Effect of soaking time on some engineering properties of cowpea (*Vignaunguiculata*)

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Abstract: The study evaluated the effect of soaking time on some selected engineering properties of black-eye pea and brown beans cowpea variety with a view to providing the necessary data that will aid the design and development of some specific process equipment such as size reduction, cleaning, sorting and grading machines as well as storage components and facilities. Mature seeds procured from the market was manually cleaned and soaked in water at room temperature within the range of 27°C -31°C for 2, 4, 6, 8, 10 minutes and the selected response parameters observed. The results showed that length, width, thickness, geometric mean diameter, mass, aspect ratio and surface area increased non-linearly from 8.10 mm to 12.00 mm, 5.28 mm to 7.89 mm, 5.23 mm to 6.91 mm, 6.20 mm to 8.05 mm, 0.33 g to 0.52 g, 0.71 to 0.77, and 132.70 mm^2 and 134.69 mm^2 respectively as soaking time increased for black-eye pea; while for brown beans variety the results showed that length, width, thickness, geometric mean diameter, mass, aspect ratio and surface area increased non-linearly from 8.03 mm to 11.60 mm, 5.25 mm to 7.78 mm, 5.18 mm to 6.69 mm, 6.17 mm to 7.85 mm, 0.34 g to 0.58 g, 0.66 to 0.74, and 131.65 mm^2 and 134.51 mm^2 respectively as soaking time increased. More so shape and bulk density decreased non-linearly from 0.86 to 0.78 and 0.77 g cm^{-3} to 0.64 g cm^{-3} with increased soaking time for black-eye pea while for brown beans, it decreased non-linearly from 0.80 to 0.73. The static coefficient of friction on three different material surfaces increased non-linearly from 0.3773 to 0.7089 on rubber, from 0.3772 to 0.6630 on stainless steel, and from 0.4177 to 0.6576 on galvanized steel as soaking time increases for both varieties; while angle of repose increased non-linearly also from 22.30° to 38.01° for both varieties when soaked. From the results, it is recommended that construction materials that have an angle of repose values lower than 31.670 should be used in the manufacture of process components requiring easy movement of products along its surface.

Keywords: black eye pea, brown beans, soaking time, engineering properties

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1 Introduction

Cowpea [*Vigna unguiculate* (L.) Walp.] is a popular leguminous crop in Africa. It is popularly known as ‘beans’ in Nigeria. The name cowpea probably originated from the fact that the plant was an important source of hay for cows in the South-eastern United States and in other parts of the world. Some important local names for cowpea around the world include “*niebe*,” “*wake*,” and “*ewa*” in much of West Africa and “*caupi*” in Brazil. In the United States, other names used to describe cowpeas include “southern peas,” “black-eyed peas,” “pinkeyes,” and “crowders.” These names reflect traditional seed and market classes that developed over time in the southern United States.

In Nigeria, as well as most West African countries, cowpea is eaten in various forms; as porridge along with fried or boiled yam or plantain, as bean cake called *akara* or *kosei* among Yoruba and Hausa respectively, eaten as *moin – moin* which is steamed – cook of wet – milled

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cowpea mixed with cooking ingredients and it is also used in preparing a popular cowpea stew called gbegiri (Babatunde, 1995). In recent years, cowpea seeds are now processed into packaged cowpea flour for further preparation into any form of food products. The grain is rich in protein to up to around 30 percent in some varieties. In addition, the grain contains micro-nutrients such as iron and zinc which are necessary for healthy living (Bouker et al., 2010). It is for these reasons, that societies endowed with cowpea have evolved different ways of utilising the grain for food.

