Some Physical Properties and Burning Characteristics of Cocoa Wood Charcoal

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ABSTRACT

Properties of cocoa wood charcoal such as apparent density, friability, calorific value, ignitability and time taken to burn to ashes were studied. The results were then compared to similar studies done on some commercially available charcoal and barbecue fuels. It was found that the density of cocoa wood charcoal is lower than most commercial charcoals while its friability and calorific values are comparable to mangrove wood charcoal, the most commonly available commercial charcoal in Southeast Asia. The low density of cocoa wood charcoal enables it to be easily ignited but it burns to ashes in a time that is comparable to some but shorter than other commercial charcoals. Over all, it is concluded that cocoa wood charcoals are in no way inferior to other commercially available charcoals.

INTRODUCTION

In Malaysia, serious cultivation of cocoa trees started some 35 years ago and today Malaysia is the world's fourth largest producer of cocoa with about 400,000 ha planted [1]. In order to maintain mature cocoa trees at a height of 3-4 m, to allow easy access for spraying and fruit harvesting, periodically pruning has to be carried out. This practice generates about 25.2 tonnes of dry organic matter per ha per year [2]. The energy content of this amount of biowastes is roughly equivalent to 70 barrels of oil per ha per year.

Cocoa trees in plantations are normally replanted after about 25 years. Lim [3] reported that fairly substantial quantities of replanting wood wastes will begin to become available in Malaysia at the turn of the century.

The current practice in most cocoa plantations in Malaysia is to allow the prunings to rot in the fields while wood wastes from replanting activities are simply burnt. In an effort to convert these biowastes to value added products Lim and Malar Vizhi [4] and Lim [5] have shown that charcoal of reasonably good quality can be produced from cocoa tree prunings. Their results are summarised and reproduced in Table 1.

In their laboratory scale carbonisation experiments, prunings of a few cm in dimension were used and the rate of heating was 5°C min^{-1}. Lim [5] also mentioned that the cocoa wood charcoal produced appears to be more friable as the raw material is rather soft wood. This suspicion however has not been examined experimentally. Other physical properties of the charcoal produced have also not been studied.

In this paper we report on studies that were carried out to determine some physical properties of cocoa wood charcoal as well as their burning characteristics. The properties and characteristics

Table 1. Yield and proximate analysis of cocoa wood charcoal.

Terminal Carbonisation Temperature (°C)	Yield (%)	Moisture Content (%)	Ash Content* (%)	Volatile Content* (%)	Fixed Carbon Content* (%)
400	32.0	7.8	10.3	30.0	59.8
450	30.6	6.9	11.4	22.0	66.6
500	28.7	7.3	10.3	17.1	72.6
550	27.3	7.6	11.8	15.1	73.2
600	27.0	8.5	11.7	12.7	75.6
650	26.0	9.6	10.3	11.5	78.2
700	25.7	9.3	9.3	10.1	80.7
750	24.3	10.2	9.9	10.0	80.2
800	24.8	10.3	9.4	9.1	81.5
Raw wood	–	11.0	2.5	77.9	19.6

* Dry basis.

studied are those considered essential by prospective consumers for good results. The properties studied were apparent density, friability, calorific value, ignitability, and time taken for a unit mass to burn to ashes. Cocoa wood charcoal samples that were produced at 3 different carbonisation temperatures of 450, 550 and 650°C and 1 h holding time were studied. One hour of holding time means that the carbonisation is allowed to proceed for 1 h once the terminal carbonisation temperature is attained.

METHOD

Apparent Density

Apparent density, defined as mass of a block of charcoal over volume enclosed within the boundary of the charcoal block, was determined simply by cutting cocoa wood charcoal into cubes, weighing the sample and dividing the mass by the volume enclosed by its boundary. Five determinations were made for each of the 3 charcoal samples studied.

Friability

Shatter tests were performed on the cocoa wood charcoal as per ASTM D440 - 86 [6]. About 100 gm of the charcoal were placed in a box whose underside could be opened. The box was held by a frame so that its bottom surface was 6 ft from the base. When the underside of the box was opened, the charcoal within dropped to the base. All the dropped charcoal pieces were gathered and returned to the box for a second drop. After this second drop, the shattered pieces of charcoal were again gathered and sieved. Square hole sieves of sizes 9.5 mm, 3.35 mm and 0.85 mm were used. From the amount of material that passed through each sieve, the friability of the cocoa wood charcoal was determined.

Experiments were done only on charcoal produced at the 650°C carbonisation temperature. A total of 5 runs were carried out.

Calorific Value

The calorific value of the cocoa wood charcoal was determined using an adiabatic bomb calorimeter (Parr, model 1241). Standard procedures were followed and 10 to 15 sets of data were gathered for each sample analysed.

Ignitability and Time Taken to Burn to Ashes

The ignitability of cocoa wood charcoal was investigated by determining the time it took for the charcoal to start catching fire when lighted.

A piece of charcoal was put over a wire gauze which sat on a stand that had air inlets. The hexamine solid fuel tablet which was placed about 7.5 cm below the gauze at the base of the stand was ignited. After some initial trials, a piece of charcoal was allowed to catch fire over the lighted fuel for a fixed interval of time. Subsequent to that fixed time interval, the charcoal piece was removed periodically to determine whether or not it had been ignited. This was done at intervals of 5 to 10 seconds. At each removal, the heated charcoal was placed over a piece of tissue paper (Scott-Purex). The charcoal was deemed to have been ignited if it was able to burn through the tissue paper.

