

CONVERSION OF WOOD PROCESSING WASTE INTO BIOCHAR AND ITS EFFECT ON SOIL FERTILITY

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Abstract: Effective management of waste and judicious use of resources are issues of paramount importance in contemporary times. The waste from the wood processing industry can be used in many ways as a secondary raw material. In this respect, the conversion of such wastes into high-value products is of great scientific and practical interest.

The current article discusses the properties of biochar derived from wood processing waste and its prospects for agricultural applications. Biochar is a carbon-rich porous material that is produced by pyrolysis of plant-based materials in the absence of oxygen. High adsorption capacity, large surface area, and positive effect on the soil environment are ecologically significant.

The conducted analyses show that biochar is an effective way to improve the physical and chemical properties of soil, for retaining moisture, preventing nutrient leaching, and improving the microbiological activity of soil. Moreover, the carbon sequestration properties of biochar suggest that it is an important factor contributing to the mitigation of climate change.

In summary, employing biochar derived from wood waste is a promising and environmentally friendly strategy that can achieve the twin objectives of waste management and the improvement of agricultural productivity.

Keywords: waste management, wood waste, biochar, soil fertility, pyrolysis process.

Introduction

In modern agrarian and ecological research, increasing soil fertility, enhancing crop productivity, and ensuring ecological sustainability stand as one of the principal priority directions [1, 6]. In this regard, the application of various organic and mineral amendments to improve the physical and chemical properties of soil has become widespread [2]. In recent years, biochar has

emerged as a subject of particular attention in this field.

Biochar is a carbon-rich substance obtained through the pyrolysis of plant-based organic materials -such as wood, agricultural waste, and similar feedstocks -by heating them at high temperatures under oxygen-free or very low-oxygen conditions. An important technological consideration in the production of biochar is the correct

selection of temperature: at temperatures exceeding 700°C, the quantity of harmful substances may increase; moreover, the gases released during the process must not be discharged into the atmosphere but should instead be captured and combusted [6].

This process was first investigated by Lehmann J. and Joseph S. The course of the process is divided into the following stages: the initial feedstock is obtained, an oxygen-free environment is created, high temperature is applied, and thermochemical decomposition -pyrolysis -takes place; as a result, gases and liquid are separated, and biochar remains as the solid residue [5].

Another method of producing biochar is hydrothermal carbonization. This process can be carried out at relatively low temperatures in the range of 180–250°C. In this process, biomass is mixed with water and placed in a closed reactor; the temperature is gradually increased to maintain stability. Depending on the temperature regime applied, the following products are obtained: below 250°C -biocoal (hydrothermal carbonization); between 250–400°C -bio-oil (hydrothermal liquefaction); and above 400°C -gaseous synthesis products such as CO, CO₂, H₂, and CH₄ (hydrothermal gasification) [7].

In the hydrothermal process, the hydrolyzed product undergoes a series of reactions -dehydration, decomposition, and isomerization -to form 5-hydroxymethylfurfural and its derivatives. In addition, hydrocarbon compounds are formed as a result of condensation, polymerization, and intramolecular dehydration reactions. The high molecular weight and complex structure of lignin complicate the mechanism: the decomposition of lignin begins with dealkylation and hydrolysis reactions, yielding phenols, catechols, syringol, and other phenolic products; in the final stage, carbon is produced through the repolymerization and cross-linking of intermediate products [7].

Another thermochemical method used in the production of biochar is gasification. In this method, carbonaceous material is converted at high temperature -in the presence of gasifying agents such as oxygen, air, and steam -into synthesis gas composed of CO, CO₂, CH₄, H₂, and hydrocarbon traces. Research indicates that reaction temperature is the most critical factor determining the composition of the synthesis gas:

as temperature increases, the proportion of carbon monoxide rises, while methane, carbon dioxide, and hydrocarbon fractions decrease [8]. The primary product of this process is synthesis gas; biochar is obtained as a lower-yield by-product.

