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Effect of Moisture Content on Engineering Properties of Finger Millet Grain

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Abstract

The study of physical, aerodynamic and mechanical properties of food grains are important and essential in the design of processing machines, storage structures and processes. The shape and size are important in the separation from foreign material and in the design and development of grading and sorting machineries. Study on engineering properties of local variety of finger millet was conducted as a function of moisture content varying from 10 to 20 % (wb) to generate information as an aid for design, development and modification of handling, processing equipments/ machine and storage system. In this moisture range, length of finger millet grain increased by 48.44 %, width was increased by 51.33 % and thickness was increased by 62.50 %. The thousand seed mass, surface area and angle of repose also increased with increasing moisture levels. True density increased from 1100 to 1233 kg/m3, the bulk density decreased from 730.80 to 701.03 kg/m^3. The porosity of the finger millet grain was found to increase from 33.56 to 43.14 %. Regression equations that could be used to adequately express the relationship existing between the above properties and seed moisture were established.

Keywords: Finger millet, Engineering properties, Moisture Content

Introduction

The millets are a group of small-seeded species of cereal crops or grains belonging to the family Gramineae and widely grown around the world for food and fodder. The most widely cultivated species in order of worldwide production are Pearl millet (*Pennisetum glaucum*), Foxtail millet (*Steria italica*), Proso millet (*Panicum miliaceum*) and Finger millet (*Eleusine coracana*). The most important characteristic of millet is their unique ability to tolerate and survive under adverse condition of continuous or intermittent drought as compared to most other cereals like maize and sorghum. Finger millet (*Eleusine coracana* L.) is also known as African millet, Koracan, Ragi (in India), Bulo (Uganda), Wimbi (Swahili) and Telebun (Sudan). India is one among the major cereal producing countries in the world. World finger millet production is 4.5 million tonnes of which about 2.5 million tonnes is produced by Africa. In India, it is cultivated in Tamil Nadu, Andhra Pradesh, Orissa, Bihar, Gujarat, Maharashtra and in the hilly regions of Utter Pradesh and

Himachal Pradesh. Finger millet is the third most important millet in India next to sorghum and pearl millet. Finger millet cultivation occupies a total area of 2.5 million hectares with a production of 2.2 million tonnes (Apoorva *et. al.,* 2010).

Finger millet is one of the most important cereal crops of Konkan region. The plant is productive and thrives in a variety of environments and condition. It has 7.4 % protein and has well balanced amino acid profile. It is good source of methionine, cystine and lysine. For this reason alone, finger millet is an important preventative against malnutrition. It also contains about 72 % carbohydrates, high proportion of which in the form of non starchy polysaccharides and dietary fibre, which helps in constipation and lowering blood glucose in blood. It is also good source of micronutrients viz. calcium, Iron, Phosphorus, Zinc, Potassium, vitamin A and vitamin B; hence it is a good source of diet for growing children, excepting woman's old age people and patients. The calcium content of finger millet is highest among all cereal grains and iodine content is also said to be highest among all the food grains, which makes it easily and slowly digestible and helps to control blood glucose levels in diabetic patients effectively (Malleshi *et. al*., 1996).

There is a growing interest in the crop because of the technological possibilities of its utilization in such industrial applications as starch production. Therefore, consequent on the large scale production and commercial of the crop is the need to study the physical and mechanical attributes of this crop, which are important in design of equipment for handling, cleaning, storing and processing (Ojediran *et. al*., 2010). To date some physical properties of millet seeds have been evaluated by Jain and Bal, 1997; Baryeh, 2002; Chukwu and Ajisegiri, 2005; Ajav and Ojediran, 2006, Subramanium and Viswanathan, 2007; Swami and Swami, 2010. Till date less literature is found on physical properties of finger millet, the present study therefore aimed at contributing to the knowledge of finger millet seeds to improve the post harvest handling and storage operations and equipment through investigation of some moisture dependent engineering properties such as axial dimensions, sphericity, surface area, bulk density, true density and porosity, terminal velocity and angle of repose.

