High School Students for Agricultural Science Research

October 2025 **Volume 14**

ESTACIÓN EXPERIMENTAL DEL ZAIDÍN

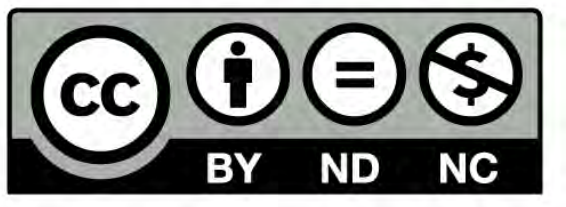
CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

High School Students for Agricultural Science Research

Volume 14 **October 2025**

ISSN: 2340-9746

Published in Granada by Estación Experimental del Zaidín. CSIC



Index

Vermicomposting is socially accepted and technically feasible for managing the bio-waste generated at the Estación Experimental del Zaidín (EEZ-CSIC)

Francisco Amador Ruiz[1], Adriana Caballero González[1], Miracle del Castillo López[1], Héctor Fernández Mérida[1], Hugo Fuentes Góngora[1], Ángela Isabel Galindo García[1], Francisco José González Girela[1], Luna Jiménez Arquelladas[1], Lorena López Rodríguez[1], Alba Moreno López[1], Adriana Benigna Navarro García[1], Iris Tribak Pérez[1], Mar Vázquez[1], Rubén Rodríguez Ramírez[2], Ana Isabel Palma Toro[3], Sara Pérez González[3], Beatriz Gómez-Muñoz[3], Rogelio Nogales Vargas-Machuca[3] and Germán Tortosa[3#]

[1]*I.E.S. Los Neveros, c/ Alhucema, 3, 18198 Huétor Vega, Granada, Spain.*

[2]*Ariadna Estrategia Ambiental SL*

[3]*Estación Experimental del Zaidín (EEZ), CSIC, c/ Profesor Albareda, 1, 18008 Granada, Spain.*

#Corresponding author: german.tortosa@eez.csic.es

Summary

Bio-waste is a valuable source of organic matter and plant nutrients, but biological treatment is required before it can be used as fertiliser. In this study, we investigated vermicomposting with *Eisenia fetida* as a sustainable strategy for managing bio-waste—mainly food and green waste—produced at the Estación Experimental del Zaidín (EEZ-CSIC). Our research combined a questionnaire-based survey with an experimental trial. The survey, completed by 46 EEZ-CSIC staff members, revealed a high level of awareness regarding mandatory bio-waste separation and a generally positive perception of on-site recycling initiatives. Respondents identified multiple benefits for EEZ-CSIC, including contributions to research, scientific outreach, gardening, and environmental sustainability. The vermicomposting experiment evaluated six mixtures of food waste (FW) and green waste (GW), varying in volume ratios and the presence or absence of *E. fetida*. Physicochemical parameters—including pH, electrical conductivity, mass and volume loss, carbon dioxide (CO_2) emissions, and worm survival—were monitored over three months. The 1:5 FW:GW ratio exhibited the highest biological stability and worm viability without requiring preconditioning. These findings support vermicomposting as a viable and socially accepted approach to decentralised bio-waste management. Future research should explore large-scale implementation, socioeconomic dimensions, educational applications, and the energy recovery potential of the process.

Keywords: *Eisenia fetida*, survival test, CO_2 emissions, green waste, food waste, clitellum, juvenile worms, cocoons.

INTRODUCTION

Bio-waste is defined as biodegradable material generated during food processing, food service activities, and the maintenance of green areas such as gardens [1]. It is produced in large quantities across all municipalities, and its management entails significant economic costs for local governments, as well as environmental impacts such as CO_2 emissions from transportation to recycling facilities [2]. One way to mitigate these impacts is through on-site treatment using low-cost technologies such as composting or vermicomposting. These approaches facilitate the transformation and valorisation of biodegradable materials into organic fertilisers and soil amendments rich in organic matter and plant nutrients [3].

Vermicomposting is a biotechnological process that uses specific earthworm species, such as *Eisenia fetida*, to biodegrade and stabilise organic waste under aerobic conditions and moderate temperatures (20–30 °C) [4]. During the process, earthworms ingest, fragment, and digest the organic matter, breaking it down through the action of digestive enzymes and gut microflora [4]. Vermicomposting is a versatile technology that can be implemented at various scales, from pilot to full-scale systems.

The Estación Experimental del Zaidín (EEZ) is one of the largest agricultural science research centers of the Spanish National Research Council (CSIC). Located in Granada, EEZ-CSIC includes over 2,000 m^2 of landscaped grounds—including a botanical garden—and a restaurant that provides daily meal services. In a previous study, the biological performance of composting bio-waste generated at EEZ-CSIC was evaluated with promising results [5]. Building on that work, the present study aims to assess vermicomposting as an environmentally sustainable strategy for managing bio-waste at EEZ-CSIC, as well as to evaluate its social acceptance among the center's staff.

MATERIAL AND METHODS

Social survey

A Google Forms questionnaire was designed to evaluate the social acceptance of vermicomposting among EEZ-CSIC staff, as well as their knowledge of bio-waste management in their municipalities. The questionnaire included six multiple-choice questions:

a) Do you think it is mandatory separate collection of bio-waste in your town?
b) Do you know if there are specific containers available for separate collection of bio-waste in your town?
c) How many kilograms of food waste do you think the restaurant of EEZ-CSIC produces per day?
d) How many containers of green waste do you think the EEZ-CSIC produces per year?
e) In what way do you think bio-waste recycling can benefit to EEZ-CSIC?
f) In what way do you think you could participate in the new bio-waste recycling program of EEZ-CSIC?

