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Review of Current Technologies Used in Vegetable Waste Treatment in China

Sisi Huang[1], Futao Zhang[1], Hui Han[1], Yanhong Wang[1, 2], Xinhui Yu[1*]

[1]College of Life Science and Technology, Heilongjiang Bayi Agricultural University, Daqing 163319, China
[2]Heilongjiang Provincial Key Laboratory of Environmental Microbiology and Recycling of Agro-waste in Cold Region, Daqing 163319, China

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***Corresponding author:** Xinhui Yu
College of Life Science and Technology, Heilongjiang Bayi Agricultural University, Daqing 163319, China

Abstract **Review Article**

With the increase in population and the acceleration of the urbanization process, the output of vegetables in China has increased yearly, accompanied by a large amount of vegetable waste. If not disposed of promptly, it will cause pollution to the environment. Therefore, the treatment of vegetable waste has become an urgent problem. This article systematically summarizes the current status of vegetable waste treatment technology, mainly introduces the methods, characteristics, limitations, and development trends of vegetable waste treatment, and summarizes the leading technologies for vegetable waste treatment.

Keywords: Vegetable Waste, Processing Mode, Feeding Utilization, Fertilizerization, Energization.

1. INTRODUCTION

China is an agricultural country, and vegetable cultivation is indispensable to domestic agricultural production. The vegetable output has increased from 692 million tons in 2017 to 791 million tons in 2022 (FAO, 2023). Vegetable wastes are non-commercial, with valueless roots, stems, leaves, and damaged vegetables produced during harvesting, storing, and transporting vegetable products. The main types of vegetable waste are cabbage, baby cabbage, celery, cauliflower, radish, and kale, accounting for about 50% of the total vegetable production (Chen *et al*., 2023). The increasing amount of vegetable waste has brought many environmental problems. Vegetable wastes are highly susceptible to rot and can breed mosquitoes and other insects. If they accumulate and decay long, they will produce a foul odor. If not handled in time and piled up on both sides of the road, it will affect the smoothness of the road and even block drainage channels (Salehiyoun *et al*., 2019). Vegetable waste contains abundant nutrients and organic matter. If it can be harmlessly treated and reused, it will bring massive value to constructing a circular economy and a conservation- oriented society (Esparza *et al*., 2020). However, if not adequately treated, it will pollute the environment and threaten the ecosystem and human health. Therefore, solving the problem of vegetable waste has become an urgent task. Various methods for handling vegetable waste include composting, biological treatment, and garbage incineration. However, each method has advantages and disadvantages and needs to combine with the actual situation.

2. VEGETABLE WASTE TREATMENT TECHNOLOGY

2.1 Feeding Utilization

Vegetable wastes contain various carbohydrates, minerals, vitamins, proteins, and other nutrients, which can be used to feed livestock. However, due to its high water content, often with pesticide residues, poor digestibility, and other reasons, directs feeding is not easy to be absorbed and utilized by animals. It is easy to cause animal diseases, so it needs further processing. Zhu *et al*., (2021) selected sheep with the same body condition to feed the basal diet, commercial fermented feed, and the basal diet and vegetable waste fermented feed, respectively. The results showed that the growth performance, slaughter performance, and meat quality of the sheep diet supplemented with vegetable waste fermented feed were improved under the same conditions. Compared with commercial fermented feed, the vegetable waste fermented feed has a better effect and can be applied to sheep production. Lan *et al*., (2021) mixed cauliflower vegetable waste with the essential diet in proportion and added compound bacteria to make cauliflower vegetable waste feed for nursery pigs. The results showed that cauliflower vegetable waste fermented feed could reduce the diarrhea rate of nursery pigs, promote intestinal development, increase the abundance and diversity of intestinal microflora, enhance immune performance, and improve growth performance and economic benefits. Cai *et al*., 2020 mixed broccoli with rice flour, rice bran, and other auxiliary materials and added lactic acid bacteria, Nacl, and other additives to make vegetable waste feed. The results showed that increasing the proportion of broccoli vegetable waste could improve the fermentation quality and feeding quality of silage, and using additives could improve the fermentation quality of broccoli vegetable waste silage. Sahoo *et al*., (2021) made fresh fruit and vegetable waste into feed to feed ewes. The results showed that the digestibility of dry matter and crude protein and the total antioxidant capacity of plasma were improved. Nisar*et et al*., (2022) selected chicks with the same body condition. They studied the growth performance of broiler chickens by using vegetable waste as a feed additive in the proportion of 0 %, 25 %, and 75 %. The results showed that adding vegetable waste did not significantly affect feed and feed intake. However, on average, the amount of vegetable waste added is 2%.

