, treatment and final disposal. Currently is possible to implement techniques to reduce them and promote the environment improvement. One of these processes is the treatment of organic waste through the composting process, which is a method that transforms organic matter via aerobic decomposition, to gives a stable product, which adds nutrients to the soil, improving its physical and chemical properties that have been attenuated by agricultural activities.

The present work evaluates the quality of the final composting products (compost and leachates) generated within a prototype composter from organic kitchen waste and organically light components that, supported by a microbial accelerator and mechanical processes, reduce the process time by 600% compared to conventional processes with a similar product quality according to existing quality parameters.

The results show that the organic fertilizer has a humidity of 73% slightly higher than established, does not present a high concentration of toxic heavy metals that are below the permissible limit and a C/N ratio of 6.5 that is adequate to be used as an additive. organic soil improver.

**Key words**: Compost, *smart* compost bin, quality indicators, biochemical parameters.

## Resumo

Um dos desafios que a sociedade atual deve enfrentar tem a ver com a acumulação, gestão, tratamento e eliminação final de resíduos orgânicos e inorgânicos. Portanto, no panorama contemporâneo, é necessária a implementação de técnicas que visem a mitigação deste problema, a fim de promover a melhoria do ambiente ambiental. Em relação ao tratamento de resíduos de origem orgânica, podem ser citadas estratégias como o processo de compostagem, método que promove a transformação da matéria orgânica por meio da decomposição aeróbica, que gera um produto final estabilizado. Este produto, quando integrado ao solo, enriquece suas propriedades físicas e químicas, que podem ter sido diminuídas devido às atividades agrícolas. Posto o exposto, o objetivo deste estudo foi avaliar a qualidade dos produtos resultantes da compostagem (composto e chorume) obtidos dentro de um protótipo de compostor, que é nutrido por resíduos orgânicos provenientes da cozinha, bem como componentes orgânicos leves. Além disso, utiliza adjuvante microbiano e processos mecânicos para reduzir o tempo de compostagem em até 600% em relação aos métodos convencionais, sem comprometer a qualidade do produto final, de acordo com os parâmetros de qualidade vigentes. Concluindo, os resultados mostram que o fertilizante orgânico obtido através deste procedimento apresenta umidade de 73%, um pouco superior ao estipulado, e carece de alta concentração de metais pesados que ultrapasse os limites permitidos. Além disso, confirma-se que a relação C/N atinge um valor de 6,5, o que o torna um aditivo orgânico ideal para melhorar as condições dos solos agrícolas.

# Introduction

Composting is a process that uses microbial degradation to transform organic matter into organic fertilizer (Riera *et al* ., 2014). To do this, it is necessary that the waste of organic origin be combined in such a way that the carbon/nitrogen (C/N) ratio does not exceed 20 units, since in this way a level of humidity can be maintained in the final product that oscillates between 40% and 60%, which ensures adequate oxygenation to support microbial activity. In other words, thanks to the action of the microorganisms present in said waste, a final product known as *humus emerges* , which is made up of fulvic acids, fulvates , humic acids, humates and humins , essential nutrients to enrich and promote soil fertility. (Acosta *et al* ., 2012; Vargas Pineda *et al* ., 2019).

Indeed, compost, as a product resulting from composting, contributes to improving the chemical, physical and biological properties of the soil thanks to its content of organic matter and slow-release fertilizer elements, such as phosphorus, nitrogen, calcium and magnesium, among others. ( Barbarian *et al* ., 2019). This material can replace commercial and organic fertilizers as long as it meets the quality standards required by current legislation (Blasco Hedo, 2013). For this, it is essential that the compost contains proteins, nutrients and minerals, so that when incorporated into the soil, it contributes to reestablishing its physicochemical properties (Nieto, 2002).

This sustainable alternative not only reduces dependence on agrochemicals and reduces exposure to toxic agents, but also prevents erosion and loss of biological activity in soils (Ramírez *et al* ., 2014). However, it should be noted that the nutrients present in compost are not inherently conserved, so it is imperative to exercise adequate control over both the composting process and the final product to guarantee its quality (Bueno Márquez *et al* ., 2008).