The questionnaire was distributed via the main institutional mailing list of EEZ-CSIC in April 2025 and remained open for one week. The form is accessible at the following link: https://forms.gle/NeftD84pStGEis7e7. Responses were analysed using Microsoft Excel 2016.

Vermicomposting experiment and analysis.

Two types of organic waste were used in the vermicomposting experiment: food waste (FW)

from the EEZ-CSIC restaurant and green waste (GW) from pruning activities performed by the Gardening Service (Figure 1). These bio-wastes are representative and abundant within EEZ-CSIC facilities, as previously described [5]. Prior to use, both types of waste were chopped and ground as finely as possible in the laboratory. FW was characterised by high moisture content, whereas GW exhibited the opposite nature [6]. Based on these properties, different FW:GW volume ratios were tested, as described in Table 1.

Table 1. Treatments evaluated in the vermicomposting experiment.
Proportions of food waste (FW) and green waste (GW) are expressed as volume ratios.

Treatments	FW (vol.)	GW (vol.)	Worms added (*E. fetida*)
T1	1	5	No
T2	1	1	No
T3	5	1	No
T4	1	5	Yes
T5	1	1	Yes
T6	5	1	Yes

Vermicomposting was conducted in 5 L PVC plastic containers (Figure 1C), each filled with 500–600 g of the fresh waste mixtures (Table 1). Twenty *E. fetida* worms were added only to the T4, T5, and T6 containers. All containers were incubated at room temperature for three months (January–April 2025). Sampling was performed every three weeks to monitor the following parameters (Figure 2):

- pH and electrical conductivity (EC): Measured using a portable meter (PCE-PHD 1-PH, PCE Instruments™) after 1:10 (w:v) aqueous extraction.
- Moisture content: Determined by weight loss after drying samples at 105 °C for 24 h.
- Temperature: Recorded using a portable temperature probe.
- Mass loss: Calculated by weighing fresh vermicompost using a 5 kg precision balance.
- Volume loss: Estimated by measuring the height of the mixtures in the reactors, assuming constant width and length.
- CO_2 emissions: Measured using a MIRA CO_2/N_2O portable analyser (Aeris Technologies, Inc; https://aerissensors.com/ultimate-precision-for-your-ghgs- measurementsthe-mira-co2-n2o/) available at Dra. Beatriz Gómez-Muñoz laboratory. Containers were sealed before measurement, and CO_2 flux was recorded over 5 minutes until a stable emission rate was reached. Results were expressed as µg C-CO_2 per kg of substrate per second.
- Worm survival test: Conducted to assess *E. fetida* adaptability. Twenty worms were introduced into treatments T4, T5 and T6 and counted after two days. A survival rate above 80% was considered indicative of good adaptation.

Figure 1. An overview of some experimental issues of this study. Green waste (A) and food waste (B) were used as organic wastes. Vermicomposting were done in 5L containers (C) and 20 *E. fetida* worms were added to each vermicomposting container.

