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Development of oil drum kiln for production of bamboo vinegar

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ABSTRACT : A 200 litre oil drum was developed and fabricated for production of bamboo vinegar. Bamboos were cut in 15 cm length and further splitted vertically. The average moisture content of air dried bamboo splits was found to be 22.77 per cent. The bamboo splits were carbonized in oil drum kiln and smoke was condensed to collect bamboo vinegar. It was observed that from 16 bamboos, the output of bamboo vinegar 2.24 litre and bamboo charcoal 22.3 kg was obtained. The average bulk density of bamboo charcoal was found to be 181.23 kg/m^3. The ash content of bamboo charcoal and raw bamboo were found to be 4.28 per cent and 7.88 per cent, respectively.

KEY WORDS : Oil drum kiln, Bamboo vinegarr, Bamboo charcoal

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Bamboo plants are identified as species of subfamily Bambusoideae, family Gramineae. They are distributed in many parts of the world. The bamboo grows most abundantly in the orient where it is native to China, Burma, India, Japan, Europe and Canada. India has annual bamboo production as 4.5 million tonnes. In Maharashtra bamboo production is 2,47,239 tonnes. The Konkan region contributes 70,000 tonnes of bamboo production (Choudhary, 2008). It has been reported that about 50 genera and 700 species of bamboo are found all over world. Asia alone accounts for 400 species. In India about 136 species in 30 genera occur in India (Suri and Chauhan, 1984). In Konkan region of Maharashtra *Dendrocalamus strictus* (Manvel), *Bambusa bambus* (Kalak), *Dendrocalamus stocksii* (Mes) *and Dendrocalamus ritchy* (Manga) varieties of bamboo are found abundantly.

When bamboo is heated at very high temperature in an airless vessel, it becomes charcoal, which is used like other charcoal products, as a fuel component, a deodorizer, or an absorbent. The vapor that comes off the heated bamboo can be condensed to produce a liquid known as bamboo vinegar. It gets this name from the high content of acetic acid, though this ingredient is accompanied by many other compounds, especially phenols, such as guaiacol and cresol. Bamboo vinegar contains 80 per cent water. When it is dehydrated the vinegar consists of about 80-200 components, that are 32 per cent organic acid, 40 per cent phenolic compound, 3 per cent aldehyde, 5 per cent alkone compound, 5per cent alcohol compound, 4 per cent ester compound, and 5 per cent others.

Bamboo vinegar is a product of bamboo carbonization. Bamboo vinegar is used as soil fungicide, plant root growth promoter and for eliminating offensive odour on dairy barns, poultry housing, sheep and goat housing etc. Bamboo vinegar is used for treatment of bamboo based product due to its fungi resistance properties. Bamboo vinegar is useful to restrain the molds and it can decrease microbiological deterioration of bamboo materials. It used to reduce toxicity of agricultural chemicals. It is also used in cosmetics, healthy drinks, medicines and health care etc.

Bamboo vinegar has been produced in Japan for many years and is used medicinally to treat eczema, atopic dermatitis, and other skin diseases; it is most commonly applied by adding to bath water. It has recently been popularized as a main ingredient in "sap sheets" applied to the feet to "draw out toxins".

Bamboo charcoal is by-product of bamboo vinegar production process specific controlled temperature regime until they become "carbonized", is they turn into charcoal. The bamboo charcoal has much higher adsorbtivity than wood charcoal can be used for wide range of different purification and absorption application, such as a deodorizer, and for certain industrial purification use. The bamboo charcoal is porous, adsorptive material that can be used for a range of purification application such as preserving the freshness of fruit and vegetables in cool chambers, in health care product,

as air filter and in industrial processes such as sugar processing.

