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Characteristics of the basic properties of biochar obtained from different types of vegetable raw materials

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Abstract: The paper presents a comparative analysis of biochar obtained from vegetable raw materials of various origins. It was found that the biochar from marine macrophytes and leaves and stems of tomato and cucumber, siderates are sufficiently enriched with available forms of nitrogen, phosphorus and potassium. The lowest content of all the studied elements is in the bio-carbon made of paper. As a rule, to improve the physical properties of soils, it is possible to use any of the studied samples of biochar but taking into account the pH values of the biochar and the soil itself. Biochar from marine macrophytes is well suited for use on acidic soils to improve acid-base soils. For the use of the biochar obtained as an organic fertilizer, additional research is needed, including vegetation experiments.
Keywords: *Biochar, Biochar production, Biochar properties.*

1. Introduction

The rapid growth of cities and the increase in population have a great anthropogenic impact on natural ecosystems. Thus, huge anthropogenic pressure is noted on agricultural systems, which increases the risks of food security [1]. In its report on food security in 2023, the Food and Agriculture Organization of the United Nations (FAO) emphasizes the need for government support for the production of healthy food at affordable prices [2].

The increase in anthropogenic load multiplies the greenhouse effect and makes it the most significant among other anthropogenic climate-forming factors. In this regard, strategies are being developed to reduce anthropogenic pressure and mitigate the effects of climate change [3].

The use of biochar is suitable for the modern concept of "green" development, since the use of biochar can be an important link in the disposal of biological waste, maintaining the balance of the ecosystem, maintaining soil health, sustainable agricultural development, and combating climate change [4, 5]. At the moment, the fight against climate change and agriculture are the two most important areas for the use of biochar [6].

The versatility of the use of biochar is associated with its wide range of properties and the possibility of production from various sources of biological raw materials. It is noted that biochar improves soil fertility, increases crop yields, is a long-term carbon keeper, reduces greenhouse gas emissions, is able to remove many organic and inorganic pollutants from soil and aquatic environments, is able to improve the properties of building mixes to act as an electrical conductor and much more [7-11]. To date, there is a lot of information about the properties of biochar from various sources of raw materials [7], however, forecasting the properties and effects of biochar is complicated by many variables [6].

Depending on the region of biochar production, there are restrictions and specifications of the feedstock. For example, in areas with intensive rice cultivation, the production of biochar from rice husks prevails.

The Far Eastern Federal Region is the largest territorial economic region of the Russian Federation. Timber processing, fish processing industry, and agriculture are among the leading

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industries in the region. The development of the economic sectors of the region is determined by the geographical features of the area. This is mainly caused by: the growth of valuable wood species; the presence of an extended coastline that gives access to the seas of the Pacific and Arctic Oceans; the presence of a large number of commercial and economic land routes (common border with China and the Democratic People's Republic of Korea) and sea routes (mainly the Asia-Pacific countries) [12].

The industry of the region produces a large amount of waste, which, along with common waste such as wastewater, biological waste, solid household waste, paper products, etc., are specific. Due to the timber processing industry, waste from coniferous and broad-leaved wood species is present in the region. The growth of Korean pine ("cedar") in the Far East causes the presence of such a specific waste as the shell of a pine nut.

The Far Eastern region has a fairly long coastline and access to 6 seas (Chukchi, East Siberian, Laptev Sea, Bering, Okhotsk, Japanese). The presence of access to the seas makes it possible to develop commercial production of fish and algae. A significant amount of commercial and potentially commercial algae is concentrated in the seas of the Far East [13]. Sea storms and active algae fishing violate the integrity of their fields of growth, as a result, a large number of algae are noted among storm emissions on the coast of the region.

Agriculture in the Far East has a low level of development, but nevertheless occupies a significant niche in the development of the region, since ensuring food security is one of the main priorities of the Far East [14, 15]. The agricultural sector is mainly concentrated in the central and southern parts of the region (Amur Region, Khabarovsk Territory, Primorsky Territory). Most soils in the Far Eastern region are heavy in terms of granulometric composition. On the one hand, the heavy granulometric composition of soils makes it possible to grow rice and soybeans in the region, which provides a large number of raw materials for the production of biochar. When growing vegetable crops, the heavy granulometric composition of soils is an unfavorable factor and improvement of soil structure is required. Since biochar has a high surface area, it can serve as a structure for the soil.