There has been a desire for improvements on the methods used locally to process, preserve, store, handle and transport cowpea with a view to adding value to the product so that domestically, it can be fully accepted as a staple with exceptional food quality and internationally, as a product with the desired export quality. In this respect, engineering methods and analysis cannot be down-played since it occupies a central role in the plan for a shift from traditional methods of post-harvest operations of biological materials to improved methods. Four critical stages are often utilized to achieve this, which are study, analysis and evaluation of the traditional methods; engineering properties of the traditionally processed, preserved and stored biological materials; analysis and utilization of the experimental values in design and simulation studies; and fabrication and testing of improved methods. Basically, the determination of the engineering properties of bio-materials is primary to the development of new methods of post-harvest operations since it offers a wide range of applications. By engineering properties of agricultural materials, we mean the response of biological materials to some input variables of engineering relevance. In light of this, scientists have made great efforts in evaluating basic physical properties of agricultural materials and have pointed out their practical utility in machine and structural design and in control engineering. Dimensions are important to design the cleaning, sizing and grading machines. Coefficient of friction is important in designing equipment for solid flow and storage structures. The coefficient of friction between seed and wall is an important parameter in the prediction of seed pressure on walls (Amin et al., 2004).

The physical properties of numerous grains, nuts and seeds have been determined by other researchers such as cocoa beans (Bart-Plange and Baryeh, 2003); pistachio nuts (Kashaninejad et al., 2006); green soybean (Sirisomboon et al., 2007); gorgon nut (Jha and Prasad, 1993); and Ogunjimi et al. (2002) for locust bean seed. The effect of moisture content on the engineering properties of some legumes such as kidney bean, dry pea, and black eyed pea seeds as well as some varieties of cowpea, Turgenialatifolia and Moringaoleigera seed have been determined and the importance of each property was identified as a major player in the design of some processing equipment by various research workers (Ebubekir and Hilal, 2007; Davies and Zibokere, 2011; Nalbandi et al., 2010; Adejumo and Abayomi, 2012) respectively. However, there is little information on the effect of soaking time on the engineering properties of bean seed on some surface materials.

As a result, this paper focuses on the determination of the engineering properties of soaked two varieties of cowpea seeds with a view to providing the basic tools of design that could lead to radical improvements in its post-harvest operations.

2 Materials and methods

2.1 Sample Preparation

In order to obtain the objectives of this study, black-eye pea and brown beans, were selected based on the fact that they have a higher market demand than some other species. Mature seeds of the selected variety were procured from the market (New market) at Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria. The procured seeds were cleaned manually to remove all foreign matter like dirt, pieces of stones, weevil-infected seeds and broken seeds. A marked bowl capable of containing enough seeds to meet the various experimental determinations was used to draw random samples as required from the lot from each replicate at a specified treatment (soaking time). The initial moisture content of the seeds was determined by oven drying at 105ºC±1ºC for 24 h (Suthar and Das, 1996). The initial moisture content of the seeds was 7% to 11% d.b after which the seeds were conditioned by soaking for 2, 4, 6, 8 and 10 minutes respectively. The moisture in the seeds was allowed to equilibrate at room temperature of 27°C for at least 72 h. Experimental determination of the engineering properties of the samples were carried out at the Department of Agricultural and Environmental Engineering Laboratory, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria, between March, 2015 to June, 2015.

2.2 Experimental Determinations

The average size of the seed, 20 seeds were randomly picked and their three linear dimensions namely, length, width and thickness were measured using a digital vernier caliper with accuracy of 0.01 mm. A single seed was placed within the vernier caliper measuring unit and the nob adjusted until the seed is just firmly held before taking its reading. The applied force on the adjustable nob of the vernier caliper was manually controlled in order to minimize damage to the sample due to excessive compressive force since the seed is wet. The process was done for three replications and the average result calculated and recorded.

Geometric mean diameter was determined for each seed at specified soaking time from the average measurements of the length, width and thickness with the expression presented by Mohsenin (1980):

$$D_g = (abc)^{1/3} \tag{1}$$

where, D_g is Geometric Mean Diameter; a is Length (Major diameter); b is Width (Minor diameter); c is Thickness (Intermediate diameter).

The aspect ratios (R_a) of the samples were calculated as recommended by Maduako and Faborode (1990) as,

$$R_a = \frac{b}{a} \times 100 \tag{2}$$

Mass was determined by weighing each unit seed of 20 seeds sampling at each soaking time on an Electronic scale with an accuracy of 0.01 g. This was done for three replications and the average mass was used.

