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Original Research Article

# Influence of pyrolysis temperature on physico-chemical characteristics of biochar for agricultural use

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## Abstract

Biochar is a promising technology for agriculture with its ability to improve soil nutrient, to sequester carbon in soil, and reducing waste. The biochar stability depends on thermo chemical conversion of the native carbon structure of the biomass to aromatic ring structures via slow pyrolysis. This study revealed that characteristics of biochar changes with pyrolytic temperature. Biochar produced from pigeon pea stalk at different pyrolytic temperature (300, 350, 400, 450 and $500^0$C) with particle size of 0.7-1.4 mm and the heating rate of $14^0$C min-1. The pH, EC, proximate analysis was determined. Total elemental C, H, N, O, and S content, calorific value and total inorganic elemental composition were measured. The surface functionality of the biochars was measured by FTIR spectroscopy. As pyrolysis temperature increased the aromaticity, carbon content, and ash content increased while the oxygen and hydrogen contents decreased. This indicates an increasing degree of carbonization. In addition, as showed by FT-IR spectroscopy biochar produced from pigeon pea stalks showed that as temperature increased, functionality decreased.

**Key Words**: Biochar, Pyrolysis Temperature, Characteristics, Carbonization.

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## INTRODUCTION

Biochar is one of the few technologies to mitigate climate and to improve soil condition that is comparatively low-cost, and broadly appropriate. There is a need to recycle organic waste into bio-products (bio-fuels, bio-char, etc.) is extremely practicable and is both sustainable and renewable. (bio-fuels, bio-char, etc.) At present, feedstock of biochar used for profit and research facilities consist of wood materials (wood chip and pellets, and bark of a tree), crop residues (straw, nutshells, and rice hulls), switch grass, dairy manure, organic wastes (paper sludge, sugarcane bagasse, distillers grain, olive waste), and sewage sludge (Sohi *et al*., 2010). The emission of greenhouse gases such as Carbon-dioxide, methane and nitrous oxide could be lower on the basis of feedstock used for the production of biochar (Lehmann *et al*., 2006 and Spokas and Reicosky, 2009). It is believed that application of biochar to soils in terrestrial ecosystems act as a potential approach for generating significant, long-term carbon storage for atmospheric CO2 i.e. the source of green house gases (Lehmann, 2007 and Kuzyakov *et al*., 2009). Application of biochar to soils in various behavior like improve soil physico-chemical properties, increase bioactivity of soil micro-flora, reduce leaching of nutrient,and increase soil organic carbon that can affect the growth of plant. (Steinbeiss *et al*., 2009 and Gaskin *et al*., 2010). In India research revealed that while using pigeon-pea as biochar, bulk density of the soil was affected, also increase the root volume and root weight of the crop during crop rotation (Zwieten *et al.*, 2009). In this study, a biochar were prepared from the straw of pigeon pea at different temperatures (300,350, 400, 450 and 500°C) by mean of oxygen-limited pyrolysis. The objectives of this study were to compare the physicochemical properties of the biochar samples. In order to achieve this objective, Biochar can be characterized included chemical tests, elemental and proximate analysis, and Fourier Transform Infrared (FTIR) spectroscopy.

## MATERIAL AND METHODS

Pigeon pea stalks were used for the preparation of biochar. Pigeonpea was collected from farmers` fields and dried. The production of biochar from pigeonpea was carried out at the Central Institute of Agricultural and Engineering (CIAE) at Nabibagh, Bhopal using a reactor with electrical heating arrangements and controller to maintain the desired temperature (Singh, A.*et al.*, 2015) To produce biochar, slow pyrolysis of the dried pigeon pea stalks was performed for 2 hrs at 300, 350, 400, 450 and 500 °C under oxygen-free conditions.

**Characterization of biochar produced from pigeon pea stalks:** The pyrolysed pigeon pea was characterized for pH, EC, Cation Exchange Capacity (CEC), and elemental composition. Proximate analyses of biomass and biochar were determined based on standard methods (moisture content: ASTM E871-82, ash: ASTM D1102-84, volatile matter: ASTM E872-82 and fixed carbon: by difference) Ultimate analyses (CHNS) were determined using an Elemental Analyzer (Carlo Erba Instruments). Oxygen was analysed by difference. Chemical functional groups were analysed by Fourier transform infrared spectra (FTIR) using SHIMADZU IR Prestige 21. pH values and EC were measured by adding biochar to de-ionized water in a mass ratio of 1:20. (Inyang *et al.*, 2010). The higher heating value (HHV) of biomass was measured by bomb calorimeter.

## RESULTS AND DISCUSSION

**Yield of Biochar:** The yield of biochar at pyrolytic temperature at 300, 350, 400, 450, 500 $^0$C of pigeon pea stalks were determined. The effect of pyrolysis temperature on the biochar yield is shown in Fig.1.The decrease in the yields of biochar with an increase of pyrolysis temperature due to greater primary decomposition or through secondary decomposition of char residues. (Singh, A *et al.*, 2013). The yield of biochar at different temperature varied from 39 to 62 %.

