Studies on Development of Concentric Drum, Brush Type Ginger Peeler

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Abstract

A concentric drum brush type ginger peeler with a capacity to peel 7 kg per batch was developed. The nylon bristles to be used for peeling were optimized in another experimental setup using a semi mechanical ginger peeler. Nylon bristles of length 25 mm and thickness 0.7 mm were optimized for fixing in the inner wooden drum of the developed mechanical ginger peeler. Experiments on peeling ginger in a concentric drum brush type ginger peeler were conducted at varying drum loads (5, 6 and 7 kg) for various speeds of inner drum (35, 40 and 45 rpm), outer drum speeds of (20 and 25 rpm) and for varying peeling durations (5, 10 and 15 min). The optimum operating conditions for peeling ginger were obtained at drum load of 7 kg, for inner drum speed of 45 rpm, outer drum speed of 20 rpm and for the peeling duration of 15 min. The peeling efficiency was 61 % and the corresponding material loss was 5.33 %.

Introduction

Ginger, the rhizome of Zingiber officinale Roscoe is one of the most widely used spices of the family Zingiberaceae. India is one of the largest ginger producing countries in the world with an annual production of 831,607 tonnes from an area of 143,861 ha during 2008-09 (Spices Board, 2012).

Ginger when used as vegetable is harvested from sixth month onwards while for preparing dry ginger, the produce is harvested after eight months of planting when the leaves of the plant turn yellow and starts drying. The harvested clumps of ginger are cleaned manually to remove the dried roots and soil clods. The clumps are then broken to sufficiently large size rhizomes suitable for preparing dry ginger. After cleaning, the rhizomes are subjected to peeling. Peeling, in case of ginger is definitely an important unit operation where the fully matured rhizomes are scraped with bamboo splits having pointed ends to remove the outer skin before drying to accelerate the drying process. Deep scraping with knifes need to be avoided to prevent the damage of oil bearing cells which are present just below the outer skin. Excessive peeling will result in the reduction of essential oil content of the dried produce. The peeled rhizomes are washed before drying. The dry ginger so obtained is valued for its aroma, flavour and pungency (Balakrishnan, 2005).

A brush type ginger peeling machine with two continuous brush belts moving vertically in the opposite direction was reported by Agrawal *et al*. (1987). The maximum peeling efficiency of ginger obtained was 84.3 % at a belt speed of 85 rpm for belt spacing of 1 cm. Ali *et al*. (1991) reported the development of an abrasive brush type ginger peeling machine consisting of two continuous vertical belts provided with 32 gauge steel wire brush, 2 cm long and having a peeling zone of 135 cm, had a maximum peeling efficiency of 85 %. Singh and Shukla (1995) developed a abrasive peeler for potato and reported that the peel loss increased linearly with peeling time, drum speed and loading intensity. However, in case of increase in loading intensity of the peeler, this trend was not followed beyond 6 min of peeling. At higher batch loads, as the peeling continued beyond 6 min, some potatoes were over peeled and some were under peeled.

Presently the process of ginger peeling is done manually and the process is highly laborious. As this is an essential process to accelerate the drying process, the present study was undertaken with an objective to develop a mechanical peeler for ginger and to evaluate its peeling efficiency.

Materials and Methods

A brush type concentric drum ginger peeler provided with nylon bristles was developed at the College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore during 2009 for mechanical peeling of ginger. The peeler consists of two concentric drums (**Figs. 1** & **2**). The inner wooden drum of size 430 × 364 mm was provided with nylon bristles (25 mm long and 0.7 mm thick) for the entire length and the outer drum of size 470 mm × 550 mm was made of mild steel diamond cut mesh. Peeling of ginger was found effective when the inner and the outer drums rotated at varying speeds in the same direction. Variable speed was obtained by using four pulleys for power transmission. Two pulleys were provided on the central shaft on which the peeler drums were mounted and another pair was provided on an intermediate shaft. A handle of length 250 mm was provided at one end of the hollow shaft to rotate the inner drum manually. The entire unit was mounted on a water holding tank of size 820 mm long, 770 mm wide and 450 mm depth. Fresh ginger was fed in to the annular space between the inner and the outer drum through the opening provided in the outer drum. Peeling of ginger was caused by the abrasion of ginger against the drum surface.