For this, the devices currently developed allow a greater degree of supervision and control over the composting process, which leads to a significant improvement in the quality of the compost obtained.

However, research has revealed that the application of immature compost can directly affect the transport of nitrogen in the soil, which can have inhibitory effects on crop growth and the appearance of phytotoxicity.

In addition to the above, it should be noted that humidity constitutes another critical parameter during the composting process. That is, initial values lower than the range of 35-40% can suppress microbial activity, hinder later stages of the process and even compromise it entirely. Furthermore, humidity greater than 65% can interrupt the transport of gases and oxygen, reduce microbial activity and provide the formation of an anaerobic atmosphere, which results in the generation of unpleasant odors and a notable decrease in process performance ( Delgado-Arroyo *et al* ., 2019).

Likewise, it has been found that the use of organic waste with a carbon/nitrogen (C/N) ratio higher than that established can interfere with the transport of nitrogen in the soil when the product is applied and cause competition between microorganisms and crops. for this nutrient, as well as promoting an increase in soil temperature and poor crop development. In other words, the scarcity of available nitrogen in the soil leads to the deposition of low molecular weight organic acids and other phytotoxic metabolites for crops (Acosta *et al* ., 2012).

Now, various parameters have been established to evaluate the quality of the product resulting from composting, which provide information on its physicochemical properties, such as pH, humidity, electrical conductivity, total organic matter, the carbon/nitrogen ratio (C /N) and the concentration of available macro and micronutrients, highlighting among them nitrogen (N), phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K) and sulfur (S). Likewise, other studies focus on the measurement of phytotoxicity, determined through the presence of products such as ammonium, phenols and volatile fatty acids ( Mazzarino *et al* ., 2012).

Furthermore, previous research has indicated the presence of heavy metals and metalloids, such as arsenic and boron, in the final composting product (Oviedo Ocaña *et al* ., 2017). It is even possible to find potentially toxic trace elements in compost, such as persistent organic compounds (POPs) ( Mazzarino *et al* ., 2012).

On the other hand, regarding the quality parameters of the final product, these depend largely on the starting material used in the composting process ( Bécares , 2014). For example, in Germany a classification system has been implemented for organic compost obtained from municipal solid waste, which includes categories such as fresh compost,

finished compost and substrate compost. Each of these categories must comply with the corresponding environmental regulations, which include analysis to detect the presence of pathogens and heavy metals.

However, it should be mentioned that despite advances in evaluating compost quality, there are still limitations in terms of accelerating the composting process. Previous studies have documented long composting times, ranging from 84, 170, and 210 days ( Cariello *et al* ., 2007). These investigations have explored the use of endogenous microbial consortia as a strategy to generate bioaugmentation and reduce the time necessary for the formation and maturation of compost.

Other works, however, have directed their efforts towards the design of equipment for composting organic waste. For example, Pansari *et al* . (2019) developed a prototype that incorporates remote monitoring of temperature, humidity, and methane gas concentration, along with sensors responsible for supervising the aerobic process in composting pile arrangements (Sepúlveda Cisneros *et al* ., 2021).

On the other hand, Wardhany *et al* . (2019) devised a smart composting system that integrates an organic waste crusher in its upper part, activated by sensors. This device is responsible for homogenizing and depositing the waste in a fermentation container while recording parameters such as temperature, humidity and height of the waste inside it.

Likewise, Elalami *et al* . (2019) presented a rotary composting system that uses a system of continuous measurement and adjustment of parameters such as temperature, pH, humidity, and ammonium concentration. The final product met the general specifications, that is, an earthy appearance, absence of unpleasant odors and lack of pathogenic microorganisms. Furthermore, the resulting compost was used as organic fertilizer that replaced commercial agrochemical fertilizers (Gordillo and Chávez , 2010).
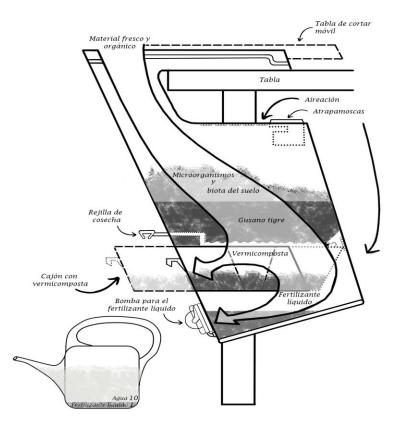
# Materials and methods

