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Determination of Engineering Properties of Coleus Pertinent to the Design of a Digging-cum-Windrowing Unit

A R SURAJA* AND P R JAYAN

ABSTRACT

Coleus (*Solenostemon rotundifolius*) is an important minor tuber crop grown in the homesteads of Kerala and Tamil Nadu. There was a demand for mechanisation for harvesting the tuber because the conventional method of harvesting followed was tedious and time-consuming. For the design and development of a coleus harvester with reduced drudgery, the design parameters were selected with respect to the tuber properties. Random sampling was carried out for determining the physical and frictional properties of coleus. The average values of physical properties such as length, width, thickness, geometric mean diameter, sphericity, surface area, volume and bulk density were found out as 44.56 mm, 27.36 mm, 24.50 mm, 30.99 mm, 0.70, 3029.69 mm^2, 15786.50 mm^3 and 718.21 kg m^{-3} respectively. The angle of repose was determined as 30.83° and the coefficient of static friction was found out as 0.73, 0.69 and 0.81 on galvanised iron, stainless steel and plywood surfaces respectively. These data were used for the design of various components of the harvester.

Keywords: Coleus, tuber, engineering properties, harvesting, windrower unit

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INTRODUCTION

Agriculture is one of the most important occupations done in India and plays a key role in Indian economy. Farmers started cultivating tuber crops, as it was considered to be a resilient crop that can grow under adverse weather conditions. Also, it was found to be sustainable on production and economic basis. Tubers provide essential dietary fibre and energy to people during challenging periods.

Coleus (*Solenostemon rotundifolius*) is an important minor tuber crop that belongs to the family of Lamiaceae. It is commonly called Chinese potato, Hausa potato, country potato, koorka or sirukizhangu. It grows under both tropical and sub-tropical conditions. A well-drained light sandy loam soil is the optimum yield condition for its growth. It is supposed to be a native of Central East Africa but later it was adapted to China and South East Asia including India and Sri Lanka. It is mostly grown in homesteads of Kerala and Tamil Nadu. It is a small herb with succulent ascending tuber that grows to a height of 15 to 30 cm (Reddy, 2015).

Conventionally, coleus is harvested by manually digging the field using hand tools such as a spade, fork or pickaxe and lifting the clumps with hands. This method is a time consuming and labour-intensive process for which mechanisation is required. The determination of engineering properties is significant for designing a machine for digging and separating the tubers from soil mass. Khura et al. (2010) conducted field experiments to determine the biometric and engineering properties of onion crops that influenced the design parameters for the development of diggers. The biometric properties of the onion bulb such as length of the plant, plant density, plant spacing, row spacing and depth were determined. The engineering properties including dimensions, bulk density and coefficient of static friction were also determined. Narender et al. (2019) determined some physical properties such as linear dimensions, geometric mean diameter, bulk density, surface area, sphericity and load required for crushing and cutting of ginger for the design of the digger. Patil and Jayan (2020) studied the biometric and engineering properties of turmeric rhizome essential for the design and development of a root crop harvester.

Although the engineering properties of the crop influences the machine parameters while designing, no relevant information was available for the design of the coleus harvester. Therefore, the purpose of the present study was to determine the engineering properties of coleus for the design of the digging unit and soil separator cum windrower unit for coleus.

MATERIALS AND METHODS

Fresh coleus was randomly chosen and was used to determine various physical and frictional properties influencing the design of the harvester. In this study, the physical properties such as linear dimensions, geometric mean diameter, sphericity, surface area and volume, bulk density and frictional properties such as angle of repose and coefficient of static friction were selected.

Size

Ten tubers were selected for the determination of dimensions. The linear dimensions of coleus, the major (a), intermediate

[1] PG Student, Dept. of Farm Machinery and Power Engg., Kelappaji College of Ag. Engg. and Technology, Kerala Agricultural University, Malappuram, Kerala, India
[2] Professor and Head, Deptt. of Farm Machinery and Power Engg., Kelappaji College of Ag. Engg. and Technology, Kerala Agricultural University, Malappuram, Kerala, India
*Corresponding Author E-mail: surajaramakrishnan18@gmail.com

(b) and minor diameters (c), also referred to as length, width and thickness respectively (Fig. 1) were measured. The measurement of each sample was carried out using a vernier calliper (0.01 cm least count).

