

# Effects of Maturity of Coconut Shells on Gold Adsorption Efficiencies of Derived Activated Carbons\*

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Buah W. K., Darmey J. and Amoako Osei F. (2019), "Effects of Maturity of Coconut Shells on Gold Adsorption Efficiencies of Derived Activated Carbons", *Ghana Mining Journal*, Vol. 19, No. 2, pp. 50-54.

## Abstract

Coconut shells are used as precursors for preparation of activated carbons. The shells could vary in terms of their maturity. The influence of the maturity of the shells on gold adsorption efficiencies of derived activated carbons (ACs) from gold cyanide solution was investigated. The shells were pyrolysed at 900 °C and the resulting chars were activated in steam at the same temperature for different durations. Assessment of the properties of the derived ACs revealed that; the hardness, gold adsorption capacities and rates of gold adsorption of the ACs depended on the maturity of the shells. The more matured the shells the harder the AC. The relative hardness and gold adsorption rates of the mature coconut shells activated carbons,  $H_M$  and  $R_M$ , respectively and those of the less mature shells,  $H_L$  and  $R_L$ , respectively were in the order of  $H_M > H_L$  and  $R_M > R_L$ . The relative hardness of the ACs derived from the more mature and less mature shells after 3 hrs activation were 99.3% and 94.0%, respectively and the gold adsorption rates were 5.78 mg Au/hr/g and 4.95 mg Au/hr/g, respectively. The adsorption rates and relative hardness depended on the duration of activation, where longer activation times resulted in increase in the adsorption rates and a decrease in relative hardness of the derived ACs.

**Keywords:** Adsorption, Activated Carbon, Coconut Shells, Maturity, Relative Hardness

## 1 Introduction

Activated carbons are carbonaceous materials having highly developed porous structure and a large internal surface area. Generally, activated carbons with higher surface areas exhibit higher adsorption capacities and their application also depends on their pore characteristics (Buah *et al.*, 2014). Activated carbons have worldwide applications including removal of colour. For example, it is used for removal of colour from sugar syrup during commercial production of sugar and also for treatment of potable water, alcoholic beverage and fats (Buah *et al.*, 2014; Mudoga *et al.*, 2008; Satyawall and Bakakrishnan, 2007; Tennant and Mazyck, 2003). In the gold industry, activated carbon is used mainly to recover dissolved gold complexes from solutions (Zhonglin *et al.*, 2017; Soleimani and Kaghazchi, 2008; Navarro *et al.*, 2006; Yalcin and Arol, 2002). Activated carbon is achieved by removal of hydrogen rich fraction and other volatile constituents from the carbonaceous raw material to produce a porous residue with a large internal surface area (Buah and Kuma, 2012). There are two methods of activation for producing activated carbon from carbonaceous materials; these are chemical and physical activation processes.

Physical activation procedure involves a two-step process that is carbonisation followed by activation using steam, oxygen or carbon dioxide as activating agent (Mohd Iqbalidin *et al.*, 2013; Yuen and

Hameed, 2009). However, in chemical activation procedure, carbonisation and activation processes occur in a single stage using chemicals such as potassium hydroxide, phosphoric acid and zinc chloride as activating agents (Mohd Iqbalidin *et al.*, 2013; Ncibi *et al.*, 2009).

Several researches have been conducted on the production of activated carbon from waste biomass such as coconut shells (Kajamani *et al.*, 2018; Mohd Iqbalidin *et al.*, 2013;). Though, the precursor material used for activated carbon production affect the pore structure of the derived activated products, investigations on the effects of maturity of the coconut shells on the derived activated carbons have not received attention. This paper investigates the effect of maturity of coconut shells on the relative hardness and gold adsorption properties of derived activated carbons.

## 2 Resources and Methods Used

### 2.1 Preparation of the Activated Carbons

Two samples of coconut shells of different maturity were collected. One sample was made up of matured coconut shells (M) (11 months old) and the other was less-matured coconut shells (L) (8 months old). The coconut shells were washed to remove dirt, sun dried, crushed and sieved to obtain the -2.8 mm + 1.4 mm fractions, which were pyrolysed at 900 °C, this temperature was measured with a thermocouple. The resulting chars obtained were physically activated in steam at the same temperature for various times, that is, 1 hr, 2 hrs and

\*Manuscript received August 13, 2019

Revised version accepted December 10, 2019

<https://dx.doi.org/10.4314/gm.v19i2.7>

3 hrs activation times. The steam dosage rate was 0.02 ml/min/g.