With the above in view, a study was undertaken with an objective to fabricate oil drum kiln for production of bamboo vinegar. Lin *et al.* (2006) evaluated the vinegar obtained from Moso bamboo, as a fungi resistant agent using the vacuum process, for testing bamboo based products and concluded that bamboo vinegar is useful to restrain the molds and that it can decrease microbiological deterioration of bamboo materials. Yoshihiko *et al.* (2007) reported bamboo vinegar solutions had pH of 2.5 to 2.8, and the amounts of organic constituents were estimated to be 2.3 to 4.6% (w/w). Volatile organic compounds (28 components) were detected by GC–MS, and among these, 11 compounds were common to three samples of bamboo vinegar. Perhaps acetic acid, 3-methyl-1,2-cyclohexadione, guaiacol, p-cresol, and syringol contributed to the characteristic odors (sour, smoky, and medicinal note) in bamboo vinegar. Tancho (2008) reported the wood vinegar could be applied to the soil surface to help to increase the population of beneficial microbes and to promote plant root growth. Additionally, the product helps to boost crop defences against disease. Ruttanavut *et al.* (2009) investigated effects of a mixture of bamboo charcoal powder and bamboo vinegar solution (SB) on growth performance and histological intestinal change. It was reported that the growth performance was improved with increasing dietary SB. In these birds, the intestinal villus height, villus area, epithelial cell area and cell mitosis in all intestinal segments tended to be increased with increasing dietary SB. Guzman (2009) reported that the wood vinegar blended with water in ratios ranging between 1:50 (1 litre wood vinegar and 50 litres water) to 1:800 was useful for improved plant production, the solution can be sprayed over plant shoots. Laemsak (2010) studied the wood vinegar was produced when smoke from charcoal production is cooled by outside air while passing through a chimney or flue pipe. The cooling effect causes condensation of pyroligneous liquor, particularly when the temperature of smoke produced by carbonization ranges between 80 and 180ºC. Khamduangdao (2010) studied the production of wood vinegar with a 200-litre horizontal drum kiln. He reported uses of wood vinegar that includes spraying wood vinegar solution to control insect pests, such as rice stem borer, as well as to reduce bad odors in and around pig pens. He also recommended the useable layer of wood vinegar can be harvested with a syringe or siphon after first sucking out the light oil layer on top. Wang *et al.* (2012) investigated the effects of bamboo vinegar as an antibiotic alternative in the diet of weaned piglets on their growth performance and faecal bacteria communities. Feed intake and weight gain of pigs were recorded at the start and at the end of the feeding trial.

METHODOLOGY

Bamboo :

The *dendrocalamus stocksii* (Mes) variety of bamboo sample was used for present study. The bamboo was collected from local area. The bamboos used were of 4 to 5 years age and up to 4.0 m to 5.0 m in length, internodes were 15 cm to 30 cm long and 2.4 cm to 4.0 cm diameter.

Fabrication of oil drum kiln :

The empty oil drum was used for making bamboo vinegar. The height of oil drum was 88.00 cm and diameter of drum was 56.00 cm. The intact top cover of drum was removed by cutter. A separate lid of G.I. sheet was fabricated to open and close the drum as and when required. A 40 mm size hole was drilled in centre of lid. In this hole one G.I. bend was fixed through welding. This bend was extended by using 40 mm F pipe of 4.0 m length. The remote end of HDPE pipe was elevated by 45º angle from the surface of lid. A slit of 10 mm was made on lower curved surface of HDPE pipe at distance of 30 cm from G.I. bend. This slit was used for collecting bamboo vinegar. The whole assembly of oil drum kiln is shown in Fig. A. The conical grate was made up of G.I. sheet. The 18 gauge thickness of sheet is used for fabrication of conical grate. On the surface of conical grate 25 mm F holes were drilled to facilitate ash to drop. On the top of conical grate a G.I. pipe of 40 cm length was fixed to exit the smoke and work as chimney. The details specifications conical grate is given in following Table A.

Chimney extension :

An extension of chimney pipe was made up of G.I. pipe.

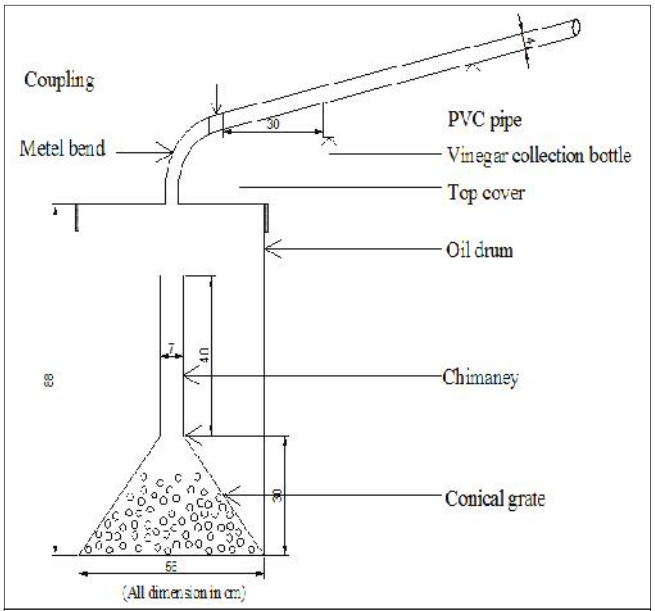

Fig. A : Sehematic representation of oil drum kiln

Table A : Specifications of conical grate with chimney

Sr. No.	Particulars	Dimensions (cm)
1.	Height of centre	30.00
2.	Slant height	44.25
3.	Base diameter	56.00
4.	Top diameter	7.00
5.	Height of chimney pipe	40.00
6.	Diameter of chimney pipe	7.00

It could be removed when lid closes drum. The diameter and height of chimney extension were 7.00 cm F and 70 cm length. It was used while ignition of bamboo initially takes place to create necessary draft.

