

# Bioconversion Progresses of Organic Solid Waste

Jianxue Hu \*

Bachelor of science, Major in Marine Biology, Dalhousie University, Halifax, NS, Canada

\* Corresponding Author Email: jianxuehu@gmail.com

**Abstract.** With the increasing shortage of global resources and energy, the green recycling and utilization of organic solid waste have become global research hotspots. As representatives of green and clean technologies, the application of bioconversion in organic solid waste has achieved remarkable progress. In this article, the research progress on the major biotechnologies utilized in organic solid waste in recent years is summarized, including landfilling, composting, anaerobic digestion, and anaerobic fermentation. Then, the achievements of bioconversion in the reduction, harmlessness, and resource utilization of different kinds of organic solid waste, such as agricultural and forestry solid organic waste, food waste, and activated sludge, are discussed. Finally, the article provides suggestions for the future development of organic solid waste.

**Keywords:** Activated Sludge, Anaerobic Digestion, Anaerobic Fermentation, Animal Composting, Bioconversion, Bio- Products, Landfilling, Microbial Composting, Organic Solid Waste.

## 1. Introduction

Organic solid waste (OSW) can be categorized into four groups: agricultural waste (including straw and grass clippings), municipal solid waste, such as food and kitchen waste, industrial waste (comprising polymers and bioplastics), and hazardous waste, including active sludge [1]. Annually, an estimated 11.2 billion tons of solid waste are produced worldwide [2], with China generating 235.117 million tons of organic solid waste in 2020 alone [3]. Organic solid waste contains abundant biodegradable organic matter, including proteins, carbohydrates, lipids, and phytonutrients, along with essential elements like nitrogen, phosphorus, and potassium [4]. Failing to effectively utilize this substantial amount of organic solid waste could result in severe environmental and ecological hazards [5]. Nevertheless, organic solid waste comprises a significant quantity of perishable organic matter and pathogenic bacteria. Without proper stabilization, it is susceptible to rapid decay, emitting unpleasant odors, spreading pathogenic bacteria, and releasing significant amounts of greenhouse gases, and damage the local ecosystem and environment [5-7].

Currently, the safe disposal and reduction of organic solid waste have become a prominent global research focus. The management of organic solid waste presents unique challenges and opportunities for effective and sustainable practices. Various treatment methods are employed, including recycling, thermochemical conversion, and biological processes. Actually, the rich composition of organic solid waste makes it an economical and readily available raw material for use in green energy production. Its high organic content and relatively low pollutant concentration render it particularly suitable for biological conversion [8-9]. Bioconversion, also known as biotransformation, is the conversion of organic materials into bio-based products or energy sources [10]. Bioconversion of OSW can be divided into four categories: landfilling, composting, anaerobic digestion, and anaerobic fermentation technology [9].

Landfilling, a widely used disposal method globally, involves a typical biodegradation process consisting of five stages [5]. During the aerobic stage, organic components undergo degradation at an adequate oxygen level, accompanied by the release of heat, resulting in an increase in temperature. In the transition stage, due to insufficient oxygen levels, anaerobic bacteria gradually become dominant bacteria in the reaction system, leading to the production of organic acid and CO<sub>2</sub>. During the subsequent acidification stage, the level of volatile fatty acids continuously increases and are converted into acetic acid, hydrogen, and CO<sub>2</sub>. Then, acetic acid and hydrogen, under certain

conditions, are turn into methane. In the maturation stage, all the organic matters would be broken down into inorganic compounds [7].

Composting technology encompasses microbial composting and animal composting. In aerobic conditions with sufficient oxygen, it decomposes organic matter into CO<sub>2</sub>, water, and minerals, generating high temperatures (54–65 °C) [5]. Animal composting major includes vermicomposting and insect composting. Vermicomposting and insect-composting, considered as bioeconomy options for controlling hazardous organic wastes, result in the production of pollutant-free and non-toxic composts, with biochar being one of the notable products [11].

