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Manufacturing of activated carbon using disposable coconut shells

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ABSTRACT

Activated carbon is a solid carbon compound that is composed of carbon in the form of charcoal. It plays a major role in some industrial applications such as water and air purification because of the strong adsorption of its surfaces and its tendency to remove some volatile organic compounds (VOC) and most of contaminants from the water, air or some other material. Various base materials are used in the manufacturing of activated carbon, including different woods and certain synthetic materials. According to the scope of new research, it is possible to produce activated carbon economically using coconut shell waste products. In our work, the coconut shells were burnt using a muffle furnace and at a range of temperatures in 300 - 390 ºC. The elemental compositions of manufactured activated carbon were analyzed using X-ray fluorescence (XRF) spectrophotometer, while the surfaces of manufactured activated carbon were microscopically analyzed using an optical microscope. Thus, the range of 330 - 350 ºC was considered as the most adequate temperatures for the manufacturing process of activated carbon from these coconut shells. Beyond the non-metal carbon, 68.85% Fe and 31.15% K are generated.

***Keywords*:** Activated carbon, Coconut shells, Burning temperature, Metallic composition, Industrial Applications

1. INTRODUCTION

Activated carbon is a solid compound that forms the majority of the carbon called 'charcoal'. It is a product used in water treatment processes as it is a relatively high porous

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material of low density [1-5]. The surface area of activated carbon is capacious; hence, it provides room for extensive chemical activity, thus enabling the chemical separation of some specific components from certain compounds as described in [1-12].

Adsorption is the result of the addiction of molecules of liquid or gaseous compounds called "adsorbates" to the surfaces of a specific solid compound called the "adsorber" upon contact. The adsorption process occurs on the surface of the adsorber because of electrostatic and Van der Waal's forces acting between the contacting materials. The efficiency and capacity of the adsorption process is dependent on the magnitude of such electrostatic forces and the broadness of the surface area of the adsorber [3-12].

Activated carbon finds considerable use in both, small scale and large scale industrial-scientific purposes and is manufactured to specification from a wide variety of raw materials such as different wood species, coconut shells, different varieties of coal and some other synthetic materials [4-10].

The properties and adsorption capacities of activated carbon vary with the used raw materials. The dominant industrial applications of activated carbon are in water and air treatments. The intended apications include [1-9]:

- Removal of volatile organic compounds (VOC) from air or water
- Creation of better taste and odor sensation
- Removal of certain metallic elements including heavy metals
- Mitigation of smoke and fumes.

The manufacturing of activated carbon using disposable or cheap material is of economic benefit for industry or individual users and the investigation of suitable material for the preparation of activated carbon is an important approach.

In this paper, the economically viable creation of quality activate carbon is explored. The raw material is domestic disposable coconut shells. The intent is to produce a quality product at minimal cost. This includes determination of suitable temperature for the burning of such coconut shells to manufacture the activated carbon, analysis of the surfaces and chemical analysis of the prepared activated carbon.

