

Varietal and moisture effect on physical properties of various pearl millet (*Pennisetum glaucum*) cultivars

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ARTICLE INFO	ABSTRACT
<p>Received : 10 January 2022 Revised : 15 April 2022 Accepted : 21 April 2022</p> <p>Available online: 26 July 2022</p> <p>Key Words: Moisture content Pearl millet Physical properties Variety</p>	<p>Engineering properties of pearl millet varieties (Pusa composite 443, Pusa composite 701, Pusa1201 and Pusa1801) were evaluated at varying moisture content (10-25% wb). A significant varietal difference was found on studied properties. GMD, Surface area, thousand grain mass, the angle of repose, porosity, internal coefficient of friction, static coefficient of friction (Poly, GI, MS and Al) increased linearly with increase in moisture content within the range of 10 to 25% (w.b.) while the bulk density, true density and hardness decreased linearly with increase in moisture content within the same range. But the value of sphericity showed that direct and indirect relation with moisture content depending variety. The mean value of different cultivars observed and found extreme high and low value of bulk density, true density and porosity for PC701 and Pusa1201, geometric mean diameter and surface area for pusa1801 to Pusa1201, sphericity and internal coefficient of friction for Pusa1201 and PC443, grain mass for Pusa1801 and PC 701, angle of repose for Pusa1201 and PC701, hardness for PC701 and PC443 respectively at moisture ranges from 10 to 25% (wb).</p>

Introduction

Pearl Millets (*Pennisetum glaucum*) are getting more attention for its gluten free nature and It belongs to the family of poaceae (Sharma & Niranjana, 2018). India is one of the largest producers of pearl millet with 8.61 MT production and 1243 kg/ha yield from the 6.93 million ha area during the period 2018-19 (Project Coordinator Review, 2020). Its nutritional composition and health benefits attracted today's market focused present health segment highlighting the commercial viability of the crop (Satankar *et al.*, 2020). Pearl millet accounts high proportion of germ and it is twice that of sorghum, so it plays a main factor in containing the higher nutritive value than other cereal crops (Andrew and Kumar 1991). (Meera *et al.*, 2019) studied about physical and mechanical properties of brown rice and paddy which is helpful

in designing instruments for various agricultural practices such as processing, milling, drying (Singh *et al.*, 2021), heating, cooling, handling, extraction (Patil *et al.*, 2020), transfer and storage of grains, thereby reducing post-harvest losses. Before designing a model for viscoelastic materials, it is important to understand the mechanical properties of the material (Satankar *et al.*, 2020). (Mwithiga & Sifuna, 2006) reported that the sorghum seed properties vary from variety to variety and these properties are also affected by moisture content. Many researchers have studied the properties of various agricultural produces like millets (Singh *et al.*, 2010)(Baryeh, 2002)(Jain & Bal, 1997), Pomegranate dried seeds (Kingsly *et al.*, 2006), grass seeds (Singh *et al.*, 2021). Although some information on the properties of pearl millet is

available (Jain & Bal, 1997) (Baryeh, 2002) (Ojediran *et al.*, 2010), data on engineering properties of pearl millet grain cultivars of India is still lacking. Thus, the objective of this study was to collect data on the effect of varietal and moisture on engineering properties of different cultivars of pearl millet grains i.e. GMD, ϕ , A, W, ρ_b , ρ_t , P, θ , μ_s on various surfaces {i.e. poly, GI, MS and Al}, μ_i , and H of the grain as a function of moisture content.

Material and Methods

The pearl millet cultivars (Pusa1201, Pusa1801, PC43 and PC701) were obtained from the farm of Genetics and Plant Breeding Division, IARI, Pusa, New Delhi for carrying out the experiments. The moisture content of the grains was determined by standard oven-dry method (AOAC, 2002). The initial moisture contents of Pusa1201, Pusa1801, PC443 and PC701 were 8.77, 9.32, 8.37 and 8.72% (w.b.) respectively. Each variety sample was divided into four equal amounts for performing different experiment. The four desired moisture contents (10, 15, 20 and 25%, w.b.) were obtained accordance with recommended procedure (Subramanian & Viswanathan, 2003). The geometric, gravimetric, mechanical and frictional properties of each pearl millet variety were determined or four moisture levels (10%, 15%, 20% and 25%). Three replications at each treatment were taken for accuracy of results. The mean of each engineering property determined at four moisture levels for each variety and standard deviation values of each engineering property were calculated, analyzed and presented (Table1).

