WEP Warwick Evans Publishing

International Journal of Agriculture and Food Sciences Research

ISSN: 3006-7685 (Print), ISSN: 3006-3736 (Online) | Volume 1, Number 2, Year 2024
DOI: https://doi.org/10.62051/ijafsr.v1n2.01
Journal homepage: https://wepub.org/index.php/IJAFSR/index



The Effect of Hydrothermal Products of Biomass Waste on the Growth of Pak Choi

Chuanyang Xu [1], Jianheng Tang [2,*], Ying Yang [2], Qing Xu [2], Yuting Shi [2], Geng Cao [2]

[1] School of Business Administration, Henan Polytechnic University, Jiaozuo, 454003, China
[2] School of Resources and Environment, Henan Polytechnic University, Jiaozuo, 454003, China

ABSTRACT

To achieve the utilization of biomass waste as fertilizer, this study processed vegetable waste and pig manure using hydrothermal methods and conducted pak choi planting experiments with the products. The results showed that among treatments using vegetable hydrothermal solid products, S210B performed the best in terms of yield and plant height of pak choi, with increases of 29.98% and 15.38% compared to CK, respectively. The nutrient content (NPK) of pak choi was best in the S180B treatment, with increases of 13.17%, 15.87%, and 13.69% compared to CK, respectively. Treatments with hydrothermal liquid products showed significantly better performance in yield, plant height, and stem circumference than those with solid products, with Y210 (30) diluted 30 times showing the best performance. All treatments with pig manure hydrothermal products promoted the growth of pak choi after 60 days of planting, with ZF180 showing the best improvement in all characteristics.

KEYWORDS

Hydrothermal technology; Vegetable waste; Livestock manure

1. INTRODUCTION

Since the late last century, the use of chemical fertilizers in China's agricultural system has grown exponentially. While traditional chemical fertilizers effectively increase crop yields, long-term single use can cause soil compaction, acidification, and other issues, leading to declines in crop yield and quality [1-4], as well as environmental problems such as ammonia volatilization, greenhouse gas emissions, and nitrate pollution [5]. Currently, organic fertilizers show great potential in improving soil environment and crop growth [6-9], reducing the problems caused by excessive use of chemical fertilizers, and reducing organic waste and environmental pollution [10]. Promoting organic fertilizer development has become a fundamental policy in China's agricultural sector [11].

The vegetable industry has been growing in importance, becoming the fourth-largest crop after wheat, corn, and rice. Livestock manure production is vast and complex, with great potential for resource utilization [12]. In earlier years, research on livestock manure resource utilization mainly focused on composting or converting it into feed, but issues such as long composting time, odors, and product quality and safety are inevitable [13]. This study aims to promote the practical application of hydrothermal technology in processing vegetable waste and pig manure by studying the effects of hydrothermal products on the growth characteristics and nutrient content of pak choi seedlings [14].

Content from this work may be used under the terms of CC BY-NC 4.0 licence (https://creativecommons.org/licenses/by-nc/4.0/).
Published by Warwick Evans Publishing.

2. EXPERIMENTAL MATERIALS

The experiment was conducted in the laboratory of the School of Resources and Environment, Henan Polytechnic University. The experimental site is located in the mid-latitudes, with four distinct seasons and a temperate continental monsoon climate. Before the experiment, stones and plant root residues were removed from the soil, which was then air-dried, ground, sieved through a 10-mesh screen, and stored at 4 ℃ for use. The physical and chemical properties of the tested soil are shown in Table 1: The hydrothermal products of vegetable waste and pig manure were solid products at 180 ℃, 210 ℃, and 240 ℃, with basic physical and chemical properties as shown in Table 2.

Table 1. Basic Physical and Chemical Properties of Tested Soil

pH	**EC(mS/cm)**	**Organic matter(g ŀkg-1)**	**Alkali-hydrolyzed nitrogen(mg ŀkg-1)**	**Available phosphorus (mg ŀkg-1)**	**Available potassium (mg ŀkg-1)**
8.3	0.617	7.11	54.6	4.3	115.45

Table 2. Basic Physical and Chemical Properties of Hydrothermal Products of Vegetable Waste and Pig Manure

