Organic pollution control of agricultural land based on straw biochar

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ABSTRACT

Organic pollution of agricultural land will cause environmental problems and agricultural economic effects. To explore the reliable effect of remediation of organic pollution in agricultural land, wheat straw biochar was prepared in this paper. Moreover, this paper uses experimental research and comparison methods to study the difference in the adsorption of phenanthrene and pyrene microorganisms in soil at the same temperature. Additionally, statistical methods are utilized in this research to do analytics and data processing on test data, and test findings are visually displayed using a combination of graphs and tables. Finally, to understand the relationship between microbial ecosystem structure and soil function, this system employs analytical approaches. The results of the experiment show that wheat straw biochar can effectively reduce soil organic pollution, which can expand the research on the restoration of other crop straw biochar on agricultural land.

Introduction

At present, the environmental effects of biochar on soil at home and abroad are mostly concentrated in the carbon sequestration and emission reduction of biochar and soil improvement. With the deepening of research, the potential of biochar for the remediation of contaminated soil has also aroused great interest in the scientific community (Zwolak et al. 2019). In essence, the bioremediation of contaminated soil is a process of human intervention to contaminated soil, which will inevitably have an impact on soil micro-ecological functions. Studies have shown that there is a close relationship between the ecological functions of soil microorganisms and soil quality, and the soil ecosystem can directly reflect the effects of various environmental factors through changes in the diversity of microbial functions. In recent years, functional genes encoding related enzymes in soil microorganisms have been used as functional markers to understand the relationship between microbial functional diversity information and soil functions, and have developed into another new research direction in microbial ecology. In particular, with the continuous development of molecular biology technology, applying advanced technologies, such as functional genomics and microarray technology, to discover genomic function and evolution information and to explore the relationship between microbial ecosystem structure and soil function from the environmental metagenomic library, has become a new field of re-understanding and evaluation of soil function (Weissmannová and Pavlovský 2017).

In recent years, with the continuous improvement of human food security and carbon sequestration and emission reduction requirements, biochar as a soil carbon sequestration and pollution remediation technology has become the focus of research in soil environmental sciences. The unique advantages of biochar provide new ideas and breakthrough points for contaminated soil remediation. At present, existing studies at home and abroad have shown that the application of biochar in soil can not only improve soil fertility and increase carbon storage time but also has a super adsorption capacity for soil pollutants, which has potential application value in situ ecological restoration of contaminated soil. However, the source of biochar, pyrolysis temperature, application rate, etc. may affect the environmental effects of biochar on the soil. At present, domestic research on the effect of biochar on soil ecosystem functions mainly focuses on biochar fertilisation and adsorption of soil pollutants, but there is a lack of in-depth research on soil microorganisms that can indicate and restore health of soil ecosystems.
Although there are some reports on the biodegradation of soil organic pollutants by biochar, it is very scattered. The impact mechanism, especially the molecular mechanism, is still unclear. It has become a key scientific problem that needs to be solved urgently in the in-situ remediation of contaminated soil by biochar. In this paper, the typical persistent organic pollutant PAHs in contaminated soil was used as the research object to carry out the study of the effect of biochar on soil microorganisms and the mechanism of bioremediation of PAHs pollution. This provides a scientific basis for the development of in-situ bioremediation technology of contaminated soil, clarifies the mechanism and ecological effects of biochar immobilised degrading bacteria to strengthen the restoration of PAHs contaminated soil and provides a scientific basis for the use of biochar for in-situ bioremediation of contaminated soil, so this has important theoretical and practical significance (Kowalska et al. 2018). PAHs (polycyclic aromatic hydrocarbons) are a type of chemical found in coal, crude oil and gasoline. Whenever fuel, oil, gasoline, wood, rubbish and tobacco are burnt, they produce them as well. PAHs produced by such causes have the ability to bind to or create tiny particles in the atmosphere. PAHs are carcinogenic and hazardous substances found in the environment that result from two parts of the process: petrogenic and pyrogenic. PAHs take a long time to degrade, and new research has found significant cumulative quantities in soil, water and the atmosphere. PAHs are mostly produced by human activities, especially inefficient consumption of organic sources (Mi et al. 2010; Zhao et al. 2021).

