**Effect of Moisture Content on Different Engineering Properties of Pigeon Pea**

**Abstract**

Pigeon pea (*Cajanus cajan*) is a crucial pulse crop cultivated across tropical and subtropical countries, with India being the largest producer. It plays an important role in food security, soil enrichment through nitrogen fixation, and adaptation to marginal environments. This study characterizes the physical properties of pigeon pea grains for optimization in agricultural and processing industries. Key physical properties, including sphericity (0.82–0.90), grain weight (96–102 g), bulk density (820–890 kg/m³), actual density (1310–1340 kg/m³), coefficient of internal friction (0.4–0.7), and angle of repose (25–28°C), were studied under varied moisture conditions. The findings indicate that moisture content significantly influences these properties, impacting handling, storage, and processing efficiency. Pigeon pea’s tolerance to hostile temperatures and its agronomic features make it a favourite crop for smallholder farmers. Understanding its physical properties is essential for optimizing post-harvest processes, improving mechanization, and enhancing overall productivity in the agricultural sector.

**Keywords: Pigeon Pea,** Moisture content, Coefficient of friction, processing efficiency, physical properties.

**1. Introduction**

Pulses are the second largest source of vegetable protein. Pigeon pea (*Cajanus cajan* L.) is one of the primarily pulse crops of India contributing 20.87% to the total production for all pulses. India accounts for 90% of the entire world production of pigeon pea (Goyal et al., 2008). The country‟s total area coverage and production of tur has been about 46 Lha and 40 Lt respectively. Maharashtra ranked first (>12 Lha) contributes 27% in area and 29% in production, whereas, Karnataka has contributed 31 per cent of area and 26% of total production and Madhya Pradesh has contributed 7 % in area and 9 % of total production (Source: DA&FW 2021-22). About than 98 per cent of pigeonpea production of the country during the period under report has been realized by 10 states of Maharashtra, Karnataka, Madhya Pradesh, Uttar Pradesh, Gujarat, Jharkhand, Telangana, Odisha, Andhra Pradesh and Tamil Nadu. It is typically used after dehulling in the form of dhal (decorticated split cotyledon). Several seed properties affect the dehulling efficiency (e.g., size and form of the grains, husk content and its thickness, adherence of the husk to the cotyledons, and moisture level). In building the equipment for aeration and storage, there is a requirement to know various physical qualities as a function of moisture content. Recently, scientists have made tremendous efforts in evaluating basic physical properties of agricultural materials and have pointed out their practical utility in machine and structure design and in control engineering. Several investigators evaluated the physical qualities of seeds at various moisture contents such as Baryeh and Mangope (2003), Mangraj et al. (2005) and Singh and Kotwaliwale (2010) for pigeon pea. However, no published investigation seems to have been carried out on the physical qualities of pigeon pea grain and their relationship with moisture content. The purpose of this study was to evaluate some moisture dependent physical parameters of pigeon pea grain namely, linear dimensions, size, thousand grains mass, sphericity, bulk density, true density, porosity, angle of repose and static coefficient of friction against different materials. Pigeon pea is a woody, perennial shrub, measuring 1-4 meters in height, typically cultivated as an annual crop. The leaves are trifoliate, complex, rather slender, lanceolate, and hairy. The flowers are either yellow or purple and are borne on racemes around 4-12 cm in length. The pods are 5-10 cm in length and are typically constricted obliquely between the seeds. The colouration of seeds varies from cream to black, encompassing various colours of yellow, red, and brown. The Pigeonpea, or dal, serves as the primary protein source for vegetarians in India, supplying approximately 15-30% of daily protein requirements through edible legumes or pulses. India is the foremost producer of pulses globally, with an annual output of over 12 million tonnes. The acreage, production, and productivity of pigeonpea in the principal states of India are enumerated here.

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| --- | --- |
| **Plate: 01 Pigeonpea Plant** | **Plate: 02 Pigeonpea Grains** |

**2. Material and Methods**

Pigeon pea or tur (*Cajanus cajan* L. Mills.) is one of the important pulse crops of India. India ranked first in area with 46.5 lakh ha which was 74% of world pigeon pea cultivated area and first in output in the world by 30.227 lakh tones with 63% of world pigeon pea production. India eats 90% of pigeon pea produced globally. (Local variety) bought from the local market of the Jabalpur were selected for the present inquiry.

