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# Engineering Properties of Certain Minor Millet Grains

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**ABSTRACT**

The millet grains are being stored and processed at various levels. Yet, modern processing mills are not available sufficiently for minor millets as in the case of major cereal crops. This necessitates the need of designing and development of various equipment required for millet grain storage and processing, for which study of engineering properties of grains is essential. A study was conducted to determine the engineering properties *viz*; moisture content, thousand kernel weight, seed volume, bulk density, true density, porosity, sphericity, surface area and angle of repose for proso millet, kodo millet, foxtail millet, little millet and barnyard millet. Thousand kernel weight for kodo millet was found to be higher (5.74 g) and for barnyard millet it was the lowest (3.08 g). Porosity was higher in little millet (51.74 %) while it was lower (29.01 %) in kodo millet. Grain hardness varied from 20.99 N for proso millet to 47.56 N for kodo millet. Sphericity which is an important feature of the grain to be considered while designing graders ranged from 0.584 for little millet to 0.760 for kodo millet. Thus, this study provides essential information to agricultural and food engineers for designing processing machinery, handling and storage systems for minor millets.

**Key words:** *Engineering properties, Minor millets.*

Cultivation and consumption of millets is increasing in India. In recent years, millets are recognized as important substitutes for major cereal to cope up with worldwide food shortage and to meet the demand of increasing population of both developing and developed countries (Kumar *et al.*, 2016)

Millets are considered as crop of food security because of their sustainability in adverse agro-climatic conditions (Ushakumari *et al.*, 2004). Sustainable crop substitutes are needed to meet the world hunger (cereal demand) and to improve income of farmers. Role of millets cannot be ignored for achieving sustainable means for nutritional security. Due to health consciousness among the people, consumption of millet foods has been increased recently.

Industrial methods for processing of millets are not as well developed as the methods used for processing of wheat and rice (FAO 2012). Therefore, with value-added strategies and appropriate processing technologies, the millet grains can find a place in the preparation of several value-added and health food-products, which may then result in high demand from large urban populations and non traditional millet users (Mal *et al*., 2010). Processing of millets decreases the anti-nutritional factors in millets and improves the bio-accessibility of nutrients. Owing to the absence of suitable primary processing, semi processed raw materials and appropriate value addition technologies, the production and processing of small millets remains constrained.

Engineering properties of millet grains play an important role in the design of equipment used for appropriate pre- and post-harvest processing and storage. The values of most physical and frictional properties depend on the grain composition, and provide useful information for designing, handling, and transportation systems. Many researchers studied the engineering properties of different millets, (Singh *et al*., 2010) on barnyard millet, (Sunil *et al*., 2016) on foxtail millet, (Kumar *et al*., 2016) on kodo millet.

## MATERIAL AND METHODS

Minor millets like foxtail millet (*Setaria italica*), little millet (*Panicum sumatrense*), kodo millet (*Paspalum scrobiculatum*), proso millet (*Panicum miliaceum*) and barnyard millet (*Echinochloa corona*) were obtained from the Agricultural Research Station, Podalakur, Acharya N G Ranga Agricultural University, Guntur, India. The grains were cleaned by manual and mechanical means to remove all foreign matter, broken and immature grains.

### Moisture content

The moisture content of proso millet, kodo millet, foxtail millet, little millet and barnyard millet were determined on triplicate sample by hot air-oven drying method by placing about 15 g of sample at 130 C for 72-96 h. (Sahay and Singh, 2001). The moisture content on wet basis (w.b.) was calculated using the following equation,

