Short Communication

Evaluation of Accelerated Biomass Composting Methodologies

Ľuboš Jurík*[1], Marta Lenartowicz[1], Andrej Válek[1, 2], Elena Aydın[1]
[1]*Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Institute of Landscape Engineering, Slovakia*
[2]*Slovak Water Management Enterprise, Slovakia*

Article Details: Received: 2026-06-24 | Accepted: 2026-06-29 | Available online: 2026-06-30

https://doi.org/10.15414/afz.2026.29.02.240-247

The issue of biological waste management is an increasingly serious challenge in urban and rural areas across Europe. Adapting to evolving European Union legislation, such as the Waste Framework Directive and the Landfill Directive, requires shifting from landfilling towards efficient recycling schemes that support a circular economy. This study aims to design a biowaste recycling methodology suitable for regions with a high share of rural settlements. Through the evaluation of parameters such as carbon-to-nitrogen (C : N) ratio, moisture content, and aeration requirements, we identified that conventional technological systems often fail to adequately handle the high nutrient and moisture levels typical of municipal organic waste. As a methodology, we analyzed advanced composting models, specifically aerated static pile and in-vessel systems, to establish baseline parameters for forced aeration and moisture control. Based on these parameters, the result is a novel proposed processing method involving the optimal mixing of biowaste with carbon-rich bulking agents (specifically immature brown coal and biochar), precise alternating aeration, vacuum moisture extraction, and final sanitization using ozone. The resulting biomass can be pelletized for easy storage and agricultural application. Because ozone acts as a sterilant, this process transforms traditional living compost into a biologically safe, nutrient-dense organic fertilizer. The originality of this approach lies in the synergistic integration of these physical and chemical treatments into a single, scalable system tailored for decentralized regions. By adopting such localized, highly controlled composting systems, municipalities can significantly reduce transport and disposal costs, while converting biowaste into certified, high-quality organic fertilizers.

Keywords: biological wastes, recycling, biomass, compost, organic fertilizer

1 Introduction

The issue of biological waste is an increasingly serious problem in urban areas today. Cities in Europe are obliged to comply with constantly developing legislation of the European Union and meet the demands of their residents. A separate part of the problem involves production areas where biodegradable waste is generated, especially during the production and processing of food and feed.

EU legislation on biodegradable waste (biowaste) is mainly governed by the Waste Framework Directive and the Landfill Directive (Directive (EU) 2018/851). These laws require separate collection, recycling and diversion of organic waste from landfills in order to promote its use, for example in the form of a circular economy (Directive (EU) 2018/851). Today, these schemes also focus on waste composition and the use of resulting properties, such as the content of organic matter, fiber, nitrogen (N), phosphorus (P), or other important elements and substances.

Several factors are important in biowaste processing. First of all, as with any process, price is important. In the case of organic waste, time is also critical. Organic wastes are subject to natural processes such as decomposition and can be a source of adverse effects such as odor, the spread of insects or pathogens. When processing them, quantity is decisive. Hundreds, perhaps thousands of technologies of technological solutions are used, but each technology is suitable for a certain amount

***Corresponding Author:** Ľuboš Jurík, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Institute of Landscape Engineering, Hospodárska 7, 979 76 Nitra, Slovakia
e-mail: lubos.jurik@uniag.sk ORCID: https://orcid.org/0000-0003-4533-5915

of material. While large-scale industrial technologies are designed for massive throughput, they are often unsuitable for Central Europe, where waste generation is distributed across a large number of small, rural sources. Centralizing this waste requires long transport distances, which increases costs and carbon footprints. Furthermore, the environmental impacts of composting practices are heavily influenced by the choice of composting location and the management of raw materials.

In our paper, we will focus primarily on addressing urban waste currently processed through composting, with a focus on food waste management. The final mature compost provides valuable, nutrient-rich organic matter needed by soils. Rules for the management of municipal biowaste streams and their processing are outlined in the European Composting Network guidelines (European Compost Network, 2014) and supported by recent studies on municipal solid waste stabilization (Onwosi et al., 2017).

The fundamental problem with municipal biodegradable waste – such as food scraps, garden waste and municipal green maintenance A fundamental hurdle for many cities is the lack of source separation. Households often mix organic waste with plastics, glass, and other wastes, making the entire batch unprocessable. Furthermore, when organic waste is mixed with general refuse and sent to landfills, it undergoes anaerobic decomposition, resulting in the emission of potent greenhouse gases like methane (Cerda et al., 2018).