Measurement of Geometric properties

GMD (mm) was calculated using the measured sizes of the pearl millet grain L (length), W (width), and T (thickness). Digital vernier caliper (least count 0.01 mm) was used for measuring dimensions of hundred randomly selected grains for each variety. GMD was calculated by using the following equation

$$GMD = (LWT)^{1/3} \text{ (Baryeh, 2002)}$$

The sphericity (decimal) of the pearl millet grain was calculated by following equation

$$\phi = (LWT)^{1/3}/L \text{ (Ramashia et al., 2018)}$$

Where, L=length (mm), W=width (mm) and T=thickness (mm)

The surface area (mm^2) of pearl millet cultivars were calculated using following equation

$$A = \pi (D_g)^2 \text{ (Sologubik et al., 2013)(Altuntaş \& Yildiz, 2007)}$$

Measurement of Gravimetric properties

Determination of the value of thousand grain mass (W) expressed in gram, was done by random selection of pearl millet sample containing hundred seeds from each variety and measured using electronic weighing balance (least count 0.01mm). Then measured values were multiplied by ten to give the value of W (Figueiredo *et al.*, 2011).

Bulk density, ρ_b (kg/m^3) was determined by using 100 ml measuring cylinder filled with grains. The weight of the sample without any compaction was recorded for known volume. The bulk density was determined by using formulae (Ramashia *et al.*, 2018)(Nwabueze *et al.*, 2020)

True density, ρ_t (kg/m^3) of the pearl millet grains was determined using the toluene displacement method. The true volume of the grain was the final volume displaced by toluene. The following equation was used to calculate the true density of grain.(Konak *et al.*, 2002)).

$$\rho_t = W / V_d$$

where, ρ_t = True density (kg/m^3),

W= weight of the sample (kg)

V_d = Displaced volume (m^3)

Porosity, P (decimal) of pearl millet grains was determined from bulk and true density using the equation given by (Figueiredo *et al.*, 2011) (Nwabueze *et al.*, 2020).

$$P = (1 - \rho_b / \rho_t) \times 100$$

Where P = porosity (%),

ρ_b = Bulk density, kg/m^3

ρ_t = True density kg/m^3 .

Frictional properties

The angle of repose (θ) was calculated using a cylindrical container with both ends open. Grain was placed in a cylindrical container, which was slowly raised until the grain formed a cone on a platform. The value of θ was then calculated using the height and diameter of a naturally formed cone. The angle of repose was calculated using the following relationship.

$$\theta = \tan^{-1} \frac{2h}{d} \text{ (Kaleemullah \& Gunasekar, 2002)}$$

where, θ = Angle of repose (degree),

h= height of cone (cm)

d= diameter of the cone (cm)

The experimental set up was fabricated for determining internal and static coefficient of friction in the workshop of Division of Agricultural Engineering, IARI, Pusa, New Delhi. Subramanian & Viswanathan (2007) studied coefficient of internal friction was calculated using the following equation

$$\mu_i = F_i/N_i$$

where μ = coefficient of internal friction

N_i = normal force in internal friction (kg)

F_i = frictional force in internal friction (kg)

The coefficient of static friction was determined on four surfaces viz. polythene (poly), galvanized iron (GI), mild steel (MS) and aluminium (Al) sheet. It was performed according to the method of Subramanian & Viswanathan (2007).

$$\mu_s = F/N$$

where μ = coefficient of static friction

N = normal force in static friction (kg), and

F = frictional force in static friction (kg)

Mechanical properties

The rupture force of pearl millet grain was measured to determine grain hardness (H) using a texture analyzer (Stable micro system, U.K.) and a load cell weighing 50 kg. The test speeds during the analysis were 2 mm/s with 50% strain. The individual grain along with its thickness loaded between horizontal plate and load cell, compressed until rupture occurred. The peak value of the force in curve was recorded as the hardness of the grain (Altuntaş & Yildiz, 2007).

Results and Discussion

The cultivars of pearl millet collected and maintained at four different equilibrium moisture content (MC) were subjected to different physical and mechanical tests. Mean values and their standard deviations of selected engineering properties measured at four different equilibrium moisture contents of 10%, 15%, 20%, 25% (wb) were presented in Table 1. Significant varietal effect was observed on all studied engineering properties except coefficient of internal friction and hardness. Figures show the mean values of engineering properties of various pearl millet cultivars at various moisture content levels. All the studied engineering properties were varying

significantly with moisture content for all the pearl millet cultivars.

Geometrical properties of pearl millet cultivars

Geometric Mean Diameter (GMD)

Dimensions play an important role in typically designing the different processing equipment. The results for the geometric mean diameter of pearl millet varieties shown in Tables 1. Significant difference in GMD values was observed for all of the pearl millet varieties. GMD for pearl millet varieties varied from 2.69±0.07 mm in PC 443 or Pusa 1201 to 2.75±0.08 mm in Pusa 1801. (Ramashia *et al.*, 2018) reported geometric mean diameter for finger millet and ranged from 2.81 ± 0.71 mm to 1.35 ± 0.06 mm. Similar results were also found for pearl millet (Nwabueze *et al.*, 2020) (Jain & Bal, 1997) (Asoiro *et al.*, 2020) (Koocheki *et al.*, 2007). The GMD value for all varieties increased linearly as the moisture level increased (Fig. 1).