## Sample collection

The samples were collected from the device called *smart composter* , which constitutes a microbial digestion bioreactor equipped with an inlet and an outlet. In the initial stage, household organic waste was introduced through the designated entrance. This device is characterized by having a comprehensive collection system for both leachate and compost resulting from the composting process. Likewise, it has two filters designed to retain gases such as carbon dioxide ($CO_2$), nitrogen dioxide ($NO_2$) and methane (figure 1).

**Figure 1. Design of the** *smart* composter prototype



Source: self made

The analyzes were carried out on the solid state compost crops and the leachates obtained from the process. For this purpose, a random and representative sample of each of these products was extracted, which were collected exactly 20 days after being introduced into the reactor, following the instructions specified in the device's user manual. Subsequently, they were stored in sterile bottles and preserved at a temperature no higher than four degrees Celsius in order to ensure their integrity until the time of their subsequent analysis.

## Proximal chemical tests
## Humidity determination

The air oven method with crucibles was used for the drying process of the samples, which were subjected to a constant weight. A uniform amount of sample was added to each to ensure consistency in the analysis.

Thermo brand oven was used. Science Lab Line, which was set to a specific temperature and operated for a certain time. Subsequently, the crucibles were cooled in a desiccator before weighing. It should be noted that each analysis was performed in duplicate.

## Determination of proteins by the Microkjeldahl method

The technique used was based on the principle of proportionality. Initially, the solid samples, previously devoid of moisture, were subjected to a digestion process using potassium sulfate and cupric sulfate as catalysts. Subsequently, concentrated sulfuric acid was added with the purpose of oxidizing the organic matter present in the samples and obtaining ammonium sulfate. In a subsequent stage, the samples were subjected to a distillation process using a Microkjeldahl equipment . To assess the nitrogen present in the samples, sodium hydroxide was added and the methyl red indicator was used as a titration medium.

## Determination of proteins in leachates

The liquid samples were continuously homogenized using a vortex mixer . Then, the same protocol used for solid samples was applied in the process of determining the protein percentage, using the Kjeldahl method.

Subsequently, the samples were subjected to a precalcination process in order to avoid inflammation. Next, they were placed in a muffle for incineration, using an FB1315M Thermo equipment. Science Thermolyne . Once the incineration process was completed, the samples were allowed to cool in a desiccator before being weighed.

### Leachates and settleable solids

The leachate sample was placed in Eppendorf tubes and homogenized by stirring in a vortex mixer . Subsequently, the samples were subjected to centrifugation using a Hermle equipment. Labortechnik Z326K. Then, the supernatant of the samples was removed in order to determine the settleable solids present in the leachates.

### Determination of hydrogen potential

The analysis was carried out exclusively on samples in liquid state (leachate). For this, a pH/ORP HI 2211 instrument from HANNA Instruments was used. Prior to measurement, the samples were homogenized using a vortex equipment .

### Trace metal analysis by ICP-MS

It is crucial to note that certain heavy metals found in sewage sludge are not essential for plant nutrition and can be toxic to humans and animals at specific concentrations. These metals include arsenic, cadmium, lead and mercury.

Thermo brand ICP-MS equipment was used. Scientific , specifically the iCAP Q model, along with *software* Qtegra for data acquisition.

### Gas chromatography coupled to HEADSPACE

The mass coupled chromatography analysis was carried out with the purpose of determining the concentration of carbon dioxide ($CO_2$) and methane, both byproducts of the composting process, as an integral part of the quality control of the *smart* composter.

For this purpose, an Agilent Technologies brand gas chromatograph was used, specifically model 7890, equipped with a 30-meter-long AGILENT HP-MOLOSIEVE capillary column, with an inner diameter of 35 micrometers and a film thickness of 0.25. µm.

The control parameters of the analysis method comprise an initial oven temperature of 50 °C maintained for five minutes, followed by a temperature increase of 5 °C per minute until reaching 100 °C, which temperature was maintained for seven minutes.

