CHARACTERIZATION OF ACTIVATED CARBONS FROM COCONUT AND PEANUT SHELLS BIOMASS

Zin Min Tun[1], Zin Min Myat[2], Than Than Win[3] and Yin Maung Maung[2]

Abstract

Biomass is organic material that comes from plants and animals, and it is a renewable source of energy. The coconut and peanut shells biochar were produced by heat decomposition of these biomasses. These biomasses were heated in a muffle furnace at 300 °C, 400 °C and 500 °C for 2 h respectively. The aim of this study was to use coconut and peanut shells in the preparation of activated carbon. The elemental compositions of these samples were analyzed by X-ray fluorescence (XRF). The surface morphology of these biomasses was determined by Scanning Electron Microscopy (SEM). Phase formation and structural properties of samples were characterized by X-ray Diffraction (XRD). Fourier Transform Infrared Spectroscopy (FTIR) was used to determine the chemical properties of the coconut and peanut shells biomass. In this research, the physicochemical characteristics of coconut and peanut shells biomass with activated carbons (ACs) were reported and discussed rapid deployment of renewable energy and energy efficiency and technological diversification of energy sources would result in significant energy security and economic benefits.

Keywords - EDXRF, FTIR, XRD, SEM, coconut and peanut shells

Introduction

Biochar is produced by thermal decomposition of biomass under oxygen-limited condition (pyrolysis), and it has received attention in soil remediation and waste disposal in recent years. Bio-char is a stable solid, rich in carbon and can endure in soil for thousands of years [Aysu et al 2013, Aigbodion V S et al 2010]. The characteristics of biochar are influenced mainly by the preparation temperature of biomass. Higher pyrolysis temperature often results in the increased surface area and carbonized fraction of bio-char leading to high absorption capability for pollutants [Anthony B V et al 2000, CANIARES, P. et al 2006]. Bio-chars derived from various source materials show different properties of surface, porosity and the amount of functional groups which are important concerning on the effect of bio-char. Bio-char has been proved to be effective in improving soil properties and increasing crop biomass. It has also been suggested that it can even enhance crop resistance to disease [Dural. M.U et al 2011, El-barbary MH, et al 2009]. Bio-char has recently been used to remediate soil with both heavy metal and organic pollutant. In addition to its potential for carbon sequestration and decrease greenhouse gas emission from agriculture, biochar is reported to have numerous benefits as a soil amendment, increased plant growth yield, improved water quality, reduced leaching of nutrients, reduced soil acidity, increased water retention and reduced irrigation and fertilizer requirements [Garg.V.K et al 2003, Karaosmanoglu et al 2005]. Bio-char carbon species vary in complexity from graphite like carbon to high molecular weight aromatic rings, which are known to persist in soil for thousands to millions of years. Biochar is a name for charcoal when it is used for particular purpose, especially as a soil amendment like all charcoal, biochar was created by pyrolysis of biomass [Lehmann. J and Joseph. S, 2009].

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Materials and Method

The raw coconut and peanut shells were cleaned with distilled water to remove the dust and impurities. These shells were dried in sun for one day and then hand crushed to smaller pieces. Then, the smaller pieces of these shells were dried at room temperature about one week. The weight of coconut and peanut shells were measured with electronic digital balance. After that carbonization process using the furnace at three different temperatures, which were 300°C, 400°C and 500°C for 2 h respectively. After carbonization, coconut and peanut shell biochars were obtained. The weight of coconut and peanut shell biochars were also measured by balance. Finally, the prepared biochars were ground into powder by pestle. Biochar powders were obtained. The obtained coconut and peanut shell biochar powders were characterized by structural analysis of XRD (X-ray Diffraction) and elemental analysis of EDXRF (Energy Dispersive X-ray Fluorescence) method. The morphology and microporous structures of biochars were determined by Scanning Electron Microscopy (SEM) and the chemical properties of biochars were examined by Fourier Transform Infrared Spectroscopy (FTIR). The block diagram for experimental procedure of coconut and peanut shell biochars were shown in figure 2.2. Table 1 and 2 showed the weight loss and shrinkage of coconut and peanut shell biochars.

