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Biochar production from arecanut waste

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ABSTRACT

Biochar is a solid material derived from biomass carbonization by destructive distillation. It may be added to soils with the intention to improve soil functions and to reduce emissions from biomass that naturally degrade to greenhouse gases. Biochar also has appreciable carbon sequestration value. These properties are measurable and verifiable in a characterization scheme or in a carbon emission compensating protocol. Apart from soil carbon sequestration, thermal conversion of biomass like *Areca catechu* to biochar can become a sustainable strategy for biomass management. In the present study areca nut shell waste was charred at different temperatures ranging from 200 to 500°C with a residence time of 30 to 120 minutes. Biochar mass yield and volatile solids decreased from 82.97 to 37.06 per cent and from 86.37 to 49.64 per cent when the pyrolytic temperatures increased from 350 to 400°C with the residence time of 15 to 75 minutes respectively.

Keywords: Biochar; areca nut; waste; temperature; residence time

INTRODUCTION

Areca nut, *Areca catechu* L is an important commercial crop being grown in humid tropics of India. It is generally raised in laterite soils of acidic nature and low nutrient retention capacity. Wider spacing and the rooting pattern of areca nut allows growing of mixed crops in the garden. An increase in the biochar heating value (HV), carbon content and surface area and decrease in biochar yield, hydrogen and nitrogen contents with increasing pyrolysis temperatures of 400, 500 and 600°C are observed in general.

Agblevor and Besler (1996) investigated that under pyrolysis conditions ash minerals like calcium, potassium and phosphorous are completely sequestrated in the biochar fraction whereas sulphur, nitrogen and chlorine are converted partially to gaseous and condensable products.

The high ash content of biochar and the low melting point of char minerals have propelled the investigation of the thermal as well as non-thermal applications for the biochar. Recent centering is pitched towards investigating technologies such as torrefaction and pyrolysis which produce more biochar than gaseous or liquid biofuels. Torrefaction is a thermal upgrading process at a temperature of 200 to 300°C in the absence of air to improve physical and chemical characteristics of the biomass to assist in advanced conversion to biofuels.

MATERIAL and METHODS

The test procedure carried out was based on Anon (2013).

Sample preparation

Air dried samples of areca nut waste were taken, spread out in open to air-dry before carrying out the analysis. The sample was size reduced to 850 ìm by grinding. Long grinding hours were avoided as the heat generated could result in the loss of volatile material.

Moisture content

The muffle furnace was heated to 750°C and previously ignited porcelain crucibles and covers were placed in the furnace for 10 minutes. The crucibles were allowed to cool down in a desiccator for 60 minutes. These were weighed and added to each approximately 1 g and weighed to the nearest 0.1 mg of the ground sample. The samples were placed in the oven at 105°C for 120 minutes, dried in a desiccator for an hour and the crucible was weighed.

Volatile matter

The muffle furnace was heated to 950°C. The crucibles used for the moisture determination were preheated with lids in place and containing the sample with the furnace door open for 2 min on the outer edge of the furnace at 300°C and then for 3 min on the edge of the furnace at 500°C. The samples were moved to the rear of the furnace for 6 min with the muffle door closed, cooled in a desiccator for an hour and weighed.

Ash content

The lids were removed and the uncovered crucible was used for the volatile matter determination. The crucible containing the sample was placed in the muffle furnace at 750°C for 6 h. The crucibles were cooled with lids in place in a desiccator for an hour and then weighed. Burning of the sample was repeated for a period of 1 hour resulting in the loss of less than 5 x10^{-4} g.

Per cent moisture in the sample was calculated as under:

$$\text{Moisture (\%)} = [(A-B)/A] \times 100$$

where A= Grams of air-dry sample used, B= Grams of sample after drying at 105°C.

Per cent volatile matter in the sample was calculated as under:

$$\text{Volatile matter (\%)} = [(B-C)/B] \times 100$$

where B= Grams of sample after drying at 105°C, C= Grams of sample after drying at 950°C

Per cent ash in the sample was calculated as under:

$$\text{Ash } (\%) = [D/B] \times 100$$

where B= Grams of sample after drying at 105°C, D= Grams of residue

Pyrolysis in muffle furnace

Fresh areca nut shell, stalk and leaf wastes were collected, air-dried and cut to small pieces of size less than 10 mm. A known quantity of air dried material was taken in closed perforated stainless steel boxes and heated in muffle furnace at different temperature (200, 250, 300, 400, 500^{o}C) and time (30, 60, 90, 120 min). The experiment was carried out in three replications. After carbonization the biochar yield was recorded. The resultant biochar was characterized for oxidizable organic carbon (OC) content by potassium dichromate oxidation method. Loss on ignition (LOI) was determined by ASTM method D-1762-84. Carbon liability index was calculated as the OC/LOI ratio. A comparative measure of stable organic matter (SOM) was calculated as below:

$$\text{SOM} = \text{LOI} - (\text{OC} \times 1.724)$$

where 1.724 is the factor to convert organic carbon to organic matter.

Stable organic matter yield index (SOMYI) was determined by the following equation:

$$\text{SOMYI} = \text{Char yield } 100 \times \text{SOM}$$

RESULTS and DISCUSSION

The results are given in Figs 1 to 10.