Design of Shaft

A hollow galvanized iron shaft was used to mount the peeling drum. The diameter of the hollow shaft was determined using the following formula considering the fact that shaft for ginger peeling unit is subjected to bending and torsion only and the axial load acting on the shaft is zero (Khurmi and Gupta, 2006).

$$d_0^3 = \frac{16}{\pi [\tau] \left\{ 1 - \left(\frac{d_i}{d_o} \right)^4 \right\}} \times \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad \text{..................(1)}$$

where, d_0 is the diameter of the shaft, mm; P is the axial load, N; M_t is the twisting moment, N mm; M_b is the bending moment, N mm; [τ] is the design shear stress, N mm^{-2}; K_b is the combined shock and fatigue factor applied to M_b; Kt is the combined shock and fatigue factor applied to M_t; τ is the shear stress, N mm^{-2}; σ_b is the bending stress, N mm^{-2}; α is the column action factor.

For revolving shaft with gradual loading the values for K_b = 1.5, K_t = 1 and [τ] = 56 MPa = 56 N/mm^2.

Torque Transmitted to the Peeling Drum The peeling drum was manually operated. Considering the human energy as 0.1 hp (Sahay, 2006) the torque transmitted to the drum by manual rotation at maximum speed of 50 rpm was calculated by the following formula:

$hp = 2\pi NT_t / 60$ ....(2)

where, hp is the horse power transmitted to the peeling drum = 1 hp = (746 W), N is the speed of peeling drum, rpm, Tt is the torque transmitted, Nm.

Maximum rotational speed of the peeling drum (assumed) = 50 rpm

Hence, Torque tranmmitted = *(74.6 × 60) / (2 × 3.14 × 50) = 14.25 N m = 14,250 N mm*

Bending Moment of the Shaft The bending moment was calculated by considering the load acting on the drum. Assuming, Mass of the peeling drum = 20 kg, Mass of ginger to be peeled = 10 kg per batch, Total mass = 30 kg (or 300 N).

The mass of the peeling drum and the ginger was considered as uniformly distributed load acting over a span length of 0.92 m. It was converted into equivalent point load acing at the centre of the shaft.

Considering the shaft as simply supported, the maximum bending moment occurs at the centre of the shaft and was calculated as (PSG, 1988):

$M_{b\ max} = PL / 4$ ....(3)

$M_{b\ max} = (300 \times 920) / 4 = 69{,}000$ N mm

Assuming d_0 / d_i = 0.82 and substituting all the values in **Eqn. 1**. d_0^3 is calculated as; d_0^3 = 17350.78

Hence, d_0^3 = 25.88 mm ≈ 26 mm

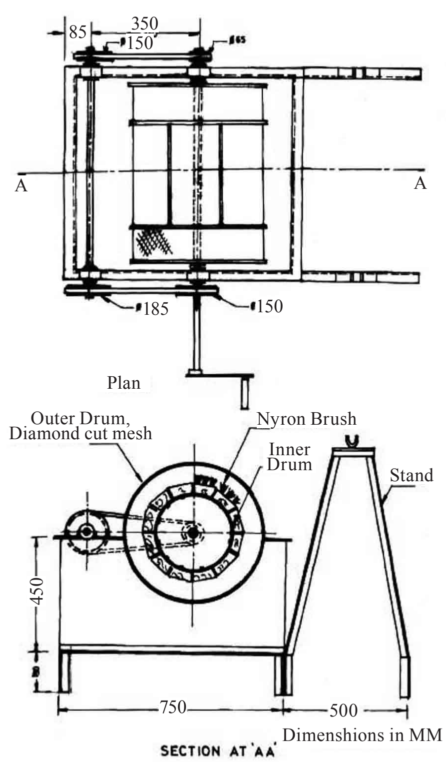
However, the shaft selected for the fabrication of the peeler was having an outer and inner diameter of 33 and 27 mm respectively and of length 1,540 mm.

