

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

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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 were considered, which is to buy from coconut supplier or to do self-collection at the coconut milk entrepreneurs location. Two carbonisation 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.

Keywords— Activated Carbon, Coconut shell, charcoal, Top Lit Up Draft, TLUD, precursor, carbonisation, pyrolysis, Pahang East Coast Malaysia

1. Introduction

The most common precursors used for the preparation of activated carbons are organic materials that is rich in carbon[1]. Nowadays, coal

end lignocellulose biomass is two major sources for the production of commercial activated carbons [2, 3]. The abundance and availability of agricultural by products make them excellent sources of raw material for activated carbon production [4]. A good example of tropical agricultural by products that has been successfully used in the preparation of activated carbon is coconut shell [2, 5]. From 1980 to 2010, the total coconut production worldwide increased rapidly from 35 to 50 million tonnes [5]. Coconut shells are suitable for preparing microporous activated carbons due to their excellent natural structure and low ash content [6]. 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 [7]. 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[8]. It is a normal practice for the manufacturer to buy coconut shell as raw material or buy the carbonised 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[9]. 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 coconut shell 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 small scale coconut milk entrepreneur to increase their income generation.

2. Economic Feasibility (Costing and Pricing)

2.1 Costing

2.1.1 Buy coconut shell from other collectors

After doing a survey around Pahang and Terengganu, It found out that there is nobody in the business of collecting coconut shells.

Table 1. Typical Costing by Coconut Dealer

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

However there are some coconut dealers doing coconut shell collection as by product or for extra income. The dealer normally acts as the distribution centre 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 tonne.

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 initial survey, we found 5 coconut milk producers which each producing around 300kg/week of coconut shells. From this, we estimate that Beserah Area is producing 1500 kg / week or 6000 kg / month.

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 in Table 2.

Table 2. Coconut Shell Availability

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

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

Carbonisation -> not less nor overbake. The carbonisation 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/mt to RM 1000/mt.

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

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 is 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.

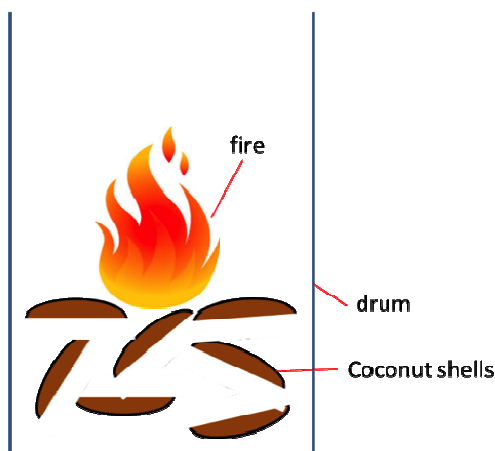


Figure 1. Schematic traditional method



Figure 2. Picture of traditional method

3.2 Top Lit Up Draft (TLUD)

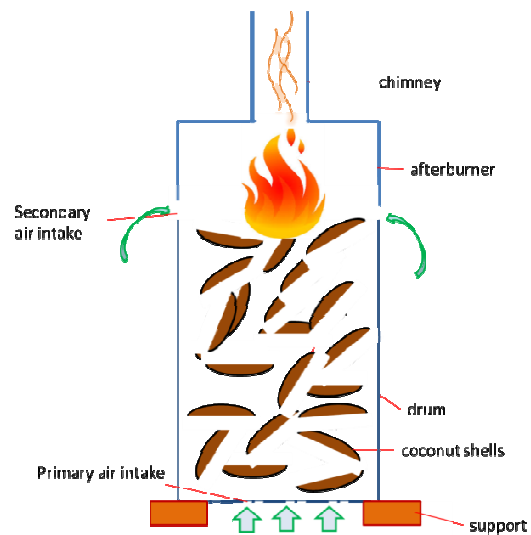


Figure 3. Schematic Top Lit Up Draft

TLUD kiln consist of the main drum with holes at the bottom, after-burner and chimney. The firing was started from 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, fire was started. The heat released from the top layer causes lower layers to pyro-lyse, which means that volatile matter is released from the coconut shells in an inert atmosphere [10, 11].

