Elucidation of unit operations and energy consumption pattern in small scale cashew nut processing mills

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A R T I C L E   I N F O

Article history:
Received 20 December 2009
Received in revised form 5 February 2010
Accepted 13 February 2010
Available online 3 March 2010

Keywords:
Cashew mills
Unit operations
Energy intensity and percent plant capacity utilization

A B S T R A C T

The different unit operations involved in small scale cashew nut processing mill in the context of Konkan region of Maharashtra, India (70°17′ to 74°31′E Longitude 15°37′ to 20°20′N Latitude) was elucidated by conducting the randomized sample survey of registered 122 small scale cashew processing mills in the region. The survey covered the unit operations performed, level and pattern of energy consumption and technologies in use for cashew nut processing. The energy consumption and production of mills was analyzed to compute the disparities in energy consumption to produce the same quantity of similar product in term of installed capacity (P), Production (Pr), percent production capacity utilization (PPCU), energy (En) and energy intensity (EI).

The study revealed that, the small scale cashew nut mills in Konkan region of Maharashtra (India) widely followed steam roasting process due to better control over the process which retain the valuable CNSL in the shell as well as generate the huge quantity of shell for further utilization as a fuel. The average working days of the mills were about 227 days in the year depending on the rainy season and availability of raw cashew nut seeds. The average installed production capacity of the surveyed mills was about 9800 kg of raw cashew nut seeds per annum. The actual raw material processed by these mills was in the tune of 5833 kg per annum, which revealed the average percent plant capacity utilization of 55% only.

The women workers were prominent in the small scale cashew nut processing mills.

The regression analysis of relationship between energy and production revealed the best fit of the form of power law i.e. $En = A \cdot \left(Pr\right)^B$ where “A” is the constant and the coefficient “B” is commonly known as the Energy Elasticity. It was observed that, the energy intensity in the cashew nut processing mills producing the similar product varied from 2.15 MJ/kg to 3.80 MJ/kg. The regression analysis of relationship between energy intensity and production revealed the best fit of the form of power law i.e. $En = A \cdot \left(Pr\right)^{B}$ The negative exponent ‘B’ shows a decline in the value of energy intensity with increase in production. It was observed that the frequency of the number of firms in each PPCU range is a bell-shaped curve, which clearly shows about 91 (75%) of the total samples were in PPCU range less than 65% with average energy intensity of 2.9 MJ/kg. This gives considerable scope for saving of energy with better utilization of installed production capacity in the tune of 25.84%.

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1. Introduction

Cashew (Anacardium occidentale L.) is one of the important tropical crops called as the “poor man’s crop, rich man’s food”. The cashew nut is native of Brazil and Portuguese travelers took the cashew tree to colonies in India, first recorded in Cochin by 1578 AD, in Goa by 1598 A.D. The crop is grown mainly in peninsular states of India particularly along the coastal states like Kerala, Karnataka, Goa, Maharashtra, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal (Smith et al., 1992). It is an important nut crop that provides food, employment and hard currency to many in developing nations.

India is the largest producer and processor of cashews (A. occidentale L.) in the world. Total area in India under cashew cultivation is about 868,000 ha with annual production of 665,000 tons giving average productivity 860 kg per hectare with highest productivity reported in Maharashtra (1500 kg/ha) from 167,000 ha land under cultivation and produced 210,000 tons of raw cashew nut seeds. India processed about 1,138,000 tones of raw cashew nut seeds through 3650 cashew processing mills scattered in many states of country which increased rapidly from 170 in 1959 to over 3650 in year 2008 provide employment to over 0.5 million people of, which 95% are women (Anon., 2009).
Maharashtra state has total 2200 cashew processing units out of which 1850 are small cottage mills which processed about 200,000 metric tones of raw cashew nut per annum mainly located in Konkan region (70°17' to 74°31'E Longitude and 15°37' to 20°20'N Latitude) of Maharashtra comprising five districts namely Mumbai, Thane, Raigadh, Ratnagiri and Sindhudurg with 131,288 ha land area under cultivation producing 192,600 tons of raw cashew per annum (Epitome, 2009).