The application of biochar in agriculture is justified by its comprehensive positive effect on the physical, chemical, and biological properties of soil. Biochar increases the water retention capacity of soil, prevents the leaching of nutrients, stabilizes the pH level of soil, and creates a favorable environment for the development of beneficial microorganisms [3]. Furthermore, the carbon-sequestering property of biochar demonstrates that it plays an important role in combating climate change [4].

In this context, the experimental investigation of the effect of biochar applied together with compost and soil on plant development is of current scientific and practical significance. In particular, a comparative analysis of the effect of various soil mixtures on the germination dynamics of plants and their early development stage can yield important results in terms of selecting efficient substrates for agriculture.

The objective of the study is to determine the effect of biochar applied together with soil and compost on the germination rate and developmental indicators of plants. To this end, soil mixtures of various compositions were prepared and their comparative effects were investigated.

Experimental part

The present study was conducted with an experimental approach to evaluate the effect of biochar on soil fertility. The method of comparative analysis was employed. All experimental variants were performed in laboratory conditions under the same ecological parameters. Temperature, lighting regime, irrigation frequency, number of seeds, and sowing depth were kept the same for all the samples, thus ensuring the objectivity of the results.

Raw Materials and Reagents. Wood shavings and small wood chips of wood-derived raw material were used for the preparation of biochar in the study. Standard Absheron soil and organic-rich compost were also used for the preparation of the substrate.

Preparation of Biochar. Biochar was obtained through a pyrolysis process under oxygen-free conditions. For this purpose, the prepared raw material was subjected to thermal treatment in a muffle furnace at a temperature of 400°C for a duration of 6 hours. During pyrolysis, thermochemical decomposition of the organic components took place, volatile substances were released, and a carbon-rich, highly porous biochar structure was formed.

Following thermal treatment, the biochar was cooled to room temperature, mechanically ground, and homogenized in order to achieve a uniform particle size.

Discussion and results

The experimental research conducted made it possible to comparatively evaluate the effect of biochar on the soil substrate. In order to correctly interpret the results, the physicochemical properties of the biochar used were first analyzed, followed by a discussion of its effect on plant development.

Physicochemical Characterization of Biochar. FTIR analysis was carried out to determine the surface functional groups of the biochar (Figure 1).