Bush

Two bushes of 40 mm long, 27

Fig. 1 Concentric drum brush type ginger peeler

Fig. 2 Plan and elevation of the ginger peeler



mm inner diameter and 33 mm outer diameter were welded at the centre of the drum cover on either side. The bush was reinforced with 3 numbers of spokes made of mild steel flats of size 230 mm long × 20 mm wide × 5 mm thick radiating from the centre towards the outer surface and welded on both the side covers.

V-block

A fabricated V- block made of mild steel flat of size 40 mm wide x 6 mm thick to a height of 40 mm rests on the outer frame of the water holding tank. The shaft with the drum was supported by the V-block.

Water Holding Tank

The water holding tank was fabricated from mild steel sheet of 20 SWG thick to a size of 820 mm long, 770 mm wide and 450 mm depth. The top of the tank was welded with a frame made of angle section of size 32 × 32 × 3 mm thick. The frame of the tank supports the V-block which in turn supports the shaft and the drum.

Handle

A handle of length 250 mm was provided at one end of the hollow shaft to rotate the drum manually.

Frame

Two 'A' shaped frames support made of mild steel flat of size 25 mm × 6 mm are fastened to the water holding tank by bolt and nut. Each A-frame is 50 mm wide at the top, 550 mm wide at the bottom with a height of 830 mm. On the top of each 'A' frame, V-block support of height 100 mm made of mild steel flat of size 25 × 6 mm are provided to rest the drum during unloading.

Drain Pipe

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 peeling of ginger in a concentric drum brush type ginger peeler were conducted at varying drum loads (5, 6 and 7 kg) for various speeds of inner drum (35, 40 and 45rpm), outer drum speeds of (20 and 25 rpm) and for varying peeling durations (5, 10 and 15 min). Freshly harvested fully matured ginger available from the local market was used for the experimental study. All the experiments were replicated thrice. Completely

Table 1 Specifications for manually operated concentric diamond cut mesh drum brush type peeler

Components	Specifications
Outer drum	
Material	Mild steel diamond cut mesh
Holding capacity	7 kg
Length	470 mm
Diameter	550 mm
Mesh size	32 × 12 mm
Side covers	Mild steel sheet 20 SWG thick
Inlet opening	170 × 230 mm
Door	170 × 230 mm
Inner drum	
Material	Wood
Length	430 mm
Outer diameter	364 mm
Drum shaft	Mild steel pipe of size 430 × 33 × 3 mm
Circular frame for fixing reaper	Mild steel flat of size 25 × 5 mm
Diameter of circular frame	254 mm
Wooden reapers	430 × 60 × 30 mm
Number of wooden reaper	30 Nos.
Nylon bristles	
Length	25 mm
Thickness	0.70 mm
Shaft	
Material	Galvanized iron pipe
Length	1250 mm
Outer diameter	33 mm
Inner diameter	27 mm
Intermediate shaft	
Length	1250 mm
Diameter	25 mm
Pulleys for power transmission	
Number and type	4 Nos. of A-type pulleys
Optimum diameters	d_1 = 65, d_2 = 150, d_3 = 170 and d_4 = 150 mm
Bearings	
Material	Gun metal
Diameter	27 mm
Numbers	2
Belt for power transmission	Perforated A-type belt
Handle	
Material	Mild steel flat of size 25 × 3 mm
Length	250 mm
Water holding tank	
Material	Mild steel sheet 20 SWG thick
Size	820 × 770 × 450 mm
Top end support	Mild steel L-angle of size 32 × 32 × 3 mm
Drain pipe	
Material	Mild steel pipe
Size	Diameter of 35 mm

Randomized Block Design was adopted to analyze the significance of the independent variables using statistical AGRES (Version 7.01) and regression analysis was done by Essential Regression (version: 2.21) softwares.