Materials and methods

Sample Preparation

The finger millet grains used in the study were obtained from local market. The seeds were cleaned to remove any foreign material such as stones; dirt, dust, chaff etc. then divided into lots and thereafter conditioned to obtain six different levels of moisture content ranging from 10 % to 20 % w.b. by adding pre-determined quantities of distilled water and thoroughly mixing. These represent the storage and processing moisture content range. The prepared samples were sealed in hermetic polyethylene bags and stored at 5 ^{0}C in a refrigerator for week to enable the moisture to be distributed uniformly throughout the sample (Nimkar and Chattopadhyay, 2001 and Garnayak *et. al.,* 2008). Before starting a test, the required quantities of samples were taken out of the refrigerator and allowed to warm to the room temperature for about 2 h (Tavakoli *et. al.,* 2009).

The moisture content was determined using the ASAE standard method (ASAE, 1993) by drying the unground millet samples in an air ventilated oven at 105 ^{0}C for 12-14 h. All physical properties were assessed at all six selected moisture content range. Three replications of each test were carried out at each moisture level.

The mean geometrical diameter (D_p) or size of the grain were assessed by measuring their three linear dimensions namely length L, width W and thickness T of 100 randomly selected grains from each set of moisture content, using vernier caliper with least count 0.001 mm. D_p of grain was calculated using the following equations (Mohsenin, 1970)

$$D_p = [LWT]^{1/3} \quad (1)$$

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

$$\phi = \frac{(LWT)^{1/3}}{L} \quad (2)$$

This equation was used to calculate the sphericity of the finger millet grains in present investigation.

The surface area 'S' of the finger millet grain was assessed by analogy with a sphere of same D_p, using Eq. (3) (McCabe *et. al.,* 1986; Dursun and Dursun, 2005; Baryeh, 2002; Al- Mahasneh and Rababah, 2007; Deshpande et al., 1993; Sessiz *et. al.,* 2007).

$$S = \pi (D_p)^2 \quad (3)$$

Thousand seed mass (M_{1000}) was determined using an electronic balance with least count 0.001 g.

The true density of a finger millet grains is defined as the ratio of the mass of a sample of finger millet grains to the solid volume occupied by the sample (Deshpande *et. al.,* 1993). The finger millet volume and its true density at each moisture level were determined using the toluene displacement method. Toluene (C_7H_8) was used instead of water because it is absorbed by finger millet to a lesser extent. Also, its surface tension is low, so that it falls even shallow dips in a finger millet and its distribution power is low. The bulk density was determined with a weight per hectoliter tester which was calibrated in kg per hectoliter (Deshpande *et. al.,* 1993). The finger millet grains at each moisture level were poured in the calibrated cylinder up to its brim from a height of about 15 cm and excess finger millet grains were removed by strike off sticks. The finger millet grains were not compacted in any way (Singh and Goswami, 1996) and then the weight (W) of 1000 ml grains of all samples were recorded.. The bulk density was assessed using Eq. (4)

$$T_b = \frac{W}{1000} \times 10^6 \quad (4)$$

The porosity P of bulk finger millet grains were computed from the values of true density and bulk density using the relationship given by Mohsenin (1970) as follows:

$$P = (1 - \frac{T_b}{T_s}) \times 100 \quad (5)$$

The shape of the finger millet grains is not spherical so the terminal velocities of these grains were measured experimentally instead of using mathematical relationship. Air column experimental device was used to measure the terminal velocity of millet grain (Gupta *et. al.,* 2007; Zewdu, 2007; Sacilik *et. al.,* 2003). A transparent plastic made hollow cylindrical air column was used for this purpose. For each test run sample of 100 g was fed into the hopper. The vibrator in the feeder dropped the materials into air stream from the top of the vertical column. The airflow rate was gradually increased to suspend the material in the air stream for 30s. The air velocity was measured using vane anemometer.

The dynamic angle of repose was the measured angle between the horizontal and the natural slope of the seeds heap. The height of the heap was measured and the dynamic angle of repose was calculated by the following relationship:

$$\theta = \tan^{-1} (\frac{2H}{D_p}) \quad (6)$$

Where, θ = Dynamic angle of repose, degree.

H = Heap height, cm and

D_p = Platform diameter, cm.

The dynamic angle of repose each level of moisture content of finger millet was including ten replicates.

