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CONTENTS

Effect of pyrolysis temperatures on major nutrients and some physical and chemical properties in biochar produced from different biosources

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ABSTRACT: The effect of different pyrolysis temperatures was examined on the major nutrient composition, nutrient ratios and some physico-chemical properties of biochars produced from pine needles, lantana and wheat straw. An increase in pyrolysis temperature increased the concentrations of C and K in all biochars except in wheat straw biochar wherein a decrease in C was noticed with an increase in pyrolysis temperature from 450°C to 550°C. Phosphorus concentration in wheat and pine needle biochars increased significantly with the increase in pyrolysis temperature from 300 to 450°C and further increase from 450 to 550°C decreased P concentration in wheat straw and pine needle biochar but an exactly opposite trend was noted for the C:P ratio. Both the pH and electrical conductivity of biochar increased with increase in pyrolysis temperature, however, increase in temperature from 450 to 550° C decreased pH of Lantana biochar and electrical conductivity of lantana and wheat straw biochar. Considering the concentrations of major nutrients and physicochemical properties of plant-based biochar, a pyrolysis temperature of 450°C appeared to be optimum for biochar production. Among different feedstocks, biochar produced from pine needles had the highest N content while the one derived from wheat straw had the highest P and K content.

Key words: Biochars, major nutrients, nutrient ratios, pyrolysis temperature

Biochar is a carbon (C) dense solid substance formed by the pyrolysis of organic material and can be used to amend the soil (Lehmann and Joseph, 2015). Carbonaceous materials used for production of biochar are subjected to thermal decomposition and converted to aromatic compounds and become highly resistant to degradation.Basically, biochar consists of many poly-condensed aromatic compounds besides few ion exchange functional groups formed as a result of dehydration and decarboxylation reactions occurring during production of biochar. Biochar can be prepared from various wastes obtained from plant and animal sources by pyrolysis which otherwise remain unused at the farm after the crop production. The properties of biochar may vary mainly with the type of feedstock used and the conditions prevailing during the pyrolysis of the biomass such as pyrolysis temperature, residence time, heating rate and oxygen supply etc. (Sohi *et al.,* 2010). In India, crop production produces a huge amount of plant residues and wastes. A report by Ministry of New and Renewable Energy (MNRE), Government of India showed that the amount of total crop residue generated in a year is about 500 million tons, out of which about 92 million tons of surplus is burned every year in our country (MNRE, 2020). The reason behind burning of such a huge amount of crop residues is the unavailability of the proper management mechanism for their safe disposal. Some crop residues are used as fodder for the animals, while many other plant residues including weeds etc are not suitable asan animal's feed, therefore, often go as waste. One option for their productive utilization is to incorporate them into soil however, in the absence of suitable and popular machinery; farmers often opt to burn these plant residues in open. Apart from these farm residues, forests also generate a huge amount of plant wastes in the form of leaf fall and various dried and dead plant parts, which have neither any commercial usage nor can be collected and used by anyone as fodder or compost. Biochar production from these agricultural and forest residues could be a good choice for the safe disposal of these residues which are otherwise unsuitable for animal feeding or composting purpose.

Biochar production and use renders an environmental service as well because it can help in lowering down the atmospheric emission of CO_2, methane and nitrous oxide by almost 12% of the anthropogenic CO_2-C emission per year (Woolf *et al.,* 2010). Biochar is a long lasting compound, so C sequestration for a very long period of time can be done by using biochar which may accumulate in soil as beneficial terrestrial C. The biochar technology has more potential for soil C sequestration over the conventional methods of residues management in Indian agriculture (Rajagopal *et al*., 2018). Greenhouse gas (GHG) emission has also been reported to be less from the soil amended with the biochar both in cropped or non-cropped conditions (Karhu *et al.,* 2011; Zhang *et al.,* 2012; Panwar *et al*., 2019). The concentration of various environmental pollutants such as inorganic chemicals, pesticides, heavy- and radioactive-metals, etc. could also been reduced by the production of biochar (Ahmad *et al.,* 2014). Biochar could be used to improve the availability of nutrients besides improving soil physical conditions and in this context an evaluation of locally available biomasses for production of biochars and their nutrient compositions is very important. The present investigation was conducted to examine the effect of different pyrolysis temperatures on the major nutrient composition, nutrient ratios and some physico-chemical properties of biochar produced from three different biological sources for their potential use in agriculture.