The increase in GMD could be due to the moisture absorption that results in the expansion of the grain dimensions (Solomon and Zewdu, 2009). The values of GMD for MC and variety interaction were found non-significant and there was no difference in cultural values of GMD at each moisture level.

Sphericity (Φ)

The sphericity of pearl millet showed a variation from 0.76± 0.01 (PC 443) to 0.83± 0.03 (Pusa 1201). The sphericity range for pearl millets was reported between 0.937-0.942 (Jain and Bal, 1997). (Kaleemullah & Gunasekar, 2002)(Meera *et al.*, 2019) showed the variation in sphericity from 45% to 56% and 0.787 to 0.723 for rice and arecanut respectively. The sphericity of PC 443 and PC 701 varieties was inversely related to moisture for 10-15% moisture but had little effect in the moisture range of 15-20% moisture; however, after that, the sphericity increased with increase in moisture. Whereas the sphericity of other varieties i.e. Pusa1201 and Pusa1801, was showing direct relation with moisture up to certain moisture level then showed inverse (Fig1). (Sologubik *et al.*, 2013) found the similar results that initial increase in sphericity followed by decrease in sphericity of barley seed.

Surface area (A)

The surface area of the various pearl varieties studied differed significantly. Surface area ranged

from $22.73 \pm 1.22 \text{ mm}^2$ in Pusa1201 to $23.87 \pm 1.72 \text{ mm}^2$ in Pusa1801. The surface area increased as the moisture content increased. This shows the hygroscopic nature of pearl millet. This increase in surface area was caused by an increase in grain dimensions as the moisture content of the grains increased. Similar trend was also observed for soyabean (Deshpande *et al.*, 1993). It was found that not much difference in values of surface area at each moisture level (fig 1).

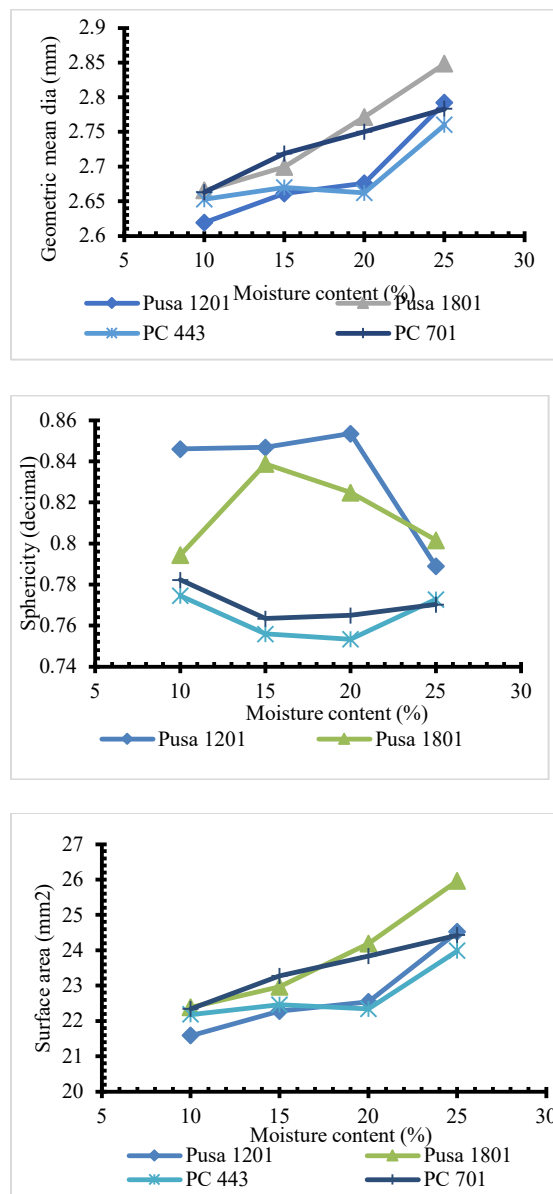


Figure 1. Varietal moisture effect on geometric characteristics of various pearl millet cultivars of India.

Gravimetric properties of pearl millet cultivars

Bulk density (pb)

The bulk density for selected pearl millet varieties significantly ($p < 0.05$) varied from $737.42 \pm 34.51 \text{ kg/m}^3$ in Pusa1201 to $765.83 \pm 43.91 \text{ kg/m}^3$ in PC 701 (Table 1). For all varieties, the bulk density was found to decrease linearly with moisture content. (Fig.2). This decrease may be due to the increase in mass caused by moisture absorption, which is less than the volumetric expansion of the bulk. Similar patterns were found for different seeds i.e. chickpea seeds, bambara groundnut, faba bean, sorghum seed, (Konak *et al.*, 2002)(Altuntaş & Yildiz, 2007)(Mwithiga & Sifuna, 2006).

