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DEVELOPMENT AND PERFORMANCE EVALUATION OF PLANTAIN PEELER CUM SLICER

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Abstract: Peeling and slicing of green mature plantains of *Nendran* variety is labour intensive and costly. Based on the physical and mechanical properties of green mature plantain the peeler cum slicer was developed. The peeling unit of the fabricated machine consists of feeding cylinders, peeling blades, conical throat and splitters. The green plantain fed into the feeding cylinder was pushed down by a pushing mechanism. Slicing unit consists of a cylindrical guide, slicing disc and blade. Slicing was achieved by rotating the disc at 300 min^{-1}. Average peeling efficiency and material loss were obtained at 88.94% and 13.69%, respectively. Diameter of feeding cylinder was significant at 1% (P<0.01) level for overall capacity of machine. The overall capacity, slicing efficiency and effective capacity of the plantain slicer was found to be 89.27 $kg \cdot h^{-1}$, 89.16 $kg \cdot h^{-1}$ and 79.59 $kg \cdot h^{-1}$, respectively. The capacity of the developed peeler cum slicer was four times higher than manual operation.

Key words*: peeler, slicer, banana, effective capacity, material loss*

INTRODUCTION

Fruits and vegetables play an important role in human diet and nutrition. They are indispensable sources of essential dietary nutrients, vitamins and minerals besides providing crude fiber. India is the largest producer of fruits and vegetables next to China. But due to lack of post harvest handling and processing facilities around 30% of the total production is lost every year [1]. The post harvest method need to develop to minimize the losses [2]. However, the thrust should be to process and convert such perishable

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commodities into value added products that can be stored for extended periods there by reducing losses and making them available through out the year.

Banana (*Musa paradisiaca*) is one of the oldest tropical fruits cultivated by man from prehistoric time in India with great socio-economic significance, interwoven in the cultural heritage of the country. It is the fourth important food crop in terms of gross value after paddy, wheat and milk products and forms an important crop for subsistence farmers. In Kerala banana is cultivated in the entire state and is an integral part of homestead farming system. It is a vegetable as well as fruit apart from being used for the preparation of various value added products. It provides a more balanced diet than any other fruit or vegetable. The green banana which becomes palatable after cooking is popularly referred as plantains, and is a staple food in coastal region of the country especially in Kerala, while the fresh fruit we consume is referred as dessert banana.

In India crop production has been steadily increasing due to advances in production technology, but improper post harvest handling and storage results for high losses [3]. Hence, the long-term objective of our country's economic development is a good balance between a strong industrial sector and a resilient agricultural sector. The development of micro, small and medium scale rural agro industry is seen as a strategic step towards achieving this goal. There are large numbers of micro and small scale food processing enterprises run by farmers, which produce a wide variety of processed foods. Processed foods or snack foods may be described as mini meals in between main meals. Snacks like banana chips light to eat and serve a variety of useful purposes in our day to day life. Banana chips making has already developed into a cottage and small scale industry in Kerala and the product is in high demand in India as well as abroad, especially in Middle East countries. The quality of the products can be monitored by online system with FT-NIR Spectroscopy [4]. There is great potential for this to be developed further, exploiting the domestic and fast increasing export demand.

Peeling and slicing of the well matured unripe plantain is a difficult operation for an unskilled person and also time consuming. Peeling is the removal of skin from green mature plantain. Slicing is carried out to reduce the size of product so as to enable it to suit the processing and consumer requirements. At present, peeling and slicing of plantain is done manually by stainless steel knives. This conventional method poses danger to operator's finger by inflicting injury. Frying quality of chips depends greatly on the uniformity of the wafers. The existing conventional method does not produce chips of uniform size. The output capacity of the system is less and the whole process is time consuming and labor intensive.

The knowledge of some important physical and mechanical properties of fruits is necessary for the design of various food processing equipments [5, 6]. In order to eliminate the drudgery involved in manual peeling, avoid injury to workers, increase efficiency and maintain high quality standards and hygiene to the prepared chips, an attempt was made at Kelappaji College of Agricultural Engineering and Technology, Tavanur to develop a plantain peeler cum slicer in terms of capacity, peeling efficiency and material loss.