The degradation of soil organisms and organic fertilisers, reduction in agricultural output and climate science caused by anthropogenic actions all pose serious concerns to the long-term viability of agricultural output. Since the addition of biochar to land as a strategy for improving soil health and where chemical fertilisers have surely played a critical role in enhancing agricultural production. It also can support greenhouse gas mitigation as well as carbon capture and storage. Biochar is extremely stable, which allows it to greatly reduce carbon dioxide emissions from biological breakdown while also regulating the flow of gas and nitrogen dioxide from the soil. Biochar, when applied to the soil, aids in the mitigation of offshore pollution. It focuses on promoting the storage of nutrients in soils, reduces the leaking of fertilisers into aquifers and protects nutrients from runoff due to the surface flowing water (Deepa et al. 2020; Orjuela et al. 2020).

In most situations, the straw would either be burned or thrown away, wasting resources and polluting the environment. For long-term agricultural production, it’s critical to make good use of straw resources. In the presence of large-scale fields, however, restoring the straws to soil is quite challenging. The effects of putting straw or biochar deep into the soil, agricultural yields and greenhouse gas emissions have been extensively observed. As a result, a longer term field study in this locality is required to gain a better understanding of the influence of straw/biochar with inorganic fertilisers on soil physicochemical and biochemical changes.

This article analyses the remediation effect of straw biochar on the organic pollution of agricultural planting soil and explores the feasibility of using biochar to remediate organic pollutants in the future.

Related work

Biochar is a carbon-rich solid produced by low-temperature (<700°C) pyrolysis of biomass such as wood chips, straw, livestock and poultry manure. Its use has a long history, which can be traced back to the slash-and-burn farming period, such as the Amazon black carbon soil formed thousands of years ago (Shi et al. 2017). However, as a multifunctional material, the great potential of biochar in soil improvement and ‘carbon sequestration’ has only recently attracted attention. Compared with raw material biomass, biochar is not easy to be oxidised/degraded by organisms and non-biological organisms, it can exist in the soil for a long time, and its half-life is as long as hundreds of years to millions of years (Delang 2017). The biochar added to the soil can also suppress the emission of greenhouse gases N2O and CH4 (Askari et al. 2020). At the same time, the pores of biochar are well developed, which can improve the permeability and water holding capacity of the soil (Salman et al. 2019), and provide a habitat for soil animals (Zhou and Liu 2018). Moreover, the alkaline components rich in biochar can slow down the pH of acidic soils (such as red soil), change the form of dissolved aluminium in the soil and reduce the toxicity of aluminium to plants (Pacwa-Plociniczak et al. 2018). The K, Ca, Mg and other elements on biochar can provide nutrients for the growth of plants and microorganisms and enhance the metabolic activities of microorganisms around crop roots (Mombo et al. 2018). At the same time, the acid–base groups on the surface of biochar endow biochar with high cation exchange capacity, which can improve the retention and use efficiency of nutrients by the soil (Terekhova et al. 2017). Biochar is not only an excellent additive for improving the structural properties of soil and enhancing soil carbon sequestration, it is also expected to become a new type of soil pollution control and remediation material. Studies have shown that the ability of
biochar to adsorb organic pollutants is much stronger than that of soil (Maslennikov et al. 2018). By adding a small amount of biochar (≤5%) to the contaminated soil, the concentration of organic pollutants in the pore water of the soil can be effectively reduced, and the mobility of pollutants and their accumulation in plants and animals can be reduced. Therefore, the addition of biochar in the soil is a potential in-situ remediation technology for organically contaminated soil.