Anaerobic digestion involves four stages for organic solid waste, hydrolysis, acidogenesis, acetogenesis (acetic acid production), and methanogenesis (methane production), ultimately leading to the degradation of waste into organic acids and methane [5,12].

Anaerobic fermentation involves decomposition of OSW into simple bioproducts in microbial environments [13]. Anaerobic fermentation, comprising dry and wet fermentation, is the primary method for the biological conversion of organic solid waste. The dry fermentation method is commonly employed for treating agricultural and forestry wastes such as straw, livestock, and poultry manure. In contrast, the wet fermentation method is suitable for treating household waste and municipal sludge [13]. Currently, directional conversion technology for anaerobic fermentation of organic solid waste has emerged as a prominent research focus.

Attributed to the fast development of biotechnology, organic solid waste has been environmentally processed to yield various products, including organic fertilizer, energy, fuel, or chemical products [8] [10]. The article primarily focuses on the bio-utilization of organic solid waste, including major biotechnologies such as landfill, composting, anaerobic digestion, and anaerobic fermentation. It reviews the bioconversion progress achieved in different types of OSW, such as agricultural and forestry waste, food waste, and activated sludge.

## **2. Major bioconversion technologies of organic solid waste**

### **2.1. Landfilling**

Landfilling disposal has become an important method to treat organic solid waste in most countries. This approach has the advantages of stability, reliability and good scale adaptability [5]. It is also a potential source of methane production. By capturing and compressing landfill gas, primarily composed of methane and carbon dioxide, greenhouse gas emissions—especially carbon dioxide—are significantly reduced by 9.5×10<sup>5</sup> kilograms per year [14]. Hence, harnessing landfill gas has a greater positive economic impact. Leachate is a liquid discharged from landfills, and its improper treatment would result in severe ecological and environmental impacts, causing harm to underground water sources [15]. Li et al. indicated that winter heating treatment and recharging of mature leachate could achieve rapid and efficient degradation of organic waste, thereby helping to maintain the stability of landfill sites, and improving landfill rates by achieving spatial reuse of existing landfill sites [16]. However, during the landfilling process, numerous volatile and semi-volatile organic compounds are emitted, posing a significant risk to public health, such as aromatic compounds (toluene, ethylbenzene, and xylene), halogenated compounds, and sulfur compounds [17]. To mitigate this impact, efforts are being made to enhance the recycling of these chemical products, thereby reducing their deposition in landfills [18].

### **2.2. Composting**

Composting technology is a primary biodegradation pathway for organic solid waste, drawing considerable attention in research and development.

Anaerobic composting is a process wherein anaerobic microbial reactions occur under conditions devoid of oxygen, facilitating the decomposition of organic matter in food waste through metabolic activities. This process results in the production of substances such as organic matter, CO<sub>2</sub>, CH<sub>4</sub> (methane), and organic acids. Advantages of anaerobic composting include its high organic load

carrying capacity, with the potential to recover biomass energy [19]. It addresses issues like homogeneity, converting organic matter into methane and carbon dioxide. However, anaerobic composting has notable disadvantages. For example, it requires significant project investment, the process is intricate, and the production of biogas slurry is substantial, posing challenges for treatment [20].

Aerobic composting refers to the process of utilizing aerobic microorganisms to absorb, oxidize, and decompose waste under conditions of ample oxygen and good ventilation [21]. The elevated temperature generated during aerobic composting is beneficial for the maximal elimination of pathogenic bacteria, facilitating faster and more thorough degradation of the organic substrate. This, in turn, results in more pronounced reduction and stabilization effects [21]. By utilizing the high temperature of aerobic composting and combining it with anaerobic processes, the bacterial pathogens could be significantly reduced. For example, the maximum removal efficiency of *Clostridium* is as high as 92.96%, thereby improving the quality of compost products [22].

