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Engineering Properties of Kodo Millet

Surpam, T. B.[1], Pardeshi, I. L.[2] and Rokade H. N.[3]

[1]*Subject Matter Specialist (Agril. Engg.), Krishi Vigyan Kendra, Khamgaon (Beed-II), VNMKV, Parbhani (MS)*
[2]*Professor and Head, Department of PHM of Food, Grain and Seed, PGI of PHM, Killa- Roha under BSKKV, Dapoli (MS)*
[3]*Senior Research Fellow, NAHEP-CAAST-, VNMKV, Parbhani (MS)*
E-mail: tushasurpam@gmail.com

Abstract: The engineering properties of kodo millet (*Paspalum scrobiculatum*) were determined at moisture content of 9.066 % (wb). The mean values obtained for length, width and thickness were 2.76, 2.15 and 1.41 mm, respectively. The average value for geometric mean diameter, sphericity, weight of thousand grains, bulk density and true density were 2.023 mm, 0.740, 3.91 g, 648.69 kg.m-3 and 1203.063 kg.m-3, respectively. The angle of repose mean value was 38°. The co-efficient of static friction on three types of structural material was found to be ranging from 0.36 (steel sheet), 0.41 (g), (galvanised iron sheet) and 0.37 (card board).

Keywords: Kodo millet, physical properties, aerodynamic properties, frictional properties, mechanical properties.

INTRODUCTION

Cereal grains have contributed to the growth of human races since ages and play a vital part in the daily diet of billions of people all over the world. However, production of the major cereal crops are dwindling in recent years because of the climate changes, crop failure due to erratic weather causing flood and draught conditions, lower productivity as a result of soil nutrient depletion, chemical residues spoiling soil health. This is putting an onus on the agricultural and food sector. Furthermore, increasing world population, rising food prices and essential commodities, and other socio-economic impacts are threatening the global agriculture and food security. The impact can be most felt by the people who live in arid and sub-arid regions, with limited resources (Saleh et al., 2013). Food for all is a great challenge to the scientists working in the area of production, processing, storage and nutrition to combat hunger and poverty.

Millets are a group of highly variable small-seeded grasses, widely grown around the world as cereal crops or grains for fodder and human food. Millets are important crops in the semiarid tropics of Asia and Africa (especially in India, Mali, Nigeria, and Niger), with 97% of millet production in developing countries (McDonough, Cassandrea M. et al., 2000)

Millets are considered as ancient grains, domesticated thousands of years ago at the beginning of human civilization. Some evidences point out about the cultivation of millets about 4000 years ago (Shahidi and Chandrasekara, 2013). India is the world's largest producer of millet. In the 1970s, all of the millet crops harvested in India were used as a food staple. By the 2000s, the annual millet production had increased in India, yet per capita consumption of millet had dropped by between 50% to 75% in different regions of the country (Basavaraj, 2010).

The kodo millet (*Paspalum scrobiculatum*), is also known as cow grass, rice grass, ditch millet, Native Paspalum, or Indian Crown Grass. It is grown in India, Pakistan, Philippines, Indonesia, Vietnam, Thailand and West Africa. It is major food source in the Deccan plateau of India (Gujarat, Karnataka and parts of Tamil Nadu),

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some regions of Maharashtra, Odisha, West Bengal, Rajasthan, Uttar Pradesh and Himalayas and consumed traditionally as health and vitality foods in rural India (Hegde and Chandra, 2005).

The local names of kodo varies from region to region and it is known as Kodo in Bengali, Kodra in Gujarati, Punjabi and Marathi, Kodon in Hindi, Harka in Kannada, Koduain Odia, Varagu in Tamil and Arikelu, Arika in Telugu. An estimation says Kodo millet is grown in area of about 907,800 ha with annual production of about 310,710 tonnes (Yadav et al., 2013). Madhya Pradesh and Tamil Nadu have the maximum share in the production and promotion of kodo millet. Government of MP also playing active role in promoting the cultivation and marketing of this crop.

This crop is drought tolerant and usually grown in semi-arid regions without any intercultural operations. Kodo is monocot and the seeds are very small and ellipsoidal, being approximately 1.5mm in width and 2mm in length; they vary in colour from being light brown to a dark grey. Kodo millet has a shallow root system which may be ideal for intercropping. The grain is enclosed in hard, corneous, persistent husks (FAO, 1995).