Table 1 Weight loss and shrinkage of coconut shell biochar

Temperature	Initial weight, W_1	Final weight, W_2	Weight loss, $W = W_1 – W_2$	Shrinkage
300 °C	5 g	2.10 g	2.90 g	58.00 %
400 °C	5 g	1.57 g	3.43 g	68.60%
500 °C	5 g	1.11 g	3.89 g	77.80 %

Table 2 Weight loss and shrinkage of peanut shell biochar

Temperature	Initial weight, W_1	Final weight, W_2	Weight loss, $W = W_1 – W_2$	Shrinkage
300 °C	5 g	2.67 g	2.33 g	46.60 %
400 °C	5 g	1.88 g	3.12 g	62.40 %
500 °C	5 g	1.35 g	3.65 g	73.00 %

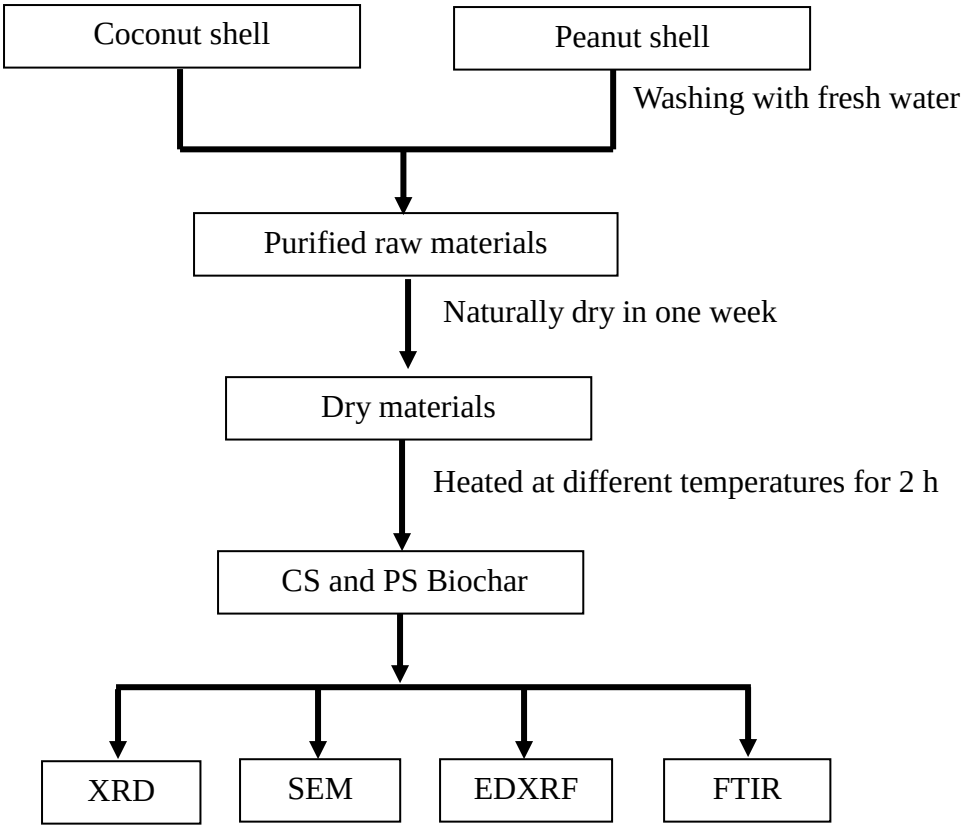


Figure 1 The block diagram for experimental procedure of coconut and peanut shell biochars

Results and discussion

X-ray diffraction analysis

X-ray diffraction is to determine the structure properties of coconut and peanut biochar using monochromatic CuKα radiation (λ = 1.54056 Å) operated at 40 kV (tube voltage) and 40 mA (tube current). Analysis of coconut and peanut shell biochar at different temperature values (300 ˚C, 400 ˚C and 500 ˚C) for 2 h were shown in figure 2.

From XRD results, these biochar exhibit the dominant diffraction peak located at around 2θ = 20˚ - 30˚ that revealed the presence of amorphous structure which was disorderly stacked up by carbon rings. The XRD patterns of the coconut and peanut shell biochar showed the asymmetric (111) peak and (110) peaks maxima which were characteristic of graphite and carbon structures.

