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Study on the physico-engineering and morphological characteristics of different seed potato tubers

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Abstract
Agriculture mechanization plays very important role for horticulture crops. Role of machineries is increasing day by day. In order to compensate for labour scarcity, reduce labour drudgery and time consumption in conventional planting of potatoes, a prototype of potato planter machine was designed, fabricated and evaluated in the field. The study was conducted to evaluate comparative study of different physical and engineering properties between round and oblong shapes of potato tubers for planting of tubers in prepared seed bed with the help of developed planter during 2019-20 in the research farm of IGKV, Raipur. The potato tubers taken for planting operation were divided into three categories i.e., round, oblong and long-oblong. Different physical and engineering properties of potato tubers was detected for designing various components of the potato tubers planter. The average moisture content of all the potato tubers was 69.39 per cent.

Keywords: Mechanization, oblong, long-oblong, round, geometric mean diameter, sphericity

Introduction
Potato (*Solanum tuberosum* L. Family-Solanaceae) popularly known as 'The king of vegetables' is the most important food crop in the world and has emerged as fourth most important food crop in India after rice, wheat and pulses. Indian vegetable basket is incomplete without potato. It is a starchy tuberous food crop containing many vitamins and minerals. Potato is temperate crop grown under subtropical conditions in India. The fleshy part of the root (potato) is commonly eaten as a vegetable. It is rich wellspring of starch and nutrients. Planting of potato is considered as quite possibly the main activity that includes factors like right seed rate, fitting profundity of seed arrangement and required seed dispersing. For planting of potato crop land is furrowed immediately and develop double cross with roto cultivator at a profundity of 24-25 cm. Potatoes are grown in almost every state in India. India's major potato-growing states include Uttar Pradesh, West Bengal, Punjab, Karnataka, Assam, Bihar, Madhya Pradesh, Jharkhand, and Chhattisgarh. Potatoes are grown on 1.97 million hectares in India, with a production of 41.55 million tonnes (Mehta *et al.*, 2016) [10]. Potato is in high demand by people from all walks of life. It is famous in far off towns just as in metropolitan regions in everyday life. Various grades of physical and engineering properties of potato tubers are widely used for development and design of potato planter units. Knowledge of physical and engineering properties and other characteristics of potato tubers are necessary to design and fabrication of various components like seed metering units, hopper capacity and densities designing, material selection for various units.

Materials and Methods
The research work was carried out at the instructional farm of IGKV, Raipur and the study was conducted to evaluate comparative study of different physical and engineering properties between round and oblong shapes of potato tubers for planting of tubers in prepared seed bed during 2019-20 in the research farm of IGKV, Raipur. The physical properties of potato tuber involved tuber mass, size, shape, volume, bulk density, porosity, surface area, dimensions, projected area, surface area etc. The size was also expressed in terms of geometric mean diameter, sphericity and equivalent surface area and calculated using the relationships reported by Mohsenin (1986) [12]. There is three category of potato seeds were taken for determination of units of the planter *viz*, size 1; Medium oval as oblong; size 2; Large oval as long-oblong; size 3; Round.

The mass (M) of potato sizes was measured with a digital balance of 0.01 g accuracy. To determine the average size of the potato tubers, one hundred samples were randomly selected and graded. The three linear maximum axial dimensions i.e., major dimension (L), intermediate dimension (W) and minor dimension (T) were measured using a digital vernier calipers with 0.02 mm least count. All these dimensions were measured at a one moisture level assuming that increasing the moisture content of the tuber does not have any significant effect on its linear dimensions.

Test weight of seed (g)
The 100 seed weights were used for recommending seed rate. The test weight was determined by selecting 100 seeds randomly from different lots with the help of an electronic balance with the accuracy of 0.01 g. The values to be reported are the mean of 100 tubers.