The calibration curve was carried out by injecting a volume of 100 microliters into 20 ml Headspace vials through a simple extraction process. Likewise, an FID detector was used with an air flow ratio of 400 ml/min and nitrogen flow rate of 30 ml/min. Helium gas was used as carrier gas with a total flow of 4.97 mL/min.

# Results and discussion

## Proximal chemical tests

## Humidity determination

The determination of the humidity of the compost focused on the collection of samples from two batches of the biological degradation device called *smart composter* . In this regard, it should be noted that the values obtained were averaged to obtain an absolute, as shown in Table 1, where a low variation in the collected data can be seen. This allows reporting 73.33% humidity of the compost harvested from the *smart* composting device.

**Table 1.** Values obtained from the humidity evaluation in three samples of compost harvested from the *smart* composting device. At the bottom is the average percentage of water presence in the product **.**

| Sample | tray weight (g) | tray weightwith sample wet (g) | Weight of tray with sample dry (g) | % humidity |
|--------|------|------|------|------|
| M1 | 1.64 | 3.71 | 2.22 | 72% |
| M2 | 1.63 | 3.69 | 2.17 | 74% |
| M3 | 1.64 | 3.69 | 2.17 | 74% |
| Average | | | | 73% |

Source: self made

## Determination of proteins by the Microkjeldahl method

The protein quantification analysis was carried out on the compost solid matter samples, which covered three different batches for this study. On the other hand, in the case of liquid samples (leachates), the test was only carried out on batch number three.

## Determination of proteins in dry solid samples

The analysis was carried out on solid compost samples collected in three different batches, and the results obtained are presented in table 2. According to the data collected, it is observed that the values of batch number two show a percentage of error less than 0.06%. Based on this information, it is determined that the percentage of nitrogen present in the dry matter is 3.623%.

**Table 2.** Data obtained from the evaluation of percentage of nitrogen and protein, where the batch number and the amount of NaOH spent are observed.

| Batch | Sample | Amount spent NaOH (ml) | % N | %P |
|-------|--------|------------------------|------|-------|
| L1 | White | 5.3 | 3.71 | 23.18 |
| L1 | M1 | 5.4 | 3.78 | 23.62 |
| L1 | M2 | 4.1 | 2.87 | 17.93 |
| L2 | White | 5.3 | 3.71 | 23.18 |
| L2 | M1 | 5.15 | 3.60 | 22.53 |
| L2 | M2 | 5.2 | 3.64 | 22.75 |
| L3 | White | 5.3 | 3.71 | 23.18 |
| L3 | M1 | 4.25 | 2.97 | 18.59 |
| L3 | M2 | 4.45 | 3.11 | 19.46 |

Source: self made

## Determination of proteins in leachates

The determination of the nitrogen and protein levels was carried out exclusively in a specific batch, and its results are detailed in table 3. In this case, it is observed that the nitrogen concentration in the compost sample in solid state is 0.11%, while the amount of protein reaches 0.73%.

**Table 3.** Percentage of nitrogen and protein in leachates harvested from the *smart* composting device; In addition, the amount of NaOH spent in the titration is shown.

| Sample | Amount of NaOH (ml) | % N | %P |
|---|---|---|---|
| B | 5.3 | 3.71 | 23.18 |
| L1 | 4.2 | 0.11 | 0.73 |
| L2 | 4.15 | 0.11 | 0.72 |
| Average | | 0.11 | 0.73 |

Source: self made

## Total ash content

For the evaluation of organic matter, two different batches were used, while the technique used to determine total ash was gravimetry. The results obtained are presented in the attached table 4. Specifically, an average total ash of 39.78% was recorded for batch one and 41.26% for batch two. With this, an average percentage of 40.52% of total ashes was calculated.

