Technical and Economic Feasibility Study of Coconut Shell Charcoal Production as precursor to Activated Carbon in East Coast Malaysia

Wan Muhammad Noor Sarbani Mat Daud[1], Shariman Mustafa[2], Syed Radzi Rahmadulla[3] Saiful Anwar Che Ghani[4] and Anwaruddin Hisyam[5]

1 Faculty of Industrial Management, Universiti Malaysia Pahang. sarbani@ump.edu.my
2 Faculty of Industrial Management, Universiti Malaysia Pahang, shariman@ump.edu.my
3 Faculty of Industrial Management, Universiti Malaysia Pahang, syedradzi@ump.edu.my
4 Faculty of Mechanical Engineering, Universiti Malaysia Pahang, anwarcg@ump.edu.my
5 Faculty Of Chemical & Natural Resources Engineering, Universiti Malaysia Pahang, ahisyam@ump.edu.my

ABSTRACT

The most common precursors used for the preparation of activated carbons are organic materials that are rich in carbon. The abundance and availability of coconut shells make them excellent sources of raw materials for activated carbon production. A survey has been conducted to identify locations for the supply of coconut shells. The survey has been conducted around a coastal village of Beserah, Kuantan. The cost calculation for two methods was considered, which is to buy from coconut supplier or to do self-collection at the coconut milk entrepreneurs location. Two carbonization methods were used in this study which is traditional drum method and Top-Lit up-Draft (TLUD) drum method. The results from the both methods were observed. The coconut shell charcoals produced were sent to activated carbon manufacturer for evaluation. The coconut shell charcoals from the different methods were priced differently. This is mainly due to different quality of the charcoals. A calculation of possible cost and sales from a small production plant was simulated to know whether a profitable production plant could be set-up. The most common precursors used for the preparation of activated carbons are organic materials that are rich in carbon. The abundance and availability of coconut shells make them excellent sources of raw materials for activated carbon production. A survey has been conducted to identify locations for the supply of coconut shells. The survey has been conducted around a coastal village of Beserah, Kuantan. The cost calculation for two methods was considered, which is to buy from coconut supplier or to do self-collection at the coconut milk entrepreneurs location. Two carbonization methods were used in this study which is traditional drum method and Top-Lit up-Draft (TLUD) drum method. The results from the both methods were observed. The coconut shell charcoals produced were sent to activated carbon manufacturer for evaluation. The coconut shell charcoals from the different methods were priced differently. This is mainly due to different quality of the charcoals. A calculation of possible cost and sales from a small production plant was simulated to know whether a profitable production plant could be set-up.

Key Words: activated carbon, coconut shell, charcoal, top lit up draft

1. INTRODUCTION

The most common precursors used for the preparation of activated carbons are organic materials that are rich in carbon(Hidayu & Muda, 2016). Nowadays, coal end lignocellulose biomass is two major sources for the production of commercial activated carbons (Alslaibi, Abustan, Ahmad, & Foul, 2013; Duman, Okutucu, Ucar, Stahl, & Yanik, 2011). The abundance and availability of agricultural by-products make them excellent sources of raw material for activated carbon production (Li et al., 2009). A good example of tropical agricultural by-products that have been successfully used in the preparation of activated carbon is coconut shell (Alslaibi et al., 2013;

Bhatnagar, Vilar, Botelho, & Boaventura, 2010). From 1980 to 2010, the total coconut production worldwide increased rapidly from 35 to 50 million tons (Bhatnagar et al., 2010). Coconut shells are suitable for preparing microporous activated carbons due to their excellent natural structure and low ash content (Yang et al., 2010).

According to Freedonia.com, World demand for activated carbon is projected to rise 8.1 percent per year to 2.1 million metric tons in 2018, driven by tightening pollution regulations and rising demand from manufacturing (Group, 2015). The demand is so high that make it very attractive for us to get involved.

