Research Article

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# Comparative performance of mechanised peeling machines for unpeeled cashew kernels – A case study

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## Abstract

Mechanization of cashewnut processing in India has become inevitable due to growing problem of non-availability of work force at various stages of processing. Peeling is the process of removing the outer skin called testa to obtain edible kernels. Traditionally, shelled kernels were peeled manually using wooden pellets or knives after drying. Qualitative and quantitative efficiency vary depending on the skill of labour involved in the operation. Mechanized peeling machines were introduced in the Indian cashew processing system for twin reasons, to tackle the problem of labour shortage and to enhance rate of production. This study deals about the performance of three different mechanised peeling machines *viz*., shear type, brush type and abrasion type available in the line of processing in terms of operational capacity, peeling efficiency and whole kernel recovery. Operational capacity found to be in the range of 108 to 332 kg $h^{-1}$ for the type of peeling machines and origin of the cashewnuts. Variation in the adherence of testa with the kernel after pre-treatment would be the key factor influencing the operation capacity with respect to different origin of cashewnuts considered. Mean values of whole kernel recovery (70.1) and peeling efficiency (79.1) recorded for shear type peeling machine and raw cashewnuts obtained from Maharashtra were found to be higher than all other trials. Whole kernels obtained at the end of peeling process were higher during the first pass than the second pass. Possibly, the forces *viz.* impact or shear or abrasion force depending on the type of peeling machine, acted on these kernels during first pass, once again applied with the same intensity during second pass resulted in a marginal reduction in the whole kernel recovery. The performance parameters such as operational capacity, whole kernel recovery and peeling efficiency were found to be non-significant among the machines considered for the present investigation. Besides, cost economics was worked out and compared with existing manual peeling process. Increase in the net benefit was 53.9, 68.4 and 47.4 per cent respectively for shear, brush and abrasion type mechanical peeling machines.

*Keywords:* Cashew, mechanized peeling, operational capacity

## Introduction

Cashew (*Anacardium occidentale* L.) is considered as a highly commercial and economical crop in India. About 48 per cent of global production of cashew is processed in this country contributing 1.5 per cent of export earnings. Various unit operations in the line of processing are nut conditioning, shelling, peeling, kernel drying, peeling and grading (Ohler, 1964). Majority of cashewnut processing units situated in Karnataka, Goa and Maharashtra follows steam treatment for nut conditioning prior to extraction of edible kernels (Balasubramanian, 2000). Cashew kernel obtained through steam treatment is preferred due to its better surface colour and this process contributes additional income through a by-product called cashew nut shell liquid (CNSL). Presently, cashew processing sector is facing the problem of non-availability of skilled personnel at different stages of processing and hence gradually progressing towards mechanization. Production of whole kernels is the ultimate aim in processing as it fetches premium price at consumer level. Process of peeling plays a key role in the development of cashewnut processing industry. Peeled cashew kernels provide convenience as well as opportunity for value added products and for expansion of market for better utilization. It is important to consider peeling

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efficiency and whole kernel recovery while adopting peeling technologies. Hence, an analysis on the performance of the commercially available peeling machines was done and the results are discussed.

## Materials and methods

### Sample preparation

Raw cashewnut obtained from three different origins *viz*., Maharashtra ($O_1$), Kerala ($O_2$) and Tanzania ($O_3$) were used for evaluating the performance of mechanised peeling machines. Cleaned raw cashewnuts were exposed to externally generated steam using steam boiler (320 kg capacity per batch) for 14 min. Nuts were dried in ambient condition for 12 to 14 h to make it hard and brittle following steam treatment. Semi-mechanised shelling gadget was used to liberate cashew kernels from steam treated nuts. Broken, slit and spoiled kernels were discarded from the shelled kernels and exposed to hot air maintained at a temperature of 80±2 ºC for 4 h inside brick constructed dryer provided with thermal insulation. Hot air supply to dryer was suspended after 4 h and unpeeled kernels were allowed for differential heating for another 10 h for tempering process. Dried kernels, thus obtained from dryer were used for peeling *i.e.* removal of kernel outer skin called testa, using various types of mechanised peeling machines under investigation.

### Moisture determination

Moisture content of unpeeled kernels used for mechanical peeling was determined following chemical distillation method and its value was expressed in dry basis (% d.b) as given below (Okwelogu *et al.,* 1969).

$$M_w = \frac{V}{W} \quad (1)$$

$$M_d = \frac{100-M_w}{M_w} \times 100 \quad (2)$$

Where,

$M_w$ is moisture content wet basis (%)

V is the volume of water collected during toluene distillation (mL)

W is the weight of raw cashewnuts taken for toluene distillation (g)

$M_d$ is moisture content in dry basis (%).