In view of the role of black carbon in regulating organic pollution, after biochar, as a kind of artificially prepared black carbon material, was proposed for soil carbon sequestration and soil improvement, its application potential in soil pollution control immediately attracted attention. Wu et al. (2019) reported the adsorption effect and mechanism of biochar on polar and non-polar organic pollutants. Renx et al. (2018) found that the biochar prepared after the pyrolysis of cow dung can not only effectively adsorb atrazine (a toxic pesticide), but also has a strong adsorption effect on lead ions in the aqueous solution. By summarising the previous studies on the adsorption and fixation of organic and inorganic pollutants in soil, Morariu et al. (2018) affirmed the potential application value of biochar in the restoration of organic and inorganic contaminated soil. At the same time, it pointed out that the long-term effects of biochar on the interception and release of pollutants in the soil and the impact on soil organisms are still unclear, and it is necessary to clarify the ecological sustainability of biochar in the control of environmental pollution. Chen et al. (2017) found that biochar can promote the bioremediation of soil contaminated by polycyclic aromatic hydrocarbons.

Biochar is a solid product produced by the pyrolysis of biomass. Its raw materials have a wide range of sources, including woody biomass (such as pine, oak, fir), straw biomass (such as rice straw, corn stalk, wheat straw), and livestock and poultry manure biomass (such as cow manure, chicken manure, pig manure) and other waste biomass (such as algae, sludge) (Holdaway and Wuyi 2018). After biomass undergoes pyrolysis treatment and incomplete combustion reaction, its biopolymer components (such as hemicellulose, cellulose, lignin) are decomposed by heat, and the cracked gas and bio-oil are synthesised and released. The solid product produced by cracking is the carbon-rich biochar particles (Fang et al. 2017). Generally, the complete pyrolysis process of biomass is divided into three steps. The first step is loss of water and a small amount of volatile components. The second step is that the biomass is cracked to produce biochar, volatile components and gases. The third step is the slow decomposition of biochar to produce volatile components and cracked gas, while the biochar itself undergoes chemical reconstruction to form a carbon-rich solid (Nishimura et al. 2018). Biochar is blackened, very permeable, compact, fine-grained and also has a large surface area in terms of physical appearance. Carbon makes up over 70% of its structure. Nitrogen, oxygen and carbon, among some other elements, make up nearly percent (Maslennikov et al. 2018). As the pyrolysis temperature increases, the hemicellulose, cellulose and lignin components in the original biomass are decomposed successively (Awa and Hadi-Barata 2020). The hydrogen bond between lignocellulose is broken, the carboxyl, hydroxyl and other polar groups are gradually eliminated, and the fatness is weakened (Oumenskou et al. 2018).

**Test materials and test methods**

We use wheat straw as the biomass raw material to prepare biochar under the pyrolysis temperature of 100–700°C. Wheat straw refers to the stalk that remains after the wheat grains have been gathered. This has been seen as garbage. Farmers in some places burn it, producing to air pollution and endangering human safety. These stalks, on the other hand, are still valuable. In the agricultural industry, efficient crop straw use is a determining element for cleaner production and long-term development. Straw has indeed been identified as a possible source of agriculture waste. Nevertheless, in many parts of the world, open-field straw combustion has always been the primary method, resulting in resources waste and poor air quality.

(1) Raw material for preparing biochar: wheat straw.
(2) Carbonisation temperature for preparing biochar: 100–700°C.
(3) Preparation process: Naturally dried wheat straws are washed four times with distilled water. After air-dried for 2 days, it was dried in an oven at 70–80°C for 12 h, and then pulverised with a grinder. Afterwards, the prepared wheat straw powder was placed in a brown bottle with a stopper and placed in a dry environment for use.