MATERIAL AND METHODS

The plantain peeler cum slicer consists of feeding unit, peeling unit, pushing unit, collection unit, slicing unit and frame assembly as shown in Fig.1.

Feeding unit. The feeding unit consists of three cylindrical guides of different diameters placed 120° apart fixed to a sleeve using three equal length mild steel flats of 28×3.15×750 mm. A cylindrical sleeve of 48×34 mm (diameter × length) was mounted on 500 mm vertical pillar. The rotation of the cylindrical guide is possible by rotating the sleeve. Three stainless steel pipes of diameters 42, 47 and 54 mm, height 200 mm each and thickness 2 mm were used for the fabrication of cylindrical guide.

Peeling unit. It is the main unit of the peeler which separates the peel from the pulp. Three high carbon steel blades of width 25 mm were bent to form circular type openings of diameters 28, 32 and 37 mm for respective cylindrical guides through which plantain passes during the peeling operation. Each cylindrical guide was connected to a conical throat of 50 mm height and 60 mm base diameter using splitter blades. The peeling blades were welded over these conical throats. Three splitting blades of medium carbon steel with length 140 mm and thickness 1 mm was welded over each throat of the peeling unit to split the peel after the peeling operation.

Pushing unit. The main parts of pushing unit are piston, rack and pinion and ratchet and pawl. The lowering and lifting of the piston is done by this unit. Ratchet and pawl is a device consisting of a toothed wheel engaged with a pivoting, spring loaded finger called a pawl that permits it to move in one direction and preventing motion in opposite direction. The teeth are uniform, having a moderate slope on one edge and a much steeper slope on the other edge. When the wheel rotates in one direction, the pawl slides over the teeth, and in opposite rotation, it catches in the teeth. The rack is a flat, toothed part of 3 mm pitch and 300 mm long. The pinion was fitted with 18 teeth. It converts the applied rotary motion to linear motion. The upward and down ward motion of the piston inside the cylindrical guide was performed by these two mechanisms.

Collection unit. The collection unit consists of outlet chute and a collecting tray. The outlet chute was made of 16 gauge Galvanized Iron sheet with 45° inclination towards the horizontal to facilitate easy discharge. Collecting tray of 300x300x300 mm was made from Aluminium sheet of 1 mm thickness. The peeled plantain slides downward through the outlet chute into the collecting tray.

Slicing unit. Slicing unit consists of a cylindrical guide, slicing disc and blade. Peeled plantain was fed to the slicing unit through the cylindrical guide of 37 mm diameter and 150 mm length. About 40 x 15 mm stainless steel blade was mounted over

110 mm diameter disc of 1.8 mm thickness. Slicing was achieved by rotating the disc at 300 min^{-1}. The slicing unit was powered with 10 A, 12 VDC motor with 32 kg·cm^{-1} torque.

Frame assembly. The frame supports the entire machine component to perform its operation satisfactorily. It was fabricated using ISA 31x6.3 mm MS section. On the frame assembly, units like pushing unit, feeding unit, peeling unit, peeled plantain outlet and slicing unit were mounted.

Performance evaluation of peeling unit. Matured *Nendran* procured from the local market were used for conducting the experiment. The plantains were graded into three sets according to their size. The two ends of the matured plantain of *Nendran* variety were chopped off and then fed through the respective cylindrical guides of diameters 42, 47 and 54 mm. Peeling was achieved by the cutting action of the circular blade followed by splitting of the peels by the splitter. The peeled plantains falls down through the inner throat and collected in the collecting tray. The split peels slides through the outer conical throat were placed in the discard tray. The time required for operation was noted and the capacity was calculated. All the experiments were replicated five times and the average value was recorded. A comparison between manual and mechanical peeling was also carried out.