Quality

The quality of peeled ginger was evaluated in terms of the peeling efficiency and the material loss as described by Ali *et al*. (1991).

$$\eta_p = [(W_{TS} - W_s) / W_{TS}] \times 100 \ldots (4)$$

$$ML = \{[(W_1 - W_{TS}) - (W_2 - W_S)] / W_1\} \times 100 \ldots (5)$$

where, η_p is the peeling efficiency of ginger peeler (%), ML is the material loss of ginger (%), W_{TS} is the theoretical weight of skin on fresh ginger (g), W_s 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).

Results and Discussion

A concentric drum brush type ginger peeler was fabricated with the design specifications detailed in **Table 1**.

Effects of Drum Speed and Peeling Duration on Peeling Efficiency

It was observed that as the outer drum speed increased from 20 rpm to 25 rpm, the peeling efficiency increased with the increase in peeling duration for increase in all inner drum speeds studied (35, 40 and 45 rpm) at a constant drum load of 6 kg. A maximum peeling efficiency of 62.86 % was obtained when the outer drum speed was 25 rpm, the inner drum speed was 45 rpm and the peeling duration was 15 min at a constant drum load of 6 kg of ginger (**Fig. 3a**).

Effects of Drum Speed and Peeling Duration on Peeling Efficiency

At a constant outer drum speed of 20 rpm, as the inner drum speed increased from 35 rpm to 45 rpm, at a given load of 6 kg and peeling duration of 15 min, the peeling efficiency increased from 48.63 to 62.86 %. At inner drum speed of 45 rpm and drum load of 6 kg as the peeling duration increased from 5 min to 15 min the peeling efficiency increased from 37.92 % to 62.86 % (**Fig. 4a**).

Peeling efficiency decreased from 63.12 % to 61.43 % when the drum load increased from 5 kg to 7 kg at inner drum speed of 45 rpm and peeling duration of 15 min. At a constant drum load of 6 kg and at the inner drum speed of 45 rpm as

Fig. 3a Peeling efficiency for various inner

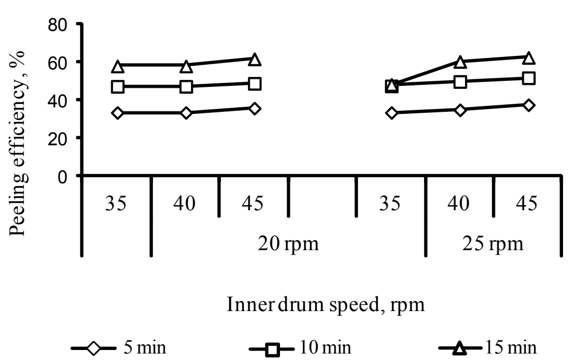


Fig. 3b Material loss for various and outer drum speeds inner and outer drum speeds

