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A study of large-cardamom curing chambers in Sikkim

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Abstract

India is the largest producer of large cardamom in the world with an annual production of 4000 tons, followed by Nepal (2500 tons/year) and Bhutan (1000 tons/year). More than 85% of the production within India is from Sikkim. Firewood is used extensively for curing cardamom in small, traditional curing chambers called "*bhattis*". The traditional curing process is not only inefficient, resulting in an estimated fuelwood wastage of 20 000 tons/year, but also yields a poor quality product. An attempt is made in the present work to analyze the thermal performance of the traditional "*bhattis*" through field survey and operational data collection. Based on the experimental observations and analysis, options for improvement such as use of a gasifier are suggested. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Crop drying; Fuel wood use; Large cardamom; Energy efficiency; Gasification; Performance evaluation

1. Introduction

India is the largest producer of large-cardamom (*Amomum subulatum* Roxburgh), which is an important spice. The annual production of large-cardamom in India is 4000 MT (metric tonne), followed by Nepal (2500 MT) and Bhutan (1000 MT) [1]. Within India, the north-eastern state of Sikkim contributes over 85% of total production (Fig. 1). With an average wholesale price of about 60 Rs/kg (~1.43 $/kg at the current exchange of Rs 42 per US dollar), cardamom worth $ 5 million is produced from Sikkim alone. Curing of large-cardamom is an energy intensive operation and currently firewood is used in traditional curing chambers (called *bhattis*) at household level or farm level. The traditional method of curing, besides being inefficient in energy terms, imparts smoky smell and tarry colour to the dried cardamom, causing loss of natural pinkish colour and pleasant odour. No data is available on the performance of these traditional *bhattis* with reference to fuel consumption, drying temperatures, drying rates etc. Even basic information such as drying characteristic curves is not available for large-cardamom. Considering that large quantities of fuel wood are being consumed every year on curing and that Sikkim is located in the ecologically sensitive Himalayan region, it is important to study the performance of traditional curing chambers. Such a study can give important information on

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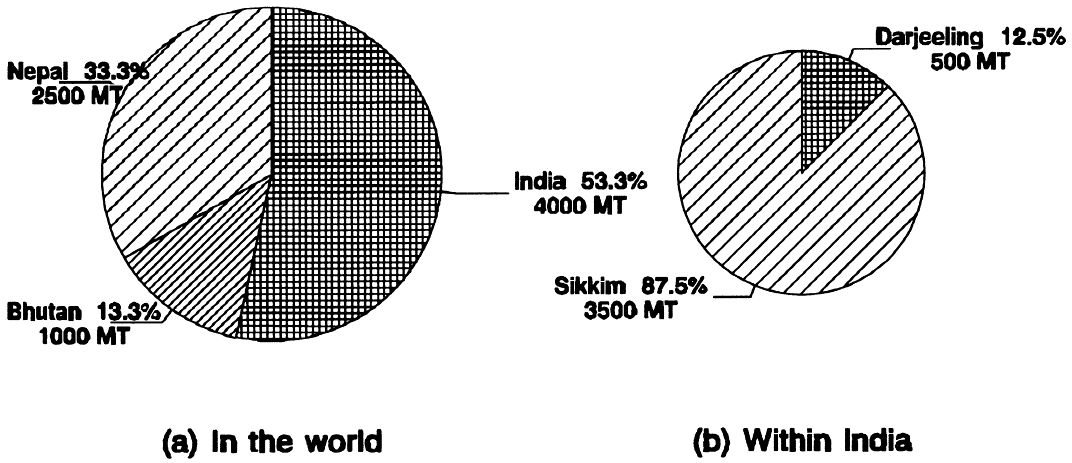

Fig. 1. Region wise production of cardamom (a) in the world (b) within India.

the various losses of energy, so that attempts can be initiated to scientifically design an improved and energy efficient curing chambers. This paper presents results of field survey and data collection in three traditional curing chambers in Sikkim.

