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Development of a hand operated diamond cut mesh drum abrasive ginger peeler

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Abstract

Peeling of fresh ginger is an important operation done before drying to enhance the drying process and is generally done manually. A mechanical ginger peeler was developed with its peeling drum made of diamond cut mesh. Peeling trials were conducted for varying drum loads (5 kg, 6 kg and 7 kg), for varying drum speeds (20 rpm, 25 rpm and 30 rpm) and for different peeling durations (5 m, 10 m and 15 m) to determine the peeling efficiency and material loss in the developed peeler. It was found that peeling of ginger was associated with the material loss. The optimum machine parameters for maximum peeling with minimum loss was obtained at a drum load of 7 kg per batch, operated at a drum speed of 30 rpm for a peeling duration of 15 min, to produce sufficiently peeled ginger. The peeling efficiency and material loss at the optimum conditions were determined as 59.43% and 4.76%, respectively. The ginger obtained after mechanical peeling was dried and the quality was determined. It was found to have essential oil of 2.0%, oleoresin of 4.6%, moisture content of 9.82% and crude fibre content of 2.5%.

Keywords: ginger, material loss, mechanical peeling, peeling efficiency, quality

Introduction

Ginger, the rhizome of *Zingiber officinale* Roscoe is one of the most widely used spices of the family *Zingiberaceae*. In the process of preparing dry ginger, peeling is considered to be the most laborious and important pre processing operation which needs to be done immediately after harvest. This is done manually in almost all the regions producing dry ginger. Fully matured fresh ginger after eight months of planting is used for preparing dry ginger. The rhizomes after surface cleaning are subjected to peeling which is done manually by using bamboo splits having pointed ends to remove the outer skin. The peeled rhizomes are washed before drying. The dry ginger so obtained is valued for its aroma, flavour and pungency (Balakrishnan 2005).

Indian dried gingers are usually rough peeled or scraped when compared to Jamaican gingers, which are clean peeled. The rhizomes are peeled only on the flat sides and much of the skin in between the fingers remains intact. The dry ginger so produced is known as the rough or

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unbleached ginger and bulk of the ginger produced in Kerala are of this quality. Kerala accounts for over 60% of the total dried ginger production and about 90% of India's ginger export trade (Madan 2005).

Ginger peeling is done manually in spite of machines developed (Agrawal *et al.* 1987; Ali *et al.* 1991). The major difficulties encountered during development of a mechanical device for ginger peeling was its uneven size and shape. Another major drawback observed when ginger is mechanically handled is the breakage. Thus, mechanically peeled ginger could not maintain the rhizome size and hence the quality in terms of grade is lowered. As peeling was an essential process to accelerate the process of drying, the present study was undertaken with an objective to develop a simple mechanical peeler for easy handling of ginger at farm and to evaluate its peeling efficiency.

Materials and methods

A hand operated mechanical ginger peeler was developed at the College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore during January 2009. The developed ginger peeler (Figs. 1 & 2) consists of a peeling drum made of diamond cut mesh of size 550 mm × 470 mm. The diamond cut mesh drum enabled peeling of ginger due to its inner abrasive surface and also facilitated the peeled skin to perforate into water in the wash water tank. The diamond cut mesh drum was welded on both the sides to a circular mild steel flat frame of size 20 mm × 5 mm. On either sides of the drum, to cover the side openings, mild steel sheet covers (20 SWG) were welded to the circular frame. On the surface of the drum an opening of size 170 mm × 230 mm was provided to feed the material. The opening was provided with a door of 170 mm × 230 mm to load and unload ginger and could be closed with a self locking lever type lock. A hollow galvanized iron shaft of diameter 1540 mm × 33 mm × 27 mm was used to mount the peeling drum. A handle of length 250 mm was provided at one end of the hollow shaft to rotate the drum manually. The peeling drum was