2. MATERIALS AND METHODS

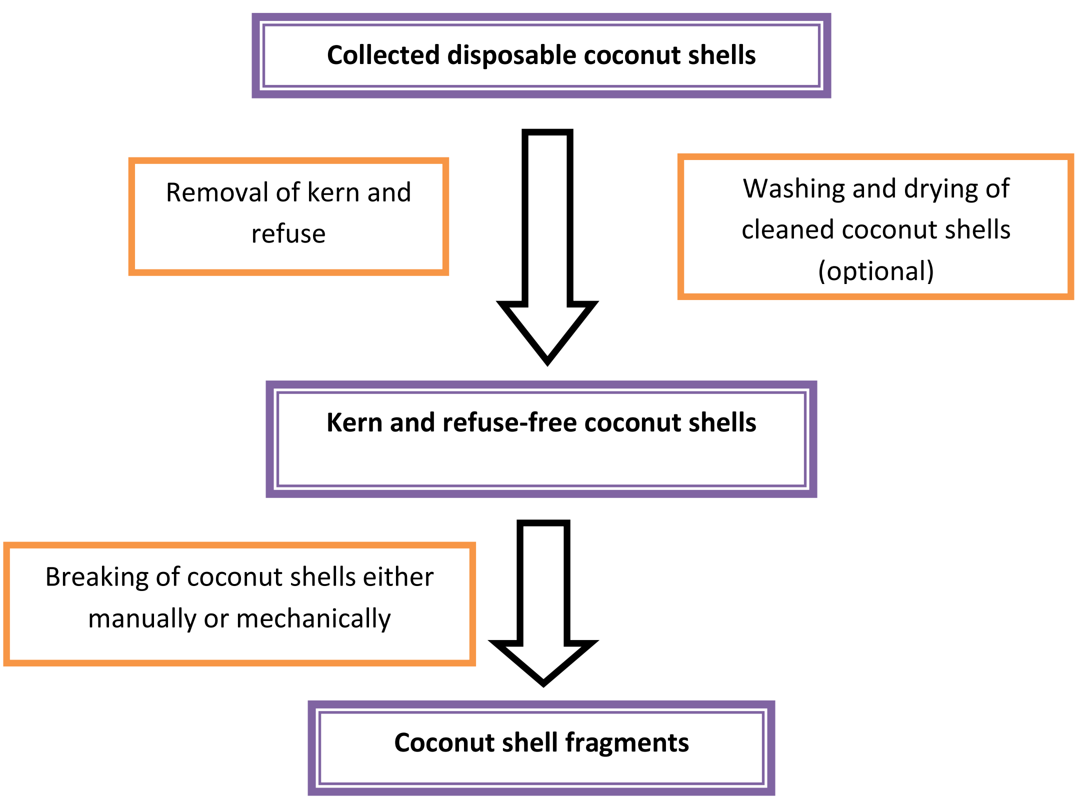
Coconut shells are a natural resource that is mainly used for heating and cooking. In the existing research, the manufacture of quality activated carbon is explored, using disposable coconut shells.

The coconut shells were domestically collected from Matale region in Matale district, Sri Lanka, and the collected coconut shells were well cleaned, this included removing kern in the inside and sirt and debris on the outside of the shell. The coconut shells were broken into small fragments, then oven dried for 24 hours under a temperature of 105 ºC until a constant weight was achieved (**Figure 1**).

The dried coconut shells were subsequently separated into six similar sets and burnt separately in a muffle furnace using a clay pot as a container under a range of temperature regimes between 300 - 390 ºC for a time interval of 30 minutes.

The resulting charcoal was crushed using a ceramic crucible and the particle sizes were maintained in a range of 2 - 5 mm sizes [3-13].