2. Large-cardamom production in Sikkim

Large-cardamom is cultivated in an area of about 23 500 ha in Sikkim. Cardamom is a shade-loving plant and the hills of Sikkim provide an ideal environment. Cardamom grows at altitudes between 600 and 2000 m where rainfall is between 1500–3500 mm and temperature varies from 6°C (min) to 33°C (max). Frost and hailstorms are injurious to plants during flowering. Cardamom thrives in moist soil. Soil moisture is usually maintained by water diverted from seasonal springs on the upper slopes and no special irrigation provisions are needed. Cardamom plantations are established mostly on unterraced sites, north and north-east facing slopes are preferred to reduce exposure to direct sunlight. Flowering of cardamom commences in the third year after planting. Flowers appear during April and May and the capsules mature in September and October. Large-cardamom is a low input crop; organic manures, fertilizers and pesticides are seldom used. Most of the management operations are done manually. Consequently, labour is the single largest input. Labour is required for cleaning (November–December), weeding (February–March and June–July) and harvesting (September–October). On average, every hectare requires 110–130 labour days per annum to carry out the various operations.

Export of large cardamom increased during the 1980s. A ten-fold increase in export volume with a three-fold increase in unit price was achieved in the last decade, making cardamom a major economic cash crop for the state. The productivity is highest in the north district, followed by the east district due to favourable shade, humid environment and soils rich in organic matter. Productivity among different plantations varies from a low of 100 kg/ha to a high of 450 kg/ha, the average being 150 kg/ha [2]. Factors such as altitude, age, and composition and density of shade trees affect yield. There are two species of cardamom grown in Sikkim, namely *Golsey* or *Bada Dana* and *Ramsey* or *Chota Dana*. Golsey is grown in the north and east districts of Sikkim, and the west and south districts grow both Golsey and Ramsey. More than 50% of the production of cardamom is from the north district.

Cardamom growing is a small-farm business. More than 85% plantations have a cultivation area of less than 2 ha. Contributing to 1/3rd of

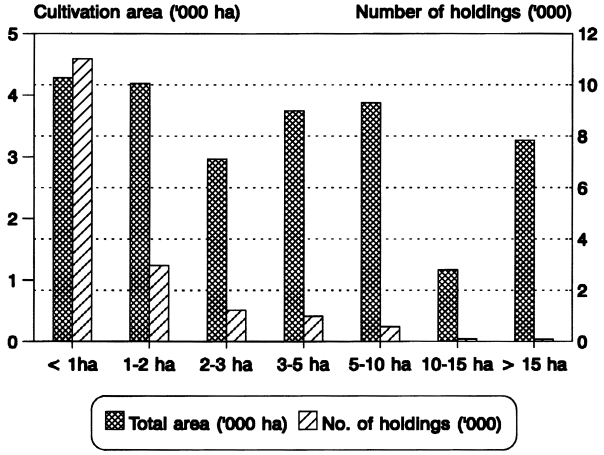

Fig. 2. No. of holdings and cultivation area under large cardamom.

the total cultivated area of cardamom, while 1% holdings have cultivation area of more than 10 ha. The land holding distribution is shown in Fig. 2.

2.1. Processing of large-cardamom

Fresh large-cardamom capsules contain about 70–80% moisture (on wet basis) depending upon the maturity level of the capsules at the time of harvest. The whole bunch of cardamom capsules is harvested and later each capsule is separated from the bunch/flower and cleaned before drying. In order to achieve a long shelf life and to bring out the aroma, the moisture content has to be brought down below 10% (wet basis) and this process is known as curing, which has to be done immediately after harvesting to avoid fungus infection.

In the traditional method, cardamom capsules are spread on a mesh and exposed directly to smoke. There is no control on fire and smoke, resulting in poor quality of the dried product. In order to overcome the drawbacks of traditional curing chambers, the Spices Board (a government agency under the Ministry of Commerce) tried to promote the flue-pipe curing chamber generally used in south India for curing of small-cardamom [3]. However, the flue-pipe method was found to be slow and also required a very large initial investment, without any energy savings, and has not crossed the demonstration stage as yet.