**Table 4.** Data obtained from the evaluation of total ashes present in the compost in solid state. The data was evaluated in two different batches (each one has the average obtained)

| | Sample | | Crucible weight (mg) | Crucible weight with sample (mg) | crucible weightwith ashes (mg) | Percentage of ashes (%) | Average (%) |
|---|---|---|---|---|---|---|---|
| lot 1 | M1 | | 27.40 | 27.94 | 27.57 | 47.26 | 39.78 |
| | M2 | | 23.59 | 24.16 | 23.78 | 32.30 | |
| lot 2 | M1 | | 27.40 | 27.90 | 27.61 | 41.24 | 41.26 |
| | M2 | | 26.84 | 27.34 | 27.05 | 41.29 | |

Source: self made

## Leachates and settleable solids

The determination of settleable solids was carried out in a batch containing the compost harvest in liquid state, also known as *leachate* . The analysis was carried out using the weight differentiation method, and its results are detailed in Table 5. According to the data obtained, it is observed that, on average, for each milliliter of leachate, 0.05 mg of settleable solids were recorded.

**Table 5.** Data obtained from the analysis of settleable solids present in leachates harvested from the *smart* composting device

| Sample | eppendorf weight (mg) | eppendorf weightwith sample (mg) | eppendorf weight with sediment (mg) | Residual weight (mg) |
|---|---|---|---|---|
| M1 | 1.03 | 1.93 | 1.09 | 0.05 |
| M2 | 0.99 | 2.00 | 1.06 | 0.06 |
| M3 | 1.03 | 1.98 | 1.08 | 0.05 |
| Average | | | | 0.05 |

Source: self made

## Determination of hydrogen potential (pH)

The pH evaluation was restricted to samples in liquid state, obtained from the leachates collected from the *smart* composting device. The results of this evaluation are presented in table 6.

**Table 6.** pH level of leachate sample from the biological degradation device ( *smart* composter)

| Sample | pH |
|--------|-----|
| M1 | 8.0 |
| M1R1 | 8.1 |
| M1R2 | 8.1 |
| Average | 8.06 |

Source: self made

## Analysis by ICP-MS

The values of the analysis of heavy metals, such as lead, cadmium, arsenic and mercury, are detailed in table 7. These evaluations were carried out on compost samples, which were previously subjected to a digestion process. Additionally, ten compost samples were examined. In this regard, it is worth highlighting that in some of these samples the presence of the aforementioned metals was not detected. The average concentration of lead (Pb) was 0.00084 mg/100 ml, cadmium (Cd) was 0.0002 mg/100 ml, arsenic (As) was 0.0028 mg/100 ml and mercury (Hg) was 0.0004 mg/ml.

**Table 7.** Amount of metals in compost samples harvested from the *smart* composting device

| Sample | Metal mg /100 mL | | | |
|---|---|---|---|---|
| | Pb | CD | Ace | Hg |
| 67 | 0.0000 | 0.0010 | 0.0000 | 0.0000 |
| 68 | 0.0000 | 0.0010 | 0.0002 | 0.0000 |
| 69 | 0.0001 | 0.0000 | 0.0002 | 0.0043 |
| 70 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 71 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 72 | 0.0040 | 0.0003 | 0.0000 | 0.0000 |
| 73 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 74 | 0.0043 | 0.0000 | 0.0027 | 0.0000 |
| 75 | 0.0000 | 0.0000 | 0.0230 | 0.0000 |
| 76 | 0.0000 | 0.0000 | 0.0020 | 0.0000 |
| Average | 0.00084 | 0.0002 | 0.0028 | 0.0004 |

Source: self made

The results obtained reflect that the compost satisfies the regulatory limits established for toxic agents or heavy metals in biosolids, in accordance with the guidelines of the United States Environmental Protection Agency (USEPA, 1996), which establish maximum admissible concentrations for lead ( Pb) of 840 mg/kg, mercury (Hg) of 57 mg/kg, arsenic (As) of 75 mg/kg and cadmium (Cd) of 85 mg/kg ( Mazzarino *et al.* , 2012).

## Gas chromatography by HEADSPACE

The data in table 8 correspond to the evaluation carried out on samples of activated carbon present in the odor traps located both at the top and at the bottom of the biological degradation device ( *smart* composter).

**Table 8.** Presence of gases in activated carbon samples

| Sample | CO2 | Methane |
|---|---|---|
| Coal free granuleshumidity | 0.225 | 0.000 |
| activated carbonbottom of the composter | 0.151 | 0.000 |
| activated carbon top part of composter | 0.102 | 0.065 |

Note: Results are reported in units of parts per million (ppm).