FTIR Analysis of Coconut and Peanut shell biochars

FTIR spectroscopy was applied to measure the chemical properties and absorption of energy from the range of 4000 cm^{-1} - 500 cm^{-1} by studied samples. Spectral registration was examined with use of solid-state samples which is made of a complex organic material. The FTIR analysis demonstrated the functional groups presented on two biochar types (coconut shell (CS) and peanut shell (PS)). The functional groups of two samples CS and PS have found to be O-H stretching vibration, C-H stretching vibration, C=O stretching vibration and C=C stretching vibration respectively. The spectrum of these samples showed some characteristic bands related

to physical and chemical changes. As shown in figure 3(a-c) and figure 4 (a-c), the infra-red spectra of these biochar types are comparable but there are some changes in the functional groups. The water O-H stretch can occur in the CS about 3373.25 cm^{-1}, 3372.85 cm^{-1} and 3372.40 cm^{-1} at three different temperatures. The strong hydroxyl group can display in the PS for about 3334.54 cm^{-1}, 3338.65 cm^{-1} and 3335.82 cm^{-1} at three different temperatures respectively. The absorption bands, between 3000 cm^{-1}-3300 cm^{-1} indicated the presence of strong carboxylic acid O-H stretch. Comparing with other biochar types, CS and PS were associated with strong absorption bands at 3180.95 cm^{-1} and 3214.62 cm^{-1}, respectively. As a observed peak of CS, C ≡ C ring stretching is associated with peak value 2110.89 cm^{-1}. The presence of the band located at 824 cm^{-1}- 600 cm^{-1} showed a C-OH out-of-plane bending modes of aromatic compounds. According to FTIR analysis, all of the absorption bands are due to hydroxyl group in cellulose, carbonyl groups of acetyl ester in hemicellulose, and carbonyl aldehyde in lignin.

SEM Analysis of Sugarcane bagasse biochar

SEM is one of the most versatile instruments available for the examination and analysis of the microstructure characteristics of a solid. The most important reason for using SEM is high resolution that can be obtained when bulk sample are examined. SEM micrographs for external morphology of CS and PS biochar at temperatures 300 °C, 400 °C and 500 °C for 2 h were shown in figure 5 (a-c) and figure 6(a-c). According to figure 5 (a-c), the clear porous nature had observed the CS biochar at 300 °C, 400 °C and 500 °C. After increasing temperature, it was found that the CS biochar had more clearer porous nature and uniform with microporous structure. From SEM analysis as shown in figure 6 (a-c), it can be observed that the microstructure of PS biochar samples by varying the pore sizes with different temperatures. At 300 °C, the pores of PS biochar were non-uniform and not clear. At 400 °C, the pores looked like tube shape and the more uniformly microporous structure was found at 500 °C of PS biochar.

For CS biochar, the average pore sizes of the samples were found to be about 5.15 µm at 300 °C, 8.80 µm at 400 °C and 5.13 µm at 500 °C and for PS biochar, 3.42 µm at 300 °C, 3.54 µm at 400 °C and 2.52 µm at 500 °C respectively.

