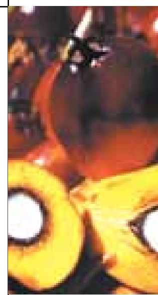
Feature Article



Development of Technologies for the Carbonisation of Palm Kernel Shells

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INTRODUCTION

Activated carbon (AC) is widely used as an adsorbent in the treatment of liquids and gases. Many industries such as pharmaceutical, gold mining, petroleum, nuclear, water treatment, food and beverages frequently use activated carbon in their processing units. For the oil palm mills, the AC can be used as material for the polishing of palm oil mill effluent (POME), especially now with the introduction of more stringent regulations that demands the BOD level of less than 20 ppm on the final POME discharged into the water courses. The important stages in the manufacture of activated carbon are the carbonisation (production of charcoal) and its activation (production of activated carbon). Most of the AC industry in Malaysia are using charcoal made from coconut shell, and the charcoal is obtained from local suppliers or imported. It is only a handful which are involved in the production of AC from oil palm biomass (specifically palm kernel shells), due to shortage of charcoal supply and the claims of the low quality of charcoal. The crucial processing stage in the production of AC is the carbonisation process, and MPOB has developed four carbonisation systems, namely; i) Hollow Plinth Brick System, ii) Closed Dome System, iii) Continuous System and iv) Microwave System. Each of these system have its own specialty features. In order to achieve sustainable production of charcoal, selection of an environmental friendly and economically viable process is crucial. With the increasing demand of charcoal for new applications, especially in the bio-energy and soil remediation agent for agricultural sectors, this carbonisation sector would eventually take it to a bright future as it could end up in the future as a reliable source of income for the millers.

HOLLOW PLINTH BRICK CARBONISATION SYSTEM

The technology reported in this paper basically consist of a foundation made up of

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refractory fire bricks laid in such a way that there will be a series of small tunnels at the bottom of the brick work. Purposely configured to provide the airways for evacuation of smoke during the carbonisation stage. *Figure 1* illustrates the system, in which the vacuum condition of the system is created by the suction through the chimney (differences in hot and cold air pressure) and the smoke emitted during the burning of palm shells will be sucked downwards through the tunnels at the bottom of the system.

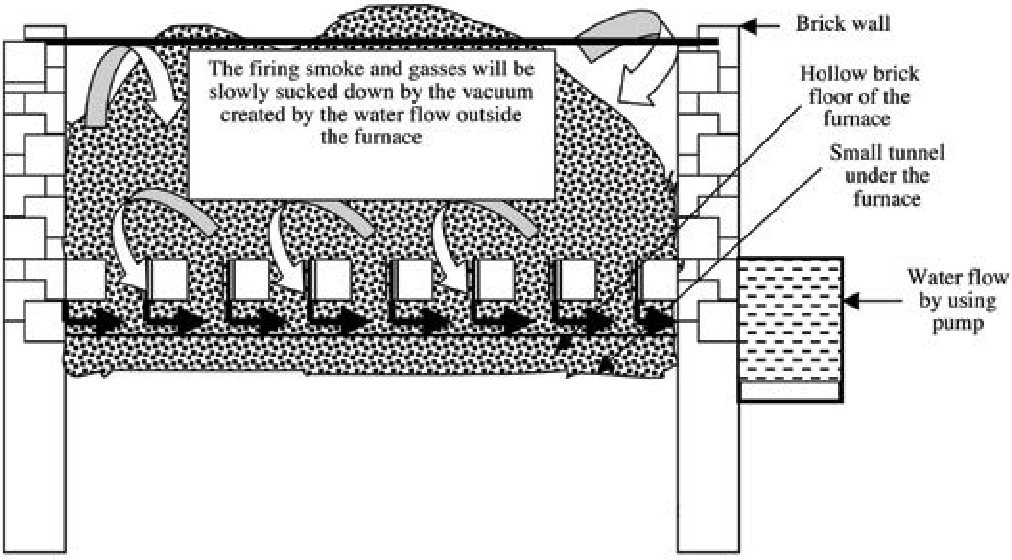

Figure 1. Illustration of the hollow plinth brick carbonisation system.

In this system, the smoke sucked from the carbonisation process will go through scrubber systems which consist of a pump, water sprinkler, sedimentation tank and the chimney. This system might not be free from smoke, but with the efficient controlling of the scrubbing system, the smoke emitted can be minimised. The steps in the building up of the system are shown in *Figure 2*. The system can carbonise up to 10 t of PKS per run of three days, and gives an average of 30%-35% charcoal. At seven runs of carbonisation per month, the payback period of this system is about 16.22 months (Astimar *et al.*, 2011).

