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Engineering properties of finger millet (*Eleusine coracana* L.) grains

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ABSTRACT : Some physical properties of finger millet (*Eleusine coracana*) grains were determined at the moisture content of 14.16 per cent (d.b.). The size, sphericity, surface area, mass of 1000 grains, volume of 1000 grains, true density, bulk density and porosity were 1.13 mm, 0.98, 4.15 mm^2, 2.87 g, 2171 mm^3, 1293 kg m^3, 803 kg/m^3 and 37.79 per cent, respectively. The frictional properties of the finger millet grains *viz.*, angle of repose, coefficient of internal friction and coefficient of external friction were also determined and the values were 29.09^o, 0.63 and 0.48, respectively. The terminal velocity of the grains was 2.94 ms^{-1}.

KEY WORDS : Finger millet, Friction, Porosity, Terminal, Velocity

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Finger millet (*Eleusine coracana* L.) is also known as African millet, Koracan, Ragi (in India), Bulo (Uganda), Wimbi (Swahili) and Telebun (Sudan). It is an important cereal crop for subsistence agriculture in the dry areas of Eastern Africa, India and Srilanka. India is one among the major cereal producing countries in the world. The finger millet production is 4.5 million tonnes in the world. In India, it is cultivated over an area of 2.65 million ha with total production of about 2.9 million tonnes. It is widely grown in Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Bihar, Gujarat and Maharashtra and in the hilly regions of Uttar Pradesh, Sikkim and Himachal Pradesh.

Finger millet has outstanding properties as subsistence food crop. Its small seeds can be stored safely for many years without insect damage. Finger millet especially valuables as it contains essential amino acid methionine which lacking in the diets of hundreds of millions of the poor who live on starchy staples such as cassava plantain, polished rice or maize as a meal. The presence of all the required nutrients in millet make them suitable for large scale utilization in the manufacture of baby food, snack foods, dietary food etc. from grain, kernel and flour (Subramanium and Viswanathan, 2007).

Physical and engineering properties are important in many problems associated with the design of machines and the analysis of the behaviour of the product during agricultural process operations such as handling, planting, harvesting, threshing, cleaning, sorting and drying. Solutions to problems in these processes involve knowledge of their physical and engineering properties (Irtawange, 2000).

Bulk density, true density, and porosity (the ratio of inter granular space to the total space occupied by the grain) can be useful in sizing grain hoppers and storage facilities; they can affect the rate of heat and mass transfer of moisture during aeration and drying processes. Grain bed with low porosity will have greater resistance to water vapour escape during the drying process, which may lead to higher power to drive the aeration fans. Cereal grain kernel densities have been of interest in breakage susceptibility and hardness studies (Ghasemi *et al*., 2008). Flow ability of agricultural grains is usually measured using the angle of repose. This is a measure of the internal friction between grains and can be useful in hopper design, since the hopper wall's inclination angle should be greater than the angle of repose to ensure the continuous flow of the materials by gravity. The static coefficient of friction is used to determine the angle at which chutes must be positioned in order to achieve consistent flow of materials through the chute. Such information is useful in sizing motor requirements for grain transportation and handling (Ghasemi *et al*., 2008). Many researchers have been determined the properties of different agricultural produces like millet (Baryeh, 2002; Subramanium and Viswanathan, 2007), moth gram (Nimkar *et al.*, 2005), sesame seed (Akintunde and Akintunde, 2004), sunflower seed (Gupta *et al.*, 2007), Baryeh (2002) studied about the properties of pearl millet, Subramanium and

Viswanathan (2007) studied some physical properties like bulk density and friction coefficient of barnyard millet grain. However, they did not consider aerodynamic and gravimetric properties of finger millet. Hence, the present work is focused on the aerodynamic property, gravimetric properties of the finger millet.

METHODOLOGY

The local variety of finger millet grains used in this study was obtained from a local market in Raichur city of Karnataka. The grains were cleaned manually to remove all foreign matter like dust, dirt stone etc., before conducting the experiments.

The moisture content of the samples was determined by oven drying at 130 ± 1^{0}C for 2 h (AOAC, 2010).

$$MC\,(d.b.) = \frac{m_i - m_d}{m_d} \times 100$$

where, MC (d.b.) = Moisture content, %

M_i = Initial mass of the grains, g

M_d =Final mass of the grains, g

The size (length, width and thickness) of randomly selected 100 grain was measured using a digital micrometer (Make: Mitutoyo) to an accuracy of 0.001mm.

The mass of thousand grains (unit mass) was determined by using a digital electronic balance (Make: Essay) having an accuracy of 0.001 g.

To evaluate the thousand grain mass, the 1000 grains were randomly selected, weighed and the value of the samples was averaged. The measurements were replicated 100 times.

The sphericity of the finger millet grains was determined by the following equation (Mohensin, 1970)

$$S = \frac{(LWT)^{1/3}}{L}$$

The surface area (A) was calculated using the formula (McCabe *et al.,* 1986).

