International Journal of Bio-resource and Stress Management https://ojs.pphouse.org/index.php/IJBSM

IJBSM April 2026, 17(4): 01-07

Article AR6838a

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2026.6838a

Effect of Moisture Content on Physical and Frictional Properties of Pearl Millet (*Pennisetum glaucum*) Seed

Naveendra Kumar Patel[1], Rahul Kumar Yadav[2], Abhishek Mishra[3] and Sunil Kumar[4]

[1]Dept. of Agricultural Engineering, Sri Karan Narendra Agriculture University, Jobner, Jaipur, Rajasthan (303 329), India
[2]Dept. of Agricultural Engineering, Dayanand College, Ajmer, Rajasthan (305 001), India
[3]Dept. of Farm Machinery and Power Engineering, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (263 145), India
[4]Dept. of Farm Machinery and Power Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh (211 007), India

Open Access

Corresponding pnaveendra7378@gmail.com

0000-0003-4498-9247

ABSTRACT

The experiment was conducted during the month of August, 2025 at the Dept. of Agril. Engg., SKNAU, Rajasthan, India, to study the effect of moisture content on physical and frictional properties of pearl millet (Bajra). The physical and frictional properties of pearl millet were determined at moisture contents ranging from 8.82% to 16.3%. The average values of length, breadth, and thickness for the RHB-223 variety of pearl millet were found to be 3.135, 1.89, and 1.39 mm, respectively. The average values of geometric, arithmetic, square and equivalent mean diameter of RHB-223 were observed to be 2.02, 2.14, 3.59 and 2.58 mm, respectively. The average data of surface area and volume for the RHB-223 variety were recorded as 14.42 mm^2 and 8.34 mmn^3 respectively. It was also observed that the average thousand seed weight of the pearl millet variety RHB-223 was 9.258 g. The average data of bulk density, true density and density ratio for the RHB-223 variety were found to be 687.558 kg m^{-3} and 1045.273 kg m^{-3} and 0.658 respectively. It was also observed that the average porosity of the pearl millet variety RHB-223 was 34.222. The average value of angle of repose for the RHB-223 variety was recorded as 27.943°. The average coefficient of static friction for pearl millet variety RHB-223 on plastic, MS sheet and plywood surface was found to be 0.384, 0.438, 0.513 respectively.

KEYWORDS: Physical properties, test weight, angle of repose and friction

***Citation* (VANCOUVER):** Patel et al., Effect of Moisture Content on Physical and Frictional Properties of Pearl Millet (*Pennisetum glaucum*) Seed. *International Journal of Bio-resource and Stress Management,* 2026; 17(4), 01-07. HTTPS://DOI.ORG/10.23910/1.2026.6838a.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The author has declared that no conflict of interest exists.

RECEIVED on 26th November 2025 RECEIVED in revised form on 02nd April 2026 ACCEPTED in final form on 15th April 2026 PUBLISHED on 21st April 2026

