Development of mini-tractor operated turmeric harvester for small farmers

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Abstract

This study was aimed to develop the mini-tractor drawn turmeric harvester cum conveyor to dig out and collect the turmeric rhizome. The physical properties of freshly harvested turmeric mother and finger rhizomes (Erode variety) relevant to the development of mini-tractor operated turmeric harvester were determined. Length, width and thickness were 7.90, 2.48, 2.32 cm, respectively. The moisture content of finger and mother rhizomes was found to be 386.85 and 231.56 % (db). The roundness of fresh finger and mother rhizomes were 0.3065 and 0.5244, respectively. Sphericity of the fresh finger and mother rhizomes recorded 0.3052 and 0.4312, respectively. The cylindricity of fresh finger and mother rhizomes was found to be 0.7604 and 0.6428, respectively. The bulk density of finger and mother rhizomes was 523.85 and 532.25 kg/m^3, respectively. Based on these physical properties, the equipment was developed with overall dimensions of 1000×1000×600 mm (L×W×H). The digger blade was designed with dimensions of 1000(l) × 200(b) × 8(t) mm. Length and width of conveyor is 700 mm and 1000 mm, respectively. Power required for digging, pulling the equipment and conveyor is 11.54 kW, 0.66 kW and 1.15 kW, respectively. Total power requirement of the unit is 13.35 kW.

Key words: Turmeric, harvester, physical property, mini-tractor, rhizome

Introduction

India is the largest producer, consumer and exporter of turmeric in the world. India accounts for about 80 per cent of total world production of turmeric, though major part of its produce is being utilized within the country (Singh 2004). Turmeric occupies about 6 per cent of the total area under spices and condiments in India (Moghe *et al.*, 2012). In Tamil Nadu, it is planted on ridges, 20 to 25 cm high and 45 to 60 cm broad. The planting distance is normally 20 to 30 cm at a depth of 7.5 cm. Madan (2008) reported that the conventional methods need more labors with less field capacity, which increase cost of production. Conventional method of manual digging results into bruising and damaging of rhizomes which affect its quality and market price. Farmers lack in machinery usage skills in turmeric cultivation particularly in planting and harvesting operation.

Zate *et al.* (2018) reported that the farmers are planting turmeric and ginger on raised beds. It is prepared 20 to 30 cm in height and 75 to 100 cm in width with a convenient length with at least 30 cm spacing between two rows of turmeric on the beds. Munde *et al.* (2010) reported that the mother rhizome or finger rhizome are either planted on raised beds of 60 to 90 cm width with 15 cm height on ridges and furrow or in flat system. The spacing is kept 30 × 15 cm or 30 × 20 cm (in beds) and 40 to 60 × 25 cm (on ridges and in furrows) and 60 × 15 cm (in flat system). Murugesan and Tajuddin (1995) developed a turmeric digger with two digger blades of size 825×150×10 mm joined together for proper penetration and to reduce draft. The tubers were left in soil without inversion. Tapare (2005) developed tractor mounted turmeric digger. The blade length was 60 cm and depth was 18-20 cm.

An appropriate digging tool with a digging blade and a soil separation and rhizome collection mechanism would make the harvester complete in all respects. If a suitable mechanism could be developed for removing the soil coming with rhizome and collecting the rhizome, it could be more efficient and beneficial to farmers.

The investigation envisaged to develop a suitable mini-tractor operated turmeric harvester to dig out and collect the turmeric rhizome.

Materials and methods

Physical properties: The important physical properties of freshly harvested turmeric mother and finger rhizomes (Erode variety) namely moisture content, size, shape and bulk density were determined with 25 randomly selected rhizomes. Moisture content of turmeric rhizomes was determined by toluene distillation method (ASTA, 1968). The moisture content was estimated as given below.

$$M = \frac{V_w}{W_s} \times \rho_w \times 100 \tag{1}$$

Where,

M is the moisture content, % (wb)

V_w is the volume of water collected in trap, cm^3

W_s is the weight of the sample, g

ρ_w is the density of water, g cm^{-3}

Size, generally refers to the characteristic of an object which determines space requirement within the limit and is described in terms of length, width and thickness. Three samples each weighing 1 kg was randomly drawn from the bulk to determine

the size of turmeric finger rhizomes. The dimensions along three mutually perpendicular axes, namely major (length), intermediate (width) and minor (thickness) of each rhizome in the natural rest position were measured using a vernier calliper having a least count of 0.1 mm.

