Analytical Chemistry: A Journal (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/analc.2023.020115
ISSN 2616-1958 Vol. 2 Num. 1

The Impact of Brewery Sludge and EM Bacteria Addition on Nutrient Release during the Fermentation of Medicine Herb Residue

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Keywords: Sludge, Medicine Herb Residue, EM Bacteria, Fermentation, Organic Fertilizer

Abstract: The reuse of solid waste resources is beneficial to green circular economy and the protection of ecological environment. Taking the reuse of sludge from a brewery and herb residue from a pharmaceutical company as the research object, our study analyzed the changes of its nutrient contents, such as organic matter, total nitrogen, total phosphorus and potassium during fermentation, by compounding the sludge and residue and adding EM bacteria, and explored the feasibility of using the medicine herb residue and brewery sludge as raw materials to produce ecological fertilizer. The results indication that compared with the control group, the addition of sludge and EM bacteria decreased the organic matter content and increased the total phosphorus and potassium contents. Among them, EM bacteria led to a higher decline in the organic matter content, while the addition of brewery sludge significantly elevated the total phosphorus and total potassium contents. When the ratio of sludge to residue was 1: 2 and the concentration of EM bacteria was 5%, after 50 days of fermentation, the organic matter content was 51.19%, the mass fraction of total nutrients (N+P2O5+K2O) was greater than 4.0%. With a well-proportioned and granular appearance and no odor, the produced ecological fertilizer conforms to the standard for organic fertilizer (NY/T525-2021).

1. Introduction

Medicine herb residue refers to the waste from the production of active pharmaceutical ingredients (APIs), Chinese medicine decoction pieces, and light chemical products containing TCM components. In recent years, with the vigorous development of Chinas big health industry, the demand for Chinese herbal medicines has increased day by day, and hundreds of millions of tons of non-medicinal parts, processing leftovers and liquid residues are produced every year. Statistics have shown that the planting area of TCM materials has grown several times compared with 10 years ago, and the annual output of solid waste of herb residue has also reached 35 million tons

[1-2]. Incineration, stacking, and burial of Chinese herb residue not only causes waste of resources and massive land appropriation, but also triggers secondary pollution to the surrounding environment, seriously restricting the sustainable development of the TCM industry [3]. The residue contains a large amount of crude fiber, crude fat, starch, polysaccharides, proteins, amino acids and trace elements, etc., which can be redeveloped to extract plant proteins or be made into animal feed and ecological fertilizer by micro-fermentation [4]. When the ecological fertilizer produced is applied back to the farmland, not only the utilization rate of herb residue can be raised, but also the content of soil organic matter can be increased, making it one of the main ways advocated by the current low-carbon and green circular economy [5].

As manifested by relevant studies, although the direct fermentation of herb residues into ecological fertilizer results in a high concentration of organic matter, the contents of nitrogen, phosphorus, and potassium are low. At present, a widely accepted approach to produce organic fertilizer is to add various nutrients externally or degrade it together with livestock and poultry manure rich in nitrogen, phosphorus, and potassium and other solid wastes [6]. Rich in organic matter and high in nitrogen and phosphorus, the activated sludge of the brewery can be used to make organic fertilizer. For example, it can be compounded with cottonseed cake and used for bagged composting, mixed with biogas residue for high-temperature composting, with sawdust as the conditioner or composted with chicken manure to reduce odor, etc. Organic fertilizer directly produced from brewery sludge doesn’t contain pathogenic substances like insect eggs, which is used to improve soil for vegetables, wheat, and other crops [7]. Brewery sludge compounded with herb residues can not only make up for the deficiency of nitrogen and phosphorus in ecological fertilizers, but also replenish microbial bacteria. However, the brewery sludge also contains a certain amount of heavy metals and the texture is relatively sticky. So far, there are few reports on whether the organic fertilizer made by compounding the two meets the nutrient standards and safety standards. In this work, by taking the compounding of herb residue and brewery sludge as the research object, we analyzed the changes in different nutrients during the experimental period after the addition of EM bacteria, in the hope of exploring the feasibility of preparing safe, reliable, and nutrient-standard organic fertilizers by compounding these kinds of two solid wastes and delivering data support for the reuse of solid waste resources and the development of green circular economy.

