Performance evaluation of mechanized shelling machine for steam treated raw cashewnuts

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Abstract

Shelling is the process of extracting edible cashew kernel from pre-treated raw cashewnuts. Manual cracking of drum roasted nuts using mallet is the oldest method followed in India. A hand-cum-pedal operated shelling gadget is predominantly used for extraction of cashew kernel from steam treated nuts. Extraction of whole kernels is the ultimate aim in cashewnut processing as it fetches premium price in the market. About 13.39 lakh MT of raw cashewnuts were processed in the cashew processing facility developed in India during the year 2010-11. In order to overcome the problem of labour scarcity, mechanized shelling machine is introduced in processing for cashew. In this study performance of the mechanized shelling machine in terms of operational capacity, shelling efficiency, whole kernel recovery and kernel intact were analysed. Shelling was performed in three different modes *viz*., manual, mechanical (Auto Feed) and mechanical (Manual Feed) and compared. On an average operational capacity was found to be 8.07, 11.39 and 9.25 kg h^{-1} irrespective of the size of the nuts for three different methods of shelling investigated. Time taken to manipulate the size, proper positioning of nut and application of force to penetrate the blades in to the shell without damaging the kernel are the major factors influencing the manual shelling process. Channel design to position the nuts and precise adjustments of shoe movement for shelling are the principal reasons for increased operational capacity. Although whole kernel recovery found to be non-significant, Mechanical (Manual Feed) showed better results (95.63%) than other two methods employed. Manual system showed better shelling efficiency due to constant attention of person operating with the shelling unit. Mechanical system recorded 18.98 per cent of kernel intact which is 37.9 per cent lower than manual method. Cost of production reveals that mechanical system is 5.16 times superior to manual method of shelling.

Keywords: Cashewnut, processing, mechanized shelling, whole kernel recovery

Introduction

Manual cracking of roasted cashewnuts was the earliest method practiced in India. Considerable skill is required for cracking the nuts with a wooden mallet without damaging the kernel. The out-turn of the whole kernel by an experienced person was about 70 to 85 per cent (Ohler, 1966). Hall (1965) carried out the first experiment on cashewnut shelling using a concave knife edge attached to one arm of a welding clamp and a short, thick, knife edged wedge attached to the other arm. Although this method was simple and easy to operate, setting the minimum separation of the jaws of the welding clamp according to the thickness of each nut was the major disadvantage. In a further series of experiments, the hand lever operation was converted to foot operation leaving both hands free, one for the transfer and locate the nut and the other for the adjustment of the pillar height to suit the size of the nut.

The shelling device developed by Tropical Product Institute (TPI) followed cutting and sawing mechanism with an outturn of 76 per cent whole kernels and capacity of 11.5 kg kernels per day. In oltremare system, the shells were cut longitudinally and separated by a pair of gripers freeing kernel with the out-turn of 80 per cent whole kernel (Hall and Banks, 1965).

In Vietnam, cutting system used two sets of blades kept in horizontal fashion. Initially, one pedal

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was pressed to move the blades towards each other to cut the shell and then the same blade is turned by about 30 to 40 degrees by pressing another pedal with other leg, Thus, even the plying open is performed by means of a pedal using the convex blade which is connected to the holder.

A total of 13.39 lakh MT of cashewnuts in shell were processed in India during the fiscal year 2010-11. In the line of processing, nuts are either heated with steam or roasted dry or in a bath of cashewnut shell liquid (CNSL) and dried in ambient environment to make the shell brittle and also to loosen the kernel from the inner surfaces of the pericarp during shelling. Preparation of cashew kernels for trade and export is an intricate procedure compared to that of other edible nuts. Raw nuts are pretreated (Drum roasting/ oil bath/ steam boiling) to facilitate cracking to liberate kernel or dried for shelling. Shelling has been the biggest problem in processing and the contributing factors are irregular shape of nut, brittle nature of kernel and the presence of CNSL as residue. In India, mechanical shelling was introduced recently to overcome the increasing problem of labour shortage and to improve the production capacity.