High population densities in cities mean there is very little physical space available for massive waste disposal sites, local composting facilities, or large-scale waste treatment plants (Onwosi et al., 2017). In our area, on the contrary, there is a large representation of rural areas, which are small sources of biowaste and most households have their own composting system.

Urban organic waste is highly fermentable, moisture-rich, and loaded with nutrients. However, to create stable compost, it requires careful management of its physical and chemical properties (Waqas et al., 2018). Urban organic waste typically has a low carbon to nitrogen (C:N) ratio. Ideal composting requires a ratio of about 25 : 1 to 30 : 1, whereas food scraps alone are often closer to 15 : 1, which can release foul odors and slow the composting process if not balanced (Guo et al., 2012; Cerda et al., 2018).

They are also problematic to process, because they are very wet, often consisting of 60% to 80% moisture. Too much moisture traps air and forces anaerobic (oxygen-starved) decomposition (Cerda et al., 2018). Because urban waste acts as the "nitrogen-rich" component, it must be mixed with "carbon-rich" bulk materials. A suitable solution is to mix them with wood chips, dry leaves, straw, sawdust or biochar to absorb excess moisture. However, their sources are often unavailable in rural areas (Waqas et al., 2018).

In rural areas, the main share of organic waste is garden waste. Its production varies heavily by season, region, and local climate. Biowaste generation in Slovakia and Czech Republic aligns more closely with general Central European averages, though these countries have actively been modernizing their biological treatment and separate collection facilities to comply with EU mandates (European Environment Agency, 2020). In Poland, roughly 60 kg of green waste is generated per capita, which equates to roughly 5,900 tons per day countrywide (European Environment Agency, 2020).

The generation rate is highly non-uniform. Daily tonnage can peak at up to 5 times or 6 times the baseline during heavy-growth spring and autumn leaf-collection months (April–May and October–November), while dropping significantly during the winter.

Despite extensive research on individual composting parameters, there remains a critical knowledge gap regarding how to efficiently combine these parameters into a decentralized, rapid-processing system for small municipalities. Current large-scale facilities are highly centralized and energy-intensive, making them environmentally and economically unviable for rural networks. Therefore, the primary aim of this study is to design a highly innovative biowaste recycling methodology that allows for localized utilization, thereby eliminating the carbon footprint associated with long-distance transport. The originality of this paper lies in proposing a synergistic engineering workflow – combining lignite/biochar bulking, negative-pressure aeration, and ozone sanitization – to bypass traditional, time-consuming composting phases. By establishing a process that rapidly locks in nutrients and eliminates pathogens, this study provides a timely, scientifically sound blueprint for converting problematic biowaste into a safe, transportable agricultural commodity.

2 Material and Methods

This study utilizes a conceptual design methodology based on evaluating current EU regulatory frameworks and analyzing existing composting parameters. Biowaste is characterized by a high moisture content, large volume, and low specific weight. Therefore, it is necessary to focus on managing these fundamental properties. While there are several technological composting systems with intensive aeration and oxygen supply through forced air, these processes alone do not resolve the primary chemical characteristic of biowaste: its high proportion of nutrients compared to its carbon content. Therefore, the C:N:P ratio must be adjusted prior to composting. For this purpose, it is advantageous to mix biowaste with carbon-rich materials.

In our methodological framework, we propose the utilization of a product derived from immature brown coal (lignite) – such as Carbomat Eco – to serve as an excellent bulking agent (Carbohort, 2020). The integration of carbon-rich additives like biochar and lignite has been proven to enhance microbial growth, optimize air-filled porosity, and limit nutrient leaching during the composting process (Sánchez-Monedero et al., 2018). As a specific regional solution, recent studies confirm that derivatives such as lignite and biochar function exceptionally well both as direct soil additives (Zydlik et al., 2023) and as highly effective co-composting components (Symanowicz & Toczko, 2023). Among other properties, lignite contains a significant amount of trace elements necessary for the processing of organic matter by microorganisms. Furthermore, as a dry material, its addition effectively reduces the initial moisture content of the substrate.

Subsequently, it is necessary to further reduce the moisture content during the process. Aeration is a suitable method for this, but the natural passage of air through the biomass is slow and is heavily influenced by microbial activity, during which both the biomass and the air heat up. The dynamic relationship between moisture content, biological drying, and metabolic heat generation makes controlled ventilation essential (Zhou et al., 2014).