Figure 1. Muffle furnace



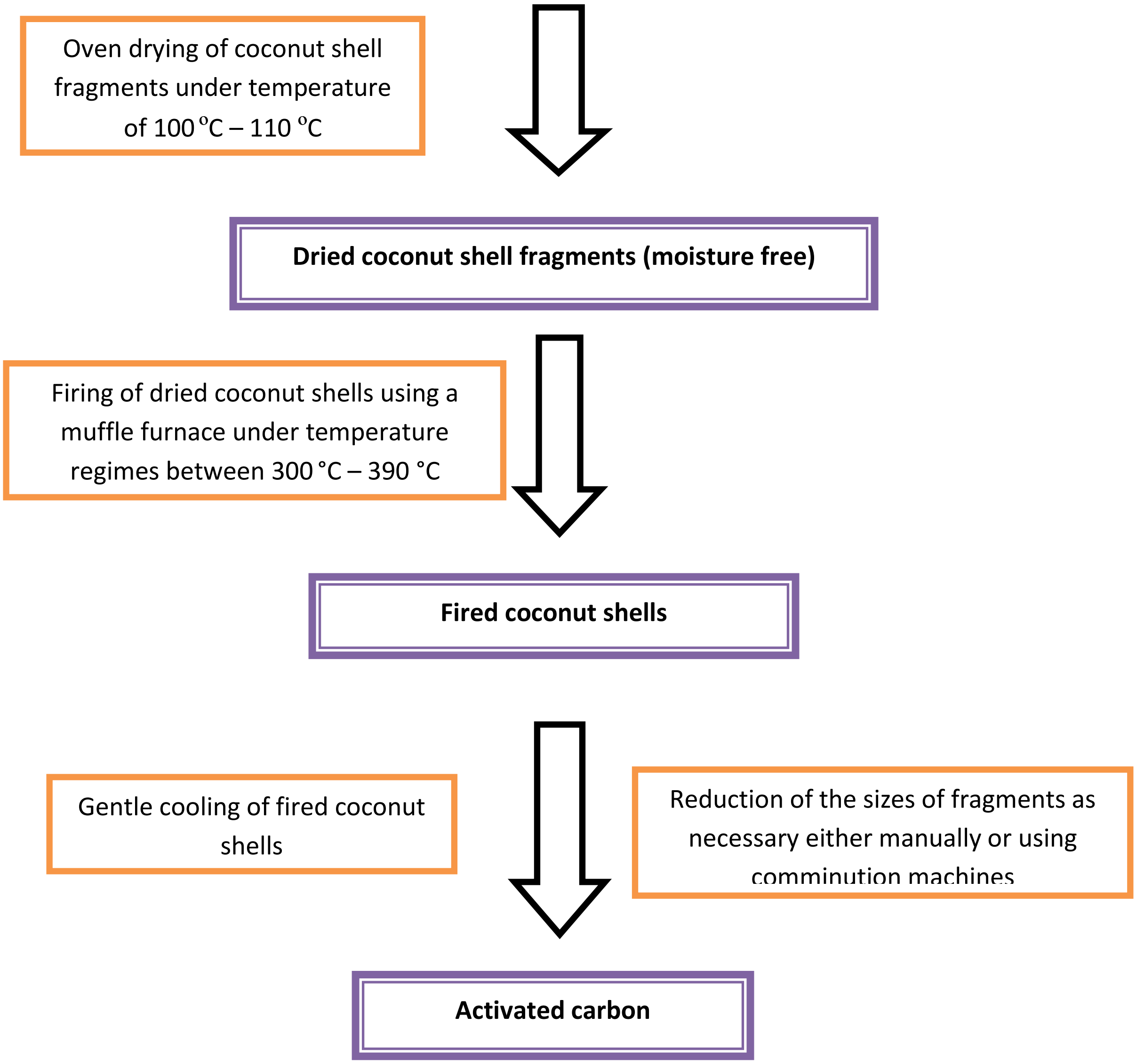


Figure 2. Process flow diagram for the manufacturing of activated using disposable coconut shells

The generated activated carbon was then examined and relevant observations were recorded. The process flow diagram for the manufacturing of activated carbon using disposable coconut shells is given in **Figure 2**.

A meager portion of the prepared activated carbon samples was sent for compositional analysis using X-Ray fluorescence (XRF) spectrophotometer so as to analyze the metallic elemental composition (**Figure 3**). Moreover, fragments of the prepared activated carbon samples were sent for microscopic analysis using an optical microscope for observation of contamination and of the surface features.