Results and discussion

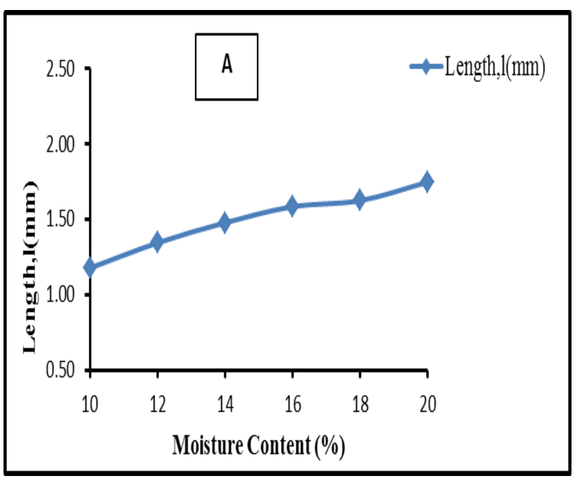
Grain dimensions

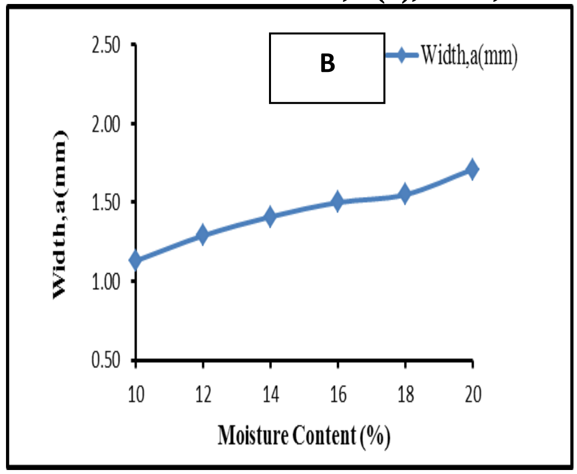
Dimensions of millet grains increased with the increase in moisture content. The grain expands in length, width and thickness. The relationship between the axial dimensions and grain moisture content is shown in Fig.1. Within the range of analyzed moistures and finger millet grain increased their length by 48.44 % (1.18 - 1.75 mm). Similarly, their width was increased by 51.33 % (1.13 – 1.71 mm) and their thickness was increased by 62.50 % (0.96-1.56 mm). The relationships existing between axial dimensions and moisture content for finger millet were found to be polynomial of the second order and can be expressed as:

$l = 0.002x^2 + 0.133x + 0.116,$
$R^2 = 0.989$ ………….(7)

$a = 0.001x^2 + 0.091x + 0.357,$
$R^2 = 0.982$ …………..(8)

$b = 0.001x^2 + 0.112x - 0.001,$
$R^2 = 0.964$ …………..(9)





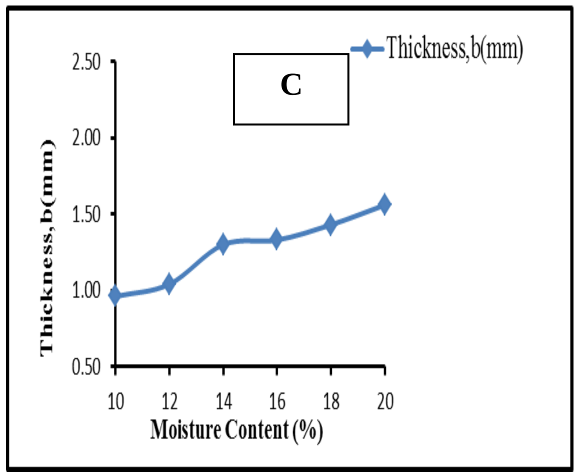


Figure 1: Effect of moisture content on finger millet grain dimensions A: length, B: width and C: thickness.

Geometric mean diameter

The variation of mean geometrical diameter of the grain upon exposure of moisture is shown in fig. 2. It is evident from the figure that mean diameter of grain increases with increase of moisture content followed second order polynomial equation shown in Eq. (3.4). The increase in moisture content from 10 to 20 %, 53.60 % increase in mean diameter was observed for grain.