2. Materials and Methods

2.1. Experimental Materials

The experimental materials were the herb residue from a pharmaceutical company (whose main ingredients were mesona, microcos, chrysanthemum, and honeysuckle) and the sludge from a brewery. The nutrient content of raw materials is shown in Table 1:

Table 1: Nutrient Content of the Raw Materials

Material	pH	Organic Matter (%)	Total Nitrogen (g/kg)	Phosphorus (g/kg)	Potassium (mg/kg)
Brewery sludge	7.68	62.09	13.47	8.6	4109.54
Medicine herb residue	7.88	70.9	16.2	2.1	47. 56

2.2. Experimental Design

The herb residue was dried and cut into 1-2 cm pieces. The residue was then mixed with the brewery sludge at a ratio of 1:2, and 5% EM bacteria were added. After that, water was added and thoroughly stirred to control the moisture content of the residue at 60%. The experiment was carried out at 30℃, and fermentation samples were taken every 10 days. The experimental period was 50 days. The collected fermentation samples were dried in a 65℃ oven for 24 h, ground and crushed with a ball mill, and made into residue powder through a 100-mesh sieve and a 60-mesh sieve, which were used to determine pH, and the organic matter content, total nitrogen, phosphorus (P_2O_5), and potassium(K_2O). The ratios and numbers of the raw materials for the fermentation experiment are shown in Table 2:

Table 2: The Ratios of the Raw Materials for Fermentation Experiment

Experimental Group	Sample Ratio	C/N
CK	Residue (control group)	25.39
A	Residue (EM5%)	25.39
B	Residue + brewery sludge (1: 2)	26.23
C	Residue + brewery sludge (1: 2) (EM5%)	26.23

2.3. Data Analysis

The experimental data were processed and analyzed using Microsoft Excel 2016 software.

3. Results and Analysis

3.1. Change of pH Value during the Fermentation

pH value is an important prerequisite for the growth of microorganisms, and too high or too low pH value will seriously affect composting efficiency [8]. As can be seen from Figure 1, the pH value of the four experimental groups varied from 8.16 to 8.29, all of which were first increasing and then decreasing. In the present experiment, the 20th day was a turning point. After the experiment was started, with the increase of days, the pH grew slowly. From the 20^{th} to 30^{th} days, the pH value grew rapidly, and the averages of pH values in CK, A, B, and C were 5.83%, 8.76%, 12.24% and 13.27%, respectively. After the 30^{th} day, it decreased slowly. At the end of the 50-day experiment, the decreasing and increasing trends in the blank control group were small, indicating stable changes. The addition of brewery sludge and EM bacteria had little effect on the pH value during the fermentation.

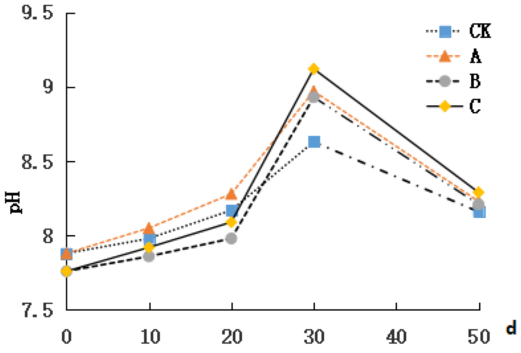

Figure 1: Changes of pH Value during Fermentation

3.2. Changes of Organic Matter during Fermentation

As can be seen from Figure 2, with the passage of time, the overall organic matter showed a downward trend. The order of decrease rates was C (21.28%) >A (19.45%) >B (15.1%) >CK (14.49%). The addition of brewery sludge resulted in a decrease in organic matter content. Compared with the blank control group CK, the experimental group B, which only added sludge without EM bacteria, showed an increase in the degradation rate of organic matter by 0.61%. The experimental group A, which only added EM bacteria without sludge, showed an increase in the degradation rate of organic matter by 4.49%. The experimental group C, which added both sludge and EM bacteria, had the highest degradation rate, surpassing the blank control group by 6.79%.

