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The effect of carbonization temperatures on proximate analysis of coconut shell

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Abstract
Carbonization is often used to enhance the structural properties of bio-fiber material like coconut shell. This research work studied the effect of two carbonization temperatures 450ºC and 850ºC on the proximate analysis of coconut shell. The coconut shell was sun dried for 48 hours before being carbonized in a heat treatment furnace. The heating rate was 5ºC/min with a soaking time of three hours. The carbonized coconut shell was then heated in a muffler furnace for proximate analysis in observance of ASTM standards E-871, E-1755, E- 872 for moisture at 110ºC, ash at 715ºC and volatile matter at 925ºC using a muffler furnace. The result of the proximate analysis showed that fixed carbon content was higher at 850ºC as a result of pyrolytic decomposition of the raw coconut shell. Also the volatile matter was drastically reduced at 850ºC. Lower ash content was again obtained at 850ºC.

Keywords: coconut shell, carbon content, temperature, carbonization, proximate analysis

Introduction

Ojha *et al*., (2016) [13] credited carbon as one of the most magnificent elements that has revolutionized material science in recent years. Their argument was based on the role carbon has played and still playing in advanced composites for engineering applications at elevated temperature.

Coconut (Cocos Nucifera) is an important member of the family, Acecacaae (palm family).

It is the only accepted species in the genus cocos and is a large palm, growing to 30m tall, with pinnate leaves, 4-16m long, pinnae, and 60-90cm in diameter.

The term coconut can refer to the entire coconut palm, the seed, or the fruit, which is not a botanical nut. The fully developed hard shell which houses the nut does not crack easily, Ewansiha *et al* (2012) [5].

Coconuts are mainly cultivated in the coastal clays and sands and sporadically distributed in other areas. The coconut takes one year from pollination to maturity and only during the second and subsequent years its fruits can be harvested.

The world production of coconut sums up to around 55 million tons annually.

The origin of coconut has been identified to be in the Malay States, the Philippine Islands, the South Sea Islands, India and Ceylon.

In Africa, the northern limits are located on the West Coast in Cape Verde (15ºN) and on the east, Djibouti (11.5ºN) with isolated coconut palms found in the far north on the Red Sea and up to 24ºN. The Southern limits in Africa is located at 15ºS on the West Coast and the Zambezi River (19ºS), on the east and also found farther south in Port Dauphin in Madagascar at 25ºS Child (1994) [4].

In Nigeria, the coconut palm is found mostly in the Southern states and in some marginal areas up to 10ºN. The largest coconut palm plantation is found in the Badagry Local Government Area of Lagos State located in the South West of Nigeria, Ode wale *et al* (2012) [10].

The fruit consists of 4 parts: about 35% husk, 12% shell, 28% meat and 25% water, Penyelidikan and Perundingan (2002) [11].

Coconut shell is available as a waste product from the coconut industry obtained during the breaking operation of coconuts. It is a durable material and not easily destroyed by microbiological action.

Coconut shell powder is widely available at very low cost, so it is an ideal reinforcement material in polymeric composites. Coconut shell powder is made from the most versatile part of the coconut which is the shell and is organic in nature, Husseinsyah and Mostapha (2011) [6].

Coconut shell is becoming an important agricultural product for tropical countries around the world as a new source of energy-bio-fuel, Bamgboye and Jekayinfa (2006) [1]. Previously, coconut shell was burnt as a means of solid waste disposal which contributed significantly to CO_2 and methane emissions, Bamgboye and Jekayinfa (2006) [1].

Presently in Nigeria, coconut shell is used as a source of fuel for the boilers, and residual coconut shell is disposed of as gravel for plantation roads maintenance. Black smiths also buy the coconut shell as fuel material in their casting and forging operations, Madakson *et al* (2012) [9]. In their work, Bamgboye and Jekayinfa (2006) [1] regretted that 90% of coconut (empty fruit bunches, fibers, fronds, trunks, shell) was discarded as waste and either burned in the open air or left to settle in waste ponds. This way the coconut processing industries waste according to them contributed significantly to CO_2 and methane emissions. Based on economic as well as environmental related issues, efforts should be directed worldwide towards coconut shell management issues i.e. utilization, storage and disposal.

Coconut shell usually contains 32% of hemicellulose, 14% cellulose, and 46% lignin, Uswatun (2012) [12]. Pyrolysis of it can provide the decomposition of these components with different rate on applied range of temperatures. The different of reactivity from each component cause competition during decomposition process, Cagnon (2009) [2].

Hemicellulose will decompose at temperature 200-260ºC, cellulose at 240-350 ºC, and lignin between temperature range of 280 and 500ºC, Cagnon (2009) [2].

Coconut shells are cheap and readily available in high quantity. Coconut shell contains about 65 – 75% volatile matter and moisture which are removed largely during the carbonization process, Chanap (2012) [3].