2.1 Aerated Static Pile (ASP) and In-Vessel Systems

Accelerated composting using an aerated static pile (ASP) represents an effective method for stabilizing high-moisture biomass, reducing the need for mechanical turning. The success of this process relies on continuous control of oxygen distribution, temperature regulation, and moisture optimization through the addition of organic materials. In practice, three main design approaches are implemented:

- Uncovered ASP: The most cost-effective solution, though highly susceptible to climatic influences (rain increases moisture, frost cools the surface).
- Covered ASP: Utilizes semi-permeable membranes (e.g., PTFE). The membrane allows water vapor to pass through but retains odors and ammonia (NH_3) while protecting the pile from precipitation. ASP methods with precisely controlled aeration rates have been shown to significantly improve generated compost quality across diverse organic waste categories (Rasapoor et al., 2009).
- In-vessel systems: Composting in tunnels or containers. This system provides 100% control over the process and emissions, reducing the primary stabilization time to less than 7 to 10 days. This method is the closest to our proposed solution and allows continuous control over the biological processes during the transformation of organic matter.

2.2 Aeration Parameters

Accelerated composting with forced aeration successfully transforms high-moisture biomass into stable compost, shortening the active phase time by 50–70% compared to passive windrows (Gao et al., 2010). The success of the system depends directly on maintaining matrix porosity (> 40%), ensuring a continuous oxygen supply (> 10%), and achieving precise temperature management (55–65 °C) to evaporate excess water without suppressing biological activity (m^3/h) (Zhou et al., 2014).

In the context of accelerated composting of high-moisture biomass (e.g., municipal and garden biowaste, manure), the correct dimensioning of airflow is critical. Air serves three main functions: providing oxygen for aerobic microorganisms, removing excess moisture, and regulating temperature to prevent the system from overheating above 65 °C, which would kill beneficial bacteria.

Recent studies emphasize that optimal aeration rates, combined with proper moisture content and C : N ratios, are the primary factors influencing compost maturity and reducing harmful gaseous emissions (Tang et al., 2023).

Furthermore, managing the airflow direction and utilizing on/off controls (pulsed aeration) significantly optimizes the composting process inside closed vessels by preventing air channeling and ensuring even oxygen distribution (Lai et al., 2024). For high-moisture biomass, the optimal specific aeration rate typically ranges between 0.05 and 0.30 m^3/min/m^3 of composted material (or 0.5 to 2.0 m^3/h/kg dry matter) depending on the process phase and management strategy (Jolanun et al., 2008).

For high-moisture biomass with an odor risk, an alternating (pulsed) mode is often used alongside thorough condensate drainage from the air piping system into the substrate.

For specific calculations, the following parameters must be determined: input moisture and tonnage of the processed biomass; the type of bulking agent available; whether the system will be open (ASP) or closed (in-vessel); and the intended subsequent use of the processed biomaterial.

In our design, garden waste is primarily composed of biodegradable plant-derived materials. Its characteristics are evaluated primarily from a processing (composting) perspective (Cerda et al., 2018). Basic physical and chemical properties include:

- Moisture: Ranges widely (often 40–80%) depending on the material type (e.g., freshly cut grass vs. dry branches) (Waqas et al., 2018).
- Structure and porosity: Determines oxygen access. Wood waste and branches provide aeration (coarse structure), while leaves and grass tend to clump and form impermeable layers (Onwosi et al., 2017).
- Density (bulk density): Depends on the degree of decomposition and compaction. Fresh material is relatively bulky with a low specific weight.
- C : N ratio: A crucial parameter for the successful transformation of organic matter. Green waste (grass) has a low nutrient ratio, decomposes rapidly, and releases N. Brown waste (dry leaves, branches) has a high carbon content, which prolongs decomposition. An ideal composting process requires a balanced C : N ratio of approximately 25 : 1 to 30 : 1 (Cerda et al., 2018). If there is an excess of N, a C source must be added to the biomass.
- pH value: Fluctuates depending on the decomposition phase. It drops slightly at the beginning of decomposition (formation of organic acids) and stabilizes at 6.5 to 8.5 during the maturation process. Composted biowaste is therefore an excellent source for regulating soil pH for plants that require neutral to slightly alkaline soils (Waqas et al., 2018).
- Nutrient content: Biowaste is a rich source of macronutrients (N, P, potassium (K)) and trace elements necessary for humus formation (Figure 1).