Given all the benefits we can get from activated carbon, there is high demand for coconut shell activated carbon. A few big companies are manufacturing the materials. In principle, the methods for preparing an activated carbon can be divided into two categories: physical activation and chemical activation. In the physical activation, a raw material is first carbonized and the carbonized material is secondary activated by steam or carbon dioxide, air or their mixtures, i.e., there are two steps: carbonization step and activation step(Li et al., 2008). It is a normal practice for the manufacturer to buy coconut shell as raw material or buy the carbonized charcoal. Therefore there exists a huge demand by this manufacturer for the raw material of coconut shell and coconut shell charcoal. At the moment most of the raw materials are now mostly imported from Indonesia or from Bagan Datoh, Perak.

Coconut meat is processed into desiccated coconut, instant milk powder, and instant coconut cream powder (Senik, 1995). From the writer's observation, there are many small-scale entrepreneurs in East Coast Malaysia who producing instant coconut milk with a lot of coconut shell waste. However, so far the usefulness of coconut shells is not fully exploited. This is mainly because they do not know the value of the coconut shells. Most of the coconut shell is just thrown away as waste or simply burned away.

This research aimed to make full use of this waste into useful activated carbon products. It will help to reduce coconut shell waste and hence leads to a cleaner environment. Other than that the selling of coconut shell charcoal will help the small scale coconut milk entrepreneurs to increase their income generation.

2. ECONOMIC FEASIBILITY (COSTING AND PRICING)

2.1. Costing

There are two methods to acquire the coconut shells around the area. The first method is by buying from other suppliers and the second method is by doing the collection by ourselves.

2.1.1 Buy coconut shells from other suppliers

After doing a survey around Pahang and Terengganu, It found out that there is nobody in the business of collecting coconut shells. However, there are some coconut dealers doing coconut shell collection as a by-product or for extra income. The dealer normally acts as the distribution center of imported coconuts. They deliver the coconuts to the coconut milk producers and markets nearby. On the way back from the dealers they would be able to collect coconut shells on the way back from the markets or coconut milk sellers' location.

From the survey of 5 coconut dealers, they are willing to sell coconut shells at the price of RM190 – RM200 per ton.

Table 1: Typical costing of the collection by coconut suppliers

Coconut shell collection cost based on 1 ton/trip	[RM/ton]
Worker	60
Fuel	20
Lorry rental	70
Total Collection	**150**
Coconut shell shipment cost	
Bulldozer to lift the coconut shells	10
Trailer	40
Total Shipment	**50**
Overall cost to reach processing plant	**200**

2.1.2 Self Collection

Alternatively, coconut shells could be collected on our own from the coconut milk entrepreneurs or from the markets. The quantity coconut shells produced every day is significant.

To start our study we have started the search of coconut shells around coastal village of Beserah. After the initial survey, we found 5 coconut milk producers which each producing around 300 kg / week of coconut shells. From this, we estimate that Beserah Area is producing 1500 kg / week or 6000 kg / month.