$$Moisture\ content\ (w.b.)\% = \frac{w_w}{w_w + w_d}$$

Where,

**Table 1. Engineering properties of minor millet grains**

| S.No. | Property of material | Proso millets | Kodo millets | Foxtail millets | Little millets | Barnyard millets |
|---|---|---|---|---|---|---|
| 1 | Principle Axial Dimensions Length of grain, mm | 2.821±0.010 | 3.029±0.19 | 2.661±0.15 | 3.266±0.15 | 3.044±0.26 |
| | Width of grain, mm | 2.013±0.10 | 2.397±0.08 | 1.742±0.08 | 1.831±0.06 | 1.89±0.07 |
| | Thickness of grain, mm | 1.526±.077 | 1.67±0.07 | 1.261±0.06 | 1.155±0.03 | 1.372±0.07 |
| 2 | Geometric mean diameter, mm | 2.053±0.07 | 2.295±0.05 | 1.80±0.07 | 1.904±0.04 | 1.99±0.11 |
| 3 | Thousand grain weight, g | 4.758±0.02 | 5.741±0.12 | 3.446±0.04 | 3.182±0.03 | 3.083±0.03 |
| 4 | Sphericity | 0.728±0.02 | 0.760±0.04 | 0.678±0.03 | 0.584±0.022 | 0.655±0.02 |
| 5 | Bulk density, g/mL | 0.587±0.01 | 0.783±0.01 | 0.773±0.004 | 0.496±0.026 | 0.552±0.02 |
| 6 | True density, g/mL | 1.136±0.00 | 1.103±0.02 | 1.190±0.00 | 1.027±0.024 | 1.00±0.00 |
| 7 | Porosity, % | 48.32±0.005 | 29.01±0.01 | 35.00±0.001 | 51.74±0.01 | 44.80±0.02 |
| 8 | Hardness, N | 20.99±0.001 | 47.56±0.03 | 29.62±0.001 | 32.85±0.05 | 31.48±0.06 |
| 9 | Angle of repose, θ | 36.20±0.04 | 25.95±0.01 | 33.75±0.02 | 35.30±0.02 | 37.10±0.05 |

The mean ± standard deviation

$w_w$ = Weight of water (moisture), g
$w_d$ = Weight of bone dry material, g

**Engineering properties of finger millet grains**

Engineering properties of millets are essential for the design equipment for cleaning, grading, processing and storing. Physical properties such as principle axial dimensions, geometric mean diameter, sphericity, thousand grain weight, bulk density, true density, porosity, mechanical property like hardness and frictional property like angle of repose for proso millet, kodo millet, foxtail millet, little millet and barnyard millet were determined.

**Principle Axial Dimensions**

Three axial dimensions namely as length, width and thickness of randomly selected proso millet, kodo millet, foxtail millet, little millet and barnyard millets were measured using a digital calipers with sensitivity of 0.01 mm (Sreenarayanan *et al.*,1988).

**Geometric Mean Diameter and Sphericity**

The geometric mean diameter also called as equivalent diameter, was calculated by using the method recommended by Sahay and Singh (2001).

$$\textit{Geometric mean diameter } (D_g) = (LWT)^{1/3}$$

Sphericity is the ratio of volume of solid to the volume of circumscribed sphere that has a diameter equal to the longest diameter of the solid so that it can be circumscribe the solid sample (Mohsenin, 1986). Sphericity was obtained from equation (Sahay and Singh, 2001)

$$\textit{Sphericity } (f) = \frac{(LWT)^{1/3}}{L}$$

Where,

*L* - Length of grain, mm
*W* - Width of grain, mm
*T* - Thickness of grain, mm

Average value of geometric mean diameter and sphericity was determined based on the ten number of sample grains.

**Thousand grain weight**

A grain weight of approximately 1 kg was roughly divided in to 10 equal portions and then 1000 numbers of grains were randomly picked from each portion, and weighed on a digital electronic balance. The measurement was repeated for 5 times and the mean value was taken.

