

BIOCHAR: AN ORGANIC SOURCE OF NUTRIENTS

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When a carbon-rich material is exposed to relatively low-temperature heat (<700⁰c) in the closed oxygen-devoid chamber, the material turns into a porous deep black material known as *biochar*. The process is commonly known as “pyrolysis”. When it comes to technical terminology, biochar is produced by thermal decomposition of organic material under restricted oxygen supply. The process of biochar production mirrors the production of charcoal but differs when it comes to heating temperature and level of oxygen present. The other basic difference is that biochar is produced with the prime intention to application in the soil as a method of carbon sequestration and a filtration agent for percolating contaminated water. Biochar is sometimes also get mentioned as ‘agrچار’ In a normally open condition, burning a carbon-rich material converts into ash which mainly contains minerals such as calcium, magnesium, carbonates, etc. In the normal burning condition, only a small portion is converted to biochar and separation of it from charcoal is physically not possible.

When it comes to differentiating the biochar from charcoal, based on chemical point of view rather than from production point; it’s become more difficult due to the fact that there is no universal standard for biochar and a wide variety of biochar can be produced based on a wide variety of biomass and charring process. The main chemical structure of biochar comprised of high carbon content made up with aromatic compounds having a ring structure of six carbon atoms linked together without any Oxygen (O) or hydrogen (H). It has the exact similar structure as graphite but the stacking of sheets. It was Rosalind Franklin who did the characterization of Biochar in the 1940s. Another similar product is ‘activated charcoal’ which is a biochar type substance which has been activated in various ways which generally increases the surface area. Activated charcoal can be used as an absorbent for agrochemical residues.

History

The history of the application of the charcoal-based product is not new and the evidence of its application has been found from various excavation work around the globe. In Brazil, a soil type is known as '*Terra preta de Indio*' contains a very high amount of biochar which proves the fact that the application of biochar is not a new thing. The same type of biochar admixed soil has been found in the Andes zone and Plaggen soils of Europe. The interesting fact is that all these zones do not fall under the same climatic condition hence justifies the fact that the application of biochar was not bound to specific climatic requirement. Because of the anthropogenic and long term effect on soil fertility; '*terra preta*' has garnered the greatest interest. Soil analysis of that area has supported the claim that biochar is very efficient in holding the plant nutrient especially nitrogen, potassium, and calcium along with high moisture content. While it is possible that pyrolysis was first used to make charcoal over 7,000 years ago for the smelting of copper, or even 30,000 years ago for the charcoal drawings of the Chauvet cave (Antal, 2003), the first decisive indication of pyrolysis for charcoal production comes from over 5,500 years ago in Southern Europe and the Middle East. By 4,000 years ago, the start of the Bronze Age, pyrolysis use for the production of charcoal must have been widespread. This is because only burning charcoal allowed the necessary temperatures to be reached to smelt tin with copper and so produce bronze

A range of compounds can be found in the natural environment that is produced by both anthropogenic and non-anthropogenic pyrolysis. These include compounds released from the incomplete burning of petrol and diesel in internal combustion engines.

Preparation of Biochar

Biochar can be made from a range of biomasses that have different chemical and physical properties. The properties of each biomass feedstock are important in the thermal conversion process, particularly the proximate analysis caloric value, fractions of fixed carbon, and volatile components; percentage of lignin, cellulose, and hemicelluloses, percentage and composition of an inorganic substance, bulk, true density, particle size, and moisture content. The most widely used material for biochar production is bioenergy crops like sugarcane, leaf litters, organic waste such as livestock excreta, crop residue, sewage sludge, etc. Carbonized organic materials can be divided into various groups based on