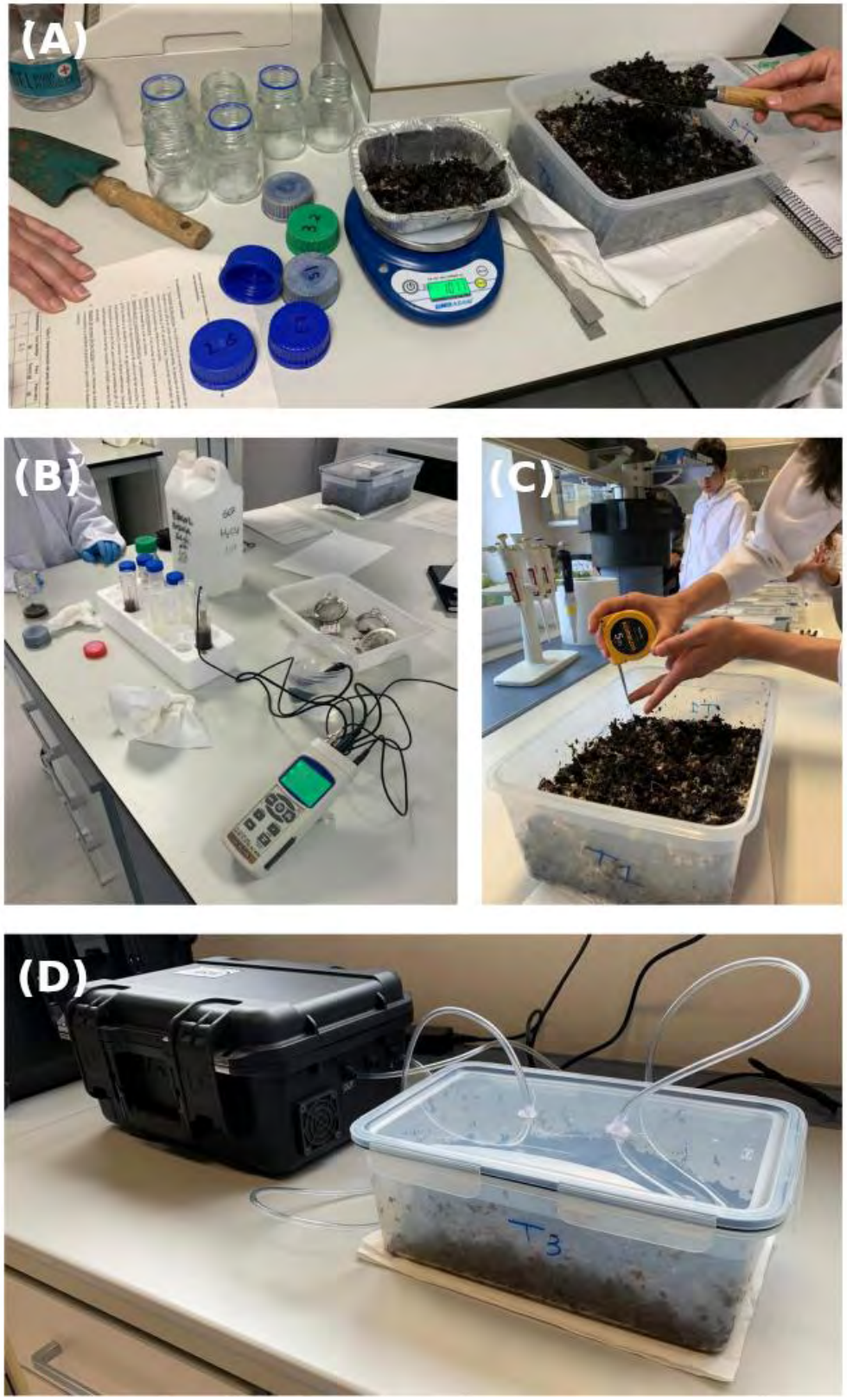


Figure 2. Moisture content determination in vermicomposting mixtures (A), pH and EC measurements after vermicompost water extraction (B), volume estimation of vermicomposting mixtures during the process (C) and the CO_2 emissions determination devise (D).

RESULTS

The online survey was completed by 46 participants, representing approximately 20–25% of the active EEZ-CSIC staff. According to their responses, 81.6% were aware that the separate collection of bio-waste is mandatory in their municipalities (Figure 3A). Additionally, 77.6% of respondents knew about the availability of specific containers for this purpose (Figure 3B). Regarding their perception of bio-waste generation, 28% estimated that the EEZ-CSIC restaurant produces between 6–10 kg or 11–20 kg of food waste (FW) per day, and 32% believed it generates more than 20 kg (Figure 3C). These results indicate an overestimation, as the actual amount of FW produced is approximately 0–5 kg per day, according to restaurant staff (Sara and co-workers). Conversely, an underestimation was observed for green waste (GW) production. According to Manolo (gardener at EEZ-CSIC), the facility produces over 10 containers per year, whereas respondents reported lower estimates: 34% believed that 2–5 containers are produced annually, and 36% estimated 6–10 containers (Figure 3D). In general, EEZ-CSIC staff expressed a positive perception of bio-waste recycling. Respondents identified multiple potential benefits of implementing such a programme at the center, including contributions to research (27%), scientific outreach and education (20%), gardening activities (25%), and environmental sustainability (27%) (Figure 3E). Furthermore, participants indicated interest in contributing to the new bio-waste recycling programme either as collaborators (24%), compost users (34%), or by acquiring knowledge about the process (40%) (Figure 3F).

The vermicomposting experiment revealed notable differences in biological stability during the initial stages of the process. Treatments with higher proportions of food waste (T2, T3, T5, and T6) exhibited a significant increase in pH, reaching values close to 8.5— approximately one unit higher than those observed in T1 and T4—after three weeks of experimentation (Figure 4A). This trend was attributed to the rapid biological degradation of food waste, which also led to increased leachate production and ultimately caused the death of all earthworms in T5 and T6. In contrast, treatments with higher proportions of green waste (T1 and T4) showed only a slight increase in pH over time. Similar trends were observed for electrical conductivity (EC) and CO_2 emissions, which also peaked during the first three weeks in treatments T2, T3, T5, and T6, corresponding to the most intense phase of organic matter degradation (Figures 4B and 4C). Mass and volume losses in the vermicompost mixtures reflected the influence of green waste content. Treatments with a higher GW proportion experienced lower losses. As shown in Table 2, T1 and T4 exhibited the lowest mass losses (44% and 42%, respectively) and volume losses (57% and 65%) compared to treatments with higher FW proportions (T2, T3, T5, and T6).

Results from the survival tests confirmed that T1 and T4 were the most biologically stable treatments at the beginning of the process, and therefore the most suitable for vermicomposting. After three months, the T4 reactor contained 21 adult worms, more than 25 juveniles, and over 500 cocoons (Figure 5). In contrast, T2, T3, T5, and T6 required a preconditioning phase before they could support healthy vermicomposting activity (Figure 6). Supporting this, a survival test conducted at the end of the experiment in T5 and T6 revealed that more than 90% of the 20 *E. fetida* worms initially introduced were still alive.