### Operation of mechanised peeling machines

Various components of impact and shear type peeling machine ($M_1$) are feed hopper, bucket elevator, revolving perforated drum, pneumatic peeling system and rotary kernel grader (Fig. 1). Dried and unpeeled cashew kernels were humidified to enhance its moisture content to 3.6% d.b suitable for the peeling operation. Vibrating feeder transferred a quantity of unpeeled cashew kernels to the horizontal peeling drum through bucket elevator. Centre shaft was fixed offset to centre of the perforated drum and revolved in opposite direction. Kernels passing through clearance between centre shaft and the perforated drum were subjected to impact and shear force by numerous spring loaded hook like structure mounted on the periphery of the centre shaft. During the process fracturing of testa took place and kernels with loose testa were conveyed to pneumatic system wherein high pressure air removed testa layer completely. Later, whole kernel (unpeeled and peeled), broken kernels and remaining testa were segregated in rotary sieve grader and collected in different outlets.

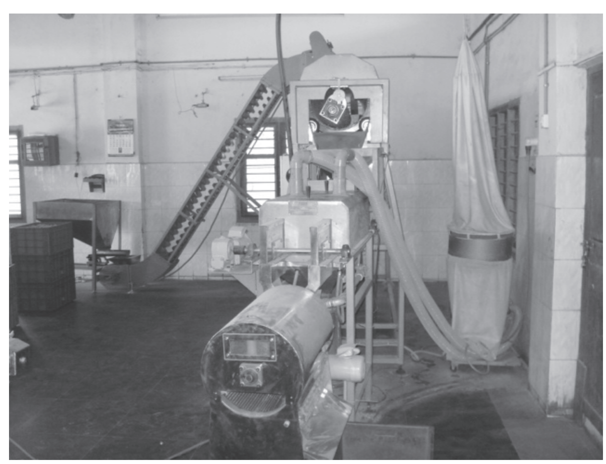

**Fig. 1. Impact and shear type peeling machine**

Figure 2 represents brush type peeling machine ($M_2$) which consisted of peeling chamber, aspirator and rotary sieve grader. As steaming of

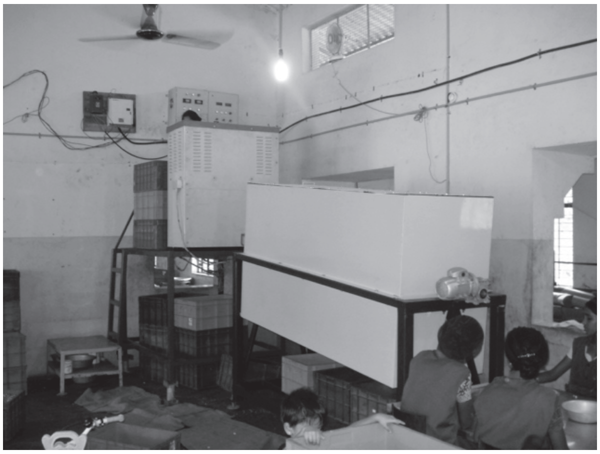

**Fig. 2. Brush type mechanised peeling machine**

unpeeled cashew kernels was the prerequisite for the peeling process using this machine, dried and unpeeled cashew kernels were exposed to externally generated steam at a pressure of 5.2 kg $cm^{-2}$ in a cubical chamber developed for the purpose for 6 min. Steam treated and unpeeled cashew kernels after drying in cross flow dryer at 75 °C for 2 h were used for peeling process in brush type peeling machine. Unpeeled cashew kernels, thus obtained were fed into the peeling chamber through inlet at the top and it passed through the clearance between two rollers having bristles on its periphery. Rollers fixed against each other revolve in opposite direction and three sets of such rollers were fixed one below another facilitating easy movement of unpeeled kernel. The layer surrounding cashew kernels (testa) were peeled off by shear and aspirated through pneumatic assembly provided at the base of machine. Afterwards, peeled and unpeeled kernels were conveyed to sieve grader by gravity wherein remaining testa, broken kernels and whole kernels were separated in different outlets.