In the proposed conceptual framework, the optimal mixture composition requires blending biowaste with 10–20% (by weight) of immature brown coal (lignite) or biochar as a bulking agent. This addition immediately improves the C:N ratio and reduces the initial moisture content to the optimal range of 55–65%. The primary active phase in in-vessel systems takes approximately 7 to 14 days, supported by alternating negative-pressure aeration. The proposed specific aeration intensity is maintained between 0.05 and 0.30 $m^3/min/m^3$ of composted material, which ensures optimal oxygen distribution, temperature regulation, and simultaneous moisture extraction via vacuum pumps (Lai et al., 2024).

3 Results and Discussion

As a result of the evaluated parameters, a new methodology tailored to regional legislative and physical requirements is proposed. The scientific value of this proposed framework is twofold. First, it addresses the biochemical limitations of highly fermentable municipal waste by physically stabilizing the rapid N release using regionally available immature coal (lignite). Second,

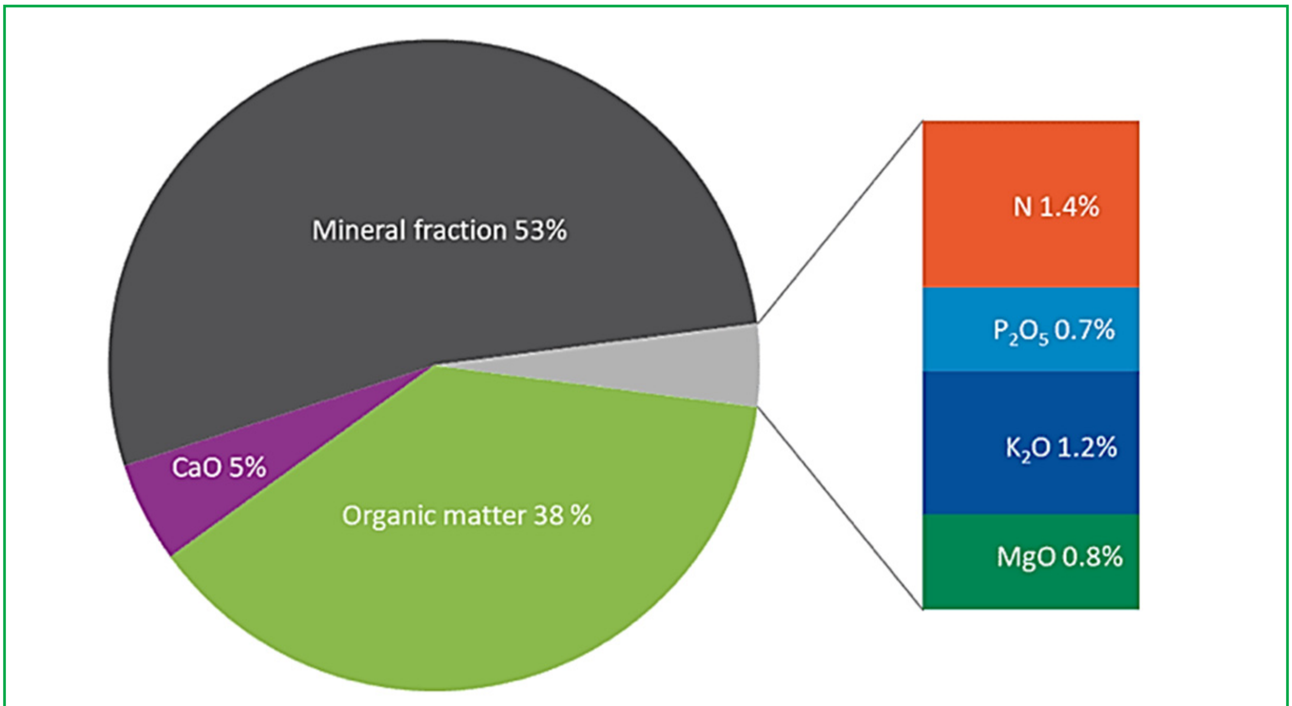

Figure 1 Typical composition of compost (%dry matter)
Source: European Compost Network, 2014

it introduces a novel engineering approach where vacuum extraction and ozone application replace the lengthy, natural maturation and hygienization phases of traditional composting.