The shape of the rhizomes may be expressed as sphere, cylinder or disc after measuring its sphericity, cylindricity and roundness. The roundness, sphericity and cylindricity of turmeric rhizomes were calculated by tracing the magnified shadowgraphs of ten rhizomes in three mutually perpendicular positions for roundness and sphericity and in two mutually perpendicular positions for cylindricity on a graph sheet, with the help of an overhead projector (Dutta *et al.,* 1988 and Kaleemullah, 1992). The roundness and sphericity were calculated by using the following formulae (Curray, 1951):

$$R = \frac{A_p}{A_c} \qquad (2)$$

$$S = \frac{d_i}{d_c} \qquad (3)$$

Where,
R - roundness, decimal
A_p - the largest projected area of rhizomes in a natural rest position, cm^2
A_c - area of the smallest circumscribing circle, cm^2
S - sphericity, decimal
d_i - diameter of the largest inscribing circle, cm
d_c - diameter of the smallest circumscribing circle, cm

Shape of the rhizomes in terms of cylindricity (C) was determined by using the following expression (Kaleemullah and Kailappan, 2003), the degree of cylindricity is expressed as:

$$C = \left[\frac{D_i^2 L_i}{D_c^2 L_c} \right]^{1/3} \qquad (4)$$

Where,
C is the cylindricity, in decimal
D_i is the diameter of the largest inscribed cylinder, cm
D_c is the diameter of the smallest circumscribed cylinder, cm
L_i is the length of the largest inscribed cylinder, cm
L_c is the length of the smallest circumscribed cylinder, cm

Bulk density was calculated as the ratio between mass and bulk volume of turmeric rhizomes. One bag of rhizomes (25 kg) was poured over a horizontal surface from a height of 50 cm slowly and the rhizomes were allowed to fall freely too. The slant height (l) of the pile was determined by measuring it at different places and taking the average. The radius (r) of the pile was calculated from the circumference of the pile formed. Using slant height l, radius of the pile r, volume of the pile was determined and then the bulk density was calculated.

$$h = \sqrt{(l^2 - r^2)} \qquad (5)$$

$$V_b = \frac{1}{3} \pi r^2 h$$

$$\rho_b = \frac{W_b}{V_b}$$

Where,
ρ_b is the bulk density of turmeric rhizomes, kg m^{-3}
W_b is the mass of bulk turmeric, kg
V_b is the volume of the pile, m^3

Development of mini-tractor operated turmeric harvester
A turmeric harvester was developed with following components based on physical properties of rhizomes *viz.,* frame, power

transmission gear box, three point hitches, digging blade and conveyor.

Frame: The main frame consists of a rectangular section of 300×1000×600 mm. On the main frame, conveyor support frames of 700×1000×600 mm channel section fabricated. The various components namely digging blade assembly, conveyor assembly and speed reduction unit were mounted on the frame by appropriate supports and frame work.

Power transmission system: The power is taken from the PTO shaft of the mini-tractor to the conveyor mechanism through gear box (to change the direction), belt and pulley drive. The speed and size of the pulley is calculated based on the equation 6 (Khurmi and Gupta, 2005).

$$\pi D_1 N_1 = \pi D_2 N_2 \qquad (6)$$

Where,
N_1 - Speed of driven pulley
N_2 - Speed of driver pulley
D_1 - driven pulley diameter
D_2 - driver pulley diameter

The length of belt is calculated based on following equation

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{1}{4C}(D_2 + D_1) \qquad (7)$$

Where,
L-Length of drive belt for pulleys 1 and 2
C-Centre distance between the two pulleys = 700 mm
L = 2 × 700 + π (80 + 80)/ 2 + (80-80)/ 4×700 = 1650 mm

Three point hitch: A three point hitch attaches the implement to the tractor so that the orientation of the implement is fixed with respect to the tractor and the arm position of the hitch. Standard dimensions of three point linkage for this category of implements are fabricated as per ASAE standard (2001).