1. INTRODUCTION

Pearl millet (*Pennisetum glaucum*) is among the most significant staple grains globally, serving as a major food source for over half of the world's population (Baby et al., 2023). Relative to maize and sorghum, the grains exhibit a better-balanced amino acid profile, elevated iron and zinc content, and superior nutritional value due to their high protein and metabolizable energy levels (Rai et al., 2008). Fermented and non-fermented flatbreads and porridges are the main dishes made from grains that are consumed by humans. During the dry season, a significant portion of animal rations consists of dry pearl millet stover (Kelley et al., 1996). A large amount of Bajra grain is utilized for non-food applications such as chicken feed, cow feed, and alcohol extraction (Basavara et al., 2010). Indian genotypes of pearl millet have 62.8–70.5 g/100 g of starch, 14.0% protein content, 5.7% fat, 2.1% ash, 2.0% crude fiber, and 76.3% carbohydrate (Suma and Urooj, 2015). The study found that linseed capsules had an average length of 79.4 mm and width of 70.8 mm, while seeds averaged 4.54 mm in length and 2.27 mm in width (Patel et al., 2021). It was found for vitamins, important micronutrients, minerals, phytochemicals, phenolic compounds, and nutraceuticals by Amadou et al. (2014). Compared to other cereals, it has a higher protein level (8–19%) and a superior amino acid balance. Millets are especially rich in ferulic acid, a kind of hydroxycinnamic acid that is well-known for its strong antioxidant properties (Jena et al., 2023). Furthermore, understanding the physical characteristics of grains at a specific moisture content is crucial for the efficient, appropriate, effective, and inexpensive design of equipment (Bhise et al., 2014). It is the most widely cultivated millet species and has been grown since ancient times across Africa and the Indian subcontinent (Meena et al., 2021). The Sahel zone of West Africa is considered both the center of its biodiversity and the likely site of its domestication. Ranking as the 6th most important cereal crop worldwide, pearl millet serves as a key dietary staple in the semi-arid regions of Asia and Africa. It is cultivated on approximately 30 million hectares globally, with major production areas located in Africa (around 18 mha) and Asia (over 10 mha) (Yadav and Rai, 2013). In Africa, pearl millet is primarily utilized in preparing traditional fermented porridges, both thick and thin varieties. The next major use is malting, which is employed in producing local fermented beverages and liquors (Nengparmoi et al., 2024). In West African nations like Senegal, millet serves as the main ingredient for dishes such as couscous, porridge, and pancakes. In Cameroon, porridges and steamed millet cakes made from pearl millet are commonly prepared for young children and infants. Malted pearl millet is also blended with legumes to produce nutritious weaning foods (Heiru et al., 2019). According to Mbaeyi-Nwaoha and Obetta (2016), a nutrient-dense complementary food can be produced from millet (Pennisetum glaucum), pigeon pea (Cajanus cajan), and seedless breadfruit (Artocarpus altillis) leaf powder blends, demonstrating significant potential for improving the nutritional quality of complementary foods. Moisture increase (8.7–21.7% d.b.) slightly affected maize geometry, increased size, density, and friction, reduced porosity, with highest friction on concrete surfaces (Sangamithra, et. al., 2016). The design of the drum seeder orifice depended on the physical and engineering properties of paddy seeds. Therefore, these properties of dry, soaked (12 h), and pregerminated (24 h soaking+12 h incubation) Basmati-370 seeds were evaluated to determine suitable orifice dimensions (Chaudhary et al., 2023).

The study at SHUATS evaluated physical properties of linseed varieties Alsi-2 and Neelam, including seed dimensions, geometric traits, 1000-grain weight, densities, porosity, and yield components at varied moisture levels (D'souza et al., 2022). Millets are once again at the fore front of cereal crops after a unanimous resolution was passed designating 2023 as the International Year of Millets, with the aim of promoting increased production and consumption (Tagade et al., 2024). The International Year of Millets, 2023, carried the theme "Healthy Millets – Healthy People" and aimed to promote understanding of the nutritional value of millets and their benefits for health (Kumar et al., 2021). The effects of toasting and cooking on color and antioxidant properties of flours from Indian pearl millet cultivars were examined, focusing on total phenolics, total flavonoids, antioxidant activity, and metal chelating activity (Siroha and Sandhu, 2017).

2. MATERIALS AND METHODS

The experiment was conducted during the month of August, 2025 at the Dept. of Agril. Engg., SKNAU, to study the effect of moisture content on physical and frictional properties of pearl millet (Bajra) seed at the Dept. of Agril. Engg., SKNAU, Jobner. The pearl millet grain (Variety: RHB-223) were obtained from the agriculture research station, SKNAU, Jobner, Jaipur (Rajasthan), India. The seeds were physically washed to remove extraneous matter before being evaluated at the Department of Agricultural Engineering, SKNCOA, SKNAU, Jobner, Jaipur (Rajasthan), India. The selected pearl millet seed variety used in the study. The physical parameters investigated included longitudinal and lateral diameter, shape, color, true and bulk density, porosity, and 1000-seed weight.

2.1. Preparation of samples

The moisture content of the grain on a dry basis was determined using the oven-dry method (Singh et al., 2009) by drying the samples at 103±2°C for 24 hours, and it was calculated according to ASAE (2006).

Moisture content (%) $=(W_o-W_1/W_{0)}\times 100$

Where,

✓ W_o-Weight of grains prior to drying, g
✓ W_1-Weight of grains post-drying, g

All physical properties of the seeds were measured at varying moisture levels in three replications using the following methods for pearl millet.