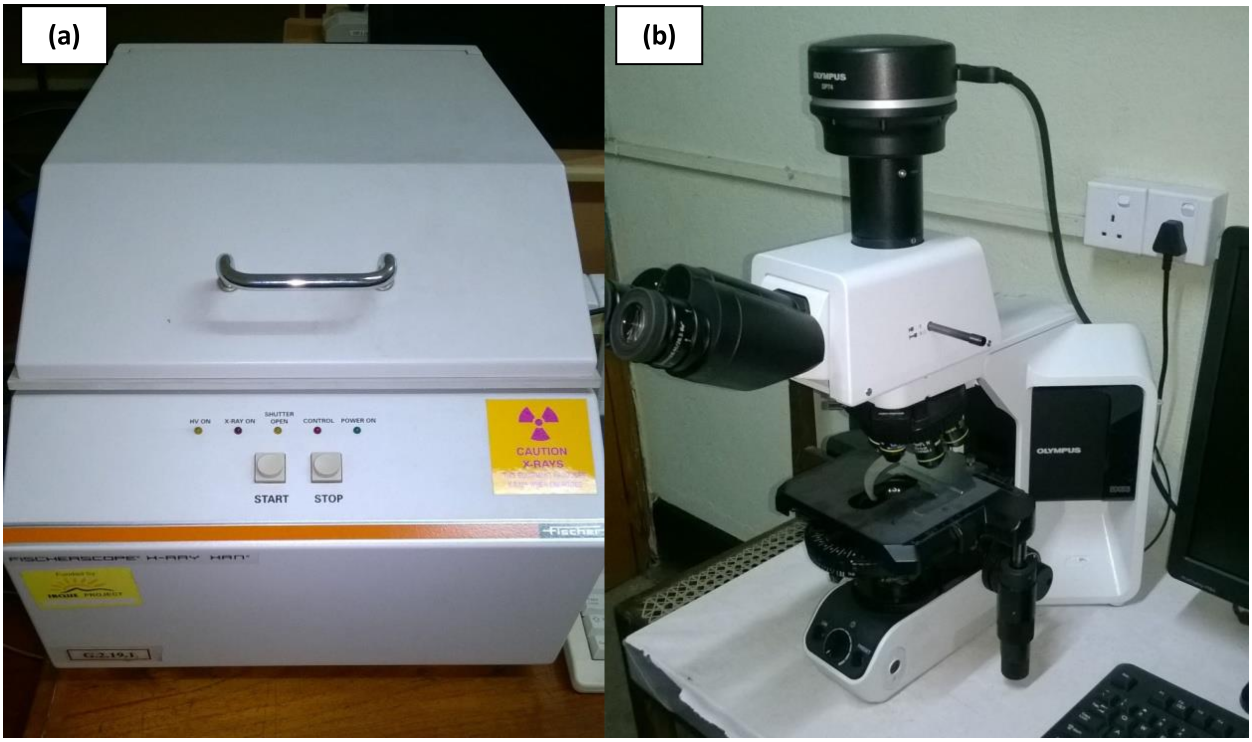


Figure 3. (a) X-Ray fluorescence (XRF) spectrophotometer and **(b)** optical microscope

3. RESULTS AND DISCUSSION

Observations in the range of different burning temperatures are summarized in **Table 1**.

Table 1. Comparison of activated carbon sample appearance versus production temperature

30 min. Burn Temperature	Observations
390 ºC	The coconut shells were completely burnt, black fume strongly occurred and only ash was retained in the furnace
360 ºC	Portion of coconut shells were completely burnt and the retained portion was sufficiently burnt, black fume slightly occurred and a small portion of ash was retained
350 ºC	The entire portion was sufficiently burnt, very slight amount of colorless fume was evident and the formed ash portion was negligible

330 ºC	The entire portion was sufficiently burnt, fume was not observed and ash was not observed
320 ºC	A majority of the entire portion was sufficiently burnt, fume was not formed and ash was not observed
300 ºC	A majority of the entire portion was insufficiently burnt, fume was not formed and ash was not observed

In reference to the obtained results and observations, it seems the effective and adequate burning temperature for these coconut shells is between 330 - 350 ºC (**Figure 4**). The effective temperature for the manufacturing of activated carbon cannot, however, be considered a constant value due to the type of coconut shell, purity of coconut shells and other possible factors that are associated with the process of manufacturing [3-15].

Figure 4. Manufactured activated carbon

Microstructure views of the manufactured activated carbon are shown in following **Figure 5**(**a**, **b**).