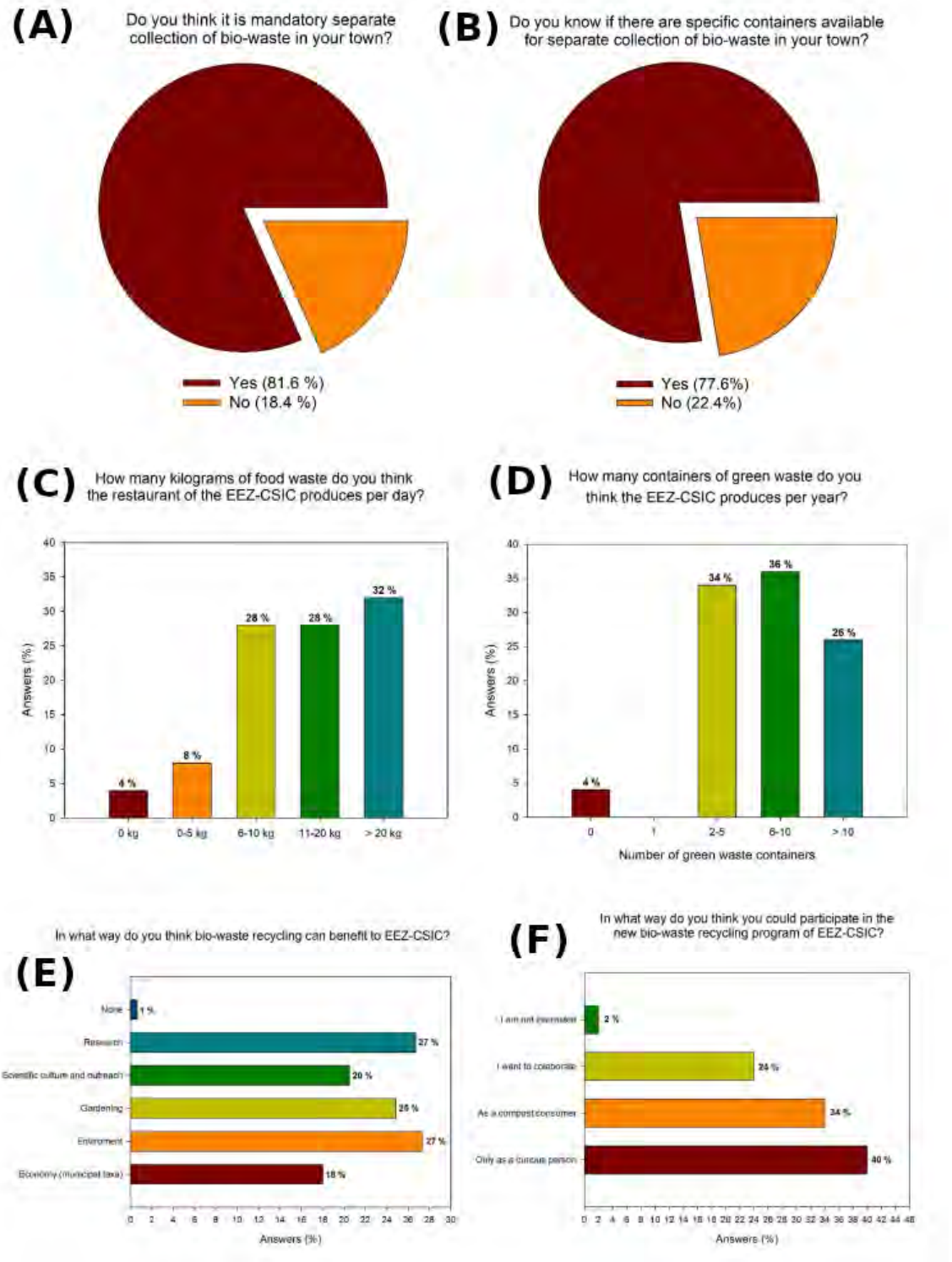


Figure 3. Results of the social survey performed to EEZ-CSIC workers about vermicomposting feasibility at EEZ-CSIC facilities.