2.2. Size and shape

Using the specified method, a set of one hundred seeds was randomly selected. A digital vernier caliper with an accuracy of 0.02 mm was used to measure the three principal dimensions of each seed: length (L), breadth (W), and thickness (T). One hundred seeds were measured at each moisture level, and the mean values were computed. These dimensions were utilized to compute the geometric (GMD), arithmetic (AMD), square (SMD), equivalent diameter (EQD), seed volume (V) and surface area (S).

$GMD=(LMT)^{1/3}$
$AMD=(L+M+T)/3$
$SMD=\sqrt{(LB+BT+TL)}$
$EQD=(D_{GM}+D_{AM}+D_{SM})/3$

2.3. Surface area

The formula suggested by Singh et al. (2010) was used to calculate surface area (S).
$S=\pi\times(D_{GM})^2$

2.4. Volume (V)

The Volume was calculated by measuring the three principal dimensions length, breadth, and thickness of pearl millet grains in ten replications, and estimating the volume using the equation given.

$V=L\times W\times T$

2.5. Weight of thousand seeds

An electronic scale with a resolution of 0.001 g was used to weigh a thousand seeds. A sample of 1000 seeds was counted and weighed ten times. The thousand seed weight was determined by averaging these values (Zareiforoush et al., 2009).

2.6. Bulk density and true density

The bulk density of a sample was determined by dividing its mass by its total volume The grains were poured into a 500 mL graduated cylinder to measure the volume. The bulk density was calculated by dividing the mass of the sample by the volume of the cylinder using the following method:

$\rho_b=m/v$

Where,

✓ ρ_b-Bulk density, kg m^{-3}

✓ m-Seed sample mass, kg

✓ v-Seed sample volume, m^3

Using the toluene displacement technique, true density was figured out as the mass of the seed sample divided by its true volume. Toluene (C_2H_4) was selected instead of water because it was less readily absorbed by the seeds (Ravi and Venkatachalam, 2015). Using this approach, 5 g of seeds were immersed in a 100 ml graduated cylinder filled with 50 ml of toluene. The volume of displaced toluene was recorded from the graduated cylinder scale, and true density was calculated as the ratio of seed mass to the displaced toluene volume

$\rho_t=m/T_{vs}$

Where,

✓ ρ_t-True density, kg m^{-3}

✓ T_{vs}-The seed sample's true volume, m^3

2.7. Density ratio

It was calculated using the specified formula and defined as the bulk density to actual density ratio.

Density ratio$=\rho_b/\rho_t$

2.8. Porosity

Porosity represented the portion of the bulk grain volume that was not occupied by the grains themselves. It was calculted using the bulk and true density values through the following relation.

$\epsilon=(\rho_t-\rho_b)/\rho_t\times 100$

Where,

✓ ϵ-Porosity,

2.9. Frictional properties

The angle of repose was defined as the angle formed with the horizontal surface at which the material naturally accumulated to form a heap. It was determined by taking measurements of the heap's base diameter and center height (Goriya et al., 2020). The resistance to motion between two stationary surfaces were represented by the coefficient of static friction (Muralidhar and Goswami, 2011). MS sheets, plywood and plastic were used as test materials. The test surface containing the cylinder was gradually tilted using a screw mechanism until the cylinder just began to slip.

Five iterations of this procedure were carried out, and observations were noted. The coefficient of friction between the pearl millet seeds and the test surface was calculated as the tangent of the measured angle

$\theta=\tan^{-1}[2h/d]$

Where,

✓ θ denotes the angle of repose, in degrees

✓ *h* represents the height of the heap, in cm

✓ *d* indicates the dia of the heap, in cm

$\mu = \tan\theta$

Where,

✓ μ-Static friction coefficient

✓ θ-Angle between the incline and the horizontal surface, °

3. RESULTS AND DISCUSSION

In the case of pearl millet (bajra), evaluations were carried out for size, shape, bulk and actual density, porosity, angle of repose, static friction coefficient, and moisture content (Rai et al., 2008). Grain size and shape were thought to have an impact on equipment design.

3.1. Effect of moisture content on size and shape dimensions

The RHB-223 variety's geometric and arithmetic mean diameters were computed, and the length, breadth, and thickness of a sample of thirty different types of seeds were measured to determine the size and form of the chosen seeds (Table 1).

