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Comparison of yield and quality of bamboo charcoal produced by external heating employing metal drum retort

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Abstract: External heating method was evaluated for the production of charcoal from *Bambusa bambos* employing metal drum retort having facility for recovering the pyrolignious vapour for burning purpose. Bamboo charcoal with low volatile (11.8%) and high fixed carbon (81.6%) was obtained. When the design of the retort was improved for recovering the distillate by condensation, charcoal with still higher quality (volatile content 9.0%, fixed carbon 84.2%) was achieved. Charcoal yield, on oven dry basis ranged from 31 to 33 per cent. The product was alkaline with a mean pH of 9.7 and mean iodine value of 256. The ash content of bamboo charcoal produced was found 6.7 per cent.

Key words: Bamboo charcoal, charcoal retort, charcoal yield, charcoal properties.

INTRODUCTION

The crooked basal portion as well as the low diameter top portion of bamboo culms are usually wasted as they cannot be utilized for any value-added product. Dhamodaran *et al.* (2006), in their attempt to make charcoal from these bamboo waste reported the yield and quality of charcoal produced by traditional methods like the pit, portable drum, Tongan drum and earthen pot methods. Their studies indicated the potential of indirect heating for producing high quality charcoal desired for industrial uses. In the earlier study, indirect heating was limited to a method employing an earthen pot where only a very limited quantity of charcoal can be made. Hence, a further study was planned to develop improved methods involving indirect heating employing metal retort for producing high quality charcoal.

MATERIALS AND METHODS

Crooked basal portions of *B. bambos* which are usually rejects for commercial uses such as for slivers for mat-woven products and poles for structural applications, were collected from bamboo depots of Palakkad District of Kerala, India. These materials were air dried, cross cut into 50 cm long pieces and used for charcoal production. Moisture content of bamboo was determined by oven drying.

Double drum retort

A double drum retort fabricated from two empty cylindrical oil drums (each of 200 l capacity) of dimensions 90 cm height and 55 cm diameter, made as per the guidelines of American Fireworks News (Anonymous, 2002) was employed in the preliminary trial for producing bamboo charcoal by indirect heating system. Digital pyrometers were connected to the drums for observing the temperature raise, for better control over the heating duration. This system (Fig. 1) was not permitting the recovery of distillate liquor; instead, the pyrolignious gas produced is recovered for combustion