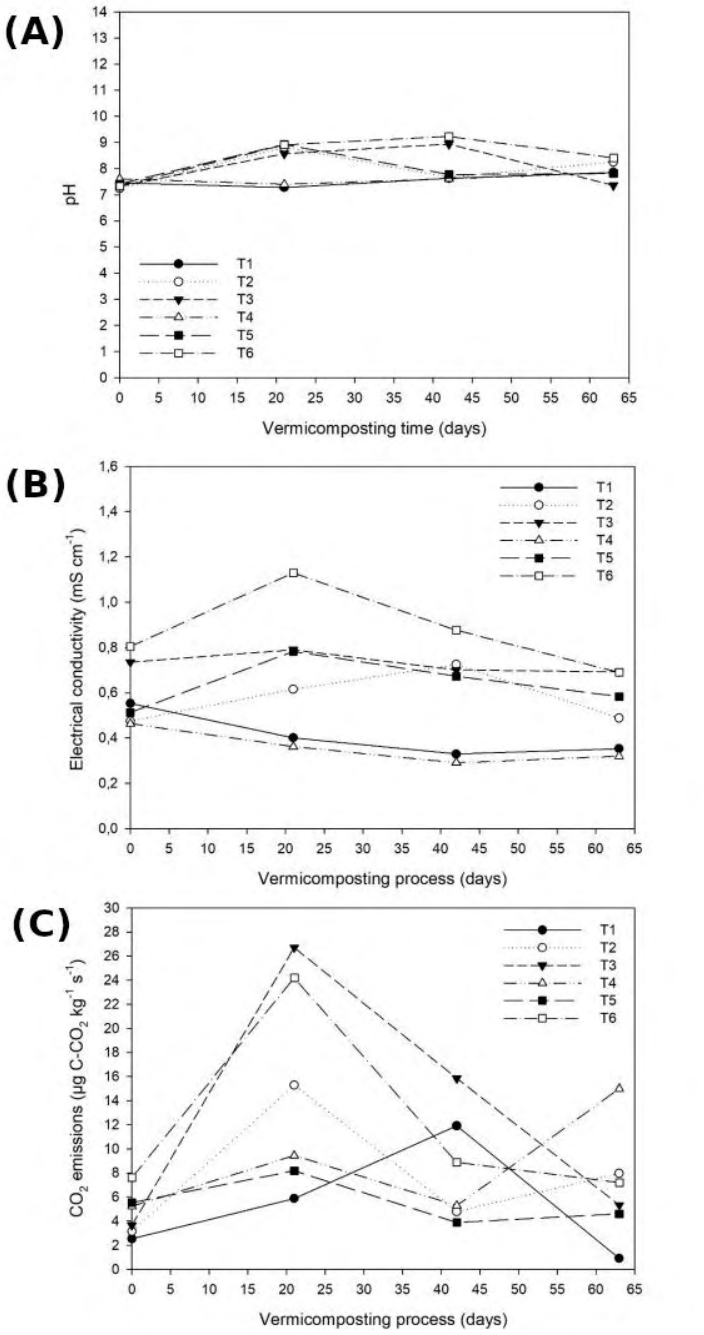


Figure 4. pH (A), electrical conductivity (B) and CO_2 emissions evolution during vermicomposing process.

Table 2. Mass and volume losses (%) of vermicompost mixtures after three months of vermicomposting.

Treatments	Mass losses (%)	Volume losses (%)
T1	44	57
T2	46	68
T3	49	63
T4	42	65
T5	48	71
T6	48	70

DISCUSSION

Bio-waste is a valuable source of organic matter and plant nutrients and is gaining increasing attention from scientists, fertiliser producers, farmers, stakeholders, and local governments, among others [7,8]. The European Fertiliser Products Regulation (EU 2019/1009) recognises bio-waste as a potential raw material for the production of compost and digestate. To meet this regulatory requirement, bio-waste must be collected separately from other waste streams. Recently, the European LIFE project BIO-BEST published a state-of-the-art report on bio-waste management [9]. According to their recommendations, one of the main barriers to implement separate bio-waste collection is the lack of effective communication and education campaigns. These barriers can be overcome through improved public communication, education, and awareness initiatives.

In this study, we conducted a staff survey to assess the level of awareness and concern regarding bio-waste management among EEZ-CSIC employees, both at the workplace and in their municipalities. Our results showed that most respondents demonstrated a strong commitment to their role as citizens in supporting separate bio-waste collection. Moreover, participants expressed a positive perception of vermicomposting, identifying potential benefits for EEZ-CSIC in the areas of scientific research, public outreach, gardening, and environmental sustainability. A number of respondents also expressed interest in participating in the new bio-waste recycling programme as collaborators or compost users.

Our experimental results showed that the most effective vermicomposting recipe was the 1:5 (v/v) ratio of food waste to green waste. This mixture appeared to be well suited for managing the bio-waste generated at EEZ-CSIC, without requiring any preconditioning. It also supported favorable biological development of *E. fetida* worms, with the vermicomposting process being completed in just three months.

Therefore, the main conclusions of this research are:

1. Vermicomposting is positively accepted among the EEZ-CSIC staff community.
2. The most suitable vermicomposting recipe was 1:5 (v/v) FW to GW.
3. The vermicomposting process duration was approximately three months.

Taking all these findings into account, some future researching lines are proposed:

- Expand the sociological study by considering the socioeconomic characteristics of participants.
- Conduct a full-scale experiment to validate the findings under real conditions.
- Explore the potential for applying this approach in other settings, such as schools or municipal facilities.
- Assess the feasibility of integrating energy recovery options within the vermicomposting process.

