Effect of carbonization temperatures on biochar formation of bamboo leaves

Abstract:
Bamboo is a typical plant native in Asia, been used in many sectors, which also produces a large volume of leaves which goes waste and not find its application for any useful purposes; is often considered as a bio-waste and normally incinerated or dumped; as its applications are not yet fully explored. However, some research work done on bamboo fibers for use as a reinforcement in making polymer matrix composite. In the present piece of research work, the influence of burning/carbonization of bamboo leaves (at different temperatures) have been studied and characterized. Proximate analysis gave the fixed carbon content (of ~nearly21%). X-Ray diffraction results revealed the presence of various phases viz. cristobalite (SiO2), Calcite (Ca2O3) etc. accompanied with changes in crystal structures. Fourier transform infrared spectroscopy results showed various modes of vibrations viz. O-H stretching bending of other bonds; (for aromatic benzene derivatives) etc. Scanning Electron Microscopic observation (of morphology) showed irregular stacking arrangements between the randomly spaced lamellae structure, with variation in carbonizing temperature. Results revealed the advantages of pyrolysis process in biochar production/formation. It appears that, the bamboo biochar can have suitable properties for its use as an alternative energy source and also for agricultural applications. Its high porosity and carbon content suggest its application as activated carbon also; after physical or chemical treatments. The present research focuses on extending the frontiers of use of bamboo leaves from being an unutilized bio-waste to its conversion into a value added product, which can be compassed in terms of sustainable applications.

EFFECT OF CARBONIZATION TEMPERATURES ON BIOCHAR FORMATION OF BAMBOO LEAVES

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INTRODUCTION

Biochar is a stable solid, rich in carbon, and can endure in soil for thousands of years. Biochar is under investigation as an approach to carbon sequestration. Biochar is a fine-grained residue produced through modern pyrolysis processes. The carbon in biochar resists degradation and can hold carbon in soils for hundreds to thousands of years. Biochar is produced through pyrolysis or gasification — processes that heat biomass in the absence (or under reduction) of oxygen. Biochar has a large microscopic surface area due to the micro pores developed during pyrolysis, and may be used as a soil amendment improving water infiltration, ion exchange capacity, nutrients retention and adsorption of pollutant [1-2]. Enders et al. (2012) [3] verified that biochars have widely varying properties, requiring more than proximate analysis for characterization. Biomass is widely being used as an alternative source of energy and various studies have also been done in order to use the same as precursor for development of several different end-products due to growing concerns of declining fossil fuel reserves and increasing energy demand. Generation of large volumes of biomass residue as well as biowastes occur from various economic activities. In order to reduce the environmental impact of charcoal using these traditional kilns, new alternatives can be implemented to convert biomass into valuable products [3].

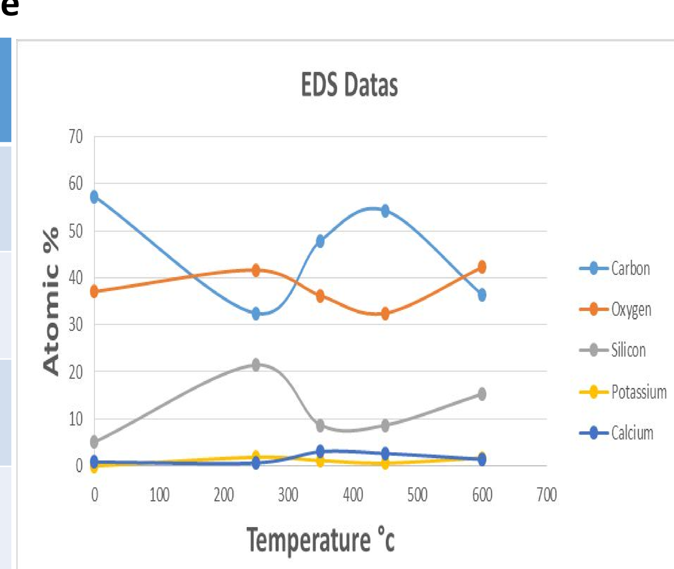
In the present study, emphasis has been given for analysis of bamboo leaves carbonized at different temperatures (ranging from 250^{OC} to 900^{OC}). Carbonization or pyrolysis of bamboo leaves was done to compare the properties of biochar obtained with the raw bamboo leaves. Proximate analysis was done to know the fixed carbon content. X-Ray diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) was performed to know the various phases, functional groups as well as morphological details of the biochar. The distribution of phases as well as resulting end-products as an outcome of carbonization was important in order to determine the potential of the biochar to be used in various suitable applications.