CLOSED DOME CARBONISATION SYSTEM (TAKI SYSTEM)

The closed dome carbonisation system that was installed in MPOB Kluang Research Station, was commissioned in end 2011. The layout diagram of the system is shown in *Figure 3*, meanwhile the carbonisation process of the system is shown in *Figure 4*. The two-kiln system can carbonise up to 2.24 t of oil palm shells, and with 30% yield will produce about 0.67 t of charcoal. Four operations can be carried out per month, producing about 2.69 t of charcoal. From each of the cycle, about 500 litres of wood vinegar can be collected, which is about 2000 litres month^{-1} (*Figure 5*). The capital cost of the system estimated then was RM 300 000 with the production cost of RM 11 190, meanwhile the selling of both wood vinegar and charcoal was estimated at RM 30 752. These bring to the profit per month of RM 19 562 and the payback period calculated then was 15.34 (Astimar *et al.*, 2012).

Figure 2. The building up of the hollow plinth brick carbonisation system.

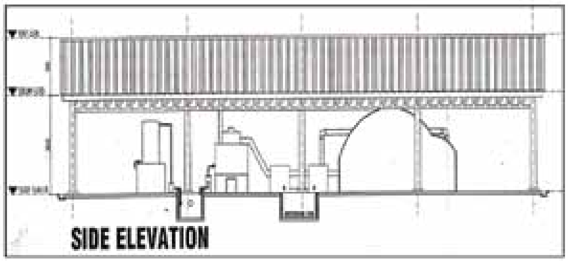

Figure 3. The layout of the taki carbonisation system (side elevation).

Figure 4. The carbonisation process, using the used wood as fuel.

THE CONTINUOUS CARBONISATION SYSTEM

This continuous carbonisation system was developed by MPOB in collaboration with our industrial partner Hakita Engineering Sdn Bhd. The pilot plant was fabricated and installed at MPOB/UKM Research Station, Selangor (*Figure 6*). In this process, the biomass is fed into a horizontal rotary kiln which is heated to the desired temperature ranging from 600ºC to 700ºC. The heat supplied from an external combustion system, using diesel as the fuel which also can be adapted when using fuels like natural gas or biogas. The adaptability of using different fuels makes the features of this plant highly suitable for installation in palm oil mills where the biogas from POME plant is readily available as fuel for the carbonisation process. If production of AC is also intended, the excess steam from the boiler can be used as the activation agent. Studies carried the activated carbon using

Figure 5. The collection of palm vinegar from the carbonisation process.

Reference Specifications	
Types of kiln	Continuous type
System of kiln	External heating system
Type of burner	Air forced system
Firing temperature	600°C -700°C
Fuel	Diesel (adaptable for LPG and biogas)

Figure 6. The rotary kiln for continuous carbonisation to comply with commercial specifications.

PKS based virgin charcoal as a raw material have shown that the activated carbon complied with the commercial specifications (Rugayah *et al.*, 2014).

The heating temperature is controlled at three points of the rotary kiln. The rotating motion of the kiln moves the carbonising materials along the kiln. The linier speed of the feed within the rotary kiln being proportional to the activation time is governed by the rotary speed of the activator drum. The combustible materials comprising gases, light oil, tar and acidic liquor are the volatile carbonisation products which are removed from the kiln by suction or may be re-routed back to the rotary kiln where the volatiles could replace the diesel fuel once the kiln has acquired its working temperature thus offering an opportunity to save fuel. The volatile recycling is a common feature found in all the conventional activators.

The system is capable of carbonising up to 2 t PKS per day. Since this is a continuous system, once the carbonisation has started, it will run for 24 hr and the system would only stop occasionally (depending on situation). In controlling the temperature, the burner will ignite and produce heat for 2 hr until it reaches about 500°C at which time the heater will automatically be cut off, and the PKS will start self-burning (exothermic process) throughout the process. From the tests that we carried out, we found that the PKS charcoal produced at 500°C gave better qualities, and the input rate of raw material also plays an important role in ensuring good carbonisation efficiency (Astimar *et al.*, 2015).

MICROWAVE CARBONISATION SYSTEM

MPOB is also looking into new emerging and clean technology on the carbonisation process and microwave system has been identified as one of the systems. Compared with conventional heating, microwave heating can be more efficient due to its rapid, selective, volumetric, and uniform heating (Jones *et al.*, 2002). The prototype of the microwave system was fabricated with the size of 0.42 m^3 using stainless steel as shown in *Figure 6*, and is installed with three magnetrons of 2 kW capacities each. From the optimisation process, about 30 kg of palm kernel shells (PKS) can be loaded into the reactor. Since that microwave system is high risk equipment to be handled, prior to the carbonisation process the materials have to be free from impurities such as metal contamination. Therefore, pretreatment of screening of the PKS using metal detector and separator is vital prior for the carbonisation process. The carbonisation process is started by switching on all the three magnetrons until the reactor temperature has reached a set value of 250°C. After that all the magnetrons are automatically shut down and the self-sustained carbonisation takes over when the volatile gases start flowing into the kiln using the exhaust fan. Stirrer was used to ensure hot air generated from microwave radiation is evenly distributed throughout the biomass. There are two k-type thermocouples that are installed inside the reactor positioned at different heights, *i.e.* T1 (0.2 m) and T2 (0.4 m). The whole process of microwave heating from start-up period until carbonisation of oil palm shells is about 8 hr. Since this is a batch process, the carbonised samples will only be ready for harvest after the temperature drops to below 50ºC.

