Loopbin Composter – An EPS@ISEP 2025 Project

Clara Díaz Martín[1], Emile Amant[1], Lianne Tibbe[1], Nathan Audy[1], Qi Xuan Tan[1], Simon Lünswilken[1], Abel J. Duarte[1,2,3], Benedita Malheiro[1,4], Cristina Ribeiro[1,5], Jorge Justo[1], Manuel F. Silva[1,4], Paulo Ferreira[1], and Pedro Guedes[1,4]

[1] ISEP, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 4249-015 Porto, Portugal
[2] REQUIMTE/LAQV, ISEP, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 4249-015 Porto, Portugal
[3] CIETI, ISEP, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 4249-015 Porto, Portugal
[4] INESC TEC, Campus of Faculdade de Engenharia da Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
[5] INEB, Rua Alfredo Allen, 208, 4200-135 Porto, Portugal
epsatisep@gmail.com
https://www.eps2025-wiki3.dee.isep.ipp.pt/

Abstract. The European Project Semester (EPS) at the Instituto Superior de Engenharia do Porto (ISEP) is a challenge-based learning framework in which engineering students from various majors and nationalities collaborate to solve real-world problems. EPS@ISEP projects provide a context for teams to jointly acquire and apply new knowledge and skills during the design, development, and testing of a proof-of-concept prototype. In spring 2025, the LeftLovers team tackled the challenge of creating an accessible, economical, ecological, and odourless kitchen food waste disposal solution for apartment dwellers. LeftLovers aimed to raise awareness of the benefits of composting food waste, educate about composting, convert food waste into compost, and use the compost to grow plants at home. The proposed Loopbin concept consists of a device and an application. The device has four vertically stacked bins: a small garden for direct compost use at the top, two compost bins in the middle, and a compost storage bin at the bottom. The compost bins are equipped with handles to turn the contents and pins to open the trap doors between connected bins. A smart system monitors the composting process, controls automatic ventilation, and communicates with the app, which displays the composting status and provides instructions to produce high-quality compost. This solution stands out for its accessibility, affordability, and inclusion of a vegetable garden.

Keywords: Engineering Education · European Project Semester · Composting · Homecomposting · Foodwaste · Fertilizer · Homegardening.

1 Introduction

The European Project Semester at the Instituto Superior de Engenharia do Porto (EPS@ISEP) is a capstone design programme for third-year engineering students focused on learning through real-world challenges, teamwork, and sustainability [1]. Teams of six international students collaborate to address real-world challenges, culminating in the development of proof-of-concept prototypes.

In spring 2025, the LeftLovers team, with six engineering students from across Europe, chose to address urban food waste. Food waste holds potential as a source of biogas and compost [2] [3]. Yet in many cities, where private gardens are rare, composting remains impractical without municipal support. For example, in Poland, only a third of respondents were initially receptive to composting, and 80 % considered doing so if it reduced waste rates by 15 % [12]. Similarly, a study conducted in Shiraz, Iran, estimated that distributing 10 000 composters could reduce landfill-related CO_2 emissions by 9 %. However, maintaining optimal moisture and temperature in composters poses a significant challenge [6]. To address this challenge, the Loobpin composter was developed as a compact, odourless, and energy-efficient solution for indoor use. The project combines product design with educational support to enable effective urban composting. It aims to make composting accessible, reduce composting time, improve compost quality, raise user awareness, and promote sustainable waste management.

The resulting prototype meets several key requirements: a 100 € budget, open-source software, EU compliance, suitable compost quality, a 4 to 6 week cycle, intuitive design, sustainable materials, and a mobile app for parameter monitoring, with the goal of producing a high-quality fertilizer.

This paper outlines the research (Section 2), proposed solution (Section 3), prototype development (Section 4), and conclusions (Section 5) of the project.

2 Preliminary Studies

Compost bins already exist in different forms and shapes, designed with different advanced materials, innovative aeration systems, and user-friendly features. As global interest in sustainability is increasing, these bins play a more important role in promoting environmentally friendly practices and reducing environmental impact. This section discusses already existing compost bins and projects or research programs related to household food waste composting, and related ethical, marketing, and sustainability issues.

2.1 Related Work

Different smart compost bins were analyzed and compared to have an idea of what already exists on the market, the features they include, and what should be included when designing a new smart compost bin.