True density (pt)

True density values for various pearl millet varieties ranged from $1208.98 \pm 31.92 \text{ kg/m}^3$ in Pusa 1201 to $1286.48 \pm 20.77 \text{ kg/m}^3$ in PC 701 (Table 1). True density significantly ($p < 0.05$) decreased for all the varieties when the moisture content increased (Fig.2). This decrease indicates that there was a smaller increase in grain mass compared to an increase in grain volume as moisture content increased. Similar results were found for minor millet and caper seed (Balasubramanian & Viswanathan, 2010) (Dursun & Dursun, 2005).

Porosity (P)

Porosity varied significantly ($p < 0.05$) among the different pearl millet cultivars. The values ranges from $39.03 \pm 1.35\%$ in Pusa 1201 to $40.51 \pm 2.47\%$ in PC 701 (Table.1). (Konak *et al.*, 2002) found that because porosity is primarily determined by bulk and true density, the magnitude of the increase in porosity can be attributed to changes in true and bulk density as moisture content increases. For all pearl millet varieties, the value of porosity was found to have a direct relationship with an increase in moisture content (Fig.2).

Thousand grain mass (W)

The thousand grain mass of pearl millet cultivars ranged from $10.19 \pm 0.68 \text{ g}$ in PC 701 to $12.95 \pm 0.68 \text{ g}$ in Pusa1801 (Table 1). For all pearl millet varieties, the thousand grain weight increased as moisture increased (Figure 2). Same results was observed by (Nwabueze *et al.*, 2020; Kingsly *et al.*, 2006; Kaleemullah & Gunasekar, 2002; Baryeh, 2002). Thousand seed mass of pearl millet increased from 7.3 to 10.1g and 9.5 to 11.94g for Ex-Borno and SOSAT C88 varieties respectively, in the moisture range of 10-20% w.b. (Ojediran *et al.*, 2010).

Table 1: Varietal effect on engineering properties of various pearl millet cultivars of India.

Property	Pearl millet cultivars				
	Pusa 1201	Pusa 1801	PC 443	PC 701	
GMD [#] (mm)	2.69 ± 0.07 ^{bc}	2.75 ± 0.08 ^a	2.69 ± 0.07 ^{bc}	2.73 ± 0.07 ^a	
Φ (decimal)	0.83 ± 0.03 ^a	0.82 ± 0.02 ^b	0.76 ± 0.01 ^c	0.77 ± 0.01 ^c	
A [#] (mm ²)	22.73 ± 1.22 ^{bc}	23.87 ± 1.72 ^a	22.74 ± 1.10 ^{bc}	23.47 ± 1.17 ^{ab}	
W (g)	12.38 ± 0.52 ^b	12.95 ± 0.68 ^a	10.53 ± 0.90 ^c	10.19 ± 0.68 ^d	
ρ _b (kg/m ³)	737.42 ± 34.51 ^c	747.08 ± 39.44 ^b	765.08 ± 41.78 ^a	765.83 ± 43.91 ^a	
ρ _t (kg/m ³)	1208.98 ± 31.92 ^d	1227.60 ± 12.19 ^c	1285.43 ± 22.22 ^a	1286.48 ± 20.77 ^a	
P (%)	39.03 ± 1.35 ^b	39.16 ± 2.73 ^b	40.51 ± 2.28 ^a	40.51 ± 2.47 ^a	
θ (degree)	28.71 ± 2.71 ^a	28.62 ± 2.64 ^a	28.58 ± 3.07 ^a	25.55 ± 2.98 ^b	
μ _i ^{##}	0.66 ± 0.10 ^a	0.65 ± 0.08 ^a	0.65 ± 0.06 ^a	0.66 ± 0.07 ^a	
μ _s	Poly	0.51 ± 0.07 ^b	0.48 ± 0.05 ^c	0.51 ± 0.08 ^b	0.54 ± 0.09 ^{ab}
	GI	0.56 ± 0.09 ^{ab}	0.53 ± 0.06 ^{bc}	0.56 ± 0.10 ^{abc}	0.57 ± 0.10 ^a
	MS	0.57 ± 0.06 ^a	0.56 ± 0.07 ^a	0.59 ± 0.10 ^a	0.58 ± 0.07 ^a
	AI	0.55 ± 0.10 ^{ab}	0.52 ± 0.08 ^b	0.53 ± 0.11 ^{ab}	0.55 ± 0.12 ^a
H ^{##} (N)	2.87 ± 1.16 ^{ab}	3.21 ± 1.01 ^{ab}	2.86 ± 0.58 ^{ab}	3.37 ± 1.23 ^a	