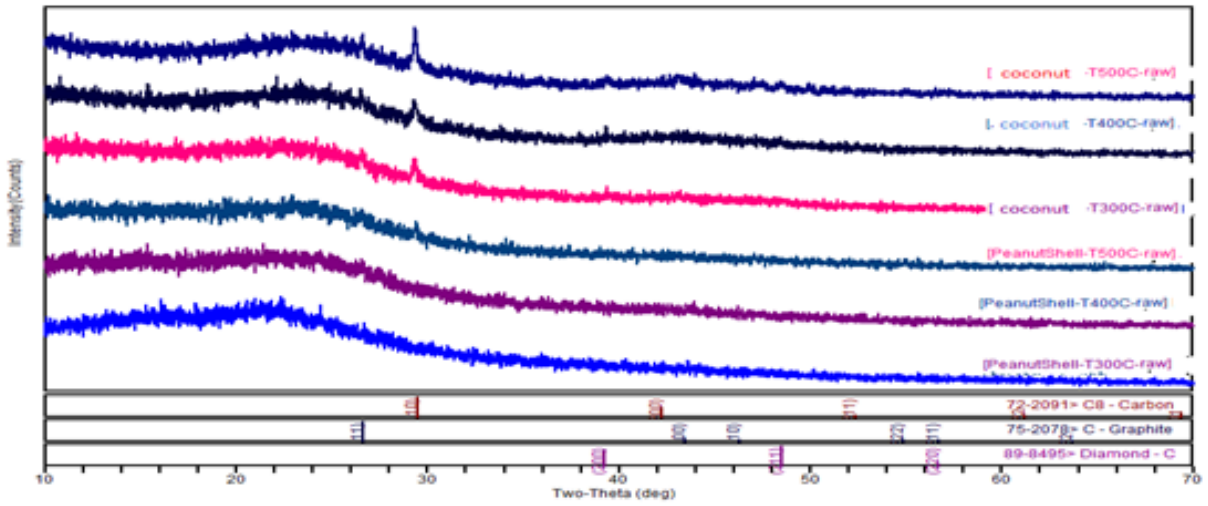
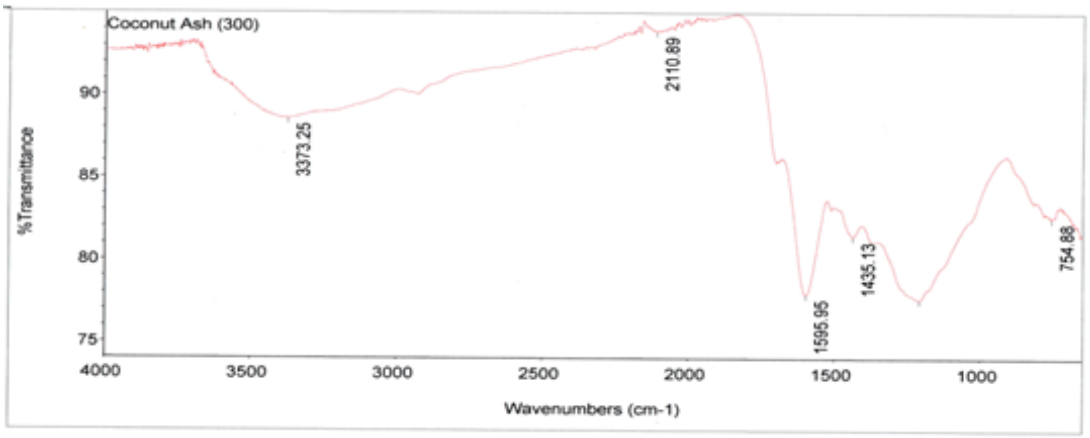
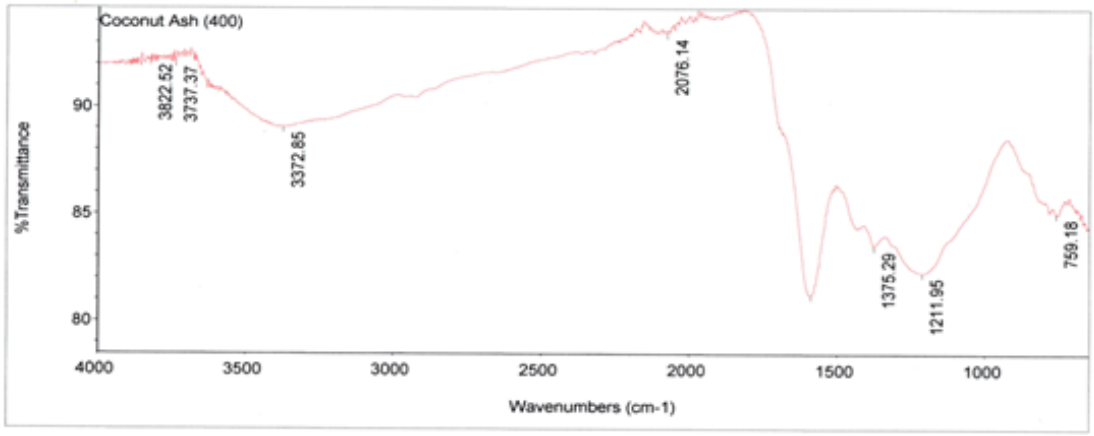


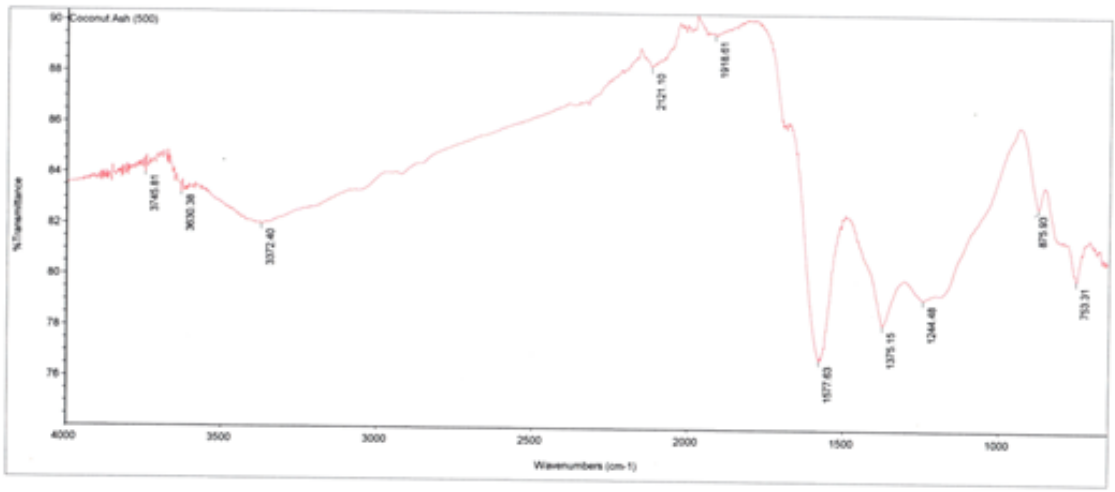
Figure 2 XRD patterns of Coconut and Peanut shell biochars at different temperatures