Geometric mean diameter (D_g, mm)
The geometric mean diameter (Dg) was calculated by using the following equation as described by Mohsenin (1970) [11]

$$D_g = (LWT)^{\frac{1}{3}}$$

Where,
L= Length;
W= Width;
T= Thickness

Surface area (S, mm^2): Tubers surface area was determined according to Baryeh (2001) [3] by the following formula;

$$S = \pi D_g$$

Sphericity, (S_p, %)
Sphericity is the ratio of surface area of a sphere having the same volume as that of tuber to the surface area of the tuber and was determined using the following formula (Mohsenin, 1986) [12];

$$S_p = \frac{D_g}{L} \times 100$$

Where, $D_g = (LWT)^{\frac{1}{3}}$

Ellipsoid and oblate spheroid volume (mm^3)
Ellipsoid volume and oblate spheroid volume were calculated from the following equation (Mohsenin, 1986) [12];

$$\text{Oblate sphare volume}, V_{osp} = \frac{\pi}{6} \times LW^2$$

$$\text{Ellipsoid volume}, V_{sp} = \frac{\pi}{6} \times LWT$$

Equivalent surface area (mm^2)
The equivalent surface area of the tuber was evaluated using equation as reported by Baryeh (2000) [3].

$$S = \pi(D_g)^2$$

Number and depth of eye and depression
One hundred seeds selected randomly and counted their eye and depression. A digital vernier caliper with a least count of 0.01mm and accuracy of ±0.02 mm was used to measure the depth of eye.

Volume (mm^3)
Volume of potato tuber samples was calculated from the equation below (Mohsenin, 1986) [12];

$$V = \frac{\pi}{6}(L \times W \times T)$$

Arithmetic diameter (A_d, mm)
Arithmetic diameter of potato tuber samples was calculated from the equation below (Mohsenin, 1986) [12];

$$A_{d,} = \frac{(L+W+T)}{3}$$

Bulk density and true density (kg/cm^3)
These properties are useful in deciding the maturity, texture and softness of the tubers, estimation of air space in the tuber tissue and design of the containers for potato planter that holds the potato tubers. The bulk density was determined in kg/m^3 for all the tuber shapes Mohsenin (1986) [12].

$$\text{Bulk density } (\rho_b) = \frac{m}{v}$$

Where,
m = mass of potato tuber
v = volume of container

True density
The volume and true density of fresh potato tuber was determined by toluene displacement method. Toluene will be used because it is absorbed by sample to a lesser extent the true density was calculated from the volume of toluene displaced and the mass of sample and calculated as reported by Mohsenin (1986) [12].

$$\text{True density } (\rho_t) = \frac{m}{v}$$

Where,
m = mass of potato tuber;
v= volume of container;

Porosity (%)
From the value of bulk density and true density, using the following expression as described by Mohsenin (1986) [12] the porosity was calculated.

$$\text{Porosity}, \gamma = 1 - \frac{\rho_b}{\rho_t} \times 100$$

Shape factor (S_f)
Shape factor was determined by equation 3.19, where a, b and c were length, width and height of the seed as mm respectively. The a, b and c dimensions have a relationship of $c < b < a$ (Mohsenin 1986) [12].

$$S_f = \frac{a^2}{bc} \times 100$$

Shape index
Shape index of the measured samples was considered according to (Ismail.1988) [6] as follows where L, W and T is the length, width and thickness of seed. The obtained data were compared with the recommended limits and classified into two main classes (spherical and oval shapes) to specify the tubers according the calculated shape index for each shape

of potato tubers. (I ≤ 1.5 for spherical while, I ≥ 1.5 for oval shape) (Gamea *et al.*, 2009) [4].

$$I = \frac{L}{WT^{\frac{1}{2}}}$$

Potato moisture content

Moisture content was determined by the official method of analysis given in AOAC (1980). Five dissimilar samples were taken into a previously weighed foil by cutting potato into small pieces. Then, it was placed in a well-ventilated oven, maintained at 105 ± 1°C for five hours. After that, it was cooled to room temperature in a desiccator and weighed. The loss in weight due to moisture loss was calculated and expressed in percentage as follows. (Mohsenin, 1986) [12].

$$\text{Moisture } (\%) = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

W_1 = Weight of sample, g
W_2 = Weight of dried sample, g

Result and discussion

The physical and engineering properties of potato tubers were studied for convenient design of potato planter seed metering device and for hopper establishment. All the mean values of hundred and thousand seed weights are depicted in Table. 1. All of the mean values of different physical properties and respectively their variance is also discussed in Table No. 2. The observations are presented as follows:

Size and shape used

Tubers larger than 45mm major diameter called medium oval or oblong shape tubers Tubers larger than 55 mm major diameter called large oval or long-oblong shapes and Tubers of 35-45mm all diameter called medium or round potato tubers (Fig. 1 and Fig. 2)

Weight varies for all categories are; round (20-35g), oblong (35-55g) and long-oblong (55-65g) tubers.