China's feed resources supply and demand have been imbalanced recently, and feed raw material prices continue to rise. We can make full use of the vegetable waste resources and feed the vegetable waste resources. In that case, it can replace the expensive traditional breeding feed, promoting the sustainable development of animal husbandry in China and providing many opportunities for solving the problem of vegetable waste disposal and environmental pollution (Cheng *et al*., 2022).

2.2 Fertilizerization

Vegetable wastes are rich in organic matter, including nitrogen, phosphorus, potassium, and other nutrients, as well as calcium, magnesium, sulfur, and other trace elements. The fertilizer made of vegetable waste is full of nutrients, long-term fertilizer, and easy to be absorbed by crops (Ma *et al*., 2022). The fertilization of vegetable waste is produced by microorganisms or enzyme preparations to release mineral nutrients in vegetable waste and decompose into organic matter and humus for crop absorption and utilization. This method can effectively alleviate the shortage of organic fertilizer and soil fertility decline. The fertilization of vegetable waste is divided into direct returning and composting treatment.

2.2.1 Direct Returning to the Field

Directly returning vegetable waste to the field entails spreading the vegetables in the soil after vegetable production, applying bacterial fertilizer, deep plowing and burying the soil with a micro rotary tiller, and eventually narrowing the field. Liu *et al*., (2020) conducted direct return treatment to the field post-harvest of cabbage. They found that the growth of the cabbage plot undergoing the treatment was more substantial than that of the control, with its disease resistance slightly more substantial. The yield increased by 12.4%, reaching a significant level. The results further indicated that the direct return of vegetable waste could increase the yield and the organic matter content in the soil (Liu *et al*., 2020). Zeng *et al*., (2006) employed microbial agents to return celery and carnation waste to the field directly, showing that celery combined with microbial agents could significantly enhance the soil pH value compared to the control. In contrast, celery and carnation waste combined with microbial agents could increase the biomass of Chinese cabbage compared to the control (Zeng *et al*., 2006).

The direct returning treatment technology is simple and low-cost. This treatment method can solve a certain amount of vegetable waste, but there are also some drawbacks. First, the risk of crop diseases and insect pests will increase after the vegetable waste is directly returned to the field without pretreatment. Secondly, it is easy to produce continuous cropping obstacles with the same crop or related crops, resulting in reduced yield, poor quality, and poor fertility. In addition, the natural decomposition rate of vegetable waste is slow. If microbial reproduction is insufficient, the vegetable waste will compete with the crop for nitrogen sources and affect the crop.

2.2.2 Composting Treatment

Composting is a standard method to treat vegetable waste by piling it together, adding an appropriate quantity of microorganisms and other substances, and utilizing microbial metabolism to decompose it, eventually producing fertilizer. Although composting is a simple, cost-effective, and environmentally-friendly treatment method, it has relatively low efficiency and a long maturation period for producing compost. Moreover, composting is an organic matter decomposition and synthesis process that offers a harmless way of treating vegetable waste. Eventually, the waste is degraded into humic acid, fulvic acid, and humus, which are challenging to biodegrade (Nisar*et et al*., 2022). Composting quality can be significantly impacted by several primary factors, such as the carbon source, nitrogen source, water content, temperature, pH value, and ventilation method utilized during the process. Lu *et al*., (2022) used solanaceous vegetable waste as composting material and set up two groups of experiments with and without pig manure. The results showed that adding pig manure could improve the pile's temperature and the product's quality. Zhao (2021) mixed rice straw and cabbage waste at a mass ratio of 7:3 and introduced a lignocellulosic degradation composite microbial system equivalent to 5% of the compost volume. The resulting findings suggested that the composite microbial system stimulated the rapid initiation of composting, extended the high-temperature period, elevated the nutrient content of the decomposed material, achieved complete decomposition of the waste, and fulfilled the requirements for a harmless process. For the control experiment, waste field leafy vegetables and soil were mixed, followed by adding a variety of bio-organic fertilizers, cow dung, or material-decomposing inoculants. The composting temperature of cow dung and material-decomposing inoculants consistently remained higher than 50 °C, maintained for over seven days, highlighting that adding cow dung or material-decomposing inoculants could help to enhance the quality of the compost (Pan *et al*., 2021). Bashir *et al*., (2021) utilized vegetable waste as a soil amendment to promote composting and mitigate the probability of corn Cd toxicity in soil. By incorporating vegetable waste into the contaminated soil, the authors observed a significant reduction in Cd absorption by the plants' roots and upper sections. This method successfully affected the plants' ability to absorb the heavy metal compared to the control soil (Bashir *et al*., 2021).