All data were means of triplicates. Values with the same superscripts in a row did not differ significantly (p≤ 0.05) by DMRT
 * Non significant w.r.t. varieties at p=0.05, # Non significant w.r.t. varieties and MC interaction at p=0.05

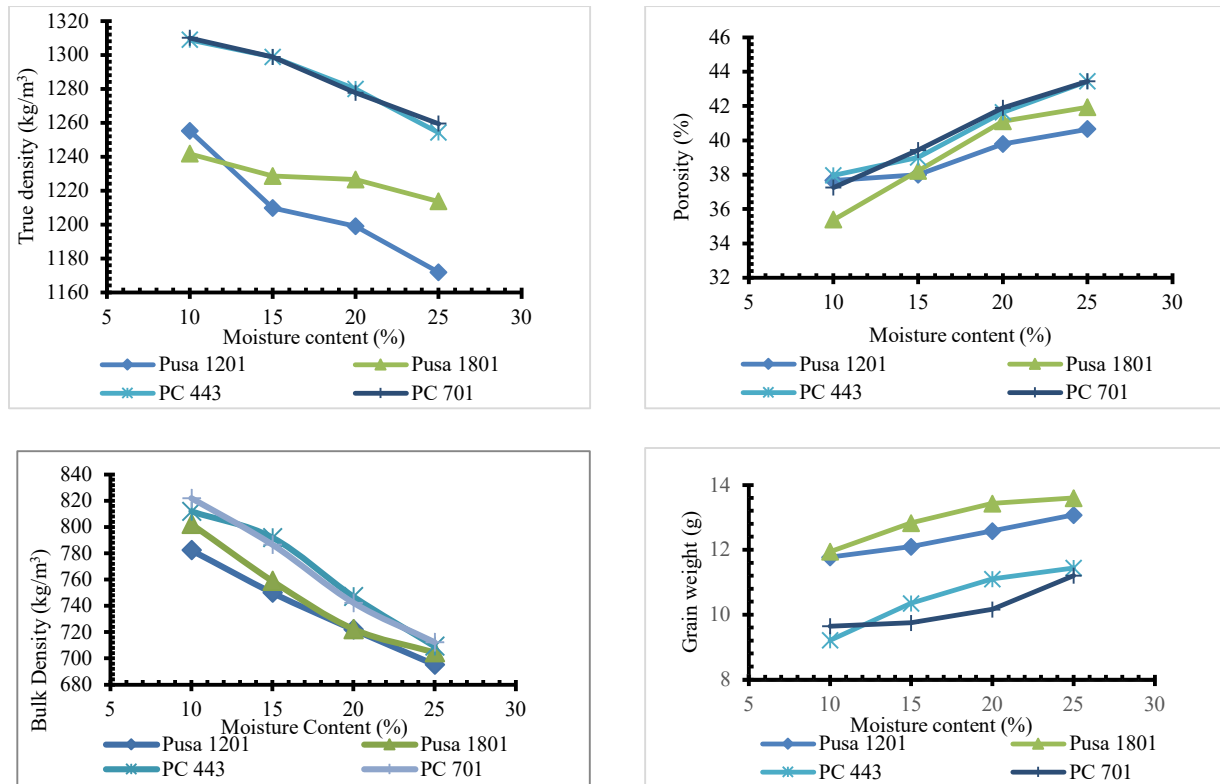


Figure 2: Varietal moisture effect on gravimetric properties of various pearl millet cultivars of India.

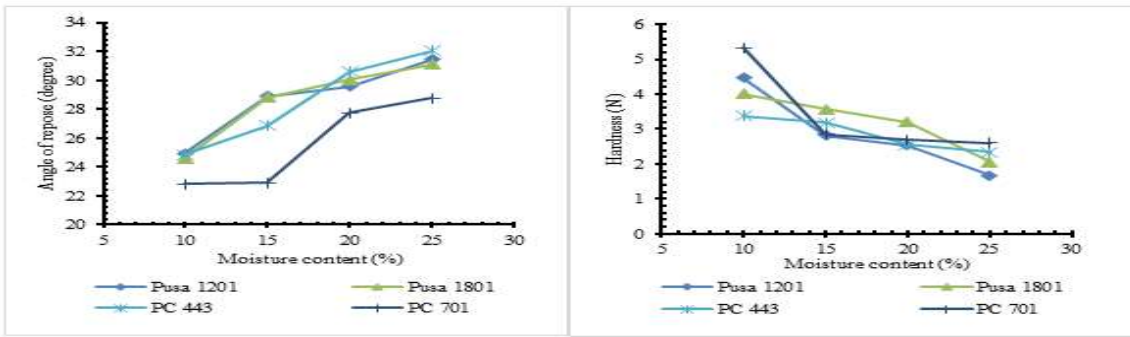


Figure 3: Varietal moisture effect on mechanical properties of various pearl millet cultivars of India.