A = ®D²

where, D=grain diameter

The true density (ρ_T) of the grains is defined as the ratio of the mass of the sample of the grains to the solid volume occupied by the sample (Deshpande *et al.,* 1993).

The volume (V) of finger millet grain and true density were determined using water displacement method (Mohensin, 1970).

$$\rho_T = \frac{M}{V}$$

where, ρ_T=True density (kg/m^3)

M = Mass of the sample

V = Volume occupied by the sample

The bulk density r_B is the ratio of the weight of the sample to its total volume of the sample. The bulk density includes void space present in the sample (Mohensin, 1970).

The porosity ρ of bulk grains was calculated from bulk and true densities using the relationship given by Mohensin (1970) as follows

$$\varepsilon = \left\{ \frac{(\rho_T - \rho_E)}{T} \right\} x\,100$$

where ε = Porosity, %

ρ_T=True density (kg/m^3)

ρ_B=Bulk density (kg/m^3)

Frictional properties:

Angle of repose:

When a granular material is allowed to flow freely from a point into a pile, the angle which the side of the pile makes with horizontal plane is called angle of repose (Kachru, 1994).

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.

The angle of repose, coefficient of internal friction and the coefficient of internal friction were determined using the formula given by the Kachru (1994).

Co-efficient of internal friction («) :

Friction between the grain mass of kernels against each other.

$$\mu = \frac{W_2 - W_1}{W}$$

where,

m = Coefficient of internal friction,

W_1 = Weight to cause sliding of empty smaller box,

W_2 = Weight to cause sliding of filled smaller box, and

W = Weight of the material inside the smaller box.

Co-efficient of external friction :

The sliding stress between the grain and the horizontal plane against the wall.

$$\mu_1 = \frac{W_2 - W_1}{W}$$

where,

m = Co-efficient of internal friction,

W_1 = Weight to cause sliding of empty smaller box,

W_2 = Weight to cause sliding of filled smaller box, and

W = Weight of the material inside the smaller box.

Aerodynamic property:

Terminal velocity:

The terminal velocity of ragi samples were measured by using an air column (Tabak and Wolf, 1998). The ragi samples were randomly selected and tested. For each experiment the selected ragi samples were dropped from the top of a 75-mm diameter, 1m long plexiglass tube. The air was blown upwards in the tube while its velocity was adjusted by using an inverter–type motor speed control until the major fraction of the sample remained suspended in the air stream. Air velocity was measured by using a anemometer (Make: Windmesser, Germany) and reported as terminal velocity. Ten replications were taken for determination of the terminal velocity of the ragi sample.

RESULTS AND DISCUSSION

The physical and frictional properties of the millets have the significant role in the design of handling and processing equipment. The relationship between the angle of repose and the flow characteristics is presented in Table1. The results of the some of the physical and frictional properties of the finger millet grains were studied and tabulated in Table 2 and 3. The mean values of moisture content, size, sphericity, surface area, volume of 1000 grains, true density, bulk density, porosity and mass of 1000 grains were found to be 14.16 per cent, 1.13 mm, 0.98, 4.15 mm^2, 2171 mm^3, 1293 kg/m^3, 803 kg/m^3, 37.79 per cent and 2.87 g, respectively. These findings of the grains make a distinct role for the suitable design and development of crop-processing machines such as sorting, grading, grinding, drying and extraction equipments (Mahbobeh *et al.*, 2011).

The frictional properties helps in the designing of storage structures like bins, godowns etc. The mean values of frictional properties of the millets like angle of repose, coefficient of internal friction and coefficient of external friction were calculated and found to be 29.09^o, 0.63 and 0.48, respectively. The frictional properties such as the angle of repose and the coefficient of external friction are recognized by engineers as important properties concerned with rational design of seed bins and other storage structures including the compressibility and flow behaviour of materials (Mirzaee *et al.*, 2009; Gharibzahedi *et al.*, 2010).

The average terminal velocity of finger millet required for suspending the grains was 2.94 ms^{-1}. This result is in accordance with Singh *et al.* (2010) for barnyard millet. This data of terminal velocity can be used in designing an aspiration unit.

The millets are gaining the tremendous demand in the production of value added products. Hence, the technical data obtained in this study may be useful in the design of machines for handling and processing of finger millet grains (Mahbobeh *et al.*, 2011).