Fig 1: Measurement of maximum, intermediate and minimum diameter of round varieties

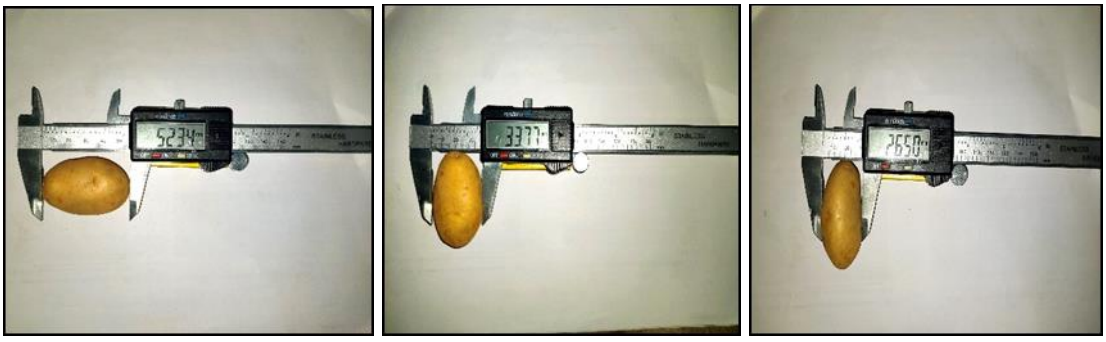

Fig 2: Measurement of Length, width and thickness of oblong and long-oblong shapes

Tuber weight

The average single tuber weight of all three categories i.e., round, oblong and long oblongs were 32.04 (±3.90), 43.85 (±3.06) g and 59.46 (±3.00) g with a C.V of 12.44, 6.98 and 5.04 per cent respectively for round, oblong and long-oblong shape. The weight of the potato tubers varied from 25.98 to 28.18 g, 42.76 to 41.58 g and 62.18 to 60.49 g for round, oblong and long-oblong shapes respectively. The average hundred seed weight were found maximum for the long-oblong type tubers (5386.34 ± 170.06g) and oblong (3491.74 ± 123.29g) followed by round (2508.87 ± 146.39g) with a coefficient of variation of 3.15, 3.53 and 5.83 per cent. Using hundred or thousand seed weight of potatoes the seed hopper capacity as well as loading capacity with rigidity of the planter was designed.

Dimensions of mean length, width, thickness, number and depth of eyes or depression

Average length (L) width (W) and thickness (T). The potato tubers were cut across a longitudinally or laterally and their traced were compared with charted standard. The shape was found round, oblong and large oval (long oblong). The average values of major diameter, intermediate diameter and minor diameter (L, W and T) were 47.64 ± 9.82, 43.87 ± 9.83 and 43.10 ± 11.30 mm with a C.V of 20.62, 22.41 and 26.23 % respectively for medium sized round seeds. The value for the average number of eyes, germinated eye and eye depression of round potato's was 6.40 ± 0.96, 4.20 ± 1.54 and 1.01 ± 0.17 with a C.V of 15.09, 36.88 and 17.11 per cent. The range of axial dimensions for oblong potato tuber were 58.93 ± 6.88, 43.19 ± 8.78 mm and 30.84 ± 7.20 for L, W and T respectively. The CV of average values was 11.68, 20.33 and 23.37 for all samples of oblong tubers. There is indication that dimension (L) is greater than (W) and (T) and dimension (W) is intermediate between (L) and (T). The value for the average number of eyes, germinated eye and eye depression of oblong potato's was 6.60 ± 1.26, 5 ± 1.41 and 0.95 ± 0.32

with a CV of 19.16, 28.28 and 34.46 per cent. Values for the large oval size seed potato tubers, the shape called long-oblong. The average length, width and thickness of long-oblong shape was 73.02 ± 11.17, 44.71 ± 5.78 and 32.63 ± 4.00 with a coefficient of variation of 15.30, 12.94 and 12.28 per cent. The value for the average number of eyes, germinated eye and eye depression of long-oblong potato tubers was 8.09 ± 2.58, 5.45 ± 1.50 and 1.16 ± 0.40 with a coefficient of variation of 31.97, 27.63 and 34.64 per cent respectively.