$y = -0.001x^2 + 0.114x + 0.141,$
$R^2 = 0.984$………. (10)

Sphericity

The sphericity of finger millet grain was calculated using Eq. (2). The value of sphericity of grain increased with increase in moisture content. The value of sphericity of finger millet grain varied from 0.90 to 0.95 with variation of moisture content from 10 to 20 % (Fig. 3). The increase in sphericity upon addition of moisture have been reported for moth gram (Nimkar *et. al.*, 2005), vetch seed (Yalçin and Özarslan, 2004), pea seed (Yalcin *et. al.*, 2007) and cotton seed (Ozarslan, 2002). These studies reported that initial rate of increase in sphericity was higher and it becomes comparatively lower at latter stage. The variation of sphericity of grain with moisture content could be represented by the Eq. (3.5).

$Y = 0.005x + 0.85$

$R^2 = 1$ …………..…. (11)

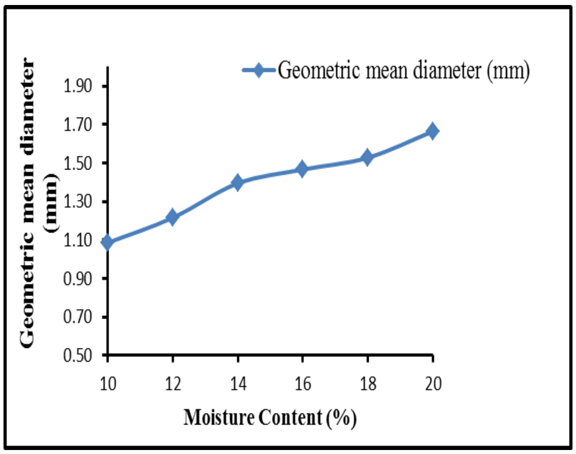


Figure 2: Effect of moisture content on mean diameter.

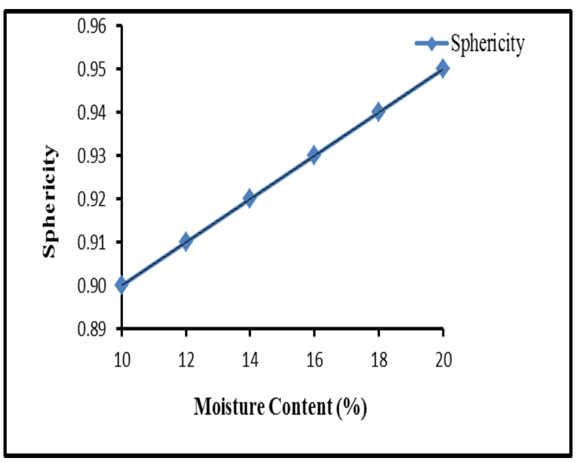


Figure 3: Effect of moisture content on sphericity.

Surface area

The value of surface area obtained for finger millet grain is graphically represented in Fig 4. The values of grain surface area increases linearly from 3.51 to 8.7 mm^2 with increase of six different levels of moisture content ranging from 10 % to 20 % w.b. represented Eq. (3.6).

$y = -0.006x^2 + 0.707x - 2.927$

$R^2 = 0.986$ ………. (12)

This increase in surface area was happened due to increase of dimensions with increase of moisture content of grains. Similar trend of increase have been reported by Altuntas and Yildiz (2007) for faba bean and Isik and Ünal (2007) for kidney bean grain.

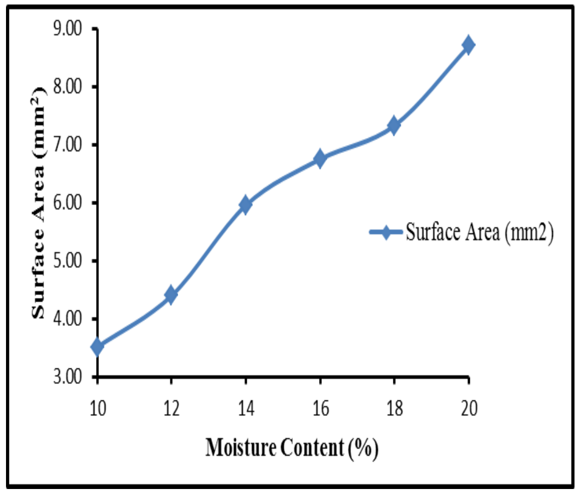


Figure 4: Effect of moisture content on surface area.

Mass of 1000 grains

The mass of 1000 finger millet grain was found to increase linearly from 2.05 – 3.45 g with increase in moisture content, as shown in Fig. 5 and Eq. (3.7).