Various food waste disposal solutions with different processes are already in place. Drying and heating are two different processes with a different goal. Drying the compost will prevent bad odors and prepare the compost for storage, while heating the compost will accelerate the breakdown of organic materials and kill pathogens and weed seeds. Heat is generated naturally during the composting process, but it can also be supplemented by artificially heating the compost.

FoodCycler Eco 3 [4] recycles food waste in 4 to 9 hours. Due to the drying process, no real compost is produced, but a by-product that can be added to the soil or backyard compost [8]. Different ratios of by-product to soil are recommended depending on the composition of the food waste. The product includes an application for the user to schedule and remotely monitor the composting process through humidity and temperature sensors. FoodCycler is self-cleaning, easy to use, and does not emit methane.

Greenzy food waste bin [5] is a composter that relies on microorganisms. The whole process of composting takes 2 months to complete, during which the user continues to add food waste to the bin. It has a fly trap on the surface to prevent flies. This standalone product does not monitor the process and has no companion application.

Lomi Bloom compost bin [7] uses three different stages to process food waste, taking from 3 to 20 hours. With the heating, grinding, and cooling stages, it mimics the natural composting process. The bin comes with an application for the user to track the food waste footprint and receive notifications, rewards, and tips. Lomi does not monitor the process.

Reencle home composter [10] transforms food waste in 24 hours by creating an optimal environment for the aerobic microbial decomposition of food scraps. It has a three-layered filtering system, with one mesh filter and two carbon filters, to prevent bad odours. Reencle offers a starter package containing activated carbon, wood pellets, glucose, and a trio of patented microbes to ignite the process. This is a standalone solution without process monitoring and a companion application. The company claims to make real compost rather than dehydrated waste.

Soilkind compost bin [11] has two chambers. In the first chamber, the food leftovers are dried and cut into smaller pieces, while in the second chamber, the pieces are broken down with the help of microorganisms. The whole process takes 48 hours. The bin monitors the process with the help of humidity and temperature sensors and produces condensation water and compost, both for plants. Soilkind includes a heat exchanger, so that the heat from composting can be used to dry the food waste in the first chamber, and an app that shares information about compost and plants.

Table 1 compares the main features of the products listed above. Loopbin is inspired by all these products.

2.2 Ethics

The ethical considerations addressed include aspects of engineering, sales and marketing, environmental responsibility, and product liability. Throughout the

Table 1. Comparison of different home composters

	Foodcycler Eco 3	**Greenzy**	**Lomi Bloom**	**Reencle**[1]	**Soilkind**
Price	412 €	899 €	479 €	458 €	1490 €
Process	Drying, Grinding, Cooling	Aerobic Composting	Heating, Grinding, Cooling	Aerobic Composting	Grinding, Drying
Time	4 h to 9 h	2 months	3 h to 20 h	24 h	48 h
Odour Filtering	Carbon	Carbon[2]	Carbon	Carbon, Mesh[3]	Carbon
Noise Level	$\leq$ 36 dB	$\leq$ 42 dB	$\leq$ 60 dB	$\leq$ 28 dB	$\leq$39 dB
Daily Capacity	$\approx$ 1.5 kg	$\approx$ 2.0 kg	$\approx$ 1.3 kg	$\approx$ 1.0 kg	$\approx$ 1.0 kg
Emptying Frequency	2 d	2 months	1 week	1 months to 3 months	1 week
App	Yes	No	Yes	No	Yes
Sensors	Humidity, Temperature	–	–	–	Humidity, Temperature
Extra Features	Smart control[4]	–	–	–	Self-cleaning, Smart control[5]

[1] Includes a compost starter pack with organic additive;
[2] Filter replacement (25 €) recommended every year;
[3] Filter replacement (45 €) recommended every 3 months;
[4] Scheduling and monitoring of the process;
[5] Scheduling, monitoring and control (via ventilation) of the process.

development process, the team adhered to the code of ethics for engineers [9], which emphasizes integrity, honesty, competence, responsibility, impartiality, and confidentiality. In sales and marketing, ethical practices are applied to the four Ps: product, price, place, and promotion to build customer trust, satisfaction, loyalty, and long-term retention. In terms of environmental protection, the team focuses on the use of recyclable and durable polyvinyl chloride (PVC) to minimize environmental impact and avoid single-use materials. Incorporating manual mixing into the design also helps reduce energy dependence. In terms of product liability, safety is a key concern. As the compost bin contains moving parts and sharp blades, the design provides a fully sealed bin. Detailed operating instructions must be included in the user manual to help reduce the risk of accidents. The product also comes with a guarantee and complies with consumer protection legislation and European Union (EU) directives to ensure legal responsibility and maintain user confidence.