Table 1 : Flow characteristics with respect to angle of repose

Flow characteristics	Angle of repose, degree
Very free-flowing	25-30
Free-flowing	30-38
Fair flowing	38-45
Cohesive or non-easy flowing	45-55
Very cohesive	Beyond 55

Source: Sahay and Singh, 2004

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Table 2 : Some physical properties of finger millet grains

Physical properties	Unit of measurement	No. of observation	Mean value	Minimum value	Maximum value	S.D
Moisture content	%	10	14.16	14.03	14.29	0.09
Size	mm	25	1.13	0.68	1.45	0.30
Spericity	%	25	0.98	0.94	0.99	0.01
Surface area	mm^2	25	4.15	1.45	6.60	1.51
Volume of 1000 grains	mm^3	10	2171	1703	2539	251.81
True density	kg/m^3	10	1293	1250	1360	39.16
Bulk density	kg/m^3	10	803	790	824	10.79
Porosity	%	10	37.79	34.08	41.32	2.37
Mass of 1000 grains (Unit mass)	g	25	2.87	2.58	3.20	0.22

Table 3 : Frictional properties

Property	Unit of measurement	No. of observation	Mean	Minimum value	Maximum value	S. D
Angle of repose	Degree	10	29.09	28.07	30.26	0.70
Coefficient of internal friction	-	10	0.63	0.58	0.68	0.00
Coefficient of external friction	-	10	0.48	0.44	0.50	0.03
Aerodynamic property						
Terminal velocity	ms^{-1}	10	2.94	2.2	3.7	3.15

Engineering, for providing the laboratory facilities for this work.

Notification:

A=Surface area of the grain, mm^2

D= Diameter of the grain, mm

L=Length of the grain, mm

T=Thickness of the grain, mm

MC= Moisture content (db), %

P=Porosity, %

m_i=Initial mass of the grains, g

m_d=Final mass of the grain, g

T=Thickness of the grain, mm

ϕ=Angle that incline makes with the horizontal when sliding begins

ρ_B= Bulk density, kg/m^3

ρ_T=True density, kg/m^3

μ=Co-efficient of internal friction

μ'=Co-efficient of external friction

S=Sphericity, %

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REFERENCES

Akintunde, T.Y.T. and Akintunde, B.O. (2004). Some physical properties of sesame seed. *Biosystems Engg.,* **8** (1) : 127–129.

AOAC (2010). ln: *Official methods of analysis*, the association of official analytical chemists (17th ed.) (ed.W. Horwitz). AOAC International, Maryland, USA.

Baryeh, E.A. (2002). Physical properties of millet. *J. Food Engg.*,**51**: 39– 46.

Deshpande, S.D., Bal, S. and Ojha, T.P. (1993). Physical properties of soybean seeds. *J. Agric. Engg. Res.*, **56**: 89–92.

Ghasemi, V.M., Obli, H.M., Jafari, A. Keyhani, A.R. Heidari, S.M., Rafiee, S. and Kheiralipour, K. (2008). Some physical properties of rough rice (*Oryza sativa*) grain. *J. Cereal Sci.*, 4**7**: 496-501.

Gharibzahedi, S.M.T., Mousavi, S.M., Moayedi, A., Taheri Garavand, A. and Alizadeh, S.M. (2010). Moisture-dependent engineering properties of black cumin (*Nigella sativa* L.) seed. *Agric Eng Int: CIGR J.*, **12** (1): 194-202.

Gupta, R.K., Arora, G. and Sharma, R. (2007). Aerodynamic properties of sunflower seed (*Helianthus annuus* L.). *J. Food Engg*., **79**:899–904.

Irtawange, S.V. (2000). The effect of accession on some physical and engineering properties of African yam bean. Ph.D. Thesis, Department of Agricultural Engineering, University of Ibadan., Nigeria.

Kachru, R.P., Gupta, R.K. and Anwar, A. (1994). Physico-Chemical Constituents and Engineering Properties of Food Crops (1st ed.) pp. 89-90.

Mahbobeh, F., Vahid, E., Seyed, M., Taghi, G. and Mohammad, G. (2011). Physical, mechanical and aerodynamic properties of Acorn (*Quercus suber* L.) as potentials for development of processing machines. *Australian J. Crop Sci.,* **5**(4) : 473:478.

Mirzaee, E., Rafiee, S., Keyhani, A. and Emam Djom-eh, Z. (2009). Physical properties of apricot to characterize best post harvesting options. *Aust. J. Crop Sci.,* **3**(2): 95-100.

Mohsenin, N.N. (1970). Physical Properties of Plant and Animal Materials. *Gordon and Breach Science Publishers,* New York, USA, Vol. 1.

Nimkar, P.M., Mandwe, D.S. and Dudhe, R.M. (2005). Physical properties of moth gram. *Biosystems Engg.,* **91** (2), 183–189.

Sahay, K.M. and Singh, K.K. (2004). Unit Operations of Agricultural Processing, pp.180–181.

Singh, K.P., Mishra, H.N. and Supradip, S. (2010). *J. Food Engg*., **96**:598–606.

Subramanium, S. and Viswanathan, R. (2007). Bulk density and friction coefficient of selected minor millet grain and flour. *J. Food Engg.,* **81**:18–126.

Tabak, S. and Wolf, D. (1998). Aerodynamic properties of cottonseeds. *J. Agric. Engg Res.,* **70** : 257-265.

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