## 2.2 Adsorption Test

A 0.2 g sample of activated carbon produced from each precursor after the various duration of activation with initial size range of -2.8 mm + 1.4 mm were placed into bottles containing 200 mL of 7.2 mg/L gold solution. The bottles were placed on rollers for 27 hours. A 0.2 g of a commercial activated carbon, Norit RO 3515 was also subjected to the same procedure. Samples of the solution were taken at various times, that is, 3, 6, 9, 12, 15, 18, 21, 24 and 27 hours and analysed for gold concentration using a Varian Fast Sequential Atomic Adsorption Spectrophotometer (Varian AA240FS).

## 2.3 Hardness Test

A 2 g sample of activated carbon produced from each precursor after the various duration of activation with initial size range of -2.8 mm + 1.4 mm were placed in a pan with a stainless steel ball and subjected to a combined rotating action for the same period of time. The particle disintegration is measured by determining the weight of carbons retained on a 0.707 mm sieve. A sample of a reference activated carbon, Norit RO 3515 was also subjected to the same procedure and the relative hardness of each activated carbon was calculated using:

$$\text{Relative Hardness} = \frac{W}{W_r} \times 100\% \quad (1)$$

Where,  $W$  represents weight of the test activated carbon retained on 0.707 mm screen;  $W_r$  represents weight of the reference activated carbon retained on the 0.707 mm screen.

## 3 Results and Discussion

### 3.1 Adsorption Performance

Adsorption of gold from gold di-cyanide solution with initial concentration of 7.2 mg/L, by the commercial activated carbon and the activated carbons derived from the matured coconut shells (M) and less-mature coconut shells (L) after various duration of activation, is presented in Figs. 1 to 3.

In Figs. 1, 2 and 3 the reference AC performed better than the derived ACs produced from M and L at 1 hr, 2 hrs and 3 hrs activation time. This is an indication that the derived activated carbons are not as active as the commercial activated carbon and therefore the need to optimise the process variables, such as the activation time, and

temperature, to enhance activation of the test precursors.

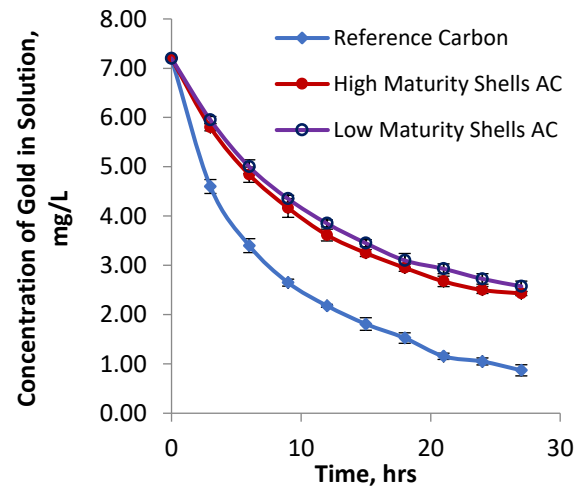


Fig. 1 Recovery of Gold from Solution by the Activated Carbons obtained after 1 hr Activation and the Reference Activated Carbon