It is difficult to overestimate the benefits of using biochar for soils. For agriculture, the use of biochar is a transition to sustainable and regenerative methods [10]. The positive effect of biochar is noted in various soil and climatic conditions [7-9, 11]. According to our previous studies, biochar in the conditions of the south of Primorsky Krai showed a positive effect on the yield of cabbage, reduced greenhouse gas emissions, a positive effect on soil pH, organic carbon content was noted [16, 17].

The manuscript describes the basic properties of biochar obtained from various types of vegetable raw materials and pyrolysis conditions.

2. Materials and Methods

The object of the study is biochar, obtained by medium and high-temperature pyrolysis of plant raw materials, which are waste products of various genesis. Pyrolysis conditions for different raw materials are presented in the table (Table 1). As a result of pyrolysis, the resulting biochar has a different appearance (Figure 1) depending on the feedstock. The study was conducted according to the methodology presented in the recommendations of the International Biochar Initiative (IBI) [18].

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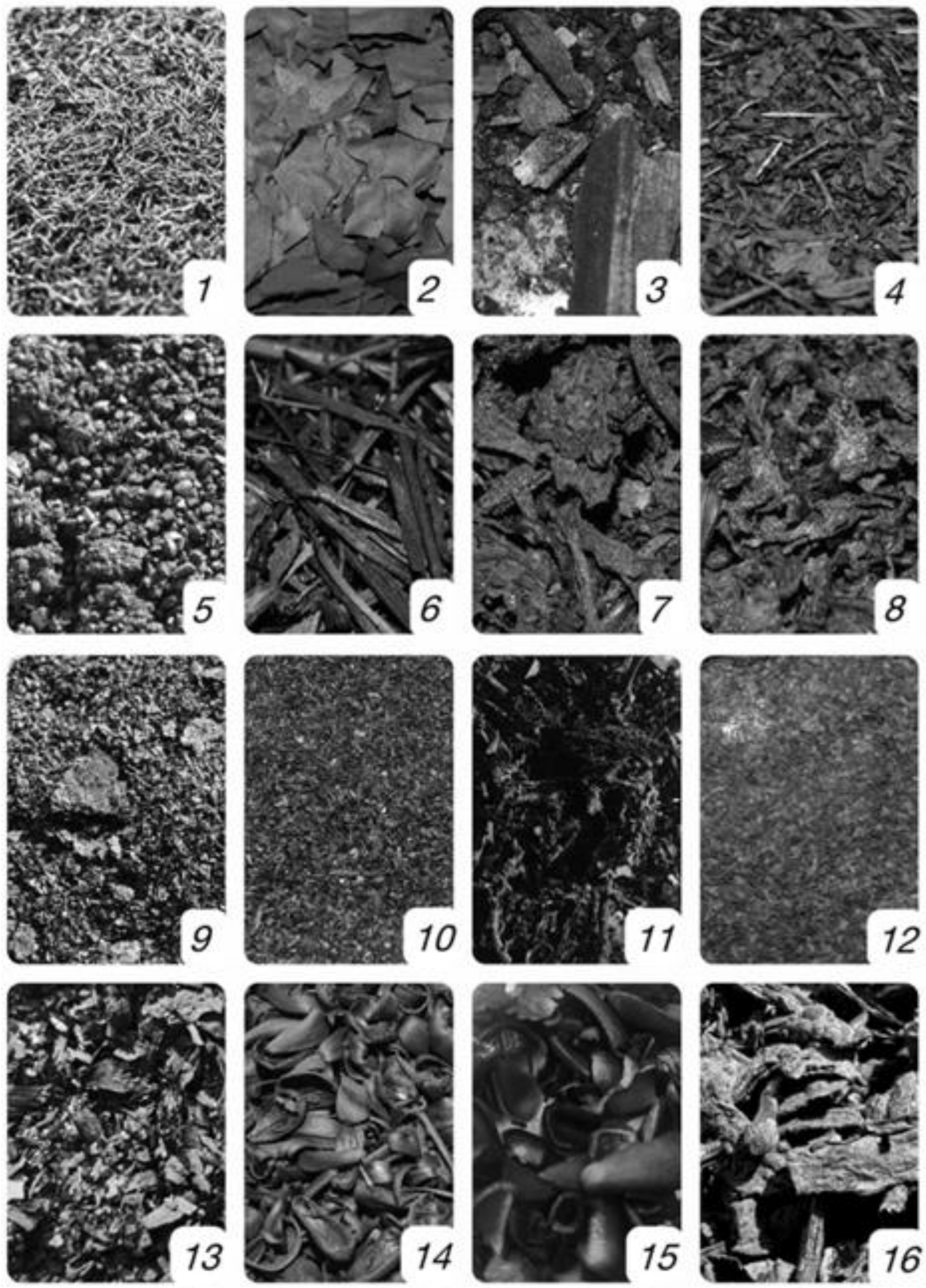