Geometric Mean Diameter

The geometric mean diameter (GMD) of the coleus was calculated using the measured linear dimensions viz., length, width and thickness. The following equation given by Mohsenin (1986) was used for calculating geometric mean diameter.

$$GMD = (abc)^{1/3}$$

where,

GMD- Geometric mean diameter, mm

a- Major diameter, mm

b- Intermediate diameter, mm

c- Minor diameter, mm

Sphericity

Sphericity is defined as the ratio of the surface area of a sphere having the same volume as that of the tuber to the surface area of the tuber. Indirectly, it defines its shape. The higher the computed value of sphericity, the closer the shape is to a sphere. It determines the tendency of tubers to roll over a surface when placed in a particular orientation. Sphericity was calculated using the measured geometric dimensions of the tuber. The following equation given by Mohsenin (1986)

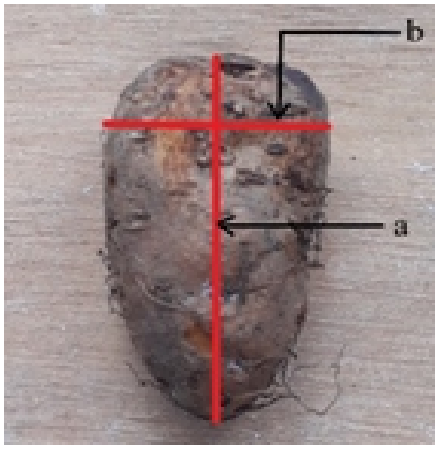

Fig. 1: Axial dimensions of coleus tuber

$$\text{Surface area} = \pi \ GMD^2$$

$$\text{Volume} = \frac{\pi}{6} GMD^3$$

Bulk density

The bulk density of the coleus was calculated by taking the ratio of the bulk weight of the tuber to its volume. A container of known volume was filled with the sample. Then, the weight of the same sample used for filling the container was weighed. The bulk density was calculated by using the following equation:

$$\varrho = \frac{M}{V}$$

where,

ϱ- Bulk density, kg m^{-3}

— Mass of the sample used for filling the container, kg

V- Volume of the container used, m^3

Angle of repose

The angle of repose was determined by using a topless box with a removable panel on one side. The box was filled with tuber with the removable panel closed. After filling upto a particular level, the side panel was removed quickly allowing the tubers to slide down on the floor forming a natural slope. The height of the tuber (h) in the box and the base distance (l) after sliding were measured. The conveyance of the material over the harvester is evaluated by considering the angle of repose.

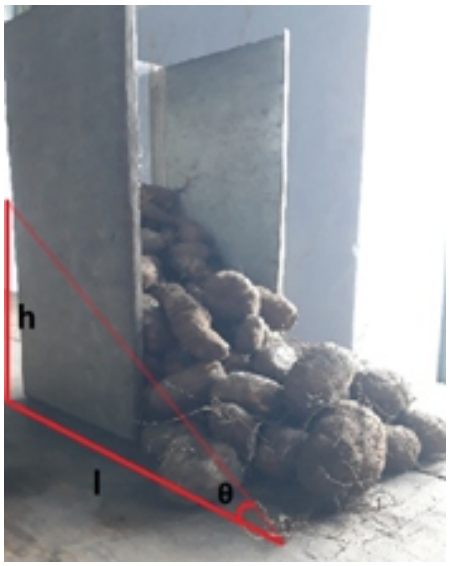

Fig. 2. Determination of angle of repose

The following equation is used to determine the angle of repose of tuber:

$$\theta = \tan^{-1}\left(\frac{h}{l}\right)$$

where,

θ- angle of repose, deg

h- the height of the heap formed after sliding, m

l- base distance of the heap formed after sliding, m

Coefficient of static friction

It is the ratio of the force required for sliding the sample over a particular surface to the weight of the sample. The coefficient of static friction was determined using three test surfaces, viz., galvanised iron, stainless steel and plywood. This was estimated as the pull force required to just start moving the sample over a flat surface divided by the sample weight. A known weight of the sample was taken in a container. This

