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Physical and mechanical properties of potato (*Kufri Jyoti*) tubers

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Abstract
An understanding of the physical and mechanical qualities of potato tubers is necessary in order to build various farm machinery components. The knowledge of these qualities could also aid in the development of a more efficient machine. Some of the physical and mechanical features of potato tubers, such as size, volume, surface area, rolling angle, coefficient of friction, and so on, are briefly examined in the present study. The average potato tuber length, width, and thickness were 64.11, 55.45, and 42.25 mm, respectively, at a moisture content of 74-76% w.b. The rolling angle and coefficient of friction were respectively 17.67^0 and 0.25.

Keywords: Potato, Kufri Jyoti, physical properties, mechanical properties

Introduction
Potatoes, after rice, wheat, and corn, are the world's most calorie dense crops and play a significant part in global food supply. India is world's second largest producer of vegetables after China producing about 191.77 million metric tonnes according to the 2019-20 second advance estimate given by National Horticulture database. India has been blessed with varied agro-climatic conditions making the cultivation of wide range of vegetables possible in one or other regions, throughout the year, comprising about 2.06 percent of the total gross cropped area (DACF, 2018) [4]. In vegetables, potato, onion and carrot are the most important root crops. Potato the king of vegetables has emerged as one of the most important food crops of India. It alone, contributing almost 25 percent of total vegetable production and has better shelf life compared to other vegetables crops. Potato is widely adaptable because of its easy planting, high productivity per unit area, and the possibility of growing them in two seasons, autumn planting and spring planting and hence requires more emphasis on its production processes it is a popular crop throughout the world and its contribution in Indian economy is manifold. Potato occupies an important place among all food crops all around the world, as in terms of nutritional value, it is the first alternative to cereal crops in solving the food problem (Horton and Sawyer, 1985) [5] as it is a cheap source of carbohydrates and is also rich in vitamin A, vitamin B, vitamin C, iron, potassium and phosphorus (Ismail, 1991) [6].
The various potato types planted in Jammu province of Jammu and Kashmir Union territory are recommended by package of practices (vegetables) published by SKUAST-J as follows: early maturing varieties (Kufri Chandermukhi, Kufri Lauvkar, Kufri Pukhraj Kufri Pukhraj, Kufri Ashoka, Kufri Surya) and medium maturing varieties (Kufri Jyoti, Kufri Bahar, Kufri Chipsona-1, Kufri Arun, Kufri Pushkar, Kufri Shailja, Kufri Chipsona-3, Kufri Himalini, Kufri Frysona, Kufri Girdhari, Kufri Sindhuri, Kufri Badshah). The early maturing varieties requires 70-90 days to give economic yield after planting whereas medium maturing varieties requires 90-100 days to give economic yield after planting. The present study was carried out in Kufri Jyoti variety of potato. Kufri Jyoti tubers, creamish white with shallow eyes, are strewn about. When grown in the warmer parts of the Central Plains, this type is excellent for processing. Early and late blight resistance is moderate in this cultivar. It is wart resistant, has binder adaptability, and a high generation flow rate for stopping. The average yield of this variety is 200- 250 quintals per hectare and 300 quintals per hectare in planes. The chosen Kufri Jyoti variety of potato is easy to cook has a waxy texture, a mild flavour, is ideal for processing, and is free from after-cooking discolouration.
The geometric and morphological characterises of an agricultural fruit are very vital for designing different machines such as for potato digger, grading, separating, handling, cleaning, processing, etc. as these characterises of the agricultural produce become the basis for different

components of above mentioned machines. So a specific knowledge and understanding of these properties can help engineers relate many problems with the design or development of specific machines and also food scientists who may find different uses. The mechanical properties of potato tubers such as rolling angle, friction angle and coefficient of friction are very vital in determining the angle of grading, cleaning and separating parts of a mechanical harvester and also prove significant in other studies such as in the design and development of planters, food processing machineries, etc. Therefore, knowledge about these mechanical properties of potato tubers can help engineers better understand the design parameters of such machines.

