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On the Biochemical Conversion Technology of Edible Fungi Cultivation Waste Based on Microbial Fermentation Process

Qiurong Yang

Quyang county forestry bureau produces deling workstation, Baoding 073100, China
937273085@qq.com

Considering the biochemical conversion parameters of cultivation waste, the secondary development of product substrates and the standardized assessment after conversion of culture substrate waste, this paper takes the cultivation waste of edible fungi as the test materials and studies the microbial conversion of such waste, and then applies the converted culture substrates in the culture of cucumber seedlings. The results show that, when the cultivation waste substrate was treated through microbial fermentation, the temperature inside the substrate changed periodically. The rapeseed cake could promote the growth of the fermenting bacteria and effectively increase their metabolism; and the mixed pearlite in the waste had a positive effect in improving the porosity and water absorption of the culture substrate. The pH value decreased during the initial microbial transformation, because large amounts of organic acids were produced through the metabolism of aerobic bacteria, and then, when the temperature rose, the thermophilic microorganisms began to decompose organic acids, resulting in the continuous rise of the pH value. The higher content of substrate there was in the cultivation waste, the smaller the germination rate would be and the lower the healthy index would be, indicating that the waste substrate contained substances that inhibited seed germination. When the seedlings became adapted to the environment of the cultivation waste substrate, the nutrients in the substrate would facilitate the late-stage growth and development of seedlings.

1. Introduction

The edible fungi (Pleurotus ostreatus, black fungus, lucid ganoderma, coprinus comatus and pleurotus eryngii, etc.) are nutritious and delicious and are thus table food widely eaten in daily life. By nutrition source, they can be divided into wood-rotting fungi and straw rotting fungi. The cultivation waste of edible fungi still contains certain nutrients, but under the traditional cultivation waste recycling technology, the cultivation waste is poorly treated and often cannot be used as the cultivation substrate for edible fungi again (Song and Xuan, 2014; Randive, 2012).

Microbial technology is a newly proposed way to treat edible fungi cultivation waste (Lakshmi and Sornaraj, 2014). Its main process is to use thermoactinomyces to maintain the overall temperature of the waste around 65 ºC so as to remove the contaminating microorganisms from the waste and at the same time convert the humus it and make it more easily absorbed by edible fungi (Li et al., 2016; Philippoussis, 2009). The current methods for microbial treatment of cultivation waste mainly include anaerobic fermentation and thermophilic aerobic fermentation.

In recent years, researchers have found that after microbial treatment, the cultivation waste can be applied not only in the cultviation of edible fungi, but also in the culture of other vegetable seedlings. Examples of successful applications include tomatoes, watermelons, pimiento, lettuce and taro (Ahmad et al., 2011; Sözbir, Bektas and Zulkadir, 2015; Wever and Straatsma, 2005). The results of the studies show that treated cultivation waste can facilitate the growth of vegetables better than regular substrates, and that the healthy index also increased significantly (Chukwurah et al., 2012; Maher, 1994). Therefore, it is of great practical significance to further study the effects of microbially treated cultivation waste in improving the vegetable cultivation results (Pardogimenez et al., 2012). Considering the biochemical conversion parameters of cultivation waste, the secondary development of product substrates and the standardized assessment after conversion of culture substrate waste (Chitamba et al., 2012; Bilal et al., 2014), this paper takes the cultivation

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waste of edible fungi as the test materials and studies the microbial conversion of such waste, and then applies the converted culture substrates in the culture of cucumber seedlings. The research conclusions can serve as theoretical references in the application of microbial conversion technologies for edible fungi cultivation waste.

2. Study of the biochemical conversion of edible fungi cultivation waste

2.1 Test materials and methods

Materials: edible fungi cultivation waste, fermenting bacteria, Chinese cabbage seeds, rapeseed cakes, perlite and related chemical reagents.

With the topsoil removed, the cultivation waste was mixed with other secondary materials. The test was divided into 4 groups - T1 (rapeseed cake 7.5kg, perlite 0kg), T2 (rapeseed cake 7.5kg, perlite 7kg), T3 (rapeseed cake 7.5kg and perlite 14kg) and T4 (rapeseed cake 0kg and perlite 7kg). In these 4 groups, the waste, fermenting bacteria and chemical reagents were the same. The internal temperature of the compost was 55 ºC and the fermentation period 12d. The internal temperature of the compost was measured every 6h, and a certain amount of sample was taken from inside the compost every 24h.