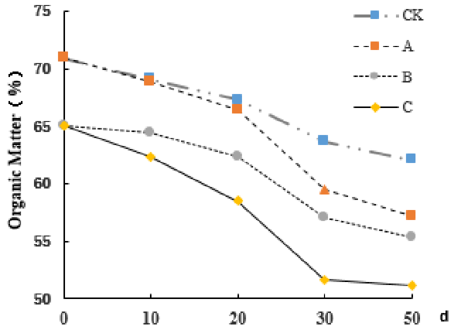

Figure 2: Changes of Organic Matter during Fermentation

3.3. Changes of Total Nitrogen during Fermentation

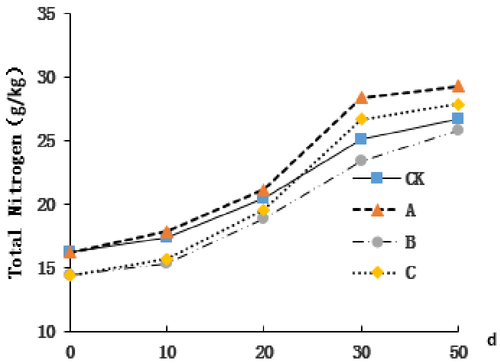

Figure 3: Changes of Total Nitrogen during Fermentation

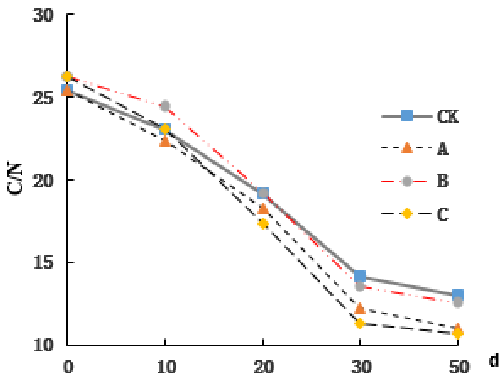

Figure 4: Changes of C/N during Fermentation

As can be seen from Figure 3, the total nitrogen in all four experimental groups showed a slow rise and then tended to level off. The order of nitrogen content from large to small was C>A>B>CK. The total nitrogen content in brewery sludge was lower than that in Chinese herb residue, so at the beginning of the experiment, the total nitrogen content of CK and A was higher than that of Groups

B and C. Compared with the blank control group CK (26.72 g/kg), the total nitrogen content increased after the addition of EM bacteria (experimental group A), reaching 29.26 g/kg at the end of the experiment. The experimental group B, which involved the addition of brewery sludge, exhibited the smallest increase of nitrogen content throughout the experiment, reaching only 25.74 g/kg at the end of the experiment. The experimental group C, which added both brewery sludge and EM bacteria, showed a significant growth in nitrogen content, higher than Group B, but lower than Group A. This suggested that the addition of brewery sludge alone cannot increase the total nitrogen content, but the addition of EM bacteria can accelerate the fermentation process and raise the total nitrogen content.

C/N is one of the important indicators to evaluate compost maturity. The introduction of microbial agents can accelerate compost maturity and shorten the composting time [8-9]. Morel [10] et al. reported that a C/N ratio less than 20 was the only essential condition for compost maturity, and they recommended using T = (final C/N ratio)/(initial C/N ratio) to evaluate maturity. When T was less than 0.6, the compost reached maturity. As can be seen from Figure 4, the C/N ratios in all experimental groups (CK, A, B, C) dropped rapidly with the increase of fermentation time and then leveled off after 30 days. On 20d of the experiment, the T values of the four experimental groups were 0.75, 0.72, 0.73, and 0.66, respectively, indicating that the compost had't reached maturity. On 30d, the T values of the four experimental groups were 0.56, 0.48, 0.52, and 0.43, respectively, indicating that all compost had reached maturity.