Currently, aerobic technology for organic solid waste has found application in the treatment of various organic wastes, including urban wet waste, kitchen waste, residual sludge from sewage plants, and livestock and poultry manure [23].

Vermicomposting is an environmentally friendly, natural, and cost-effective technology designed to address the increasingly serious issue of organic solid waste and meet the requirements of sustainable development [24]. Compared with traditional composting, vermicomposting has a more comprehensive impact on nutrient management due to slower nutrient release and higher levels of plant hormones to promote growth [25]. The natural fertilizer produced through vermicomposting not only reduces the cost of food production but also diminishes reliance on water sources, increases plant yields, and contributes to higher profits. Natural fertilizers derived from vermicomposts have the capacity to absorb more carbon, promoting carbon sequestration and effectively reducing greenhouse gas emissions [24]. Dume et al. conducted a comprehensive evaluation of the feasibility and final product quality of sewage sludge (SS) composting and vermicomposting under different C/N ratios. They strongly recommend mixing SS with pelletized wheat straw in an 18:1 ratio to obtain high-quality vermicompost from sewage sludge [26].

### 2.3. Anaerobic Digestion

The research on anaerobic digestion technology has a long history, primarily focusing on biogas production. Although anaerobic digestion is a crucial method for bioconverting organic solid waste, the traditional process relies on hydrolysis, acidification, and methane production, posing challenges such as low energy efficiency, biogas slurry treatment, and high costs for biogas purification, thus limiting its application. In recent years, several emerging technologies have significantly improved the efficiency of anaerobic digestion for organic solid waste. For instance, Abdoli and Ghasemazadeh [27] explored the enhancement of methane productivity by bioconverting municipal organic solid waste through anaerobic digestion. They noted that conditions like temperature, time, and biomass loading in hydrothermal carbonization played a crucial role in methane production. As the levels of carbon and hydrogen increased and the concentration of oxygen decreased, the highest methane yield of 251.38 ml/g was achieved. Liu et al. [28] used nanofiber membrane composites (NMCs) containing Prussian blue-like compound nanoparticles to study the anaerobic digestion process of high solid content rural organic domestic waste.

Some studies found that introducing additives during anaerobic digestion, such as polypyrrole magnetite nanocomposites (Ppy/Fe<sub>3</sub>O<sub>4</sub>), humic acid, and arsenic oxide, can significantly improve the digestion efficiency of solid organic waste [4]. Co-digestion of different organic wastes can produce significant synergistic effects. Li et al. found that increasing the total solid content of anaerobically digested organic solid waste to 25% and above induced the accumulation of inhibitory substances, reducing methane production [29].

## 2.4. Anaerobic Fermentation

The utilization of renewable resources to produce platform chemicals and fuels is crucial for achieving a circular economy. Thus, anaerobic fermentation of organic solid waste has become a research hotspot. Anaerobic fermentation only involves the first two steps of anaerobic digestion. Due to its advantages of energy conservation, reducing secondary environmental pollution, and obtaining high value-added products, it has received widespread attention in the treatment of biological waste. Popular research products include energy substances such as bio hydrogen, biogas, bioethanol, and bio butanol, as well as liquid chemicals such as succinic acid and lactic acid [30]. Fermentation parameters and microbial composition of organic solid waste, there are significant differences in the fermentation efficiency and composition of fermentation products of organic solid waste [31-32]. Regulation of operating parameters is also an important link in the anaerobic fermentation (AF) process of organic solid waste. As reported by Li et al. [33], lower acidity inhibits the anaerobic fermentation of food waste, leading to a reduction in OSW production. Moreover, the addition of fructose and molasses was identified as a factor that increased the production of organic acid and ammonia nitrogen. The addition of citric acid at temperatures ranges from 15°C to 35°C would increase the production fatty acids in Chinese cabbage waste. At optimal temperature of 25 degrees, anaerobic fermentation was found to be suitable for the production of organic acids. Additionally, different ratios of food waste and wheat bran were observed to affect the production of organic acids. Qin et al. [34] found that mixing the co-fermentation of kitchen waste with sludge, straw, and other garden waste could generate a significant amount of acid, with acetic acid and propionic acid being the main products. Meanwhile, the components of wastes collected in different seasons would influence the production of organic acid, with protein and fat content contributing to their production, while carbohydrates and certain citrus components promoted the conversion of volatile fatty acids and butyric acid.