Blade: The optimized digging blade was mounted on the frame behind the tractor through the three point linkage. The digging system made up of mild steel and it consists of straight blade with digging chisel and guiding rake behind the blades. Length of the blade (width of operation) is 1000 mm and width is 200 mm. Blade is made up of mild steel sheet and flat.

Conveyor-elevator assembly: The conveyor-elevator is made of elevator strips, sprocket and chain drive and support frame. The chain and sprocket drive system have their drives taken from the gearbox on the side through mild steel pulley and belt drive system (Fig. 3). Two pairs of 90 mm diameter sprockets are fixed with necessary support on both sides of support frame. On the sprocket, chain link supports are given to aid in the movement of the conveyor.

Results and discussion

Physical properties

The results of physical properties like moisture content, size, shape and bulk density of turmeric rhizomes are presented and discussed in this section.

Moisture content: The moisture content of fresh finger and mother rhizomes were found to be 384.56 and 228.60 % (db), respectively. Athmaselvi and Varadharaju (2002) reported 82 per cent (wb) moisture content in Erode local.
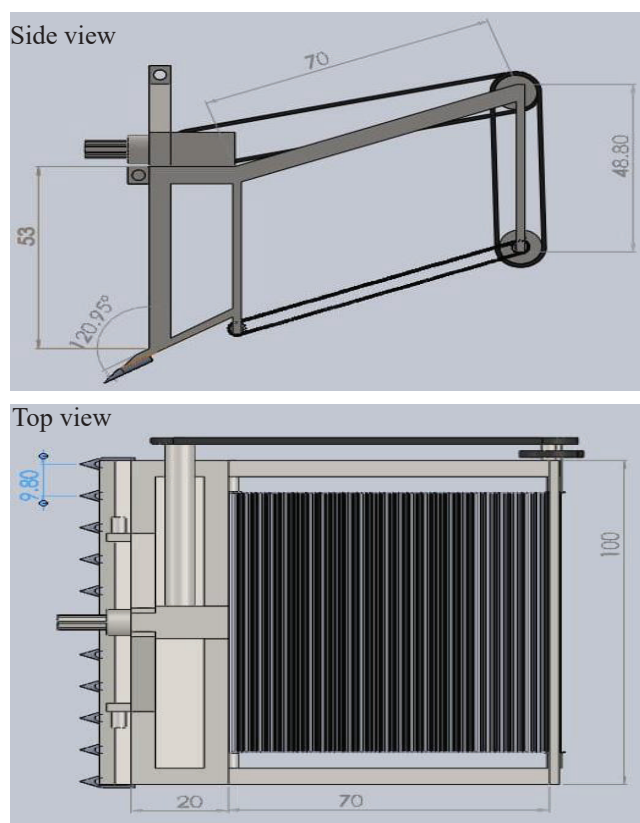
Side view

Top view

Fig. 1. Design drawing of mini-tractor operated turmeric harvester (All dimensions in cm)
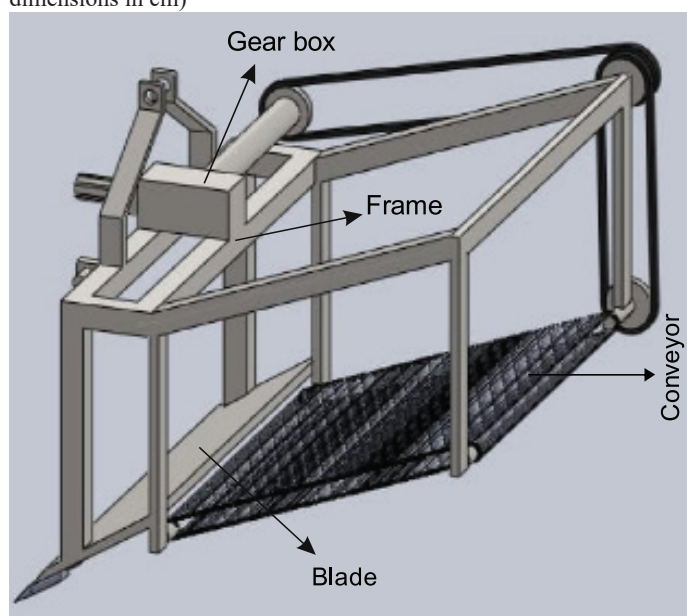