**Bulk density, True density and Porosity**

Bulk density of the grain was determined by taking known weight of 50 g millet sample and put into a 100 ml measuring cylinder. The cylinder was tapped several times on a laboratory bench to obtain a constant volume and then the volume is then computed and recorded. The experiment was replicated 10 times, and the following expression was used in determining the bulk density of the millet (Mohsenin, 1986)

$$\textit{Bulk density}\left(\frac{g}{mL}\right) = \frac{\text{Weight of the sample, g}}{\text{Volume of the grain including void space, mL}}$$

True density of the grain was defined as the actual weight of the sample per unit volume of the solids without considering the void space. In a measuring jar 50ml of toluene was taken. A known weight of grain sample was poured to the measuring jar and rise in the toluene level was recorded. The true density of the grain was calculated by using the following formula (Mohsenin, 1986).

$$\textit{True density}\left(\frac{g}{mL}\right) = \frac{\text{Weight of the sample, g}}{\text{Volume of the grain without considering void space, mL}}$$

Porosity was defined as per cent volume occupied by the voids with respect to the total volume of an unconsolidated grain sample. Porosity or bulk porosity was determined using the bulk and true densities parameters as described by Mohsenin (1986).

$$\textit{Porosity (\%)} = \left[1-\frac{\textit{Bulk density}}{\textit{True density}}\right] \times 100$$

**Hardness**

Hardness tester (PFIZER, M. B. Instruments, Delhi) was used to measure the hardness of the millet grains. The samples were placed and held on the top of the seed placing area; weight was then applied to the indenter through turning a screw which in turn presses the sample until the samples breaks (Rajsekhar *et al., 2018)*. This experiment was replicated 10 times to ascertain the mean hardness of the material.

**Angle of repose**

The angle of repose is an indicator of the products ability to flow. The size, shape, moisture content and orientation of the particles influence the angle of repose. It was determined using the apparatus described by Sreenarayanan *et al*. 1988. A cylinder was filled up to top with sample and inverted on a plane (paper) surface. The paper was taken out gradually and cylinder was raised vertically, thus conical shape of the material was formed. Angle of repose was calculated by using the following expression

$$\textit{Angle of repose}\ (\theta) = \tan^{-1}\frac{2H}{D}$$

Where,

*H* – Height of heap, mm

*D* – Base width of heap along the length of apparatus, mm

**RESULTS AND DISCUSSION**

The results of some engineering properties of certain millets like proso millet, kodo millet, foxtail millet, little millet and barnyard millet was measured at the moisture content 11.06 to 12.19 % (w.b.) as per the standard procedures and are shown in Table 1.

Dimensions of the millet grains can be used to choose the appropriate fan that can separate the millet grain from the undesirable material. However, it can also be useful to determine the sieve parameters—size, shape, and spacing of perforations (Datta, 2003). The length, width and thickness of the millet grain varied from 2.82 to 3.26, 1.74 to 2.39 and 1.15 to 1.67 mm respectively.

Thousand grain weight of the millet grain can be used to determine the type of fan and sieve that can be used to separate the millet grains from the undesirable materials. Thousand grain weight for kodo millet was found to be highest (5.74 g) and for barnyard millet it was the lowest (3.08 g). The sphericity of the millet grain were observed to be in the range of 0.584 to 0.760 and found higher for kodo millet (0.760) and lower for barnyard millet (0.584).

The knowledge of the geometric mean diameter can be used in the determination of cylinder concave clearance of the threshing unit (thresher). It is also an important parameter while determination of terminal velocity and drag coefficient (Mohsenin, 1986). The average geometric mean diameter of the millets was found to be higher in kodo millet (2.295mm) while it was lower (1.80) in foxtail millet.

The knowledge of density of agricultural products is needed in separating the product from undesirable materials, thus the design of fan. It is also used in the determination of purity of the agricultural products. The bulk density, true density and porosity were varied from 0.496 to 0.783 g/mL, 1.00 to 1.19 g/mL and 29.01 to 48.32% respectively. Higher bulk density was exhibited by kodo millet grain (0.783 g/mL) and lower by little millet (0.496 g/mL). The true density was higher in foxtail millet (1.190 g/mL) and lower by barnyard millet (1.00 g/mL). The porosity was higher in proso millet (48.32% ) and lower by kodo millet (29.01%). which are comparable with the findings of Balasubramanian and Viswanathan (2010) for kodo millet, Bora *et al*., (2018) for proso millets and Singh *et al*., (2010) for barnyard millet.