(a) FTIR spectrum for CS-300 ˚C

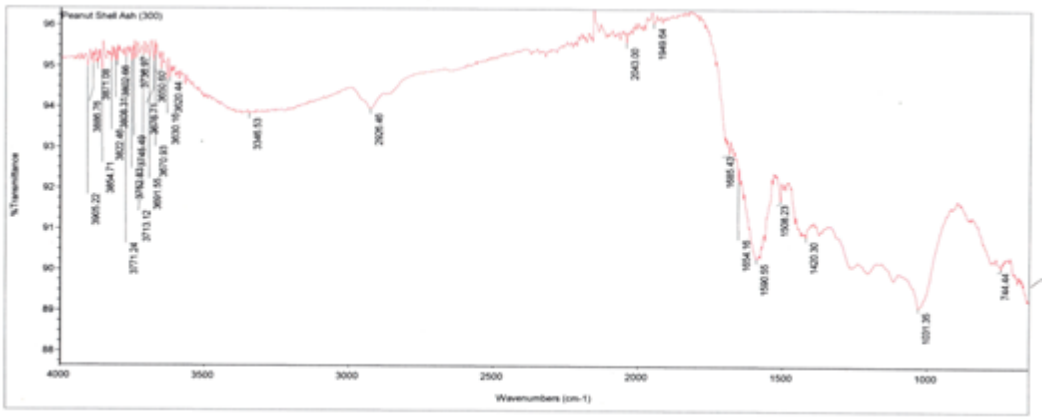


(b) FTIR spectrum for CS-400 ˚C

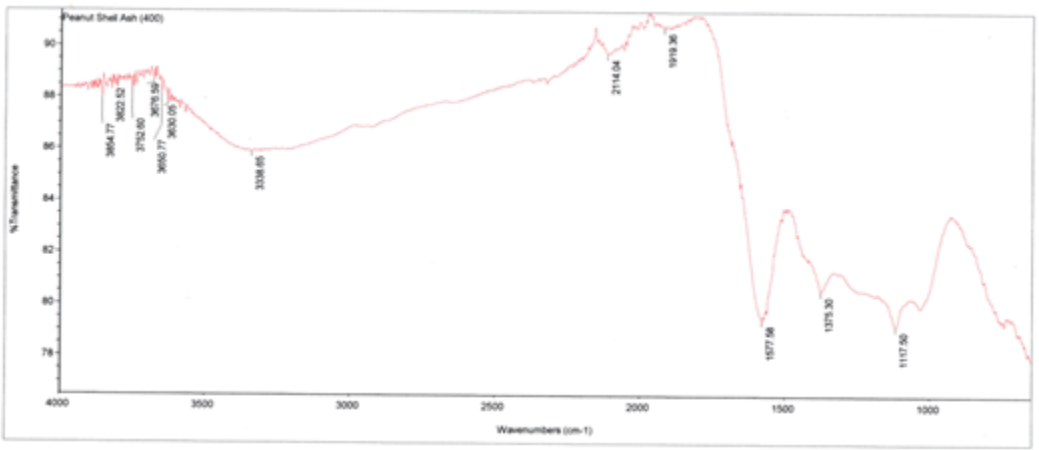


(c) FTIR spectrum for CS-500˚

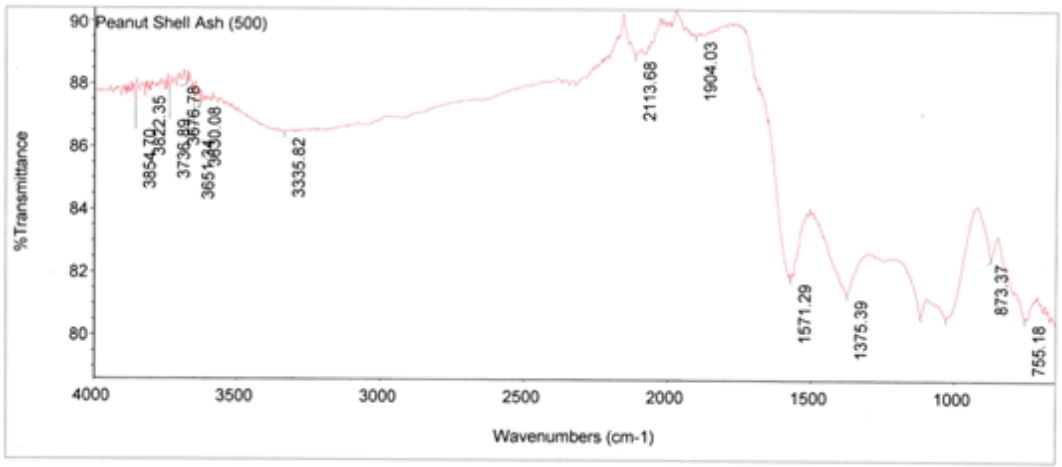
Figure 3 (a-c) FTIR spectra of CS biochar



