International Journal of Science, Environment and Technology, Vol. 5, No 2, 2016, 632 – 637

ISSN 2278-3687 (O)
2277-663X (P)

ENGINEERING PROPERTIES OF FOXTAIL MILLET (*Setaria italic* L): VARIETY- HMT 1001

Sunil, C.K., Venkatachalapathy, N., Shanmugasundaram, S., Akash Pare and Loganathan, M.
Indian Institute of Crop Processing Technology, Thanjavur, India
Email: sunil.ck@iicpt.edu.in

Abstract: The engineering properties of foxtail millet (*Setaria italic* L) variety HMT 1001 were determined at moisture content of 11.67 ± 0.078 % (wb). The mean values obtained for length, width and thickness were 2.169, 1.590 and 1.454 mm, respectively. The average value for geometric mean diameter, sphericity, weight of hundred grains, bulk density, true density and porosity were 1.703 mm, 0.785, 0.245 g, 737.127 kg.m^{-3}, 1260.132 kg.m^{-3} and 41.471 % respectively. The angle of repose mean value was 26.782^{o}. The co-efficient of static friction on four types of structural material was found to be ranging from 0.30578 (acrylic sheet), 0.35606 (glass), 0.36396 (galvanised iron sheet) and 0.44522 (card board). The mean value of hardness recorded was 32.051 N.
Keywords: HMT 1001, physical properties, aerodynamic properties, frictional properties, mechanical properties.

INTRODUCTION

India is one of the largest producer of millets and stands first in the world total production (10000 (000 MT) in 2014 (USDA,2014)). The major millets grown are Pearl millet (*Pennisetum americanum)*, Finger millet (*Eleusine coracana)*, Foxtail Millet (*Setaria italic* L) and Proso Millet *(Panicum miliaceum).* And other common millets grown are kodo millet (*Paspalum scrobiculatum)*, little millet (*Panicum miliare*) and barnyard millet (*Echinochola frumentacea*). Foxtail millet (*Setaria italic* L- formerly *Panicum italicum L.*) also known as Italian millet is widely grown in china besides India and has a history of cultivation over the years in China. The foxtail millet is a staple food of South India and is called with different names such as Tenai (Tamil), Korra (Telugu), Navane (Kannada) and Kakum (Hindi). Foxtail millet is rich in nutrients; protein (12-19 %), fat (5-9 %), soluble fibre (3-4%), minerals (3.3%), iron (2.8%) and calcium (31%).

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

*Received Mar 16, 2016 * Published April 2, 2016 * www.ijset.net*

quality or studying the behavior 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 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).

In 2011, Periera et al. have determined the physical properties of foxtail millet at a moisture range of 12 to 30% (db). Tippeswamy, 2006 has determined some of the engineering properties of foxtail millet (SIA 2642 variety). 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 Foxtail millet – HMT 1001 variety at 11.67 ± 0.078 % (wb) moisture content.

MATERIALS AND METHODS

The engineering properties of foxtail millet variety HMT 1001 with an initial moisture content of 11.67 ± 0.078 % (wb). The foxtail millet was purchased directly from a farmer near Bengaluru, Karnataka for evaluating the properties. The grains initial moisture content was determined by hot air oven method, at 105^{o}C for 24 hours (AOAC, 1995).

The important engineering properties studied were: physical properties (size, geometric mean diameter, sphericity, true density, bulk density, porosity and weight of 100 grains), frictional properties (Angle of repose and coefficient of friction) and mechanical property (Hardness).

Physical Properties:

Size**:** The size was determined using vernier calipers having a least count of 0.02 mm. Measurements were length (mm), width (mm) and thickness (mm).

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

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

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):

$$\text{Sphericity, } \Phi = D_m / L$$

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

***True Density*:** 50ml 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).

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

***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):

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

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

$$\text{Porosity, \%} = 1 - \frac{\text{Bulk Density}}{\text{True Density}} \text{ X } 100$$

***Weight of 100 grains*:** One hundred grains were randomly selected and weighed using an electronic balance with an accuracy of 0.1 g (Ghadge and Prasad, 2012). Four replications were weighed and the mean weight of one hundred grains was calculated.

Frictional Properties:

***Co-efficient of friction*:** Coefficient of friction was determined against four material surfaces namely glass, acrylic, card board and galvanised iron sheet by inclined 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;

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

Mechanical Property

***Hardness*:** The hardness of the grain was measured using texture analyser (TA-HD Plus, double column. Make- Stable Microsystems). Experimental conditions followed were load

cell: 5 kg, test mode: measure force in compression, test option: return to start, pre test speed: 2 mm/sec, test speed: 0.1 mm/s, post test speed: 2 mm/sec, strain: 70% and test probe: P 2.

RESULTS AND DISCUSSION

The results of the physical properties are presented in Table 1. The mean of individual foxtail millet length, width and thickness were 2.169, 1.590 and 1.454 mm, respectively. The values of length, width and thickness of the grains varied from 2.12-2.22 mm, 1.20-1.76 mm and 1.06-1.78 mm. The average geometric mean diameter of HMT 1001 variety was 1.703 mm and it varied between 1.42 – 1.89 mm. The projected area of the particle is used for the measurement of the sphericity. The sphericity values observed were in the range of 0.659-0.881 and the mean sphericity value is 0.785. The average hundred-grain weight of foxtail millet was 0.245 g. The bulk density, true density and porosity were 737.127 $kg.m^{-3}$, 1260.132 $kg.m^{-3}$ and 41.471 %, respectively.

