

Feed Utilization Technology of Vegetable Waste and Its Application in Livestock and Poultry Production: Postprint

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Abstract

Vegetable waste, also known as tail vegetables, possesses certain nutritional value and constitutes one of the preferable feed resources. Rational utilization of tail vegetable resources will not only facilitate the development of additional unconventional feed resources but also mitigate environmental pollution issues arising from tail vegetables to a certain extent. This article reviews the research progress on the feed utilization of tail vegetables by examining their distribution and application status, nutritional composition, feed processing technologies, and applications in livestock and poultry production, aiming to provide references for the practical application of tail vegetables as feed.

Full Text

Technologies for Feed Utilization of Vegetable Waste and Its Application in Livestock and Poultry Production

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Abstract: Vegetable waste, also known as “tail vegetables,” possesses certain nutritional value and represents a viable feed resource. Rational utilization of vegetable waste can not only expand unconventional feed resources but also mitigate environmental pollution caused by its disposal. This paper reviews research progress on vegetable waste utilization, covering its distribution and application status, nutritional composition, feed processing technologies, and applications in livestock and poultry production, aiming to provide references for the feed utilization of vegetable waste.

Key words: vegetable waste; utilization; feed; technology

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Vegetables are rich in nutrients and essential to daily life. As vegetable production continues to increase, the resulting waste—known as vegetable waste or “tail vegetables” —has also grown substantially. In farmers’ markets and fields, these waste materials are often discarded as garbage, causing environmental pollution and burdening waste management systems due to their perishable nature. This practice reduces vegetable utilization efficiency and represents a significant waste of resources [1]. Therefore, rational utilization of vegetable waste is necessary to alleviate environmental problems, achieve resource recycling, improve overall vegetable utilization efficiency, and transform waste into valuable products.

1 Overview

China is a major agricultural country, accounting for 43% of global vegetable cultivation area and 49% of world vegetable production [2], with its vegetable acreage continuing to expand. In 2015, China’s vegetable output reached 785.261 million tons, representing a 10.8% increase from 2012 and an average annual growth rate of 3.6% [3-6]. As vegetable production increases and quality requirements become more stringent, the quantity of vegetable waste has grown correspondingly.

The edible portion of vegetables averages 80% in daily life, while waste averages 20% and can reach as high as 67% [7]. For example, the national cultivation area of wild rice stem (*Zizania latifolia*) reaches 67,000 hectares, with each hectare producing over 50 tons of fresh straw annually, resulting in more than 5 million tons of wasted fresh leaf sheaths each year [8]. Taking Yangzhou City in Jiangsu Province as an example, vegetable cultivation has shown an upward trend year by year. As shown in , by the end of 2015, the cultivated land area reached 295,120 hectares, with vegetable planting area of 51,300 hectares, yielding 39.6 tons per hectare and total output of 2,033,823 tons. Based on the typical waste rate of 20-67%, annual vegetable waste in the Yangzhou region ranges from 406,764.6 to 1,362,661.41 tons.

With increasing vegetable cultivation and rising quality standards, vegetable waste quantities continue to grow. Therefore, rational utilization of vegetable waste resources is critically important for promoting ecological development, achieving resource recycling and energy conservation, reducing production costs, and improving marginal benefits of cultivation.

2 Resource Utilization Methods for Vegetable Waste

Currently, the primary resource utilization methods for vegetable waste include feed utilization, fertilizer utilization, and energy utilization.

2.1 Feed Utilization

Feed utilization refers to converting vegetable waste into feed through biological or physical processing techniques to replace or partially replace conventional feed. This approach can enhance feed nutritional value and reduce animal feeding costs. Lian et al. [14] utilized pineapple leaves for feed by producing silage through ensiling technology. Zhang et al. [15] conducted solid-state fermentation of potato and highland baby cabbage waste to produce microbial protein feed. Li et al. [16] mixed cabbage waste with wheat straw for fermentation, improving the feed utilization potential of both materials. Dai et al. [17] fermented corn straw with lotus cabbage waste using yeast, increasing crude fat and crude protein content. Yang et al. [18] developed and optimized production lines for converting celery, cabbage, and lotus cabbage waste into feed using coarse feed pelletizing and briquetting technology. Wang [19] reported that villagers in Jiangjiaying Village, Dingyuan Town, Yuzhong County, Lanzhou, successfully used ensiling technology to produce cauliflower waste silage for dairy cows with good feeding results. Xu [20] designed technology for processing vegetable waste into feed powder. Shao et al. [1] developed a liquid silage inoculant for vegetable waste, producing high-quality silage from cabbage waste and asparagus lettuce leaves. Li et al. [21] found that adding wheat bran, 2% acetic acid, and corn meal to cabbage waste produced optimal silage quality on day 30 of fermentation.