The RHB-223 variety's moisture content ranged from 8.82% to 16.3%. A sample of thirty distinct seeds was used to measure the length, breadth, and thickness of the chosen seeds. For the RHB-223 variety, geometric, arithmetic, square, and equivalent mean diameters were computed. For RHB-223, the average measurements for length, breadth, and thickness were 3.135, 1.89 and 1.39 mm, respectively. The average square and equivalent mean diameters were found to be 3.59 and 2.58 mm, respectively, whereas the average geometric and arithmetic mean diameters were recorded as 2.02 and 2.14 mm, respectively. These results were in close agreement with the findings of Panwar et al. (2023), who reported that millet grains showed comparable dimensional characteristics and that mean diameter values increased with moisture absorption due to swelling of the grain structure. Similarly, Kumar and Karmakar (2025) observed that moisture uptake significantly influenced the axial dimensions and mean diameters of cereal grains, explaining that water penetration into the seed coat increased seed volume and led to higher calculated mean diameter values. Therefore, the present results confirmed that moisture content had a direct impact on the dimensional properties of pearl millet seeds.

Table 1: Effect of moisture content on size and shape dimensions for pearl millet

MC (%)	Length (mm)	Width (mm)	Thickness (mm)	GMD (mm)	AMD (mm)	SMD (mm)	EQD (mm)
8.82	2.89	1.68	1.24	1.819	1.937	3.244	2.333
10.12	3.06	1.86	1.32	1.959	2.080	3.491	2.510
13.8	3.23	1.93	1.46	2.088	2.207	3.710	2.668
16.3	3.36	2.1	1.52	2.205	2.327	3.919	2.817
Mean	3.135	1.89	1.39	2.02	2.14	3.59	2.58
STD DEV	0.204	0.174	0.128	0.166	0.168	0.290	0.208
Variance	0.042	0.030	0.016	0.028	0.028	0.084	0.043

3.2. Effect of moisture content on surface area, volume and 1000 seed weight

The data presented in Table 2 illustrates the variations in surface area, volume and weigh a thousand seeds of pearl millet seeds (RHB-223 variety).

The surface area, volume and 1000 seed weight of pearl millet were determined within the moisture content levels of 8.82%, 10.12%, 13.8% and 16.3%. These values were presented in Table 2. The average data of surface area and volume for the RHB-223 variety were 14.42 mm^2 and 8.34 mm^3 respectively. It was also observed that the average data 9.258 g thousand seed weight for the pearl millet variety RHB-223.

Similar increasing trends in surface area and seed volume with moisture content were also reported by Gojiya et al. (2020), who explained that moisture absorption caused swelling of grains, thereby increasing their dimensional properties. Likewise, Onwe et al. (2023) observed a rise in thousand-seed weight with increasing moisture due to water uptake and the corresponding increase in grain mass. The present findings were therefore in agreement with earlier studies, confirming that moisture content significantly influenced the physical characteristics of pearl millet grains.

3.3. Effect of moisture content on density properties

The data presented in Table 3 illustrates the variations in bulk, true density, density ratio and porosity of pearl millet seeds (RHB-223 variety).

The bulk, true density, density ratio and porosity of pearl millet seed (variety RHB-223) were determined at moisture content levels of 8.82%, 10.12%, 13.8% and 16.3%. These results were presented in table 3. The average data of bulk

Table 2: Effect of moisture content on surface area, volume and thousand seed weight for pearl millet

Moisture content (%)	Surface area (mm^2)	Volume (mm^3)	Thousand seed weight (g)
M_1 (8.82)	11.783	6.020448	8.86
M_2 (10.12)	13.592	7.512912	9.25
M_3 (13.8)	15.298	9.101494	9.39
M_4 (16.3)	17.007	10.72512	9.53
Mean	14.420	8.340	9.258
STD DEV	2.244	2.028	0.289
Variance	5.033	4.111	0.083

Table 3: Effect of moisture content on density properties for pearl millet

Moisture Content (%)	Bulk density (kg m^{-3})	True density (kg m^{-3})	Density ratio	Porosity
M_1 (8.82)	691.23	1049.36	0.659	34.128
M_2 (10.12)	689.71	1046.94	0.659	34.121
M_3 (13.8)	686.03	1043.23	0.658	34.240
M_4 (16.3)	683.26	1041.56	0.656	34.400
Mean	687.558	1045.273	0.658	34.222
STD DEV	3.602	3.533	0.001	0.130
Variance	12.974	12.481	0.000	0.017

density, true density and density ratio for the RHB-223 variety were 687.558 kg m^{-3} and 1045.273 kg m^{-3} and 0.658 respectively. It was also found that the mean porosity of pearl millet variety RHB-223 was 34.222. The findings of the present study were consistent with D'souza et al. (2022), who reported that bulk density decreased while true density and porosity increased with rising moisture content due to grain swelling and increased inter-particle void spaces. Similarly, Babojanov et al. (2022) observed comparable trends in cereal grains, explaining that moisture absorption increased kernel volume more rapidly than mass, resulting in reduced bulk density and higher porosity. Thus, the obtained density and porosity values of pearl millet seeds agreed well with earlier reported observations.