Abrasive type peeling machine ($M_3$) shown in Fig. 3 has feed hopper, conveyor, peeling drums, compressor and rotary sieve grader. Dried unpeeled kernels were subjected to humidified environment for 10 to 12 h to increase the moisture content of the unpeeled kernels for better peeling process. During peeling operation, unpeeled and humidified kernels were subjected to abrasion against inner drum surface. High pressure air supplied by

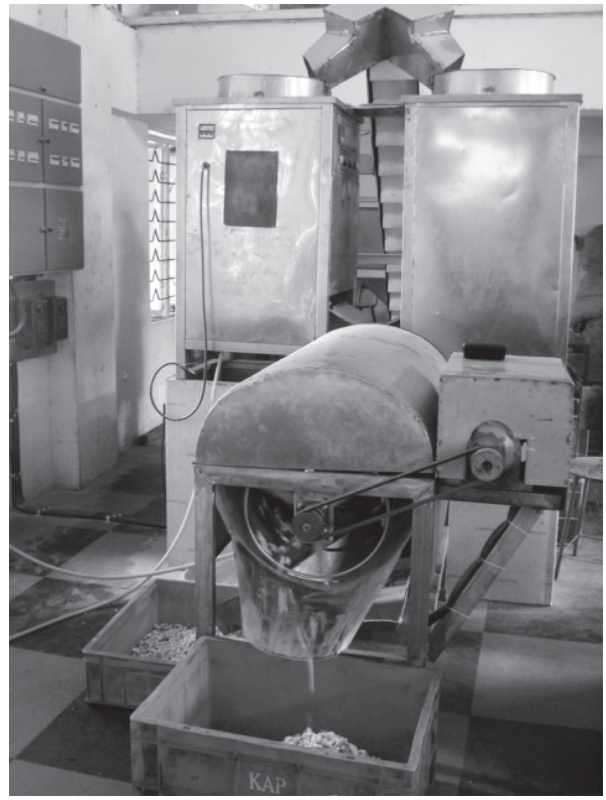


**Fig. 3. Abrasive type mechanized peeler**

compressor aided in removal of loosened testa. Peeled and unpeeled kernels were conveyed to rotary grader by gravity at the end of each batch whereas light weight testa was aspirated to separate outlet.

## Performance of peeling machines

In order to assess the performance of the peeling machine considered *viz*., shear type ($M_1$), brush type ($M_2$) and abrasive type ($M_3$), about 50 kg of pre-treated unpeeled cashew kernels *i.e.* steam treated for $M_1$ and humidified kernels for $M_2$ and $M_3$ were loaded in the machine ($1^{st}$ pass). Time taken for peeling the given quantity of unpeeled cashew kernels was noted. Products obtained in different outlet were segregated into various fractions *viz.* whole kernel (completely peeled), whole kernel (unpeeled and partially peeled), broken kernel (peeled), broken kernel (unpeeled and partially peeled) and husk (kernel testa) manually and weighed. Segregated unpeeled and partially peeled whole kernels were once again fed into the mechanised peeling machines

($2^{nd}$ pass) for peeling process and various fractions obtained at different product outlets were recorded. Performance of the mechanised peeling machine was assessed in terms operational capacity, peeling efficiency and whole kernel recovery as given below.

$$C = \frac{q}{t} \qquad (3)$$

Where,

C is the operational capacity of the machine (kg $hr^{-1}$); q is the total quantity of cashew kernel peeled (kg) and t is the time taken for peeling given quantity (h).

$$\eta_p = \frac{1-q_u}{1-q_r} \times 100 \qquad (4)$$

Where,

$\eta_p$ is the peeling efficiency of the machine; $q_u$ is the quantity of unpeeled kernels collected (%) and $q_r$ is the quantity of spoiled kernels collected (%).

$$q_{wk} = \frac{q_{pk}}{q} \times 100 \qquad (5)$$

Where,

$q_{wk}$ is the whole kernel recovered after peeling (kg); $q_{pk}$ is the completely peeled whole kernel after peeling (kg) and q is the total quantity of cashew kernel fed (kg).

Data obtained for processing parameters in various experiments were analysed using SAS statistical program and results are presented in Table 1.

## Results and discussion

Performance of mechanized peeling machines *viz.,* shear type peeling machine ($M_1$), brush type peeling machine ($M_2$) and abrasive type peeling machine ($M_3$) were evaluated in terms of operational capacity, whole kernel recovery and peeling efficiency. Cost economics was also worked out for the mechanical peeling and compared to manual process.