An appropriate amount of wheat straw powder is filled in the crucible, compacted and the crucible lid is covered (note that the crucible lid must be placed on the upper edge of the crucible body to avoid air ingress as much as possible). Then, the crucible filled with biomass powder was weighed and placed in the muffle furnace. After that, the temperature is raised to 100°C, 200°C, 300°C, 400°C, 500°C, 600°C, 700°C at a heating rate of 20°C/min, and it is carbonised for 4 h. After the temperature has cooled to room temperature, we take it out. After that, we weigh the biochar and pour...
Biochar is a product obtained from the oxygen-limited pyrolysis of biomass. The yield, ash content, and element composition of the biochar obtained from the pyrolysis of wheat straw biomass powder at different temperatures (100–700°C) are shown in Table 1, and the elements and contents are shown in Figure 1. The highest breakdown of wheat straw happened at a particle diameter with a large surface area and low pyrolysis dispersion barrier. Large particle diameter sample yielded the highest char output. The effect of various parameters on the depolymerisation of wheat straw particles, such as particle diameter, initial weight of the samples and temperature range, was explored using analysis. The results showed that with the increase of pyrolysis temperature, the pH of biochar showed an increasing trend. Depending on the starting species of plants and the manufacturing temperatures, the pH of biochar can fluctuate from 4.6 to 9.3. In general, when the temperatures of biochar formation rise, the pH of the produced biochar rises as well. When the pyrolysis temperature is higher than 100°C, it is weakly alkaline, and the yield of biochar gradually decreases, from 93.4% (100°C) to 25.1% (700°C). Among them, when the pyrolysis temperature rises from 200°C to 300°C, the biochar yield drops the fastest. The decrease was 37.4%. Followed by 100°C→200°C, the decrease is 16.6%. The reason may be the decomposition of hemicellulose, the dehydration reaction of bound water and some macromolecular groups. At 600°C→700°C, the loss is small (a difference of 0.4%). With the increase of pyrolysis temperature, the ash content in biochar shows an increasing trend, from 5% (100°C) to 18% (700°C). After ash correction, the contents of C, H, N, O in different types of biochar are shown in Table 1. In addition, with the increase of pyrolysis temperature, the C content of organic components in biochar gradually increased, from 45.1% (BC100) to 72.7% (BC700). However, the H and O content gradually decreased, the H content decreased from 7.5% (BC100) to 2.5% (BC700), and the O content decreased from 45.92% (BC100) to 23.2% (BC700). It shows that the heating and oxygen-limited pyrolysis process of wheat straw is a process in which organic components are rich in carbon and functional groups are depolarised. The atomic ratio H/C, O/C and (N+O)/C of the organic components in biochar reflect the aromaticity, hydrophilicity and polarity of the biochar sample, respectively. From the calculation results in Table 1, it can be seen that as the pyrolysis temperature increases, the atomic ratios of organic components in biochar, H/C, O/C and (N+O)/C, all gradually decrease. It can be seen that the heating pyrolysis process of wheat straw is a process in which the hydrophilicity and polarity are weakened, and the aromaticity is enhanced.

The specific surface area and pore structure of the biochar are analysed by the BET specific surface area analyser, and the specific surface area, pore volume, and pore size of the biochar at different pyrolysis temperatures are measured as shown in Table 2. To assess gas adsorption behaviour and provide a specific surface area estimate stated in terms of area per mass of the sample, the BET theory is often employed. Several reliable sources have endorsed the approach. The BET theory tries to describe the adsorption process of gas particles on a solid surface and serves as a foundation for a crucial analysis technique for calculating the specific surface area of substances. During the pyrolysis of wheat straw, as the pyrolysis temperature continues to increase, the total specific surface area, micropore surface area and external surface area, micropore volume, mesopore volume, and total pore volume of biochar generally increase. Trend, the overall average pore size shows a decreasing trend. In particular, when the pyrolysis temperature changes from 400°C→500°C→600°C, the specific surface area of biochar has a sudden change, the total specific surface area changes from 1.82 m²/g→48.8 m²/g→226.5 m²/g, and the micropore surface area changes from 1.82 m²/g→48.8 m²/g→226.5 m²/g, 1.662 m²/g→38.745 m²/g→195.358 m²/g, the external surface area changes from 0.149 m²/g→9.989 m²/g.