Similar results of the effect of grain moisture content on thousand grains mass have been reported for moth gram (Nimkar *et. al.*, 2005), green wheat (Al-Mahasneh and Rababah, 2007), and lentil seed (Amin *et al.*, 2004).

$y = -0.005x^2 + 0.329x - 0.72$

$R^2 = 0.980$ …………. (13)

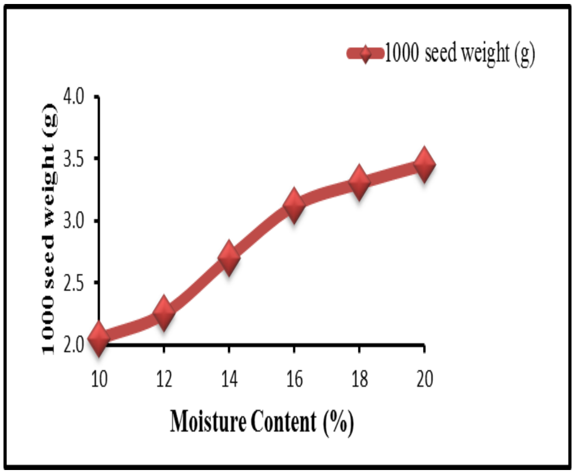


Figure 5: Effect of moisture content on 1000 seed weight.

True density (toluene displacement method)

With the increase of moisture content from 10 to 20 % (wb), the true density of grain increased in linear fashion from 1100 to 1233 kg/m^3. The variation of true density of grain with moisture content is depicted in Fig. 6. The relationship may be shown as Eq. (3.8).

$y = -7.482x^2 + 78.43x + 1029.$

$R^2 = 0.996$ …………(14)

Similar trend was observed to be found by Baryeh (2002) for millet and Isik and Ünal (2007) for kidney bean. However, Sahoo and Srivastava (2002), Al-Mahasneh and Rababah (2007), and Dursun and Dursun (2005) were found decrease in true density, in okra seed, green wheat and caper seed, with increase of moisture content. The increase in true density was mainly due to the larger increase in grain volume as compared to their masses.

Bulk Density:

The bulk density of finger millet grain decreases with increase of moisture content from 10 to 20% (wb) as shown in Fig. 7 : The decrease in bulk density may be due to increase in intergranular space with increase of moisture content. Similar trend was found by Baryeh (2002) for millet, Singh and Goswami (1996) for cumin seed.

$y = 0.629x^2 - 9.855x + 738.8$

$R^2 = 0.979$ ………………. (15)

However, Altuntas and Yildiz (2007); Nimkar et al. (2005); Isik and Ü nal (2007); Sessiz *et. al.*, (2007) and Sahoo and Srivastava (2002) were found linear decrease in faba bean, moth grain, kidney bean grain, caper fruit and okra seed respectively, with increase of moisture content.

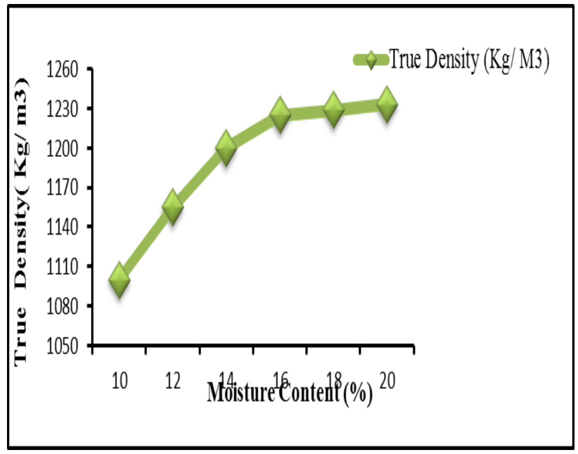


Figure 6: Effect of moisture content on true density.