2.2 Test results and analysis

Figure 1 shows the temperature changes inside when the cultivation waste was converted by microorganisms. In the 4 cases, the internal temperature of the waste showed the same overall trend, which can be divided into 3 stages. The first stage was from day 1 to day 5, during which the temperature rose from 20 ºC to 70 ºC and then dropped to 40-50 ºC; at the second stage, the temperature rapidly rose to 70 ºC and then dropped to 40 ºC; at the third stage, the temperature eventually rose to 60-70 ºC. This is because edible fungi produced a lot of heat in the early stage of decomposition, and when the internal temperature of the waste was too high, the oxygen in the compost was not enough for the aerobic bacteria to keep working, and then the temperature started to decline gradually, and after artificial turning, the waste was filled with oxygen again, making the temperature rise again.

It can also be seen from the figure that when the nitrogenous substance (rapeseed cake) was added into the waste, the internal maximum temperature was much higher than that in the case of no rapeseed cake, indicating that the rapeseed cake could promote the growth of the fermentating bacteria and effectively enhance their metabolism.

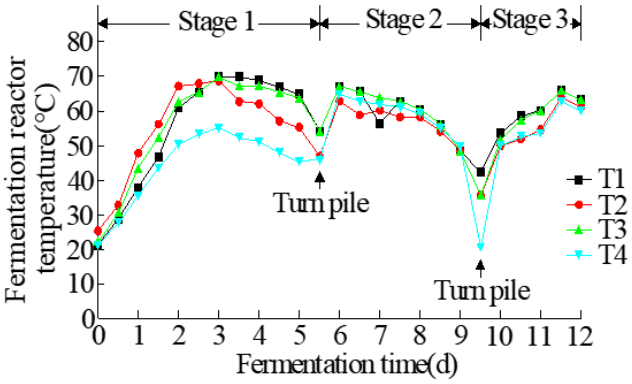

Figure 1: Changes in the internal temperature of cultivation waste

Figure 2 shows the changes in the bulk density of the waste in the 4 cases. As can be seen, after 12 days of fermentation, the bulk density of the waste all increased, but in varying degrees. Except that T1 showed a continuous increasing trend, T2-T4 all saw oscillatory growth. This is because there was not any perlite in T1, while there was in T2-T4, which changed the growth environment and physicochemical properties of the fermenting bacteria.

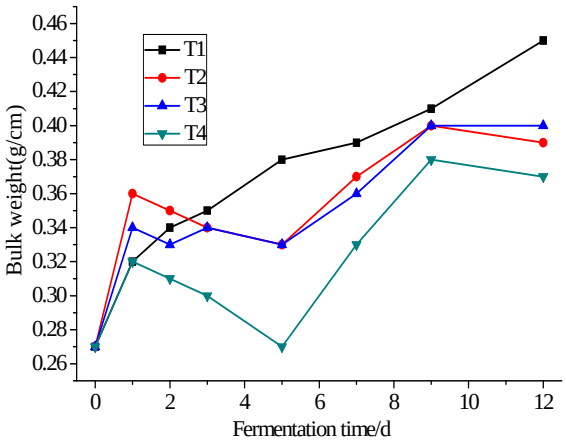

Figure 2: Changes in the bulk density of the cultivation waste

Table 1 shows the changes in the porosity of the waste in T1-T4. It can be seen that the total porosity, water absorption and water-holding porosity in the 4 cases all increased to some extent while the aeration porosity decreased compared with those before fermentation. This shows that the mixed pearlite in the waste had a positive effect in improving the porosity and water absorption of the culture substrate.

Table 1: Changes in the porosity of cultivation waste

	Total porosity (%)	Air gap (%)	Water-holding porosity (%)	Water absorption (%)
Before fermentation	50.91	16.24	37.17	111.97
T1	62.32	12.10	50.88	120.42
T2	66.45	11.98	52.83	128.39
T3	64.61	14.02	52.57	133.94
T4	65.05	15.27	51.55	129.53
Peat	82.99	9.28	74.36	856.28

