Utilizing Zeolite for Nutrient Recovery from Anaerobic Digestate to Enhance the Growth Performance of Choy Sum

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Anaerobic digestion is a cost-effective way to manage food waste, but the liquid byproduct, known as digestate liquor, lacks proper disposal methods at present. This study addresses the challenge of treating anaerobic digestate from food waste, with a focus on effective nutrient recovery using zeolite. Zeolite was employed to successfully recover ammonia nitrogen, potassium, and magnesium elements from anaerobic digestate, resulting in the preparation of solid biofertilizer. Application of this biofertilizer in Choy sum cultivation revealed a significant improvement in both yield and chlorophyll content. The growth of Chinese cabbage showed a noticeable increase, indicating a healthier ecosystem. Furthermore, the enhanced chlorophyll content further validates the positive impact of zeolite-recovered nutrients on plant growth. This research provides a viable solution for anaerobic digestate treatment and underscores the feasibility of utilizing recovered nutrients in the form of solid biofertilizer for agricultural purposes. The approach not only contributes to environmental protection but also offers a sustainable and efficient pathway for fertilizer utilization in agriculture, promoting both environmental sustainability and agricultural productivity.

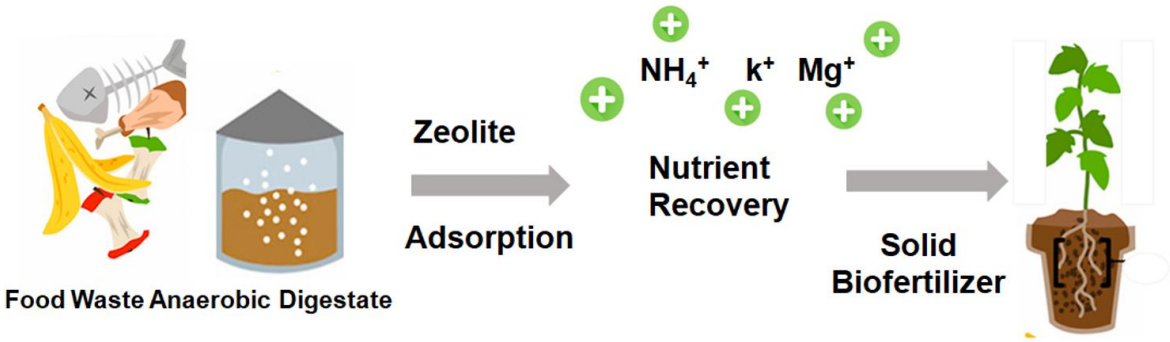

Figure 1. Graphical abstract of utilizing zeolite for nutrient recovery from digestate to improving planting.

As shown in Table 1, the use of zeolite for adsorption treatment of anaerobic digestate significantly increased the concentration of nutrient elements in the zeolites. The adsorption process resulted in a 87.5, 25.8 and 12.9 times increase in the mass fraction of magnesium, potassium, and nitrogen elements in the zeolite, respectively. Correspondingly, the adsorption treatment made the magnesium element in the digestate difficult to detect, while the concentrations of potassium ions and ammonia nitrogen decreased significantly. The above results indicate that zeolite can effectively adsorb nutrient elements from anaerobic digestate. This is likely due to the combined action of zeolite's microporous structure, ion exchange properties, and chemical activity, making it an ideal adsorbent capable of effectively removing nutrients from wastewater.

Table 1. Elemental analysis of zeolite and digestate before and after treatment.

Term	Mg	K	$N(NH_4^+)$
Raw zeolite (%w/w)	0.0004	0.0594	0.07
Zeolite after adsorption (%w/w)	0.0354	1.5924	0.97
Raw digestate (mg/L)	11.2±0.1	1657.4±121.1	1950.7±143.2
Digestate after adsorption (mg/L)	ND	370.5±42.5	563.4±111.2

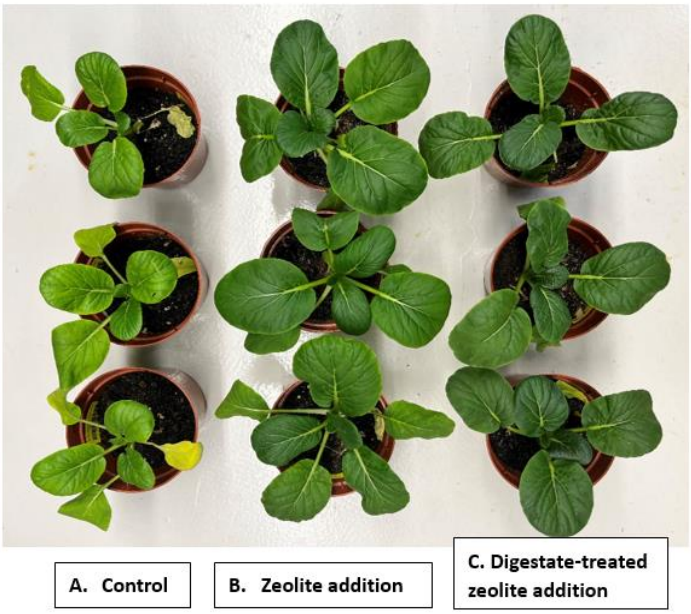

Figure 2. The Choy sum after 14 days cultivated under different conditions.

Using original zeolite and zeolite treated through adsorption as additives at a 10% concentration in the soil, their impact on Choy sum cultivation was investigated, and the results are presented in Figure 2. The control group exhibited yellowing leaves and smaller plants due to nutrient deficiency. In contrast, both zeolite and adsorption-treated zeolite significantly improved the planting performance. The addition of zeolite resulted in greener leaves and significantly larger plants, while the addition of adsorption-treated zeolite intensified the green color of the outer leaves. This improvement may be attributed to the essential nutrients carried by the zeolite after adsorption, enhancing the growth of Chinese cabbage and the synthesis of chlorophyll.

Table 2. Analysis of components of choy sum under different treatment conditions.

Term	Control	Zeolite addition	Digestate-treated zeolite addition
Mg %w/w	0.33±0.11	0.44±0.02	0.68±0.03
K %w/w	3.37±0.72	5.36±0.52	7.65±0.91
N %w/w	1.63±0.11	7.44±0.57	6.87±0.19
Chlorophyll content （SPAD）	39.0±2.4	47.8±1.2	53.3±0.9
Final wet weight (g)	3.26±0.37	7.71±2.79	6.86±1.93

The further analysis of the components of Choy sum, as shown in Table 2, revealed that the addition of zeolite significantly improved the levels of magnesium, nitrogen, and potassium in plant components. Potassium is crucial for the growth and development of plants, while the synthesis of chlorophyll is closely related to magnesium and ammonia nitrogen (Xie, et al. 2021) (Abbas, et al. 2021). Accordingly, under the conditions of adding zeolite treated through adsorption, the chlorophyll content in plants reached its highest level. In light of this, the present study successfully improved plant growth performance by utilizing zeolite to recover nutrients from anaerobic digestate of food waste. Simultaneously, it offers new insights into the treatment of digestate and the preparation of solid biofertilizers, presenting potential research and practical value.

References

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