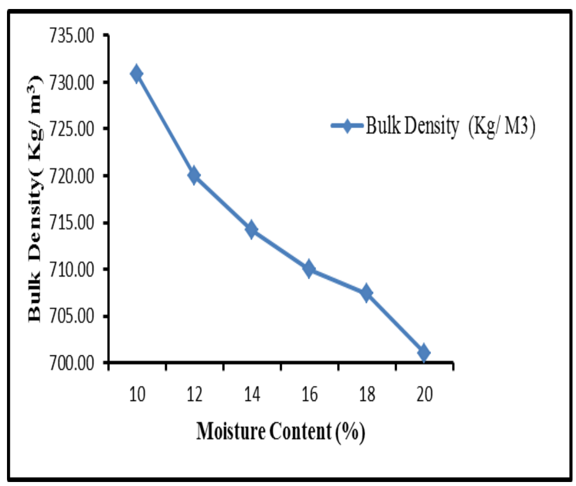


Figure 7: Effect of moisture content on bulk density.

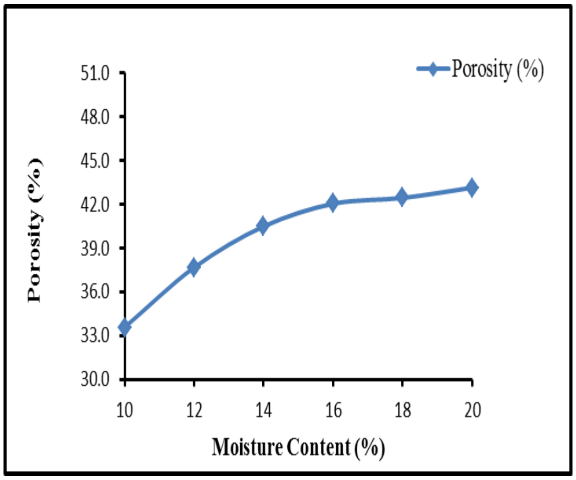


Figure 8: Effect of moisture content on porosity.

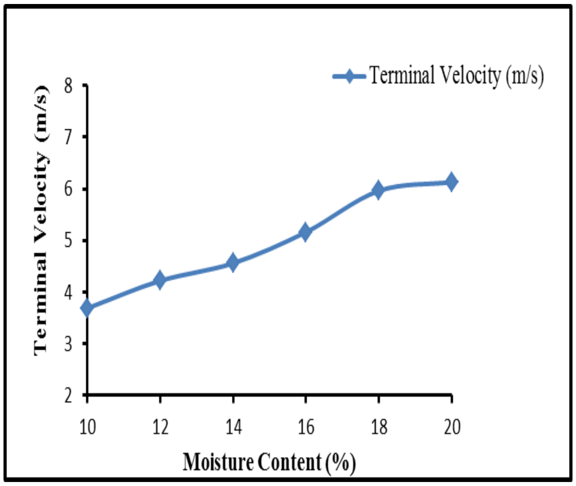


Figure 9: Effect of moisture content on terminal velocity.

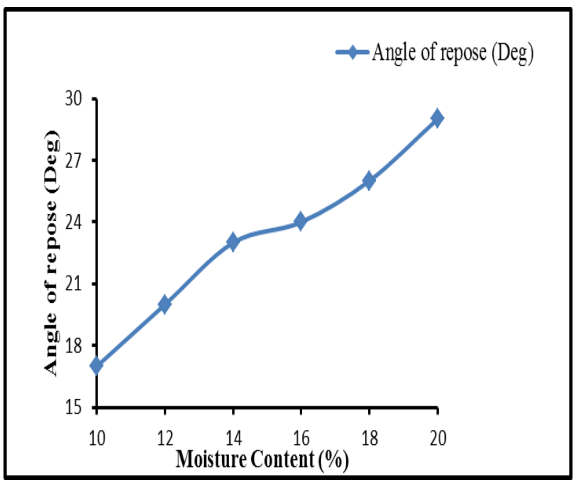


Figure 10: Effect of moisture content on angle of repose.

Porosity

The porosity of finger millet grain was calculated from their bulk density and true density using Eq. (4). Porosity of grain was found to be increase from 33.56 % to 43.14 % with the moisture content increase from 10 to 20 % (wb) as shown in Fig. 8. The grain polynomial relationship with moisture content which is shown in Eq. (3.10).