The bean surface area S (mm^2) was determined for 20 samples of bean using the following relationship given by Mc Cabe et al. (1986) as,

$$S = \pi D^2_g \tag{3}$$

The Bulk density was determined using the standard test weight procedure in which bulk seeds were poured into a standard container (20 cm×20 cm×10 cm) from a specified height of 15 cm at a constant rate at each soaking time. The surface was then levelled with a hard 30 cm meter rule without causing any considerable impact on the bulk grains. The process was replicated three times while the average determined. Mathematically:

$$Bulk\ density = \frac{Mass\ of\ samples}{Volume\ of\ the\ container} \tag{4}$$

This method has been used by Gebreselassie (2012) and Davies (2010).

The static coefficient of friction for each sample was determined with respect to three test surfaces namely, galvanized steel, stainless steel and rubber surface at each soaking time. These samples were placed on the surface of an adjustable inclined plane apparatus, which was locally constructed. The inclination of the surface was increased gradually until the sample started to slide and the angle of tilt was measured from a graduated scale attached to the edge of the apparatus, as shown in Figure 1. This was also replicated three times. The static coefficient of friction (μ_s) was calculated based on Equation 5 (Mohsenin, 1986).

$$\mu_s = \tan \alpha \tag{5}$$

where, α is the tilt angle in degree.

Figure 1 The tilting table apparatus for measuring static coefficient of friction

The angle of repose was determined using topless and bottomless cylinder of 0.15 m diameter and 0.25 m height. The cylinder was placed at the centre of a flat surface and was filled with the sample to the brim as shown in Figure 2. The cylinder was raised slowly until the samples formed a cone on a circular plane. The height of the cone was measured and the filling angle of repose ø was calculated (Ogunsina and Bamgboye, 2007) using Equation (6). The process was also replicated three times at each soaking time.

$$Tan\ Ø = \frac{Height\ of\ seed}{Radius\ of\ the\ seed\ base\ area} \tag{6}$$

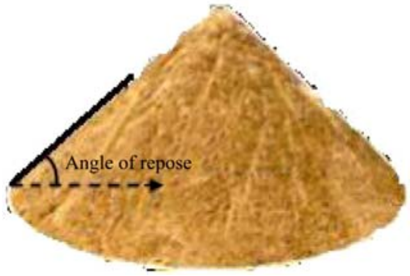

Figure 2 Angle of repose

3 Result and discussion

Specialized pieces of equipment were used to obtain observations of some response parameters of soaked cowpea. Because of the perceived physical appearance of the observed seeds, one might think that the response parameters of these seeds would not register significantly over a specified period of soaking time. However, the result from this study showed that soaking time had a significant effect on most of the selected engineering properties of cowpea seeds.

3.1 Grain dimensions

As shown in Figures 3 and 4, length, width and thickness increased partially linearly from 8.80 mm to 12.60 mm, 6.20 mm to 8.81 mm, and 5.60 mm to 6.88 mm respectively with the increased soaking time for brown bean while for black eye pea, it increases from 8.90 mm to 15.10 mm, 6.28 mm to 9.97 mm and 5.71 mm to 7.21 mm respectively with the increase in soaking time. The effect of soaking time on the length, width and thickness of both variety of beans was statistically significant (p<0.05) at some point. The increase in the grain dimensions could be as a result of the absorption of moisture as soaking time increased causing a volumetric expansion of the seeds, but their rates of expansion differ. The calculated geometric mean diameter equally eye pea it increased from 6.830 mm to 10.277 mm (Figure 5).

3.2 Sphericity

As shown in Figure 6, sphericity appeared to vary randomly from 0.663 to 0.784 for both varieties as the soaking time increased. Although a significant difference was observed amongst the samples (p<0.05), the decrease in the value of the sphericity at some point of soaking may have been occasioned by the non-linear increase in the width and thickness of the seeds during soaking. This result is in agreement with previous reports for some grain legume seeds by Ebubekir and Hilal (2007), barley grains by Mahmoud et al. (2009), three varieties of cowpea by Davies et al. (2011), and Pistachio nuts by Lella et al. (2013). This is in contrast with the work of Tef seed by Zewdu and Solomon (2006), soybean grains by Tavakoli et al. (2009), for N. lappaceum seed by Nor and Tajul (2010).