3. Observations on the traditional curing chambers

Though data on land holdings in cardamom cultivation is available, there is no record of the number of curing chambers or their location. The total number of holdings is about 17 000 in the whole state. However, the curing chambers are similar in size and capacity throughout the state. Hence farmers with large holdings would be possessing many *bhattis* in order to process all the cardamom harvested at the same time. Also, as the terrain is hilly, restricting movement of materials, different *bhattis* are constructed at different heights even for the same holding. Thus, the total number of curing chambers would be far in excess of the number of land holdings. A preliminary survey conducted in the harvesting season of October–November 1996 clearly indicated the difficulties involved in getting any sort of data on the traditional *bhattis*. Though it was obvious that huge quantities of fire wood obtained from clear felling of trees were used for curing, the farmers had no idea how much was being used in quantitative terms. There were also no standard methods of construction of the *bhattis* or standard practices for drying. However, some general observations on the structure of the *bhatti* and drying practices could be made as described below.

3.1. Constructional features of the traditional bhatti

A schematic diagram of the typical *bhatti* is shown in Fig. 3.

It consists of a stone wall structure on all four sides with an opening in the front to make fire and feed wood logs. In many cases the *bhatti* is made by digging a depression into a steep hillside. In such a case, the rear side of the *bhatti* and sometimes even two side walls, consist of an earthen surface and only the front side with