## 3. Bioconversion progresses of different organic solid waste

### 3.1. Agricultural and forestry solid organic waste

It was reported that the rapid development of agriculture, the global production of agricultural and forestry waste was approximately 20.3 billion tons in 2019 [35]. Agricultural and forestry waste can be effectively treated through composting and anaerobic fermentation methods. In the same sentence, consider specifying what "C/N ratio" stands for to enhance clarity: "...co-composted with nitrogen-rich materials to maintain a suitable Carbon/Nitrogen (C/N) ratio [36]. The by-products obtained from composting can also be used to produce organic fertilizers and biochar, improving farmland soil in the future [37, 35]. Agricultural and forestry waste, rich in carbon, phosphorus, potassium, and other beneficial elements for plants, can be transformed into a significant amount of organic fertilizer through the biocomposting action of black soldier flies, establishing a closed-loop system. In Kragt's study, the larvae of the black soldier fly were employed for insect composting to address the need for farmers to purchase feed or fertilizer [38]. Saha and Kumar found that peels from agroforestry waste or agricultural waste could be converted into organic acids, such as acetic acid, through anaerobic fermentation [1]. Agricultural and forestry wastes, abundant in wood fiber, could be utilized for methane and organic matter production.

### 3.2. Food waste

Due to rapid global population growth and economic development, the quantity of FW increased at an annual rate of approximately 4.4% [3]. The production of food waste is rapidly increasing, thereby causing increasingly prominent environmental hazards. Generally, the main components of food waste are leaves, peels, and residue, represented by high organic matter, high moisture content, easily be decayed, however low calorific value. The most common methods for treating food waste are anaerobic digestion and composting. Given that food waste contains substantial amounts of

carbon, phosphorus, and other elements beneficial for plant growth, it serves as an effective aid for plant development. Additionally, due to its content of carbohydrates, proteins, and fats, food waste can rapidly generate methane and various organic acids. [39-40]. Therefore, numerous studies were conducted to obtain high-quality compost, such as adjusting the water content, C/N, and porosity of FW. Co-composting of FW with other OSW is an efficient method. Meanwhile, the small particle compost with a particle size lower than 45 mm had high uniformity, maturity, and humility, making it suitable for use as fertilizer [40]. Han et al. [41] utilized high-temperature pretreatment to speed up the process of food waste and improve the quantity of composting products. Moreover, they found that the obtained composts would promote plant growth by changing the main microbial community and enzyme activity in the soil. Foughal et al. used *Aspergillus niger* to eliminate bacteria and pathogens in food waste, thereby accelerating the production of organic fertilizers [42]. Du et al. and Li et al. found that many fast foods contain a significant number of additives, which can inhibit anaerobic digestion, leading to a reduction in methane production [43]. However, when compared to lower additive levels, the production of organic acids can be increased by 12.5% [16].

### 3.3. Activated Sludge

Activated sludge from sewage treatment plants is another important organic solid waste. In China, the average annual increasing rate of activated sludge has reached 4.75% [44]. Due to the high content of organic matter such as proteins and carbohydrates in activated sludge, it can be utilized by microorganisms and converted into methane, hydrogen, and VFAs [13]. Presently, various research was conducted to solve the problems like low sludge decomposition rate, low substrate biodegradation and biotransformation efficiency. The addition of various raw materials, such as activated sludge and iron hydrochloride in the biorefinery process, was found to inhibit methane production while maximizing the production of fatty acids [13]. Yang et al. reported that without pretreatment of activated sludge in the biorefinery process, methane production decreases while organic acid production increases. However, the addition of a small amount of carbamazepine in the experiment had the effect of increasing short-chain fatty acids [45]. Liu et al. [46] explored the use of free ammonia to eliminate antibiotic genes and accelerate anaerobic digestion of activated sludge, resulting in a 50% boost in the ability of anaerobic digestion to treat activated sludge.