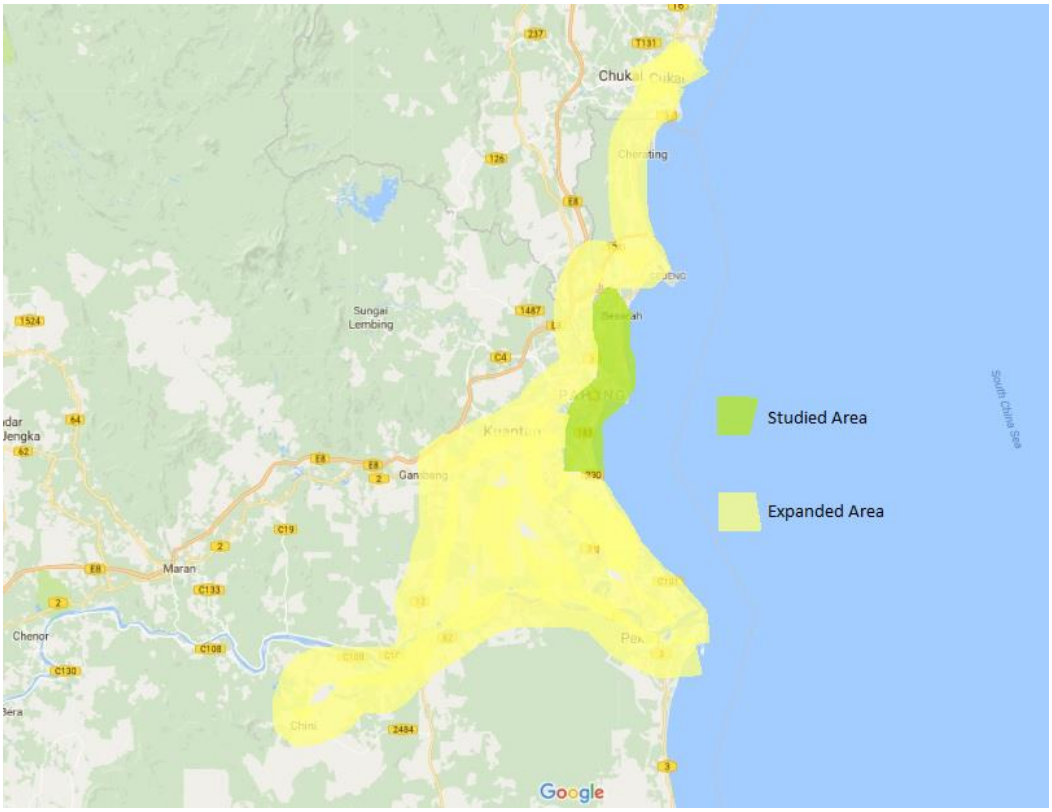

Figure 1: Survey area

We also expand the estimation to another area nearby the planned location of the plant in Kuantan. The estimation for the coconut shell availability around the planned location is as follows:

Table 2: Supply quantity according to area

Location	**Quantity [kg/month]**
Cherating	5000
Balok	3000
Pusat Bandar	6000
Beserah	6000
Indera Mahkota	6000
Jaya Gading	3000
Chini	6000
Pekan	4000
Kemaman	6000
Total	**45000**

With this supply, the collection of 1.8 ton / day is possible with 25 working days in a month. After including all collection costs such as lorry rental, helper, and fuel; the average collection cost is about RM 54 / ton.

2.2. Charcoal Price

The price of the product is determined by the quality of the charcoal. The quality criteria for the charcoal are as follows:

Hardness -> the harder the material is better
Water content -> the lower water content is better
Carbonization -> not less nor overbake. The carbonization or baking process should produce evenly baked coconut shells. Unbaked or overbaked is unwanted.
Purity -> The charcoal should be fully coconut shell only. The existence of unwanted charcoal such as charcoal from the husk would reduce the price. This is because the charcoal from the husk will become dust during crushing process.

The quality level of the products was judged by the rule of thumb, based on the criteria mentioned above. The price range would be around RM 600 / ton to RM 1000 / ton.

3. DESIGN AND METHODS OF CHARCOAL KILN

Two methods used in this study, which is traditional method and Top Lit Up Draft (TLUD)