Figure 1.
Biochar obtained as a result of pyrolysis of various vegetable raw materials: 1 - Ahnfeltia; 2 - paper; 3 - wood; 4 - strawberry leaves; 5 - coffee cake; 6 - siderates; 7 – tomato leaves and stems; 8 – cucumber leaves and stems; 9 - coffee husk; 10 - rice husks; 11 - a mixture of algae; 12 - coconut fiber; 13 - Zostera marina; 14 - sunflower seed husk; 15 - cedar husk; 16 - Saccharina japonica.

3. Results and Discussion

Studies of the acid-base properties of biochar have shown that the reaction of the medium of biochar obtained from Zostera marina, Ahnfeltia, rice husk, coconut fiber and siderates, wood, a mixture of algae, coffee cake, coffee husk strawberry leaves, sunflower seed husk and cedar husk is slightly alkaline and values range from 8.91 to 9.87 (Table 1). The reaction of the medium of biochar obtained from

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tomato leaves and stems, cucumber leaves and stems and kelp showed a value of 10.31-10.38, which refers to alkaline, and in biochar from paper, the pH value of the medium was 12.17, which refers to highly alkaline.

The main basic elements affecting soil fertility are carbon, nitrogen, phosphorus and potassium, these elements are carried out by plants in large quantities from the soil, and are also washed out as a result of precipitation.

If we talk about the carbon content, then the most promising is a biochar obtained from a mixture of siderates, coffee cake, coffee husks and strawberry leaves with a carbon content of more than 50%. The range from 40% to 49.7% includes biochar obtained from Zostera marina, Ahnfeltia, coconut fiber, a mixture of algae, wood and cedar husks. Biochar obtained from paper, rice husks, cucumber tops and sunflower seed husks fell into the range of 30% to 36.6% in terms of organic carbon content. The least amount of organic carbon is contained in the leaves and stems of tomatoes and is 25,3 %.

The indicators of total nitrogen in biochar vary greatly depending on the feedstock. The highest value falls on biochar from Ahnfeltia, in which the total nitrogen content varies from 8.2 to 10.6%. Biochar obtained from cucumber tops and coffee cake in terms of nitrogen content belong to the range from 6.3 to 7.4%, which is also high. Almost half as much nitrogen is contained in biochar from coffee husks, tomato leaves and stems, kelp and strawberry leaves and varies from 5.4 to 5.9%. Also, the content of total nitrogen includes biochar obtained from a mixture of siderates, a mixture of algae, Zostera marina and rice husk with a range from 1.6 to 3.8%. The lowest nitrogen content is observed in biochar from paper, as well as in coconut fiber, wood, sunflower seed husks and cedar husks less than 1% of total nitrogen (Table1).

There are also differences in the content of available phosphorus. As expected, no available phosphorus was found in biochar from paper, and biochar from plant material contains the most in a mixture of algae 1.10%, tomato leaves and stems 1.26%, cucumber leaves and stems 1.40% and strawberry leaves with a content of available phosphates 1.44%. In the rest of the raw materials, the phosphorus content varies in the range from 0.19 to 0.81%, except for cedar husks with a very low phosphorus content 0,005 %.

According to the content of exchangeable potassium, as expected, most of it is contained in biochar obtained from marine raw materials, as well as in agricultural production material and vary in the range from 1.68 to 19.9%, in the rest of the material the potassium content was less than 1%, the lowest is biochar obtained from 0.01% paper and cedar husks 0,03%.

Table 1.
Indicators of biochar from raw materials of various plant materials.