EXPERIMENT DETAILS

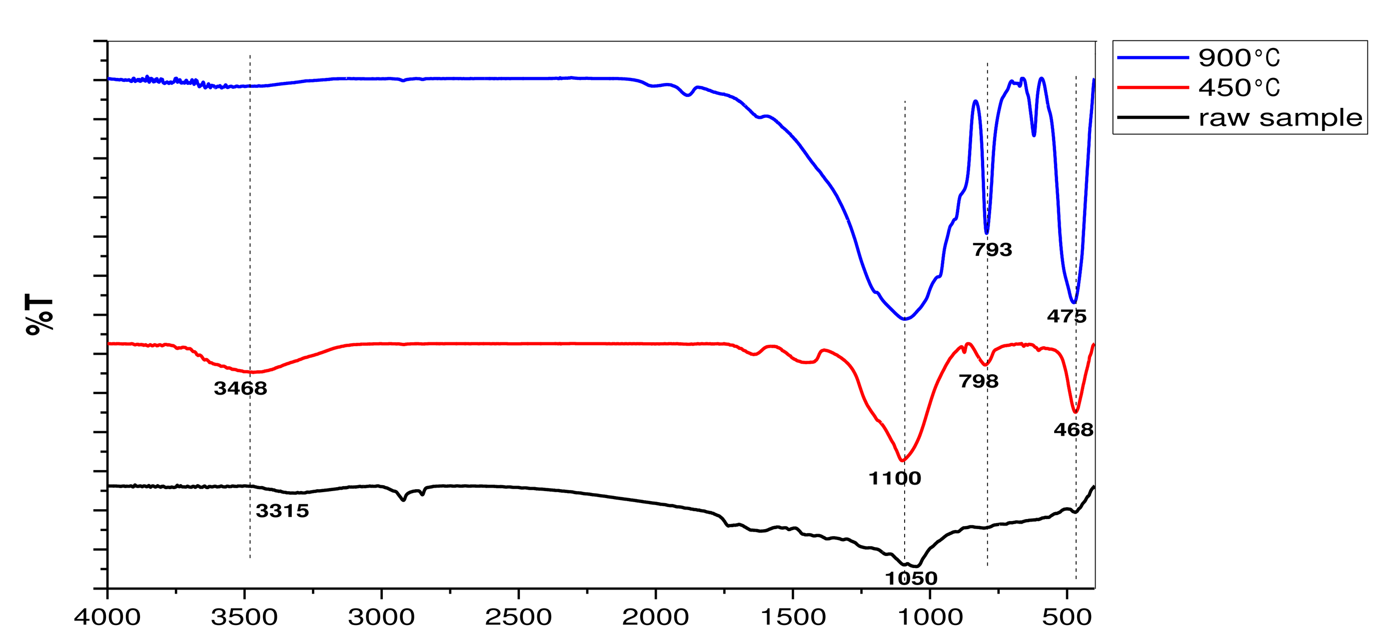
- Proximate analysis of the bamboo leaves to determine the fixed carbon content.
- Carbonization or pyrolysis experiment at different temperatures (ranging from 250^{OC} to 900^{OC}).
- Characterization (SEM, FTIR, EDS & XRD analysis) of raw material and biochars of bamboo leaves.

Atomic % of different element with paralyzing temperature

Element	Raw sample	250°c	350°c	450°c	600°c
C K-series	57.31	32.44	47.89	54.29	36.41
O K-series	34.06	41.62	36.20	32.45	42.20
Si K-series	5.06	21.45	8.69	8.66	15.29
N K-series	2.61	0.64	3.03	2.65	1.41
Ca K-series	0.82	1.84	1.14	0.60	1.68



Variation of amount of different element with paralyzing temperature



FTIR pattern for raw bamboo leaves and its biochars

Band assignment to the peaks of raw bamboo leaves

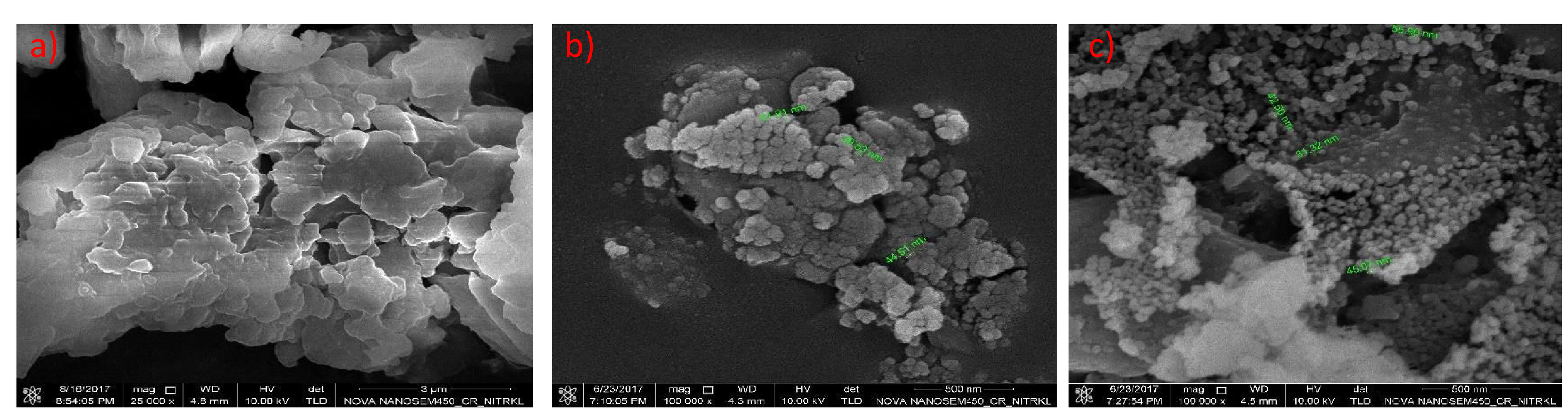
Stretching Frequency	Functional Group
3650-3200	Broad and strong, O-H stretch from hydroxyl group of alcohols
1700-1500	Broad, amine N-H / carbonyl group C=O
1100-1000	C-O stretch in C-O-H bonds of the glycosidic linkages, Or C-O-C stretch of the ethers present in lignin Or Si-O-Si stretch
800-700	C=O absorption/ Si-O-Si bond bending vibrations
700-600	Weak vibration $-CH_2$ rocking or out-of-plane ring deformation
500-400	rings in benzene derivatives / Si-O-Si out-of-plane rocking motion