3.1. Traditional Method

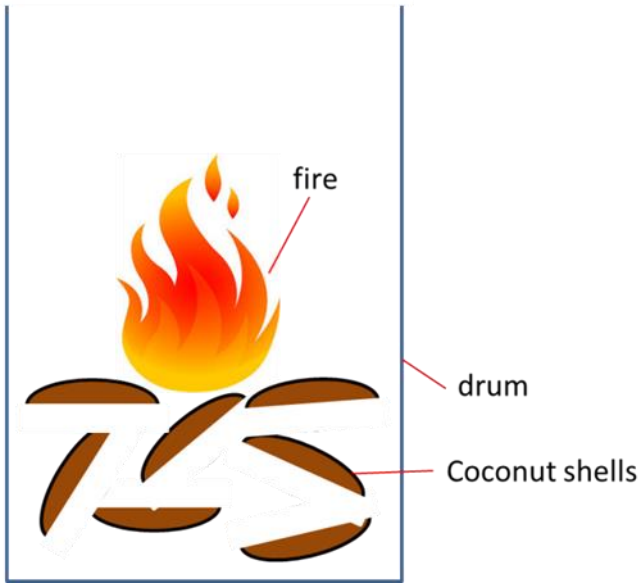

Figure 2: Schematic traditional method

Figure 3: Picture of traditional method

In the traditional method, the coconut shell is put at the bottom of the drum and fired. Once the fire is stable, more coconut shells are being put on top, once the coconut shell catch fire, more coconut shells put on top. This step was repeated until the drum is full. After all the coconut shells caught on fire, the drum was air tight closed. This method is very simple to conduct; however, it produces a lot of smoke.

3.2. Top Lit Up Draft (TLUD)

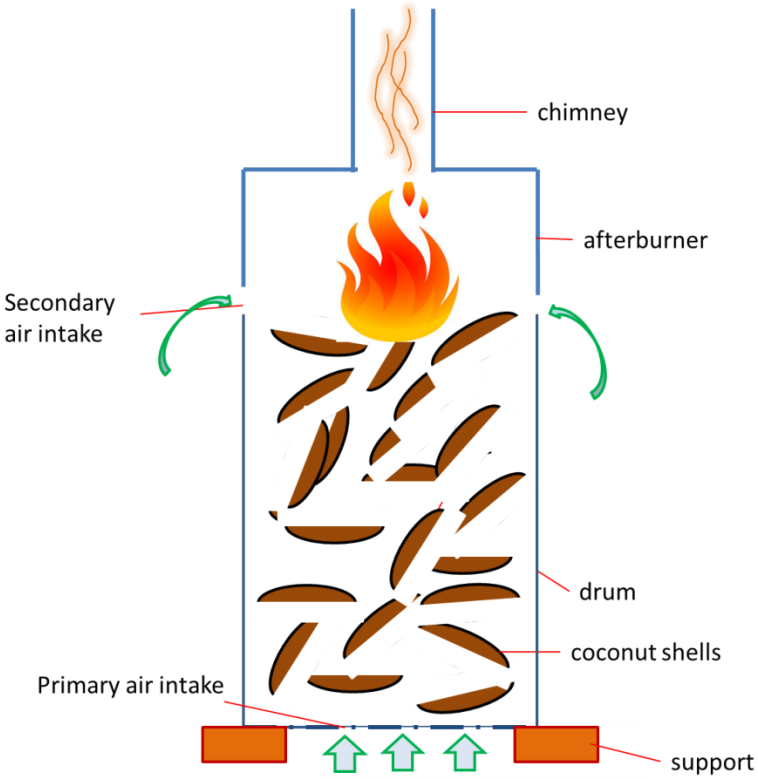

Figure 4: Schematic Top Lit Up Draft

Figure 5: Picture of top Lit Up Draft Furnace

TLUD kiln consists of the main drum with holes at the bottom, after-burner, and chimney. The firing was started from the top, not from the bottom like the traditional method. In the beginning, the

drum is filled with coconut shells until full. At the top of the drum, the fire was started. The heat released from the top layer causes lower layers to pyrolyze, which means that volatile matter is released from the coconut shells in an inert atmosphere (Kirch, Medwell, & Birzer, 2016; Kirubakaran et al., 2009). This process is called a migrating pyrolytic front (Kirch et al., 2016; Roth, 2014). After a stable fire was set-up, Afterburner and chimney were put on top of the drum. In the after-burner, the gas was burnt and flow out of the chimney. The gas came out of the chimney was clean, with only a little smoke could be observed.