Treatment	pH	N(%)	P(%)	K(%)	Organic matter(%)	Humic acid(mg/g)
S180B	4.65	3.21	0.37	2.35	65.21	197.80
S210B	4.34	3.18	0.32	2.20	74.27	246.52
S240B	4.28	2.87	0.28	1.99	75.97	219.81
CK1	5.63	4.03	0.43	3.62	82.20	129.86
CK2	6.61	39.63	15.73	5.19	498.00	158.00
ZF180	5.25	29.98	17.47	3.85	599.99	275.12
ZF210	5.52	23.81	17.74	3.39	662.48	226.02
ZF240	5.67	18.32	20.70	2.78	785.95	232.89

Note: S180B, S210B, and S240B represent solid products treated at 180 ℃, 210 ℃, and 240 ℃ respectively. CK1 represents untreated vegetable waste. CK2, ZF180, ZF210, and ZF240 represent untreated pig manure and solid products treated at 180 ℃, 210 ℃, and 240 ℃ respectively.

3. EXPERIMENTAL METHODS

Each pot was filled with 2 kg of nutrient soil and 20 g of material. Hydrothermal products were mixed into the nutrient soil to compare the effects of solid products treated at different temperatures on the growth of pak choi.

Vegetable Waste Hydrothermal Solid Product Treatment Groups:

Treatment 1: 20 g of 180 ℃ product (S180B)

Treatment 2: 20 g of 210 ℃ product (S210B)

Treatment 3: 20 g of 240 ℃ product (S240B)

Treatment 4: 20 g of untreated vegetable waste (CK1)

Application of Hydrothermal Liquid Products: When the pak choi grew to three true leaves and 5-8 cm in height, hydrothermal products were applied every five days, six times in total. The application involved foliar spraying until the leaves were just wet, followed by root drenching until the soil around the pak choi was fully moistened, with harvesting after about 35 days. The products treated at

180 ℃, 210 ℃, and 240 ℃ were diluted 15, 30, and 45 times respectively to study the effects of different concentrations on crop growth.

Pig Manure Hydrothermal Product Planting Method: Pak choi seeds were evenly sown on the soil surface in each pot, covered with about 2 cm of soil. The treatments were as follows:

Treatment 1: 20 g of untreated pig manure (CK2)

Treatment 2: 20 g of 180 ℃ solid product (ZF180)

Treatment 3: 20 g of 210 ℃ solid product (ZF210)

Treatment 4: 20 g of 240 ℃ solid product (ZF240)

4. DATA ANALYSIS

Data were processed using Microsoft Excel and Origin, and statistical analysis was conducted using SPSS 26.0 software. Duncan's new multiple range test was used for multiple comparisons of treatment means, with significant differences analyzed at p=0.05.

5. RESULTS AND ANALYSIS

5.1. Effect of Hydrothermal Products of Vegetable Waste and Pig Manure on the Growth of Pak Choi

Figures 1 and 2 show the growth conditions of pak choi treated with hydrothermal products of vegetable waste and pig manure, respectively. In Figure 1, no significant differences were observed among the treatments, with S210B showing the best growth, indicating that 210 ℃ hydrothermal treatment is most suitable for pak choi growth. In Figure 2, all treatments with pig manure hydrothermal products showed better growth than the CK control group, with ZF180 and ZF210 showing the best growth.