3.4. Changes of Total Phosphorus during Fermentation

The variation trend of total phosphorus in all experimental groups is shown in Figure 5.

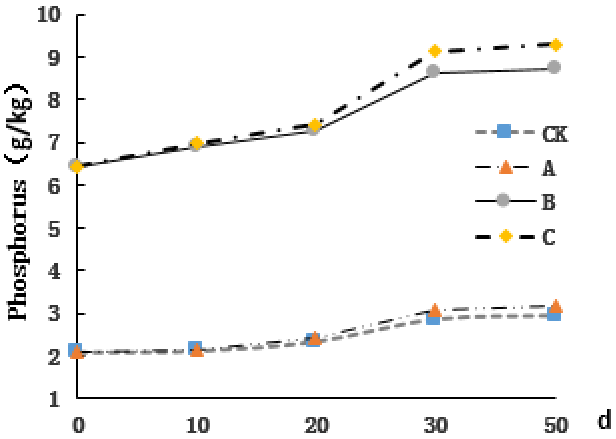

Figure 5: Changes of Total Phosphorus during Fermentation

As can be seen from Figure 5, the initial phosphorus content of the experimental groups B and C was high due to the addition of phosphorus-rich brewery sludge. Compared with the blank control group (CK), the addition of EM bacteria (experimental group A) accelerated the fermentation and raised the total phosphorus content by 0.2 g/kg. The addition of brewery sludge alone (experimental group B) raised the phosphorus content by 2.29 g/kg, while the addition of both EM bacteria and brewery sludge (experimental group C) raised the total phosphorus content by 2.86 g/kg. All of these values were significantly higher than the blank control group (increased by 0.8 g/kg), indicating that the addition of brewery sludge and EM bacteria can increase the phosphorus content, but the addition of EM bacteria yielded the most optimal phosphorus release.