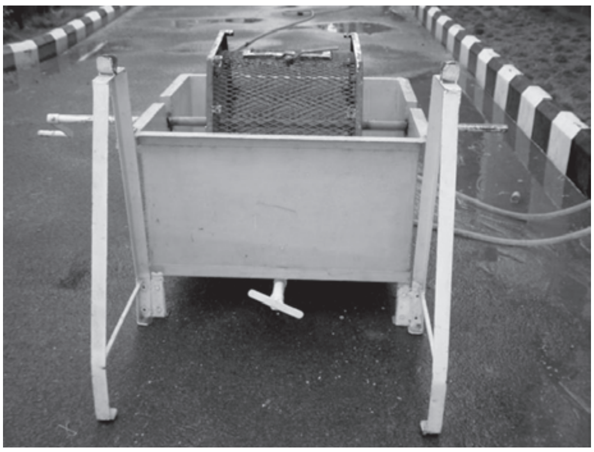

Fig. 1. Diamond cut mesh drum ginger peeler

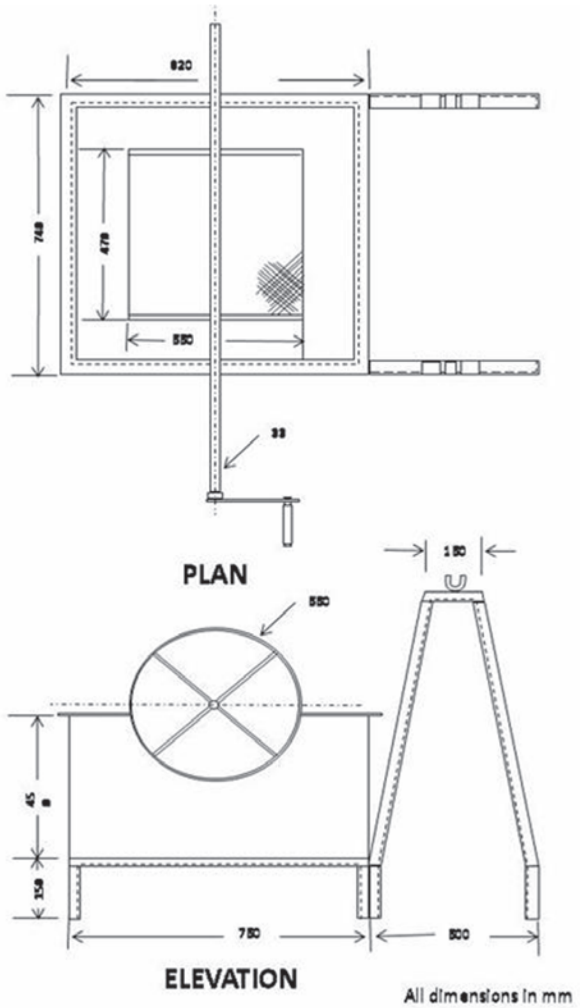

Fig. 2. Schematic diagram of the diamond cut mesh drum ginger peeler

mounted on the top of the water tank. The water holding tank was fabricated from mild steel sheet of 20 SWG thick to a size of 820 mm × 770 mm × 450 mm. Two 'A' shaped frames support made of mild steel flat of size 25 mm × 6 mm are fastened to the water holding tank, to support the peeling drum when not in use. A mild steel drain pipe of 35 mm diameter is provided at the bottom of the tank and extended outside for removal of wash water.

Experiments on ginger peeling

Experiments on peeling of fresh ginger were conducted till sufficient peeling of ginger was obtained for three varying drum capacities of 5 kg, 6 kg and 7 kg, at three different rotational speeds of 20 rpm, 25 rpm and 30 rpm and for three varying peeling durations of 5 m, 10 m and 15 m. A three factor completely randomized block design was followed to determine the effect of drum capacity, rotational speed and peeling duration on peeling efficiency and material loss of ginger. All the experiments were replicated thrice.

The quality of peeled ginger was evaluated in terms of peeling efficiency and material loss of the peeled ginger. To assess the quality of peeling, a sample (usually 10% of the total weight) was taken and the unpeeled skin on the surface of ginger sample was manually peeled and weighed. The weight of ginger skin before peeling was assessed in the fresh sample by manually separating the peel of ginger. The peeling efficiency and material loss was evaluated as follows (Ali *et al.* 1991):

$$\eta_p = (W_{TS} - W_P)/ (W_{TS}) \times 100 \quad (1)$$

$$M_L = [(W_1 - W_{TS}) - (W_2 - W_P)/ W_1] \times 100 \quad (2)$$

where, ζ_p is the peeling efficiency of ginger, %; M_L is the material loss of ginger, %; W_{TS} is the theoretical weight of skin on fresh ginger, g; W_P is the weight of skin removed by hand trimming after mechanical peeling, g; W_1 is the total weight of ginger before peeling, g; W_2 is the total weight of ginger after mechanical peeling, g.

Quality of dry ginger

The quality of dry ginger was estimated in terms of essential oil by AOAC (1975) method, oleoresin by ASTA (1968) method, moisture content by ASTA (1968) method and crude fibre by the method described in Sadasivam & Manickam (1992).