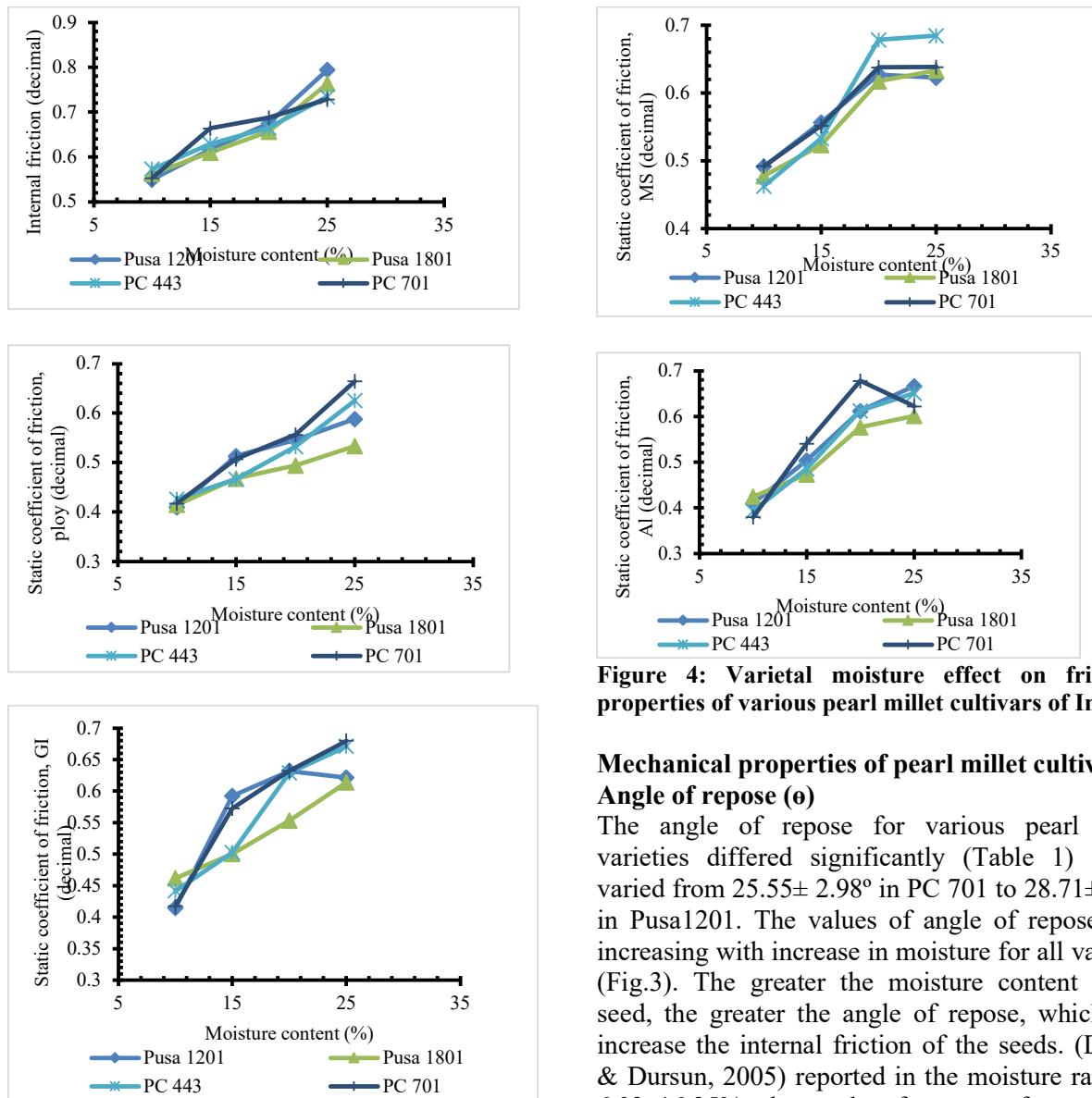


Figure 4: Varietal moisture effect on frictional properties of various pearl millet cultivars of India.

Mechanical properties of pearl millet cultivars

Angle of repose (θ)

The angle of repose for various pearl millet varieties differed significantly (Table 1) and it varied from $25.55 \pm 2.98^\circ$ in PC 701 to $28.71 \pm 2.71^\circ$ in Pusa1201. The values of angle of repose were increasing with increase in moisture for all varieties (Fig.3). The greater the moisture content of the seed, the greater the angle of repose, which may increase the internal friction of the seeds. (Dursun & Dursun, 2005) reported in the moisture range of 6.03–16.35%, the angle of repose of caper seed increases from 21° to 32° .

