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The role of biochar for agricultural and environmental purposes with best quality considerable characteristics

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Abstract

Biochar is a carbon product while the raw materials, like forest, animal compost, and plant residues, and is heated in a closed storage place under anaerobic process. It is distinguished from charcoal by its use as a soil amendment. As a soil amendment it offer several benefits, which include increased soil texture, soil carbon, nutrient retention, and cation exchange capacity, beside support to microbial diversity and it also suppress disease infestation on various crops. The overall process is known as pyrolysis. Biochar quality from different sources is determined by the potential carbon sequestration, CO_2 reduction potential and physicochemical properties. During biochar production the most important considerable's includes up to 90% on feedstock type and temperature levels are the main characters. For agricultural purpose Biochar contributed as moderately contemporary improvement, evolving in combination with soil managing, carbon confiscation or sequestration matters, and immobilization of contaminants. Also, several studies observed that biochar amended soil help proliferate plant growth promoting rhizobacteria/fungi. The environmental advantage of biochar can relieve climate change through soil fertility improvement; enhance its structure, water penetration and aeration as well as decreases synthetic fertilizer and pesticide utilization and greenhouse gases emission reduction. Areas with enough vegetative covers by the contribution of the above soil hydrological and environmental properties will have crucial role for the environmental safety of particular areas.

Keywords: Soil amendment; Pyrolysis; Carbon sequestration; Biochar; Physicochemical

1. Introduction

Biochar is a source of organic fertilizer that is receiving special consideration by researchers all over the world [1]. It is the carbon products, gained while the raw materials, like forest, animal compost, and plant residues, and is heated in a closed storage place under anaerobic process. In many technical and clearer standards, biochar is created by seeming thermal decomposition of organic substance below incomplete supply of (O_2) oxygen, and at comparatively low temperature (<700°C) [2]. Biochar is the product of thermal degradation of organic materials in the absence of air (pyrolysis) (an aerobic digestion). Anaerobic digestion (AD) is among the popular and widely applied technologies under the concept of the circular economy, which aims to recover bio energy from excess crop residues, manure, and other organic wastes from agro-processing industries [3]. The AD process recovers energy as bio methane, which is recycled back to cover the company's energy demand whilst the surplus can be supplied to local electricity grids.

It is distinguished from charcoal by its use as a soil amendment. It is a C rich material produced thorough pyrolysis process by heating any biomass like manure, organic wastes (straws, husks and weeds with easily degradation potential), bio energy crops (grasses, willows) and crop residues [3]. In addition, at the end of the AD process, the

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residues (anaerobic digestate) that remain in the reactor can be used as biofertilizer. The anaerobic digestate usually contains high concentrations of bioavailable nutrients, such as ammonium, phosphorus, potassium, magnesium, calcium, and trace elements (Fe, Ca, Mg, K, Zn, Cu, and Mn) in addition to organic matter [4]. As a soil amendment, biochar has been reported to offer several benefits, which include increased soil texture, soil carbon, nutrient retention, and cation exchange capacity, beside support to microbial diversity that increases mineralization and availability of nutrients in amended soils [5]; [6]. Biochar amendment may not only improve soil properties but also suppress disease infestation on various crops. [7] found that biochar addition to the potting medium of strawberry (*Fragaria* sp) plants suppressed foliar diseases caused by fungi having Pseudomonas in several crops. Several studies observed that biochar amended soil help proliferate plant growth promoting rhizobacteria/fungi (PGPR/F) which are known to promote plant health in addition to plant growth either by directly controlling plant pathogens or through the potentiating of plant systemic resistance responses against diseases.

Therefore this manuscript aimed at highlighting of biochar characteristics along with its concept of pyrolysis and impact on agriculture and environment with the prior considerable`s of biochar quality managements.

