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Research Article

DESIGN AND DEVELOPMENT OF TURMERIC WASHER

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Abstract: Turmeric, the rhizome of *Curcuma longa* L. is one of the most widely used spices of the family Zingeberaceae. Turmeric will require cleaning of rhizomes to improve the efficiency of operations like boiling, drying and polishing. The main components of turmeric washer are feeding mechanism, cylindrical rotary drum, water spray assembly, washed turmeric outlet, motor, pump and water collection tank. The collected waste water was filtered and re-circulated with the help of a pump. The design of feeding mechanism and turmeric washer were discussed in this paper.

Keywords: *Turmeric Washing, Feeding Mechanism, Water Spray Assembly*

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Introduction

Turmeric, the rhizome of *Curcuma longa* L. is one of the most widely used spices of the family Zingeberaceae. Turmeric is one of the important cash crops in India. India is the leading producer and exporter of turmeric with a production area of 10,52,100 metric tonnes in the year 2016-2017. Washing of turmeric is necessary to remove soil and other foreign material before sorting, grading, weighing, and counting the samples. The primary motivations for the development of a mechanical turmeric washer are improved turmeric quality, time labour savings and improved efficiency of sample handling. Jayashree and Visvanathan (2010) developed a mechanical washer for washing of ginger [1]. It consists of a rotary drum, water spray assembly, shaft, cover, motor and washed ginger collection tray. Ambrose and Annamalai (2013) developed a batch type vegetable washer [2]. The holding capacity of 10 kg was developed for washing root vegetables like carrot and radish. Verma and Karwasra (2018) developed a vegetable washer for washing carrots [3]. The vegetable washing machine consists of a rotor which runs at 25 rpm approximately. The rotating drum was made of 197 nos. of square MS bars of 0.7× 0.7 cm size on the periphery of drum of diameter 91 cm. The length of the drum is 3.60 m and mounted between two bearings fixed on the frame through a hallow shaft of diameter 5.7 cm. Stainless steel pipe carrying water was mounted on one side of the rotating drum. A centrifugal pump was used for spraying water through pipe on the carrot in the drum so that the carrots are cleaned. Power input shaft receives drive from tractor PTO shaft and transmits power to centrifugal pump and rotor assembly through V-belt and pulley and set of gears. This paper deals with design and development of turmeric washer.

Materials and Methods

Raw materials

The raw material used for experiment was freshly harvested turmeric rhizomes (variety: Orissa) were obtained from Theethipalayam, Perur in Coimbatore district of Tamil Nadu.

Design on Feeding Mechanism of Turmeric Washer

An inclined bucket elevator along with hopper was designed and fabricated for turmeric washer. The assumptions regarding bulk density and angle of repose of turmeric rhizome, bucket size, angle of inclination of the elevator were made. Detailed procedure for the design of feeding mechanism for turmeric washer is discussed as following. Design of bucket elevator as reported by Phirke (2004) was referred [4].

Dimensions of Turmeric Rhizome

Turmeric rhizome was randomly chosen for measuring dimensions. Length, width and thickness of each rhizome were measured using Vernier calliper (least count 0.01 cm). Hundred observations were made to get average values of length, width and thickness of the turmeric rhizome.

Geometric Mean Diameter (GMD)

The geometric mean diameter for the 100 rhizomes was determined using the measured geometric dimensions of length (L), width (W) and thickness (T). The equation is given below [5].

$$GMD = (LMT)^{1/3} \quad (1)$$

Surface Area and Volume

The surface area and volume of turmeric rhizome were calculated based on the geometric mean diameter (GMD) in the following equations (Mohsenin, 1970) [5].

$$S = \pi(GMD)^2 \quad (2)$$

$$V = \frac{\pi}{6}(GMD)^3 \quad (3)$$

Angle of Repose

The angle of repose is an important physical property for the design of processing, storage and conveying systems of particulate materials. When the material is smooth and rounded, the angle of repose is low. For sticky and fine materials the angle of repose is high. The angle of repose, therefore, indicates the cohesion amongst the individual units of the materials [5].