$y = -0.119x^2 + 4.485x + 0.806$

$R^2 = 0.993$ ……………(16)

Similar trend was found by Singh and Goswami (1996), for cumin seeds, Baryeh (2002) for millet, Calisir *et. al.*, (2005) for rapeseed, Deshpande *et. al.*, (1993) for soybean and Kaleemullah and Gunasekar (2002) for arecanut. However, porosity was reported to be decreased with the increase moisture content for green wheat (Al-Mahasneh and Rababah, 2007), caper seed (Dursun and Dursun, 2005) and popcorn (Karababa, 2006). The increase and decrease of porosity with increase of moisture content may be happened due to difference in shape and size of different grains.

Terminal velocity

The terminal velocity of finger millet grain increased from 3.69 to 6.13 m/s when moisture level increases from10 to 20% (wb) as shown in Fig. 9. The variation in terminal velocity of Finger millet grain and kernel follows second-order polynomial relationship with moisture content which is represented by Eq. (3.11):

$y = 0.000x^2 + 0.252x + 1.13$

$R^2 = 0.980$ ………………. (17)

This difference of terminal velocity may be due to difference in grain mass, shape and size of grain and kernel. Similar trend was observed by Zewdu (2007) for teff grain and straw material and Baryeh (2002) for millet grains.

Angle of repose:

The angle of repose of finger millet grain was observed to increase from 17 to 29^0

(Fig. 10). The increase of angle of repose was may be due to increase of internal friction with increase of contact surface area among the grain. It is fact that if internal friction among the grain increases the angle of repose will also be increased. Similar trend was observed by Baryeh (2002) in millet, Dursun and Dursun (2005) in caper seed, Nimkar *et. al.*, (2005) in moth grain and Sahoo and Srivastava (2002) in okra seeds. The values of angle of repose for finger millet grain can be shows as linear Eq. (3.11)

$$y = -0.017x^2 + 1.664x + 2.428 \quad R^2 = 0.983 \quad \ldots\ldots\ldots\ldots\ldots(18)$$

Conclusions

The following conclusions were drawn from the experiment on engineering properties of finger millet grain for moisture content range from 10 to 20 % (wb).

1. Each of physical characteristics changed with the changing of grains moisture content for the studied local variety of finger millet grain.
2. Grain dimensions (length, width and thickness) of finger millet grain were increased with increasing of moisture content at the studied range. The length was increased from 1.18 - 1.75 mm, width was increased from 1.13-1.71 mm and thickness was increased from 0.96-1.56 mm.
3. The geometric mean diameter, sphericity, grain surface area, 1000 grain mass increases with increase in moisture content.
4. True density (toluene displacement) of finger millet grain was increased while bulk density of grain decrease with increase of moisture content.
5. The calculated porosity was found to increase with the increase in moisture content.
6. The terminal velocity and angle of repose of the grain increase with increase of moisture content.
7. The physical properties of finger millet grains showed linear regression equations as a function of moisture content with high correlation.

References

Ajav, E. A. and J.O. Ojediran, (2006). Some physical and aerodynamic properties of three Nigerian cereal crops as related to their cleaning. *American Society of Agricultural and Biological Engineers.* Paper number: 066006.

Al-Mahasneh, A.M. and Rababah, T. M. (2007). Effect of moisture content on some physical properties of green wheat. *Journal of Food Engineering* 79: 1467-1473.

Altuntas, E. and Yildiz, M. (2007). Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba* L.) grains. *Journal of Food Engineering* 78: 174–183.

Amin, M. N., Hossain, M. A., Roy, K. C. (2004). Effects of moisture content on some physical properties of lentil grains. *Journal of Food Engineering* 65:83-87.

Apoorva, K. B., Prakash, S.S., Rajesh, N.L. and Nandini B. (2010). STRC approach optimizing for integrated plant supply on growth yield and economics of finger millet. *Journal of Optimizing Integrated Plant Nutrient Supply* 4(1):19-27.

ASAE (1998). Moisture Measurement – Unground seeds S352.2. American Society of Agricultural Engineers, 2950 Niles Road, St. Joseph MI 49085-9659, Michigan, USA.

Baryeh, E. A. (2002). Physical properties of millet. *Journal of Food Engineering* 51: 39-46.

Chukwu, O. and Ajisegiri, E. S. A. (2005). The effects of moisture-sorption cycles on some physical properties and nutritional contents of agricultural grains. *AU J.T* 9(2): 121-125.

Deshpande, S. D., Bal, S. and Ojha, T.P. (1993). Physical properties of soybean.