Table 1: Physical properties of coleus tuber

Sl. No.	Length (mm)	Width (mm)	Thickness (mm)	Geometric mean diameter (mm)	Sphericity	Surface area (mm^2)	Volume (mm^3)	Bulk density ($kg\ m^{-3}$)
1	47.3	25.1	23.4	30.29	0.64	2881.71	14546.19	659.23
2	42.5	28.2	24.8	30.98	0.73	3014.46	15562.82	671.14
3	47.1	25.66	24.8	31.06	0.66	3031.35	15693.79	754.87
4	42.6	24.7	24.24	29.44	0.69	2722.13	13354.81	777.43
5	38.8	26.1	21.2	27.79	0.72	2426.73	11241.05	692.18
6	46.8	26.8	25.5	31.74	0.68	3165.41	16746.32	679.31
7	45.9	32.4	27.9	34.62	0.75	3765.23	21725.04	720.51
8	39.7	26.6	24.3	29.50	0.74	2733.18	13436.22	752.12
9	48.6	33.5	25.2	34.49	0.71	3737.12	21482.27	746.87
10	46.3	24.5	23.7	29.96	0.65	2819.34	14076.48	728.42
Range	38.8-48.6	24.5-33.5	21.2-27.9	27.79-34.62	0.64-0.75	2426.73-3765.23	11241.05-21725.04	659.23-777.43
Mean	44.56	27.36	24.50	30.99	0.70	3029.67	15786.50	718.21
SD	3.24	2.99	1.62	2.06	0.04	408.94	3244.20	38.49

Table 2: Some frictional properties of coleus tuber

Sl. No.	Angle of repose (deg)	Coefficient of static friction		
		Galvanised Iron	Stainless steel	Plywood
1	32.62	0.74	0.65	0.85
2	28.18	0.72	0.78	0.83
3	30.65	0.75	0.62	0.79
4	31.10	0.69	0.74	0.81
5	31.61	0.73	0.68	0.78
Range	28.18-32.62	0.69-0.75	0.62-0.78	0.78-0.85
Mean	30.83	0.73	0.69	0.81
SD	1.48	0.02	0.06	0.03

container was connected to a pulley system to which the load is added to the hanging cord. Known loads were added to the cord till the sample just begins to slide. The coefficient of static friction was found out by taking the ratio of load on the hanging cord and the weight of the sample taken.

$$\mu = \frac{F_s}{W}$$

where,
F- coefficient of static friction
F_s- load at which the sample just begins to slide, kg
W- the weight of the sample taken, kg

RESULTS AND DISCUSSION

The physical properties of ten randomly selected coleus samples were determined and its mean and standard deviations are as shown in Table 1. It includes length, width, thickness, geometric mean diameter, sphericity, surface area and volume of coleus.

The major diameter (length), intermediate diameter (width) and minor diameter (thickness) of ten samples varied from 38.80- 48.60 mm, 24.50- 33.50 mm and 24.50- 33.50 mm respectively. The average values of all the linear dimensions were found out as 44.56, 27.36 and 24.50 mm with standard deviations of 3.24, 2.99 and 1.62 for length, width and thickness respectively. The geometric mean diameter varied from 27.79 to 34.62 mm with an average value of 30.99 mm and standard deviation of 2.06. The sphericity the samples varied from 0.64 to 0.75 and the average value and standard deviations were about 0.70 and 0.04 respectively. The surface area of the tubers varied from 2426.73 to 3765.23 mm^2 and the volume varied from 11241.05 to 21725.04 mm^3. The average value of the surface area and volume were 3029.67 mm^2 and 15786.50 mm^3 respectively. The bulk density of coleus varied from 659.23 to 777.43 kg m^{-3} with an average value of 718.21 kg m^{-3} and a standard deviation of 38.49.

Table 2 gives the values of frictional properties such as angle of repose and coefficient of static friction. The angle of repose varied from 28.18 to 32.62° with a mean value of 30.83° and standard deviation of 1.48. The coefficient of static friction on galvanised iron, stainless steel and plywood varied from 0.69 to 0.75, 0.62 to 0.78 and 0.78 to 0.85 with an average of 0.73, 0.69 and 0.81 respectively. The standard deviation of coefficient of static friction for three surfaces were observed as 0.02, 0.06 and 0.03 respectively.

Design of harvester

The machine was designed and developed by considering the tuber properties which influenced the design values. The spacing between the rods of the windrower unit was decided based on the dimensions and the shape of the coleus tubers. The spacing was fixed as 30 mm which is the average value of geometric mean diameter. The bulk density of the tuber was useful for determining the material handling capacity and the length of the windrower unit for harvester. The elevation of the soil separator was decided based on the frictional properties of the coleus.

CONCLUSION

In this research work, the mean diameter, sphericity, surface area, volume, bulk density and angle of repose were found out as 30.99 mm, 0.70, 3029.69 mm^2, 15786.50 mm^3, 718.21 kg m^{-3} and 30.83° respectively. The average coefficient of friction on galvanised iron, stainless steel and plywood was found out as 0.73, 0.69 and 0.81 respectively. These data were thus used while determining the length, interspacing of rods, inclination and material handling capacity of various components of digging cum windrowing unit.

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