Hardness (H)

The Hardness of pearl millet varied from 2.86 ± 0.58 N in PC443 to 3.37 ± 1.23 N in PC 701 (Table 1). With increasing moisture, the hardness of all pearl millet varieties decreased (Fig.3). The hardness of barnyard millet decreased linearly from 45.67 to 36 N, while the moisture content increased from 0.065 to 0.265 kg kg⁻¹ dry matter (Singh *et al.*, 2010). The results showed that the higher the moisture content, the softer all cultivars of pearl millet. At higher moisture content, the seed became soft, requiring low rupturing forces, making it more susceptible to cracking. A similar pattern was observed for minor millet and pomegranate seed (Balasubramanian & Viswanathan, 2010; Kingsly *et al.*, 2006).

Frictional properties

Internal friction (μ_i)

Non-significant difference was observed for internal friction of all the varieties of pearl millet. The value of internal friction was found between 0.64 to 0.66 (Table 1). The coefficient of internal friction ranged from 0.59 to 1.25 in the moisture content ranges of 11.11–42.86% d.b., with kodo and barnyard millet having the highest value compared to other minor millets (Balasubramanian & Viswanathan, 2010). But significant difference was found for the moisture level and direct relation was found between internal friction and moisture for pearl millet (Fig.4). This could be due to grain cohesion increasing with moisture content.

Static friction (μ_s)

Significant difference was observed for pearl millet cultivars for plastic surface, galvanized iron sheet (GI), MS and AL frictional surface. The value of static friction varied 0.48 ± 0.05 in Pusa 1801 for poly to 0.59 ± 0.10 in PC 443 for MS (Table 1).

References

- Altuntaş, E., & Yildiz, M. (2007). Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba* L.) grains. *Journal of Food Engineering*, 78(1), 174–183.
- Amin, M. N., Hossain, M. A., & Roy, K. C. (2004). Effects of moisture content on some physical properties of lentil seeds. *Journal of Food Engineering*, 65(1), 83–87.
- Andrews, D. J., & Rajewski, J. F. (1991). Pearl Millet Regional Grain Yield Trials: Preliminary Report, pp. 9. *Univ. of Nebraska-Lincoln* (mimeo).

The highest friction coefficient was found in MS, followed by galvanized iron sheet, solid plastic surface, and finally Al. This could be due to the surface roughness which is greatest in the case of MS and probably the least for Al. For all of the surfaces tested, the static coefficient of friction increased as the moisture content increased. (Fig.4). The same trend observed for lentil seed, water melon seed, arecanut, barnyard millet, minor millet (Amin *et al.*, 2004) (Koocheki *et al.*, 2007) (Kaleemullah & Gunasekar, 2002)(Singh *et al.*, 2010) (Balasubramanian & Viswanathan, 2010).

Conclusion

The GMD, sphericity, surface area, thousand grain mass, bulk density, true density, porosity, angle of repose and static coefficient of friction (Poly, GI, MS and Al) of pearl millet cultivars vary significantly from variety to variety measured at different moisture content (10%-25% w.b.) of grains. It was found that non-significant difference was obtained for internal coefficient of friction and hardness. Analysis of variance was performed for all the pearl millet cultivars showed that moisture content had a significant effect on all the engineering properties studied. The mean value of different cultivars at varying moisture content must be consider during design of different milling machinery of pearl millet. Moreover, the maximum or minimum extreme value of different cultivar at moisture range helps for the selection of cultivar on the basis of specific requirement of operation.

Conflict of interest

The authors declare that they have no conflict of interest.

- Asoiro, F. U., Ezeoha, S. L., & Anyanwu, C. N. (2020). Heliyon Physical properties of *Irvingia gabonensis*, *Detarium microcapum*, *Mucuna pruriens* and *Brachystegia eurycoma* seeds. *Heliyon*, 6(August), e04885. <https://doi.org/10.1016/j.heliyon.2020.e04885>
- Balasubramanian, S., Sharma, R., & Kumar, S. R. V. (2011). Effect of Moisture Content and Feed Rate on Size Reduction of Pearl Millet. *Journal of Food Science and Engineering* 1, 93–99.
- Balasubramanian, S., & Viswanathan, R. (2010). Influence of moisture content on physical properties of minor millets. *Journal of Food Science and Technology*, 47(3), 279–284.