RESULTS & DISCUSSION

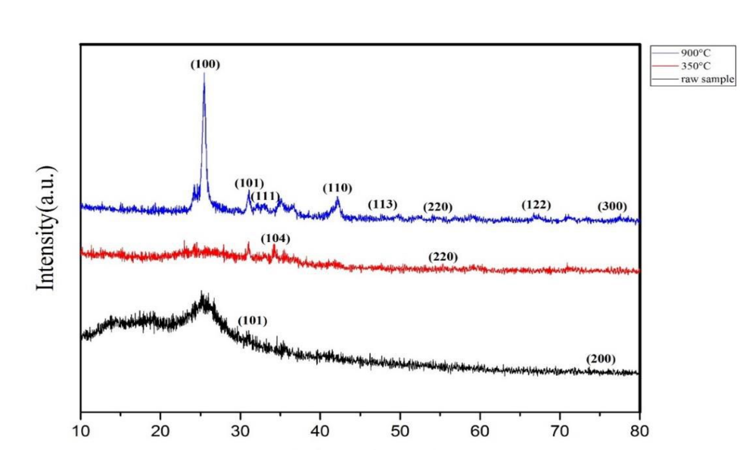
Proximate analysis of raw material

Proximate analysis of bamboo leaves	Wt.%
Moisture content	7
Volatile matter	57
Ash content	15
Fixed carbon	21

- In the present study, the moisture and ash content was very low.
- The volatile matter present is high i.e. more than 55%.

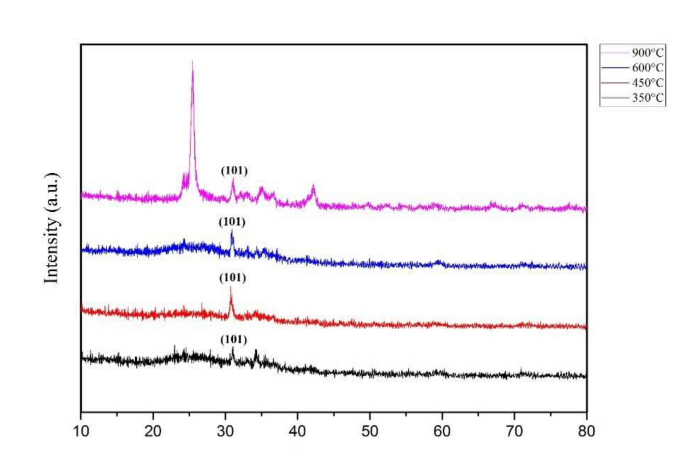


SEM of bamboo leaves (a) and its biochars at 250°C (b) & 450°C (c)



XRD pattern for raw bamboo leaves, biochar at 350°C and biochar at 900°C

A peak at ~ 31° shows the presence of silicon oxide (SiO_2) ascribed to the (101) plane for all the biochars.



XRD pattern for biochars at 350°C, 450°C, 600°C and 900°C

The peaks obtained for biochar at 900°C are shown

Peak number	Peak position(°)	Mineral name	Formula	(hkl)	Structure
1.	25.447	Silicon oxide	SiO_2	100	Hexagonal
2.	31.040	Silicon oxide	SiO_2	101	Hexagonal
3.	33.051	Silicon	Si	111	Cubic
4.	42.281	Silicon oxide	SiO_2	110	Hexagonal
5.	45.642	Calcium Carbonate	Ca_2O_3	113	Rhombohedral
6.	54.654	Calcium Fluoride	CaF_2	220	Cubic
7.	67.157	Calcium Carbonate	Ca_2O_3	122	Rhombohedral
8.	75.957	Iron oxide	Fe2O3	300	Rhombohedral

CONCLUSION

- From the proximate analysis we found the fixed carbon content in the raw bamboo leaves to be 21%.
- Variation of bonding structure and new bonds have been found after heat treatment.
- From the XRD observation of biochar, formation of new phases due to thermal treatment is recorded.
- SEM observations proved the biochar presents a higher particle density, high porosity and a lower bulk density than the particles of raw biomass.
- FTIR observations proved the presence of aromatic structures, Si-O-Si stretch as well as bend vibrational modes along with the Si-C peaks in some biochar samples.
- A biowaste can be made useful as a high value product, thereby reducing environment pollution.

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