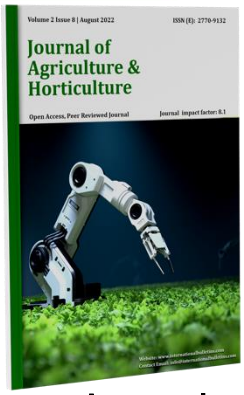

EFFECT OF PYROLYSIS DURATION ON BIOCHAR YIELD FROM WHEAT STRAW

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Annotation. In this article, the duration of pyrolysis to produce biochar from wheat straw is studied. A high amount of biochar (39%) was obtained from wheat straw by pyrolysis at 400 ^{0}C for 15 minutes.

Key words. Biochar, pyrolysis, wheat straw, temperature, pyrolysis duration, yield.

Introduction. Biochar is an organic soil amendment designed to increase the amount of organic matter in the soil, improve soil fertility, and enhance the ecological environment. Essentially, biochar is produced through the pyrolysis process, in which various types of biomass—such as maize stalks or husks, rice and wheat straw, as well as other agricultural residues—are heated at high temperatures in an oxygen-limited environment. The resulting product primarily consists of carbon and ash components [1].

Literature review. In recent years, biochar has been widely studied as an important agrotechnological tool for maintaining and stabilizing soil fertility. Research indicates that the application of biochar significantly improves the physicochemical properties of soils. Specifically, biochar enhances soil aeration, reduces the emission of greenhouse gases from the soil, prevents nutrient leaching, and regulates soil acidity [2,3], while also decreasing the need for irrigation and mineral fertilizers [5]. In addition, biochar plays a crucial role in increasing the water-holding capacity of light-textured soils [4] and stimulating microbiological activity [6].

Biochar also has a direct positive impact on plant physiology. Research findings have shown that it enhances the yield of plants that require high levels of potassium and thrive in alkaline (high pH) environments [7,8]. Furthermore, the application of biochar increases plant resistance to various fungal diseases [9].

Practical experiments demonstrate that biochar is an effective tool for restoring fertility and ensuring the long-term stability of degraded soils in tropical and subtropical regions. However, under temperate climatic conditions, its benefits remain limited [10]. Therefore, for the efficient use of biochar, careful selection of raw materials, as well as the accurate determination of pyrolysis temperature and duration, are of critical importance. In particular, these factors play a decisive role in producing high-quality biochar.

Methods. In the process of producing biochar, wheat straw was selected as a raw material due to its low cost, wide availability, and frequent occurrence in agricultural practices. This type of biomass is distinguished not only by its abundance but also by its environmental suitability for recycling.

Initially, the collected wheat straw was cut into pieces of 10–20 mm and 20–30 mm in size and subjected to a preliminary preparation stage. The samples were then dried in a Memmert UN 200 drying oven at 105 °C for 2 hours until a constant weight was achieved.

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This step is essential to completely remove moisture and to ensure stable results during the pyrolysis process.

The dried raw material and the resulting biochar mass were measured using a high-precision VLTE-1100 technical balance. Following this, the pyrolysis process was carried out in a THERMNEVO EVO mini muffle furnace.

The study investigated the effect of pyrolysis duration on the yield and quality characteristics of biochar. For this purpose, three different pyrolysis durations — 15, 30, and 45 minutes — were tested at a temperature of 400 °C. Through this experiment, the influence of time as a factor on biochar yield was determined, and efforts were made to identify the optimal parameters.

Results. In recent years, scientific interest in the potential role of biochar in mitigating global climate change has been steadily increasing [11]. Biochar is considered not only as a means to improve soil fertility, but also as an important factor in reducing greenhouse gas emissions through the long-term sequestration of carbon. Therefore, improving biochar production technology and identifying optimal conditions remain among the most pressing research priorities.

The efficiency of the pyrolysis process directly depends on several factors, including temperature level, heating rate, and pyrolysis duration [12]. By controlling these parameters, it is possible to both increase the yield of biochar and improve its quality characteristics [13]. For instance, higher biochar yields are typically observed within the temperature range of 400–500 °C, whereas at temperatures above 700 °C, the biochar output decreases significantly. It should be emphasized that the pyrolysis process at elevated temperatures occurs rapidly within a few minutes, rather than over several hours [14].