torrefaction (low-temperature pyrolysis), slow, intermediate and fast pyrolysis as well as gasification, hydrothermal carbonization (HTC) or flash carbonization used for its production. The most commonly used method for biochar used in agriculture is torrefaction and slow pyrolysis. In this process, the raw materials are heated in an oxygen-devoid Klein powered by thermal or electric sources. Pyrolysis occurs extemporaneously at high temperatures (generally above approximately 300°C for wood, with the definite temperature fluctuating with the material). It takes place in nature when vegetation is exposed to wildfires or comes into contact with lava from volcanic eruptions. At its most extreme, pyrolysis leaves only carbon as the deposit and is called carbonization. The high temperatures used in pyrolysis can persuade polymerization of the molecules within the feedstocks, whereby larger molecules are also produced (including both aromatic and aliphatic compounds), as well as the thermal decomposition of some components of the feedstocks into smaller molecules. During the pyrolysis process, a flammable gas known as *syngas* is also produced which can be further used to provide energy for subsequent pyrolysis cycle which can essentially reduce the fuel cost. Fast pyrolysis is only possible when the moisture content of the material is less than 10%. The material should be further grounded into a 2mm sieve size for rapid reaction and burning. During the pyrolysis process, Cellulose and lignin undergo thermal degradation at a temperature ranging between 240-350°C and 280-500°C respectively. The relative proportion of each component will, therefore, determine the extent to which the biomass structure is retained during pyrolysis at any given temperature. It has been found that plants with the highest lignin content produce more biochar yield. The majority of mineral content remains within the biochar even after the pyrolysis process; this is even true if the silica content is high (rice straw contains around 170 g/kg silica). It indicates the fact that the surplus rice straw of north western rice-wheat belt can be effectively used for biochar production.

Table.1: quantity proportions of nutrients (g/kg) in feedstocks

| Material | Ca (g/kg) | Mg (g/Kg) | K (g/kg) | P (g/ Kg) |
|----------------|------------|-----------|----------|-----------|
| Wheat straw | 7.70 | 4.30 | 2.90 | 0.21 |
| Rice straw | 6.9 | 4.7 | 2.3 | 0.20 |
| Maize cob | 0.18 | 1.70 | 9.40 | 0.45 |
| Maize stalk | 4.70 | 5.90 | 0.03 | 2.10 |
| Forest residue | 130 | 19 | - | - |

Source: Chan and Xu (2009)

Weed management and Biochar

Weed infestation is a major menace which accounts for around 45% of the total agricultural loss. Although in general condition weed may be considered as totally unwanted but it can be turned into useful biochar. Some weeds are very well known for their capacity to accumulate specific nutrients; converting them into biochar and further application of them into the agricultural field will ensure the close nutrient cycle. As for example, *Chenopodium album* is a very good accumulator of potassium while *Setaria lutescens* accumulate a high level of zinc (585 ppm). Converting weeds into biochar can achieve dual target i.e., weed control as well as returning valuable micro nutrient to the land.

Table.2: Physical properties of biochar (<0.50 mm size) from different weed species

| S. No. | Biochar component | Recovery (%) | Bulk Density (mg/m ³) | Particle Density(mg/m ³) | Pore space | Available moisture (%) |
|--------|-------------------|--------------|-----------------------------------|--------------------------------------|------------|------------------------|
| 1. | <i>Lantana</i> | 28.5 | 0.37 | 1.25 | 70.37 | 38.9 |
| 2. | <i>Dodonia</i> | 26.1 | 0.50 | 1.00 | 50.00 | 23.9 |
| 3. | <i>Eichornia</i> | 35.6 | 0.38 | 2.50 | 84.62 | 42.0 |
| 4. | <i>Prosopis</i> | 40.0 | 0.36 | 1.25 | 71.43 | 43.3 |
| 5. | <i>Melia</i> | 35.0 | 0.42 | 1.67 | 75.00 | 44.9 |