Moisture content, bulk density and porosity

Potatoes contain about 60 to 80 % water and remaining being the dry matter. The average weight of potato chips sample before and after oven drying was 44.06 ± 1.78 and 15.95 ± 2.21. The average moisture content of potato was 69 ± 6.22 per cent. The small self-constructed container based average values of bulk density for round group, oblong group and long-oblong group were found to be 696.13, 665.19 and 581.09 kg/m^3 respectively. The average bulk density in the case of cutting potato chips was found to 0.87 ± 0.03g/cc with a C.V of 4.04%. The average porosity of the potato was 12.34 ± 3.54 per cent. While true density ranges of samples were 0.921-1.363 g/cm^3, (mean 1.176 g/cm^3), 0.763-1.377 g/cm^3, (mean 1.149 g/cm^3) and 1.068-2.281 g/cm^3 (mean 1.193 g/cm^3) respectively. The overall true densities of the potato tubers varied between 1053 and 974 kg/m^3. The average true density was 989 kg/m^3 with a C.V of 0.38 per cent. The knowledge on bulk density and porosity will be useful in the design of hopper and handling systems.

Geometric mean diameter

The geometric mean diameter (D_g) of round potato tubers was varied from 42.33 to 60.66 mm with a mean of 44.71 ± 9.84 mm and CV of 22.02 %. The value varied from 39.39 to 48.61 mm with a mean of 42.65 ± 7.08 mm and CV of 16.60 per cent for oblong type of potatoes. Figures for geometric mean diameter of long-oblong tubers was found from 40.53 to 47.50mm and their mean was 47.34 ± 5.94 mm with a CV of 12.55 %. The data pertaining to geometric mean diameter indicates the shapes and sizes of potato tubers if any one intermediate diameter of seed has higher value the shape is called long-oblong. Metering mechanism of the developed prototype was based on values of the geometric mean diameter and sphericity of these three types of tubers that had been used.

Sphericity

The per cent sphericity range was 84.15 to 96.63 % and the average per cent sphericity was 93.91 ± 7.80 with a C.V of 8.30 per cent for the round potatoes. The high sphericity values indicate characteristics favorable to rolling of the tubers and thus have practical application in planter slant hopper operations also for other works such as conveying and grading. Sphericity percentage of oblong seed was ranges from 64.51 to 81.19 mm with mean of 72.27 ± 7.69 mm with CV of 10.64 per cent whereas the value ranged from 60.91 to 66.49 mm and mean of 65.17 ± 4.14 mm with CV of 6.35 per cent for long oblong oval potatoes. As higher as the sphericity value of the potato the seed may be round. Potato bracket cups were suited according to the 5th and 95th percentile value of the potato size. As higher as the sphericity with lower size, there may be more chances to doubles and multiple indices.

Volume, ellipsoid volume and oblate spheroid volume (mm^3) of the potatoes

The term volume and oblate spheroid volume are the same term used for potato properties (Mohsenin, 1986) [12] the values of ellipsoid and oblate spheroid volume of oblong shape tubers varied from 32012.30 to 60149.10 mm^3 and 43839.33 to 70223.41 mm^3 their mean values were 43593.3 ± 19600.89 mm^3 and 61174.38 ± 27511.33 mm^3 with a CV of 44.96 and 44.97 per cent. For round potatoes ellipsoid and oblate spheroid volume varied from 39741.6 to 116927.06 mm^3 and 47334.82 to 114348.50 mm^3 their mean values were 53144.42 ± 35944.97 mm^3 and 53990.61 ± 34157.32 mm^3 with a CV of 67.63 and 63.26 per cent.