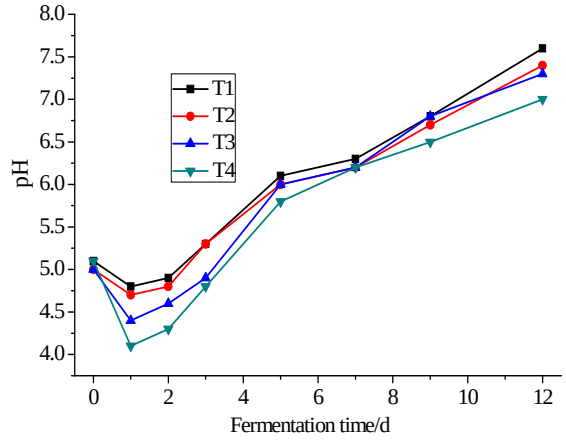

Figure 3: Changes in the pH value of the cultivation waste

Figure 3 shows the changes in the pH value of the waste in the 4 cases. It can be seen that the pH value decreased during the initial microbial transformation, because large amounts of organic acids were produced through the metabolism of aerobic bacteria, and then, when the temperature rose, the thermophilic microorganisms began to decompose organic acids, resulting in the continuous rise of the pH value. Figure 4 shows the changes in the conductivity of the waste in the 4 cases. Overall, the conductivity was gradually increasing. In T4, where there was no rapeseed cake, the conductivity of the waste was the largest, and that in T3 was the smallest. If the conductivity is too high, it will have a negative impact on the plant, so in the actual treatment of cultivation waste, T3 may be used as a reference.

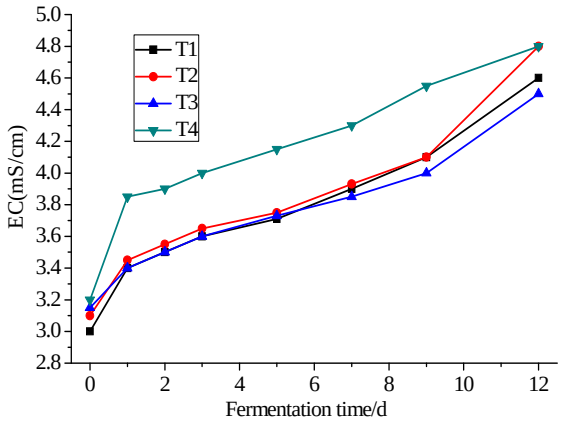

Figure 4: Changes in the conductivity of the cultivation waste

Figure 5 shows the germination rates of Chinese cabbage seeds after T1-T4 treatment. The left white bar shows the germination rate after 7 days of waste leachate culture, and the right black bar shows the germination rate after another 2 days of fresh water culture based on the 7-day leachate culture. CK is the control group with 9 days of fresh water culture. As can be seen from the figure, the germination rate in the case of leachate culture was very low because the waste leachate contained phenols and acids that inhibited the germination of Chinese cabbage seeds. When water was added, the seeds germinated rapidly, and the germination rate reached over 75% in all 4 cases, with the highest rate in T3, indicating that adding pearlite into the waste can increase the germination rate of the seeds.

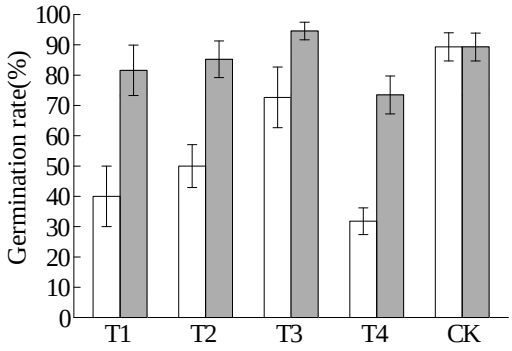

Figure 5: Comparison of the germination rates under different cultivation waste

3. Application of the microbial fermentation of edible fungi cultivation waste in vegetable seedling raising

According to the research results in the previous section, the cultivation waste after microbial fermentation was applied in the culture of vegetable seedlings. There were 6 test groups (S1-S6) and the substrate volume ratio of each group is shown in Table 2. The bulk density, porosity, water absorption and other parameters of the samples in the 6 groups are shown in Table 3. Table 4 shows the effects of cultivation waste substrate on the height of the seedling. It can be seen that the seedlings in the control group grew fastest in the first 30 days, and that the seedling height in the treatment groups (S1-S5) was all smaller than that in the control group in the first 10 days and 20 days, and only close to that in the control group after 30 days. This shows that when the seedlings adapted to the environment of the cultivation waste substrate, the nutrients in the substrate can well facilitate the growth of the seedlings in the late stage. The germination rate of the control group was the highest – up to 98% while the germination rates of S1, S2 and S4 were below 90%. From the test results, it can be seen that, the higher content of substrate there was in the cultivation waste, the smaller the germination rate would be and the lower the healthy index would be, indicating that the waste substrate contained substances that inhibited seed germination, which is consistent with the conclusion drawn in the last section. Table 5 shows the stem diameters of the seedlings under different compound substrates. It can be seen that, after 10 days of germination, the stem diameters of the seedlings in all treatment groups were

smaller than those in the control group; from day 20 on, the difference in the stem diameter between the treatment groups and the control group gradually decreased; and on day 30, the stem diameters of S3 were greater than those of the control group. This indicates that it took a long time for the seedlings to adapt to the cultivation waste substrate, but that once the seedlings became adapted, the absorption rate of nutrients began to effectively increase.