In recent years, the abuse of chemical fertilizers has led to problems such as soil nutrient imbalance and quality degradation, which affects the quality of agricultural products and agricultural development. Composting can improve soil conditions and the quality of agricultural products, which is expected to replace traditional fertilizers.

2.3 Energization

The primary means of deriving energy from vegetable waste is by implementing anaerobic fermentation technology. Anaerobic fermentation, or anaerobic digestion, involves decomposing organic matter and generating biogas (CH4 and CO2) under strictly anaerobic conditions through the coordinated metabolic activities of hydrolytic acidification bacteria, acetogenic bacteria, and methanogenic bacteria. In batch experiments, Song *et al*., (2018) explored the biogas production potential of five everyday vegetable waste products (cabbage, eggplant, carrot, potato, and cucumber). These tests demonstrated that potato and cabbage waste had the highest methane production potential, reaching 102 and 83 mL·g-1, respectively, while the production potential of cucumber waste was only approximately 35 mL·g-1. In a study by Bai *et al*., (2021), a mixture of cow dung and cabbage waste in a 2:1 ratio resulted in a 52% increase in methane production compared to the anaerobic digestion of cabbage waste alone.

Similarly, a mixture of cow dung and celery waste in a 3:1 ratio increased the methane yield by 52% compared to that of celery waste alone. Edwiges *et al*., (2020) employed a continuously stirred tank reactor to anaerobically digest a waste mixture of fruits and vegetables generated under tropical conditions. The experimental pH was stable with sufficient buffering capacity, and methane production was optimal at an organic load of 3 g·L-1·d-1. As the organic load increased, the accumulation of volatile fatty acids decreased.

The anaerobic digestion of vegetable waste is influenced by many factors that may inhibit methane production due to ammonia nitrogen or excessive acid levels. Scholars have proposed methods such as the co-digestion of vegetable waste with other materials or vegetable waste pretreatment before anaerobic digestion to overcome these challenges. These practices could enhance the effectiveness of anaerobic digestion as a means of utilizing vegetable waste resources, resulting in significant economic and social benefits.

3. CONCLUSION AND PROSPECT

The utilization of vegetable waste as a resource is versatile, but several challenges arise from the limited technical expertise and imperfect industrial supply chain. Thus, identifying practical and appropriate methods for dealing with these issues and prioritizing environmental protection and resource management is critical. Vegetable waste resource utilization and development are significant to governments and related entities. However, realizing a unified method for treating and utilizing waste requires extensive effort, given the diversity of vegetable waste types, grades, and sources. Additionally, the seasonal nature of vegetables poses a significant challenge in maintaining a balanced long-term supply, which impedes the widespread application of existing vegetable waste processing and utilization methods. Hence, improving the utilization rate of vegetable waste remains an essential task. In order to facilitate the efficient utilization of vegetable waste resources, a robust system of standardization and technical support must be established, along with research and development efforts to promote vegetable waste processing technology. Furthermore, adequate supervision and management, publicity, and education programs are necessary to ensure the success of these initiatives. Popularizing the harm of vegetable waste and the benefits of resource utilization, sharing the good experience and practice in the process of vegetable waste processing, and eliciting the enthusiasm and initiative of vegetable farmers and enterprises to deal with and utilize vegetable waste can help to gradually address the environmental problems brought by vegetable waste, protecting the agricultural production environment, promoting farmers' income, and realizing the healthy and sustainable development of vegetable waste resources.

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