The electrically operated bamboo stick sizing machine was used to cut the bamboo in the size of 15 cm. length. The splitter grills was used to cut the six bamboo pieces in vertical section. A hot air oven was used for the determination of moisture content of raw bamboo sample. The samples were kept at oven at 105°C for 24 hour and up to constant weight loss. Electric weighing balance was used for weighing the bamboo. A digital thermometer was used for recording the various temperatures during the carbonization process of bamboo.

Production of bamboo vinegar :

The production of bamboo vinegar was carried out as per the procedure given below;

– The empty oil drums were converted into a vinegar-making kiln fitted with (a) a conical grate with a chimney pipe; (b) a removable chimney extension; and (c) a lid with a 40 mm Φ hole.

– Bamboo culms were converted into small split pieces using bamboo stick sizing machine and splitter grill. In each batch, sixteen raw bamboos were used.

– On the periphery of oil drum kiln (Fig. C), equidistant three holes of 25 mm Φ were made at 15 cm height from base. These holes supply oxygen in restricted quantity.

– Ready the unit by placed the removable chimney above the fixed chimney (it should be tall enough to create necessary draft in the drum).

– Air dried bamboo splits with average moisture content 22.77 per cent were added into the drum to cover up to the conical grate.

– The bamboo splits were ignited and add remaining splits were added making sure that the bamboo splits does not burn too fast or completely.

– The chimney extension was removed when the drum

Fig. B : Water spray for smoke condensation

Fig. D : Bamboo vinegar

Fig. C : Oil drum kiln to produce bamboo vinegar

Fig. E : Bamboo charcoal

is full and the top layer is carbonized partially and the existing smoke flue is very thick and white.

– Then fixed lid with 45^0 G.I. bend, joint to HDPE pipe in the drum kiln.

– A wet cotton cloth was wrapped on the HDPE pipe. Intermittently water was sprayed to keep the cloth wet. It helped in keeping the temperature of HDPE pipe below melting point as well as condensation of smoke takes place rapidly (Fig. B).

– The bamboo vinegar (Fig. D)was collected in bottle fastened underneath one slit. The bamboo charcoal remains in the drum. (Fig. E)

Moisture content of bamboo :

The bamboo was brought to suitable moisture content *i.e.* 15 per cent to 25 per cent by air drying for using in oil drum kiln. The moisture content of fresh bamboo and air dried bamboo was measured by formula:

$$\text{Moisture content}(\%) = \frac{W_1 - W_2}{W_2} \times 100 \quad (1)$$

where,

W_1 = weight of test piece before drying (g).

W_2 = weight of test piece after drying (g).

Bulk density of bamboo charcoal :

The density stands to the mass of unit volume of bamboo charcoal. It was determined by following formula:

$$\text{Bulk density} = \frac{W_2 - W_1}{V} \quad (2)$$

where,

W_1 = weight of cylinder (kg)

W_2 = weight of cylinder with charcoal (kg)

V = volume of cylinder (m^3).

Ash content :

The bamboo sample was kept in the crucible. The crucible was heated without lid in a muffle furnace at 700 ^{0}C for half an hour. The crucible was then taken out and first cooled in air, then in desiccators and weighed. Heating, cooling and weighing was repeated, till a constant weight was obtained. The residue was reported as ash on percentage basis.

The same procedure was followed for bamboo charcoal sample also. Three replications of test were carried out. The formula used was

$$\text{Ash content}(\%) = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \quad (3)$$

where, W_1 = weight of crucible (g).

W_2 = weight of empty crucible + sample (g).

W_3 = weight of crucible + ash after drying (g).

RESULTS AND DISCUSSION

The experimental findings obtained from the present study have been discussed in following heads:

Moisture content of bamboo :

Table 1 showed that the average moisture content of air dried bamboo was 22.77 per cent.

It was found suitable for the production of bamboo vinegar. If the moisture content is too high, the carbonizing process will extend. On other hand, the bamboo culms are easy to cause crack because of not being heated uniformly in the kiln. The rapid drying of bamboo degrades bamboo charcoal. At the same time, the concentration of compounds in bamboo vinegar becomes low. If the moisture content is lower, the carbonizing process speeds up but the output of bamboo charcoal and vinegar decreases.