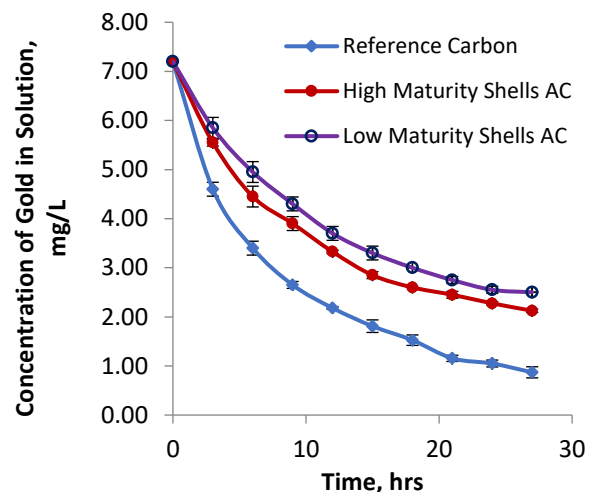
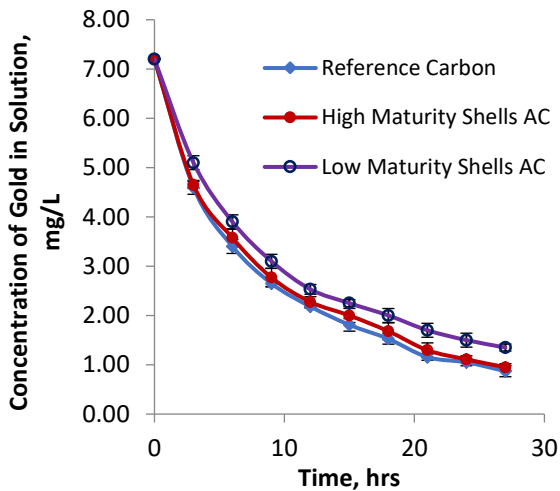


Fig. 2 Recovery of Gold from Solution by the Activated Carbons obtained after 2 hrs Activation and the Reference Activated Carbon



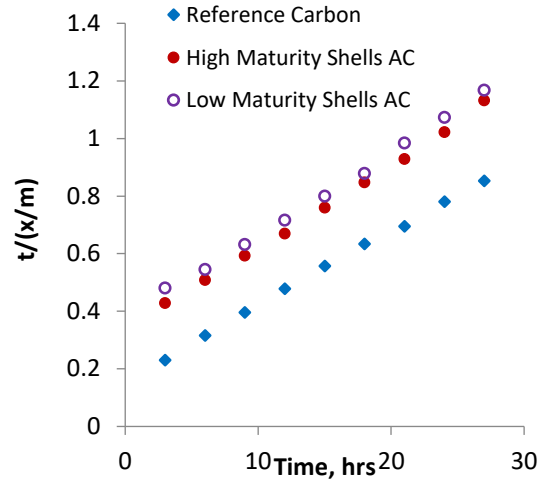
**Fig. 3 Recovery of Gold from Solution by the Activated Carbons obtained after 3 hrs Activation and the Reference Activated Carbon**

Based on the results in Figs. 1, 2 and 3 the percentage adsorption of gold by the AC derived were determined. After 27 hrs of contact with the solution gold adsorption was 87.92% (31.65 mg Au/g C), 66.25% (23.85 mg Au/g C) and 64.24% (23.13 mg Au/g C) for the reference carbon, the AC derived after 1 hr activation of the matured and less mature coconut shells, respectively. For the AC produced after two hours of activation the gold adsorption was 70.49% (25.38 mg Au/g C) and 64.58% (23.5 mg Au/g C) for of the matured and less mature coconut shells, respectively. Similar trend occurred for 3 hrs activation time, ACs derived from M had 86.61% (31.25 mg Au/g C) gold adsorption, which was greater than the gold adsorption of ACs derived from L, 81.25% (29.25 mg Au/g C). From the results in Figs. 1 to 3, graphs of  $t/(x/m)$  against time were plotted in Figs. 4 to 6 and the R-values were determined from the plots using eq. (2). The R-values of the derived ACs are presented in Table 1.

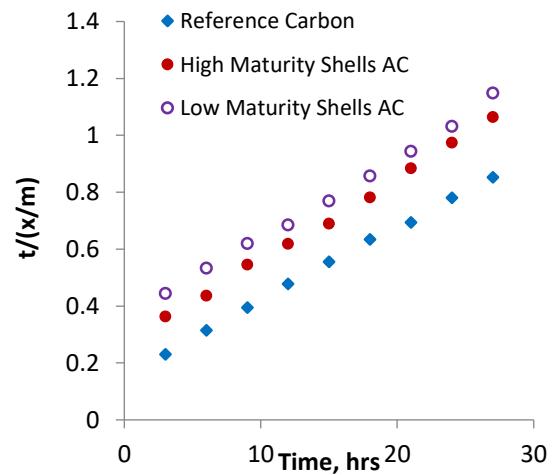
$$\frac{t}{x/m} = \frac{1}{M}t + \frac{1}{R} \quad (2)$$

where,  $x/m$  represent the carbon loading in mg Au/g of carbon,  $t$  is the time,  $M$  and  $R$  are reciprocal of the slope and the intercept at  $t=0$ .