The cashew mill in India employed different unit operations/methodology for processing and depending on variety of raw material, location, technological mechanization and availability of secured energy supply. The most energy and time intensive unit operations in cashew processing are drying of raw seed in open sun, steaming of raw nut and kernel drying with electrical energy (Balasubramanian, 2000). A wide disparity in energy consumption to produce the same quantity of similar products in cashew processing was observed. The wide variations in energy intensity of these cashew mills reveal the scope for energy conservation to be in the order of 30–48%. The wide variations in energy intensity of these mills due to variety of the fuel, installed capacity, production and percent utilization of the capacity reveals the scope for energy conservation. These operations need to study for efficient end use efficiency (Ramachandra, 1998). The main purpose of energy use assessment is to judge energy use pattern, energy loss sources and excess energy use points (Kulkarni, 2000).

2. Material and methods

The different unit operations involved in small scale cashew nut processing mill in the context of Konkan region of Maharashtra (70°17' to 74°31'E Longitude 15°37' to 20°20'N Latitude) was elucidated by conducting the randomized sample survey of registered 122 small scale cashew processing mills in the region.

The cashew processing mills in the region were classified on the basis of capacity of mill for processing of raw cashew seeds per day (Jadhav, 2006). The cashew processing mills were classified as:

- Small: Up to 60 kg of raw seed/day.
- Medium: 51–100 kg of raw seed/day.
- Large: Above 101 kg of raw seed/day.

Based on the capacity of holding steam cooker for the steaming operation in the cashew processing, the small scale cashew processing mills were further classified as:

- Small: Up to 15 kg of raw seed/batch
- Medium: 15–45 kg of raw seed/batch
- Large: 45–60 kg of raw seed/batch

A questionnaire based purposive simple random sampling survey of about 10% small scale cashew nut processing mills (122 out of 1209 mills) was carried in purposively selected districts of Konkan region of Maharashtra where cashew processing units are widely established. The direct interview method with prescribed format of survey was adopted for the collection of data. The survey of small scale cashew processing mills covered the general information, background information, process and product details and important factors that affect the data collection. The survey covered the unit operations performed, level and pattern of energy consumption and technologies in use for cashew nut processing (Kulkarni, 2000; Ramachandra, 1998). The energy consumption and production of mills was analyzed to compute the disparities in energy consumption to produce the same quantity of similar product in term of Installed capacity (P), Production (Pr), percent production capacity utilization (PPCU), Energy (En) and Energy Intensity (EI), as follows (Ramachandra, 1998).

2.1. Installed capacity (P)

The installed capacity of the mill was determined by considering the capacity of the steam cooker, number of batches performed per day and the average working days in a year.

\[
\text{Installed capacity, } P (\text{kg}) = \text{steam cooker capacity} \times \text{No. of batches/day} \times \text{average working days}
\]

2.2. Production (Pr)

The production of the mill was determined by noting the average actual raw material processed on kg per year basis. The average of last three year production data was considered for the production figures.

2.3. Percent production capacity utilization (PPCU)

The percent production capacity utilization of the mill was calculated as the ratio of actual production to the total installed capacity of the mill.

\[
\text{percent production capacity utilization (PPCU), } \% = \frac{\text{Pr}}{\text{P}} \times 100
\]

2.4. Total energy (En)

The electrical energy consumption for unit operations and lighting in the mill was estimated by direct interview method and verified from the available electrical bills on yearly basis. The quantity of biomass fuel consumed and type of biomass for processing of raw material in a year was collected by direct interview method. All the form of energy sources were converted into the common unit of energy i.e. MJ/Year.