Based on the research findings, the optimal temperature range and pyrolysis duration for different feedstocks were determined (Table 1). The experiments demonstrated that when pyrolysis was carried out for 15 minutes, the process was not fully completed in straw pieces of both sizes (10–20 mm and 20–30 mm), resulting in biochar of inadequate quality. In contrast, extending the pyrolysis duration to 30 and 45 minutes enabled the production of high-quality biochar.

Table 1.

Optimal pyrolysis duration for obtaining high-quality biochar.

Raw material particle size, mm	Pyrolysis duration, minutes		
	15	30	45
10-20	-	+	+
20-30	-	+	+

Note: – insufficient, + sufficient

The obtained results indicate that both the duration of pyrolysis and the particle size of the raw material significantly influence the quality of biochar. Under optimal conditions, not only the yield but also the physicochemical properties of biochar are improved. This, in turn, enhances its effectiveness when applied to soil.

In our study, the effect of pyrolysis duration on biochar yield from the feedstock was examined in detail. The results show that biochar yield decreases as the pyrolysis time increases. Specifically, when the pyrolysis process lasted 15 minutes, the yield relative to the raw material was 39%. When the duration was doubled to 30 minutes, the yield decreased to 35%, and when tripled to 45 minutes, it further declined to 33% (Figure 1).

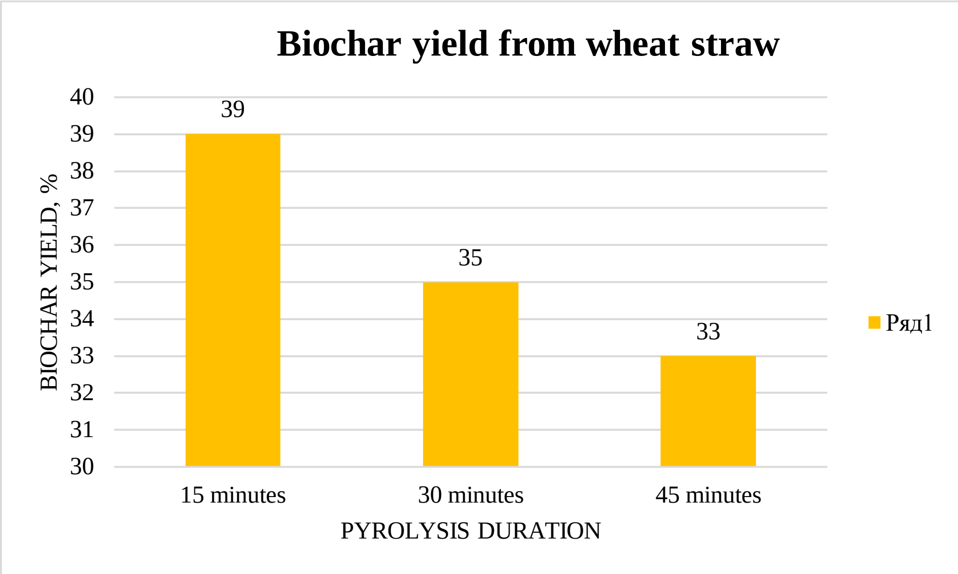

Figure 1. The effect of pyrolysis duration on biochar yield from wheat straw.

This process indicates that although biochar yield is higher during the initial shorter durations, with longer times a larger portion of organic matter is converted into gaseous products, resulting in reduced biochar yield. Therefore, selecting the optimal pyrolysis duration is crucial in biochar production, and a range of 15–30 minutes is considered most suitable for improving efficiency.

Conclusion. The results of the conducted research showed that the yield of biochar from raw materials directly depends on the duration of pyrolysis, with the amount of biochar decreasing as the processing time increases. This phenomenon is explained by the gradual conversion of organic matter into gaseous and liquid products during the pyrolysis process. It was also found that biochar yield is influenced by the type of raw material and its chemical composition.

Based on the experiments, it can be concluded that the most favorable condition for obtaining high-quality and stable biochar from wheat straw is pyrolysis at 400 °C for 30 minutes. This outcome provides practical opportunities to enhance the efficiency of biochar production and expand its application in agriculture..