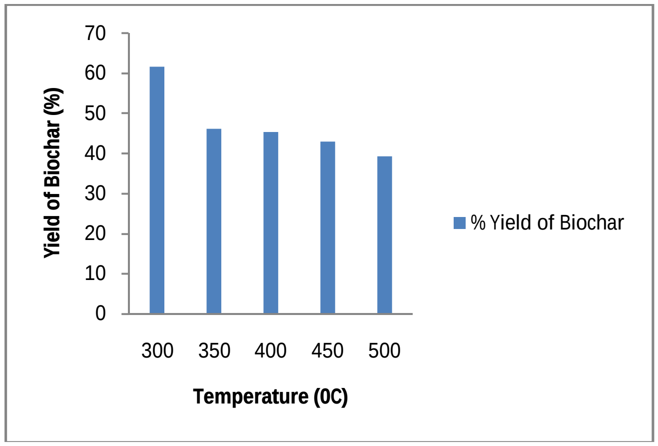


**Figure 1:** Effect of pyrolysis temperature on yield of Pigeon pea biochar

**Carbon Content:** The carbon content present in biochar produced from pigeon pea stalks at different temperature was analyzed. As the pyrolysis temperature increased from 300 to 500 $^o$C, the carbon content of the biochars increased from 60.72 to 73.44 %.

**pH values and Electrical Conductivity (EC):** The pH values and EC of the biochars produced from pigeon pea were analyzed at different pyrolytic temperature. With increase in pyrolytic temperature, the value of pH and EC increases. The pH of the biochars was found to be 7.19 to 8.91 at retention time of 60 minutes. Similarly, the EC of biochar was found to be increasing from 1.50 to 4.11 mS cm$^{-1}$ with rise in temperature of biochar from 300 to 500$^0$C.

**Proximate Analysis**: The results of the proximate analysis, and higher heating value (HHV) of biochars produced at different pyrolysis temperatures are shown in Table 1. The volatile matter content of the biochars decreased from 83.40 % to 41.75 % at a heating rate of 14 $^0$C min−1 as the pyrolysis temperature was increased from 300 to 500 $^0$C.

**Table 1:** Characteristics of pigeon pea biochars produced at different pyrolysis temperatures

| **Moisture %** | **5.52** | **3.26** | **1.76** | **1.376** | **0.796** | **0.596** |
|---|---|---|---|---|---|---|
| Ash % | 1.63 | 3.62 | 4.86 | 5.69 | 6.21 | 6.64 |
| Volatile Matter % | 83.4 | 74.36 | 61.7 | 53.19 | 48.4 | 41.75 |
| Fixed carbon % | 14.97 | 22.02 | 33.44 | 41.12 | 45.39 | 51.61 |
| HHV (MJ kg$^{-1}$) | 27.23 | 27.86 | 28.13 | 28.71 | 29.14 | 30.15 |
| Heating rate at 14 $^0$C | Biomass | 300$^0$C | 350$^0$C | 400$^0$C | 450$^0$C | 500$^0$C |

**Ultimate Analysis:** The results revealed that the elemental analysis of pigeon pea biochar obtained at various pyrolysis temperature ranged from 300 to 500 0C, the carbon content of the biochar increased from 61.2 to 73.6 %, however, the hydrogen content decreased from

4.17 to 2.24 wt %, and oxygen content decreased from 26.24 to 21.11 wt.%. With the increase in temperature, H/C and O/C atomic ratios gradually decreased, showed that the biochars became gradually more aromatic and carbonaceous (Fu *et al*., 2011).

**Nutrient properties:** The total potassium, nitrogen, sodium, calcium and magnesium in pigeon pea were found to be 0.3, 0.4, 0.1 and 0.1%, respectively. The sulphur was observed highest in pigeon pea biomass (1735 mg kg-1).The K content was found 0.81% for biochar produced at 350 $^0$C. The sulphur and phosphorus content was 443 and 1140 mg $kg^{-1}$. The cation exchange capacity of the biochar ranged 25-36 c mol kg-1. In general, the pH, EC, TOC, and all elements except S found increasing with rise in the pyrolysis temperature depending on the type of feed stalk material used for production of biochar (Huff *et al*. 2014, Hao *et al*. 2014).

**FTIR Analysis:** The FTIR analyses revealed that biochars became increasingly more aromatic and carbonaceous with increase in pyrolysis temperature, and these changes could easily be detected from FTIR spectral differences.

## CONCLUSION

Pyrolysis studies showed that it can be attained a more helpful and efficient product (biochar) from pigeon pea that can be effectively used for the preparation of activated carbon. The physicochemical as well as structural properties of the biochar were significantly influenced by pyrolysis temperature. The experimental result of FTIR showed that the degree of carbonization for biochar was also persuaded with increasing pyrolysis temperature from 300 to 500 $^0$C. Biochars produced at high pyrolysis temperatures (450 $^0$C) are suitable for carbon sequestration and agronomic use due to their high fixed carbon content, higher heating value, and low volatile matter content.

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