2.5. Energy intensity (EI)

The energy intensity of surveyed mill was calculated as the ratio of Total Energy Consumption (En) and Production (Pr).

\[
\text{Energy Index (EI), MJ/kg = } \frac{\text{Total Energy (En)}}{\text{Production (Pr)}}
\]

The relationship between the variables En and Pr, between EI and PPCU was established by using different statistical models depending upon the best fit (least error techniques).

3. Results and discussion

The result obtained from the randomized sample survey of the small scale cashew nut processing were discussed as below.

3.1. Elucidation of unit operations in small scale cashew nut processing

The small scale cashew nut processing mills in the region employed different unit operations/methodology for processing of cashew nut. The general process flow chart for cashew processing adopted in the study area for cashew nut processing is described as follows and shown in Fig. 1.

3.2. Sun drying of raw cashew nut seed

The raw nuts after harvest are sun dried for 2–3 days to reduce the moisture from 25% to 7–8% (wb) and stored in gunny bag. The well-dried seeds were stored in the 80 kg capacity gunny bags for further processing.
3.3. Steaming of raw cashew nut seed

This method now a day adopted widely all over the surveyed region. The raw nuts are steamed conditioned at about 4.5–5 kg/cm² pressure for 25–30 min and then allowed for 24 h cooling at room temperature. A cylindrical steam cooker with provision of cashew nut feeding at the top and discharging of cooked nuts from the side near bottom, has a capacity of holding 15 kg to 60 kg of cashew nut in a batch.

3.4. Cooling of steamed cashew nut seed

The cooling and tampering of the steamed nuts was carried out 10–12 h in the shed to bring the steamed nut in equilibrium with the atmospheric conditions.

3.5. Cutting and separation

Raw nuts after steaming and cooling were shelled to remove kernels with the help of hand cum pedal operated shell cutter. The separation of cashew kernel from the cut steamed nuts was carried out manually by using the sharp knife. This unit operation produced the cashew shell as by-product, further used as feedstock for the cashew nut shell liquid extraction.

3.6. Drying of cashew kernels

The kernel coming from the cutting and separation section contains a brown cover, known as ‘testa’, over it. To remove testa over the kernel and also control the moisture content in the kernels, they are exposed to prolonged and controlled heating with hot air at 65–70 °C in perforated tray for 6–8 h. About 5–8% of moisture was removed from the kernels in the process.
Regression analysis of energy and production in small scale cashew nut mills.

Table 1
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Model</th>
<th>Equation</th>
<th>Coefficients</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Linear</td>
<td>$E_n = A + B(P_r)$</td>
<td></td>
<td>17116</td>
<td>2.222</td>
<td></td>
<td>0.957</td>
</tr>
<tr>
<td>2</td>
<td>Quadratic</td>
<td>$E_n = A + B(P_r) + C(P_r)^2$</td>
<td></td>
<td>1065</td>
<td>2.516</td>
<td>-0.2</td>
<td>0.946</td>
</tr>
<tr>
<td>3</td>
<td>Exponential</td>
<td>$E_n = Ae^{B(P_r)}$</td>
<td></td>
<td>4507.6</td>
<td>0.0002</td>
<td>10^-6</td>
<td>0.879</td>
</tr>
<tr>
<td>4</td>
<td>Power</td>
<td>$E_n = A + (P_r)^B$</td>
<td></td>
<td>10.056</td>
<td>0.842</td>
<td></td>
<td>0.972</td>
</tr>
</tbody>
</table>

3.7. Cooling of cashew kernels

The cooling of hot cashew kernels from the drying operation was carried out in the shed to bring down the temperature of the kernels.

3.8. Peeling of cashew kernels

The brown testa over the kernel was peeled off manually by using the sharp knife. The women workers in the mill generally performed this operation.

3.9. Grading and packaging

The kernels were graded manually by hand/sieve. CEPC (Cashew Export and Promotion Council, India) specifications were adopted for grading of cashew kernels.