Statistical analysis

The data on peeling efficiency and material loss were analyzed by AGRES (Version 7.01, Pascal Intl software solutions) statistical software. Multiple regression models were predicted using Essential Regression (version: 2.21) statistical software.

Results and discussion

The design specifications of the developed diamond cut mesh drum peeler are presented in Table 1.

Effect of drum load and peeling duration on peeling efficiency

Experiments on mechanical peeling of ginger were done by varying the drum load for various peeling duration (Fig. 3a). As the drum load increased from 5 kg to 7 kg, for a peeling duration of 10 min, the peeling efficiency decreased from 45.69% to 42.62%. But for a given drum load of 6 kg, as the peeling duration increased from 5 min to 15 min the peeling efficiency increased from 34.12% to 57.23%. The peeling efficiency thus decreased with increase in drum load and increased with increase in peeling duration.

Effect of drum speed and peeling duration on peeling efficiency

As the drum speed varied from 20 rpm to 30 rpm, for peeling duration of 10 min at a constant drum load of 6 kg, the peeling efficiency increased from 41.59% to 48.29% (Fig. 3b). At the drum speed of 25 rpm, as the peeling duration varied from 5 min to 15 min, the peeling efficiency increased from 34.15% to 57.63%.

Effect of drum load and drum speed on peeling efficiency

A decrease in peeling efficiency was observed for increase in drum load. The peeling efficiency reduced significantly from 42.61% to 40.39% as

Table 1. Specifications of diamond cut mesh drum ginger peeler

Sl. No.	Components	Specifications
1.	Peeler drum	
	Material	Mild steel diamond cut mesh
	Holding capacity	7 kg
	Length	470 mm
	Diameter	550 mm
	Mesh size	32 mm × 12 mm
	Side covers of the drum	Mild steel sheet 20 SWG thick
	Inlet opening	170 mm × 230 mm
	Door	170 mm × 230 mm
2.	Shaft	
	Material	Galvanized iron pipe
	Outer diameter	33 mm
	Inner diameter	27 mm
	Length	1540 mm
3.	Bush (2 Nos.)	
	Material	Mild steel pipe
	Size of the bush	30 mm × 33 mm × 3 mm
4.	Water holding tank	
	Material	Mild steel sheet 20 SWG thick
	Size	820 mm × 770 mm × 450 mm
	'V' block support	Mild steel flat, 40 mm × 6 mm
	Height of 'V' block support	45 mm
	Top end support	Mild steel L-angle of size 32 mm × 32 mm × 3 mm
5.	Handle	
	Material	Mild steel flat of size 25 mm × 3 mm
	Length	250 mm
6.	'A' frame support (2 Nos.)	
	Material	Mild steel flat of size 25 mm × 6 mm
	Size of 'A' frame	830 mm × 150 mm × 550 mm
	'V' block support	MS flat of size 25 mm × 6 mm
	Height of 'V' block support	40 mm
7.	Drain pipe	
	Material	Mild steel pipe
	Size	Diameter of 35 mm

the drum load increased from 5 kg to 7 kg at a drum speed of 30 rpm for 10 min peeling duration (Fig. 3c). But as the drum speed increased from 20 rpm to 30 rpm at a drum load of 5 kg, the peeling efficiency increased from 42.61% to 48.98%.

Statistical analysis showed that the effect of all the independent variables like the drum load, drum speed and peeling duration were significant ($p<0.01$) in determining the peeling efficiency of ginger in a mechanical peeler. However, the interactions between the