After ignition the charcoal piece was removed from the wire gauze and transferred to a holder where it was allowed to burn to ashes. The time taken for this to occur was similarly determined.

All the above procedures were conducted in a fume cupboard with air blowing at 0.6 m s^{-1}. For each of the 3 charcoal samples studied 5 experiments were performed.

Commercial Charcoal and Barbecue Fuel

Some of the above properties were similarly determined for charcoals and a barbecue fuel that are already available commercially in the market so that a comparison could be made with the cocoa wood charcoal. Commercial charcoals studied included those produced from Malaysian mangrove (b. carophylloides) and rubber woods, American mesquite wood and an Australian barbecue fuel. Again, for each charcoal type, at least 5 runs were carried out for each of the properties studied.

RESULTS AND DISCUSSION

The results of the experiments for the determination of apparent density, calorific value, ignitability and time taken to burn to ashes are as shown in Table 2 while Table 3 shows the results of shatter tests for friability studies.

Charcoal produced at a 450°C carbonisation temperature has an apparent density that is lower than that produced at 550 and 650°C. Samples from the latter two carbonisation conditions have apparent densities that are comparable to one another and also to that of rubber wood charcoal. The apparent densities of the mangrove wood and mesquite wood charcoals and the Australian barbecue fuel are however much higher. This can perhaps be attributed to the fact that the mangrove and mesquite woods are harder woods, while the Australian barbecue fuel is a compacted pillow-shaped fuel.

Table 2. Comparison of some properties of cocoa wood charcoal with some other commercially available charcoal and barbecue fuel.

	Cocoa Wood Charcoal (450°C)*	Cocoa Wood Charcoal (550°C)*	Cocoa Wood Charcoal (650°C)*	Malaysian Mangrove Wood Charcoal	Malaysian Rubber Wood Charcoal	American Mesquite Wood Charcoal	Australian Barbecue Fuel
Apparent density (g/cm^3)	0.23 ± 0.01	0.34 ± 0.03	0.32 ± 0.03	1.01 ± 0.09	0.36 ± 0.03	1.22 ± 0.10	1.59 ± 0.09
Calorific value (kcal/kg)	6428 ± 34	6880 ± 40	6609 ± 153	–	–	–	–
Time taken to ignite (seconds)	75 ± 12	90 ± 9	84 ± 14	130 ± 9	181 ± 9	297 ± 33	234 ± 12
Time taken for 1 gm to burn to ashes (seconds)	663 ± 134	718 ± 48	932 ± 88	1806 ± 193	1198 ± 56	1347 ± 132	982 ± 31

Notes: The errors shown are standard errors.

* indicates charcoal produced at the respective carbonisation temperature.

Table 3. Percentage of the original weight of dropped charcoal that passed through each sieve after the shatter tests.

Sieve Size (mm)	Cocoa Wood Charcoal (650°C)	Mangrove Wood Charcoal
9.50	3.68 ± 0.57	3.52 ± 0.65
3.35	1.36 ± 0.19	1.23 ± 0.24
0.85	0.84 ± 0.13	0.63 ± 0.16

Notes: The errors shown are standard errors.
The cocoa wood charcoals studied are those produced at a 650°C carbonisation temperature.

The calorific values of the 3 samples of cocoa wood charcoal do not differ significantly from one another though samples produced at a 550°C carbonisation temperature appear to have a slightly higher calorific value. These calorific values are comparable, if not higher than the calorific value of commercial mangrove wood charcoal, which has a reported value of about 6282 kcal/kg [7].

The times taken to ignite the 3 samples of cocoa wood charcoal also do not differ significantly from one another but are substantially lower than the values of the other commercial charcoals studied. This observation implies that cocoa wood charcoals are more easily ignited; a property that is consistent with its low density.

The time taken for one gram of cocoa wood charcoal to burn to ashes appears to increase as the carbonisation temperature for the production of the charcoals increases. The value for charcoal produced at a carbonisation temperature of 650°C is significantly different from the value of charcoal produced at the other 2 carbonisation temperatures. This observation concurs with the results reported previously that charcoals with higher fixed carbon and lower volatile contents are produced at higher carbonisation temperatures [5]. In fact it was suggested that for industrial scale projects, a carbonisation temperature of 650° to 700°C suffices [5]. When compared to the time taken by 1 gm of the other commercial charcoals to burn to ashes, the value for the cocoa wood charcoal produced at 650°C carbonisation temperature is not much less than the value for rubber wood charcoal or Australian barbecue fuel. Mangrove wood and mesquite wood charcoals however burn for a significantly longer time.

The data in Table 3 show the percentage of dropped charcoal that passed through each of the 3 sieve sizes after the shatter tests. The percentages shown are based on the original weight of the charcoal dropped. Even though it was initially suspected that cocoa wood charcoal, produced from a rather soft wood, would be more friable, the results in Table 3 do not indicate this to be so. When compared to the friability of mangrove wood charcoal, the values obtained for cocoa wood charcoal are not significantly different.

The above results, together with those reported earlier, indicate that, overall, cocoa wood charcoal has properties that is no way inferior to other commercially available charcoals. Though it burns off faster when compared to mangrove and mesquite wood charcoals, it is more easily ignited.

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