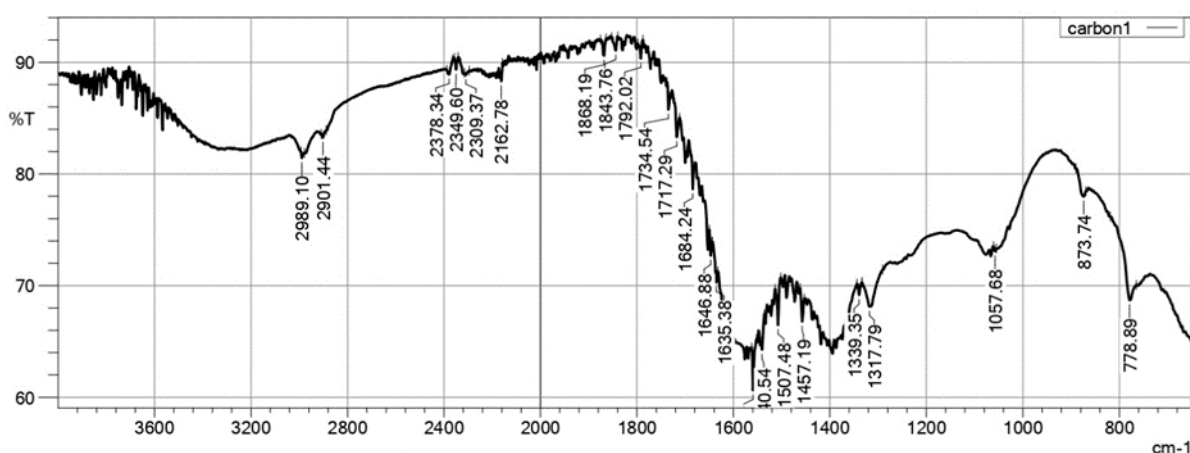


Figure 1. FTIR analysis of the obtained biochar

The analysis of the FTIR spectrum confirms the presence of various functional groups on the surface of the biochar. The peaks recorded in the 778–873 cm^{-1} interval are associated with the vibrational modes of aromatic C–H bonds. This indicates that aromatic rings predominate in the structure of the biochar and reflects a high degree of aromatization. Such a structure enhances the chemical stability of the biochar and creates conditions for it to remain in the soil for an extended period without decomposition.

The peaks observed in the 1057–1339 cm^{-1} range are attributed to C–O bonds and C–H deformation vibrations. These signals indicate that partially oxygenated functional groups -such as phenol and ether -are retained within the biochar. The peaks recorded in the 1457–1559 cm^{-1} interval correspond to aromatic C=C and carbonyl (C=O) groups. This region confirms that the aromatic structure of the biochar has been

formed and that the pyrolysis process proceeded effectively. The wide absorption bands in the range 1635–1717 cm^{-1} indicate the presence of carbonyl (C=O) and aromatic C=C bonds, which are active adsorption centers on the surface of the biochar and ensure the retention of various substances on the surface. Weak to moderate intensity peaks at 2309–2989 cm^{-1} are related to aliphatic C-H and CO₂, showing small amounts of volatile components and incompletely decomposed organic residues in the biochar. Overall, FTIR analysis indicated that the biochar produced at 400°C gave a good compromise between high aromaticity and suitable surface functionalization. The strong signals of aromatic C–H and C=C bonds indicate a well-carbonized biochar with a stable structure, which is beneficial for the long-term stability of the biochar in the soil and its carbon sequestration capacity. Furthermore, the weak C–O peaks at the range

of 1000–1400 cm^{-1} suggest that the important biopolymers such as cellulose and lignin have been degraded significantly. This is a testimony to the efficiency of the pyrolysis process and indicates the suitability of biochar for soil amendment. The weak peaks in the region $>2300 \text{ cm}^{-1}$ suggest that most of the volatile matter was released during pyrolysis, which is an important aspect of the stability of the biochar. The FTIR analysis performed demonstrated that the biochar obtained is stable and durable due to its highly aromatic carbon structure; it possesses an adsorption capacity due to the functional groups on its surface; and it presents a good degree of carbonization, as shown by its low volatile matter content. The acid-base properties of the biochar were measured by the pH method, and it was found that the biochar has an alkaline character ($\text{pH} = 9.4$). In order to evaluate the adsorption capacity, two equal volumes (100 ml) of distilled water were homogeneously prepared by adding equal amounts of methylene blue, one of the samples was spiked with pre-ground biochar and the other was used as control solution. The sample to which biochar had been added was mixed intensively, and the time was recorded from the moment of mixing. Both solutions were kept under identical conditions and observed at defined time intervals.

By visual observation, it was seen that the methylene blue color intensity of the biochar treated solution decreased faster with time and the solution became lighter in color. No color change was observed in the control sample. This observation was taken as a preliminary result that biochar has the capacity to remove the dye from the solution. This method provides indirect information regarding the specific surface area and porosity characteristics of the biochar.

These properties provide scientific justification for the expectation that, when biochar is added to the soil substrate, it will improve the retention of water and nutrients and may exert a positive effect on plant development.

