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Research Paper :

Physical properties of finger millet (*Eleusine coracana*)

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ABSTRACT

Physical and mechanical properties of finger millet (*Eleusine coracana*) are necessary for the design of equipment to handle, transport, process and store the crop. The physical properties have been evaluated as a function of grain moisture content varying from 13 to 48% (db). In this moisture range, true density increased from 1120 to 1130 kg/m^3; the bulk density increased from 709 to 775 kg/m^3. The porosity of the finger millet grain was found to increase from 13.00 to 41.72%. The geometric mean diameter increased linearly 1.608 to 1.822 mm. The sphericity of the finger millet grains were in the range of 0.960 to 0.987 for the grain moisture content varying from 13 to 48% (db). The surface area and the surface volume were in the range of 9.00 to 10.2 mm^2 and the surface volume was 2.8 to 3.2 mm^2 and found to increase with the increase in moisture content of the grains.

Key words : Physical properties, True density, Angle of repose, Finger millet (*Eleusine coracana*)

Finger millet (*Eleusine coracana*) also known as *ragi*, *nachani* or *nagli*, is one of the important millets in India. Finger millet is extensively grown on hilly areas and southern part of India and is widely consumed in the form of dumping by vast section of people (Vidyavati *et al.,* 2004). Finger millet is a rich source of Ca (300-350 mg%), phosphorus (283 mg%) and Fe 3.9% (Gopalan *et al*., 2000). It has a well-balanced amino-acid profile and is a good source of methionine, cystine and lysine. These essential amino acids are of special benefit to those who depend on plant food for their protein nourishment (that is most of Indian people). It also contains about 72% carbohydrates, a high proportion of which is in the form of non-starchy polysaccharides and dietary fibre, which helps in constipation, and lowering of glucose in blood. It is a rich source of vitamins *viz.,* thiamine, riboflavin, folic acid and niacin (Vidyavati *et al.,* 2004).

Finger millet serves as a staple food for the large number of people in Konkan region, who consume it in the form of unleavened bread and soup locally called as the *ambil* and *Papad*. Among the urban areas there is a problem of malnutrition such as obesity, heart diseases and diabetes mellitus are ever increasing for which *ragi* can be better suited staple cereal grain than any of the refined cereals such as rice or wheat (Vaidehi, 1980). *Ragi* is nutritionally comparable to rice or wheat and also very useful for preparation of low cost diet and ready to eat nutritious food product like *ragi malt puff*, *dumping*, *bhakri*, *ragi*, *halwa*, bread biscuits and cookies. Hence, finger millet offers many opportunities for utilization in diversified products due to its abundant production, cost effectiveness and better nutritional qualities.

The grain is variable in shape, size and colour. It may be elliptical, oblanceolate, hexagonal or globular in shape and grayesh white or red in colour. The physical properties of finger millets like those of other grains and seeds, are essential for the design of equipment for handling, harvesting, processing and storing the grain. They affect the conveying characteristics of solid materials by air or water and cooling and heating loads of food materials (Sahay and Singh, 1994). It is therefore necessary to determine these properties. The properties of different types of grains have been determined by other researchers (Shepherd and Bhardwaj, 1986; Dutta *et al*., 1988; Joshi *et al*., 1993; Singh and Goswami, 1996; Deshpande and Ojha, 1993; Suthar and Das, 1996; Oloso and Clarke, 1993; Hsu *et al.*, 1991; Carman, 1996; Aviara *et al.*, 1999; Chandrasekar and Viswanathan, 1999; Ogut, 1998; Visvanathan *et al.*, 1996). Jain and Bal (1997) have studied some physical properties and oil content of P.typhoides variety of pearl millet. Till date no literature is found on physical properties of finger millet.

Theoretical considerations:

According to Mohsenin (1970), the degree of sphericity, ϕ can be expressed as follows:

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

where L is the grain length, W the grain width and T is the grain thickness.

$$D_g = (LWT)^{1/3} \quad (2)$$

$$\varphi = \frac{D_g}{L}, \quad (3)$$

The geometric mean diameter, D_g is given by (Sreenarayanan *et al.*, 1985; Sharma *et al.*, 1985); Jain and Bal (1997) have also stated that the sphericity, f seed volume, V and grain surface area, S may be given by:

$$\varphi = \left[\frac{B(2L-B)}{L^2}\right]^{1/3}, \quad (4)$$

$$V = \frac{\pi B^2 L^2}{6(2L-B)}, \quad (5)$$

$$S = \frac{\pi B L^2}{2L-B}, \quad (6)$$

where $B = (WT)^{0.5}$

The surface area, S was also found by McCabe *et al.* (1986) to be given by;