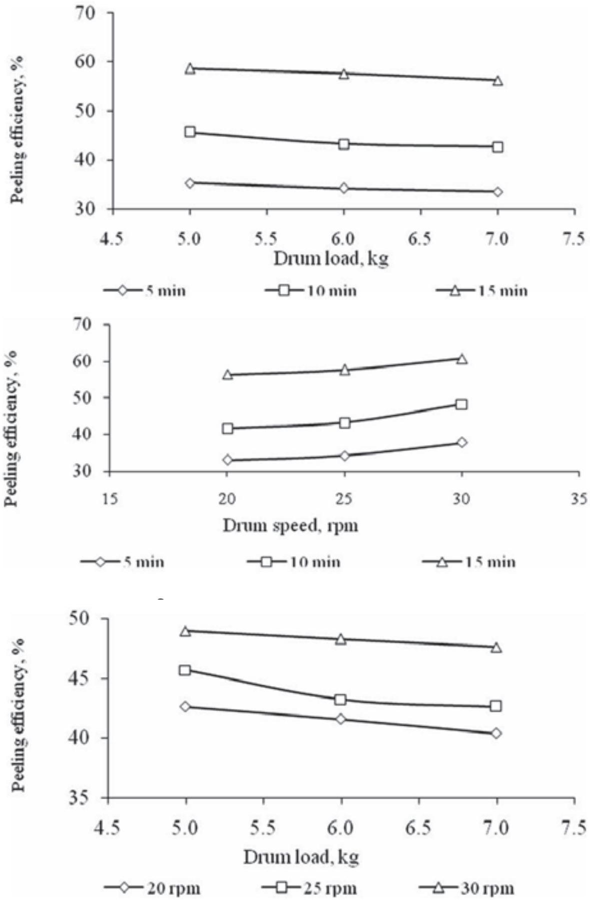

Fig. 3. Peeling efficiency in a diamond cut mesh drum ginger peeler for varying
a) Drum load and peeling duration; b) Drum speed and peeling duration; c) Drum load and drum speed

independent variables were non significant (Table 2). Singh & Shukla (1995) reported that during abrasive peeling of potatoes in an abrasive drum type peeler, peeling efficiency increased with time. Similarly, peeling efficiency also increased with the increase in drum speed. However, in case of increase in material load of the peeler, this trend was not followed beyond 6 min of peeling. This was because at the initial stage, peeling took place only on the outer surface of potatoes. But as the peeling continued beyond 6 min at higher batch loads some potatoes were over peeled and some were under peeled.

Effect of drum load and peeling duration on material loss

As the drum load increased from 5 kg to 7 kg, for a peeling duration of 10 min and drum speed of 25 rpm, the material loss decreased from 2.62% to 2.49% (Fig. 4a). But for a given drum load of 6 kg and for drum speed of 25 rpm, as the peeling duration increased from 5 m to 15 m the material loss increased from 1.33% to 4.72%. The material loss thus decreased with increase in drum load and increased with increase in peeling duration.

Effect of drum speed and peeling duration on material loss

Material loss of ginger during mechanical peeling was found to increase as the drum speed and peeling duration increased. The material loss increased from 1.25% to 1.51% as the drum speed increased from 20 rpm to 30 rpm (Fig. 4b). But at a drum speed of 25 rpm as the peeling duration increased from 5 m to 15 min the material loss increased from 1.33% to 4.72%.

Effect of drum load and drum speed on material loss

A decrease in material loss was observed for

Table 2. Statistical analysis for the peeling data

Parameters	Peeling efficiency, h_P			Material loss, M_L		
	F value	CD (P<0.05)	SE	F-value	CD (P<0.05)	SE
Drum load (L)	9.18**	1.02	0.51	65.36 **	0.68	0.90
Drum speed (S)	61.67**	1.02	0.51	9.59**	0.68	0.90
Peeling duration (T)	1048.12**	1.02	0.51	4361.33**	0.68	0.90
L × S	0.47 NS	1.77	0.88	28.48 **	0.12	0.16
S × T	0.98 NS	1.77	0.88	29.64 **	0.12	0.16
L × T	0.12 NS	1.77	0.88	29.57**	0.12	0.16
L × S × T	0.25 NS	3.07	0.88	30.71**	0.20	0.27