2.3 Marketing

The target market for Loopbin consists of urban residents without access to a garden. What sets this product apart from other organic waste bins is the integrated garden on top. This gives the user the opportunity to use the compost they produce directly by growing new herbs or vegetables. Another distinguishing feature is the application, which provides real-time insight into the composting process and notifies the user when action is needed. The product appeals to environmentally conscious consumers with modest income who are looking for practical ways to reduce their food waste. The main goal is to keep the price as affordable as possible while maintaining customer satisfaction and profitability. The Loopbin will be available through a dedicated website. Additionally, retail partnerships with gardening stores can be explored, as these locations attract customers who fit the target market. Promotion will mainly focus on social media platforms, supported by advertisements in places that are frequently visited by the target market, such as garden centers and urban areas.

The name of the team and of the potential company is Leftlovers, a play on the "leftovers" and "lovers" words. The Leftlovers logo in Figure 1 (left) consists solely of the word "LeftLovers", with a capitalized "L" in the center to continue highlighting the word "leftover". The "V" in the logo is represented by cutlery and a heart symbol placed above to represent "Lovers." The name "Loopbin" reflects its circular process – turning organic waste into compost, then using it to grow fresh herbs and vegetables. Figure 1 (centre) shows the designed logo, with the two "o"s, the "i" and "n" connected, symbolizing the continuous cycle of waste transformation. The smaller logo – Figure 1 (right) – features the two connected pairs, creating a loop-like shape.

Fig. 1. LeftLovers and Loopbin brand logos

2.4 Sustainability

The project promotes sustainable development by addressing environmental, economic and social aspects. Composting food waste gives it a second life by nourishing plants, which helps create a greener environment and reduces trips to the supermarket when growing common herbs at home. Designed for small spaces, this compact compost bin has a planting area on top. The main structure of the bin is made of recyclable PVC. The mixing assembly and blades are made of stainless steel, a material that prevents damage during the composting process. Moreover, its power consumption is extremely low (0.23 kWh/month) and does not require additional maintenance, such as changing carbon filters. To achieve these goals and prevent odours, the bin has built-in sensors that optimise composting conditions. The integrated manual mixing function not only saves on electricity costs but also allows the user to participate in the composting process. The companion app supports user engagement by guiding beginners through the composting process step-by-step, encouraging sustainable habits at home, and raising awareness of food waste.

3 Proposed Solution

This chapter discusses the theoretical solution proposed by the team. Both the concept and the design (structural and electronics) are explained.

3.1 Concept

The concept of this compost bin is to divide the bin into three rooms: two for the composting process and one at the bottom to store the ready-to-use compost. Figure 2 illustrates how the process works. The input of the compost bin is compost and green and brown food waste. To accelerate composting, materials are first shredded. The status of the composting process is verified by assessing soil parameters such as temperature and moisture and analyzing the gas composition. These values are displayed to the user via an app, which also provides instructions for further steps, encouraging the user to actively and properly manage the composting process. Since compost turning only needs to be done twice a week, this task is performed manually by the operator. This ensures user involvement in the process and helps reduce costs. In addition, an automated ventilation system ensures proper airflow, creates optimal conditions, and prevents unpleasant odours. This optimized composting process yields high-quality fertilizer, used as the base for the Loopbin's integrated plant box.

With an estimated cost of 400 €, Loopbin process food waste in 4 to 6 weeks, and handles up to 0.350 kg per day. Odour is managed by maintaining a healthy compost mix, monitoring gas emissions and controlling ventilation.