The results of frictional properties are shown in table 2. The mean value of angle of repose of millet was 26.782°. 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 glass, acrylic sheet, card board and galvanized iron sheet were 0.35606, 0.30578, 0.44522 and 0.36396 respectively. Card board had higher friction followed by galvanized iron sheet, glass and acrylic sheet. Similar observations were done by Tippeswamy (2006) for foxtail millet (Variety- SIA-2642) at 9% (wb) moisture content. The Hardness measured was ranging from 24.211 to 39.835 N. The mean hardness value was 32.051 N (Table 3).

CONCLUSION

The engineering properties of Foxtail millet (HMT 1001) was measured at 11.67 ± 0.078 % (w.b). The mean values obtained for length, width and thickness were 2.169, 1.590 and 1.454 mm, respectively. The average value for geometric mean diameter, sphericity, weight of hundred grains, bulk density, true density and porosity were 1.703 mm, 0.785, 0.245 g, 737.127 $kg.m^{-3}$, 1260.132 $kg.m^{-3}$ and 41.471 % respectively. The angle of repose mean value was 26.782 ^{o}. The co-efficient of static friction on four types of structural material was found to be ranging from 0.30578 (acrylic sheet), 0.35606 (glass), 0.36396 (galvanised iron sheet) and 0.44522 (card board). The mean value of hardness recorded was 32.051 N. These properties can be used for design of equipment for handling and processing of the foxtail millet.

REFERENCES

[1] AOAC, 1995, Official Methods of Analysis. Association of Official Analytical Chemists, Washington D.C.

[2] Balsubramanian, S. and Viswanathan, R., 2010, Influence of moisture content on physical properties of minor millets. *J. Food Sci technol*., **47**(3): 279-284.

[3] Konak, M., K. Çarman and C. Aydin, 2002. Postharvest technology: Physical properties of chick pea seeds. Biosys. Eng., 82(1): 73-78.

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

[5] Ojediran, J.O., Adamu, M.A. and Jim, D.L., 2010, Some physical properties of Pearl millet (*Pennisetum glaucum*) seeds as a function of moisture content. *Afr. J. Gen. Agric*., **6**(1).

[6] Periera, A.V. and Periera, M.C. 2011. Some physical properties and thin-layer drying parameters of foxtail millet (*Setaria italica* L.). Presented at ICEF 2011, Athens.

[7] Ramappa, K.T., Batagurki, S.B., Karegoudar, A.V. and Shanrnakumar, H., 2011, Study on physical properties of finger millet. *Inter J. Agric Engg.,* **4**(1):13-15.

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

[9] Singh, K.P., Mishra, H.N. and Saha, S., 2010, Moisture-dependent properties of barnyard millet grain and kernel. *J. Food Engg*., **96**: 598-606.

[10] Swami, S.S. and Swami, S.B. 2010. Physical properties of finger millet (*Eleusine coracana*) I*nternational Journal of Agricultural Engineering,* 3(1): 156-160

[11] Tippeswamy, S.N., 2006, Studies on processing technology and identification of suitable dehusking machine for foxtail millet. M. Tech. Thesis, UAS, Bangalore.

Table 1. Physical Properties of foxtail millet (HMT 1001)

Property	No. of Observation	Minimum Value	Maximum value	Mean Value	Std deviation	C.V
Length(mm)	50	2.12	2.22	2.169	0.0034	0.0158
Width (mm)	50	1.20	1.74	1.590	0.0189	0.1192
Thickness (mm)	50	1.06	1.78	1.454	0.0269	0.1848
Geometric mean diameter (mm)	10	1.42	1.89	1.703	0.0155	0.0907
Sphericity	10	0.659	0.881	0.785	0.0707	0.0899
True Density ($kg.m^{-3}$)	10	1204.82	1315.79	1260.132	30.9569	0.0246
Bulk density ($kg.m^{-3}$)	10	734.83	739.70	737.127	1.5051	0.0020
Porosity (%)	10	40.08	43.92	41.471	1.4968	0.0360
Weight of 100 grains (g)	10	0.216	0.292	0.245	0.0248	0.1011

Table 2. Frictional Properties of foxtail millet (HMT 1001)

Property	No. of Observation	Mean Value	Minimum Value	Maximum value	Std deviation	C.V
Angle of repose (degree)	10	26.782	25.8733	27.474	0.5543	0.0207
Static co-efficient of friction						
Glass	5	0.35606	0.3443	0.3639	0.0107	0.0302
Acrylic sheet	5	0.30578	0.2867	0.3249	0.0191	0.0625
Cardboard	5	0.44522	0.4348	0.4557	0.0074	0.0166
Galvanised Iron sheet	5	0.36396	0.3443	0.3838	0.0139	0.0384

Table 3. Mechanical Property of foxtail millet (HMT 1001)

Property	No. of Observation	Mean Value	Minimum Value	Maximum value	Std deviation	C.V
Hardness (N)	5	32.051	24.211	39.835	6.0084	0.1875