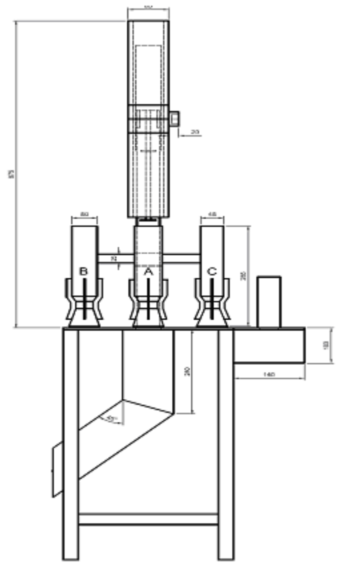

Figure 1. Plantain peeler cum slicer

Capacity. The capacity of the peeler which is the kilogram of peeled plantain produced by the machine in one hour was calculated by noting the weight of the peeled plantain produced and the time taken for the same. It was expressed in $kg \cdot h^{-1}$.

Peeling Efficiency. The initial weights of the different samples of plantain were taken. Then each sample was subjected to peeling action. After peeling, the weight of the peeled product and the peel obtained were noted. The peel remaining on the plantain was removed manually for each of the samples and the weights were noted. Peeling efficiency was then calculated using the formula [7].

$$Peeling\ efficiency = (X-Y) \times 100 / X \quad (1)$$

where:

X [g] - weight of the total peel,

Y [g] - weight of peel remaining on plantain to be removed manually after mechanical peeling.

Material loss. Material loss for each sample was calculated based on the following formula:

$$Material\ loss\ (\%) = Z / (W+Z) \quad (2)$$

where:
Z [g] - weight of flesh obtained from the peel,
W [g] - total weight of plantain after mechanical peeling.

Performance evaluation of slicing unit. The peeled samples were fed to the cylindrical guide of the slicing unit to achieve slicing operation. The slices were collected in a tray and kept below the blade set. The time required for the operation was noted and operating capacity, percentage damage and slicing efficiency was evaluated.

Overall Capacity. The operating capacity of the fabricated slicer was calculated by weighing all the cut slices irrespective of damage per unit time.

Slicing Efficiency. The efficiency of slicer was evaluated by weighing the damaged and round slices separately and using the expression [8].

$$Slicing\ Efficiency\ (\eta), \% = \frac{Weight\ of\ all\ slices - Weight\ of\ damaged\ slices}{Weight\ of\ all\ slices} \times 100 \quad (3)$$

Percentage damage. The percentage damage of the slicer was evaluated using the following expression:

$$\text{Percentage damage, } \% = \frac{\text{Weight of damaged slices}}{\text{Weight of all slices}} \times 100 \quad (4)$$

Effective capacity. The effective capacity found by using the expression [9].

$$Effective\ capacity = Overall\ capacity\ x\ \eta/100 \quad (5)$$

Statistical analysis. Data were analyzed using AGRES software. Data of experiment were analyzed by a randomized block design using factorial arrangements of treatments [10].

RESULTS AND DISCUSSION

Capacity. The capacity of the peeler for 42, 47 and 54 mm diameter feeding cylinder are presented in Tab 1. The over all capacity was found to be 34.21, 49.74 and 68.48 $kg \cdot h^{-1}$ for 42, 47 and 54 mm diameter cylindrical guides, respectively.

From the table, it was observed that the capacity of the machine increased with the diameter of feeding cylinder. Maximum capacity was obtained using 54 mm diameter cylindrical guide and minimum for 42 mm. This may be due to the size of the plantain increases with weight. But there is no significant change in time taken for peeling plantains through a single cylindrical guide.

The overall capacity were statistically analyzed and presented in Table 2. From the table, it was observed that the feeding cylinder diameter was significant at 1% ($P<0.01$) level.

Peeling efficiency. The peeling efficiency of the machine is presented in Fig.2. The average peeling efficiency of the machine using 42, 47 and 54 mm diameter feeding cylinder were obtained as 89.19, 88.27 and 89.37%, respectively.

From the results, it was revealed that there is no significant (P>0.01) variation in the efficiency of peeling operation (Tab. 2). For a particular cylindrical guide, peeling efficiency increases if the plantain correctly fits into the guide. Lower peeling efficiency was observed in plantains with slightly curved shape.