The carbonization process involves converting the coconut shells to char (charcoal). The charring process (making of charcoal) is known as Pyrolysis, which is chemical decomposition of the shell by heating in the absence of oxygen. During the carbonization of coconut shells, volatiles amounting to 70% of the mass of coconut shells on dry weight basis were released to the atmosphere, yielding 30% of coconut shell mass of charcoal. The volatile released during the carbonization process consists mainly of methane, CO_2 and wide range of organic vapors. The carbonization temperature ranges between 400ºC and 850ºC sometimes reaches 1000ºC, Chanap (2012) [3].

In this research work, carbonization temperatures of 400ºC and 700ºC, were used to study the effects temperature has on the composition of coconut shell with the view of achieving better coconut shell management in terms of utilization, storage and disposal. This will ensure a better friendly environment and produce a quality product for industrial application.

2. Material and Methods

2.1 Material

Coconut shell was the main material used in this research work.

2.2 Methods

2.2.1 Drying of coconut shell

The coconut shell was sun dried six hours per day for six days. It was divided into two portions and one portion carbonized and the other uncarbonized.

2.2.2 Coconut shell processing (Carbonization)

The coconut shell that was sun dried for 36 hours were packed in an earthen pot, covered with a lid and heated in electric resistance furnace model KGVB Kohaszat Gyarepito Vallalat, Type –Koo 80/50-120 "Temperature -950ºC 513-4124 -0730/B at temperatures of about 450ºC and 850ºC with a heating rate of 5ºC per minute and a soaking time of three hours.

2.2.3 Chemical Characterization of Coconut Shell by Proximate Analysis

Proximate Analysis which provided information on moisture, ash, volatile matter and fixed carbon contents on dry or weight basis was used to determine the chemical composition of the coconut shell. It is one of the characterization methods used to analyze bio-fiber material like coconut shell. The proximate analysis was carried out in observance of ASTM standards E-871, E-1755, E- 872 for moisture at 110ºC, ash at 715ºC and volatile matter at 925ºC using a muffler furnace. The fixed carbon content was determined by subtracting the sum of the values of weight percent of moisture, ash and volatile matter from 100%. It was carried out at Scientific Equipment Development Institute, (SEDI) Akwuke, Enugu.

Fixed Carbon (FC) (%) = 100 - (Ash% + Moisture + Volatile Matter)

3. Results and Discussions

Table 1: Proximate Analysis Result at 450ºC (wt %)

	Fixed Carbon	Volatile Matter	Ash	Moisture
Raw coconut shell	18.63	66.71	3.63	11.03
Carbonized coconut shell (450°C)	53.6	36.47	4.28	5.65

Table 2: Proximate Analysis Result at 850ºC (wt %)

	Fixed Carbon	Volatile Matter	Ash	Moisture
Raw coconut shell	18.63	66.71	3.63	11.03
Carbonized coconut shell (850°C)	78.6	16.21	2.24	2.95

3.1 Chemical analysis result

Tables 1 & 2 above show the result of proximate analysis of the coconut shell at 450ºC and 850ºC respectively. The ash content of a carbon is the residue that remains when the carbonaceous materials is burned off and is an indication of the presence of carbon compounds and inorganic components in the form of salts and oxides in the shell of coconut. As Jabit, (2007) [8] reported, the inorganic material contained in activated carbon is measured as ash content, generally in the range between 2 and 10% and this agrees with the result of this work. The fixed carbon content of the carbonized coconut shell was higher at 850ºC than at 450ºC. This represents about 46.62% increase in carbon content and may be attributed to increase in carbonization temperature. Therefore, carbonization temperature affects the carbon content of coconut shell. In addition, the volatile matter content of the carbonized coconut shell sample at 850ºC was lower than that at 450ºC. The volatile matter contains most of the cellulose, hemi-cellulose, lignin and other organic matter in coconut shell as was indicated in the work of Chanap (2012) [3]. Yang *et al* (2006), reported that in thermal analysis, the pyrolysis of hemicellulose mainly happens at 220–315 °C, that of cellulose is at 315–400 °C, Chanap (2012) [3], stated that lignin is more difficult to decompose, as its weight loss happens in a wide temperature range (from 160 to 900 °C). This could possibly explain the lower volatile matter content of the coconut shell at 850ºC.

Also, lignin and cellulose contain most of the polar hydroxyl (OH) group in coconut shell Iloabachie *et al*., (2017) [7]. Therefore carbonization temperature lowers the water absorption capacity of coconut shell. Lower moisture content was also observed at 850ºC. Hence, it could be said that the higher the carbonization temperature, the lower the moisture content of coconut shell.

4. Conclusion

The effect of carbonization temperature on the proximate analysis of coconut shell has been studied; therefore, the following conclusion can be made:

1. Higher carbonization temperature results in lower volatile matter in coconut shell.
2. To achieve higher yield of carbon in coconut shell will require increase in carbonization temperature.
3. The inorganic salt content of coconut shell will be lower at higher carbonization temperature.

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