Source: self made

The determination of $CO_2$ and methane was carried out using the HeadSpace method , which involved the analysis of activated carbon samples. This material is responsible for capturing the odors generated during the composting process and is located at the bottom of the device (table 9).

In the case of $CO_2$, a concentration of 0.151 ppm was recorded in the odor trap located at the bottom of the device. Furthermore, no presence of methane was detected in this sample. On the other hand, in the odor trap located at the top of the device, a CO2 concentration of 0.102 ppm and a methane amount of 0.065 ppm were identified.

**Table 9.** Presence of gases in leachate samples

| Sample | CO2 | Methane |
|---|---|---|
| White | 0.098 | 0.431 |
| Leachate 1 | 0.128 | 0.642 |
| Leachate 2 | 0.116 | 0.094 |
| Leachate 3 | 0.137 | 0.091 |
| Average | 0.127 | 0.276 |

Note: Results are reported in units of parts per million (ppm).

Source: self made

Based on the previous data, an increase in the concentration of $CO_2$ can be indicated, since an average of 0.127 ppm is recorded. On the other hand, a methane concentration of 0.276 ppm is determined in leachate samples, which completes the analysis of the gases generated. Finally, the set of parameters evaluated is shown in table 10.

**Table 10.** Final values of the analysis of products and by-products of the biological degradation device ( *smart* composter)

| Parameter | Amount reported |
|---|---|
| Percentage of humidity (%) | 73 |
| Subject organic (%) | 40.5 |
| Carbon organic (%) | 23.6 |
| Nitrogen (%) | 3.6 |
| Relationship C/N | 6.5:1 |
| Pb (ppm) | 0.84 |
| CD (ppm) | 0.2 |
| As (ppm) | 2.8 |
| Hg (ppm) | 0.4 |
| Air (ppm) | 0.045 |
| Methane (ppm) | 0.065 |
| CO2 (ppm) trap superior | 0.102 |
| CO2 (ppm) trap lower | 0.151 |
| Air (ppm) leachates | 0.065 |
| Methane (ppm) leachates | 0.276 |

Source: self made

## Discussion

The data obtained in this work demonstrate that the compost has a moisture content of 73%, which does not agree with what was reported by Delgado Arroyo *et al*. (2019), who point out that this figure should not exceed 60%.

On the other hand, it is demonstrated that the compost complies with the permitted limits of toxic agents or heavy metals in biosolids, in accordance with the rules of the USEPA (1993), where maximum concentrations for lead (Pb) of 840 mg/kg are established. , mercury (Hg) of 57 mg/kg , arsenic (As) of 75 mg/kg, and cadmium (Cd) of 85 mg/kg ( Mazzarino *et al* ., 2012).

Likewise, the carbon-nitrogen ratio (C/N) is within acceptable limits, with a value of 6.5, so that it meets the standards of values less than 20. In addition, the levels of organic matter exceed the lower limit 25%, that is, it adequately meets this quality parameter (Delgado Arroyo *et al* ., 2019).

Regarding the percentage of nitrogen at the end of the process, it is 3.6%, which exceeds the permitted limit of one percent established in RD 506/2013 (Blasco Hedo, 2013). Finally, it is confirmed that the presence of toxic metals does not exceed the permitted limits established by the USEPA (1993) for biosolid products.

## Conclusions

The products resulting from the process carried out using the *smart* composter have been tested and it has been confirmed that they comply with current regulations. Therefore, they can be used as soil improving additives for agricultural or forestry applications. Likewise, it is important to highlight that while traditional treatments usually require composting times of up to 210 days to achieve the adequate quality of the compost, this project has managed to achieve a product of comparable quality in just 20 days of treatment , which has been possible thanks to the application of the microbial super-accelerator .

## Future lines of research

Thanks to the help of a microbial accelerator, the design of the *smart composter* ensures the production of quality compost, comparable to that of commercial products. This development promotes the exploration of new study perspectives related to the longevity of the microbial accelerator and the determination of appropriate doses of accelerator and water per load of residual organic matter. These investigations are essential to maintain constant product quality and, eventually, to consider the commercialization of the *Smart composter* .

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