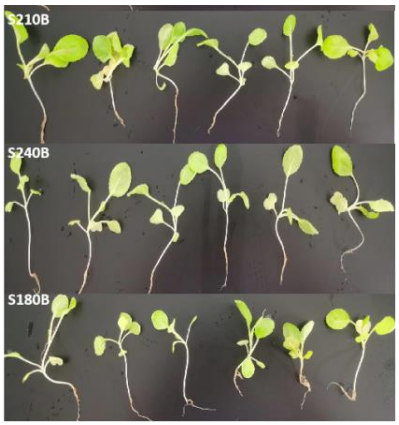


Figure 1. Effect of Vegetable Waste Hydrothermal Products on Pak Choi Traits



Figure 2. Effect of Pig Manure Hydrothermal Products on Pak Choi Traits

5.2. Effects of Pig Manure on the Growth Indicators of Pak Choi Seedlings

Table 3 shows the growth characteristics of pak choi under different treatments. Compared with the CK control group, the fresh weight of pak choi in all treatment groups significantly increased ($P<0.05$), and there were also significant differences among the different treatments ($P<0.05$). The fresh weight of pak choi in the ZF0, ZF120, ZF150, ZF180, ZF210, and ZF240 treatment groups increased by 25.00%, 66.30%, 122.80%, 225.17%, 84.12%, and 39.36% respectively, compared with the CK control group, with the ZF180 treatment group showing the most significant impact on fresh weight. Similarly, the aboveground biomass of pak choi in all treatment groups significantly increased ($P<0.05$) compared with the CK control group, with increases of 25.11%, 66.43%, 122.96%, 225.39%, 84.22%, and 39.45% respectively, with the ZF180 treatment group showing the most significant impact on aboveground biomass. Compared with the CK control group, all treatment groups except ZF0 showed a significant increase in the underground biomass of pak choi ($P<0.05$). Except for the ZF150 and ZF210 treatment groups, there were significant differences among the other treatment groups ($P<0.05$). Compared with the CK control group, the plant height of pak choi in all treatment groups significantly increased ($P<0.05$), with increases of 17.32%, 23.14%, 42.61%, 61.50%, 45.69%, and 37.06% respectively, with the ZF180 treatment group showing the most significant impact on plant height. Similarly, the leaf area of pak choi in all treatment groups significantly increased ($P<0.05$), except for the ZF0 and ZF120 treatment groups, with significant differences among the other treatment groups ($P<0.05$). The leaf area of pak choi in the ZF0, ZF120, ZF150, ZF180, ZF210, and ZF240 treatment groups increased by 14.37%, 18.09%, 40.39%, 104.78%, 67.62%, and 48.12% respectively, with the ZF180 treatment group showing the most significant impact on leaf area. The root length of pak choi in all treatment groups significantly increased ($P<0.05$), with increases of 18.22%, 46.22%, 65.11%, 90.67%, 45.11%, and 41.78% respectively, with the ZF180 treatment group showing the most significant impact on root length. The root weight of pak choi in all treatment groups significantly increased ($P<0.05$), with significant differences among all treatment groups ($P<0.05$). Except for the ZF0 treatment group, there were significant differences in the harvest index of pak choi among all treatment groups compared with the CK control group ($P<0.05$).

Table 3. Growth Characteristics of Pak Choi under Different Treatments

Treatment	Fresh Weight (g)	Biomass (g)		Plant Height (cm)	Leaf Area (cm2)	Root Length (cm)	Root Weight (g)
		Aboveground (g)	Underground(g)				
CK	11.84±0.94g	0.697±0.02g	0.029±0.01e	15.30±0.75e	63.24±1.07f	4.50±0.003e	0.147±0.003g
ZF0	14.80±0.45f	0.872±0.04f	0.040±0.03e	17.95±0.21d	72.33±2.03	5.32±0.012d	0.174±0.001f
ZF120	19.69±1.01e	1.160±0.01e	0.118±0.02d	18.84±0.90d	74.68±1.24	6.58±0.031a	0.751±0.005e
ZF150	26.38±0.63d	1.554±0.03d	0.176±0.01b	21.82±0.12a	88.78±1.09	7.43±0.032c	0.792±0.002d
ZF180	38.50±1.45c	2.268±0.06c	0.559±0.04c	24.71±0.78c	129.50±3.2	8.58±0.054b	2.02±0.001c
ZF210	21.80±0.98b	1.284±0.03b	0.187±0.02b	22.29±0.45b	106.00±1.9	6.53±0.013a	0.607±0.004b
ZF240	16.50±0.33a	0.972±0.01a	0.153±0.01a	20.97±0.22a	93.67±2.31	6.38±0.026a	0.550±0.006a

By analyzing the growth characteristics of pak choi under different treatments in Table 3, it was found that the addition of pig manure and its hydrothermal solid products had a positive effect on the fresh weight, aboveground biomass, underground biomass, plant height, leaf area, root length, root weight,

and harvest index of pak choi. Overall, compared with the CK control group, all treatment groups promoted the growth of pak choi, with the ZF180 treatment group showing the best improvement in all characteristics. This may be due to the highest humic acid content and humification rate of ZF180, which best enhanced the soil's humic acid content, thus positively affecting various traits of pak choi.