3.5. Changes of Potassium Content during Fermentation

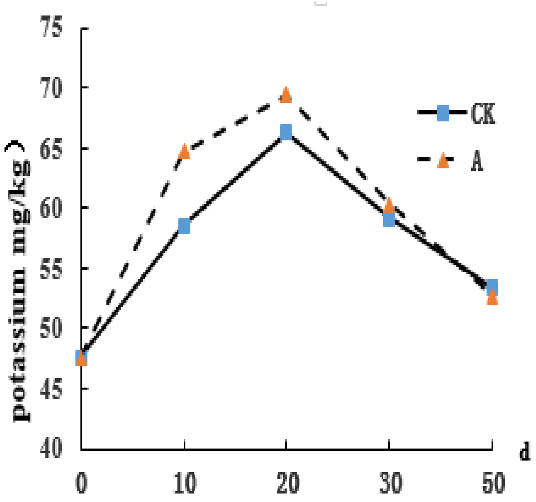

Figure 6: Changes of Potassium in the Experimental Group without Sludge

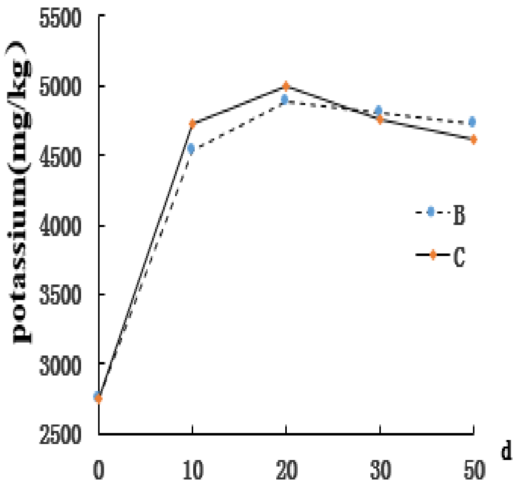

Figure 7: Changes of Potassium in the Experimental Group with Sludge

As can be seen from Figures 6 and 7, CK and sludge showed a trend of first increasing and then decreasing throughout the experiment. From the beginning of fermentation to 20 d, the potassium content grew from 47.56 mg/kg to 66.31 mg/kg, with an increase rate of 39%. The main reason for this increase was that the organic matter in the raw materials was consumed by microorganisms and decomposed into water and CO_2, leading to a rapid decline in its proportion in the raw material and an increase in potassium content. The overall trend of Group A was similar to that of the blank group, but a big difference was that the potassium content grew rapidly from 47.56 mg/kg to 69.36 mg/kg, with an increase rate of 45.84%, from the beginning of fermentation to 20 d. The addition of EM bacteria in Group A accelerated the fermentation and led to a rapid increase in potassium content. Group B, which added brewery sludge showed an overall trend of first rising and then leveling off, and Group C, which added both EM bacteria and brewery sludge, showed a similar trend to Group B.

3.6. Evaluation of Fertility Indicators of Ecological Fertilizer

At the end of the experiment, the fermented raw materials showed a well-proportioned and granular appearance, without odor. The contents of heavy metals, such as arsenic (As), hydrargyrum (Hg), plumbum (Pb), cadmium (Cd), and chromium (Cr) in all groups were lower than those in the Organic Fertilizer Standard (NY 525/T-2021). The pH value and organic matter content of CK, A, and B met the Organic Fertilizer Standard (NY 525/T-2021). However, the mass fraction of total nutrients ($N+P_2O_5+K_2O$) in the experimental group without brewery sludge was less than 4.0% below than the standard. In contrast, the organic matter content, total nitrogen content, total phosphorus content, and potassium content of Group C, which added both brewery sludge and EM bacteria, were 51.19%, 27.82 g/kg, 9.29 g/kg and 4613.15 mg/kg, respectively, and the mass fraction of total nutrients was 4.17%, reaching the Organic Fertilizer Standard (NY 525/T-2021). The data comparison of the experiment is shown in Table 3:

Table 3: Comparison of Fertility Indicators of the Organic Fertilizer Compounded from Brewery Sludge and Chinese Herb Residue (n=3)

Item	NY 525/T-2021 Standard	Measured Value	Measured Value	Measured Value	Measured Value
		CK	A	B	C
Mass fraction of organic matter (%)	≥30	62.05	57.12	55.32	51.19
Mass fraction of total nutrients (N+P2O5+K2O) (%)	≥4.0	2.97	3.26	3.92	4.17
Power of hydrogen (Ph)	5.5~8.5	8.16	8.23	8.21	8.29
Arsenic (As) (mg/kg)	≦15	0.45	0.37	0.34	0.26
Hydrargyrum (Hg) mg/kg	2	0.15	0.16	0.85	0.86
Plumbum (Pb) mg/kg	≦50	6.51	5.90	6.95	10.95
Cadmium (Cd) mg/kg	≦3	0.05	0.06	0.63	0.65
Chromium (Cr) mg/kg	≦150	13.03	13.42	70.57	72.27

4. Conclusion

In this experiment, we demonstrate that the addition of EM bacteria alone can accelerate the fermentation process, stimulate the decomposition of organic matter, and partly promote the release of total nitrogen and total phosphorus. The addition of brewery sludge alone can also facilitate the degradation of organic matter and quickly replenish the phosphorus and potassium content lacking in Chinese herb residue. However, due to the low nitrogen, phosphorus, and potassium contents in the herb residue, producing ecological organic fertilizer directly may make the nutrient content fail to meet the standards and requirements for nitrogen, phosphorus, and potassium nutrients. When the ratio of sludge to residue was 1:2 and 5% EM microbial bacteria was added, there was a noticeable improvement in the degradation of organic matter and a substantial increase in nutrient content. After 50 days of experiment, the nutrient content of the produced ecological fertilizers, including organic matter, nitrogen, phosphorus, and potassium reached the standard, and the heavy metals were within safe limits.

Acknowledgments

This work was supported by the National Innovation Training Program for college students at Jiaying University (Project No. 622A0106), Guangdong Rural Revitalization Strategy funded by Meizhou Science and Technology Bureau in 2021 (2021A0304010).

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