Table 2: Substrate volume ratios of the 6 test groups

	S1	S2	S3	S4	S5	S6	CK
Mushroom biomatrix	3	2	2	2	2	2	0
Vermiculite	2	2	1	2	1	1	1
Peat	0	0	0	1	0	1	2

Table 3: Bulk density, porosity and water absorption of the 6 test groups

	Bulk weight(g/cm^3)	Total voidage (%)	Air gap (%)	Water-holding porosity (%)	Water absorption (%)
S1	0.39	73.6	15.2	60.2	250.1
S2	0.40	72.5	16.9	56.6	266.3
S3	0.21	68.2	23.6	48.7	295.5
S4	0.37	68.4	15.4	52.5	289.0
S5	0.36	79.1	15.8	62.0	311.8
S6	0.27	63.5	14.0	51.3	304.5
CK	0.14	62.9	17.9	45.6	479.9

Table 4: Growth heights of the seedlings in different compound substrates

Sowing time(d)	S1	S2	S3	S4	S5	S6	CK
10	3.87	4.51	5.72	4.69	5.54	6.82	7.37
20	7.33	7.28	7.88	6.79	8.11	9.59	9.70
30	7.68	8.89	9.76	6.83	8.67	11.24	10.66

Table 5: Stem diameters of the seedlings in different compound substrates

Sowing time(d)	S1	S2	S3	S4	S5	S6	CK
10	1.8	2.3	2.6	2.2	2.2	2.5	3.3
20	3.2	4.4	4.0	2.9	2.6	3.7	4.9
30	3.9	4.2	5.3	4.4	3.8	4.5	4.5

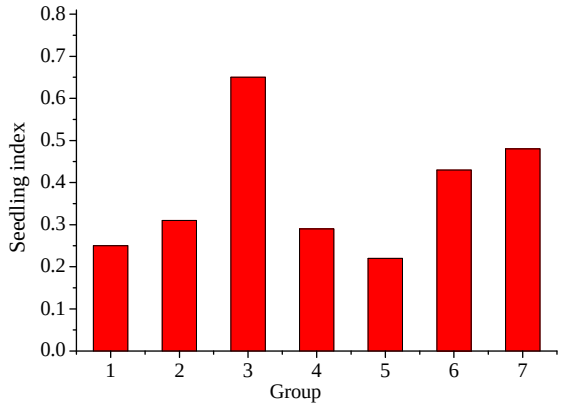

Figure 6: Healthy indices of the cucumber seedlings in different cultivation waste

Figure 6 shows the healthy indices of the cucumber seedlings in different compound substrates. Bar 1-7 in the figure represent S1-S6 and CK, respectively. As can be seen, when the substrate content in the cultivation waste was higher, the healthy index became lower.

4. Conclusions

Considering the biochemical conversion parameters of cultivation waste, the secondary development of product substrates and the standardized assessment after conversion of culture substrate waste, this paper takes the cultivation waste of edible fungi as the test materials and studies the microbial conversion of such waste, and then applies the converted culture substrates in the culture of cucumber seedlings. The research conclusions are as follows:

(1) When the cultivation waste substrate was treated through microbial fermentation, the temperature inside the substrate changed periodically. The rapeseed cake could promote the growth of the fermenting bacteria and effectively increase their metabolism; and the mixed pearlite in the waste had a positive effect in improving the porosity and water absorption of the culture substrate. The pH value decreased during the initial microbial transformation, because large amounts of organic acids were produced through the metabolism of aerobic bacteria, and then, when the temperature rose, the thermophilic microorganisms began to decompose organic acids, resulting in the continuous rise of the pH value.

(2) The higher content of substrate there was in the cultivation waste, the smaller the germination rate would be and the lower the healthy index would be, indicating that the waste substrate contained substances that inhibited seed germination. When the seedlings became adapted to the environment of the cultivation waste substrate, the nutrients in the substrate would facilitate the late-stage growth and development of seedlings.

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