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Physical and engineering properties of groundnut varieties commonly cultivated in Chhattisgarh

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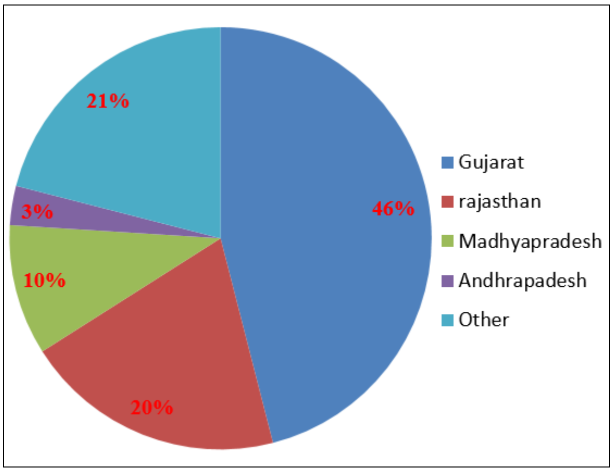
Abstract
Groundnut (*Arachis hypogaea* L.), commonly known as the poor man's nut, plays a significant role in India's oilseed production, ranking second globally in groundnut cultivation. With an estimated cultivation area of 47.07 lakh hectares and a production of 101.80 lakh tons, groundnut serves as a major source of edible oil, protein (25.30%), and fat (40.10%), along with essential nutrients like calcium, iron, and vitamins. Despite its economic importance, groundnut production faces multiple challenges such as climate variability, selection of suitable seeds, and inefficient post-harvest equipment design. In developing countries, lack of data on physical and engineering properties of groundnut pods-such as size, sphericity, bulk density, friction, and rupture force-impacts the design and efficiency of agricultural machinery, leading to crop losses and reduced productivity.
This study evaluates the physical and engineering properties of three groundnut varieties (Jyoti, ICGV00440, and Kadri-9) to provide essential data for equipment design. The average values observed were: length (28.18 mm), width (13.05 mm), thickness (12.07 mm), arithmetic mean diameter (17.77 mm), geometric mean diameter (16.39 mm), sphericity (0.58), bulk density (246.45 kg/m³), true density (438.79 kg/m³), and angle of repose (26.73°). Rupture forces were 31.24 N (longitudinal) and 245.41 N (vertical). These parameters are vital for designing threshing, shelling, handling, and storage systems to minimize losses, improve efficiency, and enhance post-harvest processing.

Keywords: Groundnut, *Arachis hypogaea*, Physical properties

Introduction
The groundnut or peanut is commonly referred to as the poor man's nut. India ranks as the world's second-largest groundnut producer and it is among the oilseed crops. The total area cultivated and production with groundnuts are 47.07 lakh hectares and 101.80 lakh tons, respectively (AMIC; 2025). It has an average fat content of 40.10% and a protein content of 25.30%. Additionally, it is a rich source of calcium, iron, and vitamin B complex components such as thiamine, riboflavin, niacin, and vitamin A. It serves many purposes. It uses on different way like cooking medium, manufacturing of soaps, cosmetics, shaving cream and lubricates. Groundnut (*Arachis hypogaea* L.) crop residues offer significant feed resources for livestock production (Parakhia *et al*., 2017) [12].
The cultivation of groundnuts also poses challenges, including climate change, the selection of suitable seeds, and effective land preparation methods. These factors significantly affect groundnut production and necessitate the use of new technology. In developing countries such as India, the equipment utilized for groundnut processing is typically designed without considering the physical and engineering properties of groundnuts. The agricultural processing equipment designed for cultivation operation, harvesting, threshing, processing, handling, storing and transporting agricultural materials is often considered to have low efficiency regarding the quality of its output and the economy of its use. Moreover, if threshing is delayed, this causes the next crop's sowing to be postponed, which in turn leads to a reduced yield. This perception stems from a lack of data and other engineering properties - such as shape-size, bulk mass, densities and sphericity necessary for designing such machines (Singh and Goswami, 1996; Chukwu and Sunmonu, 2010; Hoque, 2019) [5, 7, 6].



Source: Ministry of Agriculture & farmer welfare, 2024-25

Fig 1: Groundnut production status in India

Materials and Methods

Physical Properties of Groundnut Pods

Groundnut varieties (*Jyoti*, ICGV00440, and *Kadri*-9) weighing 10 kg each were sourced from local farmers near Raipur in Chhattisgarh and measured at the Department of Agricultural Processing and Food Engineering, SV College of Agricultural Engineering & Technology and Research Station, IGKV, Raipur, India.