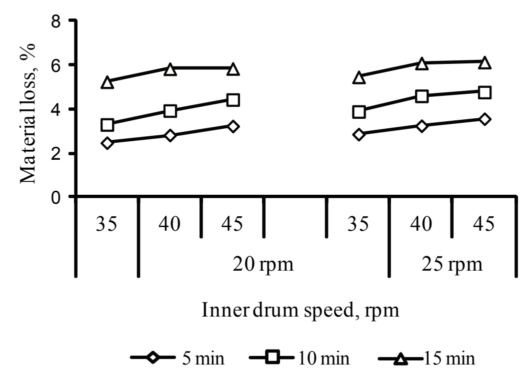


Fig. 4a Peeling efficiency for various inner speeds

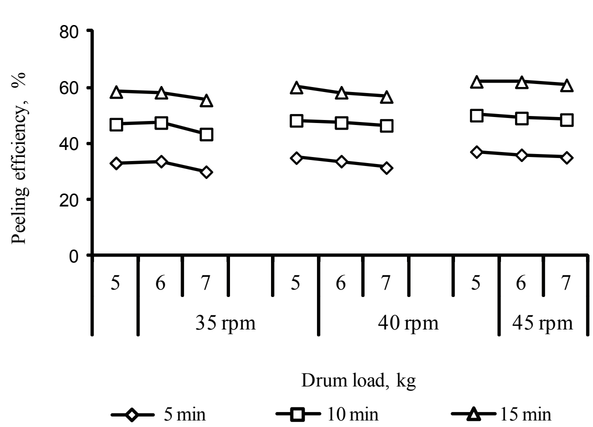
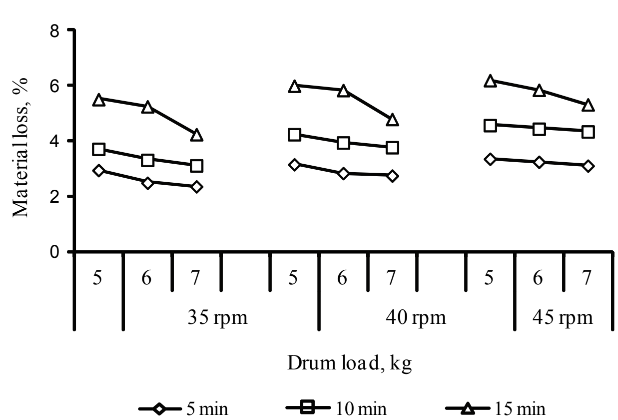


Fig. 4b Material loss for various inner drum and drum loads speeds and drum loads



the peeling duration increased from 5 min to 15 min, the peeling efficiency increased from 37.92 % to 62.86 % (**Fig. 5a**).

It was observed that increase in peeling duration increased the peeling efficiency. The peeling efficiency also increased with increase in the speed of inner drum but it however decreased with increase in drum load. Analysis of variance showed a significant ($p < 0.01$) influence of the independent variables on the peeling efficiency of ginger in the mechanical peeler but no significant influence was observed for their interactions.

Effects of Drum Speed and Peeling Duration on Material Loss

It was found that at a given drum load, as the outer drum speed increased from 20 rpm to 25 rpm, the material loss increased with the increase in peeling duration and for the increase in the speeds of inner drum i.e. 35, 40 and 45 rpm (**Fig. 3b**). A maximum material loss of 6.15 % was observed when the outer drum speed was 25 rpm, the inner drum speed was 45 rpm for the peeling duration was 15 min when the drum load was constant at 6 kg of ginger. It was further observed that for all the cases of higher outer drum speed, the material loss was higher and hence 20 rpm of outer drum speed was considered as optimum.

Effects of Drum Speed and Peeling Duration on Material Loss

At a constant outer drum speed of 20 rpm, as the inner drum speed increased from 35 rpm to 45 rpm, at a given load of 6 kg and peeling duration of 15 min, the material loss increased from 5.26 to 5.86 %. At inner drum speed of 45 rpm and drum load of 6 kg as the peeling duration increased from 5 min to 15 min the material loss increased from 3.25 % to 5.86 % (**Fig. 4b**).

Material loss decreased from 6.21 % to 5.33 % when the drum load increased from 5 kg to 7 kg at inner drum speed of 45 rpm and peeling duration of 15 min. At a constant drum load of 6 kg and at the inner drum speed of 45 rpm as the peeling duration increased from 5 min to 15 min, the material loss increased from 3.25 % to 5.86 % (**Fig. 5b**).

It was observed that increase in peeling duration increased the material loss. The material loss also increased with increase in the speed of inner drum but it however decreased with increase in drum load. Analysis of variance showed a significant ($p < 0.01$) influence of the independent variables on the material loss of ginger in the mechanical peeler but no significant influence was observed for the interaction of the independent variables.