(a) FTIR spectrum for PS-300 ˚C

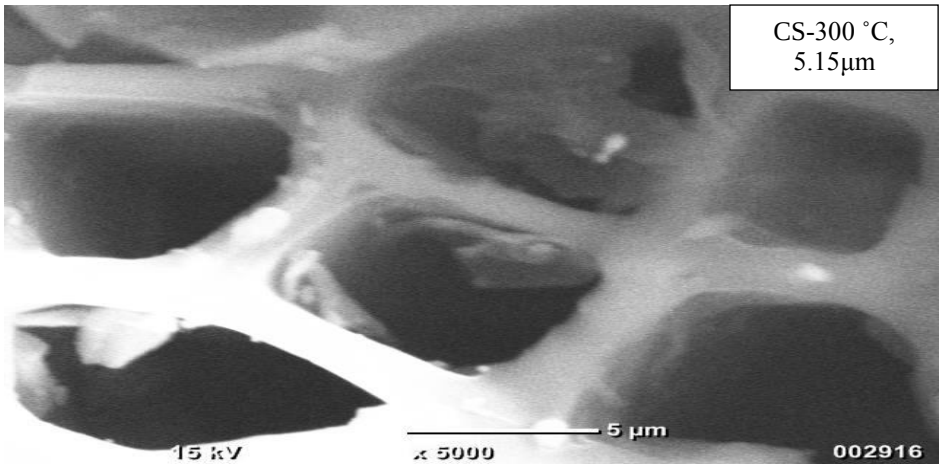


(b) FTIR spectrum for PS-400 ˚C

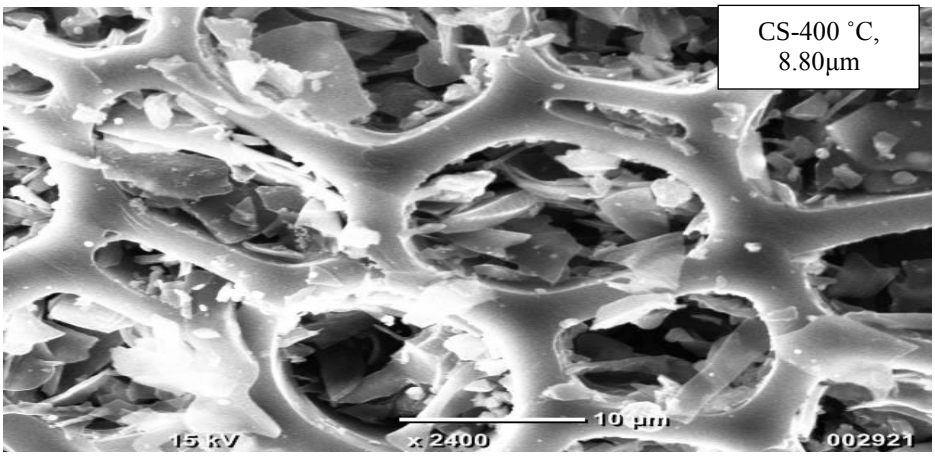


(c) FTIR spectrum for PS-500 ˚C

Figure 4 (a-c) FTIR spectra of PS biochar



(a)