1.1. Concept of Pyrolysis process

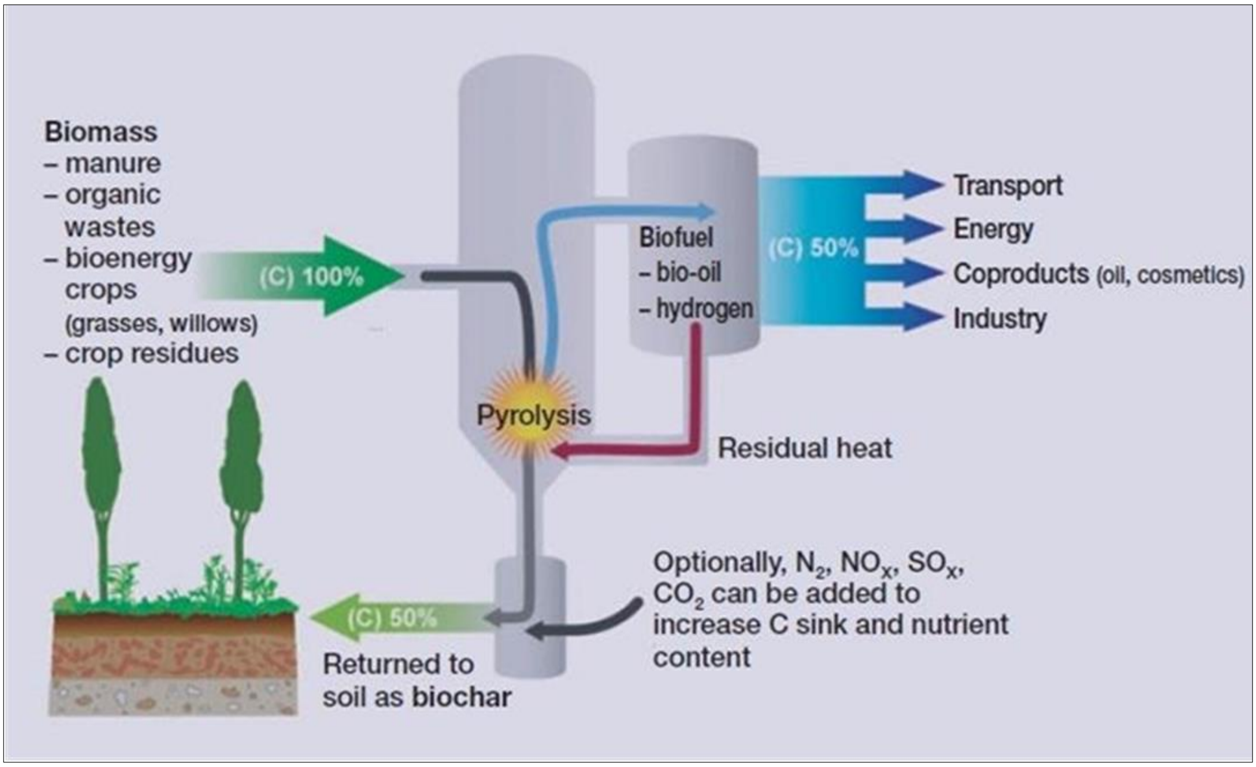

Figure 1 Concept of pyrolysis process with biochar sequestration uploaded by [8]

2. Characterization of Biochar quality from different sources

2.1. For Carbon sequestration

The amount of biochar produced from 1 kg of plant residue (waste) can be calculated using the amount of yield achieved after the pyrolysis of the residues at all temperature levels. With the calculated amount of biochar, the amount of potential carbon in 1Kg of plant residue (waste) can be determined based on the percentage of fixed carbon detected during the proximate analysis. Using the following equation:-

Total Potential Carbon= Total biochar produced * %Fixed Carbon

Carbon sequestrated= Total potential carbon * Carbon stability of 80%

CO_2 Reduction Potential= Carbon sequestrated amount *44/12.

Using the total potential carbon, the amounts of carbon sequestered and the carbon dioxide reduced in the atmosphere in one year will be calculated based on the altered carbon cycle during the biochar application. Conventionally, biochar establishes a carbon sink and shows a net carbon withdrawal from the atmosphere by 20% of carbon, hence 80% remains in a stable state. Hence, this will be converted to the potential carbon sequestered and used in the calculation of the carbon dioxide reduction potential [9].

The molar ratios of elements can be calculated to estimate the aromaticity (H/C) and polarity (O/C, (O + N)/C, and (O+ N + S)/C) of the biochar. The molar ratios of elements suggested an increased in aromaticity and a decreased in polarity of biochar with increasing pyrolysis temperature [10]. Increasing pyrolysis temperature results in decreased nitrogen content due to volatilization and increased cation exchange capacity [11], and carbon content, surface area, and ash content in biochar.