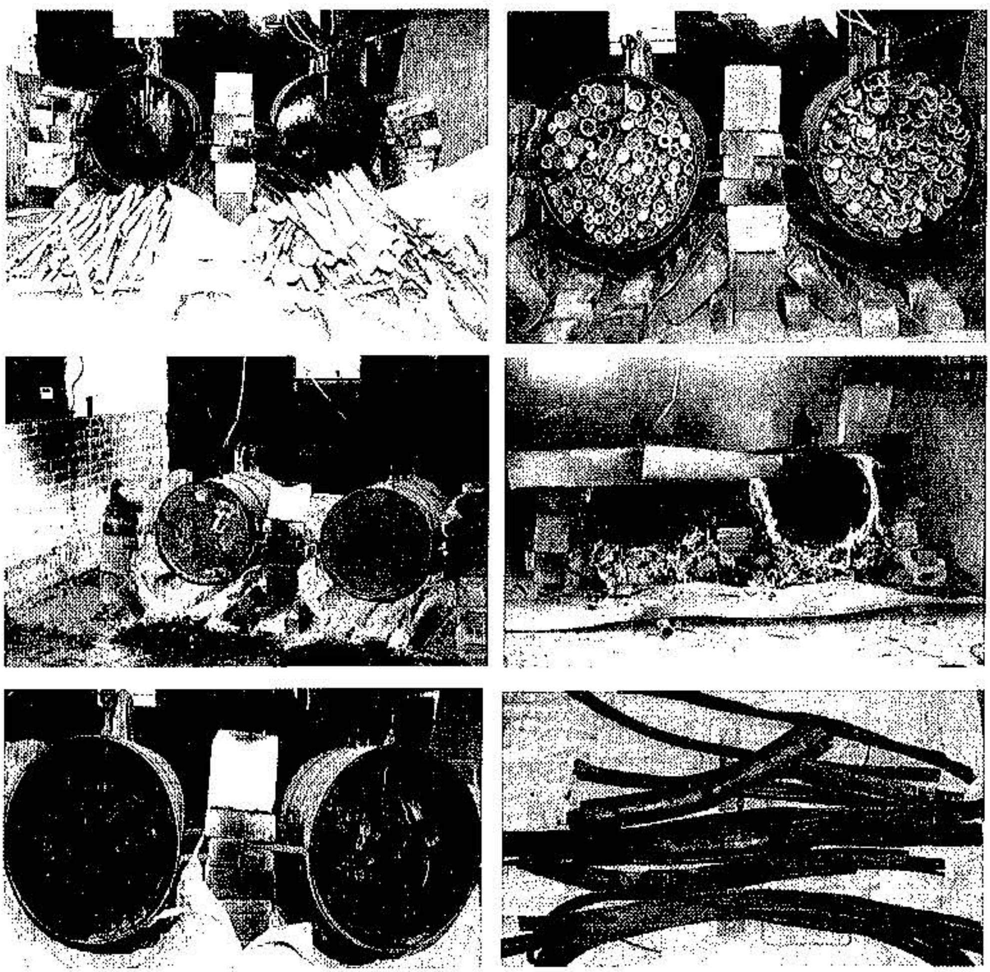

Figure 1. a-f: Bamboo charcoal production by external heating employing double drum retort with facility of recovering the pyrolignious vapour formed for burning – various stages of operation (f: bamboo charcoal produced)

in the fireplace. Both the drums were fully loaded with weighed quantity of bamboo of known moisture content and the system was closed air-tight by using the lid of the drums and metal ring clips. The edges of both the drums were sealed with mud plaster to avoid any further entry of air. Fire was lighted in the fireplace below the drums. Increase in temperature inside the carbonizing chambers was noted in regular time intervals. The external heating was regulated in such a way that the temperature inside the retort is stabilized at 600° C. When the temperature inside the drums was stabilized at 600° C, external heating was stopped. Once more the edges of the drum and the lid were given an additional sealing with mud plaster to secure the system from entry of air while cooling. The double drum retort was allowed to cool overnight. In the next day morning, the system was opened, charcoal was unloaded, cooled and weighed to determine the yield.

Improved drum retort

An improved single drum retort was designed and fabricated for facilitating the recovery of the distillate liquor. A pipe starting from the top side of the horizontally laid drum retort was further attached to multiple condensing pipes enclosed in a cover pipe with facility for water cooling the upcoming vapour. The distillate was collected in a mud pot placed below the condenser tap. This system (Fig.2) was connected with

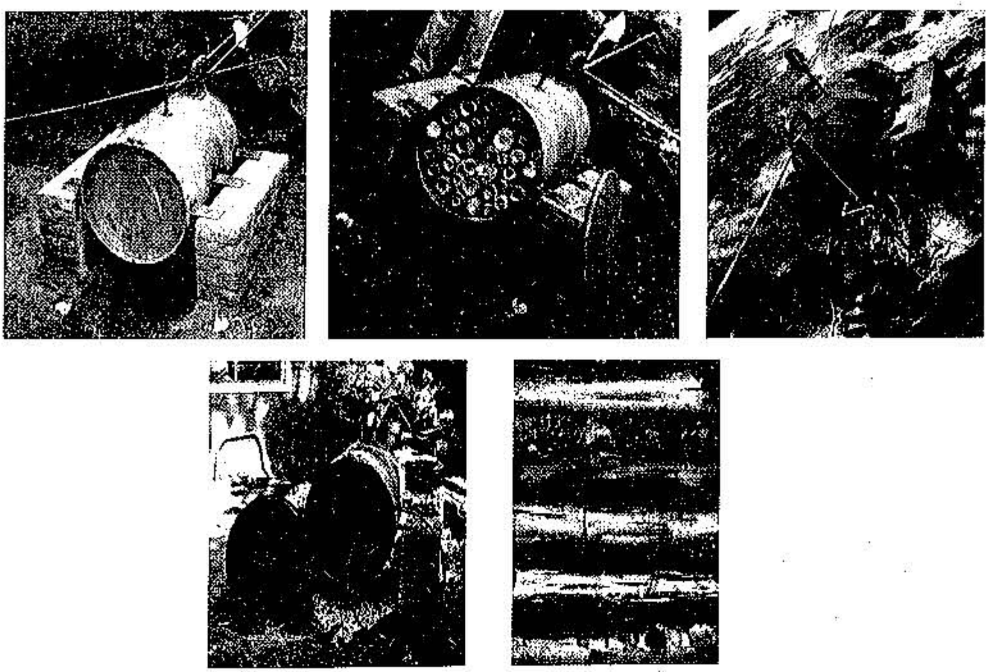

Figure 2. a-e: Bamboo charcoal production by external heating employing the improved drum retort with facility for collection of distillate – various stages of operation (e: bamboo charcoal produced)

a digital pyrometer to observe the temperature changes inside the retort. As mentioned earlier, the drum retort was fully loaded with weighed quantity of bamboo of known moisture content and the system was closed air-tight with its lid and the metallic ring clip; the edges of the drum was sealed with mud plaster to avoid any further entry of air. External heating was made with firewood in the fire-place. When the temperature inside the drum reached 600°C, heating was discontinued; the edges of the drum were given an additional sealing with mud plaster and the system was allowed to cool overnight. In the Next day, morning the system was opened, charcoal was unloaded, cooled and weighed for yield determination.