$$S = \pi D_g^{\ 2} \quad (7)$$

According to Mohsenin (1970) and Thompson and Isaacs(1967), the porosity, e is given by:

$$\varepsilon = \frac{[(\rho_g - \rho_b)100]}{\rho_g}, \quad (8)$$

where, ρ_b is the bulk density and r_g is the true or grain density

METHODOLOGY

The finger millet grain moisture range investigated was 13- 48 % (db) since harvesting, transportation, storage and most of the handling and processing operations of the crop are performed in this moisture range. For determination of various engineering properties, the finger millet variety used was Dapoli-1. It was brought from research farm of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth. Dapoli when the average moisture content of the finger millet grain was 13.65 (% d.b.). The grains were soaked with rain water for 1 h and put into polythene bags. The bags were put in a humid chamber to enable the moisture to distribute uniformly throughout the grains and reduce the grain moisture loss negligibly. Polythene bags were selected randomly from the bags, and dried down to the desired moisture content by the vacuum oven method (Joshi et al., 1993; Singh and Goswami, 1996; Suthar and Das, 1996) before the test were conducted on them.

50 grains were selected at random from the chamber, dried down to the desired moisture content, and the length, width and thickness were measured in three mutually perpendicular directions using a micrometer gauge reading to 0.001mm. Several investigators (Sheperd and Bhardwaj, 1986; Dutta *et al.*, 1988; Joshi *et al.*, 1993; Mohsenin, 1970; Singh and Goswami, 1996; Deshpande and Ojha, 1993) have measured these dimensions for other grains and seeds in a similar manner to determine size and shape properties. The sphericity was calculated using Eqs.(1) and (4), the volume using Eq.(5) and surface area using Eqs.(6) and (7). Grain mass was measured with a sensitive electronic bslance of 0.001g sensitivity.

After the determinations of the dimensions, all the measurements, which followed, were replicated five times at the moisture content considered and the averages were calculated. The grain or true density was determined using the tolune displacement (Singh and Goswami, 1996). The bulk density was determined with a weight per hectoliter tester which was calibrated in kg per hectoliter (Deshpande and Ojha, 1993, Sharma et al., 1985; Suthar and Das, 1996; Jain and Bal, 1997). This may also be done using air comparison pycnometer (Thompson and Isaacs, 1967). The porosity was then calculated using Eq.(8).

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been summarized under following heads:

True density and bulk density:

The true density increases linearly from 1120 to 1130 kg/m^3 as grain moisture content increases from 13 to 47.93(%db). The relationship may be expressed as (eq.(9)):

$$\rho_g = 1.7851X + 699.25 \qquad R^2 = 0.81 \quad (9)$$

where,
ρ_g = True density (kg/m^3)
X= moisture content (% d.b.)

Fig.1 shows the effect of grain moisture content (db) on bulk density (ρ_g, kg/m^3) and true density (ρ_g, kg/m^3)

This increase indicates that there is a higher grain mass increase in comparison to its volume increase as its moisture content increases. These results are agreement with findings of Singh and Goswami (1996) for cumin seeds for sunflower seeds, Aviara *et al.* (1999) for guna seeds and Chandrasekar and Viswanathan (1999) for coffee.

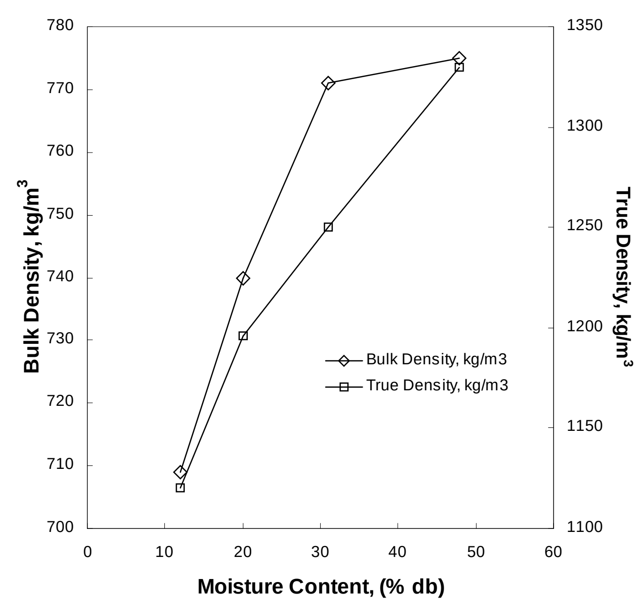

Fig. 1 : Effect of Bulk and true density variation with finger millet grain moisture content