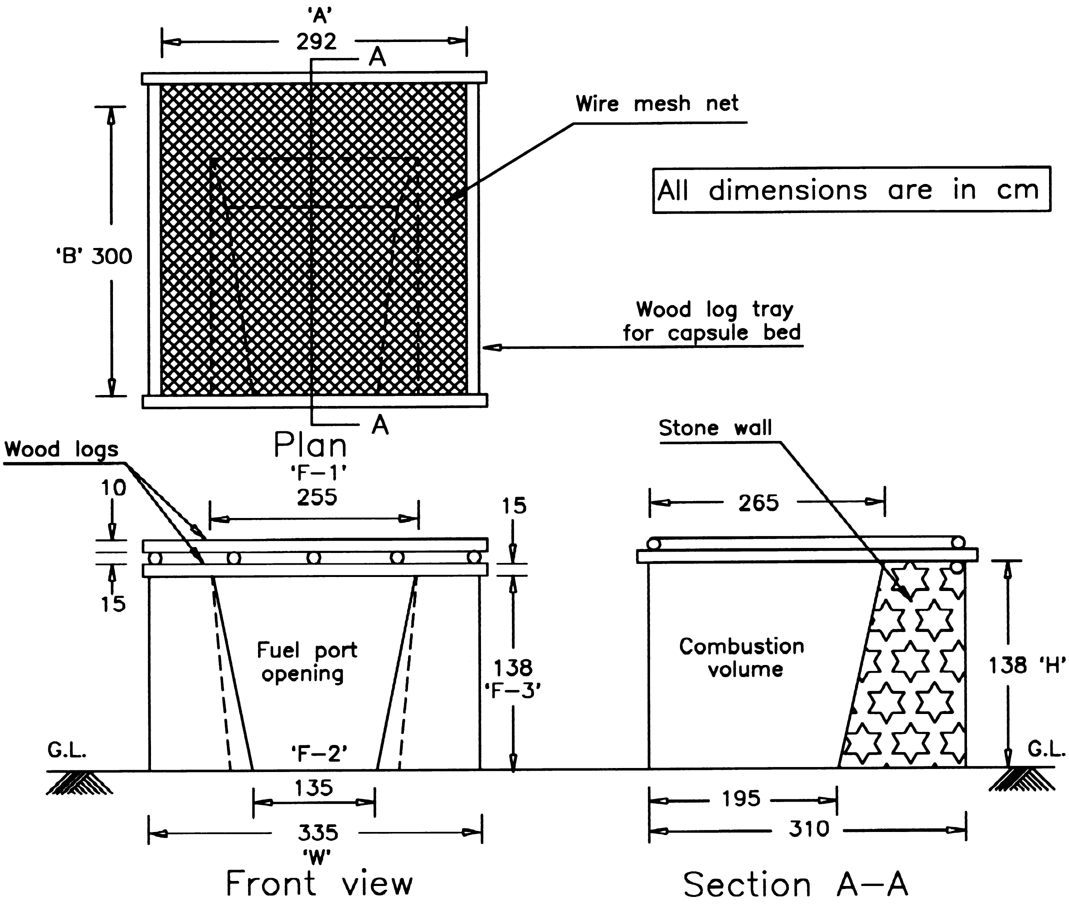

Fig. 3. Schematic diagram of traditional *bhatti* system (Naga unit).

opening is constructed with stone. Some *bhatti* also use conventional building materials like brick and cement. A meshed platform, usually made of locally available bamboo mat, is placed on top of the *bhatti*, and is supported by 0.1–0.15 m (4–6 inch) dia wood logs. In some *bhattis* a metallic wiremesh (chicken wiremesh) is used instead of a bamboo mat to reduce the risk of a fire hazard. The mesh is placed about 1.2–1.8 m above the ground level where the fire is located. This height is required primarily to avoid charging and burning of cardamom capsules and to reduce the chance of sparks reaching the cardamom bed. This height also ensures that the temperature of flue gases reaching the cardamom bed is adequate for drying, though no literature is available on the range of desirable drying temperatures. A side enclosure is built above the mesh on all four sides with wooden planks or wood logs so as to contain the cardamom capsules within the enclosure. The depth of the cardamom bed is usually 0.2–0.3 m (8–12 inch). This is contrary to the practice followed in south India where small-cardamom capsules are spread in monolayers in trays. The cross-sectional area of the cardamom bed varies between 4 to 9 m^2. The quality of construction of the majority of the *bhattis* is poor, resulting in cracks and gaps allowing hot flue gases to escape. The resulting heat loss could be quite high. The fuel port opening of the *bhatti* generally faces the valley, ostensibly because the prevailing winds push the smoke through the *bhatti*. However, this can result in a large amount of excess entering the fire zone to poor efficiencies.

3.2. Drying process

Cardamom capsules collected from the field throughout the day are brought to the curing chamber in gunny bags (old or discarded sack-cloth packaging bags) or in bamboo baskets. Individual capsules are separated from the bunch and spread on the mesh for drying with the help of a bamboo or a spoon-like wooden spreader. After this, fire is started and maintained till the drying is complete.

After 20–24 h of drying, the capsules are overturned so that relatively more dried bottom capsules are brought to the top of the bed and the under-dried top capsules go to the bottom layers. This is done sometimes by removing the well-dried capsules and keeping them in sack-cloth bags, spreading the less-dried capsules on the mesh and then putting the well-dried capsules back in the *bhatti*. Practices differ slightly from place to place, but some kind of reshuffling is always done to maintain uniformity in drying. Many *bhattis* have a permanent shed of galvanized iron sheet, bamboo or asbestos sheet above the cardamom bed to prevent moisture absorption from atmosphere (dew formation) in the night. Wherever there is no permanent shed, the cardamom bed is covered with a plastic sheet.

Where bamboo mesh is used, the operator keeps the fire at a low level or tries to reduce flame height by keeping fresh wood over burning wood. In spite of precautions, many times the flying sparks manage to reach a cardamom bed, causing fire. Whenever there is a fire, which can be noticed by smoke from the mesh structure, the operator sprinkles water from the bottom onto the mesh.

The total time of drying varies from 25–40 h in the traditional *bhattis*, depending on factors such as initial moisture content of the capsules, *bhatti* structure, fire management and ambient weather conditions.