Hardness is resistance to indentation. Hardness of the millet grains can be used to determine the type of materials to be used in selecting cylinder beaters and construction materials (metal type) of the thresher, and also used while development of de-hulling and decortication machinery. The grain hardness varied from 20.99 N for proso millet to 47.56 N for kodo millet.

The angle of repose is an important property for determination of the maximum angle of a pile of grain in the horizontal plane, and is important in the filling of a flat storage facility. The mean value of angle of repose of millets varies from 25.95 to 37.10Ú. These values are in conformity with findings of Chaturvedi *et al*., 2019.

## CONCLUSION

Some engineering properties viz., length, width, thickness, geometric mean diameter, thousand grain weight, sphericity, bulk density, true density, porosity and angle of repose of minor millets were determined. These properties can be very much useful while design of post-harvest machines and equipments such as millet thresher, de-stoner, grader, de-huller and storage structure.

## LITERATURE CITED

**Balasubramanian S and Viswanathan 2010** Influence of moisture content on physical properties of minor millet. *J. Food Sci. Tech.* CIPHET Ludhiana.47 (3): pp 279-284.

**Bora P and Das P 2018** Some Physical and Functional Properties of Proso Millet (*Panicum miliaceum* L.*)* Grown in Assam. *Int.J.Pure App. Biosci.* 6(2): 1188-1194.

**Chaturvedi S, Shrivastava A K, Koutu G K, Ramakrishnan S and Singh S 2019** Study of Physical Property of Kodo (*Paspalum scrobiculatum* L.) Millet. *Int.J.Curr.Microbiol.App.Sci 8*(12): 1503-1510.

**Datta A C 2003** *Handbook of Postharvest Technology (cereals, fruits, vegetables, tea, and spices)*. Published by Marcel Dekker, Inc. New York, 2003. pp 57-118.

**Kumar D, Patel S, Naik R K and Mishra N K 2016** Study on Physical Properties of Indira Kodo-I (Paspalum Scrobiculatum L.) Millet. *International Journal of Engineering Research & Technology (IJERT)* Vol. 5 (1): 39-45.

**Mal B, Padulosi S and Ravi S B 2010** *Minor millets in South Asia: learnings from IFAD-NUS Project in India and Nepal.* Maccarese, Rome, Italy: Bioversity Intl and Chennai, India: M.S. Swaminathan Research Foundation. p 1–185.

**Mohsenin N N 1986** *Physical Properties of Plant and Animal Materials*, 2nd edition. Gordon and Breach Science Publishers, New York.

**Rajasekhar M, Edukondalu L, Smith D D and Veeraprasad G 2018** Changes in Engineering Properties of Finger Millet (*PPR-2700*, *Vakula*) on Hydrothermal Treatment. *The Andhra Agric. J* 65 (2): 420-429

**Sahay and Singh 2001** *Unit operations of Agricultural processing*. Vikas Publishing house Pvt Ltd, New Delhi

**Singh K P, Mishara H N and Suha S 2010** Moisture-dependant properties of barnyard millet grain and kernel. *Journal of Food Engineering* 96 (2010). pp 598-606.

**Sreenarayanan V V, Viswanathan R, Subramanian V 1988** Physical and thermal properties of soybean. *J Agric Eng* 25:76–82.

**Sunil C K, Venkatachalapathy N, Shanmuga-sundaram S, Akash Pare and Loganathan M 2016** Engineering properties of foxtail millet (*setaria italic* l): variety- hmt 1001. *International Journal of Science, Environment and Technology*, Vol. 5(2), 632 – 637.

**Ushakumari S R, Shrikantan L and Malleshi N G 2004** The functional properties of popped, flaked, extruded and roller dried foxtail millet (*Setaria italica*). *International Journal of Food Science and Technology*, 39: 907-915.