### Operational capacity

Average capacity of peeling pre treated cashew kernels by various machines *i.e.* $M_1$, $M_2$ and $M_3$ were found out to be 237.0, 229.7 and 212.4 kg $h^{-1}$ respectively (Table 1). There was no significant difference between $M_1$ and $M_2$, but varied from values of $M_3$. Conditioning of unpeeled cashew kernels could be the major factor for effective peeling in $M_1$ and $M_2$ machines used. Operational capacity was found to be non-significant for the origin of cashewnuts is in different mode of peeling machines investigated. Variation in the adherence of testa with the kernel after pre treatment would be the factor influencing the operation capacity with respect to different origin considered for the present study.

### Whole kernel recovery

Whole kernel recovery in cashewnut processing is defined as the ratio between quantity of completely peeled kernel after peeling process and the total quantity of unpeeled kernels devoid of spoiled kernels. On an average, whole kernel recovered after peeling process using $M_1$, $M_2$ and $M_3$ were worked out to be 79.1, 75.5 and 70.8 per cent for the first pass and 69.4, 66.0 and 64.3 per cent after the second pass respectively. It clearly indicated that whole kernels obtained at the end of peeling process were higher during the first pass. Possibly, the forces *viz.,* impact or shear or abrasion force depending on the type of peeling machine, acted on these kernels during first pass, when applied with the same intensity during second pass resulted in a marginal reduction in the whole kernel recovery. Therefore, amount of load applied during peeling process and condition of unpeeled kernel at the time of peeling are the decisive factors to obtain whole kernels recovery at the end of process. Values of whole kernel recovery for $O_3$ were found to be highly significant with $O_1$ and $O_2$ irrespective of type of peeling machines and number of passes. Initial moisture content of the unpeeled cashew kernels and adherence of testa were major contributing factors. Whole kernel recovery recorded a higher value of 84.8 per cent after first pass for $M_1O_1$ and lower value for $M_3O_3$ (60.8 per cent) after second pass.

Table 1. Mean of various performance parameters related to mechanized peeling machines

| Performance parameters | Peeling efficiency (%) | | | | | | | | Whole kernel recovery (%) | | | | | | | | Operational capacity (kg $h^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Peeling methods (M) | 1st pass (%) | | | Mean | 2nd pass (%) | | | Mean | 1st pass (%) | | | Mean | 2nd pass (%) | | | Mean | | | | Mean |
| Origin of raw cashewnuts | $O_1$ | $O_2$ | $O_3$ | | $O_1$ | $O_2$ | $O_3$ | | $O_1$ | $O_2$ | $O_3$ | | $O_1$ | $O_2$ | $O_3$ | | $O_1$ | $O_2$ | $O_3$ | |
| $M_1$ (Shear type) | 77.5 | 75.4 | 57.4 | 70.1 | 65.8 | 61.9 | 46.8 | 58.1 | 84.8 | 80.7 | 71.9 | 79.1 | 73.9 | 71.1 | 63.2 | 69.4 | 250.0 | 332.0 | 120.1 | 237.0 |
| $M_2$ (Brush type) | 72.4 | 71.1 | 55.0 | 66.1 | 63.3 | 60.2 | 44.9 | 56.1 | 79.9 | 78.5 | 68.1 | 75.5 | 69.9 | 68.1 | 59.9 | 66.0 | 247.1 | 327.7 | 114.3 | 229.7 |
| $M_3$ (Abrasion type) | 64.4 | 62.9 | 49.5 | 59.0 | 55.0 | 51.5 | 37.4 | 48.0 | 73.5 | 72.1 | 66.7 | 70.8 | 68.1 | 65.7 | 59.2 | 64.3 | 222.4 | 306.3 | 108.4 | 212.4 |
| Mean | 71.4 | 69.8 | 54.0 | | 61.4 | 57.8 | 43.0 | | 79.4 | 77.1 | 68.9 | | 70.6 | 68.3 | 60.8 | | 242.8 | 322.0 | 114.3 | |
| Sources | | M | O | M x O | | M | O | M x O | | M | O | M x O | | M | O | M x O | | M | O | M x O |
| LSD (0.05) | | 4.9 | 4.9 | NS | | 3.6 | 3.6 | NS | | 5.3 | 5.3 | NS | | 3.8 | 3.8 | NS | | 14.1 | 14.1 | NS |