5.3. Effects of Hydrothermal Products of Vegetable Waste on the Growth Characteristics of Pak Choi

The effects of different treatments on the growth of pak choi are shown in Figures 6 and 7. Compared with CK, other treatments significantly improved various indicators. In the treatments with solid products, S210B showed the best performance in yield and plant height, with increases of 29.98% and 15.38% compared to CK, respectively. The nutrient content (NPK) of pak choi was best in the S180B treatment, with statistically significant differences ($p<0.05$) compared to CK, increasing by 13.17%, 15.87%, and 13.69%, respectively. Treatments with liquid products showed significantly better performance in yield, plant height, and stem circumference than those with solid products. The treatment group with Y210 (30) diluted 30 times showed the best performance among the diluted products. The treatment with the liquid product diluted 15 times performed worse than the treatment diluted 30 times, possibly due to the higher concentration of the liquid product having some biological toxicity.

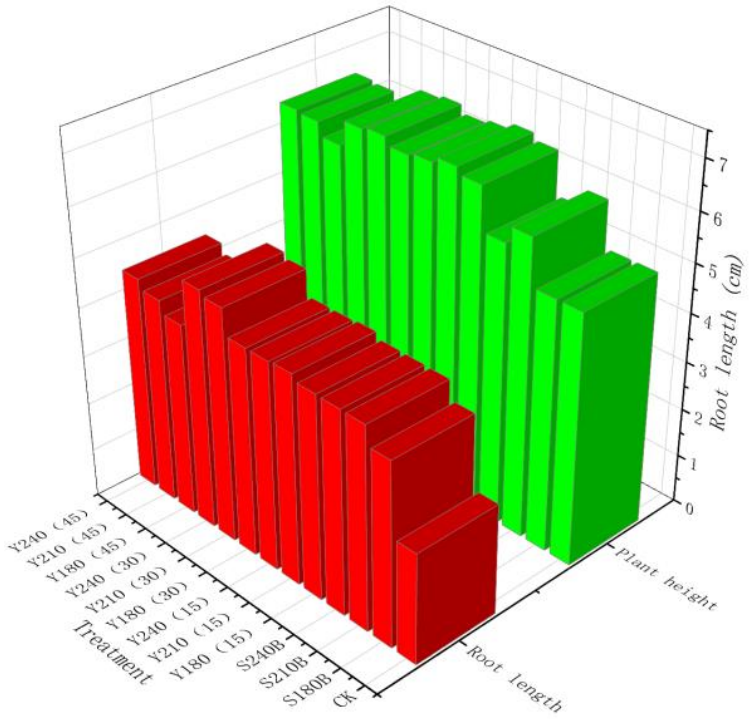


Figure 3. Effects of Hydrothermal Products of Vegetable Waste on Root Length and Plant Height of Pak Choi

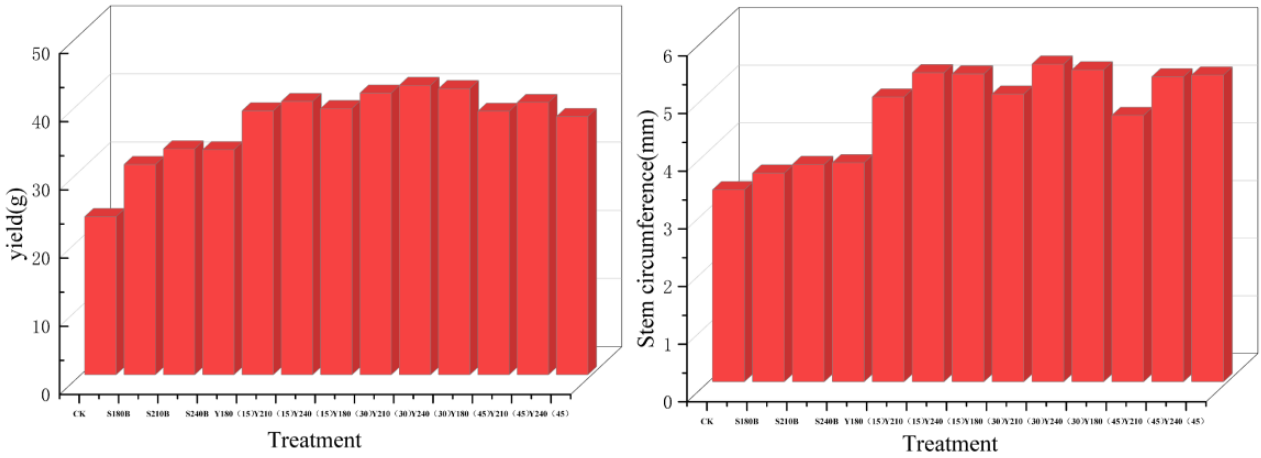


Figure 4. Effects of Hydrothermal Products of Vegetable Waste on Yield and Stem Circumference of Pak Choi