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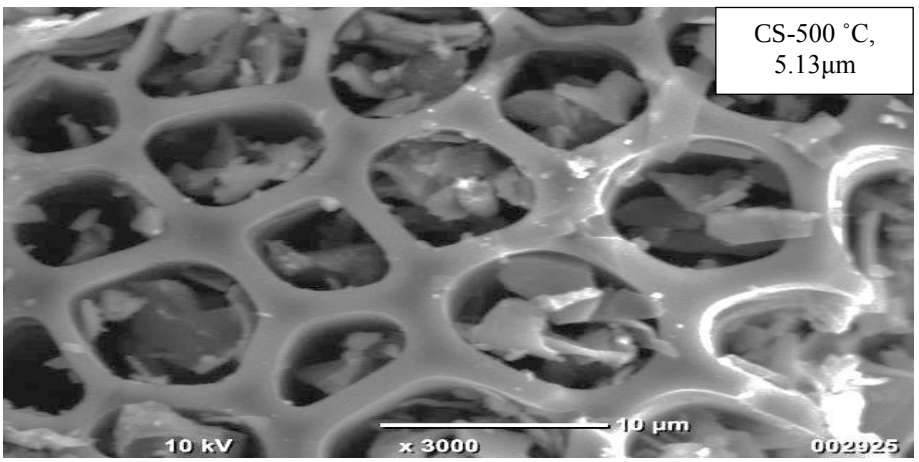
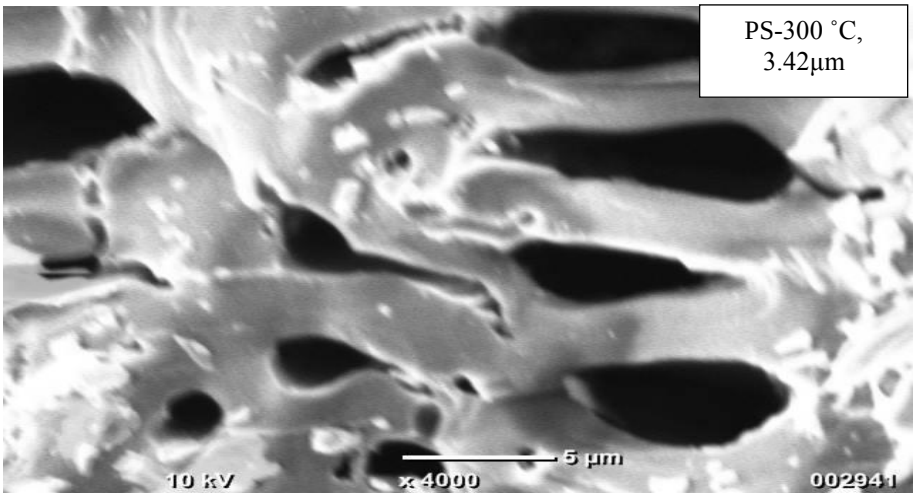
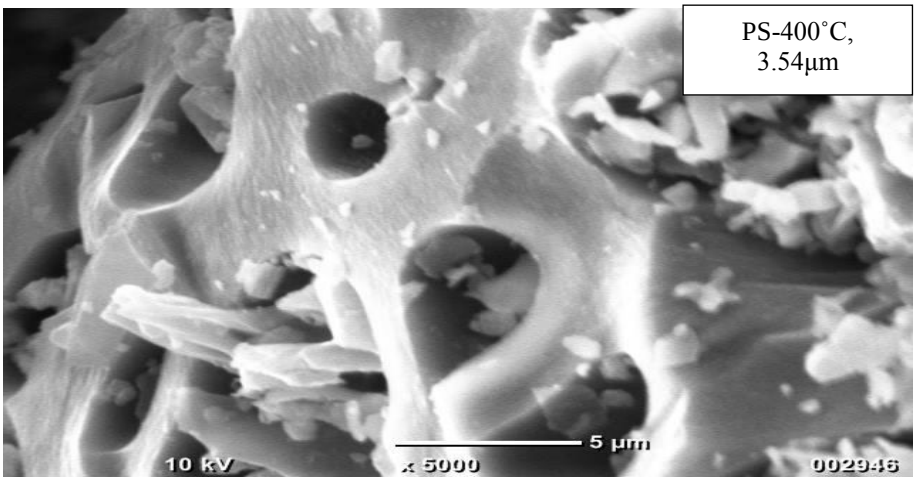


(c)

Figure 5 (a-c) SEM micrographs of CS biochar at different temperatures



(a)