Materials and Methods

Geometric and Morphological Properties of Potato tuber

The physical properties of the selected variety of potato crop studied for the development of the prototype are presented below:

Dimensions

The dimensions of potato tubers such as length (L), width (*W*) and thickness (*T*) were measured in millimetre with the help of a digital vernier caliper having a least count of 10^{-5} mm by selecting a sample space of 100 potato tubers at random and the values were recorded.

Geometric mean diameter

The geometric mean diameter (D_g) in mm was calculated with the help of the following expression (Mohsenin, 1986) [7]:

$$\mathrm{Dg} = LWT^{1/3}$$

Where

L = length of the potato tuber, mm
W = width of the potato tuber, mm
T = thickness of the potato tuber mm

Arithmetic mean diameter

The arithmetic mean diameter (D_g) in mm was calculated using the following formula (Mohsenin, 1986) [7]:

$$(\mathrm{Dg}) = \frac{\mathrm{L} + \mathrm{W} + \mathrm{T}}{3}$$

Where

L = length of the potato tuber, mm
W = width of the potato tuber, mm
T = thickness of the potato tuber, mm

Aspect Ratio

The aspect ratio R_a of potato tuber is determined in order to classify the shape of the potato tuber and has been calculated by mathematical expression (Omobuwajo *et al*., 2000) [9]:

$$\mathrm{Ra} = \frac{\mathrm{W}}{\mathrm{L}}$$

Where

W = width of the potato tuber, mm
L = length of the potato tuber, mm

Surface Area

The potato tubers surface area (S) in mm^2 was determined by as suggested by Baryeh (2001) by the following expression:

$$S = \pi D_g^2$$

Where

D_g = geometric mean diameter, mm^2

Volume

The volume (V) in mm^3 of potato tubers was calculated by the following formula as suggested by Mohsenin, 1986 [7].

$$V = \left(\frac{\pi}{6}\right)(LWT)$$

Where

L = length of the potato tuber, mm
W = width of the potato tuber, mm
T = thickness of the potato tuber, mm

Mass

The mass (M) of each potato tuber in gram was measured by using a digital scale with a least count of 10^{-4} gram.

True Density

The true density of the potato tubers was calculate by using the following expression (Mohsenin, 1986) [7]:

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

Where

M = mass of potato tuber, g
V = volume of potato tuber, cm^3

Bulk Density

The bulk density of the potato tubers was calculate by using the following expression (Mohsenin, 1986) [7]:

$$\rho_b = \frac{M}{V_{measured}}$$

Where

M = bulk mass of potato tubers, kg
$V_{measured}$ = measured volume of potato tuber, cm^3

The volume was measured by using a cylindrical flask of known volume filled with water. Potato tubers in bulk were placed in the flask and volume of water raised was measured.
1.10 Porosity

The porosity (ε) was calculated using the formula (Mohsenin, 1986) [7].

$$\epsilon = \left(\frac{\rho_t - \rho_b}{\rho_t}\right) \times 100$$

Where

ϵ - porosity, %
ρb - bulk density, $kg \cdot m^{-3}$
ρt - true density, $kg \cdot m^{-3}$

Sphericity

The sphericity (∅) is defined as the ratio of the surface area to the sphere, has the same volume as that of the fruit to the surface area of the fruit and is generally calculated to estimate the shape of the potato tuber which has been determined by the following mathematical method (Mohsenin, 1986) [7]:

$$\emptyset = \frac{Dg}{L}$$

Where
$\emptyset$ = sphericity of potato tuber, %
D_g = arithmetic mean diameter of potato tuber, mm
L = length of potato tuber, mm

Mechanical properties of Potato tubers
The mechanical parameters of the selected potato crop variety examined for the prototype developed are:

Rolling angle
The rolling angle of potato tubers was calculated by placing randomly selected potato tubers on a horizontal surface one by one and gradually increasing the vertical angle till the tubers begin to roll. The experiment was repeated with 50 randomly selected tubers and the average was estimated for the angle of maximum stability.

Friction Angle
In order to calculate the friction angle of potato tubers, potato tubers were randomly selected and placed in a group of ten tubers bounded together on a horizontal surface then the vertical angle that is the angle of inclination was increased gradually until the potato tubers began sliding without rolling. The experiment was repeated 5 times and the average was calculated.