The bulk density increased linearly from 709 to 775 kg/m^3 as grain moisture content increased from 13 to 47.93 (% d.b.). Fig. 1 shows the effect of moisture content on the bulk density of finger millet grains. Eq.(10) represent the relationship between the bulk density (kg/m^3) and the moisture content (%db).

$$\rho_b = 5.6187X + 1068.2 \qquad R^2 = 0.97 \qquad (10)$$

where,
ρ_g = Bulk density, (kg/m^3)
X= moisture content (% db)

The same results were obtained by Suthar and Das (1996), Chandrasekar and Viswanathan (1999) and Hsu *et al.* (1991) of Karigda seeds, coffee and Pistachios, respectively.

Porosity (Č):

The Fig. 2 shows the porosity, ∈ variation with increase in grain moisture content.

The porosity started at 36.62% at 13 % M.C. (% db) and increased gradually to 41.72 % at 47.93 grain moisture content (% db). The relationship may be

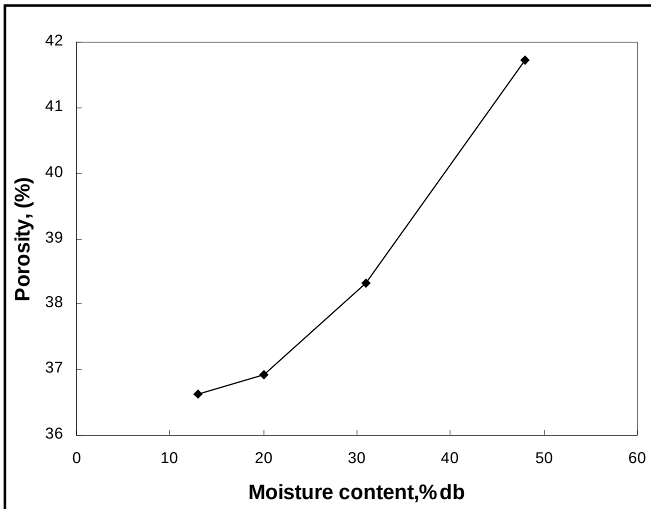

Fig. 2 : Effect of porosity variation with finger millet grain moisture content

expressed as Eq.(11):

$$\in = 0.775X^2 - 2.205X + 38.095 \quad R^2 = 0.99 \qquad (11)$$

where,
∈ = Porosity (%)
X= moisture content (% d.b.)

Ogut (1998), Carman (1996) and Singh and Goswami (1996) found that porosity of sunflower seeds, white lupin, lentil seeds and cumin seeds, respectively increased with increase in moisture content.

Geometric mean diameter (D_g):

Fig.3 shows the effect of moisture content on the geometric mean diameter of finger millet grains.The geometric mean diameter varied from 1.608 to 1.822 mm. The geometric mean diameter, (Dg) increased linearly with respect to increase in moisture content (% db) from 13 to 48 (% db).

The relationship between geometric mean diameter and grain moisture content may be represented mathematically as follows (Eq.12):

$$D_g = 0.067X + 1.5455 \qquad R^2 = 0.96 \qquad (12)$$

where,
D_g =Geometric mean diameter
X= Moisture content (% d.b.)

This indicates that with the increase in moisture content from 13-48%, the grains expanded in length, width, thickness and geometric mean diameter. Similar results were observed for millets grain by Baryeh (2002).

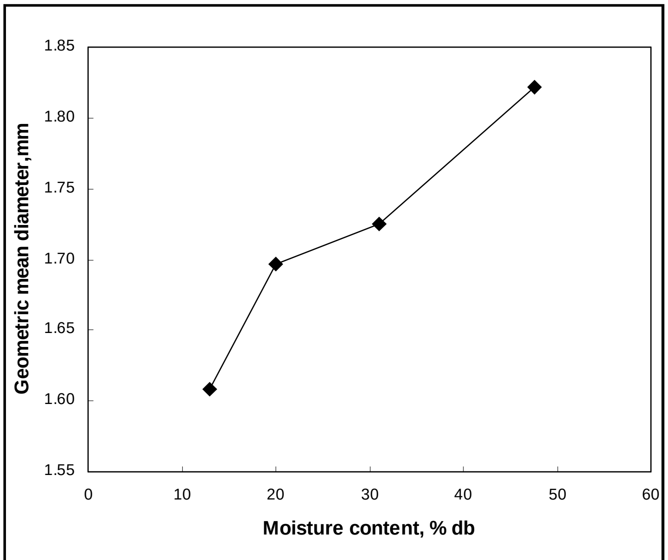

Fig. 3 : Geometric mean diameter variation with increase in finger millet grain moisture content

Sphericity(¤):

Fig.4 shows the effect of moisture content on the sphericity of finger millet grains.