4. RESULT AND DISCUSSION

4.1. Traditional Method

Traditional method trial was conducted. The firing process took around 1 and half hour and another 2 hours for cooling. Someone need to monitor the process and adding new coconut shells once the coconut shell inside catch fire. As expected, the firing process produced a lot of smoke. The product, however, is evenly baked with high quality and can be sold at the upper range of the price scale.

Figure 6: Charcoal produced using traditional method

After weighing the weight of coconut shell input and compared to the output weight. The weight of charcoal out of the trial is about 1/3 of the weight coconut shell before the bake. This finding is very similar to the finding by (Bhatnagar et al., 2010) which says carbonization of one ton of coconut shells produces 300 kg of charcoal, which can be converted into 120 kg of activated carbon.

4.2. Top Lift up Draft (TLUD) Method

Trials using TLUD method also has been conducted. This method needs a little extra effort to put on burner and chimney on top of the drum. As expected, the firing using TLUD is very clean and quick. The firing process took just around 45 minutes. 3 hours in total including the cooling period.

The charcoal produced, however, less impressive. The weight loss is quite high. Charcoal Produced weigh only 1/5 of its original weight. This is because most of the volatiles matter has been burnt. The structure is very porous and the hardness is lower. The charcoals could be easily broken by a little force. This has caused a little concern that it might crush into dust in the next crushing process. This is related to what has been explained by (Misginna, Rajabu, & Mekelle,

2012) that the produced charcoal has volatile matter less than 30% makes it more friable with subsequent difficulty in handling and transportation.

Figure 7: Charcoal produced using TLUD

Due to lower quality of the charcoal, it could be sold at a lower range of the price scale.

4.3. Economic Feasibility Calculation

The operation cost for the charcoal production was calculated. Worker salary, fuel consumption, utilities, lifter and delivery cost was included. To reduce delivery cost, the products would be piled up until one full load of the trailer is achieved. It is estimated that one trailer can bring 16-18 ton per trip.

4.3.1. Traditional Method

With the daily collection and baking of coconut shells of 1.8 tons /day, the operation cost as follows:

Table 3: The operation cost for production

Fixed Cost

No	Item	quantity	Cost/unit	total
	Operator Salary+EPF+SOCSO	2	1000	**2000**
	Electricity	1	100	**100**
	Water	1	100	**100**
	Land rent	1	500	**500**

Variable Cost			
Coconut shell (ton)	45	54.44	**2450**
JCB/forklift Cost	1	100	**100**
Delivery to Customer	1	1500	**1500**
Total Cost			**6750**

The quality of the product using this method is good and can be sold at a higher range of the price scale. For the benefits of calculation, we use RM 900 / ton as the selling price.

Sales	
Price Charcoal/ton	**900**
Weight/trip (ton)	**16**
Total Sales	**13500**

The gross profit we could earn monthly using this method is around RM 6750 / month.

4.3.2. TLUD Method

By using this method, the ratio coconut shell to charcoal output is 1:5. The quality of the charcoal is also less. The calculation for production cost using this method is the same as a traditional method which is around RM 6750 per month.

However since the quality of the product is of lower grade the selling price is different. For calculation purpose, the price taken is of RM 600 / ton.

Sales	
Price Charcoal/ton	**600**
Weight/trip (ton)	**16**
Total Sales	**5400**

The gross profit we could earn from using this method is then –RM 1350. Basically, we were going to lose money if the production plant produces using this TLUD method.

5. CONCLUSION

Based on the survey and the trials conducted, we can conclude that it is feasible to open up a plant in Kuantan. The production must use traditional method since it produces higher quality charcoal and therefore profitable. This plant, however, should be located outskirt of town and far from the resident area since it will produce some amount of smoke. This project could offer at least 1 entrepreneurial position for degree level staff and 2 positions for people without a degree.

To open up a production plant using TLUD method is not possible because the revenue from the sales at lower grade is not enough to cover operation cost. However, TLUD method is useful to be applied by the coconut milk entrepreneur themselves. All they need was to bake the coconut

shell and sell it. Even it sells at a lower price; they still generate extra income at almost no extra effort and no extra cost. They can do nearby their premises because this process does not produce heavy smoke as baking using the traditional method.