## 4. Conclusion and Perspective

Organic solid waste has dual attributes of pollutants and resources. If not properly managed and utilized, it will not only cause serious environmental pollution and resource waste, but also bring serious environmental problems. The conversion of organic solid waste into valuable products such as bio fertilizers, biogas, organic acids, bio feed, bioethanol, bio-hydrogen, enzymes, and bioplastics. Transformation is a green and sustainable way for the management and application of achieve OSW.

Suggestions for the highly efficient and high-yield utilization of organic solid waste in the future are as follows: (1) Based on the concept of biorefinery and the process integration coupling, different technologies should be applied to the biological conversion process of organic solid waste to prolong the chain from raw materials to products, increasing product added value, and improving the resource utilization of organic waste. (2) Given the differences in the physical and chemical properties of organic solid waste, further research should be conducted on the co-digestion of multi-source waste to achieve optimal nutrient composition and physical structure of raw materials. This will enhance the stability of the organic solid waste biological conversion process, increase product yield, and reduce overall operating costs. (3) Many technologies have achieved significant success in the laboratory stage. For example, earthworm composting and insect composting technologies have the potential to effectively remove pollutants such as heavy metals, antibiotic genes, and microplastics from sludge. The industrialization of these technologies should be accelerated in the future. (4) Improve and develop technologies for each operating unit involved in the conversion of raw material to products from organic solid waste. This includes but is not limited to technologies for controlling

the generation of secondary pollutants, organic solid waste pretreatment and saccharification technologies, and the development of new biological conversion technologies and equipment.