Bulk density

The bulk density of rhizomes was calculated by filling a circular container of known volume and weighing the content. The bulk density is expressed as the ratio of weight to volume [5].

$$Bulk\ density = \frac{Weight\ of\ turmeric\ rhizomes,(kg)}{Volume\ of\ the\ container,(m3)} \quad (4)$$

True density

The true density of turmeric rhizomes was determined by platform scale method (Mohsenin, 1970) [5]. The turmeric samples were weighed using an electronic balance. The weighed sample was then immersed into a container having known volume of water. The increase in mass of the displaced water is noted. True density of the turmeric rhizome was determined by using the following expression.

$$True\ density = \frac{Mass\ of\ water\ displaced,(kg)}{volume\ of\ the\ container,(m3)} \quad (5)$$

Porosity

Porosity is a vital physical property that characterizes the amount of air spaces in a bulk. It is needed in modeling and design of various heat and mass transfer processes. It is defined as the volume fraction of air in the bulk sample and is calculated by Mohsenin, (1970) [5].

$$\text{Porosity, P} = \frac{\rho_t - \rho_b}{\rho_t} X\ 100 \quad (6)$$

Where,

ρ_t is the true density, kg/m^3

ρ_b is the bulk density, kg/m^3

Coefficient of Friction

The coefficient of static friction was determined on four different structural surfaces namely plywood, galvanized steel sheet, rubber and glass. Each rhizome was placed on the surface and raised gradually by screw until the rhizome begins to slide. The angle θ of the inclined surface with the horizontal platform at the beginning of the sliding was measured. The coefficient of static friction (μs) was calculated using the following equation [5].

$$\mu_s = tan\theta \quad (7)$$

Selection of bucket

In order to reduce the damage to rhizomes during feeding, PVC buckets were selected. Volume of each bucket was measured to be 0.00128 m^3. Each bucket can carry 440 g of turmeric rhizomes. Spacing of buckets was assumed to be 20 cm and therefore number of buckets per meter length of belt were estimated to be 5.

Assumed values for feed mechanism

In order to optimize feed rate for turmeric washer, range of conveying capacity was assumed to be 300 - 400 kg / hr. Inclination of proposed elevator was assumed to be 45O. Based on assumed inclination angle, slant height of elevator was estimated to be 2 m.

Determination of diameter of head pulley

For selected bucket, measured width is 20 cm. therefore width of belt was selected as 25 cm. number of plies for selected width of belt were 4.

Therefore,

$$Diameter\ of\ head\ pulley = \frac{Number\ of\ belt\ plies\ X}{\frac{coefficient\ of\ discharge}{1000}} \quad (8)$$

Speed of drive pulley (n)

$$n = \frac{60\ X\ Vb}{Dp\ X\ 3.15} \quad (9)$$

Where,

n = rpm of drive pulley

Vb = speed of belt, m/s

Dp = diameter of drive pulley, m

Calculation of belt pull and power requirement

i. Weight of material on belt, kg

$$\text{weight of material on belt} = \frac{Qt}{3.6\ X\ Vb} \quad (10)$$

Where,

Qt = conveying capacity of elevator, t/hr

ii. Weight of belt and bucket per meter length were assumed to be 1 kg each.

iii. Scooping pull by material during filling, N

Ps = 3 x weight of material on belt x 9.81 (11)

iv. Tension in belt on tight side of boot pulley, N

$$P1 = \frac{[Ps+9.81(Wm\ X\ H+Wb\ X\ Hc)]-[1.37\ X\ Wb\ X\ 9.81\ X\ Hc]}{0.37} \quad (12)$$