MATERIALS AND METHODS

Three different plant residues namely; wheat straw, *Lantana camara* (a bushy weed) and dried pine needles were collected from N.B. Crop Research Centre and guest house, respectively. These plant residues were dried in an electric oven at 60°C for 72 h till the removal of moisture. The dried materials were chopped into small pieces to make them ready for the biochar preparation. Thereafter, these materials were enclosed in aluminum boxes provided with a loosely closed lid and the contents pyrolyzed in the muffle furnace at controlled temperature of 300, 450 and 550°C for 5 h under limited oxygen. The charred materials obtained after pyrolysis were crushed in a pestle and mortar to make them fine and homogenous powder. Crushed samples were passed through a sieve having openings of 0.5 mm diameter and stored in plastic containers for subsequent analysis and use.

Total organic carbon content of the biochar was estimated by the colorimetric analysis of C content after refluxing the biochar samples with potassium dichromate and concentrated sulphuric acid. Total N concentration in biochar samples was determined by using Duma's method based N-analyzer (Elementar N cube). Phosphorus and potassium concentrations in biochars were determined in di-acid (HNO_3: $HClO_4$, 3:1 v/v) digests by yellow molybdo-vanadate colorimetric method and flame photometry (Tandon, 1993). Physico-chemical properties like pH and electrical conductivity of biochar were determined in 1: 10 biochar-water suspensions using pH meter with combined glass electrode and conductivity meter.

The data were statistically analyzed by two factorial completely randomized design, variable effects were tested by F-test (Amdekar, 2014). The critical differences were computed at $p \leq 0.05$.

RESULTS AND DISCUSSION

As regards the main effect of pyrolysis temperature it is clearly evident from the data that an increase in the pyrolysis temperature significantly influenced the average concentration of C, P, K, C: N, C: P ratios in biochar materials (Table 1). The average concentrations of C and K significantly and regularly increased with an increase in pyrolysis temperature. Taghizadeh *et al.* (2012) also noted an increase in C content of biochar with increase in pyrolysis temperature. An increase in pyrolysis temperature from 300 to 450°C significantly increased the average concentration of P but decreased the average C: P ratio, however no significant change occurred in C: N ratio. Further, an increase in pyrolysis temperature from 450 to 550°C significantly decreased the average concentration of P but increased the average C:N and C:P ratio. Cantrell *et al.* (2012) also observed that higher pyrolysis temperature decreased N content but increased P and

Table 1: Effect of pyrolysis temperature and biomass sources on nutrient composition and nutrient ratios of biochars

Pyrolysis temp. (°C)	Biomass source	C (g/kg)	N (g/kg)	P (g/kg)	K (g/kg)	C:N	C:P
	WHEAT STRAW	567.7	6.7	0.64	10.3	85.2	900
300	PINE NEEDLE	597.2	14.2	0.88	4.7	44.4	676.8
	LANTANA	597.2	9.3	0.41	8.8	64	1454
	Average	587.4	10.1	0.64	7.9	64.5	1010.3
	WHEAT STRAW	606.9	6.5	0.96	18.8	93.9	632.8
450	PINE NEEDLE	604.6	15.4	1.29	9.1	40.3	467.2
	LANTANA	656.2	8.6	0.47	14.4	77.4	1391.1
	Average	622.6	10.2	0.91	14.1	70.5	830.4
	WHEAT STRAW	575.1	5.8	0.78	17.8	99.9	745.4
550	PINE NEEDLE	663.6	12.4	0.35	10.9	53.3	1897.1
	LANTANA	781.6	8.4	0.53	18.1	93.1	1467.3
	Average	673.4	8.9	0.55	15.6	82.1	1369.9
	WHEAT STRAW	583.2	6.3	0.79	15.6	93	759.4
Average	PINE NEEDLE	621.8	14	0.84	8.2	46	1013.7
	LANTANA	678.3	8.8	0.47	13.8	78.2	1437.5
C.D. ($p \leq 0.05$)	Pyrolysis temp. (T)	0.6	NS	0.04	1.3	6.2	62.3
	Biomass Source (B)	0.6	1.7	0.04	6.2	6.2	62.3
	T x B	1.1	NS	0.07	2.2	NS	107.9

K content of biochars prepared from different animal wastes. Regarding the effect of biomass sources, wheat straw biochar had the lowest average concentrations of C, N, and C: P ratio but had the highest average concentration of K and C:N ratio. The biochar produced from pine needles had the highest average concentration of N, P but the lowest concentration of K and C: N ratio. The biochar produced from lantana had the highest average concentration of C and C: P ratio but the lowest average concentration of P.