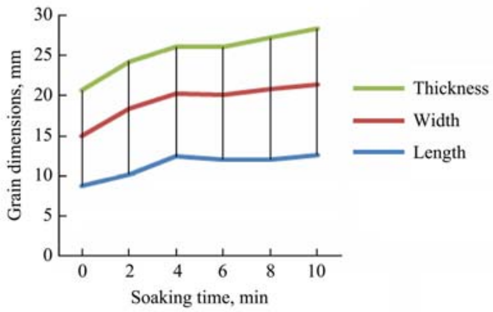

Figure 3 Variation of grain dimension with soaking time for brown beans

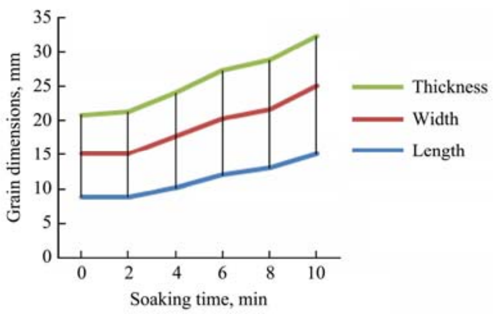

Figure 4 Variation of grain dimensions with soaking time for black eye pea

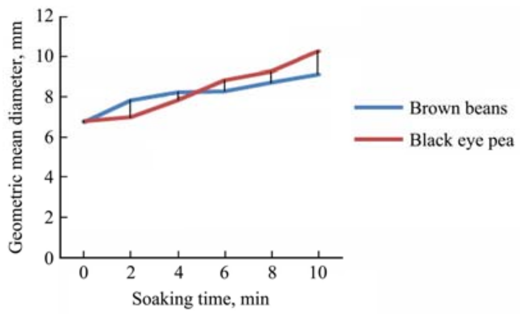

Figure 5 Variation of geometric mean diameter with soaking time for both varieties

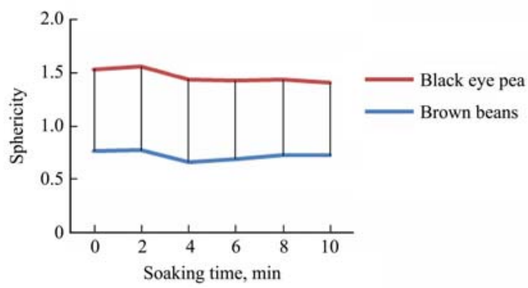

Figure 6 Variation of sphericity with soaking time on both varieties of beans

3.3 Mass

The mass of both varieties of cowpea seeds varied from 0.21 g to 0.75 g, indicating an increase in mass as soaking time increased (Figure 7). The values were statistically different (p<0.05). The increment might be as a result of the increased water retention capacity within the cell walls of the seeds and their test a resulting in an increase in their overall matter content due to steady prolonged contact with water. At 5% standardized range, the effect of soaking time on mass was found to be significantly different.

Previous works conducted by Ebubekir and Hilal (2007), Polat et al. (2007), Nalbandi et al. (2010), Lella et al. (2013) reported similar results for some grain legume seeds, Pistachio nuts, T. L. seeds and wheat kernels, and Pistachio nuts respectively.

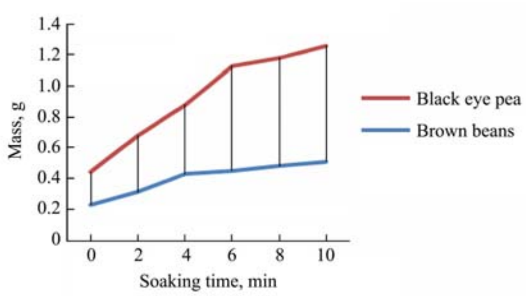

Figure 7 Variation of mass with soaking time for both varieties

3.4 Bulk Density

Figure 8 shows average values of bulk density of cowpea samples at different treatments. The results indicated that bulk density decreased from 0.7119 g cm^{-3} to 0.6310 g cm^{-3} as soaking time increased for black eye pea while for brown beans it decreased from 0.7704 g cm^{-3} to 0.6310 g cm^{-3} as soaking time increased. At 5% level, the results were found to be statistically significant.