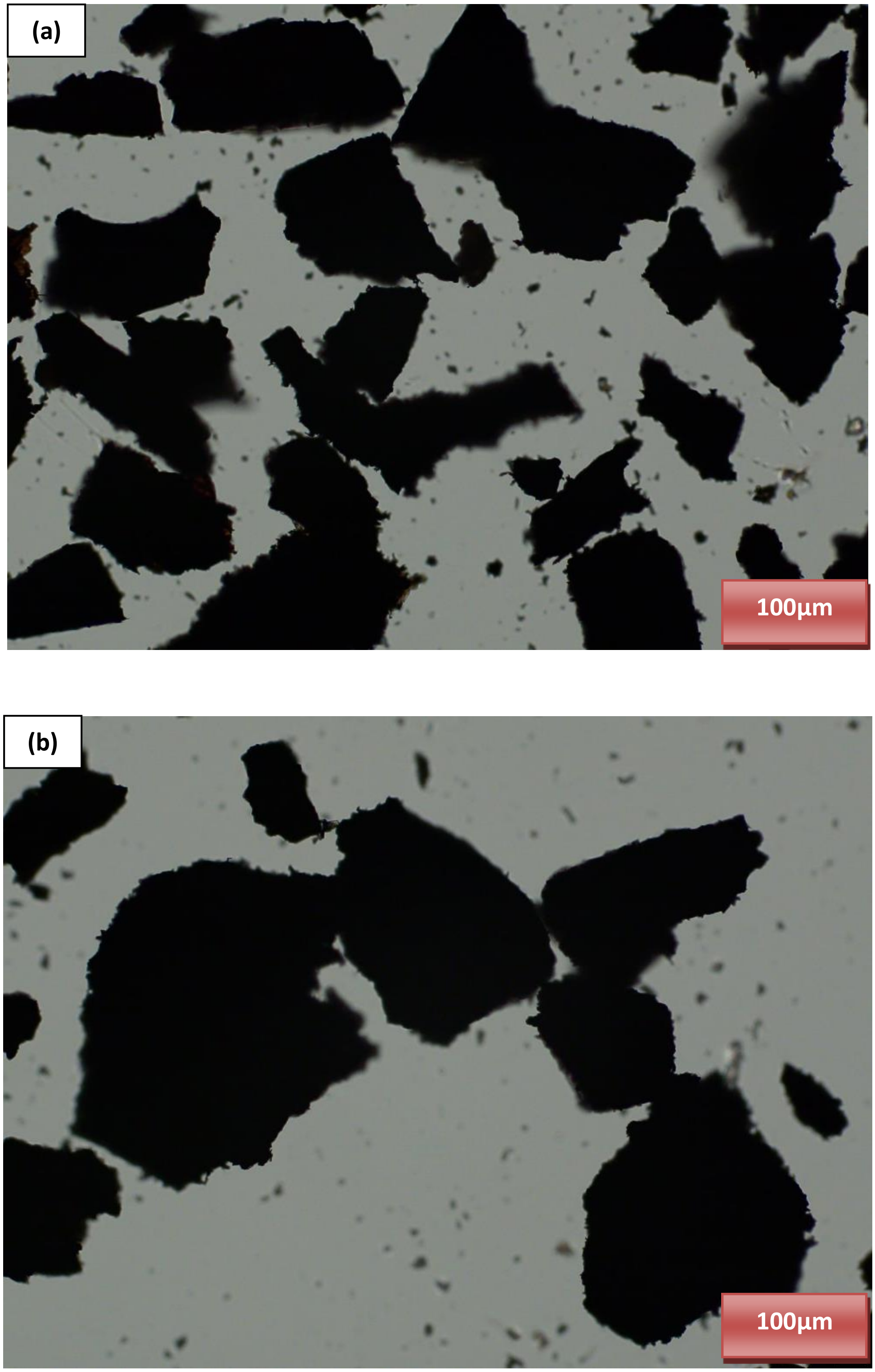


Figure 5(a,b). Microscopic views of the manufactured activated carbon

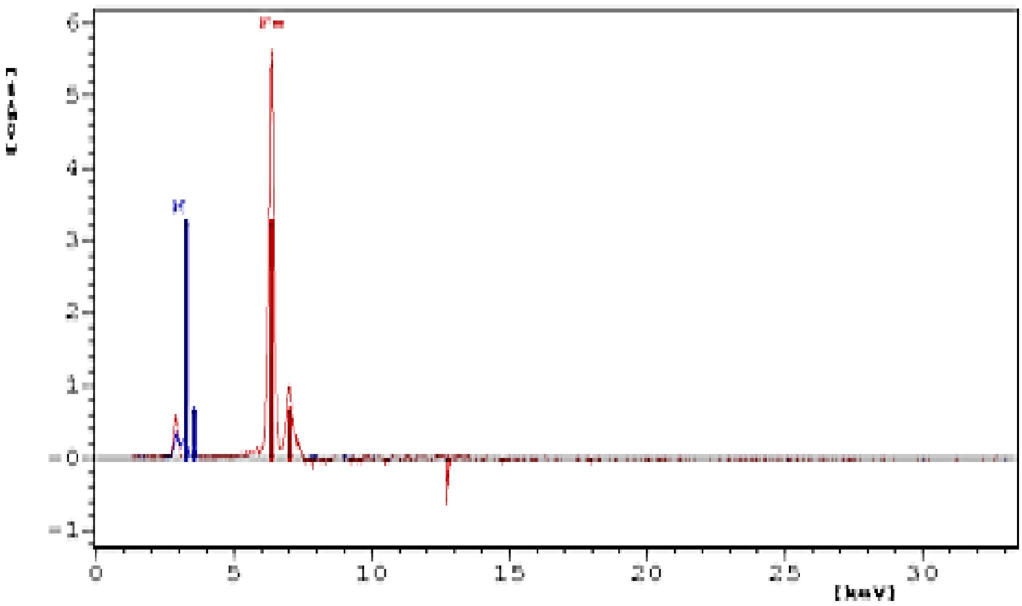


Figure 6. X-Ray fluorescence spectroscopy of activated carbon

We observed pure black color surfaces and different shaped fragments of activated carbon. Unfortunately, the existing microscopic analysis was found to be insufficient for the noticeable analysis of the pores of the activated carbon body. Therefore, advanced microscopic analysis would be beneficial in a more successful and descriptive investigation.

According to X-Ray fluorescence (XRF) analysis, the obtained results have been interpreted in the below (**Fig. 6**). The elemental composition of the created activated carbon according to X-Ray fluorescence (XRF) analysis is interpreted in Figure 6, and given in **Table 2**.

Table 2. Elemental composition of activated carbon

Color of the Peak	Element	Atomic Number (amu)	Content (%)
	Iron (Fe)	26	68.85
	Potassium (K)	19	31.15

The X-Ray fluorescence (XRF) results show a relatively higher Fe content and intermediate K content in the created activated carbon. No radio-active or heavy metal contaminants were observed. Therefore, these activated carbons can be used for water treatment applications [6-18].

The product is especially recommended for application in the treatment of highly polluted water such as leachate. Leachate is a liquid that is generated in landfill dump sites because of the percolation of rain water through the body of the compacted or non compacted accumulated waste/polluted materials. Usually the characteristics of the leachate depend upon the age of the dumpsite and the types of accumulated waste in the dumpsite. The typical characteristics of leachate are [3, 17, 18]:

- Unsavory odor