Material loss. The material loss or flesh loss of the plantain during mechanical peeling was found and presented in Fig. 2. It was revealed that, the material loss depends on the shape and size of the plantain. The percent material loss for 42, 47 and 54 mm cylinders were calculated as 13.27, 13.18 and 14.63% respectively. For a particular cylindrical guide, it was found that the percent material loss increases with weight of the plantain. This is due to the constant size of the peeling blade. From the Tab. 2, it was observed that feeding cylinder diameter was not significant (df=2; F=. 0.80) for material loss.

Table 1. Capacity of the peeler

Sl. no.	*Weight of peeled plantain [g]*	*Time taken for peeling [s]*	*Capacity of the developed peeler [kg·h^{-1}]*
42 mm diameter feeding cylinder			
1.	*117.27*	*14.05*	*30.04*
2.	*116.84*	*13.13*	*32.03*
3.	*114.31*	*10.25*	*40.14*
4.	*106.77*	*12.95*	*29.68*
5.	*112.83*	*10.37*	*39.16*
		Mean	*34.21*
47 mm diameter feeding cylinder			
6.	*148.07*	*11.27*	*47.29*
7.	*160.54*	*12.21*	*47.33*
8.	*149.64*	*10.42*	*51.69*
9.	*151.53*	*10.33*	*52.80*
10.	*147.42*	*10.70*	*49.59*
		Mean	*49.74*
54 mm diameter feeding cylinder			
11.	*221.49*	*13.45*	*59.28*
12.	*218.04*	*12.78*	*61.41*
13.	*229.28*	*10.53*	*78.38*
14.	*220.52*	*11.67*	*68.02*
15.	*225.45*	*10.77*	*75.35*
		Mean	*68.48*

Performance evaluation of slicing unit. The slicing unit was evaluated in terms of overall capacity, slicing efficiency and percent damage. Results are furnished in Tab. 3, 4 and 5 for overall capacity, slicing efficiency and percent damage, respectively.

The overall capacity, slicing efficiency, percentage damage and effective capacity of the plantain slicer were found to be 89.27 kg·h^{-1}, 89.16%, 10.82% and 79.59 kg·h^{-1} respectively.

Table 2. Analysis of variance for overall capacity, peeling efficiency and material loss

Variable	Capacity		Peeling efficiency		Material loss	
	df	F	df	F	df	F
Cylinder diameter	2	177.53**	2	0.1871NS	2	0.8020NS
Error	5.05		4.08		2.01	
Total	244.67		2.42		1.40	
SEd	1.83		1.65		1.15	
CV, %	4.46		2.26		10.25	

Table 3. Overall capacity of slicer

Sl. No.	Weight of peeled plantain [g]	Time taken for slicing [s]	Over all capacity [kg·h^{-1}]
1.	54.08	6.38	88.20
2.	51.34	5.47	89.34
3.	52.85	6.29	88.09
4.	45.94	4.8	89.55
5.	45.2	3.99	91.17
		Mean	89.27

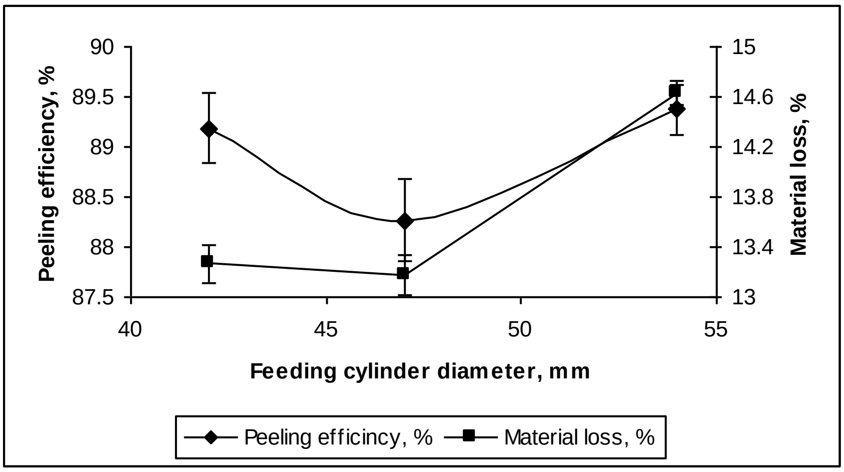

Figure 2. Effect of feeding cylinder diameter on peeling efficiency and material loss