In practice, the subsequent use of compost is also highly important. Small municipalities attempt to meet EU requirements by processing local biomass. However, the subsequent utilization of processed biomass remains a challenge. Most frequently, it is collected free of charge by residents or transported to facilities for energetic use as fuel. EU documentation primarily aims to create conditions for direct application to agricultural land, provided that qualitative criteria are met.

Beforehand, however, it is necessary to prepare the technological process of biomass treatment so that the resulting product is suitable for use.

In the following tables (Table 1–3), current EU and Slovak requirements for individual resulting biomass products are discussed. Since universal pan-European End-of-Waste (EoW) regulations do not yet apply to all biodegradable municipal waste (BMW), individual member states have their own national conditions and limit values. These determine when compost or digestate becomes a fertilizer/substrate. In Slovakia, this issue is governed by decrees of the Ministry of the Environment of the Slovak Republic and other legislative regulations:

- Act No. 79/2015 Coll. on waste as amended, and Slovak technical standard (STS) 465735 Industry composts.
- Act No. 136/2000 Coll. on fertilizers.
- Act No. 56/2018 Coll. on conformity assessment of products made available on the market.

After biowaste has gone through a recovering process it is considered compost, but such a product cannot be marketed unless it is certified by an authorized person according to Act No. 56/2018 Coll. Key criteria for the biomass status include:

- Quality parameter for final compost – STS 46 57 35.
- Process parameter (sanitization) – STS 46 57 36.
- Quality approval by acknowledged laboratory or quality assurance organization – Act No. 56/2018 Coll.

Based on the provided data and existing technologies, we propose a new method for processing biowaste and similar organic materials using strong compressed air support to facilitate biological composting processes (Figure 2).

The biomass processing procedure is based on creating an optimal mixture. This mixture must ensure a suitable nutrient-to-carbon ratio, an adequate supply of microorganisms at the inlet, and optimal moisture.

The mixture prepared in this way is introduced into the facility, where it gradually moves through a space with an alternating air supply. Simultaneously, excess air, along with the heat generated from the transformation process, is removed using vacuum pumps. The implementation of negative pressure aeration (vacuum extraction)

Table 1 Permissible values for biomass hygienization

Indicator	Sewage sludge (Act No. 188/2003 Coll.)		Fuels from waste (Decree No. 251/2023 Coll.)		Organic fertilizers with waste (Decree No. 577/2005 Coll.)	
Thermotolerant coliform bacteria	CFU/g DM	≤ 2.10^6			number of pcs/g or pcs/ml	≤ 10
Fecal streptococci	CFU/g DM	≤ 2.10^6			number of pcs/g or pcs/ml	≤ 10
Salmonella					number in 2 × 10 g or 2 × 10 ml	negative
Human intestinal parasites					number in 100 g or 100 ml	negative

CFU/g DM – colony-forming unit per gram of dry matter

Table 2 Minimum nutrient content of biomass

Indicator	Sewage sludge (Act No. 188/2003 Coll.)		Organic fertilizers with waste (Decree No. 577/2005 Coll.)	
($P_{total.}$) phosphorus			% in DM	≥ 0.5
($N_{total.}$) nitrogen			% in DM	≥ 1.0
(K) potassium			% in DM	≥ 0.5
(Ca) calcium			% in DM	≥ 1.0
(Mg) magnesium			% in DM	≥ 0.5

DM – dry matter

Table 3 Maximum permissible content of risk elements in the basic separate

Element	Sewage sludge (Act No. 188/2003 Coll.)		Fuels from waste (Decree No. 251/2023 Coll.)		Organic fertilizers with waste (Decree No. 577/2005 Coll.)	
(As) arsenic	mg/kg DM	≤ 20	mg/MJ median	< 0.80	mg/kg	≤ 10
(Cd) cadmium	mg/kg DM	≤ 10	mg/MJ median	< 0.05	mg/kg	≤ 2
(Cr) chromium	mg/kg DM	≤ 1,000	mg/MJ median	< 1.40	mg/kg	≤ 100
(Cu) copper	mg/kg DM	≤ 1,000	mg/MJ median		mg/kg	≤ 200
(Hg) mercury	mg/kg DM	≤ 10	mg/MJ median	< 0.02	mg/kg	≤ 1
(Ni) nickel	mg/kg DM	≤ 300	mg/MJ median	< 1.60	mg/kg	≤ 50
(Pb) lead	mg/kg DM	≤ 750	mg/MJ median	< 4.00	mg/kg	≤ 100
(Zn) zinc	mg/kg DM	≤ 2,500	mg/MJ median	< 1.50	mg/kg	≤ 400
(Se) selenium					mg/kg	≤ 5
(Cl) chlorine			mg/MJ median	< 100.00		
(S) sulfur			g/MJ median	< 0.35		
(B) boron			mg/MJ median	< 10.00		
(Si) silica			mg/MJ median	< 15.00		
(Sb) antimony			mg/MJ median	< 0.50		
(Co) cobalt			mg/MJ median	< 0.70		