**=significant at P<0.01; NS=nonsignificant

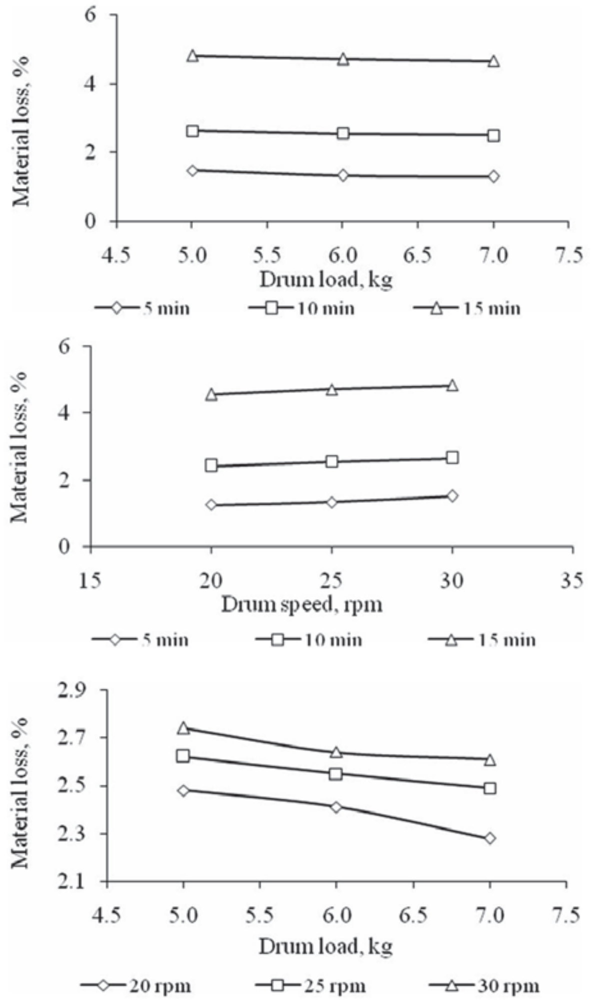

Fig. 4. Material loss in a diamond cut mesh drum ginger peeler for varying
a) Drum load and peeling duration; b) Drum speed and peeling duration; c) Drum load and drum speed

increase in drum load. The material loss reduced from 2.48% to 2.28% as the drum load increased from 5 kg to 7 kg at a drum speed of 20 rpm for 10 min peeling duration (Fig. 4c). But as the drum speed increased from 20 rpm to 30 rpm, at a drum load of 5 kg and peeling duration of 10 min, the material loss increased from 2.48% to 2.74%.

The significance of the effect of drum load, drum speed and peeling duration on the material loss was statistically analyzed. Analysis of variance for material loss in a diamond cut mesh drum peeler showed that the material loss was significantly influenced ($P<0.01$) by drum load, drum speed, peeling duration and their interactions were highly significant. The peel loss of potatoes in an abrasive drum peeler was evaluated by Singh & Shukla (1995) and reported that the peel loss varied from 3.80% to 10.37% for batch load varying from 5 kg to 20 kg, for time varying from 4 m to 10 m and speed varying from 30 rpm to 50 rpm. Peel loss increased linearly with peeling time, drum speed and loading intensity.

The relationship between peeling efficiency (η_P) and material loss (M_L) for various drum loads (L), drum speeds (S) and peeling duration (T) in a diamond cut mesh drum peeler was predicted by multiple regression models as follows:

$$\eta_P = 21.06 + 2.851\ T + 0.245\ S - 2.604\ L - 0.01307\ T\ S - 0.03283\ T\ L + 0.07350\ S\ L\ (R^2= 0.99) \quad (3)$$

$$M_L = -0.659 + 0.330\ T + 0.02556\ S - 0.07222\ L + 0.000133\ T\ L\ (R^2=0.97) \quad (4)$$

From the equation (3), it was observed that peeling efficiency was in positive correlation with the peeling duration and drum speed but in negative correlation with the drum load. The coefficients of the independent variables indicated that the influence of peeling duration was the highest, followed by drum load and drum speed. The equation (4), explains that the material loss was in positive correlation with the peeling duration and drum speed but in negative correlation with the drum load. The coefficients of the independent variables, indicated that the influence of peeling durations was the highest, followed by drum load and drum speed.

Analysis of variance for the linear regression model (3) to determine the peeling efficiency indicated that the regression model was significant ($P<0.01$), as is evident from R^2 value (0.99). Similarly analysis of variance for the linear regression model (4) to determine the material loss described that the regression model was also significant ($P<0.01$) as observed from the R^2 value (0.97). Hence, the developed models were adequate to describe the relationship between all treatment combinations of drum load, drum speed and peeling duration with respect to peeling efficiency and material loss of ginger in the diamond cut mesh single drum mechanical peeler.

Optimization of parameters for mechanical peeling

From the trials on mechanical peeling of ginger in a diamond cut mesh drum peeler, it was understood that peeling of ginger was associated with material loss. For the production of dry ginger of commercial grade, it was necessary that material loss was minimized so that the quality of dry ginger was not affected. The maximum optimum output from the peeler was obtained at a drum load of 7 kg, for drum speed of 30 rpm and for peeling duration of 15 min. At these conditions the peeling efficiency was 59.43% and the material loss was 4.76%.

Quality

The quality of sun dried ginger obtained at the optimum operating conditions of the developed ginger peeler was determined and was found to have essential oil of 2%, oleoresin of 4.6%, moisture content of 9.82% and crude fibre content of 2.5%.

To conclude, a hand operated mechanical ginger peeling unit with a capacity to hold 7 kg of fresh ginger per batch was developed. The unit had a peeling drum made of diamond cut mesh with inner abrasive surface. Maximum peeling efficiency of 59.43% was obtained when operated at drum load of 7 kg at a rotating speed of 30 rpm and for peeling duration of 15 min and the material loss associated with peeling was estimated as 4.76%.

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