### Table 1. Yield, ash content and element composition of biochar.

| Sample | BC100 | BC200 | BC300 | BC400 | BC500 | BC600 | BC700 |
|--------|-------|-------|-------|-------|-------|-------|-------|
| Ash (%)| 5%    | 6%    | 10%   | 12%   | 13%   | 15%   | 18%   |
| Yield  | 94.30%| 77.55%| 39.79%| 52.69%| 67.17%| 66.83%| 71.15%|
| pH     | 6.67  | 7.19  | 8.06  | 8.39  | 8.63  | 8.87  | 9.21  |
| C%     | 45.48 | 52.69 | 67.17 | 66.83 | 65.39 | 71.15 | 73.39 |
| H%     | 7.49  | 6.84  | 5.23  | 4.48  | 3.26  | 2.81  | 2.45  |
| N%     | 1.65  | 1.49  | 1.68  | 1.66  | 1.66  | 1.74  | 1.83  |
| O%     | 46.38 | 39.98 | 26.93 | 28.18 | 30.68 | 25.30 | 23.33 |
| (N+O)/C| 0.81  | 0.60  | 0.32  | 0.34  | 0.37  | 0.29  | 0.26  |
| O/C    | 0.77  | 0.58  | 0.35  | 0.32  | 0.35  | 0.27  | 0.24  |
| H/C    | 2.00  | 1.58  | 0.94  | 0.82  | 0.61  | 0.47  | 0.40  |
The total specific surface area of biochar, which is much larger than its external surface area, indicates that there are a large number of internal pores. With the increase of pyrolysis temperature, the micropore volume and total pore volume will change suddenly, and the micropore volume will change from 0.001 cm$^3$/g to 0.020 cm$^3$/g, and the total pore volume changes from 0.007 cm$^3$/g to 0.025 cm$^3$/g. The proportion of micropore volume changes from 10.09% to 77.93%, and the mesoporous pore volume changes little. It can be concluded that the abrupt changes in specific surface area and pore volume are mainly caused by the large number of microporous structures. The changes in the specific surface area and pore volume of the micropores are consistent with the results obtained from the nitrogen adsorption–desorption curve. When the pyrolysis temperature is ≤400°C, the number of micropores in the prepared carbon is small, and when the pyrolysis temperature >400°C, the carbon number of micropores in the mass increased significantly. It can be seen that the pyrolysis temperature of 400°C is the turning point of the change in the pore structure of wheat straw biochar. It is calculated that when the pyrolysis temperature is ≥500°C, the micropore volume in the prepared biochar accounts for more than 75% of the total pore volume. Therefore, as the pyrolysis temperature increases, the increase in the number of pores in the biochar is mainly due to the increase in the number of pores in the micropores, resulting in a gradual decrease in the average pore size of biochar. The changes in the specific surface area and pore structure of biochar are mainly due to the loss of aliphatic and unstable components in wheat straw biomass with the increase of pyrolysis temperature, and the conversion of amorphous carbon in biochar into crystalline carbon.
temperature range of 400–600°C, the sudden jumps in the specific surface area and pore volume of biochar are mainly caused by the massive decomposition of cellulose, hemicellulose and fat components of wheat straw during the pyrolysis process.

The pore size distribution of biochar prepared at different pyrolysis temperatures is shown in Figure 2. It can be seen that the microporous structure formed by BC100–BC400 is less, and the structure is mainly mesoporous. As the pyrolysis temperature continues to increase, the micropores in biochar increase. In particular, the pore size of high-temperature biochar BC500–BC700 is mainly concentrated in the range of 1.8–1.9 nm. In addition, according to the measurement results of mesopore volume, micropore volume and total pore volume, it can be seen that the macropore volume of BC100 is $6.1 \times 10^{-4}$ cm$^3$/g, and the macropore volume of BC600 is $9.2 \times 10^{-3}$ cm$^3$/g, the macropore volume of BC700 is $1.16 \times 10^{-2}$ cm$^3$/g, and the macropore volume of high-temperature pyrolysis carbon BC600 and BC700 is significantly higher than that of low-temperature pyrolysis carbon.