Agrawal *et al.* (1987) reported a material loss of 5.1 % at the maximum peeling efficiency of 84.3 % in a vertical brush type ginger peeling machine when the belt speed was 85 rpm and belt spacing was 1 cm. Ali *et al.* (1991) reported a material loss of 3.27% in an abrasive brush type ginger peeling machine when the peeling efficiency was 85.56 %.

The relationship between peeling efficiency (η_P) and material loss (ML) with the variables like drum load (M_P), inner drum speed (S_i), outer drum speed (S_o) and peeling duration (t_p) in a concentric drum brush type ginger peeler was predicted by multiple regression models as follows:

$$\eta_P = 7.275 - 1.551\ M_P + 0.406\ S_i + 0.353\ S_o + 2.529\ t_p\ (R^2 = 0.93) \quad \text{......(6)}$$

$$ML_P = -1.263 - 0.341\ M_P + 0.083\ S_i + 0.078\ S_o + 0.255\ t_p\ (R^2 = 0.97) \quad \text{......(7)}$$

Eqn. 6 shows that peeling efficiency was in positive correlation with peeling duration, inner drum speed, outer drum speed and 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, inner drum speed and outer drum speed. From the **Eqn. 7**, it is observed that the material loss was in positive correlation with the peeling duration, inner drum speed, outer drum speed and in negative correlation with the drum load.

Fig. 5a Peeling efficiency for various inner speeds

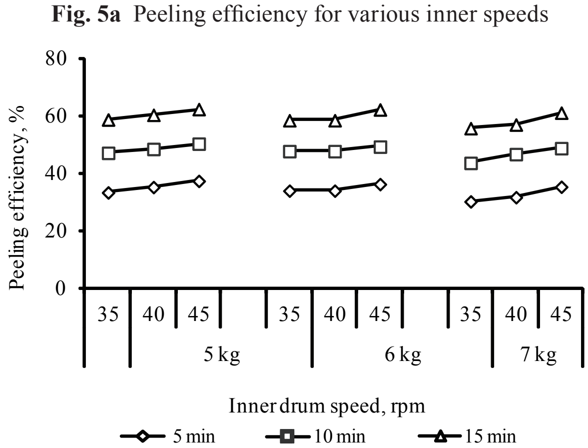
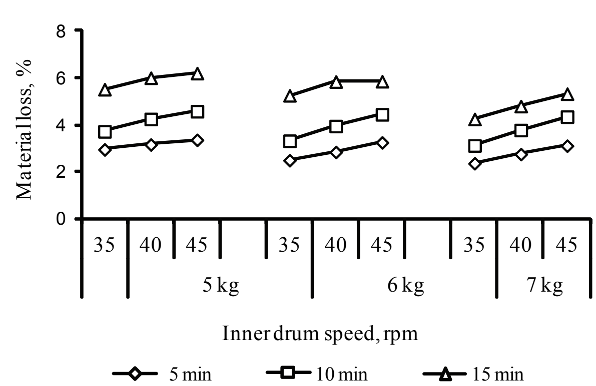


Fig. 5b Material loss for various inner speeds and drum loads and drum loads



Optimization of Machine Parameter for Peeling

The process of peeling in a concentric drum brush type ginger peeler was optimized for the conditions at which the peeling efficiency was maximum and the material loss was minimum. Considering these factors it could be found that maximum peeling efficiency of 61 % with corresponding material loss of 5.33 % when the drum load was 7 kg, at an inner drum speed of 45 rpm, outer drum speed of 20 rpm and for peeling duration of 15 min.

Conclusions

1. A concentric drum brush type ginger peeler with a capacity to peel 7 kg of ginger per batch was developed.

2. To accelerate the process of peeling, nylon bristles of length 25 mm and thickness 0.7 mm were fixed in the inner wooden drum of the developed mechanical ginger peeler.

3. The optimum operating conditions for peeling of ginger was obtained at drum load of 7 kg, for inner drum speed of 45 rpm, outer drum speed of 20 rpm and for the peeling duration of 15 min.

4. The maximum peeling efficiency obtained in the peeler was 61 % and the corresponding material loss was 5.33 %.

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