mg/MJ median – milligrams of the element per megajoule of energy produced (median value); DM – dry matter

is a proven strategy not only for rapid moisture removal but also for significantly mitigating ammonia emissions and global warming potential during the active phase (Wang et al., 2018). This procedure can be repeated several times to achieve a significant volume reduction and sufficient transformation of the input organic matter by microorganisms. Re-mixing before each subsequent air application is crucial.

Finally, the almost-finished compost, deprived of moisture, is moved to a device where ozone is added for the hygienic stabilization of the generated mass. Traditional compost is defined as a stabilized, mature biological matrix characterized by an active, beneficial microbial community. However, the application of ozone (e.g., at gaseous doses of 0.5 to 2.0 mg/L) fundamentally alters this biological profile. Ozone acts as a powerful oxidant and sterilant, effectively eradicating both pathogenic organisms (e.g., *Salmonella*, fecal streptococci) and the active decomposing microbiota (Dastpak et al., 2020). Consequently, after ozonation, the material no longer meets the biological definition of "living" compost. Instead, it transitions into a stabilized, safe, and nutrient-dense "processed biomass" or "organic fertilizer". The initial agronomic value of this sterilized

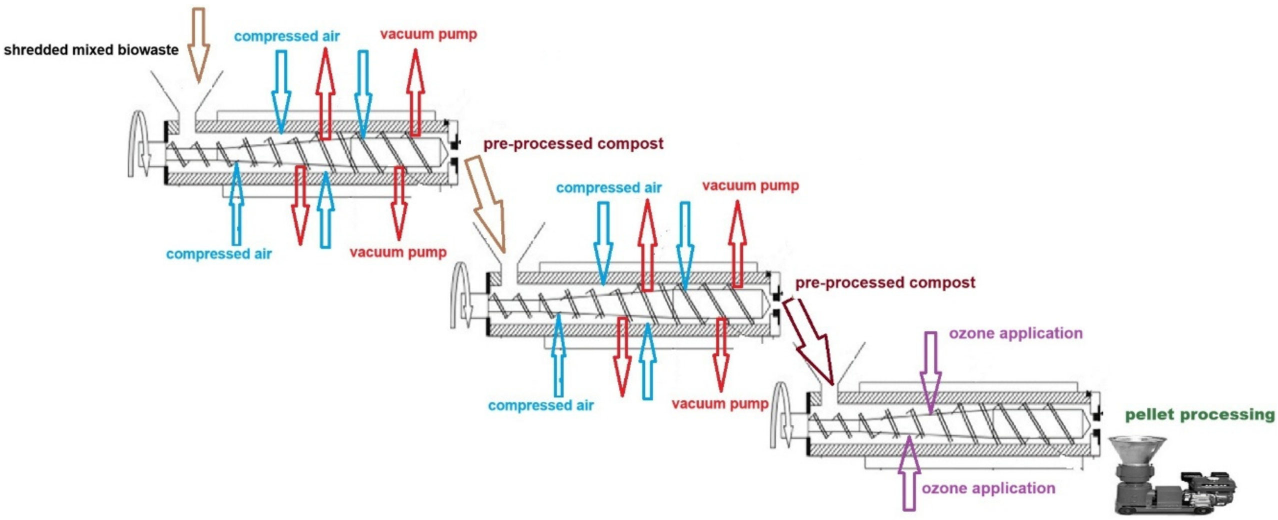

Figure 2 Basic structure of processing compost into pellets with strong aeration – proposed technological scheme
Source: Ľuboš Jurík – own elaboration

product lies in its high physical stability, standardized nutrient content, and absolute biological safety, completely mitigating the risk of pathogen re-growth during storage, pelletization, or field application (Szostek et al., 2022). Furthermore, when this final co-composted organic fertilizer is combined with lignite or biochar bases, it has been shown to offer superior crop growth and long-term soil aggregate stability upon application in the field (Cooper et al., 2020).