## References

- [1] Saha, D., & Kumar Das, P. (2023). Bioconversion of Agricultural and Food Wastes to Vinegar. IntechOpen.
- [2] Maalouf, A., & Mavropoulos, A. (2022). Re-assessing Global Municipal Solid Waste generation. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, 41(4), 936–947.
- [3] Zhang, Y., Zhou, C., Du, J., Wang, M., Wu, W., & Liu, G. (2023). Material flow analysis and characteristics of multiple-source organic solid wastes from a perspective of ecological network analysis: A case study in Hefei, China. *Waste Management & Research*, 41(5), 987–996.
- [4] Ugwu, S. N., & Enweremadu, C. C. (2023). Optimization of iron-enhanced anaerobic digestion of agro-wastes for biomethane production and phosphate release. *Environmental Technology*, 44(5), 721–738.
- [5] Adetunji, A. I., Oberholster, P. J., & Erasmus, M. (2023). From garbage to treasure: A review on biorefinery of organic solid wastes into valuable biobased products. *Bioresource Technology Reports*, 24, 101610-.
- [6] Wei, J., Li, H., & Liu, J. (2022). Heavy metal pollution in the soil around municipal solid waste incinerators and its health risks in China. *Environmental Research*, 203, 111871.
- [7] Nanda, S., & Berruti, F. (2021). A technical review of bioenergy and resource recovery from municipal solid waste. *Journal of Hazardous Materials*, 403, 123970–123970.
- [8] Vats, P., Hiranmai, R. Y., & Neeraj, A. (2023). Bioconversion of organic waste for solid waste management and sustainable agriculture—emphasized impact of Bioelectromagnetic Energy. *Sustainable and Cleaner Technologies for Environmental Remediation*, 193–220.
- [9] Qureshi, T., Farooq, M., Munir, M. A., Imran, S., Javed, M. A., Sohoo, I., Sultan, M., Rehman, A. U., Farhan, M., Asim, M., & Andresen, J. M. (2024). Structural and thermal investigation of lignocellulosic biomass conversion for enhancing sustainable imperative in progressive organic refinery paradigm for waste-to-energy applications. *Environmental Research*, 118129-.
- [10] Raj, T., Sompura, S., Chandrasekhar, K., Singh, S. K., Pandey, S., Singh, L. K., Rajput, M. S., Kumar, D., Bhatia, S. K., Patel, A. K., & Singhanian, R. R. (2023). Technology development and challenges for the transformation of municipal solid waste into sustainable energy production. *Biomass & Bioenergy*, 178, 106965-.
- [11] Pedraza Torres, A. M., & Sanchez-Hernandez, J. C. (2023). Bioconversion of hazardous organic wastes using invertebrates. *Fate of Biological Contaminants During Recycling of Organic Wastes*, 297–357.
- [12] Gupta, J., Kumari, M., Mishra, A., Swati, Akram, M., & Thakur, I. S. (2022). Agro-forestry waste management- A review. *Chemosphere (Oxford)*, 287(Pt 3), 132321–132321.
- [13] Wang, Y., Zhang, G., Zhang, P., Yang, G., Song, H., & Yang, A. (2016). Research progress of hydrogen production through anaerobic fermentation of waste sludge. *Shui Zi Yuan Bao Hu*, 32(4), 109–116.
- [14] Un, C. (2023). A Sustainable Approach to the Conversion of Waste into Energy: Landfill Gas-to-Fuel Technology. *Sustainability (Basel, Switzerland)*, 15(20), 14782-.
- [15] Abedi, S., Nozarpour, A., & Tavakoli, O. (2023). Evaluation of biogas production rate and leachate treatment in Landfill through a water-energy nexus framework for integrated waste management. *Energy Nexus*, 11, 100218-.
- [16] Li, K., Xu, W., Chen, Y., Zhan, L., Ke, H., Xu, H., & Xiao, D. (2023). Biochemical, hydrological and mechanical behaviors of high food waste content MSW landfill: Numerical simulation analysis of a large-scale experiment. *Waste Management (Elmsford)*, 171, 557–567.
- [17] Ghosh, A., Kumar, S., & Das, J. (2023). Impact of leachate and landfill gas on the ecosystem and health: Research trends and the way forward towards sustainability. *Journal of Environmental Management*, 336, 117708–117708.
- [18] Yang, C., Fu, T., Wang, H., Chen, R., Wang, B., He, T., Pi, Y., Zhou, J., Liang, T., & Chen, M. (2021). Removal of organic pollutants by effluent recirculation constructed wetlands system treating landfill leachate. *Environmental Technology & Innovation*, 24, 101843-.