- Heavy metallic contents
- Organic pollutants
- Abnormal color
- Natural organic matter.

4. CONCLUSIONS AND REMARKS FOR FUTURE RESEARCH WORKS

We identified the range of 330 - 350 ºC as being most suitable for the successive progress of the manufacturing of activated carbon from these batches of coconut shells. After firing, 68.85% of Fe and 31.15% of K were found as the composed metallic elements. The following modification stages are recommended for future improvements:

- Analysis of the carbon content of the resulting activated carbon should be done using an advanced analytical method and instrument such as Thermogravimetric Analysis (TGA) or Elemental Analysis (CHN/S Analyzer)
- The existing methodology should be altered to assess the effect of preparation of activated carbon from some other similar disposable materials such as Palmyra shells and fesult shells of fesult – both of which belong to the palm family
- Surface and structural analysis of such activated carbon should be assessed using an advanced microscopic analysis method such as scanning electron microscope (SEM), scanning probe microscope (SPM) or transmittance electron microscope (TEM)
- Possible applications for various industrial purposes such as water treatment and medicinal purposes of the resulting activated carbon should be explored
- Exhaust gas should be collected while burning these activated carbons, and analysed.
- More characterization of the activated carbon, including particle size, shape, porosity, surfaces area and some advanced chemical analysis such as the presence organic and inorganic functional groups using Fourier Transform Infrared Spectroscopy (FT-IR) or Attenuated Total Reflection Infrared Spectroscopy (ATR-IR), should be undertaken.

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