Subsequently, this final biomass is processed into pellets to allow for long-term storage and to facilitate easy application on agricultural land or municipal green spaces.

4 Conclusions

The issue of composting organic waste in municipalities, as well as from vegetable processing or other agricultural and industrial production, is becoming increasingly relevant. Over the last three years, the EU has introduced significant legislative changes regarding the use of biofertilizers from recycled sources, including in vulnerable areas. It is necessary to prepare conditions in national legislation and ensure the interest of end consumers in their utilization. Therefore, certification of such products is required to ensure they do not endanger human health, cultivated crops, or the environment.

The solution proposed in this study, designed on the basis of small-scale verifications, directly addresses these needs. Its primary innovativeness lies in overcoming the limitations of classical composting methods, which typically struggle with processing materials that are rich in nutrients but severely deficient in carbon. This carbon deficit traditionally leads to a slowed composting process and poor transformation of biological material. However, the recent market availability of low-cost, natural products with high carbon and trace element contents (such as lignite-based additives) fundamentally changes the dynamics of biomass processing, ensuring a significantly higher quality of the final product.

Furthermore, this methodology introduces a highly optimized engineering approach. Utilizing a closed composting space with continuous mixing and a regulated air supply – where excess air and generated metabolic heat are continuously extracted – optimizes the environment for microbial decomposition and significantly shortens the overall composting time. While traditional composting relies heavily on peak self-generated heat for hygienic stabilization, our methodology achieves optimal biological transformation at lower temperatures and subsequently guarantees strict sanitization by treating the final product with ozone.

This technology is highly flexible and scalable. It is perfectly suited for small sources of organic matter, such as rural municipalities, but can be scaled up to accommodate larger sources like agricultural and food production facilities, or even urban centers. Ultimately, this approach offers a paradigm shift from passive waste disposal to active, decentralized resource recovery. It provides policymakers, engineers, and local governments with a scientifically validated, affordable pathway to convert problematic local biowaste into transportable, legally compliant, and sterile organic fertilizer pellets.

Acknowledgments

This research was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I01-03-V04-00075/2025/VA.

Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

Ľuboš Jurík: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing – original draft. Marta Lenartowicz: Investigation, Data curation, Writing – Review & Editing, Validation. Andrej Válek: Data curation, Validation, Writing – Review & Editing. Elena Aydın: Data curation, Investigation, Methodology, Formal analysis, Writing – Review & Editing.

AI and AI-assisted technologies use declaration

The following AI tools-AI-assisted technologies were used during the preparation of the manuscript: Google Gemini [AI tool used for language refinement and formatting alignment with journal guidelines]. The authors take full responsibility for the content of the article.

References

Carbohort. (2020). *Innovative carbon products.* Retrieved March 15, 2026, from http://carbohort.com/en/home-en/

Cerda, A., Artola, A., Font, X., Barrena, R., Gea, T., & Sánchez, A. (2018). Composting of food wastes: Status and challenges. *Bioresource Technology*, 248, 57–67. https://doi.org/10.1016/j.biortech.2017.06.133

Cooper, J., Greenberg, I., Ludwig, B., Hippich, L., Fischer, D., Glaser, B., & Kaiser, M. (2020). Effect of biochar and compost on soil properties and organic matter in aggregate size fractions under field conditions. *Agriculture, Ecosystems & Environment,* 295, 106882. https://doi.org/10.1016/j.agee.2020.106882

Dastpak, H., Pasalari, H., Jafari, A.J., Gholami, M., & Farzadkia, M. (2020). Improvement of co-composting by a combined pretreatment ozonation/ultrasonic process in stabilization of raw activated sludge. *Scientific Reports*, 10, 1070. https://doi.org/10.1038/s41598-020-58054-y

Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste. (2018). *Official Journal of the European Union*, L 150, 109–140. https://eur-lex.europa.eu/eli/dir/2018/851/oj

European Compost Network. (2014). *Summary. ECN Quality Manual – Quality Assurance for Compost and Digestate.* European Compost Network. https://www.compostnetwork.info/wordpress/wp-content/uploads/141015_ECN-QAS-Manual_2nd-edition_final_summary.pdf