3.2 Design

Structure The Loopbin was developed by combining theoretical knowledge, initial sketches, and an idealised concept. As shown in Figure 3, its casing is divided into segments to facilitate assembly. The composting area is divided into upper and lower chambers: the top contains fixed cutting blades and a manual mixer to shred leftovers, while the bottom, equipped with a second manual mixer, promotes compost aeration. A fixed structure with a hatch, operated by a manual opener, separates the two chambers. The main electronic system is located on the backside, while the sensors are positioned inside the composting chambers. Concerning material selection, after evaluating different options for

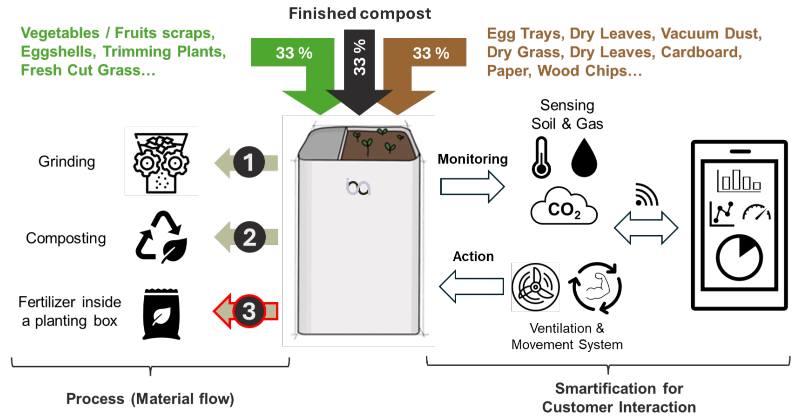


Fig. 2. Loopbin concept

their suitability in composting applications, PVC was chosen as the primary material for the castings. The cutting part and the mixer, which require durability and corrosion resistance, are made of stainless steel.

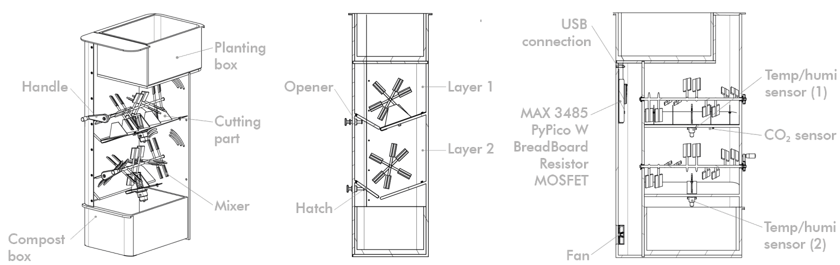


Fig. 3. Loopbin structure

Smart Monitoring Smart monitoring refers to the use of sensors, connected to an app, to monitor the state of the compost. The measured characteristics are the temperature and humidity of the compost, as well as the level of CO_2 in the bin. The various sensors and a fan, to aerate the compost, are connected to an ESP32/Pi Pico W microcontroller board equipped with Wi-Fi.

Web/Mobile Application Wi-Fi connectivity enables real-time data transmission to a server, allowing an app to display sensor readings and offer user tips, such as mixing compost or activating the fan. These actions optimize microbial growth conditions, promoting faster and healthier composting. On the technical side, the microcontroller transmits information in JavaScript Object Notation (JSON) format, over Wi-Fi, to a Linux server. On this server, the back-end processes the values and sends the information to a mobile application developed in JavaScript via ReactNative. The front-end displays the values of the various sensors, using a Web interface.

Packaging To reduce waste, the team designed a packaging solution with a second life. The bin is shipped in a cork box—lightweight, durable, biodegradable, and locally sourced in Portugal—which can be repurposed as a window planter. A cardboard sleeve protects the cork box during transport and can be composted directly in the bin after unpacking, eliminating waste. An instruction manual and additional accessories, such as a hook or rope, help users easily convert the box into a planter.

4 Prototype Development

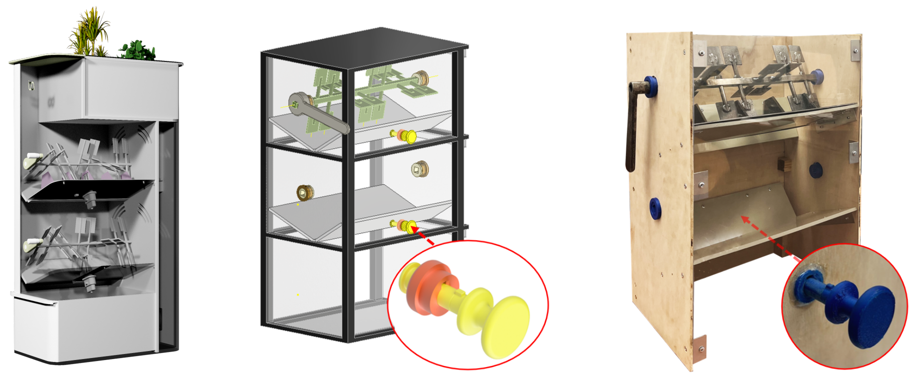
The prototype was developed in three separate areas: structure, smart control, and application. This made it possible for experts from different fields to test the mechanical, electronic and computing functions independently. First, the development of the prototype is described, followed by the test results.