Table 1 : Moisture content of bamboo

Sample No.	W_1 (g.)	W_2 (g.)	Moisture content (%)
1.	187.0	157.0	19.10
2.	155.0	124.0	25.00
3.	128.0	105.0	21.90
4.	63.00	51.00	23.00
5.	73.00	62.00	17.00
6.	70.00	59.00	18.64
	Avg. Moisture content (%)		22.77

Production of bamboo vinegar :

Table 2 revealed the output of production of bamboo vinegar and bamboo charcoal.

Table 2 : Production of bamboo vinegar

Sr. No.	Particulars	Production	
		Test 1	Test 2
1.	Total material, kg	60.00	60.00
2.	Bamboo vinegar, litre	1.220	1.020
3.	Bamboo charcoal, kg	11.100	11.20
4.	Ash, kg	0.50	0.60
5.	Un burnt or partially burnt, kg	2.00	3.0

Along with bamboo vinegar, charcoal was obtained. Some bamboo remains un burnt and was not converted in to charcoal. During test one and test two 60.00 kg bamboo pieces were used. It leads to 1.220 ml and 1.020 ml of bamboo vinegar, respectively (Table 2). The ash produced was very less and it was obtained 0.50 kg and 0.60 kg during test one and test two, respectively. The bamboo charcoal was obtained 11.1 kg and 11.2 kg during test one and test two, respectively. The total un burnt bamboo was 5.0 kg during both the test. The maximum temperature of 310^{o}C was recorded during tests. Table 3 showed the cost of raw material and of bamboo vinegar and bamboo charcoal.

During experiment 16 bamboos were used which weighted to total 90 kg. The bamboo were purchased at the rate of Rs. 30/- per bamboo which sum the investment of raw material to Rs. 480/- (Table 3). The bamboo vinegar 2.240 litre and bamboo charcoal 22.30 kg was obtained after the experiment. In Indian rupees rate of bamboo vinegar is Rs. 300/- per litre. The bamboo charcoal rate is Rs. 5.0 per kg. Thus, the output of total production sums to Rs. 783.50/ -. Thus, saving to the tune of Rs. 303.50 was observed during the experiment. The life of oil drum kiln is five years.

Bulk density of bamboo charcoal :

Table 4 shows the observation of bulk density of bamboo charcoal obtained as by-product during bamboo vinegar production process.

The bulk density of sample was in range of 178.16 kg/ m^3 to 184.34 kg/m^3 (Table 4). The average bulk density was found to be 181.23 kg/m^3. The bulk density decides capacity of charcoal storage structure and transport vehicles and resulting load which must be taken into consideration in the design of vehicle components.

Ash content of bamboo and bamboo charcoal :

The average ash content of bamboo charcoal was 4.28 per cent and that of raw bamboo was 7.88 per cent as shown in Table 5 and 6.

Thus, higher ash content was found in raw bamboo than bamboo charcoal.

Conclusion:

– The oil drum kiln is suitable for the production of bamboo vinegar at the rate of 19.22 ml per kg of bamboo (Mes).

– The average moisture content 22.77 per cent was found suitable for production of bamboo vinegar.

– The ash content of raw bamboo was more than bamboo charcoal

Table 3 : Costs of bamboo, bamboo vinegar and charcoal

Sr. No.	Particulars	Quantity	Rate (Rs.)	Amount (Rs.)
1.	Bamboo	16 no.	30.00 per No.	480.00
2.	Bamboo vinegar	2.240 litre	300.00 per litre	672.00
3.	Bamboo charcoal	22.30 kg	5.00	111.50

Table 4 : Bulk density of bamboo charcoal

Sr. No.	Weight of cylinder, W_1 (kg)	Weight of charcoal, W_2 (kg)	Diameter of cylinder (m)	Height of cylinder (m)	Volume of cylinder (m^3x10^{-3})	Bulk density (kg/m^3)
1.	0.086	0.259	0.075	0.22	0.971	178.16
2.	0.086	0.262	0.075	0.22	0.971	181.25
3.	0.086	0.264	0.075	0.22	0.971	183.31
4.	0.086	0.260	0.075	0.22	0.971	179.10
5.	0.086	0.265	0.075	0.22	0.971	184.34
					Average bulk density	181.23

Table 5 : Ash content of bamboo charcoal

Sample No.	W_1	W_2	W_3	Ash content (%)
1.	55.75	70.76	56.47	4.79
2.	55.50	70.71	56.21	4.66
3.	56.00	70.74	56.50	3.40
			Average of ash content (%)	4.28

Table 6 : Ash content of raw bamboo

Sample No.	W_1	W_2	W_3	Ash content (%)
1.	54.96	62.72	55.55	7.60
2.	54.92	63.70	55.57	7.40
3.	54.82	62.79	55.51	8.65
			Average of ash content (%)	7.88

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