There are no indicators to decide if the drying process is complete. Many times this causes either over-drying or under-drying. Under-drying will cause fungus and fetches low prices for farmers. Some times the farmers feel that the product is over-dried and sprinkle water to increase weight. This practice has an adverse effect on the storage life of cardamom as it invariably leads to fungus growth.

The cardamom capsule has a tail portion and capsules without the tail fetch a higher price. Generally the tail is cut with a scissor and this operation requires additional labour. However, if the cardamom is dried well, the tail portion can be removed easily by rubbing.

There is a misconception that exposing the cardamom to smoke is essential to preserve it. This is scientifically not correct, as it is well known that reduction of moisture to the desired level is a necessary and sufficient condition for safe preservation.

4. Detailed study on the operation of traditional *bhattis*

In order to collect data on the performance of the traditional *bhattis* and to identify the various energy losses, detailed energy audit studies were undertaken on three units. The units selected are:

1. Managan Malling unit, Managan, north Sikkim
2. Naga unit, north Sikkim, and
3. Ningang unit, Ravangala, south Sikkim

The first two units represent the high altitude region of north Sikkim, while the last unit represents the lower altitude region of south Sikkim. Table 1 gives structure details of the three *bhattis*.

4.1. Instrumentation and data collection

For obtaining the initial and final weights of cardamom and to weigh the total quantity of fuel consumed during a batch of drying, a special weighing arrangement was made. A dial gauge type spring balance of 100 kg capacity was hung either from a tree top or from a tripod formed

Table 1
Details of traditional *bhattis* studied

Particulars/unit name[a]	Mangan Malling	Naga	Ravangala
Cardamom bed size ("A" cm × "B" cm)	274 × 307	292 × 300	222 × 225
Location of cardamom bed above ground level ("H" cm)	176	138	179
Overall width of the *bhatti* ("W" cm)	315	335	300
Overall breadth of the *bhatti* ("B" cm)	300	310	325
Fuel port opening at top ("F1" cm)	175	255	62
Fuel port opening at bottom ("F2" cm)	90	135	62
Fuel port height from bottom ("F3" cm)	141	138	109
Average O_2% in flue gas above the fuel bed	19.7	18.5	17.5
Wall material	Stone/rock	Stone/rock	Stone/rock
Type of mesh used	Wire mesh supported on wood rafters	Bamboo mesh	Wire mesh supported on wood rafters
Shed type	Temporary PVC sheet shed	Permanent bamboo shed	Permanent shed

[a] Note: Dimensions A, B, H, W, F are referred in Fig. 3.

Table 2
Summary of experimental data taken during drying of one batch

Parameter/unit name	Mangan Malling	Naga	Ravangala
Initial weight of fresh cardamom capsules (kg)	747.0	507.5	580.0
Final weight of cured cardamom capsules (kg)	221.0	134.0	143.0
Quantity of fuelwood consumed (kg)	860	1149	464
Total drying time (h)	35	40	26
Moisture content of fresh cardamom (% w.b.)	72.3	76.2	76.3
Moisture content of dry cardamom (% w.b.)	6.3	9.9	4.1
Moisture content of wood (% w.b.)	18.0	22.0	27.4
Calorific value of fuelwood (MJ/kg)	14.4	15.3	15.5

by three wooden poles. Cardamom bags or fire wood logs were then connected to the hook of the balance by means of ropes. A portable, battery operated analog moisture meter (Japsin make) with a needle probe was used to measure the moisture content of cardamom and firewood. Bulk density of the capsules (fresh as well as dried) was obtained by weighing a known volume (using a measuring flask) of capsules on a single pan balance of 500 g capacity and 10 g least count. Portable digital temperature meter (0–1200°C) was used for temperature measurements at various locations inside the *bhatti*. A Fuel Efficiency Monitor (FEM-500, Neutronics make, 0–1200°C temperature range and 0–21% oxygen range) was used to measure the oxygen present in flue gases to estimate excess air levels. The calorific value of wood was measured using a bomb calorimeter. Samples of firewood and cardamom were collected from the site and brought to Delhi in plastic bags to determine calorific value (wood) and moisture contents.