The randomized sample survey of 122 small scale cashew nut processing mills revealed that, the small scale cashew nut mills in Konkan region of Maharashtra (India) widely followed steam roasting process due to better control over the process which retain the valuable Cashew Nut Shell Liquid (CNSL) in the shell as well as generate the huge quantity of shell for further utilization as a fuel. The average working days of the mills were about 227 days in the year depending on the rainy season and availability of raw cashew nut seeds. The average installed production capacity of the surveyed mills was about 9800 kg of raw cashew nut seeds per annum. The actual raw material processed by these mills was in the tune of 5833 kg, which revealed the average percent plant efficiency of 55% only. The women workers were prominent in the small scale cashew nut processing mills.

The unit operations performed in the mills were semi automatic type using different machineries supplied by the registered manufacturer of Govt. of Maharashtra. Most of the small scale cashew nut processing mills used indirect type of baby boiler with cooker for steam generation (above 90%). Very small amount of the cashew nut shell was used for the extraction of the valuable cashew nut shell oil. The secure and constant electricity supply play an important role as the processing as most of the kernel drying ovens were operated on the electricity for hot air generation (Balasubramanian, 2007). The pictorial form of different unit operations in small scale cashew nut processing and different output finished material were presented in Fig. 2.

3.10. Energy consumption pattern in small scale cashew processing mills

3.10.1. Relationship between energy ($E_n$) and production ($P_r$)

The relationship between energy consumption and production based on actual raw material processed per annum was established. The variation of energy consumption ($E_n$/annum) with respect to production ($P_r$/annum) based on actual raw material processed during the last three year is shown in Fig. 3.

It was observed that, the energy consumption in the small scale cashew nut processing mills varied from 1898 MJ/kg to 34122 MJ/kg depending on the production capacity. The production capacity in term of raw material processed per annum was varied from 500 kg/yr to maximum as 15,000 kg/yr against the maximum installed capacity of 19,800 kg/yr.

The relationship between the variables $E_n$ and $P_r$ was established by using different statistical models depending upon the best fit (least error techniques) by using Curve-Expert 1.4 statistical tool. The statistical models with various coefficients to establish the relationship between energy and production in small scale cashew nut processing mills were summarized in Table 1.

The regression analysis of relationship between energy and production revealed the best fit of the form of power law i.e. $E_n = A \cdot (P_r)^B$ where “A” is the constant and the coefficient “B” is commonly known as the Energy Elasticity. The energy coefficient is expressed in terms of the proportionate change in energy ($E_n$) to the proportionate change in Production ($P_r$). The lower the value of “B”, the lower is the change in energy for the corresponding change in production. The value of the Energy coefficient “B” being less than one, which means d$E_n$/d$P_r$ declines sharply with increase in production in a cashew nut processing mill. This implies better utilization of the installed production capacity of boilers and driers.
The intra and inter variation in energy intensity among the cashew nut processing mills producing similar products revealed the extent of inefficient/efficient energy consumption. The regression analysis of relationship between energy intensity and production revealed the best fit of the form of power law i.e. $E_n = A \cdot (Pr)^B$. The negative exponent $B$ shows a decline in the value of energy intensity with increase in production. This again may be inferred, as the energy efficiency improves with better efficiency utilization of the installed production capacity.

### 3.10.3. Relationship between energy and percent production capacity utilization

The relationship between energy intensity ($E_I$) and percent production capacity utilization (PPCU) based on actual raw material processed per annum was established. The distribution of the small scale cashew nut processing mills in different PPCU range were summarized in Table 3. The variation of average energy intensity (MJ/kg) with respect to different percent production capacity utilization (%) range is shown in Fig. 5. It was observed that the frequency of the number of firms in each PPCU range is a bell-shaped curve, which clearly shows about 91 (75%) of the total samples were in PPCU range less than 65% with average energy intensity of 2.9 MJ/kg. This gives considerable scope for saving of energy with better utilization of installed production capacity in the tune of 25.84%. The average percent plant capacity utilization of small scale cashew nut processing mills was found to be 55% with average energy intensity of 2.74 MJ/kg. This revealed the overall scope for saving of 21.53% energy in the mills with better utilization of installed capacity.