Based on the above analysis, the effect of straw biochar on the remediation of organic pollutants in agricultural soil can be analysed. The whole experiment was carried out under the conditions of flooding, avoiding light and a constant temperature of 25°C. There are five treatment groups in the experiment: control group (SD), biochar BC100 treatment group, biochar BC300 treatment group, biochar BC500 treatment group and biochar BC700 treatment group. Each treatment group contains nine and three samples from each treatment group are taken as parallel samples at each sampling time. The specific experiment process is as follows.

First, we use an electronic balance to accurately weigh 30 g of poisonous soil and 0.6 g of biochar at different carbonisation temperatures into the bottle, slowly inject aerated distilled water and soak for 15 min, and ensure that the soil in each sample bottle is in a flooded state. After that, we use tin foil to protect from light, place it in an artificial climate box, control the temperature at $(25 \pm 1)$°C, and regularly replenish water to keep the sample in the bottle in a flooded state. The system is running for 36 days, and samples are taken for analysis on day 0, day 6, and day 36 respectively. Some of the collected soil samples are used to determine the PAHs content in the pore water, and the rest of the soil samples are freeze-dried for 24 h, ground through an 80-mesh sieve, and stored in a refrigerator at $-20$°C for further analysis. PAHs can be found in a variety of stages such as water, suspended material, colloidal materials, and sedimentary solids. With the exception of naphthene, increasing the sodium levels diminishes the extraction efficiency of all PAHs. The effects of salinity on solvent removal efficiencies are believed to be linked to the analytes' soluble and polarisation. Phenanthrene, like most PAHs, is often used to create colours, polymers, insecticides, bombs, and pharmaceuticals. Bile acids, cholesterol, and corticosteroids have all been made with it.

**Test results**

The degradation rate data of phenanthrene and pyrene in different treatment groups were calculated by calculation as shown in Table 3 and Figure 3. At the end of the experiment, the degradation rates of phenanthrene and pyrene in the control group are 34.95% and 26.6%, respectively, which are significantly higher than the BC300 and BC500 treatment groups ($p < 0.05$). It can be seen that the addition of these two kinds of biochar has a strong fixing effect on the PAHs in the soil and inhibits the degradation of organic matter in the soil. The degradation rate of phenanthrene and pyrene in the BC100 treatment group is higher than that in the BC300 and BC500 treatment groups ($p < 0.05$).
This may be due to the lower adsorption performance of BC100 and weaker ability to fix organic matter compared with the latter two. However, the degradation rates of phenanthrene and pyrene in the treatment group added with high-temperature pyrolysis biochar BC700 were 30.2% and 20.1%, which were similar to the control group ($p > 0.05$), and significantly higher than the BC300 and BC500 treatment groups ($p < 0.05$). From the previous adsorption performance results, it can be seen that BC700 has a stronger fixation capacity for organic matter phenanthrene and pyrene than lower temperature pyrolysis charcoal, but it does not significantly inhibit the degradation of organic matter after it is added to the soil.