For recording the cardamom processed, the weights of fresh cardamom and dried are noted. The difference gives the total amount of moisture removed in the drying process. To measure the firewood consumed in a batch, the operator was instructed to use wood from a pre-weighed pile only. The difference in weight of the pile before the start of fire and at the end of the drying session gives the firewood consumption. At the end of the drying session any burning wood was quenched and the remains added to the pile. Specific fuel consumption can then be obtained by dividing the firewood consumed by the cardamom processed in the batch. The percentage of oxygen in the flue gases just above the fire gives an indication of the excess air in combustion and is a measure of how controlled the combustion is. Hence the flue gases were sampled just above the fire zone.

In an attempt to get an approximate drying characteristic curve, a fixed number (100) of cardamom capsules were removed from the bed at

Table 3
Summary of analysis of field experimental data on traditional *bhattis*

Unit name	Mangan Malling	Naga	Ravangala
Amount of moisture evaporated (kg)	526.0	373.5	437.0
Thermal efficiency (%)	10.8	5.4	15.5
Specific fuel consumption (kg fuel per kg fresh cardamom)	1.15	2.26	0.80
Specific fuel consumption (kg fuel per kg dry cardamom)	3.89	8.57	3.24
Fuel burning rate (kg/h)	24.6	28.7	17.8
Fuel port opening (m^2)	1.87	2.69	0.67
Combustion volume (m^3)	9.6	7.9	5.8

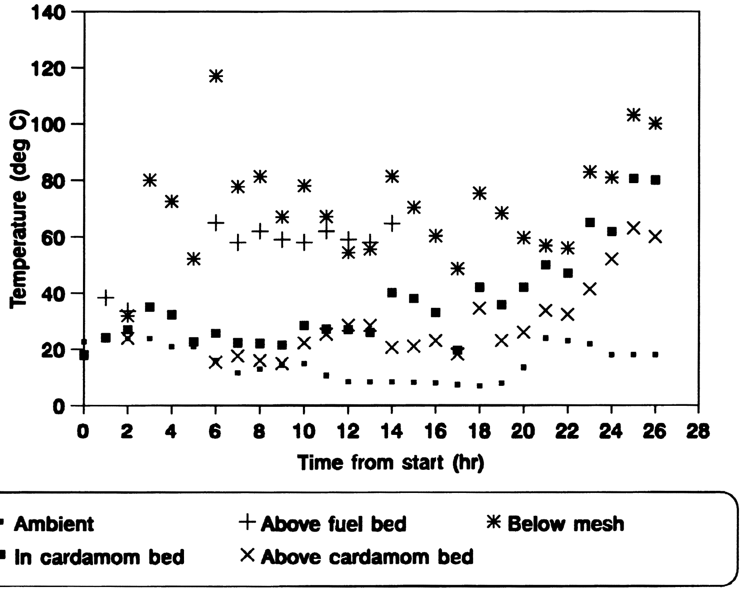

Fig. 4. Temperature at various locations monitored in cardamom *bhatti* at Ravangala.

1 h intervals and weighed. This data was processed as described in the next section. Table 2 gives a summary.

4.2. Results and analysis

The thermal efficiency of the curing chamber can be defined as

$$\eta = \frac{W\lambda}{F.\mathrm{CV}} \times 100 \quad (1)$$

where

η = thermal efficiency (%)
W = mass of water removed (kg)
λ = latent heat of vapourization (kJ/kg)
F = mass of fuel consumed (kg)
CV = calorific value of the fuel (kJ/kg)

The summary of calculations for thermal efficiency and other parameters is shown in Table 3.