Analysis

Eight replicates of charcoal samples from each method were analyzed for moisture, volatiles, ash and fixed carbon content by ASTM methods (ASTM, 1981). Volatiles and ash contents were corrected to moisture free basis and accordingly fixed carbon content was determined. The pH was determined from the extract of 10 g charcoal dust in 100 ml distilled water. Iodine number of charcoal was determined as per the procedure of the Indian Standards (BIS, 1995).

RESULTS AND DISCUSSION

The mean moisture content of air-dry bamboo used for charcoal making was 15 per cent. As slow carbonization at comparatively low temperature is known to yield better quality charcoal, the raise in temperature inside the carbonizing retorts was controlled by regulating the external heating. As seen from the record of the temperature raise inside the retort at regular time intervals (Fig. 3), the external heating was controlled in such a way that the targeted carbonizing temperature of 600°C is attained within a time span of about 1.75 hours after starting the external heating. It is at this stage the external heating was discontinued and allowed the system to cool overnight.

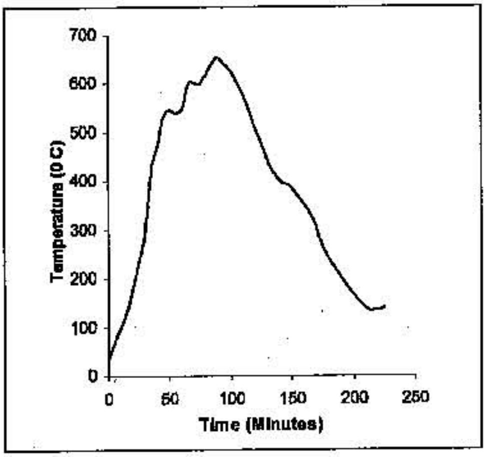

Figure 3. Temperature raise inside the retort

The yield and quality of product, on oven-dry basis, from both the trials are given in Table 1. In general, drum retorts employing external heating yielded an average moisture-free charcoal yield of 31-33 per cent. Charcoal with comparatively high fixed carbon (around 83%) and low volatile content (9-12%), desired for industrial uses is obtained by employing the drum retorts. The average ash content of bamboo charcoal produced was found to be 6.7 per cent.

Table 1. Yield and quality of bamboo charcoal produced by external heating (CV values are given in parenthesis)

Method of production	Charcoal yield (%) (on moisture free basis)	Charcoal quality * Mean volatile content (%)	Mean ash content (%)	Mean fixed carbon content (%)	pH	Iodine number (mg/g)
Double drum retort with facility for recovering the pyroligninous vapour for burning purpose	31.1	11.8 (8.6)	6.6 (2.9)	81.6 (1.3)	9.8	254 (3.8)
Improved single drum retort with facility for recovering the condensed distillate liquor	33.1	9.0 (12.1)	6.8 (7.0)	84.2 (0.9)	9.6	258 (4.6)
Pooled Mean	32.1	10.4	6.7	82.9	9.7	256
CV%	(4.4)	(3.6)	(2.1)	(2.2)	(1.5)	(1.1)

* n = 8; Yield of distillate = 3.4% v/wt

A better product with low volatile content (9%) and high fixed carbon (about 84%) is obtained from the improved drum retort where facility for the recovery of the condensed volatile distillate is incorporated. Bamboo charcoal with reduced volatile content and high fixed carbon content is found achievable by separating the volatile gases generated by condensation. Bamboo charcoal produced by traditional methods yielded products with high volatile (14-19%) and low fixed carbon contents (74-75%) (Dhamodaran *et. al.* 2006), whereas employing the retort, especially the one with facility to separate the condensable volatiles is found to have better quality in terms of low volatile and high fixed carbon content. Bamboo charcoal produced by both the retorts is alkaline; pH of products from both the trials does not vary much (mean pH 9.7), indicating the need of mild acid washing to produce neutral product. The iodine number of the products from both the trials does not vary significantly (mean iodine value of 256), indicating the adsorption capability of bamboo charcoal. The yield of distillate was found 3.4 per cent volume/weight.

CONCLUSION

External heating system with facility for condensing and separating the pyroligninous vapour formed while carbonizing is found producing high quality bamboo charcoal (low volatile content up to the level of 9 per cent and high fixed carbon up to 84%, rounded) suitable for industrial uses. Retort with improved design facilitating the collection of distillate liquor is found producing better quality bamboo charcoal than the retort where the volatile gases are recovered just for burning. The general indication is that for high quality bamboo charcoal production, the design of the carbonizing retort should be in such a way that the percolation of the volatile pyrolignious gases formed with the charcoal already formed inside the retort is to be avoided by incorporating condensation and separation facility of the volatiles formed.

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