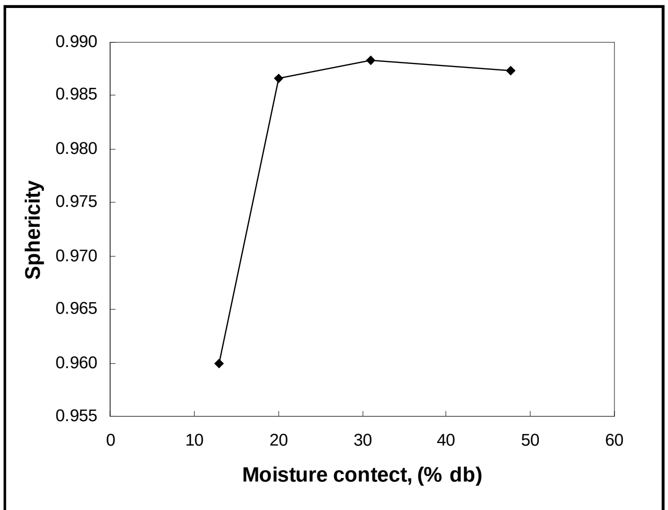

Fig. 4 : Effect of moisture content on sphericity of finger millet grains

The sphericity, (ϕ) increased sharply from 0.960-0.985 in a moisture range of 13-20%. Then it increased gradually and linearly(0.987). The relationship may be given as follows (Eq.13):

$$\varphi = 0.0069X^2 + 0.042X + 0.925 \quad R^2=0.95 \quad (13)$$

where,

ϕ =Sphericity

X= Moisture content (% d.b.)

Deshpande and Ojha (1993) reported that the sphericity of soybean increased linearly with the moisture content upto 25%. Jain and Bal (1997) found the sphericity of different varieties of pearl millet to be 0.94 at 7.4 % grain moisture content.

Surface area (S) and surface volume (V):

The variation of surface area, S (mm^2) and volume, V (mm^3) with increase in grain moisture content of finger millet is shown in Fig. 5.

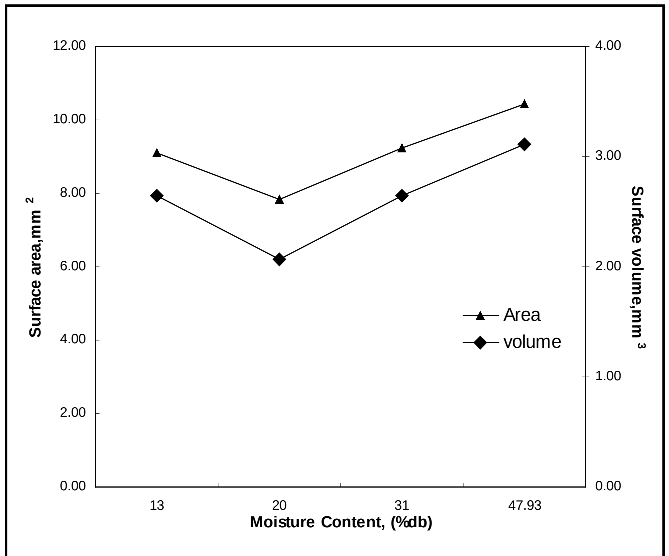

Fig. 5 : Effect of moisture content (% db) on surface area (S), mm^2 and surface volume (V), mm^3 of finger millet grain

The surface area varied from 9.00 to 10.2 mm^2 and surface volume varied from 2.8 to 3.2 mm^3. The surface area and volume decreased up to 20% moisture content and increased thereafter linearly. The relationship may be given as follows Eq (14 and 15), respectively:

$$S = 0.6155X^2 - 2.5395X + 3.438 \quad R^2=0.879 \quad (14)$$

$$V = 0.2637X^2 - 1.120X + 3.438 \quad R^2=0.854 \quad (15)$$

where,

X= Moisture content (%db)

These results are in agreement with Baryeh (2002).

Conclusion:

– All linear dimensions of finger millet grain, grain surface area, grain volume, true density, bulk density increase with increased in grain moisture content.

– Linear dimension ratios were very different and were highly correlated.

– Sphericity increased sharply with grain moisture content 0.960 to 0.985 and then increased gradually up to 0.987.

– True density was higher than bulk density at all grain moisture content studies.

– Porosity increased with increase in grain moisture content.

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