duced from all systems comply with the minimal standard requirement for activated carbon. In terms of yield, the Hollow Plinth Brick and Closed Dome gave higher results, in which can be explained as due to the differences in the mechanism of the carbonisation process. Both systems operate for long period of time with minimal exposure or interaction with air especially during the

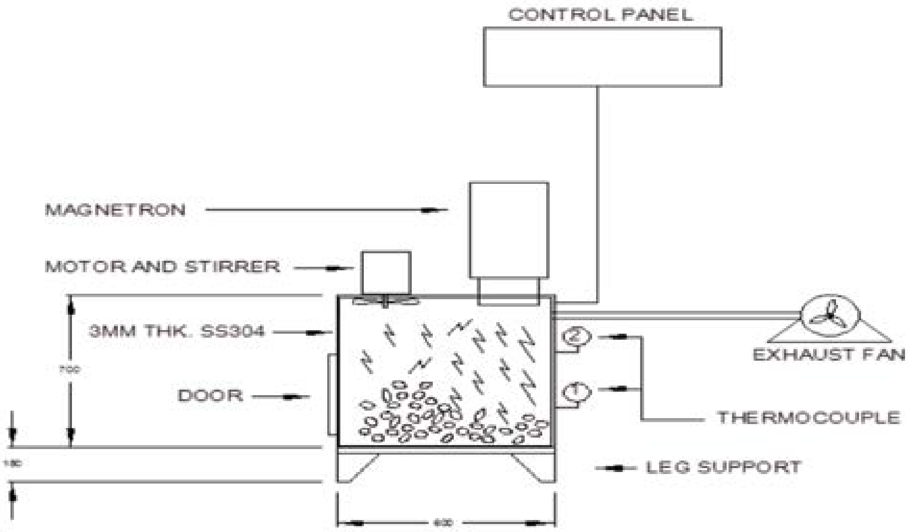

Figure 7. Schematic diagram of microwave carbonisation system.

The results of the qualities of the PKC charcoal prepared from different carbonisation method are shown in *Table 1*. From the results it can be summarised that different carbonisation process may give slightly different yield as well as the qualities of the PKS charcoal, but overall the charcoal pro-

long cooling period. Longer cooling time is required as the heat sustained in the PKS charcoal will cause the charcoal oxidize causing a reduction in fixed carbon content. Charcoal from Closed Dome system give the highest fixed carbon results, with moderately low ash and moisture content. The

TABLE 1. CHARACTERISATIONS OF PKS CHARCOAL PREPARED FROM DIFFERENT CARBONISATION SYSTEM

Analysis	Carbonisation system			
	Hollow plinth brick	Closed dome	Continuous	Microwave
Yield (%)	30-35	30-35	28-35	25-30
Ash	4.31	4.95	8.16	4.56
Fixed C	75.20	82.79	78.14	67.39
Moisture content	7.85	1.98	8.16	4.79

microwave system produced lowest charcoal yield, which may be due of the pyrolysis effect of the microwave radiation which tend to dissolve the lignocellulose materials into bio-oil (Huang *et al.*, 2016).

CONCLUSION

Charcoal and activated carbon industry are getting much attention lately in many sectors including the filtration products, wastewater treatment, agronomy as well as food and health products. Palm oil industry which has abundance of oil palm biomass, especially the palm oil mills have to take the opportunity to commercialise this product including using the charcoal or activated product for the POME polishing treatment. Issue on environment would be one of the challenges, but recent technologies on smoke treatment is available and the palm oil mills are well versed on this issue. For economic feasibility, the energy source for the carbonisation process can be obtained from the biogas plant or the heat from the carbonisation process could be recycled. The continuous carbonisation system would be one of the best alternative in producing charcoal in big capacity, meanwhile the microwave carbonisation would be a potential future for more 'green' and sustainable carbonisation or pyrolysis process.

REFERENCES

ASTIMAR, A A and ROPANDI, M (2011). Charcoal from palm kernel shells (Hollow Plinth Carbonisation Furnace System). *MPOB Information Series No. 494*.

ASTIMAR, A A and ROPANDI, M (2012). The production of oil palm-based activated carbon and pyroligneous acid (wood vinegar). *MPOB Information Series No. 515*.

ASTIMAR, A A; ROPANDI, M and NAHRUL HAYAWIN, Z (2015). Continuous carbonisation system for the production of charcoal from oil palm biomass. *MPOB Information Series No. 569*.

HUANG, Y F; CHIUEH, P T; KUAN, W H and LO, S L (2016). Microwave pyrolysis of lignocellulosic biomass: Heating performance and reaction kinetics. *Energy, 100*: 137-144.

JONES, D A; LELYVELD, T P; MAUROFIDIS, S D; KINGMAN, S W and MILES, N J (2002). Microwave heating applications in environmental engineering - A review. *Resour Conserv Recycl., 34*: 75-90.