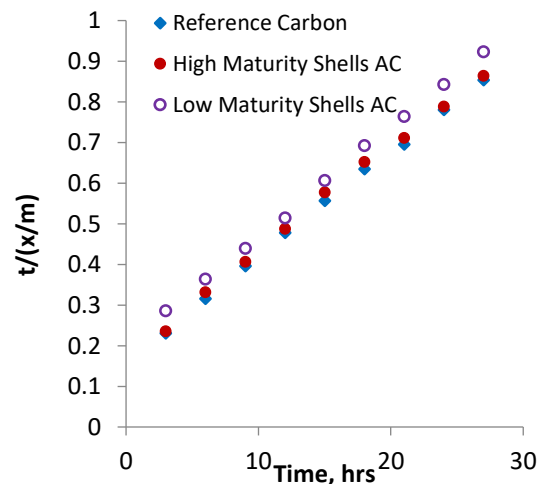
A higher R-value of a carbon indicates faster adsorption, implying less gold loss at the plant, as stated by Yalcin and Arol (2002). From Table 1, ACs from M have a higher R-value than ACs from L no matter the activation time.



**Fig 4 Adsorption Rate of ACs obtained after 1 Hour Activation**



**Fig. 5 Adsorption Rate of ACs Obtain after 2 Hours Activation**



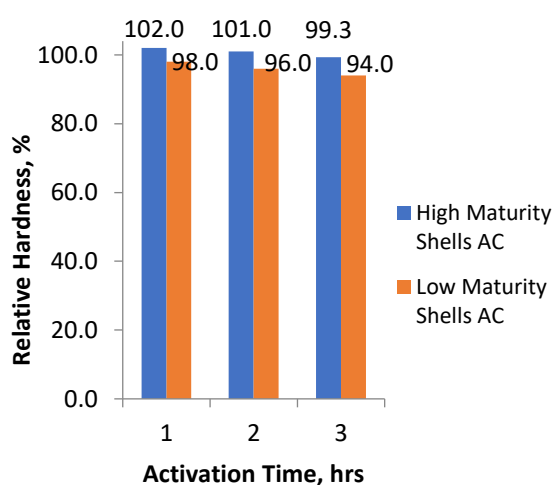
**Fig 6 Adsorption Rate of ACs obtained after 3 Hours Activation**

**Table 1 R-values of ACs Produced**

Duration of Activation	1 Hour		2 Hours		3 Hours	
	M	L	M	L	M	L
R-Value, mg Au/hr/g	3.01	2.67	3.72	2.82	5.78	4.95

### 3.2 Hardness

The hardness of ACs produced from M and L at 1 hr 2 hrs and 3 hrs activation times are represented by Fig. 7.



**Fig. 7 Relative Hardness of Activated Carbons Obtained after 1 hr, 2 hrs and 3 hrs Activation**

AC from M is harder than AC from L, with AC from M having 102 %, 101% and 99.3% relative hardness after 1 hr, 2 hrs and 3 hrs activation times respectively. AC from L had 98%, 96% and 94% relative hardness at 1 hr, 2 hrs and 3 hrs activation times respectively. The decrease in hardness of the ACs with increased activation time is due to generation of more pores in the carbons as the activation time increases.

### 4 Conclusions

The activated carbon produced from the matured coconut shells adsorbed better than the activated carbon produced from less matured coconut shells. Also, activated carbon produced from the matured coconut shells was harder than the activated carbon produced from less matured coconut shells. The adsorption rates and relative hardness also depended on the duration of activation, where longer activation times resulted in increase in the

adsorption rates and a decrease relative hardness of the derived ACs.

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