2.2. For physicochemical Property

To produce quality biochar the major consideration should be physic chemical property of pyrolysed product. Although the input or row material used for pyrolysis can determines the quality and temperature levels of pyrolysis considerable properties to determine the quality of biochar are physical and chemical compositions in the byproduct. The physical properties are pH measurement, Elemental analysis, BET (Brunauer, Emmett and Teller equation), FTIR (Fourier Transform Infrared Spectroscopy, Boehm titration, CEC (Cation Exchange Capacity) analysis and Gas chromatography are compulsory to determine the physical property of biochar. The second one is chemical characterization such as SEM (Scanning electron microscopy), XANES (XRay Absorption Near-Edge Structure), Particle size distribution, Ash content, Moisture content, Bulk density and Pore volume are important parameters.

The other properties of biochar, like (SA) surface area, pH, ash, (BD) bulk density, volatiles, (WHC) water holding capacity and (PV) pore-volume, are sensitive purposes of pyrolysis biomass and procedure conditions. Surface area is easily noticeable through classical adsorption mechanisms, such as nitrogen adsorp- tion investigated by the (BET) Brunauer-Emmett-Teller, adsorption isotherm [12], whilst proximate analysis offers quantification of fixed carbon, volatile and residual ash.

2.3. Considerable's at biochar production

Among soil organic amendments, biochar is considered as a more stable nutrient source than others [13]. Organic C content in biochar has been reported up to 90% depending upon its feedstock, which enhances C sequestration in soil [2].

Different scholars provide insight into the pyrolysis process and the resultant biochars based on chosen feedstock; they go on to present a summary of the types of biochars that provide positive yield responses and the economics of biochar creation, transportation, and utilization, following a whole-systems approach.

Feed stocks utilized for biochar production (e.g., woody biomass, crop residues, grasses, and manures) influence biochar characteristics, including concentrations of elemental constituents, density, porosity, and hardness . Composition of feedstock refers to the cellulose, hemicelluloses and lignin component of biomass. The breakdown rate of each component is different. The organic components of biomass cellulose, hemicelluloses and lignin material are considering a key factor for establishing suitable temperature and feedstock for biochar and bio-fuel production. Optimizing biochar for a specific application may require selection of a feedstock as well as pyrolysis production technique and conditions including pyrolysis temperature to produce biochars with specific characteristics. In many technical and clearer standards, biochar is created by seeming thermal decomposition of organic substance below incomplete supply of (O_2) oxygen, and at comparatively low temperature (<700˚C). [14] reported that cellulose and hemicelluloses decompose at 220–400 °C, whereas lignin is resistant to decomposition above 400 °C. Furthermore, biochar originates from the lignin component of the biomass, whereas bio-oil comes from cellulose at a pyrolysis temperature of 500 °C.

According to many scholars when biochars characterized as a product from three feed stocks pyrolyzed at various temperatures. In general, straw based biochars had greater soluble elemental concentrations than two woody-based biochars, although nutrient concentrations were not high enough to promote the direct use as a soil fertilizer. Increasing pyrolysis temperature increased biochar specific surface area, which may benefit sandy soils by increasing sorption sites or may improve the retention of non polar pollutants in soils. The authors also show that increasing pyrolysis temperatures affected the polycyclic aromatic hydrocarbon (PAH) content of biochar; PAHs are relatively recalcitrant and potentially toxic aromatic hydrocarbons formed during incomplete combustion. The C contents in the biochars were 58%, 62%, and 64% at 300, 500, and 700 °C, indicating that the biochar became more carbonaceous as temperature was increased. The biochar produced at high pyrolysis temperature indicate an increase in aromaticity and a decrease in polarity. By using X-ray diffraction analysis, the authors concluded that increasing pyrolysis temperature, cellulose loss and crystalline mineral components increased. [10] Reported that carbon content in biochar increased and H, N, and O contents decreased with increasing pyrolysis temperature, which indicate high carbonization at elevated temperature. The straw based biochar polycyclic aromatic hydrocarbon content increased with increasing pyrolysis temperatures whereas wood-based biochar PAH content tended to decrease with increasing temperature [15].