Effect on Plant Development. To evaluate the effect of biochar on plant development and soil substrate, three different experimental variants were prepared:

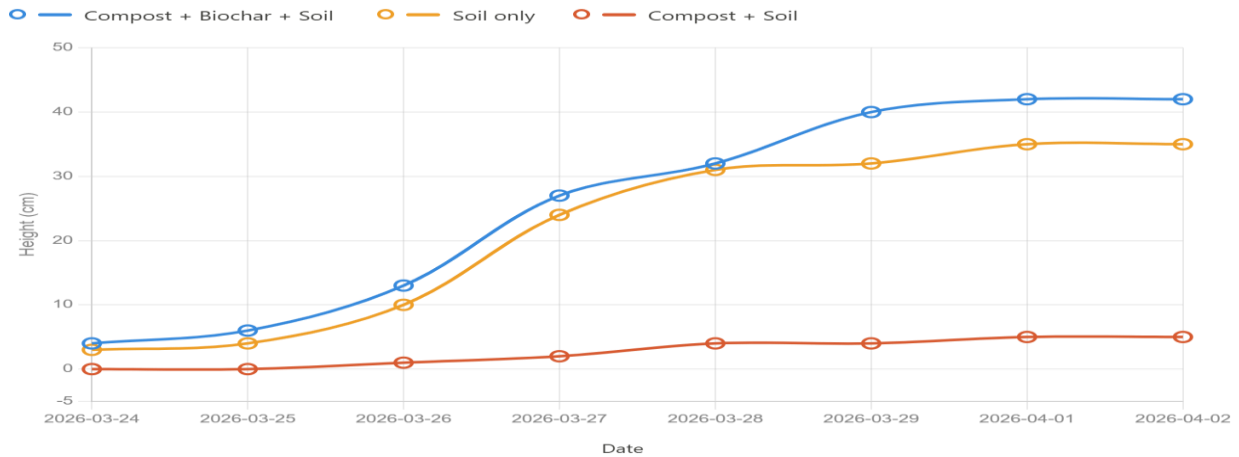
- V1: biochar + compost + soil
- V2: compost + soil
- V3: soil only (control group)

For each part, the components were mixed in pre-determined proportions, and a homogeneous substrate environment was created. Seeds of the same bean variety (*Phaseolus vulgaris*) were sown in all variants.

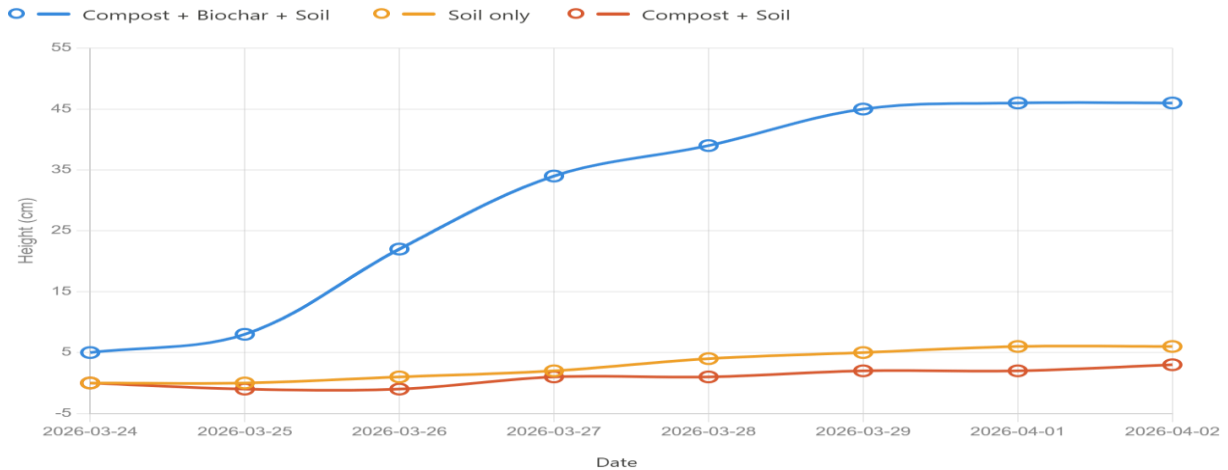
The development of the plants was observed daily during the whole experiment. The assessment was conducted by the following indicators: germination period (days), germination percentage (%), and dynamics of plants' morphological development.