Thivavarnvongs *et al.* (1995) found out that the force required to crack treated nut was 20 kg while applying across the width of the nut and applied principle of press twist actions of the sheller's blade for developing semi-automatic sheller. The sheller resulted in whole kernel recovery of higher than 80 per cent and lowered possible machinery investment. Shelling efficiency of manually operated cashewnut decorticator having top blade assembly developed at the Kerala Agriculture University model (Bastian and Jacob, 1994) was 88 per cent whole kernels and the capacity was determined as 900 nuts hr^{-1}. A power-operated cashewnut sheller was developed based on the principles of compression and shear. Cam was used to transmit the mechanical energy to vertically reciprocating blade to cut open the shells in the power driven cashewnut detacher rated capacity of the sheller was observed to be 18 kg h^{-1} of roasted nuts with shelling efficiency of 70 per cent. The yields in terms of whole, half-splits and broken were 22 per cent and 28 per cent respectively (Anonymous, 2000). Mechanized shelling machine developed at Kollam, Kerala followed impact and shearing force to deshell the treated cashewnuts. Overall analysis indicates that shelling capacity of the machine was in the range of 12 to 32 kg hr^{-1} and shelling efficiency found to be in the range of 77 to 90 per cent (Pillai, 2009).

The principal constraints in developing mechanical devices for shelling cashewnuts are the tough and elastic nature of the outer shell wall and the peculiar shape of the cashewnut, where the curvature of the sides varies considerably with individual cashewnuts. Avoiding the contamination of kernel by the corrosive CNSL and minimizing kernel breakage are the two major considerations while shelling cashewnut (Balasubramanian, 2010). Therefore a study was carried out in order to assess the performance of mechanized shelling machine and compare the cost of production with existing shelling method.

Materials and methods

Raw cashewnuts were selected for the present study and exposed to steam using twin bottle type boiler of 320 kg per batch capacity for 12 min rising its pressure level to 5.2 kg cm^{-2}. Steamed nuts, thus obtained were dried in ambient condition for 12 to 14 h and used for all the experiments. Initially raw materials were fed into the shelling machine through feed hoppers attached to it. Nuts in the feed hopper were lifted up vertically by sliding component and transferred to shelling component (Mechanical – Auto feed). After positioning the nuts in the channel, nut was pressed down by a shoe against off-set blades provided on either side. Due to the application of high force, nuts slits around its contour and split open by the blades. Each shelling unit was provided with two such shelling mechanisms deriving mechanical power for its operation from 0.37 KW single phase electric motor (Fig. 1). After shelling a definite quantity of cashewnuts for a given period of time, various fractions *viz*., whole kernels, broken kernels, unshelled nuts, kernel intact *i.e.*, kernels not separated from shell halves, rejects and shells were separated manually and weighed.

Nuts were graded based on major axis dimension *viz*., large (>30 mm), medium (26 to 30 mm), small (<26 mm) and mixed size and used in all experiments to find out the influence of nut size on shelling efficiency. Moisture content of the steam