The relationship between the variables energy intensity ($E_I$) and percent production capacity utilization (PPCU) was established by using different statistical models depending upon the best fit (least error techniques) and summarized in Table 4. The regression analysis of relationship between energy intensity and percent production capacity utilization revealed the best fit of the form of power law i.e. $E_n = A \cdot (PPCU)^B$. The negative exponent $B$ shows a decline in the value of energy intensity with increase in percent production capacity utilization. This again may be inferred, as the energy efficiency improves with better efficiency utilization of the installed production capacity.

### Table 2

Regression analysis of energy intensity and production in small scale cashew nut mills.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Model</th>
<th>Equation</th>
<th>Coefficients</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Linear</td>
<td>$E_I = A + B(Pr)$</td>
<td>3.235</td>
<td>0.465</td>
</tr>
<tr>
<td>2</td>
<td>Quadratic</td>
<td>$E_I = A + B(Pr) + C(Pr)^2$</td>
<td>3.592</td>
<td>0.567</td>
</tr>
<tr>
<td>3</td>
<td>Exponential</td>
<td>$E_I = A e^{B(Pr)}$</td>
<td>3.2116</td>
<td>0.492</td>
</tr>
<tr>
<td>4</td>
<td>Power law</td>
<td>$E_I = A + (Pr)^B$</td>
<td>10.47</td>
<td>0.612</td>
</tr>
</tbody>
</table>

### Table 3

Distribution of sscp mills in different PPCU range.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>PPCU range</th>
<th>No. of mills (%)</th>
<th>Energy intensity, MJ/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25–35%</td>
<td>09 (7.4%)</td>
<td>3.19</td>
</tr>
<tr>
<td>2</td>
<td>36–45%</td>
<td>25 (20.5%)</td>
<td>3.05</td>
</tr>
<tr>
<td>3</td>
<td>46–55%</td>
<td>30 (24.6%)</td>
<td>2.85</td>
</tr>
<tr>
<td>4</td>
<td>56–65%</td>
<td>27 (22.1%)</td>
<td>2.54</td>
</tr>
<tr>
<td>5</td>
<td>66–75%</td>
<td>25 (20.5%)</td>
<td>2.44</td>
</tr>
<tr>
<td>6</td>
<td>76–85%</td>
<td>06 (4.9%)</td>
<td>2.40</td>
</tr>
<tr>
<td>Avg</td>
<td></td>
<td>122 (100%)</td>
<td>2.74</td>
</tr>
</tbody>
</table>

### Table 4

Regression analysis of energy intensity and % plant capacity utilization.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Model</th>
<th>Equation</th>
<th>Coefficients</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Linear</td>
<td>$E_I = A + B(PPCU)$</td>
<td>3.353</td>
<td>0.954</td>
</tr>
<tr>
<td>2</td>
<td>Quadratic</td>
<td>$E_I = A + B(PPCU) + C(PPCU)^2$</td>
<td>3.497</td>
<td>0.950</td>
</tr>
<tr>
<td>3</td>
<td>Exponential</td>
<td>$E_I = A e^{B(PPCU)}$</td>
<td>3.401</td>
<td>0.957</td>
</tr>
<tr>
<td>4</td>
<td>Power law</td>
<td>$E_I = A + (PPCU)^B$</td>
<td>3.303</td>
<td>0.969</td>
</tr>
</tbody>
</table>
4. Conclusion

The cashew mill in India employed different unit operations/methodology for processing depends on variety of raw material, location, technological mechanization and availability of secured energy supply. The analysis of the data recorded during the survey of small scale cashew nut processing mills in the study area revealed the better correlation between the various variables like energy, energy intensity and percent production capacity utilization. The variation in energy intensity revealed the scope for the saving of the energy in the mills. The result obtained from the survey data and analysis were showed the similar trends with the published result of earlier studies reported by Ramachandra (1998) and Ramachandra and Subramanian (1987).

References


