Postprint: Biochar Yield and Physicochemical Properties of Five Halophytes

Authors: Mao Mingyue

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Abstract

To understand the interspecific differences in biochar properties derived from different halophytes, five Chenopodiaceae halophytes—Suaeda salsa, Salicornia europaea, Suaeda altissima, Atripex aucheri, and Halostachys caspica—were selected as research subjects and pyrolyzed at 500°C to prepare biochar. Through physicochemical property analysis combined with principal component analysis, the influence of halophyte feedstock on biochar property variations was investigated. The results showed that biochar yield was affected by the ash content of the halophyte feedstock. Furthermore, the ash, nutrient, and cation contents of biochar were influenced by the chemical composition of the halophyte feedstock. Pyrolysis significantly increased the ash content of the biomass; compared with the raw materials, the ash content of the five biochars increased by 67.23%-169.32%. Concurrently, with the increase in ash content, water-soluble Na+, K+, and other monovalent ions were enriched, pH and electrical conductivity (EC) increased, and alkalinity was enhanced. This study provides fundamental data and theoretical references for the application of halophyte-derived biochar in ameliorating acidic soils and selecting pyrolysis feedstocks.

Full Text

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Authors: MAO Ming-yue[1,2], ZHAO Zhen-yong[1], WANG Shou-le[1,2], TIAN Chang-yan[1], ZHANG Ke[1], GONG Jiang-ping[3], ZHANG Zheng[3], JING Wei-min[1]

Affiliations:
[1] State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, Xinjiang, China

[2] University of Chinese Academy of Sciences, Beijing 100049, China
[3] Karamay City Architecture Planning and Design (Institution) Co. Ltd, Karamay 834000, Xinjiang, China

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Correspondence: mao⋯; tianchy@ms.xjb.ac.cn

Abstract

The purposes of this research were to figure out the difference of biochar yield and physicochemical properties among five halophyte species, i.e., *Suaeda salsa*, *Salicornia europaea*, *Suaeda altissima*, *Atriplex aucheri*, and *Halostachys caspica* under 500℃ carbonization condition. The results showed that the biochar yield was positively correlated with the ash content of raw material, but negatively correlated with the lignin content of raw material ($P<0.01$). There was a significant correlation between the raw material and the biochar in ash content and total carbon content ($P<0.01$). In addition, the contents of elements in the raw materials determined the amount of elemental content in biochar. Noticeably, carbonization increased effectively the ash content in five halophyte species, it was increased by 132.45% in *S. salsa*, 91.62% in *S. europaea*, 121.79% in *S. altissima*, 169.24% in *A. aucheri*, and 67.22% in *H. caspica*, respectively. Besides, the amount of sodium and potassium ions abstracted by distilled water was increased with the increase of ash content. Moreover, carbonization could effectively increase the pH (70.76%-82.33%) and EC (68.19%-144.96%) values of halophyte species. This study could be referred in researching the biochar yield and improving acidic soil by the biochar of halophytes.

Keywords: halophyte; biochar; yield; ash; physicochemical property

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1. Introduction

Halophytes are important plant resources in saline-alkali environments, and their utilization has attracted increasing attention in recent years. Previous studies have investigated the ecological functions of halophytes in salt-affected soils〔10〕, as well as their potential applications in bioenergy production〔11-12〕. Research on biochar derived from halophytes has also explored its effects on soil improvement and carbon sequestration〔13-14〕.

Biochar production from halophyte biomass offers a promising approach for both waste utilization and soil amendment. The physicochemical properties of biochar are influenced by feedstock composition and pyrolysis conditions〔15〕. Understanding the relationship between raw material characteristics and biochar properties is essential for optimizing the carbonization process and predicting biochar performance in field applications.

This study investigated five halophyte species: *Suaeda salsa* (U+bc), *Salicornia europaea* (Ude), *Suaeda altissima* (fbc), *Atriplex aucheri* (ghijk), and *Halostachys caspica* (Ul<). The objectives were to determine the biochar yield and physicochemical properties under uniform carbonization conditions at 500℃, and to examine the correlations between feedstock composition and biochar characteristics.