Table 4. Efficiency of slicer

Sl. No.	Weight of all slices [g]	Weight of damaged slices [g]	Efficiency [%]
1.	323.03	29.47	90.87
2.	260.45	28.61	89.01
3.	340.65	37.55	88.97
4.	345.79	39.41	88.60
5.	350.95	40.74	88.39
		Mean	89.16

Table 5. Percentage damage of the slicer

Sl. No.	*Weight of all slices [g]*	*Weight of damaged slices [g]*	*Percentage damage [%]*
1.	*323.03*	*29.47*	*9.12*
2.	*260.45*	*28.61*	*10.98*
3.	*340.65*	*37.55*	*11.02*
4.	*345.79*	*39.41*	*11.39*
5.	*350.95*	*40.74*	*11.60*
		Mean	*10.82*

Comparative evaluation of manual and mechanical peeling cum slicing operation. As illustrated in Tab. 6 results of manual peeling indicates that a skilled labour can peel 14.8 kg plantains per hour and slice 18.52 kg·h^{-1}. Under the same conditions, the fabricated peeler could peel 48.9 kg·h^{-1} and slice 89.63 kg·h^{-1}. The peeling and slicing capacity of the fabricated machine is found to be four times more effective than manual peeling and slicing. Besides, peeling and slicing efficiency is high. Also, even and more uniform slices can be obtained by the fabricated machine. The machine eliminates the drudgery involved in manual peeling and slicing operations and save time. The machine is simple in construction and operation and required only one person to operate it.

Table 6. Comparison of manual and mechanical peeling cum slicing operation

Sl No.	*Time required for peeling of one sample [s]*		*Time required for slicing of one sample [s]*	
	Manual	*Mechanical feeling using 47 mm feeding cylinder*	*Manual*	*Mechanical*
1.	*36.5*	*11.4*	*29.8*	*6.8*
2.	*35.9*	*10.7*	*28.5*	*5.2*
3.	*36.0*	*10.9*	*28.8*	*5.7*
4.	*36.2*	*11.2*	*29.5*	*6.4*

CONCLUSIONS

In India, the peeling and slicing of plantain is carried out manually and no means of mechanical peeling and slicing device has been commercialized. The conventional method of peeling and slicing is done by using stainless steel knives. This poses danger to operator's finger by inflicting injury and also does not produce chips of uniform size. Peeling was achieved by the cutting action of the circular shaped blade that would force the peel from the plantain as it passes through the mechanism. The slicing unit was powered with 10 A, 12 VDC motor with 32 kg·cm^{-1} torque. The actual capacity of the peeling unit was calculated as 18.54, 25.98 and 36.87 kg·h^{-1} respectively for small, medium and large sized plantains. The machine eliminates the drudgery involved in manual peeling and slicing operations and save the time as compared to conventional method.

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RAZVOJ I OCENA KARAKTERISTIKA MAŠINE ZA LJUŠTENJE I REZANJE

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Sažetak: Ljuštenje i rezanje zelenih zrelih banana varijeteta *Nendran* je veoma intenzivan i skup postupak, Na osnovu fizičkih i mehaničkih osobina zelenih zrelih banana razvijena je mašina za ljuštenje i rezanje. Jedinica za ljuštenje ove mašine se sastoji od dostavljačkih cilindara, noževa za ljuštenje, konusnog grla i razdeljivača. Zelene banana se ubacuju u privodni cilindar i guračem potiskuju dole. Rezni uređaj se sastoji od cilindrične vođice, režućeg diska i noža. Rezanje se postiže rotacijom diska sa 300 min^{-1}. Srednja efikasnost ljuštenja i gubici materijala su iznosili 88.94% i 13.69%, redom. Uticaj prečnika privodnog cilindra bio je značajan na nivou 1% (P<0.01) za ukupni kapacitet mašine. Ukupni kapacitet, efikasnost sečenja i efektivni kapacitet sekača iznosili su 89.27 kg·h^{-1}, 89.16 kg·h^{-1} i 79.59 kg·h^{-1}, redom.

Ključne reči: *ljuštenje, rezanje, banana, efektivni kapacitet, gubici*

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