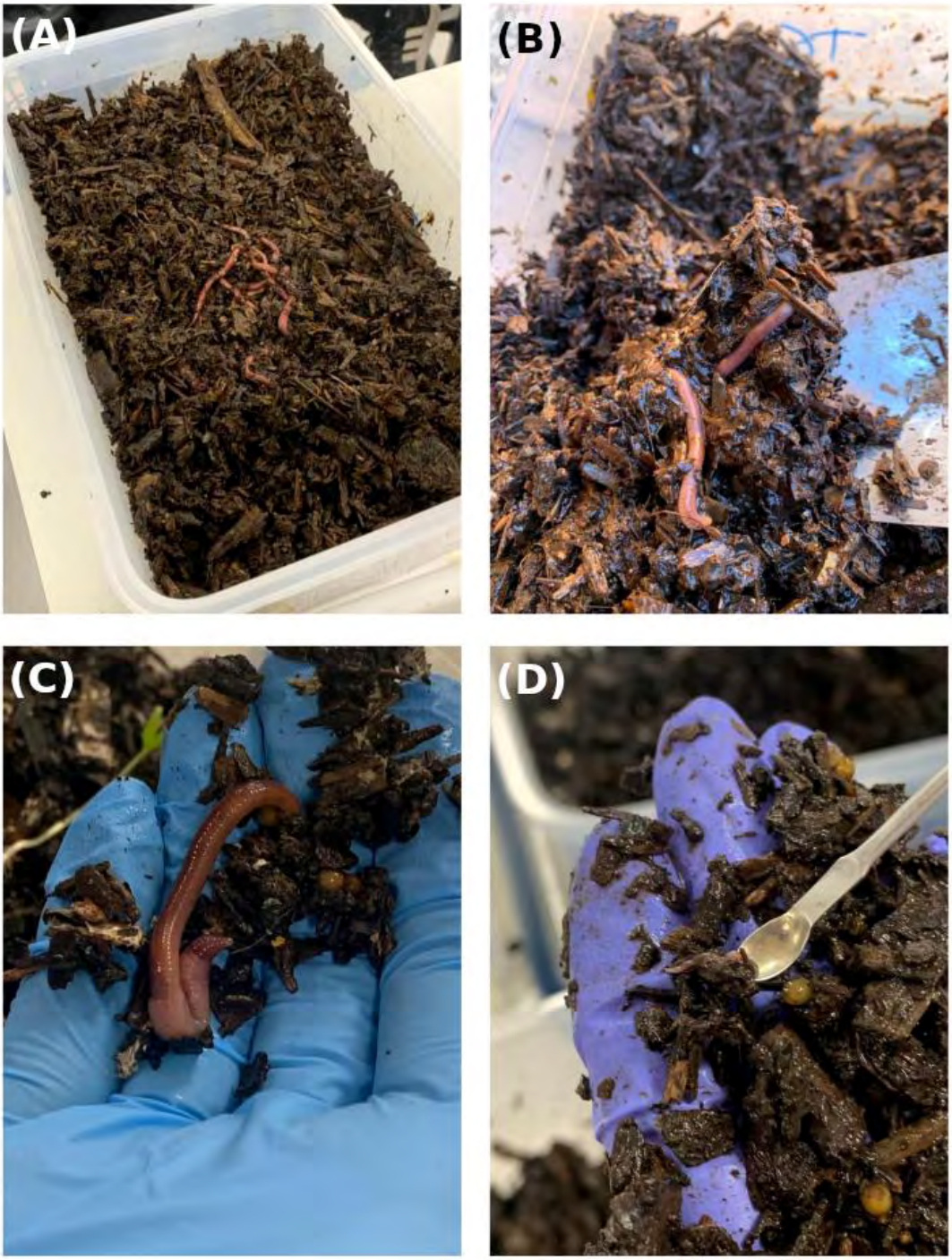


Figure 5. Results of the survival test in T5 and T6 vermicompost recipes (A and B) and the worms' development in T1 (C and D). 20 *E. fetida* worms were added to vermicomposting T2 and T3 mixtures after 3 months of experimentation (A) and their presence were checked after 3 days (B). Some life cycle stages of *E. fetida* worms found in T1 vermicompost: worms with clitellum (C), juvenile worms and cocoons (D).