References:

1. https://en.wikipedia.org/wiki/Biochar
2. Wang, Yuchen; Gu, Jiayu; Ni, Junjun (1 December 2023). "Influence of biochar on soil air permeability and greenhouse gas emissions in vegetated soil: A review". Biogeotechnics. 1 (4):100040. Bibcode :2023Biogt. 100040W. doi:10.1016/j. bgtech. 2023. 100040. ISSN 2949-9291.
3. Dai, Zhongmin; Zhang, Xiaojie; Tang, C.; Muhammad, Niaz; Wu, Jianjun; Brookes, Philip C.; Xu, Jianming (1 March 2017). "Potential role of biochars in decreasing soil acidification - A critical review". The Science of the Total Environment. 581–582: 601–611. Bibcode: 2017ScTEn.581..601 D. doi:10.1016/j.scitotenv. 2016.12.169. ISSN 1879-1026. PMID 28063658.

4. Razzaghi, Fatemeh; Obour, Peter Bilson; Arthur, Emmanuel (1 March 2020). "Does biochar improve soil water retention? A systematic review and meta-analysis". Geoderma. 361:114055. doi:10.1016/j.geoderma. 2019.114055. ISSN 0016-7061.

5. Economical CO2, SOx, and NOx capture from fossil-fuel utilization with combined renewable hydrogen production and large-scale carbon sequestration". Fuel and Energy Abstracts. 47 (2): 92. March 2006. doi:10.1016/s0140-6701(06)80597-7. ISSN 0140-6701. "Interview with Dr Elaine Ingham - NEEDFIRE". 17 February 2015.

6"Interview with Dr Elaine Ingham - NEEDFIRE". 17 February 2015. Archived from the original on 17 February 2015. Retrieved 16 August 2021.

7. Lehmann, Johannes; Pereira da Silva, Jose; Steiner, Christoph; Nehls, Thomas; Zech, Wolfgang; Glaser, Bruno (1 February 2003). "Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments". Plant and Soil. 249 (2): 343–357. doi:10.1023/A:1022833116184. ISSN 1573-036. S2CID 2420708. Archived from the original on 22 November 2021. Retrieved 16 August 2021.

8. Tenic, E.; Ghogare, R.; Dhingra, A. (2020). "Biochar—A Panacea for Agriculture or Just Carbon?". Horticulturae. 6 (3): 37. doi:10.3390/horticulturae6030037.

9. Jaiswal, A.K.; Elad, Y.; Graber, E.R.; Frenkel, O. (2014). "Rhizoctonia solani suppression and plant growth promotion in cucumber as affected by biochar pyrolysis temperature, feedstock and concentration". Soil Biology and Biochemistry. 69: 110–118. Bibcode: 2014S BiBi..69..110J. doi:10.1016/j.soilbio.2013.10.051

10. Vijay, Vandit; Shreedhar, Sowmya; Adlak, Komalkant; Payyanad, Sachin; Sreedharan, Vandana; Gopi, Girigan; Sophia van der Voort, Tessa; Malarvizhi, P; Yi, Susan; Gebert, Julia; Aravind, PV (2021). "Review of Large-Scale Biochar Field-Trials for Soil Amendment and the Observed Influences on Crop Yield Variations". Frontiers in Energy Research. 9: 499. doi:10.3389/fenrg.2021.710766. ISSN 2296-598X

11. Lean, Geoffrey (7 December 2008). "Ancient skills 'could reverse global warming'". The Independent. Archived from the original on 13 September 2011. Retrieved 1 October 2011.

12. Tripathi, Manoj; Sabu, J.N.; Ganesan, P. (21 November 2015). "Effect of process parameters on production of biochar from biomass waste through pyrolysis: A review". Renewable and Sustainable Energy Reviews. 55: 467–481. doi:10.1016/j.rser.2015.10.122. ISSN 1364-0321.

13. Gaunt, John L.; Lehmann, Johannes (2008). "Energy Balance and Emissions Associated with Biochar Sequestration and pyrolysis Bioenergy Production". Environmental Science & Technology. 42 (11): 4152–4158. Bibcode:2008 EnST... 42.4152G. doi:10.1021/es071361i. PMID 18589980.

14. Winsley, Peter (2007). "Biochar and bioenergy production for climate change mitigation". New Zealand Science Review. 64. (See Table 1 for differences in output for Fast, Intermediate, Slow, and Gasification).