**2.1 Measurement of physical properties of Pigeon Pea.**

The physical properties of pigeon pea is important todesign the processing machineries and equipment. Thephysical properties such as length, width and thicknessof pigeon pea was considered for designing the size reduction, drying, grading and storage machine.

**2.2 Moisture content.**

Universal moisture meter is basically used for measurement of moisture content of any food commodity. The Universal moisture meter work on the principle of resistance and its relative code which varies for different commodities.

**2.3 Thousand Grain Weight**

1 kg of pigeon pea grains were divided into 10 equal portions, and 1000 grains were randomly selected from each portion and weighed with a digital electronic balance with an accuracy of 0.001g. The mean value of thousand grains weight of sorghum was determined using three replications (Khedekar, 2013).

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**Plate: 3 Universal Moisture Meter**

**2.4 Determination of length (L), width (W) and thickness (T) of pigeon pea.**

Pigeon pea grains were measured for length (l), breadth (b), and thickness (t). The dimensions of grain kernels selected for the present investigation were measured using a digital Vernier Caliper with 0.001 mm accuracy in three orientations. A total of 20 randomly selected pigeon pea kernels were collected (Daheriya *et al*., 2022).

**2.5 Equivalent diameter and sphericity**.

Equivalent diameter (Dp) and sphericity (∅) of sorghum kernels were determined using the equations (V.P. Sangani\* and P.R. Davara 2013), as given below.

Where,

l = Length of the grain, mm

b = Width of the grain, mm

t = Thickness of the grain, mm

**2.6 Bulk density, True density and Porosity measurement**.

The bulk density was determined byfilling a 1000ml container with pigeon pea grainsto a height of about 150 mm, striking the top level, andthen weighing the content. The ratio of weight of thesample and volume occupied by it is expressed as bulkdensity, g/ml (Konak et al., 2002).

The true density of the Pigeon pea grains was determined by the toluene displacement method. Pigeon pea grains (about 5g) were submerged in toluene in a measuring cylinder. The increase in volume due to pigeon pea grains was noted as the true volume of pigeon pea grains, which was then used to determine the true density of the pigeon pea grains (Wandkar et al., 2013).

Porosity (έ) is the ratio of volume of internal pores to its bulk volume. It was calculated as the ratio of the difference between the true density and bulk density to the true density and expressed by Mohsenin (1986) as:-

Where,

**2.7 Coefficient of Static Friction**

The coefficient of static friction of each crop seed was tested by using inclined plane method on mild steel surface. The seed was kept separately on a horizontal surface and the slope was increased progressively. The angle at which the materials started to slip was recorded. The coefficient of static friction was computed by applying the following formula:

Where, μ- Coefficient of friction

F- Friction Force, Kg

N- Normal Force, Kg

**2.8 Angle of Repose:** A cylindrical container with a discharge port at the bottom was utilized to ascertain the angle of repose of pigeon pea grains. The container was filled with the sample, after which the bottom port was unlocked, permitting the sample to flow freely and accumulate into a heap. The angle of repose was determined from the following equation.

Where,

H = Height of Cone, mm

D = Diameter of cone, mm

**3. Statistical analysis**

The statistical analysis of experimental data regarding various physical attributes at four moisture content levels was conducted utilising a completely randomised design, and regression analysis (curve fitting) was performed utilising Microsoft Excel software.

**4. Result and Discussion**

* 1. **Physical properties of pigeon pea**.

**4.2 Determination of Physical Properties**

A sample of 100 grain of pigeon pea randomly selected a variety (BAHAR) were measured for size, sphericity, volume, bulk density, true density, angle of repose, coefficient of static friction and thousands seed weight.

**4.3 Kernel dimensions**

The data obtained on size of pigeonpea seeds is presented in Table 1. The length, width, thickness and geometric diameter of the pigeonpea seeds varied from 4.9 to 6.9 mm, 4.52 to 5.40 mm, 4.10 to 4.70 mm and 4.95 to 5.45 mm respectively. The length, width, thickness, geometric mean diameter of the pigeonpea seeds were found to increase linearly with increase in the moisture content.