Journal of Agricultural Engineering Research 56(2):89-98.

Dursun, E. and Dursun, I. (2005). Some physical properties of caper seed. *Biosystems Engineering* 92(2):237-245.

Garnayak, D. K., Pradhan, R. C., Naik, S. N. and Bhatnagar, N. (2008). Moisture-dependent physical properties of Jatropha seed (*Jatropha curcas* L.). *Industrial Crops and Products* 27:123–129.

Gupta, R. K., Arora, G., Sharma, R., (2007). Aerodynamic properties of sunflower seed (*Helianthus annuus* L.). *Journal of Food Engineering* 79:899-904.

Isik, E. and Ünal, H. (2007). Moisture-dependent physical properties of white speckled red kidney bean grains. *Journal of Food Engineering* 82:209-216.

Jain, R. K. and Bal, S. (1997). Physical properties of pearl millet. *Journal of Agricultural Engineering Research* 54:219-229.

Kaleemullah, S. and Gunasekar, J. J. (2002). Moisture-dependent physical properties of arecanut kernels. *Biosystems Engineering* 82(3): 331-338.

Malleshi, N. G., Hadimani, N. A., Chinnaswamy, R. and Klopfenstein, C.F. (1996). Physical and nutritional qualities of extruded weaning foods containing sorghum, pearl millet, or finger millet blended with mung beans and nonfat dried milk. *Plant foods for human nutrition* 49:181-189.

McCabe, W. L., Smith, J. C. and Harriott, P. (1986). Unit Operation of Chemical Engineering. McGraw-Hill, New York.

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

Nimkar, P. M., Chattopadhyay, P. K. (2001). Some physical properties of green gram. *Journal of Agricultural Engineering Research* 80(2): 183–189.

Obilana A. B. and Manyasa, E. (2002). Millets. Page 176-217 in: Pseudocereals and less common cereals: Grain properties and utilization potential. P.S. Belton and J.R.N. Taylor, eds. Springer-Verlag: Berlin.

Ojediran, J. O., Adamu, M.A. and Jim-George, D. L. (2010). Some physical properties of Pearl millet (*Pennisetum glaucum*) seeds as a function of moisture content. *African Journal of General Agriculture* 6(1):39-46.

Ozarslan, C., (2002). Physical properties of cotton seed. *Biosystems Engineering* 83(2): 169–174.

Sacilik, K., Ozturk, R. and Keskin, R. (2003). Some physical properties of hemp seed. *Biosystems Engineering* 86 (2): 191–198.

Sahoo, P. K. and Srivastava, A. P. (2002). Physical properties of okra seed. *Biosystems Engineering* 83(4): 441–448.

Sessiz, A., Esgici, R. and Kizil, S. (2007). Moisture-dependent physical properties of caper (*Capparis sp*.) fruit. *Journal of Food Engineering* 79: 1426-1431.

Singh, K. K. and Goswami, T.K. (1996). Physical properties of cumin seed. *Journal of Agricultural Engineering Research* 64(2): 93–98.

Subramanium, S. and Viswanathan, R. (2007). Bulk density and friction coefficient of selected minor millet grain and flour. *Journal of Food Engineering* 81: 118–126.

Swami S. S. and S. B. Swami. (2010). Physical properties of finger millet (*Eleusine coracana*). *International Journal of Agricultural Engineering* 3(1): 156-160.

Tavakoli, H., Rajabipour, A. and Mohtasebi, S.S. (2009). Moisture-dependent Some Engineering Properties of Soybean Grains. *Agricultural Engineering International: the CIGR E-Journal*, Vol. XI. Manuscript 1110.

Yalcin, I., Özarsalan, C. and Akbas, T. (2007). Physical properties of pea (*Pisum* *sativum*) seed. *J. of Food Engg* 79 (2): 731–735.

Yalçin, I. and Özarslan, C. (2004). Physical properties of vetch seed. *Bio systems Engg.* 88(4): 507–512.

Yalcin, I. (2007). Physical properties of cowpea (*Vigna sinensis* L.) seed. *J. of Food Engg*79: 57–62.

Zewdu, A.D. (2007). Aerodynamic properties of teff grain and straw material. *Bio systems Engg.* 98: 307-309.