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2. Materials and Methods

2.1 Sample Collection and Preparation

The five halophyte species were collected and processed for biochar production. Raw materials were characterized for their initial physicochemical properties prior to carbonization〔25〕. *Halostachys caspica* and other species were prepared following standard protocols for biomass pyrolysis.

2.2 Carbonization Procedure

Pyrolysis was conducted at 500℃ under controlled conditions. The biochar yield was calculated as the mass percentage of the final product relative to the raw material. All experiments were performed with three replicates to ensure statistical reliability.

2.3 Analytical Methods

Physicochemical properties were analyzed using standard procedures. Ash content, total carbon content, and elemental composition (C, H, O, N, S, Ca^{2} , Mg^{2} , Na , K) were determined 〔27–29〕. The pH and electrical conductivity (EC) were measured in aqueous extracts. Water-extractable sodium and potassium ions were quantified to assess the solubility of alkaline components.

Statistical analysis was performed using SPSS 19.0 software. Significant differences among species were evaluated using analysis of variance (ANOVA) with post-hoc comparisons. Pearson correlation analysis was applied to examine relationships between feedstock properties and biochar characteristics. Significance levels were set at $P<0.05$ and $P<0.01$.

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3. Results

3.1 Biochar Yield and Ash Content

The biochar yield ranged from 7.51% to 35.68% among the five halophyte species, with *Salicornia europaea* showing the highest yield (35.68%). Statistical analysis revealed that biochar yield was significantly and positively correlated with the ash content of raw material (P<0.01), but negatively correlated with lignin content (P<0.01).

Carbonization effectively increased the ash content in all five halophyte species. The ash content increased by 132.45% in *Suaeda salsa*, 91.62% in *Salicornia europaea*, 121.79% in *Suaeda altissima*, 169.24% in *Atriplex aucheri*, and 67.22% in *Halostachys caspica*, respectively. A significant correlation existed between raw material and biochar ash content (P<0.01).

3.2 Elemental Composition

The elemental contents in biochar were determined by the composition of raw materials. Total carbon content showed significant correlation between raw materials and biochar products (P<0.01). The distribution of major elements (C, H, O, N, S, Ca, Mg, Na, K) varied among species, reflecting differences in feedstock composition.

3.3 pH and Electrical Conductivity

Carbonization substantially increased the pH values of all halophyte biochars by 70.76% to 82.33%. The EC values also increased significantly, ranging from 68.19% to 144.96% compared to raw materials. These increases were positively associated with the ash content of biochar.

3.4 Water-Extractable Ions

The amounts of sodium and potassium ions extracted by distilled water increased with increasing ash content, indicating that higher ash content enhances the release of alkaline ions. This property is beneficial for ameliorating acidic soils.

Tab. 1 Physicochemical properties of five halophyte species

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4. Discussion

The significant positive correlation between biochar yield and ash content suggests that mineral components in halophytes contribute to char formation during pyrolysis. Conversely, the negative correlation with lignin content indicates that lignaceous materials are more readily volatilized at high temperatures [17-18].

The substantial increase in ash content after carbonization demonstrates that pyrolysis concentrates mineral elements while decomposing organic compounds.

This concentration effect enhances the potential of halophyte biochar as a soil amendment, particularly for acidic soils [32-34].

The elevated pH and EC values following carbonization are consistent with previous studies on biochar from various feedstocks [35]. The increased water-extractable Na and K ions further support the utility of halophyte biochar in neutralizing soil acidity and providing essential nutrients.

The variation in biochar properties among the five species reflects inherent differences in their chemical composition. *Salicornia europaea* exhibited the highest biochar yield and significant increases in key parameters, making it a particularly promising feedstock for biochar production in saline environments.

References

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[Additional references appear in the original text but are too corrupted to accurately transcribe]

Note: Figure translations are in progress. See original paper for figures.