A sample of 20 g of areca nut leaf, branch and areca nut shell waste was taken in the containers as shown in the Fig 5 and Fig 6. The wastes were taken in the container and subjected to carbonization at the temperature of 200, 250, 300, 350 and 400ºC for time period of 15, 30, 45, 60 and 75 minutes inside the muffle furnace.

The container was covered with a lid in order to prevent the combustion of the biomass waste and resulting in ash. The biochar yield from the pyrolysis process at the various time intervals and temperatures was recorded. A graph was drawn to illustrate the biochar yield for the five different time periods and temperatures. The graph depicts the biochar yield for the various temperatures at different time intervals. A graph was also drawn to depict the biochar yield at various temperatures and time durations of the sample placed in the muffle furnace.

Biochar yield decreased with increase in time and temperature. The biochar yield derived at 30 min for 200,

Fig 1. Nut shell powder sample

Fig 2. Stalk and leaf waste

Fig 3. Proximate analysis of areca nut waste

Fig 4. Muffle furnace utilized for the destructive distillation of areca nut waste

Fig 5. Biochar production from the areca nut stalk and leaf

Fig 6. Biochar produced from the areca nut shell waste

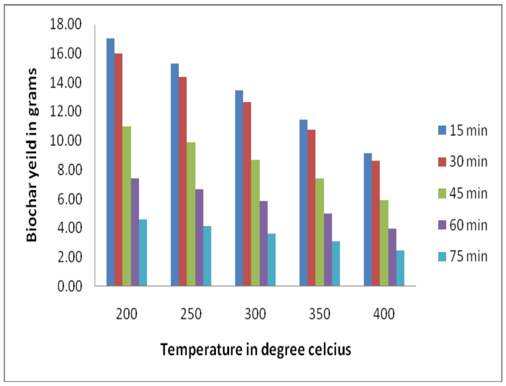

Fig 7. Biochar yeild from areca nut shell waste

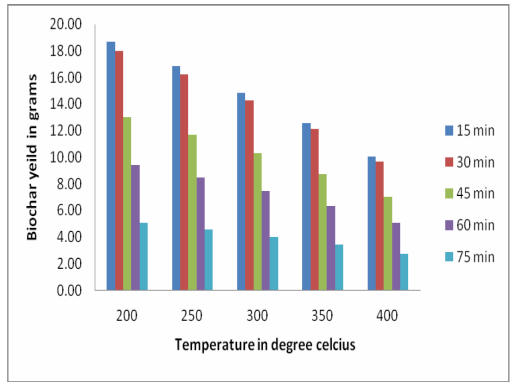

Fig 8. Biochar yeild from areca nut leaf and branch waste

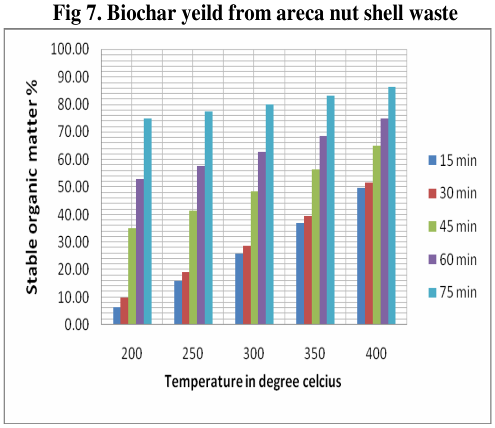

Fig 9. Per cent stable organic matter for areca waste

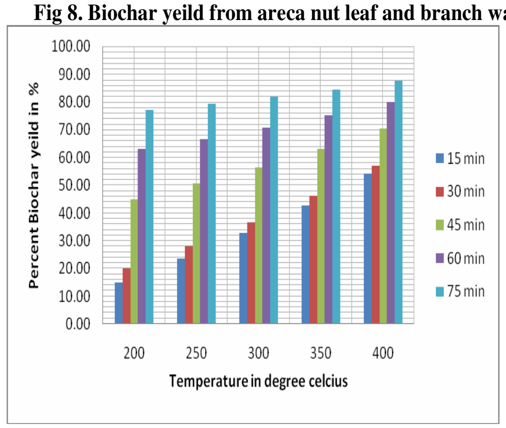

Fig 10. Per cent biochar yield from areca nut leaf and branch waste

250, 300 and 400°C was 54, 42, 32, 23 and 15 per cent respectively. Greater temperature releases more volatile components due to the severe pyrolysis conditions that increase the decomposition of biomass (Masek et al 2011).

At the temperature of 400°C, the biochar yield was observed to decrease, at 30 min time the yield of biochar decreased from 56 to 20 per cent. In spite of the increase in the stability of biochar carbon with increase in the temperature of pyrolysis, the stable organic matter yield index was higher at low temperature of 300 and 350°C.

CONCLUSION

Based on the above discussion it is clear that biochar prepared at higher temperature contains a higher proportion of the stable organic matter than that of lower temperatures. The stable organic matter yield index increased up to 300 to 350°C and thereafter it decreased. This low temperature pyrolysis is much applicable for using biochar for soil carbon sequestration. The lower temperatures of pyrolysis condition viz 300 and 350°C are good enough for the preparation of biochar.

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