- [19] Chynoweth, D. P., Owens, J., O'Keefe, D., Earle, J. F. K., Bosch, G., & Legrand, R. (1992). Sequential Batch Anaerobic Composting of the Organic Fraction of Municipal Solid Waste. *Water Science and Technology*, 25(7), 327–339.
- [20] Zafiu, C., Binner, E., Höck, L., Świechowski, K., & Huber-Humer, M. (2023). Study on the degradability of plastics with prodegradant additives during anaerobic and aerobic biological waste treatment processes. *Journal of Material Cycles and Waste Management*, 25(6), 3545–3556.
- [21] Yamada, Y., & Kawase, Y. (2006). Aerobic composting of waste activated sludge: Kinetic analysis for microbiological reaction and oxygen consumption. *Waste Management (Elmsford)*, 26(1), 49–61.
- [22] Li, H., Xu, Y., Zheng, X., Tan, L., Cheng, W., Zhang, C., Wang, Q., Yang, B., & Gao, Y. (2022). Optimising mixed aerobic and anaerobic composting process parameters for reducing bacterial pathogenicity in compost-derived products. *Journal of Environmental Management*, 304, 114293–114293.
- [23] Ma, S., Shen, Y., Ding, J., Cheng, H., Zhou, H., Ge, M., Wang, J., Cheng, Q., Zhang, D., Zhang, Y., Xu, P., & Zhang, P. (2024). Effects of biochar and volcanic rock addition on humification and microbial community during aerobic composting of cow manure. *Bioresource Technology*, 391, 129973–129973.
- [24] Dey Chowdhury, S., Suhaib, K. H., Bhunia, P., & Surampalli, R. Y. (2023). A critical review on the vermicomposting of organic wastes as a strategy in circular bioeconomy: mechanism, performance, and future perspectives. *Environmental Technology*, ahead-of-print(ahead-of-print), 1–38.
- [25] Rékási, M., Mazsu, N., Draskovits, E., Bernhardt, B., Szabó, A., Rivier, P.-A., Farkas, C., Borsányi, B., Pirkó, B., Molnár, S., Kátay, G., & Uzinger, N. (2019). Comparing the agrochemical properties of compost and vermicomposts produced from municipal sewage sludge digestate. *Bioresource Technology*, 291, 121861–121861.
- [26] Dume, B., Hanc, A., Svehla, P., Michal, P., Chane, A. D., & Nigussie, A. (2023). Composting and vermicomposting of sewage sludge at various C/N ratios: Technological feasibility and end-product quality. *Ecotoxicology and Environmental Safety*, 263, 115255–115255.
- [27] Abdoli, M. A., & Ghasemzadeh, R. (2024). Evaluation and optimization of hydrothermal carbonization condition for hydrochar and methane yield from anaerobic digestion of organic fraction of municipal solid waste (OFMSW). *Fuel (Guildford)*, 355, 129531-.
- [28] Liu, Y., Xi, Y., Ye, X., Zhang, Y., Wang, C., Jia, Z., Cao, C., Han, T., Du, J., Kong, X., & Chen, Z. (2024). Composite nanofiber membranes to enhance the performance of high solids anaerobic digestion of organic rural household waste resources. *Renewable Energy*, 220, 119564-.
- [29] Li, Y., Qi, C., Zhang, Y., Li, Y., Wang, Y., Li, G., & Luo, W. (2021). Anaerobic digestion of agricultural wastes from liquid to solid state: Performance and environ-economic comparison. *Bioresource Technology*, 332, 125080-.
- [30] Zhang, Y., Wang, X., Zhu, W., Zhao, Y., Wang, N., Gao, M., & Wang, Q. (2023). Anaerobic fermentation of organic solid waste: Recent updates in substrates, products, and the process with multiple products co-production. *Environmental Research*, 233, 116444–116444.
- [31] Chen, H., Zeng, X., Zhou, Y., Yang, X., Lam, S. S., & Wang, D. (2020). Influence of roxithromycin as antibiotic residue on volatile fatty acids recovery in anaerobic fermentation of waste activated sludge. *Journal of Hazardous Materials*, 394, 122570–122570.
- [32] Gao, Y., Tang, X., Zhong, L., Zhang, B., Li, S., Wang, M., Xiao, H., Fan, C., & Zheng, J. (2024). Co-pretreatment (calcium peroxide + freeze) to improve anaerobic fermentation of waste activated sludge: Method optimization and mechanism insights. *Chemical Engineering Journal (Lausanne, Switzerland: 1996)*, 480, 148339-.
- [33] Li, J., Meng, Q., Wang, C., Song, C., Lyu, Y., Li, J., & Shan, A. (2023). The interaction between temperature and citric acid treatment in the anaerobic fermentation of Chinese cabbage waste. *Journal of Cleaner Production*, 383, 135502-.
- [34] Qin, W., Han, S., Meng, F., Chen, K., Gao, Y., Li, J., Lin, L., Hu, E., & Jiang, J. (2023). Impacts of seasonal variation on volatile fatty acids production of food waste anaerobic fermentation. *The Science of the Total Environment*, 912, 168764–168764.
- [35] Yu, S., Zhang, W., Dong, X., Wang, F., Yang, W., Liu, C., & Chen, D. (2024). A review on recent advances of biochar from agricultural and forestry wastes: Preparation, modification and applications in wastewater treatment. *Journal of Environmental Chemical Engineering*, 12(1), 111638-.