Where,

Wm = weight of material on belt, kg

H = height of elevator, m

Wb = weight of bucket and belt per unit length, kg

Hc = Centre to centre distance between head and boot pulley

Tension in belt on slack side of boot pulley, N

P2=P1+Ps (13)

v. Tension in belt on slack side of head pulley, N

P3 = P2 + [9.81 X (Wm X H + Wb X Hc)] (14)

vi. Tension in belt on tight side of head pulley

P4 = P1 +[Wb X 9.81 X Hc] (15)

vii. Total pull on head pulley, N

Pt=P3–P4 (16)

viii. Power requirement at drive shaft, kW

pds= [Pt X Vb] / 986 (17)

hp= (pds X 1000) / 745.7 (18)

Water spray assembly

The water spray assembly is made up of uPVC pipe of 3cm diameter inside the drum and GI pipe of 3cm outside the drum. On the uPVC pipe, perforations are drilled. A gate valve was provided to control the water flow rate into the drum. The rectangular tank was fixed below the rotating drum with dimensions 200 x 61 x 25cm of 300 liters water capacity for collecting the sprayed water from the rotating drum. The collected waste water was filtered and re-circulated with the help of a pump.

The flow rate of water is measured by ratio of the capacity of fluid stored to the given time.

$$Q = \frac{C}{t} \quad (19)$$

Where,

Q - Flow rate of water, m^3/s

C - Capacity of fluid stored, m^3

T - Time, s

Velocity of the fluid is calculated by dividing flow rate of fluid in a pipe by flow area.

$$V = \frac{Q}{A} \quad (20)$$

Where,

V – Velocity of the fluid, m/s

Q - Flow rate of water, m^3/s

A - Flow area, m^2

Results and discussion

Design on feeding mechanism of turmeric washer

A sample of 30 turmeric rhizomes of Orissa variety at 82 % moisture content (w.b.) were measured using Vernier calliper (least count 0.01 cm) to determine its length (L), width (W) and thickness (T) and their physical properties were listed in [Table-1]. Similar results were obtained in the case of Balasubramanian *et al* (2012) [6] Dhineshkumar and Anandakumar (2016) [7] and Wasiya *et al* (2017) [8] in IISR Alleppy Supreme and Krishna varieties respectively.

Feeding mechanism

The feed hopper was fabricated using a mild steel sheet. It was formed by welding two pairs of the steel sheets to give a trapezoidal shape. The trapezoidal shape allows the easy passage of rhizome into the buckets. The upper part of the hopper has a dimension of 0.5 m by 0.5 m while the lower part has a dimension of 0.12 mm by 0.21 m. An inclined bucket elevator along with hopper was designed and fabricated for turmeric washer. The Physical properties of turmeric rhizomes were measured for design consideration of feeding mechanism.

It consists of 20 buckets and were mounted on the belt at an interval of 0.19 m each mainly by means of special bucket bolts with a big flat disc head which was pressed through holes in the elevator belt. The total length of the belt was 2 m. The bucket elevator was driven by 1 hp motor. The speed of the elevator can be altered using variable speed motor. The schematic and isometric view of feeding mechanism for turmeric washer were shown in Fig- 1 and Fig- 2.

Table-1 *Physical Properties of Turmeric rhizome*

S	Physical Properties	Values
1	Length (L)	9.58 ± 1.59 cm
2	Width (W)	4.44 ± 1.31 cm
3	Thickness (T)	2.67 ± 0.49 cm
4	Geometric Mean Diameter(GMD)	4.78 ± 0.72 cm
5	Surface Area	73.35 ± 21.65 cm^2
6	Volume	60.82 ± 26.29 cm^3
7	Angle of repose	46.33 ± 1.15°
8	Coefficient of friction at different surfaces a. Leather sheet b. Plywood c. Aluminum sheet d. Galvanized Iron sheet	 0.69 0.58 0.65 0.74
9	Bulk density	393.5 ± 19.28 kg/m^3
10	True density	1032.38 ± 32.02 kg/m^3.
11	Porosity	83.56 ± 1.38 %.