The data acquired were analyzed using comparative methods, yielding reliable results through systematic observation and statistical recording techniques. The performed experimental studies allowed to comparatively evaluate the effect of biochar on the soil substrate. The obtained results showed that the composition of the substrate has a direct influence on the germination dynamics of the plants and the early stage of development. In variant V1 – a mixture of biochar, compost, and soil – germination was observed earlier, from days 2–3. At day 4–5, plant development in this variant was more intensive, with a higher rate of stem elongation and leaf formation. This structure provides a more stable moisture environment to the seed, which accounts for the high porosity and water retention capacity of biochar. In variant V3 (soil only), germination was recorded, but the development rate was lower than in V1. However, the developmental parameters recorded in variant V3 were higher than those recorded in variant V2 (compost and soil mixture). The late germination and poor development in the V2 variant can be explained by unfavorable physical properties of compost (air permeability and water regime) or by limited availability of nutrients in a form immediately accessible to plants.

Subsequent observations demonstrated that, in the environment where biochar was applied, the soil remained moist for a longer period, thereby stabilizing the water supply to the plants. As a result, the overall condition of the plants in variant V1 was more stable, and vegetative development was more intensive in character. The comparative growth dynamics of bean seeds are presented in Figure 2.



Seed 1



Seed 2

Figure 2. Growth development dynamics of bean seeds

Conclusion

The results obtained demonstrate that the application of biochar comprehensively improves the physical and chemical properties of soil. Specifically, the porous structure enhances the water holding capacity, and the surface functional groups guarantee the adsorption of nutrients and avoid their washing out. These factors together stimulate the development of the plant.

In general, it was confirmed that the best results were obtained with the use of biochar in combination with compost and soil (V1). However, the application of compost alone did not have the

expected positive effect and even performed worse than the soil-only part in some cases.

REFERENCES

1. Blanco-Canqui, H. Biochar and soil physical properties. *Soil Science Society of America Journal*, 2017, 81(4), s. 687–711.
2. Agegnehu, G., Bass, A. M., Nelson, P. N., Bird, M. I. Benefits of biochar, compost, and biochar-compost for soil quality, maize yield, and greenhouse gas emissions. *Science of the Total Environment*, 2016, 543, s. 295–306.

3. Ding, Y., Liu, Y., Liu, S., Li, Z., Tan, X., Huang, X., Zeng, G., Zhou, L., Zheng, B. Biochar improves soil fertility. *Agronomy for Sustainable Development*, 2017, 37(6), s. 1–18.
4. Wang, J., Xiong, Z., Kuzyakov, Y. Biochar stability in soil: meta-analysis of decomposition and priming effects. *Global Change Biology*, 2016, 22(3), s.1111–1121.
5. Lehmann, J., & Joseph, S. (Eds.). (2015). *Biochar for environmental management: Science, technology and implementation* (2nd ed.). Routledge.
6. International Biochar Initiative. (n.d.). Biochar production and by-products. <https://biochar.international/the-biochar-opportunity/biochar-production-and-by-products/>
7. Yaashikaa, P. R., Kumar, P. S., Varjani, S., & Saravanan, A. (2020). A critical review on the biochar production techniques, characterization, stability, and applications for the circular bioeconomy. *Biotechnology Reports*, 28, e00570. <https://doi.org/10.1016/j.btre.2020.e00570>
8. Ahmad, M., Rajapaksha, A. U., Lim, J. E., Zhang, M., Bolan, N., Mohan, D., Vithanage, M., Lee, S. S., & Ok, Y. S. (2014). Biochar as a sorbent for contaminant management in soil and water: A review. *Chemosphere*, 99, 19–33. <https://doi.org/10.1016/j.chemosphere.2013.10.071>

AĞAC EMALI TULLANTILARININ BIOÇARA ÇEVİLMƏSİ VƏ ONUN TORPAQ MƏHSUL-DARLIĞINA TƏSİRİ

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Xülasə: Müasir dövrdə tullantıların səmərəli idarə olunması və resurslardan düzgün istifadə mühüm məsələ hesab olunur. Ağac emalı sənayesində yaranan tullantılar, ikinci dərəcəli xammal kimi geniş tətbiq imkanlarına malikdir. Bu baxımdan, onların yüksək əlavə dəyər yaradan məhsullara çevrilməsi mühüm elmi və praktiki əhəmiyyət kəsb edir.