3. Biochar role for agricultural purpose

In the context of agro-processing and the soil grown food chain, the adoption of the 'circular economy approach' could improve resource use efficiency through value-added utilization of agricultural wastes focused on nutrients and energy recovery [15]. The expression "Biochar" is a moderately contemporary improvement, evolving in combination with soil managing, carbon confiscation or sequestration matters, and immobilization of contaminants [16]. Organic C content in biochar has been reported up to 90% depending upon its feedstock, which enhances C Sequestration in soil [2]. Different types of biochar can be used for improving soil properties and increasing agricultural production. A study conducted by [17] showed that the growth and yield of soybean (Glycine max (L.) Merr.) was increased due to addition of rice husk biochar. Likewise, soil properties such as soil pH, organic C, soil nitrogen (N), calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) changes due to the application of rice husk biochar in soil. Similarly, [18] reported that biochar significantly increased grain and straw yields of wheat (Triticum aestivum L.) by 15.7 and 16.5%, respectively, over the NPK application.

Biochar amendment may not only improve soil properties but also suppress disease infestation on various crops. [7] Found that biochar addition to the potting medium of strawberry (*Fragaria* sp.) plants suppressed foliar diseases caused by fungi having *Pseudomonas* in several crops.

Several studies observed that biochar amended soil help proliferate plant growth promoting rhizobacteria/fungi (PGPR/F) which are known to promote plant health in addition to plant growth either by directly controlling plant pathogens or through the potentiating of plant systemic resistance responses against diseases. [19] Demonstrated that addition of biochar to soil increased beneficial microorganism populations that promote plant growth and improve resistance against biotic stresses.

4. Biochar as environmental advantage

Biochar represents a tool management for quality of soil on the long period, with climate change mitigation. Presently, scientific of research, on the environmental advantages and agricultural scope of biochar is being published at growing rate. However, biochar is the main ingredient in a new carbon-negative strategy to resolution numerous critical current ecological, economic and energy defies. If properly made and used, biochar can relieve climate change and other environ-

mental effects: 1) Rise soil fertility & agricultural yields; 2) sequester carbon; 3) enhance soil structure, water penetration & aeration; 4) decrease use of pesticides and synthetic fertilizers; 5)

reduce methane emission from soil and nitrous oxide; 6) decrease farm chemicals leaching into watersheds and nitrate; 7) create or Produce renewable fuels from feedstock's; 8) change green & brown residues into valuable resources; 9) decrease dependence on imported oil; 10) support local, distributed energy production and distribution; 11) increase energy security and community food; 12) construct local jobs and economic cycles [8].

On the basis of their results, the authors suggest that biochars containing the following will be effective C sequestration agents when applied to soils: O:C ratio < 0.4, H:C ratio < 0.6 (O:C:H ratios serve as an indicator for the degree of carbonization that influences the stability of biochar in soil environments); black carbon content >15% C (black C is resistant to degradation) [20]. They further suggest other standards, including N–Brunauer–Emmett–Teller surface area > 100 $m^2\,g^{-1}$ (this may help predict the biochar effect on soil moisture levels) and recommend that biochar PAHs be less than background levels in soils for its utilization as a soil amendment [20].

Several field experiments showed that a decreased in bulk density of sandy loam soil by addition of biochar were recorded. Furthermore authors found increase in aggregate stability by 7–9% and 17–20% after two growing seasons.

According to [21] application of rice hull derived biochar increased the percentage of water stable aggregates by 36–69% directly indicates biochar role on edaphic environment. also literatures showed amending soil with biochar has significant effect on soil hydrological properties (i.e., moisture content, water holding capacity, water retention, hydraulic conductivity, water infiltration rate), have an impact on the total vegetative cover of the area which leads to the environmental safety and unsympathetic. Because of areas with enough vegetative covers by the contribution of the above soil hydrological and environmental properties will have crucial role for the environmental safety of particular areas.

5. Conclusion

Biochar is a source of organic fertilizer created by seeming thermal decomposition of organic substance below incomplete supply of (O_2) oxygen. This anaerobic digestion aims to recover bio energy from excess crop residues, manure, and other organic wastes from agro-processing industries. The byproduct from such process has been used as a soil amendment, soil physicochemical and structural properties improvement. Biochar production has its own basic concept of residue utilization, pyrolysis and byproduct production for soil organic amendment. This by product needs special consideration on temperature and waste sources for successful biochar production. Biochar has also several advantages for agricultural and environmental advantage.

Compliance with ethical standards

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