Table-2 *Designed specification for feeding mechanism*

SN	Specification	
1	Diameter of head pulley	0.35 m
2	Theoretical scooping pull	73.5 N
3	Tension in belt on tight side of boot pulley	265.46 N
4	Tension in belt on slack side of boot pulley	338.96 N
5	Tension in belt on slack side of head pulley	417.44 N
6	Tension in belt on tight side of head pulley	304.7 N
7	Total pull on head pulley	112.74 N

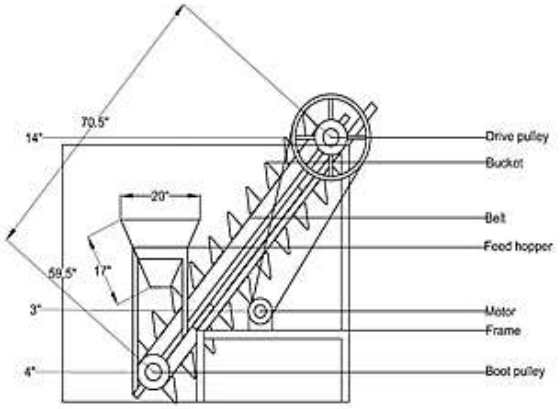

Fig-1 Schematic diagram of feeding mechanism for turmeric washer

Fig-2 Feeding mechanism for turmeric washer

Turmeric washer

A rotary drum continuous type mechanical washer was developed for washing turmeric rhizomes. It was used to perform mechanical washing of turmeric and its washing efficiency was evaluated. The washer consists of rotary drum, water spray assembly, helical gear, cover, and motor and washer turmeric collection tray. The details of the various components of the turmeric washer are described in detail as follows:

Rotary drum

The washer consists of a rotary drum of 180 cm long and 60 cm diameter. The drum is made up of stainless sheet with rectangular holes of 6 mm x 25 mm punched on it.

Water spray assembly

The water spray assembly is made up of uPVC pipe of 0.03 m diameter inside the drum and GI pipe of 0.03 m outside the drum. On the uPVC pipe, perforations are drilled. A gate valve was provided to control the water flow rate into the drum. The rectangular tank was fixed below the rotating drum with dimensions 2 x 0.61 x 0.25 m of 300 liters water capacity for collecting the sprayed water from the rotating drum. The collected waste water was filtered and re-circulated with the help of a pump. The water flows at the rate of 1.8 m^3/h and pressure inside the pipe is 0.2 kg/cm^2.

Triangular hole type

The triangular hole spray type (A) consist of three holes of diameter 3 mm. The three holes were drilled at an angle of 60° and the distance between each hole was 10 mm. the diameter of the hole was 3 mm. There are 17 holes drilled at an interval of 10 cm on the uPVC pipe. A water flow valve was fitted at the end of the pipe to control the pressure inside the pipe. Here the velocity of spray is 3.1 m/s. The triangular hole spray type (A) was shown in Fig- 4.

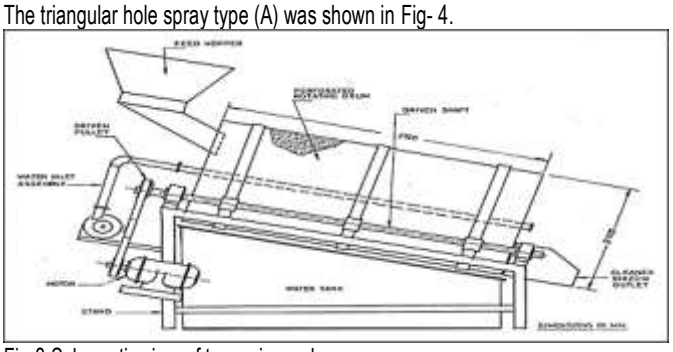

Fig-3 Schematic view of turmeric washer

Fig-4 Triangular spray type

Slotted hole type

The slotted hole spray type (B) consist of a pair of slotted hole of dimension 10 mm × 3 mm. The distance between the pair was 10 mm. There are 17 holes drilled at an interval of 10 cm on the uPVC pipe. A water flow valve was fitted at the end of the pipe to control the pressure inside the pipe. Here the velocity of spray is 2.6 m/s. The slotted hole type (B) was shown in Fig- 5.