3.4. Effect of moisture content on frictional properties

The coefficient of friction was measured on three surfaces namely Plastic, MS sheet and plywood. The data presented in Table 4 displayed the various frictional properties of pearl millet seeds (RHB-223 variety).

The moisture content ranges of 8.82%, 10.12%, 13.8%, and 16.3% were used to calculate the angle of repose and coefficient of friction of pearl millet (variety RHB-223). These results were presented in table 4. The average data of angle of repose for the RHB-223 variety was 27.943°. The average coefficient of static friction for pearl millet variety RHB-223 on plastic, MS sheet and plywood surface was found to be 0.384, 0.438, 0.513 respectively. The present results were in close agreement with Nyorere and Uguru (2018), who reported that the angle of repose of grains increased with increasing moisture content due to higher cohesiveness and surface adhesion between particles. Similarly, Gampala et al. (2021) observed that the coefficient of static friction rose with moisture content because absorbed water increased surface stickiness and resistance to sliding. Further, Verma et al. (2024) also reported higher friction values on rough surfaces such as plywood compared to smoother surfaces like plastic, which supported the present trend of maximum friction on plywood and minimum on plastic.

Table 4: Effect of moisture content on frictional properties for pearl millet

Moisture content (%)	Angle of repose (°)	Coefficient of static friction		
		Plastic	MS sheet	Plywood
M_1 (8.82)	27.4	0.364	0.425	0.492
M_2 (10.12)	27.82	0.382	0.432	0.512
M_3 (13.8)	28.1	0.391	0.441	0.518
M_4 (16.3)	28.45	0.397	0.452	0.529
Mean	27.943	0.384	0.438	0.513
STD DEV	0.444	0.014	0.012	0.016
Variance	0.197	0.000207	0.000136333	0.000240917

4. CONCLUSION

An increase in moisture content resulted in a corresponding rise in the size and shape parameters of pearl millet grains. The surface area, volume, and thousand-seed weight of pearl millet grains also increased with increasing moisture content. As the moisture content increased, the bulk density, true density, and density ratio of pearl millet grains decreased. Higher moisture content caused the angle of repose of pearl millet grains to increase. Similarly, increasing the moisture level caused an increase in the coefficient of static friction of pearl millet grains on plastic, MS sheet, and plywood surfaces.

5. REFERENCES

Adebowale, AA., Fetuga, G.O., Apata, C.B., Sanni, L.O., 2012. Effect of variety and initial moisture content on physical properties of improved millet grains. Nigerian Food Journal 30(1), 5–10. https://doi.org/10.1016/S0189-7241(15)30007-2.

Amadou, I., Gounga, M.E., Shi, Y.H., Le, G.W., 2014. Fermentation and heat moisture treatment induced changes on the physicochemical properties of foxtail millet (*Setaria italica*) flour. Food and Bioproducts Processing 92(1), 38–45. https://doi.org/10.1016/j.fbp.2013.07.009.

Basavaraj, G., Parthasarathy, Rao, P., Bhagavatula, S., Ahmed, W., 2010. Availability and utilization of pearl millet in India. International Crops Research Institute for the Semi-Arid Tropics 8(1–6). https://www.researchgate.net/publication/266529722_.

Bhise, S., Kaur, A., Manikantan, M., 2014. Moisture dependent physical properties of maize (PMH-1). Acta Alimentaria 43(3), 394–401. https://doi.org/10.1556/AAlim.43.2014.3.5.

Babojanov, A.B., Dulliev, A.K., Turdibekov, A.R., 2022, August. Development of a seeder design for precise sowing of carrot seeds on a ridge. In IOP Conference Series: Earth and Environmental Science 1076(1), 012071. IOP Publishing. DOI: 10.1088/1755-1315/1076/1/012071.