The interaction effect of pyrolysis temperature and biomass sources had a significant influence on nutrient concentration and nutrient ratios except the concentration of N and C: N ratio. An increase in pyrolysis temperature regularly increased the concentration of C in all biochars except in wheat straw where a significant decrease in the concentration of C occurred possibly due to conversion of some biomass into volatile matter. Wu *et al.* (2012) reported that an increase in pyrolysis temperature increased the aromatization of the rice straw biochar. The concentration of P in wheat and pine needle biochar increased significantly with the increase in pyrolysis temperature but no significant increase was noted in the case of lantana biochar. Further, an increase in pyrolysis temperature from 450 to 550°C decreased the concentration of P in wheat straw and pine needle biochar but no such effect was noted for lantana biochar which could be possibly related to woody nature of lantana biomass (twigs).The concentration of K in all biochar increased significantly with the increase in pyrolysis temperature from 300 to 450°C and further increase in pyrolysis temperature from 450 to 550°C increased the concentration of K significantly in lantana biochar alone while the increase recorded in concentration of K for wheat straw and pine needles biochar was found to be statistically not significant.

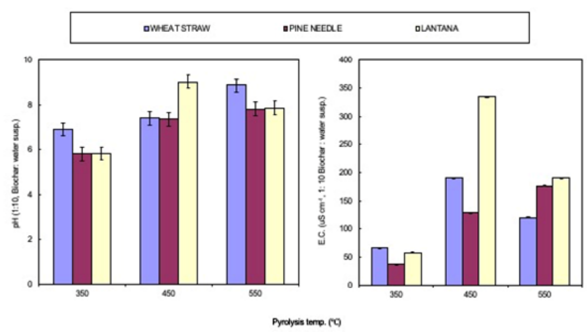

Fig. 1: Effect of pyrolysis temperature and biomass sources on equilibrium pH and electrical conductance of biochars

The C: P ratio of wheat straw and pine needle biochar decreased significantly with the increase in pyrolysis temperature from 300 to 450°C but no such effect was recorded for lantana biochar. Further increase in pyrolysis temperature from 450 to 550°C increased the C: P ratio significantly for wheat straw and pine needle biochar but no such effect was recorded for lantana biochar.

Some physico-chemical properties

The values on effect of pyrolysis temperature and biomass sources on pH and electrical conductivity of biochars are presented in Fig. 1.As shown in Fig. 1 the equilibrium pH of all three biochars increased significantly with the increase in pyrolysis temperature from 300 to 450°C. Novak *et al.* (2009) also observed that biochar pH increased with increase in pyrolysis temperature. Further increase in pyrolysis temperature from 450 to 550°C significantly increased the equilibrium pH of wheat straw and pine needle biochar but in case of lantana biochar such increase in pyrolysis temperature caused a decrease in equilibrium pH partly due to loss of alkaline and alkaline earth metals as oxides in ash and also the variations in the acidity of thermal decomposition products formed from different biomasses.

The equilibrium EC of all three biochars also increased significantly with the increase in pyrolysis temperature from 300 to 450°C and the highest increase was registered in lantana biochar. Further increase in pyrolysis temperature from 450 to 550°C also significantly increased EC of pine needle biochar while for wheat straw and lantana biochar, the equilibrium EC decreased significantly with the increase pyrolysis temperature possibly due to loss of soluble salts in ash. Similar trend was recorded by Taghizadeh *et al.* (2012) for biochar manufactured from Monterey Pine wood chips.

CONCLUSION

Considering the concentrations of major nutrients in biochars, their equilibrium pH and electrical conductivity, the pyrolysis temperature of 450°C appeared to be optimum for biochar production. Among different feedstock biomasses, biochar produced from Pine needles had the highest N content while the one from wheat straw had the highest P and K content.

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