2.2 Fertilizer Utilization

Vegetable waste can be fermented and converted into fertilizer for vegetable cultivation, achieving cyclic utilization. Under certain conditions, vegetable waste can serve as an ecological substitute for conventional chemical fertilizers, reducing environmental pollution while improving vegetable quality. Yang et al. [22] conducted aerobic fermentation experiments mixing vegetable waste with cattle manure, finding optimal fermentation at a 3:1 mass ratio, 2 hours of daily aeration, and 40 days of fermentation time. Wang [23] irrigated pak choi with biogas slurry from vegetable waste, finding that high-level biogas slurry application produced the highest yield (730 kg per mu), while medium-level application increased vitamin C content by 30.2% and soluble sugar content by 65.5% compared to the control group.

2.3 Energy Utilization

Energy utilization primarily involves converting vegetable waste into biogas through anaerobic fermentation to replace natural gas and coal. Wang [23] studied biogas fermentation of vegetable waste, finding that a 30% inoculum concentration produced optimal methane content (42.81%) and total gas production of 7,790.81 mL. Adding nickel (Ni), iron (Fe), and cobalt (Co) increased biogas production by 37.11% and methane content by 40.34%. Temperature experiments showed optimal results at 34-36°C, with total gas production of 5,892 mL and methane content of 77.8%. Ren et al. [24] found that mixing dry corn straw with cabbage waste (73% moisture) at a 21:27 ratio could be stored for 60

days, with methane production increasing by approximately 61.67% compared to dry yellow straw alone.

3 Nutritional Composition of Vegetable Waste

Vegetable waste contains relatively high levels of organic matter, including carbohydrates, proteins, crude fiber, lipids, inorganic salts, hemicellulose, cellulose, and lignin. The nutritional content varies by vegetable type, as shown in for selected vegetables and wild rice stem leaf sheaths.

Cabbage is a common vegetable with high demand in autumn and winter and relatively low prices. Its outer leaves and roots are typically removed and discarded as waste. With high moisture content and good palatability, cabbage contains substantial protein and amino acids in its dry matter, making it excellent livestock feed. Lettuce also has high moisture content, low crude fiber, and good palatability, and can be used in livestock diets at appropriate proportions. Wild rice stem and lotus root are aquatic vegetables primarily produced in southern China. In 2008, Yangzhou's aquatic vegetable cultivation area reached 10,866.7 hectares, mainly comprising lotus root and wild rice stem. During summer and autumn harvest seasons, wild rice stem leaf sheaths are removed as waste and easily decompose, causing environmental pollution. However, these sheaths have high fiber content and are suitable as ruminant feed after ensiling. Lotus root has relatively high starch content compared to other vegetables and can serve as a good feed source through appropriate processing. Failure to process these waste materials promptly not only impacts the environment but also becomes a burden for vegetable growers.

Feed processing technologies can transform this waste into valuable resources, alleviating the burden on vegetable growers while developing unconventional feed resources for livestock production.

4 Feed Utilization Technologies for Vegetable Waste

Primary processing methods include silage and feed powder production. Numerous researchers have investigated vegetable waste ensiling. Lian et al. [14] reported that ensiled pineapple leaf waste contained 5.42% crude protein, 20.61% crude fiber, 8.40% crude fat, 0.23% calcium, 0.065% total phosphorus, and pH 3.5. Shao et al. [1] found optimal ensiling results when using a 2:1 ratio of *Lactobacillus plantarum* to *Lactobacillus fermentum*. Qian et al. [30] observed that ensiled wild rice stem leaves showed 6.69% higher crude protein, 5.35% lower dry matter, and 21.18% higher soluble reducing sugar compared to fresh leaves, with no significant changes in acid detergent fiber or neutral detergent fiber. Zheng et al. [31] added 0.2 g/kg cellulase to sugarcane tops during ensiling, and after 90 days found pH increased by 3.6%, lactic acid decreased by 3.0%, dry matter increased by 1.16%, crude ash increased by 15.42%, crude fat increased by 6.2%, nitrogen-free extract increased by 3.2%, crude protein decreased by 7.5%, crude fiber decreased by 3.2%, calcium decreased by 8.8%,

and phosphorus decreased by 28.0% compared to the control. Niu [32] utilized highland summer vegetable waste for feed production, achieving pH 3.8 after ensiling, and found optimal silage quality at a wheat straw to vegetable waste ratio of 1:8 with 0.005% inoculant addition, which reduced neutral detergent fiber content and improved palatability and intake.