Baby, T., Raheem, M.A., Kumar, V.S., Gokari, P., Yadav, A., Kaur, A., 2023. Pearl millet (*Pennisetum glaucum*) production in the 21st century. The Pharma Innovation Journal 12(2), 2045–2047. DOI: https://doi.org/10.22271/tpi.2023.v12.i2y.18694.

Chaudhary, D., Sharma, S., Sharma, M.K., Bhardwaj, S., 2023. Physical and engineering properties of dry, soaked and pregerminated paddy seed (Basmati-370). Emerging Issues in Agricultural Sciences 1(1), 160–170. DOI: 10.9734/bpi/eias/v1/5659A.

D'souza, P.M., Aalam, R.N., Moses, S.C., Patel, N.K., 2022. Development and ergonomic assessment of manually operated modified linseed crop thresher for studying the physical properties of the linseed seed. International Journal of Environment and Climate Change 12(11), 3026–3033. https://doi.org/10.9734/ijecc/2022/v12i111348.

Gojiya, D.K., Dobariya, U.D., Pandya, P.A., Gojiya, K.M., 2020. Studies on physical properties of peanut Seed. Acta Scientific Agriculture 4(3), 1–5. DOI: 10.31080/ASAG.2020.04.0814.

Heiru, M., Bultosa, G., Busa, N., 2019. Effect of grain finger millet and peanut blending ratio and processing condition on weaning food quality. Cogent Food and Agriculture 5(1), 1671116. https://doi.org/10.1080/23311932.2019.1671116.

Jena, A., Sharma, V., Dutta, U., 2023. Millets as superfoods: Let thy cereal be thy medicine. Indian Journal of Gastroenterology 42(3), 304–307. https://doi.org/10.1007/s12664-023-01377-1.

Kelley, T.G., Parthasarathy, Rao, P., Weltzien, E., Purohit, M.L., 1996. Adoption of improved cultivars of pearl millet in an arid environment: straw yield and quality considerations in western Rajasthan. Experimental Agriculture 32, 161–171. https://doi.org/10.1017/S0014479700026077.

Kumar, A., M.K., Tripathi, D., Joshi, V., Kumar., 2021. Millets and millet technology. Published by Springer Nature. https://doi. org/10.1007/978-981-16-0676-2.

Kumar, S., Karmakar, S., 2025. Engineering properties of maize, groundnut and paddy seeds for the design of seed metering mechanism of multi crop planter. Journal of Scientific Research and Reports 31(7), 766–773. DOI: 10.9734/jsrr/2025/v31i73296.

Mbaeyi-Nwaoha, I.E., Obetta, F.C., 2016. Production and evaluation of nutrient-dense complementary food from millet (*Pennisetum glaucum*), pigeon pea (*Cajanus cajan*) and seedless breadfruit (*Artocarpus altillis*) leaf powder blends. African Journal of Food Science 10(9), 143–156. https://doi.org/10.5897/AJFS2015.1393.

Meghwal, M., Goswami, T.K., 2011. Effect of moisture content on physical properties of black pepper. Journal of Agricultural Engineering 48(2), 8–14. Available from: https://www.researchgate.net/publication/272295320.

Meena, R.P., Joshi, D., Bisht, J.K., Kant, L., 2021. Global scenario of millets cultivation. In Millets and millet technology. Singapore: Springer Singapore, pp. 33–50. https://doi.org/10.1007/978-981-16-0676-2_2?urlappend=%3Futm_source%3Dresearchgate.net%26utm_medium%3Darticle.

Nyorere, O., Uguru, H., 2018. Effect of seed size on the mechanical properties of gmelina seed. International Journal of Scientific & Engineering Research 9(8), 853–856. Available from: https://www.researchgate.net/publication/337882165.

Narendra, Gampala, Edukondalu, L., Someswarao, C.H., Haribabu, H., 2021. Studies on physical properties of pearl millet grains. International Journal of Advanced Chemistry Research 3(1), 50–53. DOI: https://doi.org/10.33545/26646781.2021.v3.i1a.70.

Nengparmoi, T., Ghorband, A.S., Yadav, P., Sahu, R., Anbarasan, S., Reddy, V.S., Panotra, N., 2024. pearl millet processing methods and products: An in-depth analysis. European Journal of Nutrition and Food Safety 16(8), 180–192. https://doi.org/10.9734/ejnfs/2024/v16i81506.