European Environment Agency. (2020). *Bio-waste in Europe – turning challenges into opportunities.* EEA Report No 04/2020. https://www.eea.europa.eu/en/analysis/publications/bio-waste-in-europe

Gao, M. C., Li, B., Yu, A., Liang, F. Y., Yang, L. J., & Sun, Y. X. (2010). The effect of aeration rate on forced-aeration composting of chicken manure and sawdust. *Bioresource Technology,* 101(6), 1899–1903. https://doi.org/10.1016/j.biortech.2009.10.027

Jolanun, B., Towprayoon, S., & Chiemchaisri, C. (2008). Aeration improvement in fed batch composting of vegetable and fruit wastes. *Environmental Progress*, 27(2), 250–256. https://doi.org/10.1002/ep.10259

Lai, J. C., Then, Y. L., San Hwang, S., & Lee, C. S. (2024). Optimal aeration management strategy for a small-scale food waste composting. *Carbon Resources Conversion*, 7(1), 100190. https://doi.org/10.1016/j.crcon.2023.06.002

Onwosi, C. O., Igbokwe, V. C., Odimba, J. N., Eke, I. E., Nwankwoala, M. O., Iroh, I. N., & Ezeogu, L. I. (2017). Composting technology in waste stabilization: On the methods, challenges and future prospects. *Journal of Environmental Management*, 190, 140–157. https://doi.org/10.1016/j.jenvman.2016.12.051

Rasapoor, M., Nasrabadi, T., Kamali, M., & Hoveidi, H. (2009). The effects of aeration rate on generated compost quality, using aerated static pile method. *Waste Management*, 29(2), 570–573. https://doi.org/10.1016/j.wasman.2008.04.012

Sánchez-Monedero, M. A., Cayuela, M. L., Roig, A., Jindo, K., Mondini, C., & Bolan, N. (2018). Role of biochar as an additive in organic waste composting. *Bioresource Technology*, 247, 1155–1164. https://doi.org/10.1016/j.biortech.2017.09.193

Szostek, M., Kosowski, P., Szpunar-Krok, E., Jańczak-Pieniążek, M., Matłok, N., Skrobacz, K., Pieniążek, R., & Balawejder, M. (2022). The usefulness of ozone-stabilized municipal sewage sludge for fertilization of maize (*Zea mays* L.). *Agriculture*, 12(3), 387. https://doi.org/10.3390/agriculture12030387

Symanowicz, B., & Toczko, R. (2023). Brown Coal Waste in Agriculture and Environmental Protection: A Review. *Sustainability*, 15(18), 13371. https://doi.org/10.3390/su151813371

Tang, R., Liu, Y., Ma, R., Zhang, L., Li, Y., Li, G., Wang, D., Lin, J., Li, Q., & Yuan, J. (2023). Effect of moisture content, aeration rate, and C/N on maturity and gaseous emissions during kitchen waste rapid composting. *Journal of Environmental Management*, 326, 116662. https://doi.org/10.1016/j.jenvman.2022.116662

Wang, X., Bai, Z., Yao, Y., Gao, B., Chadwick, D., Chen, Q., Hu, Ch., & Ma, L. (2018). Composting with negative pressure aeration for the mitigation of ammonia emissions and global warming potential. *Journal of Cleaner Production*, 195, 448–457. https://doi.org/10.1016/j.jclepro.2018.05.146

Waqas, M., Nizami, A. S., Aburiazaiza, A. S., Barakat, M. A., Ismail, I. M. I., & Rashid, M. I. (2018). Optimization of food waste compost with the use of biochar. *Journal of Environmental Management*, 216, 70–81. https://doi.org/10.1016/j.jenvman.2017.06.015

Zhou, H. B., Chen, T. B., Gao, D., Zheng, G. D., Chen, J., Pan, T. H., Liu, H. T., & Gu, R. Y. (2014). Simulation of water removal process and optimization of aeration strategy in sewage sludge composting. *Bioresource Technology*, 171, 452–460. https://doi.org/10.1016/j.biortech.2014.07.006

Zydlik, Z., Zydlik, P., Jarosz, Z., & Wieczorek, R. (2023). The Use of Organic Additives for Replanted Soil in Apple Tree Production in a Fruit Tree Nursery. *Agriculture*, 13(5), 973. https://doi.org/10.3390/agriculture13050973