It can be observed from Table 3 that the traditional *bhattis*operate with poor thermal efficiency values of the order of 5–15%. Among the three *bhattis* studies, the Ravangala unit had the best performance. This is due to the fact that the Ravangala unit has a good design. It had a smaller fuel port opening, smaller combustion volume, lesser burning rate and well constructed wall structure, all contributing to better thermal efficiency. However, there are not many *bhattis* in Sikkim constructed this way, and the Ravangala unit will probably represent the upper limit of efficiency in traditional *bhattis*. It can also be observed from Table 3 that higher thermal efficiencies correlate with lower burning rate, smaller fuel port opening, and lower drying period.

The high (17.5–19.7) percentages of oxygen in flue gas indicate high excess air levels and very little control on air supply for combustion. Flue gas temperatures at different locations in the Ravangala unit are shown in Fig. 4 for the entire drying period. It can be seen that the temperature of the flue gas just below the mesh is in the range of 75–80°C, which is higher than the recommended range of 55–60°C for small-cardamom in south India. As is the case in south India, there is not enough laboratory data on drying characteristics of large-cardamom to suggest an optimum range for drying tempera-

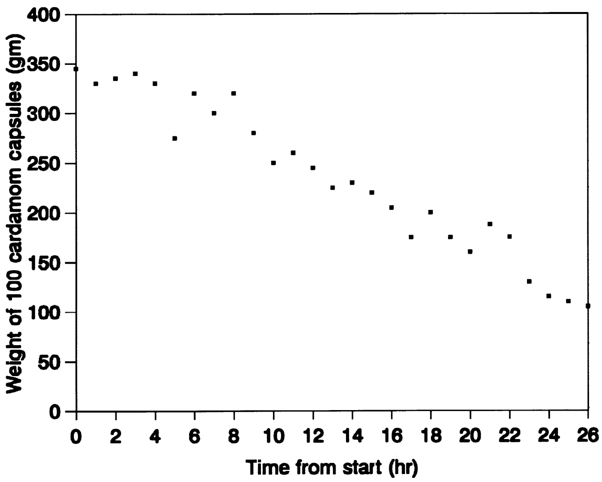

Fig. _5. Weight loss curve for 100 capsules monitored from cardamom bed with time.

tures. Thus achieving better thermal performance, the following retrofitting measures can be suggested.

- reduce the size of fuel port to the minimum required for easy charging of fuel,
- reduce the burning rate,
- reduce the excess air levels, perhaps by introducing a grate,
- reduce combustion volume,
- minimize flue gas leakage by sealing cracks and wide openings in the flue gas path.

4.3. Drying rate characteristics

The variation of the weight of a fixed (100) number of cardamom capsules with time is shown in Fig. 5. The data in this figure was used to construct an approximate drying-rate curve as follows:

1. the moisture content of fresh cardamom is known (76.3%). From this the dry weight of the first batch of 100 capsules was obtained by multiplying the total weight with 0.237. This dry weight, calculated as 81.76 g for 100 capsules, will be constant for all the subsequent samples.
2. the total weight of the next batch of 100 capsules minus 81.76 g gives the weight of moist-