Onwe, D.N., Okoko, P., Akpan, M.G., 2023. Determination of some physical and mechanical properties of gmelina arborea seed. Asian Journal of Advances in Agricultural Research 21(3), 23–29. DOI: 10.9734/AJAAR/2023/v21i3419.

Patel, G., Naik, R.K., Patel, K.K., 2021. Studies on some physical and engineering properties of linseed. Biological Forum–An International Journal 13(3), 303–308. Available from: https://www.researchgate.net/publication/354402005_Studies_on_Some_Physical_and_Engineering_Properties_of_Linseed.

Panwar, G., Swarnkar, R., Kumar, N., Shukla, K., 2023. Evaluation of physical properties of maize and pigeonpea seeds for seed metering mechanism. Journal of Experimental Agriculture International 45(12), 89–97. DOI: 10.9734/JEAI/2023/v45i122269.

Rai, K.N., Gowda, C.L.L., Reddy, B.V.S., Sehgal, S., 2008. Adaptation and potential uses of sorghum and pearl millet in alternative and health foods. Comprehensive Reviews in Food Science and Food Safety 7(4), 340–352. Available from: https://oar.icrisat.org/id/eprint/7913.

Ravi, P., Venkatachalam, T., 2015. Important engineering properties of paddy. Scientific Journal Agricultural Engineering 2014, 73–83. Available from: https://www.researchgate.net/publication/304351942.

Singh, K.P., Mishra, H.N., Saha, S., 2010. Moisture-dependent properties of barnyard millet grain and kernel. Journal of Food Engineering (JFE) 96(4), 598–606. https://doi.org/10.1016/j.jfoodeng.2009.09.007.

Singh, V.V., Singh, S., Verma, V., Meena, S.S., Kumar, A., 2009. Genetic variability for seedling traits in Indian mustard under moisture stress conditions. Indian Journal of Plant Genetic Resources 22(01), 46–49. Available from: https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Genetic%20variability%20for%20seedling%20traits%20in%20Indian%20mustard%20under%20moisture%20stress%20conditions.

Suma, P.F., Urooj, A., 2015. Isolation and characterization of starch from pearl millet (*Pennisetum typhoidium*) flours. International Journal of Food Properties 18, 2675–2687. https://doi.org/10.1080/10942912.2014.981640?urlappend=%3Futm_source%3Dresearchgate.net%26utm_medium%3Darticle.

Sangamithra, A., Gabriela, J.S., Prema, R.S., Nandini, K., Kannan, K., Sasikala, S., Suganya, P., 2016. Moisture dependent physical properties of maize kernels. International Food Research Journal 23(1), 109–115. Available from: https://www.researchgate.net/publication/291135789_.

Siroha, A.K., Sandhu, K.S., 2017. Effect of heat processing on the antioxidant properties of pearl millet (*Pennisetum glaucum* L.) cultivars. Journal of Food Measurement and Characterization 11(2), 872–878. https://doi.org/10.1007/s11694-016-9458-1?urlappend=%3Futm_source%3Dresearchgate.net%26utm_medium%3Darticle.

Tagade, A., Kandpal, S., Sawarkar, A.N., 2024. Insights into pyrolysis of pearl millet (*Pennisetum glaucum*) straw through thermogravimetric analysis: physico-chemical characterization, kinetics, and reaction mechanism. Bioresource Technology 391, 129930. https://doi.org/10.1016/j.biortech.2023.129930.

Verma, P.D., Verma, A., Naik, R.K., Jogdand, S.V., Rajput, A.S., 2024. Exploring certain physical and engineering attributes of okra seeds. International Journal of Advanced Biochemistry Research 8(2S), 296–299. DOI: 10.33545/26174693.2024.v8.i2Sd.578.

Yadav, O.P., Rai, K.N., 2013. Genetic improvement of pearl millet in India. Agricultural Research 2(4), 275–292. http://dx.doi.org/10.1007/s40003-013-0089-z.

Zareiforoush, H., Komarizadeh, M.H., Alizadeh, M.R., 2009. Effect of moisture content on some physical properties of paddy grains. Research Journal of Applied Sciences, Engineering and Technology 1(3), 132–139. Available from: https://www.researchgate.net/publication/286782680.