The ellipsoid and oblate spheroid volume found maximum for long-oblong type of potato tubers and their values varied from 34866.66 to 56144.24 mm^3 and 49203.49 to 84385.21 mm^3 their mean values were 58067.72 ± 24058.23 mm^3 and 34305.08 ± 34305.08 mm^3 with a CV of 41.43 and 42.83 per cent.

Surface area

The mean surface area of round, oblong and long-oblong potato tubers was 140.46 ± 30.94 mm^2, 134.01 ± 22.25 mm^2 and 148.75 ± 18.66 mm^2 with a CV of 22.02, 16.60 and 12.55 per cent.

Equivalent surface area

Equivalent surface area of potatoes was maximum for long-oblong tubers. The average values of equivalent surface area of round, oblong and long-oblong potato was 6554.46 ± 2928.27 mm^2, 5858.72 ± 1835.97 mm^2 and 7144.05 ± 1881.47 mm^2 with a CV of 44.67, 31.33 and 26.33 per cent.

Arithmetic diameter (A_d, mm)

Mean arithmetic diameter was 44.87 ± 9.80, 44.32 ± 6.78 and 50.12 ± 6.53 with CV of 21.85, 15.30 and 13.03 per cent for round, oblong and long-oblong potatoes respectively.

Shape factor

The average shape factor of round, oblong and long oblong potatoes was found maximum for long-oblong type and their values were 125.67 ± 33.97, 281.29 ± 87.06 and 369.16 ± 70.15 with a CV of 27.03, 30.95 and 19.03 per cent respectively.

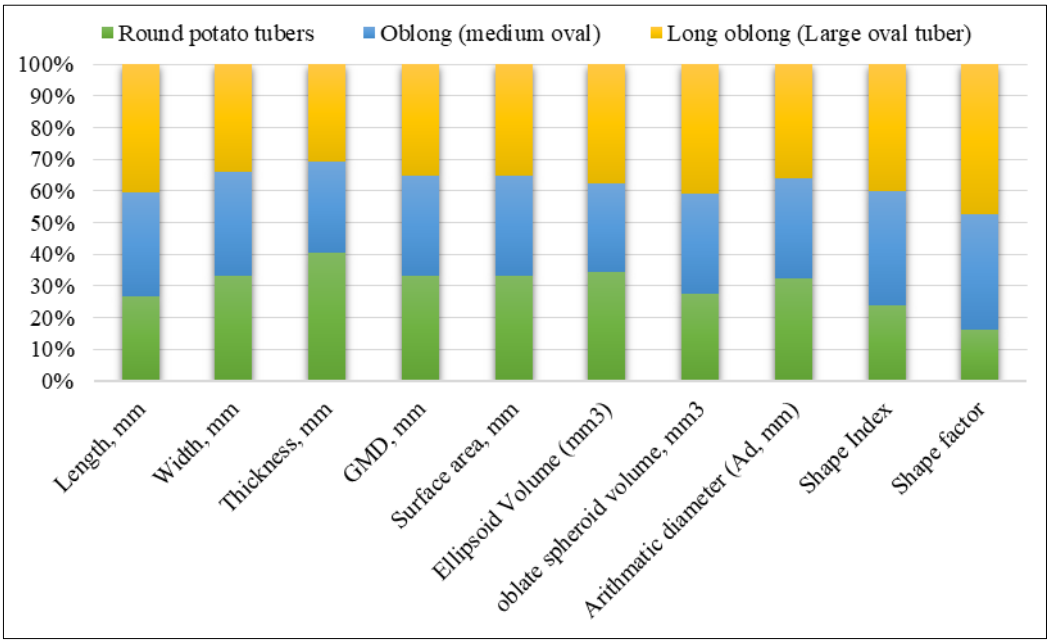

Fig 3: Interaction of physical properties of all the shapes

Shape index

Shape index of potato tubers was found maximum for long-oblong type of potatoes the values of all shapes was ranged from 0.198 to 0.137 mean (0.171 ± 0.03), 0.317 to 0.198 mean (0.258 ±0.06) and 0.343 to 0.267 mean (0.287 ± 0.03) with a CV of 20.95, 23.80 and 10.96 per cent for round, oblong and long-oblong shapes respectively.