5.4. Effects of Hydrothermal Products of Vegetable Waste on the Nutrient Content of Pak Choi

As shown in Figure 5, the phosphorus and potassium content of pak choi plants treated with liquid products was generally higher than those treated with solid products, but there was no significant difference in nitrogen content between the two treatment methods. Overall, the S210B and Y210 (30) treatments performed the best among the different products. Compared with CK, both treatments showed improvements to varying degrees. Similar to the results of the field experiment mentioned above, the best performance was observed with the 210 ℃ hydrothermal treatment, confirming that the optimal hydrothermal treatment temperature for vegetable waste is around 210 ℃, with the products treated at this temperature having the best fertilizer efficiency.

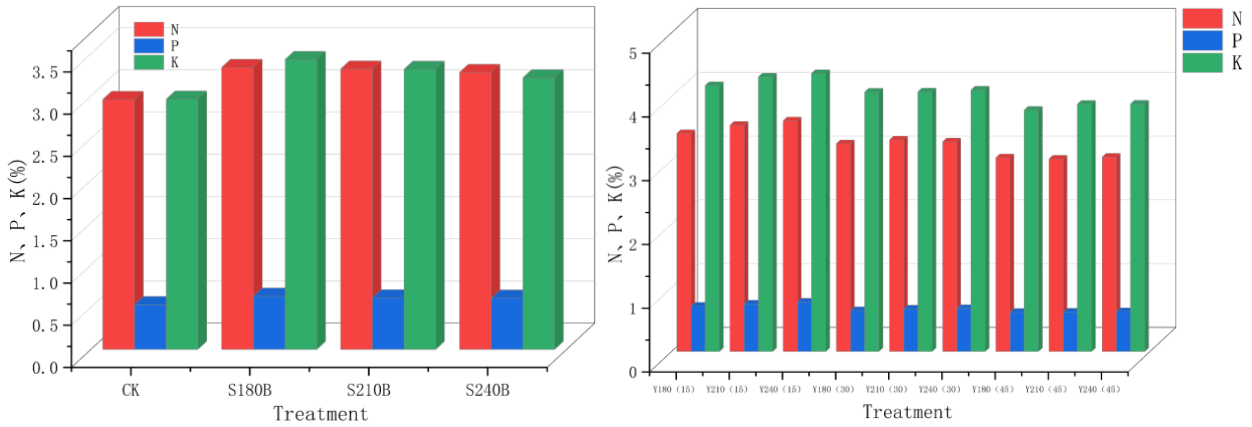


Figure 5. Changes in Nutrient Content of Pak Choi Plants

6. SUMMARY

This chapter mainly studied the effects of hydrothermal products of vegetable waste and pig manure on the growth and nutrient content of pak choi. The results are as follows:

In the solid product treatments, S210B showed the best performance in yield and plant height, with increases of 29.98% and 15.38% compared to CK, respectively. The nutrient content (NPK) of pak choi was best in the S180B treatment, with increases of 13.17%, 15.87%, and 13.69% compared to CK, respectively. Treatments with liquid products showed significantly better performance in yield, plant height, and stem circumference than those with solid products, with Y210 (30) diluted 30 times

showing the best performance. Overall, S210B and Y210 (30) treatments showed the best results among the different products.

After adding pig manure and its hydrothermal solid products, no significant differences were observed in the growth of pak choi among the different treatment groups and the CK control group after about 10 days. After 30 days, the growth of pak choi in the ZF0 and ZF120 treatment groups showed no significant difference compared to the CK control group, while the growth in the ZF150, ZF180, ZF210, and ZF240 treatment groups was better than the CK control group, with ZF180 and ZF210 showing the best growth. After 60 days, the root system of pak choi in all treatment groups was better than the CK control group, with the roots in the ZF150, ZF180, and ZF210 treatment groups being noticeably more robust than the CK control group.

After 60 days of planting, the addition of pig manure and its hydrothermal solid products had a positive effect on the fresh weight, aboveground biomass, underground biomass, plant height, leaf area, root length, root weight, and harvest index of pak choi. Overall, all treatment groups promoted the growth of pak choi compared to the CK control group, with the ZF180 treatment group showing the best improvement in all characteristics. This may be due to the highest humic acid content and humification rate of ZF180, which best enhanced the soil's humic acid content, thereby positively affecting various traits of pak choi.