4.1 Assembly

Structure Figure 4 shows the development process of the final prototype. Starting from the final product shown in Figure 4a, a 3D model was created (Figure 4b). The three essential layers of the system are also visible in this model. The main difference is that only a single mixing part was produced, allowing both the shredding and mixing functions to be tested within one unit. The prototype replicates the different layers as closely as possible to the original design and implements the opening mechanism with 3D-printed components. However, since the original plastic containers were not available, a closed wooden structure was built instead (Figure 4c). This alternative construction allowed all functions to be tested effectively.

Smart Monitoring The prototype only uses the humidity sensor. To ensure consistent operation, the other sensors will be simulated. To do this, a random function is integrated into the C++ code. Thus, when the server receives a measurement request, a request is made to the sensor. The other two values are defined randomly. The fan operates slower than expected because, for simplicity, it is powered on 5 V instead of 12 V.

Web/Mobile Application The application was developed in React Native, using Expo (in JavaScript). It includes user management (Sign In/Log In), sensor value display, composting process time tracking, and advice display. In the



(a) Final concept (b) Prototype concept (c) Manufactured prototype

Fig. 4. Loopbin downsizing process

login page, users enter their credentials or access the account creation page. The accounts are stored on the Linux server, with a hash for password security. Once logged in, users are taken to the home page. It features compost status, buttons to access sensor readings, and a message on the bottom banner.

4.2 Tests & Results

Since testing is crucial to identify weaknesses and guide improvements, the team conducted structural, functional, performance, and usability tests. Stress analysis was performed using Autodesk Inventor, while software, electronics, and mechanical components were individually tested for functionality and usability.

Structure Stress analyses were performed on the 3D model of the product to ensure sufficient structural strength. Boundary conditions were defined for the mixer, blades, opening mechanisms of both layers, and the housing structure, representing worst-case scenarios. These were evaluated based on the material properties of each component. The goal was to design all parts so that the resulting stresses remained below the material yield strength. The results summarized in Table 2 confirm that all components possess sufficient structural integrity.

Table 2: Results of the stress and strength analysis

Part	**Material**	**Yield Strength** (MPa)	**Results** (MPa)
Mixer	X5CrNi18-10	225	213.0
Knife	X5CrNi18-10	225	80.0
Handle	PVC	40	22.4
Lid	PVC	40	10.1

...continued

Part	**Material**	**Yield Strength** (MPa)	**Results** (MPa)
Opener	PVC	40	24.2
Housing	PVC	40	11.0

Smart Control Table 3 presents the functional test results of the smart control system, confirming that all components operate as intended.

Table 3: Device: functional results

Use Case	**Result**
Receive sensor information	Pass
Send information in JSON	Pass
Retrieve the state of the "state" variable	Pass
Receive a measurement	Pass
Display in HTML	Pass
Timing	Pass
Measurement button	Pass

Web/Mobile Software Application Table 4 summarizes the functional and performance evaluation of the back-end Application Programming Interface (API). With a latency of less than 400 ms, the system works consistently and stably.

Table 4: API: functional and performance results

Operation	**Method**	**Result**	**Size** (B)	**Latency** (ms)	
				μ	σ
Get data	GET	Pass	264	309	12
State variable	GET	Pass	187	341	15
HTML display	POST	Pass	409	328	13
Trigger	GET	Pass	168	317	14
Sign up	POST	Pass	409	345	17
Log in	POST	Pass	409	318	12

Although not the endpoint with the highest latency, the most frequently used operation – `Get Data` – was tested to ensure reliable performance. As shown in Table 5, a slightly higher standard deviation was observed in low request volumes. However, as the number of requests increased, the standard deviation decreased, indicating stable system behavior under load. Furthermore, the operation with the highest latency – `Sign up` – was also tested as shown in Table 5. Although its latency increased more noticeably, the standard deviation again decreased with larger sample sizes, indicating consistent system behavior.