Pearl millet, little millet, finger millet, proso millet, and foxtail millet are also important crop species. In the developed world, millets are less important. For example, in the United States the only significant crop is proso millet, which is mostly grown for bird seed.

Indian organizations are discussing ways to increase millet use as food to encourage more production; however, they have found that some consumers now prefer the taste of other grains (Jayaraman, Gayatri, 2012).

Knowledge of the engineering properties is important, useful and necessary in the design of processes, machines, structures and controls. These properties are used in analyzing and determining the efficiency of the machine and operation or process as well as determining quality or studying the behaviour of the product during agricultural processing unit operations. Basic information on these engineering properties is of great importance and help engineers towards efficient process and equipment development. The physical properties such as size, shape, surface area, volume, density, porosity, color and appearance are important in designing a particular equipment or determining the behaviour of the product for its handling.

Basic information on these engineering properties is of great importance and help engineers towards efficient process and equipment development. The engineering properties like size, shape, geometric mean diameter, surface area, volume, sphericity, 1000 seed mass, true density, bulk density, porosity, angle of repose, coefficient of static friction, coefficient of internal friction, hardness and terminal velocity for different millets at different moisture content have been studied and determined by many researchers (Balasubramanian and Vishwanathan, 2010; Ojediran et al. 2010; Swami and Swami, 2010; Singh et al., 2010; Ramappa et al., 2011). The properties of the millets vary with varietal difference, moisture content and agronomical conditions it is grown (Konak et al., 2002), which may result in significant variation in the processing of the millets. Hence, the objective of this study was to determine engineering properties of Sorghum– HMT 1001 variety at 11.67 ± 0.078 % (wb) moisture content.

MATERIALS AND METHODS

The experiments were carried out at the Department of Agricultural Process Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The local variety of Kodo millet was procured from the local market. The important engineering properties studied were: physical properties (Longitudinal and lateral diameter, shape, colour, true & bulk density, porosity and weight of 1000 grains), frictional properties (Angle of repose and coefficient of friction) for kodo millet.

Determination of Physical Properties

Shape and size: The size of the sorghum grain was determined by measuring the linear dimensions – length (L), width (W) and thickness (T) measured using a digital calliper having the least count of 0.01 mm. The average size of the kodo millet grains was calculated from randomly selected 10 grain samples.

Geometric Mean Diameter: The geometric mean diameter was calculated by using the relationship (Mohesenin, 1986).

Geometric mean diameter, Dm= $[LBT]^{1/3}$

Where, L= longest intercept (Length), B= longest intercept normal to L (Width) and T= longest intercept normal to L and B (Thickness)

Sphericity: The sphericity is used to describe the shape of the grain. The sphericity was calculated using the relationship (Mohesenin, 1986).

Sphericity, Φ = Dm/ L

Where, Dm= Geometric mean diameter and L= longest intercept (Length).

True Density: 50 ml of toluene was taken in a measuring jar. 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)

$$True\,density, kg/m^2 = \frac{Weight\ of\ gains\,(kg)}{Volume\ of\ grains\ excluding\ void\ space\,(m^3)}$$

Bulk density: Bulk density was determined by using a container of known volume. The sample was taken into the container for the known volume and weighed. The bulk density was determined using the formula (Mohsenin, 1986).

$$Bulk\,density, kg/m^3 = \frac{Weight\ of\ gains\,(kg)}{Volume\ of\ berries\ including\ pore\ space\,(m^3)}$$

Porosity: Porosity of kodo millet grains was calculated from the bulk density and true density values (that were found earlier) by using the following formula (Mohesenin, 1986):

$$Porosity, \% = 1 - \frac{Bulk\ density}{True\ density} \times 100$$

Weight of 1000 grains: One thousand grains were randomly selected and weighed using an electronic balance with an accuracy of 0.1 g. Ten replications were weighed and the mean weight of one thousand grains was calculated.

Frictional Properties

Co-efficient of friction: Coefficient of friction was determined against three material surfaces namely steel sheet, wooden and galvanised iron sheet by surface method. The static angle of friction was recorded when the grain just began to slide on the test surface (Mohsenin, 1986).

Angle of repose: Angle of repose is the angle between base and slope of the cone formed on a free vertical fall of grains on to a horizontal plane. It was determined by following the procedure described by Sahay and Singh (2001). It was found by measuring the height (H, mm) and diameter (D, mm) of the grains heaped in natural piles by using the expression;

Angle of repose, θ (degree) = $\tan^{-1}[2H/D]$

Aerodynamic properties: Aerodynamic properties of agricultural products are important and required for design of air conveying systems and the separation equipment (Sahay and Singh, 1994).