- [36] D. Phadtare, P., & R. Kalbande, S. (2022). Biochar Production Technologies from Agricultural Waste, Its Utilization in Agriculture and Current Global Biochar Market: A Comprehensive Review. *International Journal of Environment and Climate Change*, 1010–1031.
- [37] Elmnifi, M., Almaktar, M., Vambol, S., Trush, O., Sydorenko, V., & Mykhailov, V. (2023). Agricultural waste in Libya as a resource for biochar and methane production: An analytical study. *Ecological Questions*, 35(2), 1–20.
- [38] Kragt, M. E., Dempster, F., & Subroy, V. (2023). Black soldier fly fertilisers by bioconversion of livestock waste: Farmers' perceptions and willingness-to-pay. *Journal of Cleaner Production*, 411, 137271-.
- [39] Xu, Z., Qi, C., Zhang, L., Ma, Y., Li, J., Li, G., & Luo, W. (2021). Bacterial dynamics and functions for gaseous emissions and humification in response to aeration intensities during kitchen waste composting. *Bioresource Technology*, 337, 125369–125369.
- [40] Peng, L., Ma, R., Jiang, S., Luo, W., Li, Y., Wang, G., Xu, Z., Wang, Y., Qi, C., Li, Y., Li, G., & Yuan, J. (2022). Co-composting of kitchen waste with agriculture and forestry residues and characteristics of compost with different particle size: An industrial scale case study. *Waste Management (Elmsford)*, 149, 313–322.
- [41] Han, L., Li, L., Xu, X., Ye, W., Zhang, F., Xu, Y., Peng, X., & Zhen, F. (2024). Utilization of short-term high temperature pretreatment for food waste composting: Effects of end-products on soil properties and plant growth. *Journal of Cleaner Production*, 438, 140790-.
- [42] Foughal, T., Doublali, F. E., Ozi, F. Z., Hadidi, M., Louanjli, F. A., Bahlaouan, B., Antri, S. E., & Boutaleb, N. (2023). Biofertilization potential of products from biotransformation of organic waste in Morocco: comparing between aerobic and anaerobic mode. *Biomass Conversion and Biorefinery*.
- [43] Du, M., Liu, X., Li, C., Long, S., Luo, L., Guo, Y., & Wang, D. (2023). Uncovering the Mechanisms of How Capsaicin Affects Short-Chain Fatty Acid Production during Food Waste Valorization. *ACS ES&T Engineering*, 3(11), 1986–1996.
- [44] Luo, J., Huang, W., Zhu, Y., Guo, W., Yibing, L., Wu, L., Zhang, Q., Wu, Y., Fang, F., & Cao, J. (2020). Influences of different iron forms activated peroxydisulfate on volatile fatty acids production during waste activated sludge anaerobic fermentation. *The Science of the Total Environment*, 705, 135878–135878.
- [45] Yang, J., Wang, J., Wang, F., Meng, F., Yang, X., Pan, Q., Liu, X., Duan, A., & Wang, D. (2023). Insights into the effect of carbamazepine on the anaerobic fermentation of waste activated sludge: Performance, mechanisms and regulation. *Chemical Engineering Journal (Lausanne, Switzerland: 1996)*, 452, 139549-.
- [46] Liu, H., Li, X., Zhang, Z., Nghiem, L. D., Gao, L., Batstone, D. J., & Wang, Q. (2023). Achieving expanded sludge treatment capacity with additional benefits for an anaerobic digester using free ammonia pretreatment. *Chemical Engineering Journal (Lausanne, Switzerland : 1996)*, 465, 142846-.