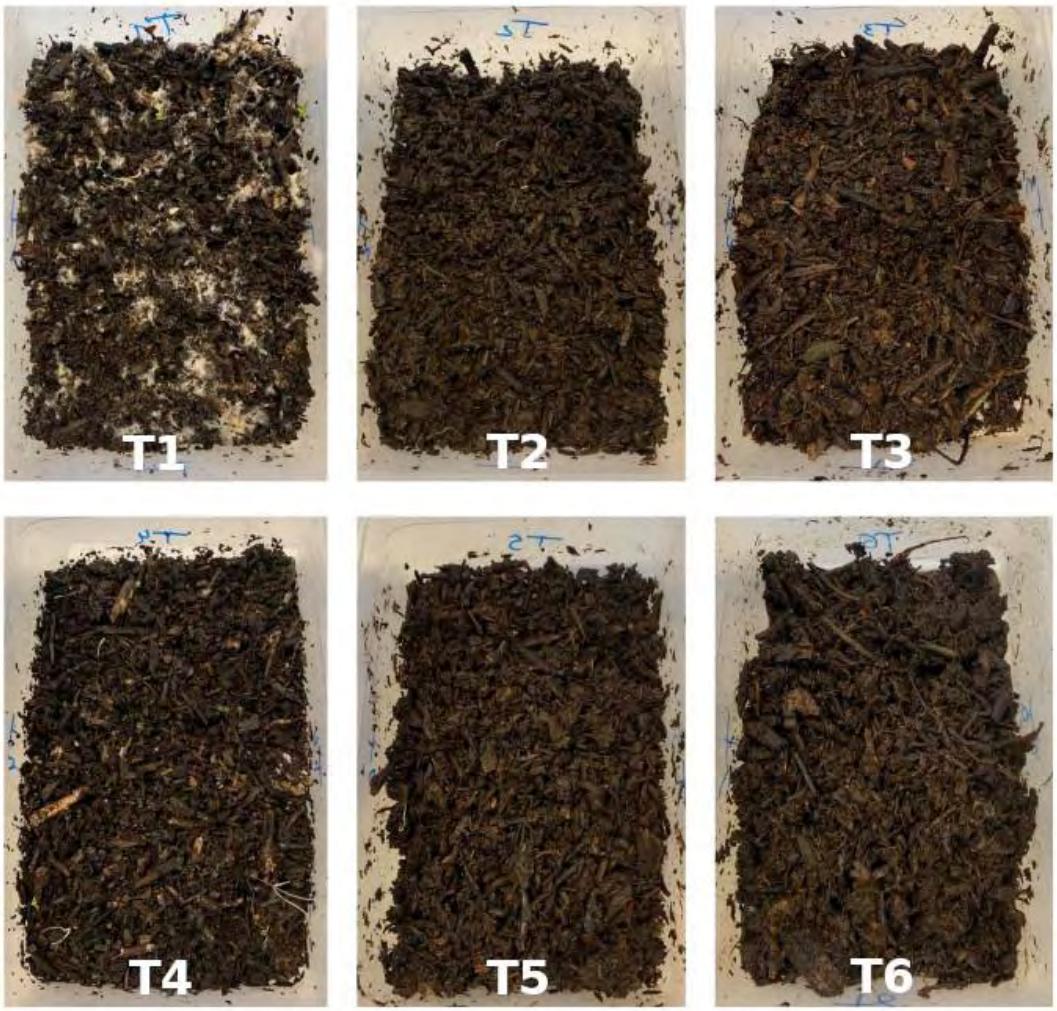


Figure 6. Appereance of the vermicomposts obtained in this study. The recipes of green waste (GW) and food waste (FW) (volume to volume ratio) were: T1 and T4 (5:1), T2 and T4 (1:1), and T3 and T6 (1:5). 20 *E. fetida* worms were added only to T4, T5 and T6 misxtures.

Acknowledgements

Authors want to thank to all EEZ-CSIC workers who have participated in the social survey as well as the restaurant and gardening staff for their interest in the project.

References

[1] Definition of Biodegradable Waste. European Commission. https://ec.europa.eu/environment/waste/compost/index.htm

[2] Brambilla V., Confalonieri A., Krutova I., Lopez E., Giavini M. & Ricci M. (2024). LIFE BIOBEST D3.1 Guidelines on the separate collection of bio-waste.

[3] Díaz-Arco A., Molina-Muñoz M, Navarro-García E., Ortega-Fernández C., Palma-Pérez L., Sarmiento-Vega M.C., Castellano-Hinojosa A., Tortosa G.*, Bedmar E.J. 2016. Biofertilisers with olive-oil taste: isolation of plant growth-promoting rhizobacteria (PGPR) from "alperujo" compost. High School Students for Agricultural Science Research. 5, 42-50. ISSN: 2340-9746.

[4] Nogales, R. 2015. Vermicompostaje: una alternativa para el reciclado/valorización de residuos orgánicos. 5º Seminario sobre Compostaje doméstico y comunitario, Granada. Available at: https://www.compostaenred.org/proyectos/JornadasGranada2015/presentaciones/Nogales.pdf.

[5] Díaz J.M., Moro C., Coletti Y., de la Torre A., de la Torre J., Rolland A., Ledesma D., Bedmar E.J., Tortosa G. 2020. Biological insights of Estación Experimental del Zaidín (EEZ) bio-waste composting. High School Students for Agricultural Science Research, 9, 14-26. ISSN: 2340-9746.

[6] Barros Wilkinson C., Fernández Fernández E., García Romero E., Gómez Álvarez C., Mota Salceanu N., Vallberg Fernández E., Vázquez Vázquez M.M., Rodríguez Ramírez R., Pérez González S., Juárez- Martos R.A., Tortosa G. 2024. Moisture and mixture recipe strongly influence the abundance and biodiversity of invertebrates of bio-waste composting. High School Students for Agricultural Science Research. 13, 77-87. ISSN: 2340-9746.

[7] Robles-López M.J., Carbajal-Ramírez L.F., Martínez-Carrasco S., Motos-Torrente Y., Pérez-Avilés M., Robles-Martínez S., Ruíz-Cifuentes M., Torrente-Sánchez J.A., Carrasco-Blázquez L., Tortosa G. 2021. Liquid organic fertilizers prepared from bio-waste can promote common bean growth and development. High School Students for Agricultural Science Research, 10, 43-50. ISSN: 2340-9746.

[8] Biowaste Generates Organic Matter. Available at: https://www.compostnetwork.info/policy/from- waste/biowaste-generates-organic-matter/

[9] Bio-waste separate collection takes off. 2024. Available at: https://zerowasteeurope.eu/2024/02/bio-waste-separate-collection-takes-off/.

MY OWN IDEAS

Francisco Amador Ruiz

This project has given me the opportunity to explore a specific area within this vast field in greater depth. This is the first submission I am participating in, and I am more than satisfied with the work done. At first, it was quite a challenge. However, with the knowledge gained during the experience, we have been able to overcome the difficulties. I can only thank Maria del Mar Vázquez and Germán Tortosa for the opportunity provided and for being able to participate in the upcoming editions.

Este proyecto me ha brindado la posibilidad de explorar con mayor profundidad un área específica dentro de este extenso campo. Esta es la primera entrega en la que participo, y me he quedado más que satisfecho con el trabajo realizado. Al principio, fue todo un reto. Sin embargo, con los conocimientos adquiridos durante la experiencia nos hemos podido anteponer a las dificultades. Solo me queda dar las gracias a María del Mar Vázquez y a Germán Tortosa por la oportunidad brindada y poder participar en las próximas ediciones.

Adriana Caballero González

CAOS was a very good experience for me because it allowed me to break away from the routine of being in class and see science from a different perspective. I learned new things and saw how interesting projects can be done. At the conference we attended, I really enjoyed seeing other people's diverse work. I found what they do there very interesting, and I also enjoyed working in a lab. It was a different and entertaining way to connect with science. I'm very glad I participated.