Terminal velocity: Terminal velocity is required to decide the velocity of winnowing air blown to separate a lighter material (Sahay and Singh, 1994). Terminal velocity is equal to air velocity at which the particle remains in suspended state in a vertical pipe. In this study, only terminal velocity of sorghum was measured using an air column. For each test, a sample was dropped into the air stream from the top of the air column and air was blown up the column to suspend the material in the air stream. The air velocity near the location of the sample suspension was measured by digital anemometer having a least count of 0.1 m/s (Gharibzahedi et al., 2010).

RESULTS AND DISCUSSION

The results of the physical properties are presented in Table 1. The mean of individual kodo millet length, width and thickness were 2.764, 2.149 and 1.409 mm, respectively. The values of length, width and thickness of the grains varied from 2-3.14 mm, 2.02-2.27 mm and 1.3-1.51 mm. The average geometric mean diameter was 2.023 mm and it varied between 1.831-2.207 mm. The projected area of the particle is used for the measurement of the sphericity. The sphericity values observed were in the range of 0.703-0.915 and the mean sphericity value is 0.740. The average thousand-grain weight was 3.913 g. The bulk density and true density were in the range 641.9-657.18 kg.m-3 and 1122.88-1267.12 kg.m-3 respectively. The mean of bulk density and true density were 648.69 kg.m-3 and 1203.06 kg.m-3 respectively.

Table 1: Physical Properties of Kodo millet

Property	*No. of observation*	*Minimum Value*	*Maximum Value*	*Mean Value*	*Std Deviation*	*C.V*
Moisture content (%wb)	10	7.98	8.17	8.118	0.068	0.844
Length (mm)	10	2	3.14	2.764	0.298	0.108
Width (mm)	10	2.02	2.27	2.149	0.075	0.035
Thickness (mm)	10	1.3	1.51	1.409	0.070	0.050
Geometric mean diameter (Dm)	10	1.831	2.207	2.023	0.106	5.266
Sherisity	10	0.703	0.915	0.740	0.067	9.066
True Density (kg.m3)	10	1122.888	1267.125	1203.06	74.907	6.226
Bulk Density (kg.m3)	10	641.9	657.18	648.69	6.558	1.011
Weight of 1000 grains(g)	10	3.82	4.09	3.913	0.105	0.027

The results of frictional properties are shown in table 2. The mean value of angle of repose of millet was 38°. The angle of repose is important for determining the maximum angle of a pile of grain in the horizontal plane, and is important in the filling of a flat storage facility. The average values of static coefficient of friction against steel, galvanized iron sheet and wooden plate were 0.36, 0.418 and 0.37, respectively.

The aerodynamic property measured was ranging from 1.54 to 1.66 m/s. The mean value was 1.595 m/s (Table 3).

Table 2: Frictional Properties of Kodo millet

Property	*Frictional Properties of Kodo millet*					
	No. of observation	*Minimum Value*	*Maximum Value*	*Mean Value*	*Std Deviation*	*C.V*
Angle of Repose	10	35	40	38	1.632	0.043
Static coefficient of sorghum						
Steel	10	0.33	0.4	0.36	0.024	0.067
GI	10	0.39	0.45	0.418	0.018	0.042
Wooden	10	0.32	0.39	0.37	0.021	0.057

Table 3: Aerodynamic Properties of Kodo millet

Aerodynamic Properties of Kodo millet					
No. of observation	*Minimum Value*	*Maximum Value*	*Mean Value*	*Std Deviation*	*C.V*
10	1.54	1.66	1.595	0.0383695	0.024

CONCLUSION

The engineering properties of kodo millet was measured at 9.066 % (w.b). The mean of individual kodo millet length, width and thickness were 2.764, 2.149 and 1.409 mm, respectively. The average value for geometric mean diameter, sphericity, thousand grain weight, bulk density and true density were 2.023 mm, 0.740, 3.913 g, 648.69 kg.m-3 and 1203.06 kg.m-3 respectively. The mean value of angle of repose of millet was 38°. The average values of static coefficient of friction against steel, galvanized iron sheet and wooden plate were 0.36, 0.418 and 0.37, respectively. The mean value of aerodynamic property was found 1.595 m/s. These properties can be used for design of equipment for handling and processing of the kodo millet.

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