Coefficient of friction
The coefficient of friction of potato tubers was calculated using the friction angle value and determined by the following formula (Buyanov and Voronyuk, 1985) [3]:

$$\mu = tan\,\theta$$

Where
μ = coefficient of friction
θ = friction angle, degree

Results and Discussion
The potato plant had a compact canopy with green stem having red brown pigment highly scattered throughout whereas the potato tubers were white-cream, ovoid with shallow eyes and cream flesh. The potatoes were dug manually using a *khurpi* and were separated from clods and loose soil by hand. The good potato tubers harvested were identified and selected for the study at random. The average moisture content of tubers was determined according to AOAC (2003) [1] as 75.2% w.b.

Physical properties of potato tubers
The dimensions of the harvested potato tubers were calculated as explained in section 1 with a sample space of 100 tubers randomly selected. The results showed that the length, width and thickness of potato tubers varied from 90.85-46.72, 75.43-39.72 and 58.51-33.70 mm averaging at 64.11, 55.45 and 42.25 mm, respectively. The results also revealed that the potato tubers weighing at 96.24 g on an average (220-40 g) had an average surface area of 9035 mm^2 with an average aspect ratio of 0.87. The study showed that the potato tubers of *Kufri Jyoti* were 84.86% spherical on an average with maximum sphericity of 92.96 percent and minimum sphericity of 69.69%.

Mechanical properties of potato tubers
The mechanical properties of selected potato variety were evaluated in accordance with section 2 and the results showed that the average value of rolling angle, friction angle and coefficient of friction (for steel) were 17.67^0, 14^0 and 0.25 for *Kufri Jyoti* potato tubers.
The various physical and mechanical properties of potato tubers like length, width, thickness, arithmetic diameter, geometric mean diameter, volume surface area, aspect ratio, sphericity, tuber weight, rolling angle, true density, etc., were calculated are presented in Table 1. The data was analysed using descriptive statistics in MS Excel.

Table 1: Physical and mechanical properties of Kufri Jyoti variety of potato

S. No.	Physical Property	Maximum	Minimum	Mean	Standard Deviation	Sample Variance
1	Length (mm)	90.85	46.72	64.11	12.90	166.44
2	Width (mm)	75.43	39.72	55.45	9.51	90.40
3	Thickness (mm)	58.51	33.70	42.25	5.60	31.36
4	Geometric mean diameter (mm)	73.74	40.62	53.03	8.20	67.28
5	Arithmetic mean diameter (mm)	74.93	40.85	53.94	8.63	74.53
6	Aspect ratio	0.97	0.61	0.87	0.070	0.006
7	Surface area (mm^2)	10782.42	5182.94	9035.08	2913.66	8489440
8	Volume (mm^3)	209941.2	35086.35	83627.92	42309.3	1.79E+09
9	Mass (g)	220	40	96.24	47.69	2274.09
10	True density ($g.cm^{-3}$)	1.34	1.03	1.15	0.09	0.008
11	Bulk density ($g.cm^{-3}$)	0.69	0.52	0.61	0.05	0.003
12	Porosity (%)	52.69	42.93	46.73	2.96	8.77
13	Sphericity (%)	92.96	69.69	84.86	5.14	26.44
Mechanical properties of potato tubers						
12	Rolling angle (degree)	24	9	17.67	5.02	25.25
13	Friction angle (degree)	17	12	14	2.12	4.5
14	Coefficient of friction (degree)	0.31	0.21	0.25	0.04	0.0018

Conclusion
Potato is one of the most popular and important root crop grown all around the world. In Jammu division of Jammu and Kashmir, Kufri Jyoti variety of potato is known for its cooking quality and better shelf life. The various physical and mechanical properties of potato tubers such as length, width, thickness, arithmetic diameter, geometric mean diameter, volume surface area, aspect ratio, sphericity, tuber weight, rolling angle, true density, etc., were calculated in the study. The study concluded that at moisture content of 74-76%

(w.b.), the average tuber length, width, thickness, sphericity and aspect ratio were 64.11 mm, 55.45 mm, 42.25 mm, 34.93 and 84.86% respectively.

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