This feasibility study can be expanded to other areas around Malaysia as well. The expansion of this study will help reduce the amount of wasted coconut shells around the country drastically and at the same time helping coconut milk entrepreneurs adding extra income from the charcoal sales.

ACKNOWLEDGEMENT

The authors are grateful to Encik Zainal from Beserah for supporting this research. He supplied the coconut shells for free and shared his knowledge of the business situation. The author also would like to thank Encik Muhammad Fairuz from Ata Rashi Enterprise for the support in the collection and transportation of the coconut shells.

REFERENCES

Alslaibi, T. M., Abustan, I., Ahmad, M. A., & Foul, A. A. (2013). A review: production of activated carbon from agricultural byproducts via conventional and microwave heating. *Journal of Chemical Technology and Biotechnology, 88*(7), 1183-1190.

Bhatnagar, A., Vilar, V. J., Botelho, C. M., & Boaventura, R. A. (2010). Coconut-based biosorbents for water treatment—a review of the recent literature. *Advances in Colloid and Interface Science, 160*(1), 1-15.

Duman, G., Okutucu, C., Ucar, S., Stahl, R., & Yanik, J. (2011). The slow and fast pyrolysis of cherry seed. *Bioresource Technology, 102*(2), 1869-1878. doi:http://dx.doi.org/10.1016/j.biortech.2010.07.051

Group, T. F. (2015). World Activated Carbon - Demand and Sales Forecasts, Market Share, Market Size, Market Leaders.

Hidayu, A. R., & Muda, N. (2016). Preparation and Characterization of Impregnated Activated Carbon from Palm Kernel Shell and Coconut Shell for CO2 Capture. *Procedia Engineering, 148*, 106-113. doi:http://dx.doi.org/10.1016/j.proeng.2016.06.463

Kirch, T., Medwell, P. R., & Birzer, C. H. (2016). Natural draft and forced primary air combustion properties of a top-lit up-draft research furnace. *Biomass and Bioenergy, 91*, 108-115.

Kirubakaran, V., Sivaramakrishnan, V., Nalini, R., Sekar, T., Premalatha, M., & Subramanian, P. (2009). A review on gasification of biomass. *Renewable and Sustainable Energy Reviews, 13*(1), 179-186. doi:http://dx.doi.org/10.1016/j.rser.2007.07.001

Li, W., Peng, J., Zhang, L., Yang, K., Xia, H., Zhang, S., & Guo, S.-h. (2009). Preparation of activated carbon from coconut shell chars in pilot-scale microwave heating equipment at 60kW. *Waste Management, 29*(2), 756-760.

Li, W., Yang, K., Peng, J., Zhang, L., Guo, S., & Xia, H. (2008). Effects of carbonization temperatures on characteristics of porosity in coconut shell chars and activated carbons derived from carbonized coconut shell chars. *Industrial Crops and Products, 28*(2), 190-198.

Misginna, M. T., Rajabu, H. M., & Mekelle, E. (2012). *Yield and chemical characteristics of charcoal produced by TLUDND gasifier cookstove using eucalyptus wood as feedstock.* Paper presented at the Second International Conference on Advances in Engineering and Technology, Nagapattinam, India.

Roth, C. (2014). *Micro-gasification: Cooking with Gas from Dry Biomass: an Introduction to Concepts and Applications of Wood-gas Burning Technologies Für Cooking*.

Senik, G. (1995). *Small-scale food processing enterprises in Malaysia*: ASPAC Food & Fertilizer Technology Center.

Yang, K., Peng, J., Xia, H., Zhang, L., Srinivasakannan, C., & Guo, S. (2010). Textural characteristics of activated carbon by single step CO 2 activation from coconut shells. *Journal of the Taiwan Institute of Chemical Engineers, 41*(3), 367-372.