From the concentration of bioavailable and unavailable PAHs in different treatment groups, it can be seen that the content of bioavailable phenanthrene and pyrene in all treatment groups gradually decreased over time. In the three samplings, the biochar BC700 added biochar in the treatment group The contents of available phenanthrene and pyrene were significantly lower than other treatment groups ($p < 0.05$). At the end of the experiment, the content of bioavailable PAHs in the treatment group added with BC700 was the lowest ($p < 0.05$), followed by the BC500 treatment group ($p < 0.05$). It is calculated that at the end of the experiment, the addition of higher temperature pyrolysis biochar has a better effect on reducing the bioavailability in the soil than lower temperature pyrolysis charcoal. In addition, from the results of changes in the content of effective phenanthrene and pyrene, it was found that the reduction of effective phenanthrene was greater than that of effective pyrene. The study found that when activated carbon was applied to the sediment, the reduction in bioavailability to naphthalene was significantly higher than that of phenanthrene, showing PAHs The molecular structure and properties of biochar have a certain influence on the adsorption of biochar. During the experiment, the proportion of bioavailable PAHs in different treatment groups changed as shown in Table 4 and Figure 4 and Figure 5. In the treatment group with the addition of biochar, the proportion of bioavailable PAHs in the total decreased significantly ($p < 0.05$), and the decline was mainly concentrated in the first 6 days. Correspondingly, the proportion of bio-unavailable PAHs gradually increased; while the proportion of bio-available PAHs in the control group decreased less with time ($p < 0.05$). According to calculations, the content of bioavailable phenanthrene and pyrene in the control group during the experiment was more than 75% of their total, which is the main form of PAHs in the soil, indicating that the bioavailability of PAHs is high. At the same sampling time, the proportion of bio-available PAHs in the treatment group added with BC700 was the smallest ($p < 0.05$), followed by the BC500 treatment group ($p < 0.05$), and the proportion of bioavailable PAHs in the BC300 and BC100 treatment groups was slightly higher. In the control group ($p < 0.05$), in general, the higher the pyrolysis temperature, the lower the proportion of bioavailable PAHs in the biochar treatment group. From the changes in the content and proportion of bioavailable PAHs in the charcoal treatment group in Table 4, it can be concluded that the application of biochar has a strong fixing effect on the PAHs in the soil, and can promote the conversion of organic matter in the soil from bioavailable state to biologically unavailable state. In the utilisation state, the higher the pyrolysis temperature of the biochar, the better the effect of reducing the bioavailability of organic matter.

### Table 4. Changes in the proportion of bioavailable PAHs in different treatment groups.

| Proportion (%) | 0 days | 6 days | 0 days | 6 days | 0 days | 6 days |
|----------------|--------|--------|--------|--------|--------|--------|
| sampling time  |        |        |        |        |        |        |
| SD             | 89.67  | 63.58  | SD     | 89.67  | 63.58  | SD     |
| BC100          | 78.05  | 66.49  | BC100  | 78.05  | 66.49  | BC100  |
| BC300          | 74.18  | 53.66  | BC300  | 74.18  | 53.66  | BC300  |
| BC500          | 75.72  | 43.51  | BC500  | 75.72  | 43.51  | BC500  |
| BC700          | 46.03  | 26.49  | BC700  | 46.03  | 26.49  | BC700  |
The activity of polyphenol oxidase in different treatment groups is shown in Table 5 and Figure 6. On the 36th day of the experiment, although the polyphenol oxidase activity in the control group decreases, the difference is not significant ($p > 0.05$), which may be related to the stable soil environment. At the end of the experiment, the activity of polyphenol oxidase in the BC100, BC300 and BC500 treatment groups was significantly reduced ($p < 0.05$), while the BC700 treatment group had no significant change ($p > 0.05$). At the end of the experiment, the activity of polyphenol oxidase in the BC700 treatment group was significantly higher than that in the other charcoal treatment groups ($p < 0.05$), but there was no significant difference compared with the control group ($p > 0.05$). This shows that compared with other temperature biochar, the degradation activity of microorganisms in the BC700 treatment group is higher, and the degradation degree of PAHs is higher.

The addition of biochar can reduce the concentration of bioavailable phenanthrene and pyrene in the soil, and reduce the concentration of dissolved phenanthrene and pyrene in soil pore water. Moreover, the higher the pyrolysis temperature, the more significant the effect of biochar, which indicates that the addition of biochar can reduce the bioavailability of PAHs in the soil, thereby reducing the toxic effects of organic pollutants on organisms.