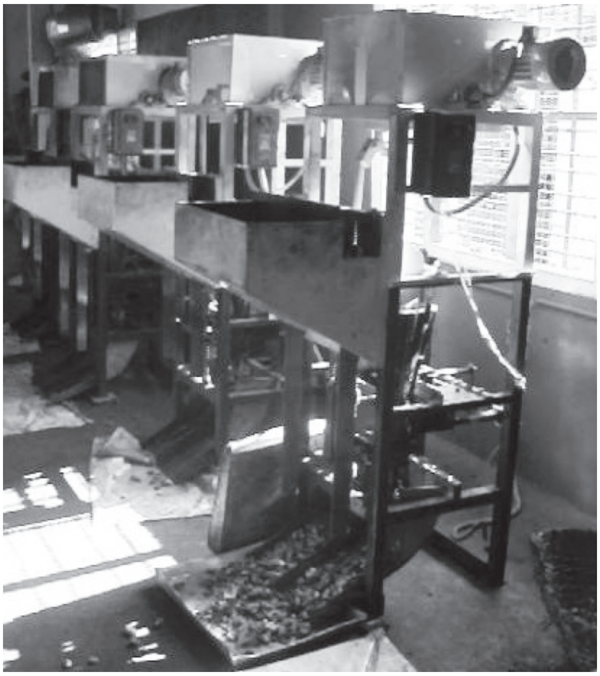

Fig. 1. Mechanised shelling machine for steamed cashew nuts

treated nuts was determined by chemical distillation method (Okwelogu and Mackay, 1969). Kernel intact with shells were extracted carefully and its fractions *viz*., whole, broken and shell were weighed to work out the shelling percentage. As the cashewnuts could not be fed continuously while conducting the trials with auto feed system, due to irregular shape of the cashewnuts, experiments were also conducted by feeding various grades of the nuts manually into the shelling component directly (Mechanical – Manual feed). Due care was taken while feeding the nuts so that only one nut reaches the channel for shelling at a time. Nut fractions collected at the outlet were weighed to work out the performance of the mechanized shelling machine in terms of operational capacity, shelling efficiency, whole kernel recovery and kernel intact using the formula given below. In the same manner, a specified quantity of pre treated raw cashewnuts were shelled manually using hand cum pedal operated shelling machine and various fractions of the output as mentioned were weighed for comparison.

Moisture determination

Moisture content of steamed raw cashewnuts used in mechanical shelling was determined following chemical distillation method and its value was expressed in per cent dry basis as given below.

$$M_w = \frac{v}{w} \quad .....(1)$$

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

Where,

M_w is moisture content wet basis, (%) v is the volume of water collected during toluene distillation, (mL) w is the weight of in-shell cashew nuts taken for toluene distillation, (gm) and M_d is moisture content in dry basis, (%)

Operational capacity

$$c = \frac{q_t}{t} \quad .....(3)$$

Where, c is the operational capacity of the shelling machine (kg hr^{-1}), q_t is the total quantity of steamed cashew nuts used for shelling (kg) and t is the time taken for shelling given quantity (hr)

Shelling efficiency

$$\eta_s = \frac{(1-q_{us})}{q_t} x100 \quad .....(4)$$

Where η_s is the shelling efficiency of the machine (%), q_t is the total quantity of steamed cashew nuts used for shelling (kg) and q_{us} is the total quantity of unshelled steamed cashewnuts (kg)

Whole kernel recovery

$$q_{wk} = \frac{q_{sk}}{q_k} \quad .....(5)$$

Where, q_{wk} is the whole kernel recovery after shelling (kg), q_{sk} is the whole kernel obtained after shelling (kg) and q_k is the total quantity of cashew kernel obtained after shelling (kg)

Kernel intact

$$KI = \frac{q_{ki}}{q_k} \ x\ 100 \quad .....(6)$$

Where, KI is the kernel intact (%), q_{ki} is the total quantity of kernel intact after shelling (kg) and

q_k is the total quantity of cashew kernel obtained after shelling (kg)

Data analysis was carried out using SAS statistical program and results are presented in Table 1.

Results and discussion

Comparative performance of mechanized shelling machine

Performance of mechanized shelling machine for steam treated raw cashewnuts was evaluated for its performance in terms of operational capacity, whole kernel recovery, shelling percentage and kernel intact and compared with existing manual shelling method.

Operational capacity

Operational capacity of manual, mechanical (Manual feed–MF) and mechanical (Auto feed–AF) were found to be in the range of 5.88 to 9.30, 8.38 to 14.52, 7.93 to 10.18 kg hr^{-1} for various size of nuts used in the investigation (Table 1). Although total number of nuts shelled in a given period remained same, variation in the shelling capacity is mainly due to weight of the nuts depending on the size. In the case of manual shelling, operator needs to manipulate the nut according to the size and apply the force. This application of force is limited in such a way that blades penetrate to the required depth without damaging the kernel inside the shell. As the shelling machine is operated in standing posture, operators experienced drudgery as the time elapsed, therefore the average capacity per labour recorded as 8.07 kg hr^{-1} which is lower than mechanical shelling. Degree of skill, condition of the shelling machine and proportion of various size in the given lot of nuts influences the operational capacity. In mechanized shelling machine, nuts were lifted one by one and transferred to the shelling channel. Operational capacity was varied according to the size and positioning of the nut during shelling process. When nuts were regulated by manual feed into the shelling channel, operation capacity increased by 41.13 per cent and 23.06 per cent over manual and mechanical shelling respectively,

Table 1. Mean of performance indicators of manual and mechanical shelling of cashewnuts