Table 1: Values for the single, 100 and 1000 seed t weight of round, oblong and long oblong potato tubers

Shapes	Round			Oblong			Long oblong		
	Single tuber weight, g	100 seed weight, g	1000 seed weight, g	Single tuber weight, g	100 seed weight, g	1000 seed weight, g	Single tuber weight, g	100 seed weight, g	1000 seed weight, g
Mean(x̄)	32.04	2508.87	25088.00	43.85	3491.74	34917.00	59.46	5386.34	53863.00
Sd (σ)	3.90	146.39	14.63	3.06	123.29	12.32	3.00	170.06	17.00
CV%	12.17	5.83	5.83	6.98	3.53	3.53	5.04	3.15	3.15
SE(m)	1.23	65.46	6.54	0.96	55.13	5.51	0.94	76.05	7.60

Physical properties of all the shapes of potato tubers

Particular	Round			Oblong			Long-oblong		
	Mean (x̄)	CV%	SE(m)	Mean (x̄)	CV%	SE(m)	Mean (x̄)	CV%	SE(m)
Length, mm	47.64 ± 9.82	20.62	3.11	58.93 ± 6.89	11.68	2.18	73.02 ± 11.18	15.30	3.37
Width, mm	43.87 ± 9.83	22.41	3.11	43.19 ± 8.78	20.33	2.78	44.713 ± 5.79	12.95	1.75
Thickness, mm	43.10 ± 11.31	26.23	3.58	30.84 ± 7.21	23.37	2.28	32.63 ± 4.01	12.28	1.21
No. of eye	6.40 ± 0.97	15.10	0.31	6.60 ± 1.26	19.17	0.40	8.09 ± 2.59	31.97	0.78
Germinated	4.20 ± 1.55	36.89	0.49	5.00 ± 1.41	28.28	0.45	5.45 ± 1.51	27.64	0.45
Eye depth, mm	1.01 ± 0.17	17.12	0.05	0.95 ± 0.33	34.47	0.10	1.16 ± 0.40	34.65	0.12
G.M.D.	44.71 ± 9.85	22.03	3.11	42.65 ± 7.09	16.61	2.24	47.34 ± 5.94	12.55	1.79
ESA, mm	6554.46 ± 2928.27	44.68	926.00	5858.72 ± 1835.97	31.34	580.59	7144.05 ± 1881.47	26.34	567.29
Sphericity, %	93.91 ± 7.80	08.31	2.47	72.27 ± 7.69	10.65	2.43	65.17 ± 4.14	06.36	1.25
Surface area, mm	140.46 ± 30.94	22.02	9.78	134.01 ± 22.26	16.61	7.04	148.75 ± 18.67	12.55	5.63
EV (mm^3)	53144.42 ± 35944.98	67.63	11366.80	43593.30±19600.89	44.96	6198.35	58067.72 ± 24058.24	41.43	7253.83
OSV, mm^3	53990.61 ± 34157.33	63.26	10801.40	61174.38±27511.33	44.97	8699.85	80079.15 ± 34305.09	42.84	10343.37
Ad, mm	44.87 ± 9.80	21.85	3.10	44.32 ± 6.78	15.30	2.15	50.12 ± 6.53	13.03	1.97
Shape Index, %	0.17 ± 0.03	20.95	0.01	0.25 ± 0.06	23.81	0.02	0.28 ± 0.03	10.97	0.01
Shape factor	125.67 ± 33.97	27.03	10.74	281.29 ± 87.07	30.95	27.53	369.16 ± 70.15	19.00	21.15

*GMD = Geometric mean diameter, AD = Arithmetic diameter, OSV=Oblate spheroid volume, EV= Ellipsoid Volume, ESA= Equivalent surface area

Conclusion

It was concluded that various physical and engineering properties of potato seeds commonly used in Chhattisgarh were determined to design the potato planter components. Practical aspects of different physical and engineering characteristics of potato tubers are presented in the paper. Determination of Physico-engineering properties of different potato tubers before designing a planter is crucial. In this investigation all the required properties were determined first and used in designing the machine which can perform tilling, planting, fertilizing and ditching jobs. The machine which we have invented is working appropriately in laboratory as well as in field with these three categorized tubers. The design and fabrication are matched conferring to the physical and

morphological properties of the seed potato tubers according to requirement.

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