ACKNOWLEDGMENT

This research was supported by the Henan Science and Technology Project (232102321049).

REFERENCES

[1] Huang Guofeng, Wu Qitang, Meng Qingqiang, et al. Material changes and maturity evaluation of pig manure composting [J]. Journal of South China Agricultural University, 2002(03): 1-4.

[2] Ren Shengnan, Liu Ling, Guo Xiaoping, et al. Effects of different conditioners on the maturity of aerobic composting of two submerged plants [J]. Journal of Environmental Engineering, 2021, 15(11): 3660-3668.

[3] Tang Jiangwu. Screening of efficient bacteria for aerobic composting of pig manure, process optimization and application research [D]. Zhejiang University, 2008.

[4] Qin Yuanyuan, Guo Wenzhong, Li Jing, et al. Research progress on resource utilization of vegetable waste [J]. China Vegetables, 2018(10): 17-24.

[5] Yan H, Cai F, Wang L, et al. Compositional components and methane production potential of typical vegetable wastes [J]. Environmental Science and Pollution Research, 2021, 28: 54177-54186.

[6] Chang Ruixue. Construction of ultra-high temperature composting process of vegetable waste and study on nitrogen loss during the process [D]. China Agricultural University, 2017.

[7] Liu Anhui, Li Jijin, Sun Qinping, et al. Yield, quality and nitrogen effect of vegetable waste compost applied to rape [J]. Chinese Agricultural Science Bulletin, 2011, 27(10): 224-229.

[8] He X, Liu Z, Niu W, et al. Effects of pyrolysis temperature on the physicochemical properties of gas and biochar obtained from pyrolysis of crop residues [J]. Energy, 2018, 143: 746-756.

[9] Lee J T E, Khan M U, Tian H, et al. Improving methane yield of oil palm empty fruit bunches by wet oxidation pretreatment: Mesophilic and thermophilic anaerobic digestion conditions and the associated global warming potential effects [J]. Energy Conversion and Management, 2020, 225.

[10] Ilanidis D, Wu G, Stagge S, et al. Effects of redox environment on hydrothermal pretreatment of lignocellulosic biomass under acidic conditions [J]. Bioresource Technology, 2021, 319: 124211.

[11] Zhou Jiangmin, Dai Jingyu, Pan Genxing. Structural characteristics and environmental significance of water-soluble organic matter in soil [J]. Journal of Agricultural Environmental Sciences, 2003(06): 731-735.

[12] Huang Guofeng, Wu Qitang, Meng Qingqiang, et al. Material changes and maturity evaluation of pig manure composting [J]. Journal of South China Agricultural University, 2002(03): 1-4.

[13] Pu Tianxiang. Resource utilization of pig manure and ecological breeding technology model [J]. Animal Husbandry and Veterinary Science Information, 2021, (12): 19.

[14] Zha Xiangyi. Analysis of resource utilization of livestock and poultry farming waste [J]. Rural Science and Technology, 2018, (02): 110-111.

[15] Fu Qiang, Wang Jingru, Song Haiyan, et al. Research progress on the treatment technology of main pollutants in livestock and poultry manure [J]. Shandong Animal Husbandry and Veterinary, 2024, 45(02): 79-82+86.

[16] Liu Yuan. Exploring the road of resource utilization of livestock and poultry manure: Livestock and poultry manure treatment and comprehensive utilization technology model seminar held in Beijing [J]. China Animal Husbandry, 2016(14): 11-13.

[17] Deng Liangwei, Wu Youlin, Ding Nengshui, He Ting, Liu Yi, Zhang Yunhong. Research progress on energy utilization of livestock and poultry manure [J]. China Biogas, 2019, 37(05): 3-14.

[18] Shi Xiaoxiao, Zheng Guodi, Gao Ding, Chen Tongbin. Total nutrient resources of livestock and poultry manure in China and its potential to replace chemical fertilizers [J]. Resource Science, 2021, 43(02): 403-411.

[19] Li Li, Yang Xinjian, He Jiajun, Jia Dingxin, Wu Hao, Xie Xiangxue. Current status and prospects of resource utilization of livestock and poultry manure in China [J]. China Dairy Cattle, 2020(11): 55-60.