Method of shelling (M)	Size of raw cashewnuts (S)	Whole kernel recovery	Shelling efficiency (η)	Kernel intact %	Capacity
Manual	Large	83.84	100.00	22.63	9.30
	Medium	83.66	100.00	25.34	8.95
	Small	74.13	100.00	29.48	5.88
	Mixed	80.70	100.00	27.23	8.14
	Mean	80.58	100.00	26.17	8.07
Mechanical (MF)	Large	99.91	92.79	17.34	14.52
	Medium	98.50	93.19	19.05	11.44
	Small	88.25	87.59	19.45	8.38
	Mixed	95.84	93.61	17.13	11.21
	Mean	95.63	91.79	18.24	11.39
Mechanical (AF)	Large	99.88	88.42	15.80	10.18
	Medium	95.52	87.55	19.60	9.47
	Small	85.74	84.93	23.27	7.93
	Mixed	94.16	87.93	20.17	9.44
	Mean	93.83	87.21	19.71	9.25
Source	Method (M)	0.3125	1.63	1.18	1.31
LSD (P>0.05)	Size (S)	0.36	1.88	1.37	1.51
	M x S	S	NS	S	S

indicating that nut lifting mechanism needs refinement.

Whole kernel recovery

Ultimate aim in cashewnut processing is to extract whole kernels as it has strong bearing on the cost economics of processing. Pertinent data revealed that whole kernel recovery was found to be non-significant as far as mode of shelling adopted and nut size selected for the investigation. Positioning the nut in the channel before shelling decides whole kernel recovery. When the blade penetrates at the contour of the nut *i.e.* line connecting two halves of the shell, nut splitting will be better. Mechanical (MF) showed better results (95.63%) than other two methods *viz*., manual and mechanical (AF) employed. Shoe movement is precisely adjusted, ensuring nut passage in proper fashion when pressed against blades for splitting of shells. Lower whole kernel recovery in the case of manual shelling is due to mismatching of blade and contour of the nut.

Shelling efficiency and kernel intact

Shelling efficiency is the ratio of quantity of shelled nuts to the total quantity of nuts fed. As far as the shelling efficiency is concerned, manual method found to be higher than mechanical owing to constant attention of the personnel operating the shelling unit. Nuts after shelling had kernel intact with shell halves and requires extra labour to scoop out carefully to extract whole kernels incurring higher operational cost. Average value of kernel intact for manual and mechanical methods of shelling was worked out to be 26.17 and 18.98 per cent respectively. Significant difference in these two modes of shelling was mainly due to the positioning of nut and depth of blade penetration in to the shell.

Table 2. Comparative cost of production of shelling by manual and mechanical methods

Shelling method	Manual	Mechanical (AF)
Capacity per day (kg)	55	185
Whole kernel recovery (%)	90	95
Broken kernels (%)	9	4
Spoiled kernels (%)	1	1
Cost (₹)	202.32	131.90
Cost per kg (₹)	3.68	0.71
Benefit over manual system		5.16

Slit kernels ranges from 10 to 12 per cent in manual shelling
Kernel breakage is comparatively lower in mechanical shelling
Shelling work load is reduced to greater extent

Cost of production

Comparative cost of production of shelling steam treated nuts is given in Table 2. Accounting average value of whole kernel recovery for manual and mechanical mode of shelling, cost of production per day was worked out to be ₹ 202 and ₹ 132 respectively. Cost incurred for shelling revealed that mechanical method lead to 5.16 times lesser than manual method. Besides, it reduced the quantity of slit kernels after shelling to greater extent.

Conclusion

Average values of operational capacity for mechanical auto feed and manual feed was found to be 9.25 and 11.39 kg hr^{-1} which is 41 and 15 % higher than manual shelling process. Drudgery experienced during manual shelling and manipulation of nuts according to size of nut are the major reasons for the lower output. Shelling efficiency recorded maximum for mechanical (AF) *i.e.,* 95.63 per cent among the various methods of shelling investigated. Average value of kernel intact for manual and mechanical methods of shelling was observed to be 26.17 and 18.98 per cent respectively. Cost of production per day was worked out to be ₹ 202 and ₹ 132 for manual and mechanical shelling.

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