Regarding feed powder technology, Xu [20] designed a physical processing system to convert vegetable waste into feed powder. Shen et al. [33] added broccoli stem and leaf powder to duckling diets, finding improved digestion and determining the optimal inclusion rate at 8%. Kuang et al. [34] added mulberry branch and leaf powder to pig diets, finding that 10% inclusion in 60 kg pigs improved pork quality and flavor after 50 days of feeding.

These results demonstrate that ensiling technology enhances feed palatability and nutritional value, while feed powder processing can improve animal digestion and product quality, also providing auxiliary benefits for ensiling vegetable waste.

5 Application of Vegetable Waste Feed in Livestock and Poultry Production

Applying vegetable waste feed in animal production can save feed costs, improve nutritional value and palatability, enhance animal performance and product quality, and reduce feeding expenses. Li et al. [35] fed ruminants with ensiled pineapple leaf waste, achieving good results and demonstrating suitability for pig feeding. When replacing 50% of conventional green feed with pineapple leaf silage for growing and finishing pigs, performance remained normal with good weight gain, while feed cost decreased by 0.35 yuan per kg of weight gain. Ni et al. [36] found that feeding pigs with diets containing enoki mushroom substrate significantly increased weight gain, improved hair coat and skin condition, increased feed intake, enhanced health status, and reduced mortality. Feed cost per pig decreased by 8 yuan, value per pig increased by 11.78 yuan, and net profit per pig increased by 19.78 yuan.

Chen [37] ensiled bamboo shoot waste, increasing dry matter to 23.8%, crude protein to 16.7%, crude fiber to 34.7%, and pH to 3.9. When replacing 20% of concentrate feed with ensiled bamboo shoot waste, Hu sheep achieved the best weight gain at 206 g daily. In beef cattle, replacing barley and wheat with bamboo shoot silage increased average intake by 7.1%, average daily gain by 9.7% compared to control, reduced feed cost by 0.92%, and increased profit by 17.72%. Hu [38] ensiled wild rice stem leaf sheaths, improving both nutritional value and palatability beyond conventional forage. When added to Hu sheep diets, weight gain increased by 7.7% in spring, 11.2% in autumn, and 9.45% annually, with no clinical diseases during the trial period. Niu [32] ensiled highland summer vegetable waste and conducted fattening trials on Tibetan sheep, finding that two treatment groups fed vegetable waste silage showed daily weight gain increases of 8.91% and 15.04%, weight gain rate increases of 11.32%

and 16.42%, and economic benefit increases of 19.37% and 29.30% compared to the control group fed whole corn plant silage.

Lian et al. [14] added 6 kg/head/day of pineapple leaf silage to dairy cow diets, increasing milk yield by 9.7% and milk specific gravity above 26.8°, while saving 10-80 yuan per ton of feed. Liu et al. [39] used ensiled bamboo shoot shells as dairy cattle roughage, improving intake and performance. Qian et al. [30] produced wild rice stem leaf silage with pH 4.52 and total nitrogen 3.71%, increasing weight gain by 7.18% in Tiantai yellow cattle compared to control. Research also indicates that rabbits typically digest less than 40% of dietary crude fiber, while cattle and sheep digest more than rabbits [40].

These findings demonstrate that vegetable waste feed utilization can reduce production costs, improve feed palatability and intake, enhance animal performance, and ultimately increase economic benefits for producers.

6 Conclusion

Vegetable waste is relatively inexpensive and abundant. Converting it into feed can improve utilization efficiency, develop unconventional feed resources, alleviate competition for grain between humans and livestock, and increase economic benefits from vegetable cultivation. Biological processing technologies such as ensiling can enhance feed nutritional value, and feeding processed vegetable waste to livestock can improve weight gain, product yield and quality, and animal health while reducing feeding costs and increasing producer income. Additionally, as waste for vegetable production, processing, and transportation enterprises, vegetable waste is relatively low-cost, and its feed utilization can improve economic returns from vegetable cultivation. Furthermore, enhanced resource utilization of vegetable waste plays an important role in mitigating environmental pollution and improving ecological conditions.

Therefore, feed utilization of vegetable waste shows promising development prospects, though further research is needed to advance processing technologies and feeding applications.

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