Determination of the size of the groundnut pods

A total of one hundred groundnut pods were chosen at random, and their three main dimensions (length, width, and thickness) were measured with a digital Vernier caliper that has an accuracy of 0.01 mm. The arithmetic mean diameter (AMD), geometric mean diameter (GMD), sphericity (S), aspect ratio (A_r) and surface area (S_a) were calculated by using Equations (1), (2), (3), (4) and (5) respectively given by:

$$AMD = \frac{L + W + T}{3} \quad (1)$$

$$GMD = (L \times W \times T)^{\frac{1}{3}} \quad (2)$$

$$S = \frac{(L \times W \times T)^{\frac{1}{3}}}{L} \quad (3)$$

$$A_R = \frac{W}{L} \times 100 \quad (4)$$

$$S_a = \pi(GMD)^2 \quad (5)$$

Where, L = Length of groundnut pod; W = width of groundnut pod; T= Thickness of groundnut Pod; AMD = Arithmetic mean diameter; GMD = Geometric mean diameter; S= sphericity; A_r = Aspect ratio and S_a = Surface area.

Determine shape of the groundnut pods

The shape of groundnut pods was established using the formula described by Abd Alla *et al*., (1995); Choudhary *et al*., (2020) [16]. It was proposed that if the index-K value is greater than 1.5, the grain appears oblong, while if the index-K value is less than or equal to 1.5, the grain appears spherical. The mean measurements of the length, width, and thickness of the groundnut pods were inserted into Eq. 6.

$$\text{Index} - K = \frac{L}{\sqrt{W \times T}} \quad (6)$$

Determination of average weight of the groundnut pods

To find out the average weight, a random sample of 1000 groundnut pods was chosen and weighed on a digital balance with an accuracy of 0.01 g. To reduce the error, the experiments were conducted five times (Choudhary *et al*, 2020) [16].

Determination of bulk density and true density of the groundnut pods and kernels

To find out the bulk density, a cylindrical container with a volume of 1000 ml was filled with the pods from a height of 500 mm at a consistent speed, after which the contents were weighed. Pods were not manually compacted separately. The mass of the bulk material divided by the volume that contains this mass was used to calculate the bulk density. The true density is calculated by dividing the weight of the groundnut pod by its true volume, which is determined through the toluene (C_7H_8) displacement method. Water was replaced with toluene, as pods absorb it to a lesser degree. A weighted quantity of pod was immersed in the measured toluene to determine the volume of toluene displaced (Garnayak *et al*., 2008; Ghosal & Rath, 2020) [13, 1].

Determination of angle of repose of the groundnut pods

To measure the angle of repose, a square box with a transparent wall and a hole in the base was used. The box was elevated to a height of 300 mm. Initially, it was filled with pods, sealing the hole. When the hole was opened, the pods were allowed to fall freely. This process was repeated twenty times, and the angle of repose was calculated using the formula described by Karababa (2006) [14] and Ghosal & Rath (2020) [1].

i.e. $\tan\theta = 2H/D$; where H = Height of pile (cone) formed and D = Diameter of formed pile (cone), the angle of repose θ was calculated.

Coefficient of static friction

The force capable of initiating movement determines the coefficient of static friction for any biological material. This is contingent upon the type and nature of the materials or surfaces that are in contact. Data regarding the coefficient of friction are essential for hoppers and conveying units utilized in the decorticator. The static friction coefficient of the pod was measured in relation to a galvanized iron (GI) sheet, plastic, and plywood, which are readily accessible and inexpensive. For the experiments, pods were placed in a four-sided plywood container (200 mm × 80 mm × 50 mm) that was open at both ends and set on a flat surface made of galvanized iron sheet, plastic, or plywood. The entire structure was mounted on a frame that was 1 meter off the ground. A pulley is positioned at the midpoint of the edge of the setup. The weighing plate is supplied with a thread that is hooked to the box. The box moves along a flat surface, while the weighing plate hangs down through a thread that passes over the pulley. Initially, the box was placed at the center position to align with the pulley, ensuring a straight line between the box and the pulley. Subsequently, the box was filled with pods, leaving the other end weightless. Weights were added until the box filled with pods began to slide. The weights of the box together with the pod, as well as the weight applied to make it slide, were determined.