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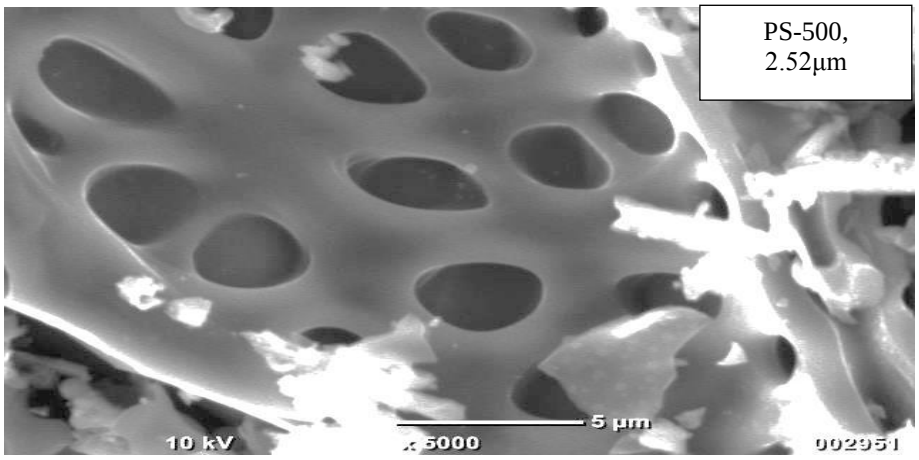

(c)

Figure 6 (a-c) SEM micrographs of PS biochar at different temperatures

EDXRF Analysis

In this research, two kinds of CS and PS biochar were analyzed by the EDXRF technique. The concentrations of elements contained in the samples were measured by using the SHIMADZU Energy Dispersive X-ray Fluorescence Spectrometer (EDX-7000). According to the result, it was found that the concentration of elements contained in CS and PS biochar at different temperatures were shown in Table 3 and Table 4.

Table 4.1 The concentration of elements contained in coconut shell biochar at different temperatures

Coconut Shell	**Relative concentration of elements (% wt)**		
Elements	**300 ˚C**	**400 ˚C**	**500 ˚C**
K	58.444	59.388	64.047
Cl	21.177	19.308	15.672
Ca	12.093	10.552	9.849
Si	6.604	7.728	5.473
P	-	0.937	0.687
S	0.691	0.733	0.767
Fe	0.525	0.785	0.394
Cu	0.153	0.125	0.128
Mn	-	0.082	-
Cr	-	0.067	-
Ti	0.132	0.194	2.655
Zn	0.077	0.031	0.087
Ag	0.042	-	-
Br	0.036	0.027	0.024
Rb	0.027	0.027	0.029
Sr	-	0.015	-

Table 4.2 The concentration of elements contained in peanut shell biochar at different temperatures

Peanut Shell	**Relative concentration of elements (% wt)**		
Elements	**300 ˚C**	**400 ˚C**	**500 ˚C**
K	51.391	49.318	53.623
Ca	22.433	20.303	20.821
Si	11.041	11.540	9.260
Fe	6.868	9.652	7.719
S	3.730	4.034	2.810
P	2.611	1.573	2.676
Ti	0.884	1.992	1.777
Mn	0.581	0.740	0.580
Cr	-	0.280	-
Cu	0.241	-	0.204
Zn	0.106	0.201	0.140
Ni	0.083	0.095	0.072
Sr	0.032	0.068	0.044

Conclusion

The present investigation shows that the activated carbon obtained from coconut and peanut shell biochar were prepared and characterized by studying physical, chemical and mechanical properties. In the physical properties measurements, the biochar weight loss and shrinkage increased with increasing the reaction temperatures. Coconut and peanut biomass provides the solution to use it and produce the low cost, energy efficient and clean energy in the form of briquetted biomass. According to FTIR analysis, low temperature, 300 °C both biochar types is more suitable for their absorption bands due to hydroxyl group in cellulose, carbonyl groups of acetyl ester in hemicellulose, and carbonyl aldehyde in lignin. According to XRD result, there are several diffracted peaks were observed. They were not perfectly identified. It could be say that the CS and PS samples were found to be amorphous structure with little crystalline. XRD patterns of CS and PS were quite acceptable. Almost all the reflections were found to be consistent with carbon. SEM investigation showed that the porous structure of both samples. Besides, in this study, the quantitative data calculated by the EDX-7000 spectrometer were based on the 100 percent of weightiness of just inorganic elements contained in the sample of interest and not considered on the organic compounds and dark matrix elements. It means that the data show the relative concentration of elements contained in the samples of analysis. From the EDXRF results obtained, the major element of each biochar samples were potassium (K), calcium (Ca), chlorine (Cl), silicon (Si), iron (Fe) and phosphorous (P). These elements (K, Ca, Cl, Si, Fe and P) concentrations in each sample were much more than other elements. So it was mostly effective for plants growth.

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