№	Indicators	Pyrolysis temperature. ºC	Pyrolysis time. hour	pH	N %	P_2O_5. %	K_2O. %	C org. %
1	Used paper	800	1	12.47	0.2-0.4	н/о	0.01	36.6
2	Zostera marina	550	1	8.91	1.8-3.2	0.46	1.95	46.7
3	Ahnfeltia	500	1	8.48	8.2-10.6	0.36	1.68	49.7
4	Rice husks	500	1	9.3	1.6-2.3	0.32	0.06	34.4
5	Coconut Fiber	500	1	9.59	0.3-0.6	0.19	0.07	40.7
6	A mixture of siderates	500	1	9.67	3.2-3.8	0.81	5.75	52.4
7	Wood	500	1	8.09	0.96	0.38	0.07	48.7
8	A mixture of algae	500	1	8.65	3.2	1.10	13.9	41.5
9	Coffee cake	500	1	9.53	6.3	0.26	0.15	51.8
10	coconut fiber	500	1	9.87	5.4	0.60	6.5	53.9
11	Tomato leaves and stems	500	1	10.31	5.9	1.26	7.1	25.3
12	Cucumber leaves and stems	500	1	10.38	7.4	1.40	5.8	31.1
13	Strawberry Leaves	500	1	9.74	5.8	1.44	4.5	50.2
14	Sunflower Seed Husk	500	1	9.62	0.68	0.34	0.9	32.5
15	Saccharina japonica	500	1	10.38	5.8	0.43	19.9	31.8
16	Cedar husk	500	1	9.79	0.81	0.005	0.03	42.2

The analysis of biochar from different types of plant material showed that biochar has a predominantly alkaline reaction of the medium, which means it can be used on acidic soils.

According to the content of organic carbon, the most promising is biochar obtained from a mixture of siderates, coffee cake, coffee husks and strawberry leaves with a carbon content of more than 50%. Most of the biochar in terms of organic carbon content are in the range from 49 to 36.6%. The least organic carbon is contained in the leaves and stems of tomatoes with a value of 25,3 %.

According to the content of available phosphates, as expected, no available phosphorus was found in biochar from paper, but most of all it is contained in a mixture of algae (1.10%), tomato leaves and stems (1.26%), cucumber leaves and stems (1.40%) and strawberry leaves (1.44%), the rest of the raw materials contain available phosphorus it varies from 0.19 to 0.81%, except for cedar husks with a very low phosphorus content 0,005 %.

According to the content of exchangeable potassium, the highest content is in biochar obtained from a mixture of algae and Saccharina japonica, as well as in the leaves and stems of tomato, cucumber, cedar husk and its content varies from 1.68 to 19.9%, in the rest of the material the potassium content was less than 1%, the lowest is in biochar obtained from 0.01 paper % and cedar husks 0,03%.

As a rule, to improve the physical properties of soils, it is possible to use any of the studied samples of biochar, but taking into account the pH values of the biochar and the soil itself. Biochar from marine macrophytes is well suited for use on acidic soils to improve acid-base soils. For the use of the biochar obtained as an organic fertilizer, additional research is needed, including vegetation experiments.