Fig. 2. Design drawing-Isometric view

Size: The turmeric finger rhizomes have branching of varying size and shape. Hence, relatively smaller primary and secondary developments (fingers) were removed and all the measurements were made only for main fingers as reported by Parveen *et al.* (2009). Tri-axial linear dimensions *viz.*, major (length), intermediate (width) and minor (thickness) of turmeric finger rhizome in the natural rest position were found to be 78.5, 24.5, 23 mm, respectively.

Shape: The shape of turmeric finger and mother rhizomes in terms of roundness, sphericity and cylindricity were measured at a moisture content of 384.56 and 228.60 % (db) for fresh finger

Fig. 3. Developed mini-tractor operated turmeric harvester

and mother rhizomes, respectively and it was found that the roundness of fresh finger and mother rhizomes were 0.3065 and 0.5244, respectively. Sphericity of the fresh finger and mother rhizomes was 0.3052 and 0.4312, respectively. The cylindricity of fresh finger and mother rhizomes were found to be 0.7604 and 0.6428, respectively. As both finger and mother rhizomes cylindricity values were higher than roundness and sphericity values, the shape of the fresh finger and mother rhizomes can be considered as cylinder for all practical purposes.

Bulk density: The bulk density of finger and mother rhizomes was found to be 623.50 and 630.35 kg m^{-3}, respectively. The decrease in bulk density with decrease in moisture content indicates that the decrease in weight owing to moisture loss in the sample is greater than the accompanying volumetric contraction of the bulk. Athmaselvi and Varadharaju (2002) reported that the bulk density of Erode Local varied from 753 to 801 kg m^{-3} at the moisture range of 10 to 70 per cent (wb).

Development of mini-tractor operated turmeric harvester

Design of digger blade thickness: The digger blade was assumed as a simply supported beam by three shanks at its sides.

Resistance force for cutting for blade = 16480/3 = 5493.3 N

The blade was made of mild steel (0.5 × 0.2 m)

Draft / unit length, w = 5493.3/0.33 = 16646.5 N m^{-1}
Maximum bending moment = wl^2/8
= (16646.5× 0.33× 0.33)/8 = 226.6 Nm
Allowable bending stress for mild steel section, f = 120 ×10^6 N m^{-2}

Flexural formula states, M/I = f/y

Where, M = Bending moment
I = Moment of inertia = bt^3/12
Where, b = width of blade, m
t = thickness of blade, m
y = t/2
I = 0.2 t^3/12 = 0.0167 t^3

By flexural formula,

$$\frac{226.6}{0.0167\,t^3} = \frac{120 \times 10^6}{t/2}$$

t = 0.0075 m = 7.5 mm

Therefore, a mild steel plate of 8 mm thickness was selected for

the digger blade. Therefore, the dimensions of the digger blade were 1000(l) × 200(b) × 8(t) mm.

Power required for digging: The row spacing adopted was 450 mm and hence the width of cut for a single blade for two rows over a total width of 900 mm was selected. The maximum depth of operation required is 200 mm (Kawale *et al.*, 2018).

Area of cross section of soil dugout by blade = depth × width

= 0.2 × 1 m

= 0.2 m²

The maximum unit draft of soil = 0.103 × 10⁶ N m⁻²

Since, the implement is operated in the soil which is relatively loose compared to unploughed field, the unit draft is taken as 80 % of assumed value.