The coefficient of friction can be calculated using the formula $\mu = F_s/N_l$, where F_s represents the applied force and N_l denotes the normal load or force (Ghosal & Rath, 2020) [1].

Rupture force

The pod's rupture force was gauged using an application of force via a universal testing machine found in the department. The sample was positioned on the unmoving lower platform and pressed with the upper platform, which was in motion. Appropriate probe was utilized in the experiment and linked to the computer. The experiment was carried out with a loading speed of 2 mm/min.

Results and Discussion

Physical Properties of Groundnut Pods

Table 1 presents the documented physical characteristics of groundnut pods. The average measurements of length, width, and thickness for groundnut pods of the (*Jyoti*, ICGV00440, and *Kadri*-9) varieties were 28.18 mm, 13.05 mm, and 12.07 mm, respectively. These measured dimensions will be beneficial in designing of hopper, the opening of the concave, crushing drum, and clearance between drum and concave unit as described by (Maduako and Hamman, 2005; Choudhary *et al*., 2020) [15, 16]. The average value of arithmetic mean diameter, geometric mean diameter, sphericity, Aspect ratio, surface area and indek- K of groundnut pods were found to be 17.77 mm, 16.39 mm, 0.58, 47.49, 862.46 mm2 and 2.24, respectively. To ensure effective pod separation without kernel crushing, the arithmetic mean diameter and geometric mean diameter of the groundnut pods are used to determine the appropriate clearance between the threshing drum and concave screen. Sphericity aids in the design of sieves and separation systems by affecting the rolling and passing behavior of pods and kernels through openings. The shape and arrangement of the threshing pegs or beaters are guided by the aspect ratio to ensure they effectively strike the pods while minimizing kernel breakage. Finally, the pods' surface area is essential for the design of the pneumatic cleaning system. The average true density and bulk density of groundnut pods were determined to be 438.79 kg/m^3 and 246.45 kg/m^3, respectively. It was found that the index-K value for groundnut pods is 2.96. Due to the fact that the value of the Index-K is greater than 1.5, it denotes an oblong shape. The densities measured, along with the average weight of groundnut kernels and pods, will inform the determination of the size and capacity of the hopper and threshing chamber, ensuring that the machine operates stably.

Engineering properties of groundnut pod

The groundnut pods exhibited an angle of repose of 26.73° and a coefficient of friction of 0.41. According to Sahay and Singh (2003) [17], the static coefficient of groundnut pods is essential for designing storage bins, pneumatic conveyor systems, screw conveyors, and threshing equipment. The average rupture forces were recorded as 31.24N and 245.41N, depending on the loading orientation (laterally and vertically, respectively). The analysis could indicate that the maximum rupture force needed occurs when the load is applied laterally, as opposed to vertically. The rupture forces were helpful in determining the energy usage for breaking the groundnut pods.

Table 1: Average values of physical properties of different varieties (*Jyoti*, ICGV00440 and *Kadri*-9) groundnut pods

S. No.	Properties	Mean value	Standard division
1.	Length, mm	28.18	± 6.91
2.	Width, mm	13.05	± 1.44
3.	Thickness, mm	12.07	± 1.78
4.	Arithmetic mean diameter, mm	17.77	± 3.33
5.	Geometric mean diameter, mm	16.39	± 2.69
6.	Sphericity	0.58	± 0.04
7.	Aspect ratio	47.49	± 5.78
8.	Surface area, mm^2	862.46	± 291.58
9.	Index-k	2.24	± 0.27
10.	Bulk density, kg/m^3	246.45	± 7.02
11.	True density, kg/m^3	438.79	± 21.40
12.	1000 pod weight, g	1159.58	361.87
13.	Shape	Oblong	

S. No.	Properties	Mean value
1.	Angle of repose, °	26.73
2.	Terminal velocity, m/s	10.11
3.	**Coefficient of static friction**	
	Plywood	0.53
	MS sheet	0.41
	Wood	0.61
4.	**Rupture force, N**	
	Longitudinally	31.24
	Vertically	245.41

Conclusion

Ultimately, the physical and engineering characteristics of groundnut pods are essential parameters that offer a basic understanding useful for designing agricultural machinery involved in harvesting, threshing, shelling, and post-harvest processing tasks. The engineering characteristics of groundnut pods at various loading orientations are crucial for designing units for threshing, milling, handling, storage, and transport. Insufficient understanding of engineering properties may result in a higher incidence of pod breakage during threshing, which can lead to a reduced germination rate and an increased likelihood of insect and pest infestations affecting the quality of the final product.

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