Table 2. Comparative cost economics of various peeling systems

**Assumptions**

| | | | | | |
|---|---|---|---|---|---|
| Average peeling capacity per head per day (kg) | : | 11.20 | Repair and maintenance cost (%) | : | 5.00 |
| Electrical cost per unit (₹) | : | 6.50 | Average price of whole kernels (₹) | : | 408.00 |
| Wages for peeling per hr (₹) | : | 16.80 | Average price of broken kernels (₹) | : | 263.00 |

| | Production day$^{-1}$(kg) | Peeling output (%) | | Production cost (₹) | | Gain over manual peeling (%) | Sales realization (₹) | | Loss over sales realized (%) | Net benefit per day (₹) | % increase over manual peeling |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Whole | Broken | Manual | Mechanical | | Manual* | Mechanical | | | |
| Shear type ($M_1$) | 237 | 70.1 | 18.8 | 20191 | 3604 | 82 | 36706 | 33523 | 8.7 | 19770 | 53.9 |
| Brush type ($M_2$) | 230 | 66.1 | 19.5 | 22096 | 1608 | 93 | 36706 | 32088 | 12.6 | 25107 | 68.4 |
| Abrasion type ($M_3$) | 212 | 59.0 | 26.0 | 14257 | 2682 | 81 | 36706 | 30884 | 15.9 | 17397 | 47.4 |

*Includes dearness allowance of ₹ 58.50 per day per person; **Whole and broken kernel obtained in manual peeling are 79.8 % and 15.8 % respectively

### Peeling efficiency

Ratio between completely peeled kernels and the total unpeeled kernels devoid of spoiled kernels, gives peeling efficiency of the peeling system. The mean values of peeling efficiency for the various peeling machines with respect to three different origin of raw cashewnuts used for the study is given in the Table 1. Peeling efficiency of $M_1$, $M_2$ and $M_3$ were worked out to be 79.1, 75.5, 70.8 per cent after the first pass and 69.4, 66.0 and 64.3 per cent at the end of second pass respectively, indicating there was no significant difference among the machines used for peeling. In the case of origin of cashewnuts used as raw material, peeling efficiency resulted 79.4, 77.1, 68.9 and 70.6, 68.3 and 60.8 after first and second pass for the corresponding peeling machines. Data on unpeeled cashew kernels after peeling process using various mechanized machines clearly indicated that adherence of testa would be the cause for the variation in the peeling efficiency for $O_3$ than $O_1$ and $O_2$. Moisture content of the unpeeled cashew kernels before peeling process needs to be adjusted to suit for the given peeling machines for better performance.

### Cost economics of peeling process

Cost economics of various peeling machines *viz.,* shear type peeling machine ($M_1$), brush type peeling machine ($M_2$) and abrasive type peeling machine ($M_3$) were worked out based on certain assumptions and compared with existing method of manual peeling (Table 2). There was a substantial gain of ₹ 16,587, ₹ 20488 and ₹11575 over manual peeling process as for as production cost per day is concerned for the peeling machines $M_1$, $M_2$, and $M_3$ respectively which was equivalent to 82.1, 92.7 and 81.2 per cent higher than the production cost involved in manual system. Increase in the operational capacity contributed to the gain over existing manual process. But sales realization indicated that peeling kernels using mechanised machines incurred loss of 8.7, 12.6 and 15.9 per cent respectively for $M_1$, $M_2$ and $M_3$ in comparison to manual peeling due to increased broken kernels. Comparative cost economics revealed that net benefit recorded 53.9, 68.4 and 47.4 per cent for

**Table 3. Basic details of the mechanised peeling machines**

| Peeling machine type | Cost (in lakh ₹) | Floor space requirement ($m^3$) | Power requirement (KWH) |
|---|---|---|---|
| Shear type ($M_1$) | 5.8 | 9.5 x 10.0 x 2.7 | 44.0 |
| Brush type ($M_2$) | 11.1 | 3.0 x 1.5 x 2.7 | 5.1 |
| Abrasion type ($M_3$) | 28.5 | 4.8 x 1.5 x 2.4 | 12.6 |

Cost indicated w.r.t year 2010

$M_1$, $M_2$ and $M_3$ respectively higher than manual peeling. Indicative price, floor space and electric supply requirement are presented in Table 3. Variation in the net gain irrespective of machines followed depends on the speculative price of cashew kernels in the market.

## Conclusions

Operational capacity of various peeling machines considered for the study varied between 108 to 332 $h^{-1}$ for the raw cashewnuts obtained from three different origin *viz.,* Maharashtra, Kerala and Tanzania were found to be non significant. Nut parameters *viz.,* moisture content of unpeeled kernels and adherence of testa surrounding edible kernels were the major factors influencing the performance of the machines.

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