Therefore, unit draft = 0.103 × 10⁶ × 0.8 = 82400 N m⁻²

Soil resistance for cutting = unit draft × area of cross section of soil cut

= 82400 × 0.2 = 16480 N

Assuming the forward speed of tractor = 0.7 m s⁻¹

Power required = draft × speed = 16480 × 0.7 = 11536 W or 11.54 kW

Power required for pulling implement

Total weight of the implement with hitch frame = 1177 N (120 kg)

Force required to pull the unit, F = μR

Where,

μ = coefficient of friction

R = weight of the unit, N

Coefficient of friction was taken as 0.8 (Kepner *et al.*, 2003)

Therefore, F = 0.8 × 1177 = 941.6 N

= 941.6 × 0.7 = 660 W or 0.66 kW

Power required for conveyor

Weight of the soil rhizome mass to be conveyed per second on conveyor = 250 kg

Assuming 50 % of soil mass would fall down at the time of conveying, the net mass to be conveyed = 125 kg s⁻¹

Conveyor speed = 2.5 km h⁻¹ or 0.7 m s⁻¹.

Slip factor= 0.25

Therefore,

$$\text{Power required from PTO} = \frac{125 \times 9.8 \times 0.7}{0.75} = 1.15 \text{ kW}$$

Total power requirement of the unit = digging + pulling implement + conveyor

= 11.54 kW + 0.66 kW + 1.15 kW = 13.35 kW

Volume of soil with rhizome conveyed: The forward speed of the tractor should be operated at 2.5 km h⁻¹. So that the optimum quantity of digged soil and rhizome will pass to the conveyor and the conveyor also convey that in efficient manner without any lagging.

The forward speed of tractor = 2.5 km h⁻¹ = 0.7 m s⁻¹

The area of digging of soil = 1 × 0.2 m = 0.2 m²

The volume of soil conveyed to conveyor = 0.14 m³s⁻¹

The moisture content of finger and mother rhizomes was found to be 386.85 and 231.56 % (db). The length, width and thickness of turmeric rhizomes were found to be 7.90, 2.48 and 2.32 cm, respectively. The roundness of fresh finger and mother rhizomes were 0.3065 and 0.5244, respectively. In case of sphericity, the fresh finger and mother rhizomes recorded 0.3052 and 0.4312, respectively. The cylindricity of fresh finger and mother rhizomes were found to be 0.7604 and 0.6428, respectively. The bulk density of finger and mother rhizomes was 523.85 and 532.25 kg m⁻³, respectively. Overall dimensions of the equipment are

Specification of mini-tractor operated turmeric harvester

S.No.	Parameters	Specifications
1	Overall dimensions (L×W×H), mm	1000×1000×600
2	Power source	25 hp
3	Blade width × thickness, mm	1000×8
4	Length of belt, mm	1650
5	Digging depth , mm	Upto 200
6	Length of conveyor, mm	700
7	Gear box speed ratio	2:1
8	Type of conveyor	Chain conveyor
9	Numbers of conveyor flats	18
10	Spacing between the conveyor flats, mm	50
11	Power transmission	Belt drive
12	Slope of conveyor, degree	20
13	Weight of the unit, kg	120

1000×1000×600 mm. The digger blade was designed with dimensions of 1000(l) × 200(b) × 8(t) mm. Length and width of conveyor was 700 mm and 1000 mm, respectively. Power required for digging, pulling an equipment and conveyor are 11.54 kW, 0.66 kW and 1.15 kW. Total power requirement of the unit is 13.35 kW.

An turmeric harvesting equipment was developed with overall dimensions of 1000×1000×600 mm (L×W×H). The digger blade was designed with dimensions of 1000(l) × 200(b) × 8(t) mm. Power required for digging, pulling the equipment and conveyor is 11.54 kW, 0.66 kW and 1.15 kW, respectively. Total power requirement of the unit is 13.35 kW.

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