- Baryeh, E. A. (2002). Physical properties of millet. *Journal of Food Engineering*, 51(1), 39–46.
- Deshpande, S. D., Bal, S., & Ojha, T. P. (1993). Physical Properties of Soybean. *Journal of Agricultural Engineering Research*, 56(2), 89–98.
- Dursun, E., & Dursun, I. (2005). Some physical properties of caper seed. *Biosystems Engineering*, 92(2), 237–245.
- Figueiredo, A. K. De, Baümler, E., Riccobene, I. C., & Nolasco, S. M. (2011). Moisture-dependent engineering properties of sunflower seeds with different structural characteristics. *Journal of Food Engineering*, 102(1), 58–65.
- Jain, R. K., & Bal, S. (1997). Properties of pearl millet. *Journal of Agricultural and Engineering Research*, 66(2), 85–91.
- Kaleemullah, S., & Gunasekar, J. J. (2002). Moisture-dependent physical properties of arecanut kernels. *Biosystems Engineering*, 82(3), 331–338.
- Kingsly, A. R. P., Singh, D. B., Manikantan, M. R., & Jain, R. K. (2006). Moisture dependent physical properties of dried pomegranate seeds (Anardana). *Journal of Food Engineering*, 75(4), 492–496.
- Konak, M., Çarman, K., & Aydin, C. (2002). Physical properties of chick pea seeds. *Biosystems Engineering*, 82(1), 73–78.
- Koocheki, A., Razavi, S. M. A., Milani, E., Moghadam, T. M., Abedini, M., Alamatyian, S., & Izadkhah, S. (2007). Physical properties of watermelon seed as a function of moisture content and variety. *International Agrophysics*, 21(4), 349–359.
- Meera, K., Smita, M., & Haripriya, S. (2019). Varietal distinctness in physical and engineering properties of paddy and brown rice from southern India. *Journal of Food Science and Technology*, 56(3), 1473–1483.
- Mwithiga, G., & Sifuna, M. M. (2006). Effect of moisture content on the physical properties of three varieties of sorghum seeds. *Journal of Food Engineering*, 75(4), 480–486.
- Nwabueze, D., Charles, K., Adebisi, W., & Samuel, I. (2020). Comparative analysis of moisture-dependent physical and mechanical properties of two varieties of African star apple (*Chrysophyllum albidum*) seeds relevant in engineering design. *Scientific African*, 8, e00303.
- Ogunjimi, L. A. O., Aviara, N. A., & Aregbesola, O. A. (2002). Some engineering properties of locust bean seed. *Journal of Food Engineering*, 55(2), 95–99.
- Ojediran, J. O., Adamu, M. A., & George, D. L. J. (2010). Some physical properties of Pearl millet (*Pennisetum glaucum*) seeds as a function of moisture content . *African Journal of General Agriculture*, 6(1), 39–46.
- Patil A. K., Satankar M., Kautkar S. & Rehana Raj (2020). Cloud Point Extraction: A Novel Approach for Extraction of Bioactive Compounds from Fruit and Vegetable Waste. *Chemical Science Review and Letters*, 34(9), 324-328.
- Ramashia, S. E., Gwata, E. T., Meddows-taylor, S., Anyasi, T. A., & Jideani, A. I. O. (2018). Some physical and functional properties of finger millet (*Eleusine coracana*) obtained in sub-Saharan Africa. *Food Research International*, 104, 110–118.
- Satankar, M., Patil A. K., Kautkar S., & Utkarsh Kumar (2020). Pearl Millet: A Fundamental Review on Underutilized Source of Nutrition. *Multilogic In Science*, 34(10), 1081-1084.
- Satankar, M., Patil, A. K., Verma, D. K., & Singh, M. (2020). Characterization of Viscoelastic Behavior of Ripe Deseeded Tamarind Subjected to Uniaxial Compressive Loading. *Current Journal of Applied Science and Technology*, 39(5), 73-79.
- Sharma, N., & Niranjana, K. (2018). Foxtail millet: Properties, processing, health benefits, and uses. In *Food Reviews International*, 34(4), 329–363.
- Singh, K. P., Mishra, H. N., & Saha, S. (2010). Moisture-dependent properties of barnyard millet grain and kernel. *Journal of Food Engineering*, 96(4), 598–606.
- Singh, S. K., Kautkar S., & Patil A. K. (2021). Impact of engineering properties of grass seeds in developing post-harvest operations and machineries. *Environment Conservation Journal*, 22(3), 395–399.
- Singh, S. K., Samsheer, Singh, B., Senger R., Kumar P., & Patil A. K. (2021). Drying characteristics and prediction of best fitted drying model for coriander leaves. *Environment Conservation Journal*, 22(3), 243–251.
- Sologubik, C. A., Campañone, L. A., Pagano, A. M., & Gely, M. C. (2013). Effect of moisture content on some physical properties of barley. *Industrial Crops and Products*, 43(1), 762–767.
- Subramanian, S., & Viswanathan, R. (2003). Thermal properties of minor millet grains and flours. *Biosystems Engineering*, 84(3), 289–296.
- Subramanian, S., & Viswanathan, R. (2007). Bulk density and friction coefficients of selected minor millet grains and flours. *Journal of Food Engineering*, 81(1), 118–126.
- Viswanathan, R., Palanisamy, P. T., Gothandapani, L., & Sreenarayanan, V. V. (1996). Physical Properties of Neem Nut. *Journal of Agricultural Engineering Research*, 36(1), 19–25.

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