Miracle del Castillo López

The project in which I have participated has been interesting, as I have had the opportunity to work with more senior researchers and get closer to science, something that I find fascinating. Although I have a phobia of worms, experience has taught me that I am strong enough to overcome this fear. It has also made me realize the beauty of research and I have fallen even more in love with science. I have to thank my teacher and colleagues who made this experience so fun, with whom I was able to share the trajectory of the experiment. I look forward to participating in another such interesting project.

Héctor Fernández Mérida

I found this project very interesting. At first I didn't know much about vermicomposting, but throughout the project I have learned both about the process and about the importance of recycling and caring for the environment. One of the things that surprised me the most was to see how worms can turn food scraps, such as fruit and vegetable peels, into a nutrient-rich humus. From the beginning I found it very curious, interesting and even fun to work with them. Thanks to this project, I am now more aware of the impact of our waste and how easy it is to reuse it in a natural way. I really enjoyed working as a team and learning so much about something I had never heard of before. Germán has also helped and guided us throughout the project with a smile on his face and encouraged us to experiment. If a project like this were to be repeated, I would definitely come back because I had a great time and I was able to learn how to work in a laboratory.

Hugo Fuentes Góngora

My name is Hugo Fuentes Góngora and this has been my first year on the CAOS project. During this time we have learned and worked on the vermicompost, which is, for what it is used, etc. This project has seemed very useful to me as I would like to work in a laboratory and these lived experiences would be a preparation for such a situation, In addition, we have had good tutors (Germán and Rubén) who have taught us how to work in a lab. It was surprising how well we have adapted to the working environment, I do not know if in other courses it has been similar but in our case it did not involve much difficulty. The truth is that these have been interesting learning sessions and I would be very happy to work in a laboratory like EEZ-CSIC, is certainly an experience that I would recommend to anyone who is familiar with or enjoys biology and working in a team with their classmates, although I must admit that to enjoy this experience is better being with people with whom you have a good relationship because if you do not get along with anyone or you only there are moments where the experience can be a bit dense.

Angela Isabel Galindo García

This experiment has been a new experience for me, as it has allowed me to learn about different areas of biology I wasn't familiar with before, and it has also allowed me to experience what life in a laboratory is like, something I really liked and enjoyed. It has also been a very informative project, and I would definitely do it again. I also found everything we worked on very interesting, as working with vermicomposting allowed us to appreciate things that went unnoticed in our daily lives. I would love to repeat this project with all my classmates; it has been a unique opportunity.

Francisco José González Girela

This year I had the opportunity to participate for the first time in the CAOS Congress, and what this experience taught me, at academicals and personal levels, is something I am proud of and I would like to repeat. Our project focused on vermicomposting with worms and how this natural process can improve soil fertility and make it more productive. As we began, we learned the processes for creating compost and vermicompost and, as we progressed, we learned more about the scientific process and how to follow the steps to develop a hypothesis and confirm it, in this way, we did several tests that would help us prove our hypothesis. This process has taught us not only to work in a more scientific way, collecting data, making hypotheses and drawing conclusions, but also to value the importance of caring for the environment. Thanks to this congress and the development during several months that our research has lasted, I have come closer to the scientific world and I have acquired knowledge and experiences which bring me closer to the development of new sciences. I am very grateful for having been able to be part of this conference and I hope to have the opportunity to repeat this experience in the future.

Luna Jiménez Arquelladas

Ever since we were first approached about the CAOS project, I've always found it very interesting. When we first went, we were nervous about what it would bring, and from that day on, we were counting the days until we could return to the EEZ. We learned so much about bio-waste and vermicomposting and were privileged to receive talks from experts in the field. We really enjoyed presenting our work at the conference and were pleased to see

how much people enjoyed it. I hope to work with CAOS again on another project as interesting as this one.

Lorena López Rodríguez

At first, I didn't know much about vermicomposting, but I thought it was interesting to work with worms to make natural fertilizer. When we started the project, I learned that these worms eat food scraps like fruit and vegetable peels and turn them into a type of soil that's really good for plants. What I liked the most was seeing how the waste slowly turned into something useful. It also helped me become more aware of recycling and how much we can actually do at home to help the environment. At first, I thought it was a little gross, but then I got used to it and even found the worms kind of cool. It was a fun experience and I learned a lot. Now I want to keep doing it at home and maybe show others how it works.

Adriana Navarro García

When I started the vermicomposting project, I didn't have high expectations. I thought it would be something boring and wouldn't work very well. However, as the weeks went by, I was amazed to see how food scraps transformed into compost thanks to the silent work of the worms. I learned not only about the biological process, but also about the responsibility of reducing waste and caring for the environment. This experience has made me appreciate small, sustainable gestures more and has sparked an interest in topics that hadn't previously caught my attention.

Iris Tribak Pérez

Participating in this project on the feasibility of vermicomposting at the EEZ-CSIC has been a very enriching experience both academically and personally. Thanks to the collaboration of our teacher, my colleagues and the researcher Germán Tortosa, I have been able to know closely how vermicomposting works and its potential to reduce biological waste generated in the station. I was surprised to discover how efficient earthworms are in decomposing organic matter and how this process can be transformed into a sustainable and environmentally beneficial method. In addition, the project has been very practical, allowing me to apply my knowledge of biology and chemistry in a real and tangible way. I have learned about waste management, controlling variables such as humidity and temperature, and the importance of maintaining balance in the vermicompost ecosystem. I would certainly recommend participating in such a project to other students, as it develops teamwork and scientific thinking in addition to learning. Personally, I would love to repeat a similar experience.