Table.3: Chemical properties of biochar (<0.50 mm size) from different weed species

| S. No. | Biochar component | EC (dS/m) 1:5 | pH (1:5) | CEC (cmol (p+)/kg) | N (%) | P (%) | K(%) |
|--------|-------------------|---------------|----------|--------------------|-------|--------|-------|
| 1. | <i>Lantana</i> | 4.07 | 10.29 | 18.0 | 0.923 | 0.0390 | 1.797 |
| 2. | <i>Dodonia</i> | 1.50 | 9.10 | 13.8 | 0.426 | 0.100 | 0.194 |
| 3. | <i>Eichornia</i> | 7.50 | 10.38 | 23.8 | 1.421 | 0.671 | 3.096 |
| 4. | <i>Prosopis</i> | 3.03 | 9.80 | 18.8 | 1.03 | 0.160 | 1.226 |
| 5. | <i>Melia</i> | 2.93 | 9.94 | 23.0 | 0.848 | 0.199 | 1.670 |

Table.4: Micro nutrient content of biochar (<0.50 mm size) from different weed species

| S. No. | Biochar component | Zn (µg/g) | Fe (µg/g) | Cu (µg/g) | Mn (µg/g) |
|--------|-------------------|------------|------------|------------|------------|
| 1. | <i>Lantana</i> | 33.9 | 760.0 | 21.2 | 79.2 |
| 2. | <i>Dodonia</i> | 13.4 | 418.5 | 13.4 | 46.1 |
| 3. | <i>Eichornia</i> | 85.5 | 5089.0 | 20.2 | 449.3 |
| 4. | <i>Prosopis</i> | 14.4 | 526.3 | 19.1 | 39.6 |
| 5. | <i>Melia</i> | 24.7 | 3246.8 | 25.0 | 188.0 |

Source: Sellamuthu *et. al.* (2018).

Various research conducted in the past indicates that various allelochemicals (such as ambrosin in Parthenium) lost during the pyrolysis process. Moreover, soil microbial biomass carbon also increases with an increased dose of biochar.

Biochar Application Method

The way biochar is applied to soils can have a considerable impression on soil processes and functioning, including facets of the behavior and fate of biochar particles in the soil and the wider environment. In the case of topsoil incorporation; biochar can be applied on its own or combined with compost or manures. The cultivation techniques influence the degree of mixing. In case of the conventional tillage system; the biochar should be homogeneously thoroughly mixed with the top soil. Being lighter in weight the biochar dust particle is very much prone to wind and water erosion hence it is always better to place the biochar in the root zone. This method is often referred to as ‘deep- banding’.

GHG mitigation through Biochar

The charcoal formation pathway is known for sequestering atmospheric carbon into the terrestrial reservoir via stabilization of short term cycling biogenic carbon into long term carbon pool. The Upper 100 cm surface soil of Earth contains around 1200-1600 Gt global organic carbon pool which has massive sequestration potential as if we consider the global emission of CO₂ carbon from the combustion of fossil fuel which is around 270 Gt since 1850 to 2000.

Effect of Biochar

The biochar contains over 95% of micropores within it which can effectively store plant available water. Biochar also changes the soil color; various literature indicates that the Munsell value to decrease from 5.5 to 4.8. The darker color results in less albedo. The modeling approaches indicate that the large scale application of biochar in a wide area can even intensify the monsoon. It also helps in plant establishment during the winter season. Biochar has seven times larger external surface area than the internal surface area, hence it has better CEC. As biochar is neutral to alkaline in nature; it can be effectively used as a liming material. Several experiments also indicate that the application of biochar may lead to decreased nutrient leaching. Biochar directly contributes to nutrient adsorption through charge or covalent interactions on a high surface area.

Conclusion

Biochar improves the soil physical properties as well as soil processes. It can be incorporated directly into the top soils or may be mixed with farmyard manure or compost and applied to the soil. Biochar is an important source of nutrient which provides the nutrients for improvement of soil fertility. It also helps in mitigation of GHG by carbon sequestration in the soil. Keeping in view all the physical and chemical properties of biochar it may be recommended to the agriculture for optimum utilization and benefits.

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