Table 5: API: load tests for “Get data” and ‘Sign up”

Requests	**Operation**	**Method**	**Results**	**Size** (B)	**Latency** (ms)	
					μ	σ
10	Get data	GET	10	265	100	7
100			100		100	5
1000			1000		102	4
10	Sign up	POST	10	409	345	14
100			100		349	11
1000			1000		355	9

Based on feedback from 10 users, the app received a System Usability Scale score of 85, corresponding to a top score.

5 Conclusion

5.1 Project Outcomes

As a design-based educational project, Loopbin provided a project-based ethics- and sustainability-driven learning experience. The team successfully developed a functional prototype, supported by structural drawings and documentation. A comprehensive analysis of existing products was conducted to support ideation and identify key features. The project achieved its primary goal of reducing food waste by enabling users to compost and garden in limited spaces. In addition, the integrated app allows users to monitor the composting process in real time, helping to establish composting as a sustainable daily habit.

5.2 Personal Outcomes

Working in a multicultural team was a valuable challenge for all members. Throughout the project, the strengths and weaknesses of each team member were identified and considered when distributing the tasks. The project also highlighted the importance of clear and precise communication between team members, improving collaboration and preventing conflicts.

5.3 Future Development

Future development should focus on improving ergonomic design to make handling easier and more user-friendly. A key area for improvement is smarter material selection and use to reduce production waste and enhance environmental sustainability. Incorporating transparent materials into the design would allow users to observe the composting process, particularly in cases where the mixing mechanism becomes blocked. In addition, integrating retractable handles could help reduce the risk of falling or injury near the product. Improvements in the installation layout of electronic components would contribute to a greater ease of assembly and maintenance. Lastly, strengthening the cybersecurity features of the application is essential, including the implementation of data protection measures to prevent potential leaks.

Acknowledgements This work was partially funded by Portuguese national funds through FCT – Fundação para a Ciência e a Tecnologia, I.P., under the support UID/50014/2025 (https://doi.org/10.54499/UID/50014/2025).

References

1. Duarte, A.J., Malheiro, B., Arnó, E., Perat, I., Silva, M.F., Fuentes-Durá, P., Guedes, P., Ferreira, P.: Engineering education for sustainable development: The European Project Semester approach. IEEE Transactions on Education **63**(2), 108–117 (2020). https://doi.org/10.1109/TE.2019.2926944
2. European Compost Network: Treatment of bio-waste in europe (2021), https://www.compostnetwork.info/policy/biowaste-in-europe/treatment-bio-waste-europe/, Accessed: April 2025
3. Food Safety: Food waste (2021), https://food.ec.europa.eu/food-safety/food-waste_en, Accessed: April 2025
4. FoodCycler: Features | FoodCycler (2021), https://foodcycler.com/pages/features, Accessed: April 2025
5. Greenzy: Écologie et élégance | composteur intelligent et sans odeur (2021), https://greenzy.eu/pages/le-composteur, Accessed: April 2025
6. Jalalipour, H., Binaee Haghighi, A., Ferronato, N., Bottausci, S., Bonoli, A., Nelles, M.: Social, economic and environmental benefits of organic waste home composting in iran. Waste management & research : the journal of the International Solid Wastes and Public Cleansing Association, ISWA **43**(1), 97–111 (2025). https://doi.org/10.1177/0734242X241227377
7. Lomi: Kitchen countertop food recycler | lomi (2021), https://lomi.com, Accessed: April 2025
8. Merk, K.: The best kitchen composters (2025), https://www.wired.com/story/home-composters-buying-guide, Accessed: April 2025
9. NSPE: Code of ethics for engineers (2021), https://www.nspe.org/career-growth/nspe-code-ethics-engineers, Accessed: May 2025
10. Reencle: Reencle homepage (2021), https://reencle.co/pages/main-b, Accessed: April 2025
11. Soilkind: Composter from soilkind | fresh compost in 48 hours (2021), https://www.soilkind.com, Accessed: April 2025
12. Sulewski, P., Kais, K., Gołaś, M., Rawa, G., Urbańska, K., Wąs, A.: Home bio-waste composting for the circular economy. Energies **14**(19), 6164 (2021). https://doi.org/10.3390/en14196164