Biochar has a huge specific surface area and pore volume, and the surface of the charcoal is weakly polar, highly aromatic and hydrophobic. These superior structural characteristics all determine its strong adsorption performance and larger adsorption capacity for hydrophobic non-polar organics phenanthrene and pyrene. High-temperature pyrolysis biochar has a huge specific surface area, which makes it have a large adsorption capacity for PAHs. Moreover, the high aromaticity and low polarity of its surface can well fix the adsorbed PAHs, so that it is not easy to be desorbed. These structural characteristics of biochar lead to the reduction of the effective PAHs content in the soil and keep it at a low level.
There are differences in the degradation degree of PAHs in different treatment groups. The addition of low-temperature pyrolysis charcoal (BC100, BC300, BC500) will inhibit the degradation of PAHs in the soil to a certain extent due to its fixing ability. However, although the addition of BC700 has a stronger ability to fix organic matter, it does not significantly inhibit the degradation of PAHs in the soil, which indicates that the fixed organic matter can still be degraded to a certain extent.

The results of preliminary experiments found that the removal rate of PAHs in the sterilisation group added with the corresponding biochar was very low and could be ignored. Therefore, abiotic effects were not the main reason for the removal of PAHs in the soil, and microbial degradation was the main way. Although most studies believe that microorganisms can only use PAHs that are soluble in water, there are also studies that have shown that microorganisms can use adsorbed organic matter and have a stronger ability to degrade them. Under the same other conditions, there are differences in the degradation effect of biochar treatment groups with different pyrolysis temperatures, which may be related to the structural properties of biochar.

In addition to enriching organic pollutants, the developed pore structure and huge specific surface area of biochar can also provide more attachment sites and larger living space for the survival of microorganisms. Due to the large size of microorganisms and their sizes are generally micron-sized, if the microorganisms want to enter the pores of biochar to use the enriched nutrients, the pore size of the biochar should be two to five times larger than the size of the microbial cells. The higher the pyrolysis temperature, the more fully the carbonisation effect of the biochar is. The high-temperature pyrolysis biochar BC700 has become a hollow structure due to the full carbonisation. At the same time, micron-sized large-sized pore structures appeared between the walls of the biochar rack. These hollow and large-sized pore structures make it easier for microorganisms to enter the inside of the biochar, so that they can more fully contact the organic matter adsorbed on the surface of the biochar, and use it as a nutrient substance for growth and reproduction. Biochar itself is also a substance rich in organic carbon and high ash content. Moreover, it also has a certain adsorption effect on N and P, and can also improve the moisture and oxygen content of the soil. The improvement of these conditions is conducive to the growth of microorganisms in the environment.

The findings of this study suggest that adding biochar and crop straw to farm land can significantly increase its contents. On the one hand, in the pyrolysis process of biochar, the basic cations present in the feedstock biomass may be transformed into oxide, hydroxides, and carbonates, which might contribute to increased soil nutrient levels. According to the findings, these straw materials improved the physicochemical integrity of agriculture land when compared with the control group.

Conclusion
At present, many studies have confirmed that biochar has strong adsorption capacity and can hold organic pollutants, which can significantly reduce the bioavailability of organic pollutants in the soil and reduce the environmental risk of difficult-to-degrade pollutants. However, the adsorption and immobilisation of biochar cannot completely remove environmental pollutants. To truly control the environmental risks of pollutants in the soil, it is necessary to rely on the degradation of microorganisms. In recent years, the interaction between biochar, organic pollutants and soil microorganisms has received increasing attention. However, most of the current research in this area is still on the effect of biochar on the adsorption and desorption of pollutants, and the research on the effect of biochar on the microbial effectiveness of pollutants in agricultural soil is still lacking. This paper designs an experiment to study the remediation effect of straw biochar on the organic pollution of agricultural planting soil. Through the analysis of experimental research, it can be seen from the experimental results that the straw biochar has a very good remediation effect on the pollution of organic pollutants in agricultural planting soil.

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