**Table. 1 Dimensions of pigeon pea grains**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Moisture content % db** | **Length (mm)** | **Width ( mm)** | **Thickness (mm)** | **Geometric mean diameter (mm)** |
| 13.30 | 4.90 | 4.52 | 4.10 | 4.95 |
| 14.00 | 5.10 | 4.90 | 4.25 | 5.10 |
| 14.60 | 6.22 | 5.20 | 4.44 | 5.37 |
| 15.00 | 6.90 | 5.40 | 4.70 | 5.45 |

**4.4 Physical properties**

**Table. 2 Physical properties of pigeonpea at different moisture content**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No.** | **Moisture Content (%)** | **Sphericity** | **1000 grains weight (g)** | **Bulk density (Kg/m3)** | **True density (Kg/m3)** | **Coefficient**  **of static**  **friction** | **Angle of repose (degree)** |
| 1 | 10.3 | 0.82 | 96 | 820 | 1310 | 0.4 | 25 |
| 2 | 13.6 | 0.86 | 97 | 850 | 1315 | 0.5 | 26 |
| 3 | 16.8 | 0.90 | 100 | 860 | 1320 | 0.6 | 27 |
| 4 | 20.3 | 0.92 | 102 | 890 | 1340 | 0.7 | 28 |

**4.41 Sphericity**

The relation between sphericity and moisture content of pigeonpea seeds is illustrated in (figure 1). The sphericity of the pigeonpea seeds sample increased with the rise in moisture content. The sphericity of pigeonpea seeds varied from 0.82 to 0.92 (table.2).

**Fig..1 Effect of moisture content on sphericity of pigeon pea**

**4.42 1000 grains weight**

The relationship between pigeonpea grains weight and moisture content is illustrated in (figure 2); it is found that the 1000 grains weight increased linearly from 96.4 to 102.5g as the moisture content increased from 10.30 to 20.30 % d.b (table 2).

**Fig. 2: Effect of moisture content on 1000 grains weight of pigeonpea**

**4.43 Bulk Density:**

Bulk density of the pigeon pea grains at various moisture content varied from 820 to 890 kg/m3 with the moisture content range from 10.30 to 20.30% d.b (table 2). A nonlinear increase in bulk density was explored for varying moisture content (figure.3.).

**Fig. 3 Effect of moisture content on bulk density of pigeonpea**

**4.44 True density**

True density of the pigeonpea grains with different moisture content varied from1310 to 1340 kg/m3 with the moisture content range from 10.30 to 20.30% d.b (table 2). A nonlinear increase in true density was explored for varying moisture content (figure 4); and this increase in real density may be related to the larger rate of increase in mass than the volumetric expansion of the grains.

**Fig. 4 Effect of moisture content on true density of pigeonpea**

**4.45 Coefficients of static friction**

Coefficient of static friction of pigeonpea grains was calculated with respect to metal sheet a surface is provided in (figure 5). At different moisture content ranges, coefficients of friction varied from 0.44 to 0.50, with the moisture range of 10.30 to 20.30 % d.b (table 2). The coefficient of static friction increased dramatically as the moisture content of the grains increased.

**Fig. 5 Effect of moisture content on coefficient of static friction of Pigeonpea**

**4.46 Angle of repose**

The angle of repose for pigeon pea grains exhibited a range between 25° and 28° across varied moisture levels, with moisture content ranging from 10.3% to 20.3% (Table 2). A quadratic increase in the angle of repose was seen with the progressive rise in moisture content (Figure.6). This rise can be due to the elevated surface tension, which improves adhesion between the moisture layer wrapping the grains and the aggregated kernel structure, hence increasing inter-particle cohesion and resistance to flow.

**Fig. 6 Effect of moisture content on angle of repose of pigeonpea**

**5. Conclusion:**

The physical characteristics of pigeon pea grains increase linearly with rising moisture content. At varying moisture levels, the physical properties of pigeon pea grains are observed as follows: sphericity (0.82–0.90), 1000 grains weight (96–102 g), bulk density (820–890 kg/m³), actual density (1310–1340 kg/m³), coefficient of internal friction (0.4–0.7), and angle of repose (25–28°).

**6. FUTURE SCOPE**

Engineering qualities are those that are beneficial and necessary in the design and operation of agricultural processing equipment, as well as the design and development of other processing equipment. Unit operations include cleaning, grading, drying, dehydration, storage, milling, handling, and transportation. Physical properties such as size, shape, surface area, volume, density, porosity, colour, and appearance are important when designing a specific machinery or determining the behaviour and handling of a product (Sahay and Singh 2001).

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