Single hole type

The single hole spray type (C) consist of single hole of diameter 3 mm. There are 17 holes drilled at an interval of 10 cm on the uPVC pipe. A gate valve was fitted at the end of the pipe to control the pressure inside the pipe. Here the velocity of spray is 5 m/s. The Single hole spray (C) was shown in Fig- 6.

Fig-5 Slotted hole spray type

Fig-6 Single hole spray type

Motor

1 hp single-phase variable speed DC motor (10-1400 rpm) was provided to rotate the drum. The motor is fixed on a separate frame, which is attached to the main frame. The power from the motor is transmitted by a 6.25 cm diameter pulley to 15 cm diameter pulley for variable speed and the power was then transmitted to a helical gear assembly of the rotating drum.

Helical gear

Helical gear can run with high pitch line velocity and can achieve much higher efficiency. Helical gear that enables a favorable bearing contact and a reduced level of vibration. Helical gear wheel diameter 666mm x inner diameter 605mm x 25mm thickness with 212 teeth. To improve the smoothness of rotating drum, three pulleys have been provided through helical gear.

Collection chamber

The washed turmeric was received at a trapezoidal shaped collection chamber of 46 cm top width, 20 cm bottom width, 50 cm length and 10 cm height were fabricated with stainless steel 2mm thickness to drain the excess wash water draining from the surface of turmeric after washing. At the end of this outlet tray, cleaned turmeric rhizomes were collected in separate boxes.

Cover

The half circle cover is made of stainless-steel sheet of thickness 0.2cm. The cover is bended to fit the dimensions of rotating drum and it is hinged to the main frame with closing at both ends. The top concave cover is of size 197cm length with diameter of 72cm. An inter-space of 7 cm has been provided between rotating drum and cover.

Conclusion

The freshly harvested turmeric rhizomes were loaded in the elevator and were conveyed into the mechanical washer for washing. The experiments were conducted at different combinations such as feed rate (290 kg/h, 320 kg/h, and 350 kg/h), spray type (A, B and C) and drum speed (40 and 50 rpm). Performance of turmeric washer was evaluated in terms of mechanical washing efficiency, colour values and bruise index to optimize the above combinations. The maximum mechanical washing efficiency of 94.02 % was found in slotted hole spray type (B) at 40 rpm drum speed and at 290 kg/h feed rate. The L*, a* and b* value of unwashed turmeric rhizomes were 35.45 ± 1.62, 8.39 ± 0.28 and 12.20 ± 0.39 respectively. The maximum L* value of 42.94 ± 0.60 was found in slotted hole spray type (B) at 40 rpm drum speed during washing.

Application of research: The main aims of this machine are to remove the field soil, dust and dirt adhered into rhizomes, to reduce the surface microbial load, to remove fungicides, insecticides and other pesticides adhered on the surface of the roots and to improve the quality and physical appearance of turmeric and thereby its marketability.

Research Category: Agricultural engineering

Abbreviations: %: Percentage, cm: Centimetre, m: Meter, mm: millimetre, w.b.: Wet basis, g: Gram, kg: Kilogram, min: Minutes, h: Hour , s: Second, PVC: Poly Vinyl Chloride, uPVC: Unplasticized olyvinyl choride **Acknowledgement / Funding**: Authors are thankful to Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, 641003.

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Study area / Sample Collection: Theethipalayam, Perur in Coimbatore district of Tamil Nadu.

Cultivar / Variety / Breed name: Turmeric rhizomes- variety: Orissa

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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