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References
[1] S. Khan, S. Irshad, K. Mehmood, Z. Hasnain, M. Nawaz, A. Rais, S. Gul, M. A. Wahid, A. Hashem, E. F. Abd_Allah, D. Ibrar, "Biochar production and characteristics, its impacts on soil health, crop production, and yield enhancement: a review," *Plants*, vol. 13, no. 2, 166, 2024, https://doi.org/10.3390/plants13020166.
[2] FAO, IFAD, UNICEF, WFP and WHO, "The State of Food Security and Nutrition in the World 2023. Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum," *Rome: FAO*, 316 p., 2023, https://doi.org/10.4060/cc3017en
[3] V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.), "IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change," *United Kingdom and New York: Cambridge University Press*, 2391 p., 2021, https://doi.org/10.1017/9781009157896.
[4] H. Yu, W. Zou, J. Chen, H. Chen, Z. Yu, J. Huang, H. Tang, X. Wei, B. Gao, "Biochar amendment improves crop production in problem soils: a review," *Journal of Environmental Management*, vol. 232, pp. 8-21, 2019, https://doi.org/10.1016/j.jenvman.2018.10.117.
[5] Ya. Zhang, J. Wang, Y. Feng, "The effects of biochar addition on soil physicochemical properties: a review," *Catena*, vol. 202, 105284, 2021, https://doi.org/10.1016/j.catena.2021.105284.
[6] S. P. Galinato, J. K. Yoder, D. Granatstein, "The economic value of biochar in crop production and carbon sequestration," *Energy Policy*, vol. 39. no. 10, pp. 6344-6350, 2011, https://doi.org/10.1016/j.enpol.2011.07.035.
[7] A. Singh, R. Sharma, D. Pant, P. Malaviya, "Engineered algal biochar for contaminant remediation and electrochemical applications," *Science of The Total Environment*, vol. 774, 145676, 2021, https://doi.org/10.1016/j.scitotenv.2021.145676.
[8] S. Farhangi-Abriz, S. Torabian, R. Qin, C. Noulas, Y. Lu, S. Gao, "Biochar effects on yield of cereal and legume crops using meta-analysis," *Science of the Total Envaironvent*, vol. 775, no. 12, 145869, 2021, http://dx.doi.org/10.1016/j.scitotenv.2021.145869.
[9] S. Guo, Y. Li, Y. Wang, L. Wang, L. Sun, L. Liu, "Recent advances in biochar-based adsorbents for CO_2 capture," *Carbon Capture Science and Technology*, vol. 4, 100059, 2022, https://doi.org/10.1016/j.ccst.2022.100059
[10] H. Sarptaş, E. Gödekmerdan, B. Baştabak, "Biochar on the path from biomass energy to regenerative agriculture," *Conference: 5. Bioenergy Studies Symposium*, 2024, https://doi.org/10.13140/RG.2.2.27664.38406.
[11] B. T. Nguyen, L. B. Le, L. P. Pham, H. T. Nguyen, T. D. Tran, N. V. Thai, "The effects of biochar on the biomass yield of elephant grass (Pennisetum Purpureum Schumach) and properties of acidic soils," *Industrial Crops and Product*, vol. 161, pp. 1 – 11, 2021, https://doi.org/10.1016/j.indcrop.2020.113224.
[12] Makarov, "Where is the Far East heading? How to ensure accelerated economic development of the Asian part of Russia?" *Russia in global politics*, vol. 16, pp. 8-24, 2018.
[13] N. V. Evseeva, V. B. Matyushkin, M. O. Berezina, R. A. Melnik, A. L. Levitsky, D. O. Vlasov, E. M. Saenko, L. V. Zhiltsova, M. N. Belyj, A. A. Dulenin, N. Y. Prokhorova, D. O. Sologub, D. A. Botnev, "State of resources and fishery of commercial Seaweeds and Seagrasses in the Seas of Russia in 2000–2020," T*rudy VNIRO*, vol. 195, pp. 232-248, 2024, https://doi.org/10.36038/2307-3497-2024-195-232-248.
[14] D. Yakovenko, "Food Security in the Far East: New Approaches to Solving the Problem," *BIO Web of Conferences*, vol. 140, 06005, 2024, https://doi.org/10.1051/bioconf/202414006005.
[15] Trofimov, L. Trofimova, E. Yakovleva, "The Russian Far East: Global and Regional Aspects of Agricultural Development," *The Age of Globalization*, vol. 50, no. 2, pp. 171-183, 2024, https://doi.org/10.30884/vglob/2024.02.14.
[16] M. A. Bovsun, S. Castaldi, O. V. Nesterova, V. A. Semal, N. A. Sakara, A. V. Brikmans, A. I. Khokhlova, T. Y. Karpenko, "Effect of biochar on soil CO_2 fluxes from agricultural field experiments in Russian Far East," *Agronomy*, vol. 11, no. 8, 1559, 2021, https://doi.org/10.3390/agronomy11081559.
[17] M. A. Bovsun, O. V. Nesterova, V. A. Semal, N. A. Sakara, A. V. Brikmans, T. Y. Karpenko, T. S. Tarasova, "The effect of applying biochar on crop yield," *Vestnik Tomskogo Gosudarstvennogo Universiteta, Biologiya*, vol. 61, pp. 6 – 26, 2023.
[18] International Biochar Initiative, [Internet] [cited 2024 Oct 7], Available from: https://biochar-international.org/