This process is called a migrating pyrolytic front [10, 12]. After stable fire was set-up. After-burner and chimney was put on top of the drum. In the after-burner, the gas was burnt and flown out of the chimney. The gas came out of the chimney was clean, with only little smoke could be observed.



Figure 4. Picture of top Lit Up Draft Furnace

4. Results 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 needs 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 upper range of the price scale.

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 bake.



Figure 5. Charcoal produced using traditional method

4.2 TLUD Method

Trials using TLUD method also has been conducted. This method needs a little extra effort to put after 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. 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.



Figure 6. Charcoal produced using TLUD

Due to lower quality of the charcoal, it could be sold at 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 were included. To reduce delivery cost, the products would be piled

up until one full load of trailer is achieved. It is estimated that one trailer can bring 16-18 mt per trip.

4.3.1 Traditional Method

With the daily collection and baking of coconut shells of 1.8 mt/day, the operation costs are:

Fixed Cost			
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 (mT)	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 higher range of the price scale. For the benefits of calculation, we use RM 900 / mt as the selling price.

Sales	
Price Charcoal/mT	900
Weight/trip (mT)	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 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 / mt.

Sales	
Price Charcoal/mT	600
Weight/trip (mT)	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 around Kuantan. The production must use traditional method since it produces higher quality charcoal and therefore profitable. This plant however should be located outskirts of town and far from 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 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 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 traditional method.

Acknowledgments

The authors are grateful to Encik Zainal from Beserah for supporting this research. He supplied the coconut shells for free and shared his knowledge in 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

- [1] A. R. Hidayu and N. Muda, "Preparation and Characterization of Impregnated Activated Carbon from Palm Kernel Shell and Coconut Shell for CO₂ Capture," *Procedia Engineering*, vol. 148, pp. 106-113, // 2016.
- [2] T. M. Alslaibi, I. Abustan, M. A. Ahmad, and A. A. Foul, "A review: production of activated carbon from agricultural byproducts via conventional and microwave heating," *Journal of Chemical Technology and Biotechnology*, vol. 88, pp. 1183-1190, 2013.
- [3] G. Duman, C. Okutucu, S. Ucar, R. Stahl, and J. Yanik, "The slow and fast pyrolysis of

- cherry seed," *Bioresource Technology*, vol. 102, pp. 1869-1878, 1// 2011.
- [4] W. Li, J. Peng, L. Zhang, K. Yang, H. Xia, S. Zhang, *et al.*, "Preparation of activated carbon from coconut shell chars in pilot-scale microwave heating equipment at 60kW," *Waste management*, vol. 29, pp. 756-760, 2009.
- [5] A. Bhatnagar, V. J. Vilar, C. M. Botelho, and R. A. Boaventura, "Coconut-based biosorbents for water treatment—a review of the recent literature," *Advances in Colloid and Interface Science*, vol. 160, pp. 1-15, 2010.
- [6] K. Yang, J. Peng, H. Xia, L. Zhang, C. Srinivasakannan, and S. Guo, "Textural characteristics of activated carbon by single step CO₂ activation from coconut shells," *Journal of the Taiwan Institute of Chemical Engineers*, vol. 41, pp. 367-372, 2010.
- [7] T. F. Group, "World Activated Carbon - Demand and Sales Forecasts, Market Share, Market Size, Market Leaders," 2015.
- [8] W. Li, K. Yang, J. Peng, L. Zhang, S. Guo, and H. Xia, "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*, vol. 28, pp. 190-198, 2008.
- [9] G. Senik, *Small-scale food processing enterprises in Malaysia*: ASPAC Food & Fertilizer Technology Center, 1995.
- [10] T. Kirch, P. R. Medwell, and C. H. Birzer, "Natural draft and forced primary air combustion properties of a top-lit up-draft research furnace," *Biomass and Bioenergy*, vol. 91, pp. 108-115, 2016.
- [11] V. Kirubakaran, V. Sivaramakrishnan, R. Nalini, T. Sekar, M. Premalatha, and P. Subramanian, "A review on gasification of biomass," *Renewable and Sustainable Energy Reviews*, vol. 13, pp. 179-186, 1// 2009.
- [12] C. Roth, *Micro-gasification: Cooking with Gas from Dry Biomass: an Introduction to Concepts and Applications of Wood-gas Burning Technologies Für Cooking*, 2014.