Bu məqalədə ağac emalı tullantılarından alınan *bioçarın* xüsusiyyətləri və onun kənd təsərrüfatında tətbiq perspektivləri araşdırılmışdır. *Bioçar* bitki mənşəli materialların oksigensiz şəraitdə piroliz nəticəsində əldə olunan karbonla zəngin, məsaməli quruluşa malik maddə kimi səciyyəlandırılır. Onun yüksək adsorbsiya qabiliyyəti, geniş səth sahəsi və torpaq mühitinə müsbət təsiri bu materialı ekoloji baxımdan əhəmiyyətli edir.

Aparılan təhlillər göstərir ki, *bioçar* torpağın fiziki və kimyəvi xüsusiyyətlərini yaxşılaşdırmaq, rütubətin saxlanması təmin etmək, qida maddələrinin yuyulmasının qarşısını almaq və torpağın mikrobioloji aktivliyini artırmaq baxımından effektiv vasitədir. Bununla yanaşı, *bioçarın* karbon saxlayıcı xüsusiyyəti onun iqlim dəyişikliklərinin azaldılmasına töhfə verən mühüm amil olduğunu göstərir.

Nəticə etibarilə, ağac tullantılarından əldə olunan *bioçarın* tətbiqi həm tullantıların səmərəli istifadəsinə, həm də kənd təsərrüfatında məhsuldarlığın artırılmasına xidmət edən perspektivli və ekoloji cəhətdən dayanıqlı yanaşma kimi qiymətləndirilə bilər.

Açar sözlər: tullantıların təkrar istifadəsi, oduncaq tullantıları, bioçar, torpaq münbitliyi, piroliz prosesi

ПРЕОБРАЗОВАНИЕ ОТХОДОВ ДЕРЕВООБРАБОТКИ В БИОЧАР И ЕГО ВЛИЯНИЕ НА ПЛОДОРОДИЕ ПОЧВЫ

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Аннотация. В современную эпоху эффективное управление отходами и рациональное использование ресурсов считаются вопросами первостепенной важности. Отходы, образующиеся в деревообрабатывающей промышленности, обладают широким потенциалом применения в качестве вторичного сырья. В этой связи их преобразование в продукты с высокой добавленной стоимостью имеет важное научное и практическое значение.

В данной статье исследованы свойства биочара, полученного из отходов деревообработки, и перспективы его применения в сельском хозяйстве. Биочар характеризуется как богатый углеродом пористый материал, получаемый в результате пиролиза растительных материалов в бескислородной среде. Его высокая адсорбционная способность, большая площадь поверхности и положительное воздействие на почвенную среду делают этот материал экологически значимым.

Проведённые анализы показывают, что биочар является эффективным средством улучшения физических и химических свойств почвы, обеспечения удержания влаги, предотвращения вымывания питательных веществ и повышения микробиологической активности почвы. Кроме того, углерод-секвестрирующие свойства биочара свидетельствуют о том, что он является важным фактором, способствующим снижению последствий изменения климата.

В заключение, применение биочара, полученного из древесных отходов, может быть оценено как перспективный и экологически устойчивый подход, служащий как эффективному использованию отходов, так и повышению продуктивности в сельском хозяйстве.

Ключевые слова: повторное использование отходов, древесные отходы, биочар, плодородие почвы, процесс пиролиза.