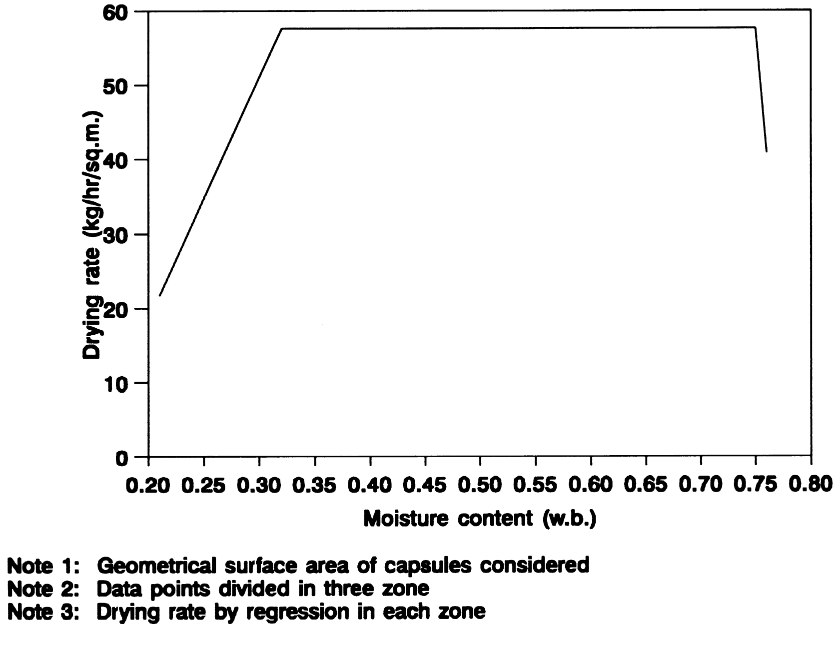

Fig. 6. Approximate drying rate curve for large cardamom.

ure in the second batch. The weight of moisture thus obtained, divided by the total weight, multiplied by 100 gives percentage moisture content for the second batch.
3. the moisture contents of the third and subsequent batches are calculated in the same manner.
4. the weight of the first batch minus that of the second batch, divided by the time period, gives the rate of moisture loss in kg/h. This, divided by the average surface area of the capsules, gives drying rate in $kg/h/m^2$.
5. the weight loss curve of Fig. 5 was divided into three zones and drying rates for each interval were calculated by numerical differentiation. The drying rates in each zone were smoothed out by regression analysis.

The drying characteristics curve obtained as above is shown in Fig. 6. It can be seen that the drying characteristic has a constant rate followed by a falling rate as the drying progresses, which is typical for most agricultural products. The relatively large constant rate period shows that most of the moisture is unbound and hence can be removed faster by increased flue gas velocities. The latter can be achieved by reducing the resistance to flow, for example by spreading the capsules in several thin layers instead of one thick layer. The drying rate curve obtained as above, is, however, not accurate enough to be used for design purposes.

A laboratory determination of drying rate characteristics has since been initiated and will be reported in the future.

4.4. Scope for future work

Retrofitting measures suggested in the earlier section will definitely result in fuel savings, but may not necessarily improve the quality. Besides, there are some general difficulties of popularizing retrofitting with the farmers, as listed below.

- There is nothing to be sold as a package, and hence commercial means of dissemination is not feasible.
- Fuel saving is not the primary concern for the farmers at present, as they do not purchase it.
- The masons/labour who construct the *bhattis* will have to be trained over a prolonged period in construction of retrofits, which is a slow and arduous task.

On the other hand, development and promotion of a low cost wood gasifier would be a promising option as, (i) it offers a high conversion efficiency from wood to producer gas, (ii) the gas can be burnt more efficiently resulting in overall improvement of thermal efficiency and (iii) the flue gases obtained by burning the gas are clean and smokeless, and can result in better colour and smell of dried cardamom.

Development and field testing of a simple, low-cost gasifier system for curing of large-cardamom will be reported in future.

5. Conclusions

Large cardamom curing is a small farmers activity using primitive curing (smoking) methods. From a field survey, experimental study and data analysis of traditional *bhattis* used for drying large cardamom, it was found that they operate with very low thermal efficiency of the order of 5–15% and produce very poor quality product (smoky appearance and loss of volatile oil content). Based on the data analysis, retrofitting and gasifier options are proposed to improve the fuel efficiency as well as quality of dry cardamom produced.

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References

[1] Berrig Ch, Koechilin R, Tarnutzer A. A preliminary profile with particular emphasis on horticulture and animal husbandry. Study group on institutions. Human Actions and Resource Management, Institute of Geography, University of Zurich, 1993. p. 47–51.

[2] Singh VB, Singh K. Spices. New Delhi: New Age International Publishers, 1996.

[3] Kishore VVN, Rastogi SK. Thermal analysis of cardamom curing chambers. Energy in Agriculture 1987;6:245–53.