One might think that these results would have been otherwise considering the fact that both mass and volume increased as soaking time increased and as such, their ratios ought to have increased likewise. The reason for this decrease is not very clear. However, some researchers (Zewdu and Solomon 2006; Tavakoli et al., 2009; Seyed et al., 2010; Nor and Tajul, 2010) have reported similar results as moisture content increased for Tef seed, soybean grains, Black cumin seed, and N. lappaceum seed respectively.

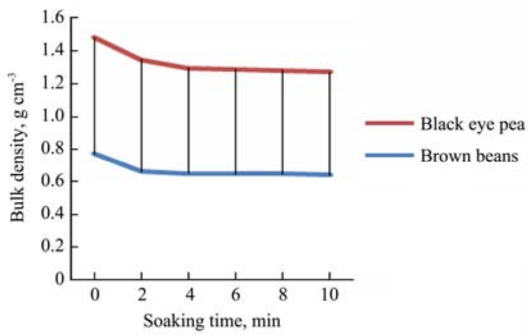

Figure 8 Variation of bulk density with soaking time for both varieties

3.5 Surface Area

From Figure 9, it can be seen that the surface area for both varieties of cowpea ranges from 142.50 mm^2 to 262.50 mm^2 for brown pea while for black eye pea it ranges from 146.55 mm^2 to 331.80 mm^2 as moisture content increases. The observed values were significantly different at P<0.05. Similar trend was observed by Tunde-Akintunde and Akintunde (2007) for bean seed. The surface area affects the velocity of air stream that can be used in other to separate the seed from unwanted material in pneumatic separator or to convey seed in pneumatic conveying.

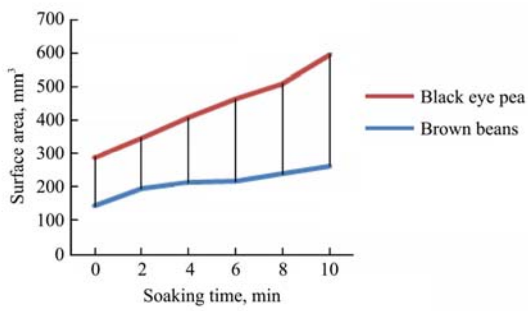

Figure 9 Variation of surface area with soaking time for both varieties

3.6 Coefficient of Static Friction

Figures 10 and 11 showed that static coefficient of friction increased from 0.3705 to 0.7089 for the three-tested body as soaking time increased for both varieties. The increment might have occurred as a result of the fact that as the moisture content increased the adhesion between seeds and surfaces increased. This led to increasing values of static coefficient of friction (Nalbandi et al., 2010). At 5% standardized range, the effect of soaking time on static coefficient of friction was found to be significantly different. Among the three surfaces tested, rubber had the highest coefficient of static friction (0.6169) followed by stainless steel (0.5851), and galvanized steel 0.6009 at 10 minutes soaking time for black eye pea as shown in Figure 10 while for brown pearubber had the highest coefficient of static friction (0.7089) followed by stainless steel (0.6330), and galvanized steel 0.6576 at 10 minutes soaking time as shown in Figure 11. There is variation in static coefficient of friction on the three surfaces due to variation in roughness of the surfaces. This value is needed in the design of agricultural machine hoppers and other conveying equipment. It determines how a pack of grain or seed will flow in these systems

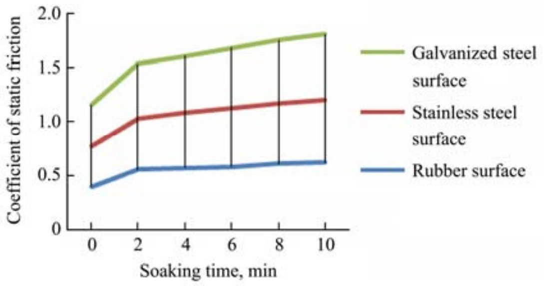

Figure 10 Variation of coefficient of static friction with soaking time for black eye pea

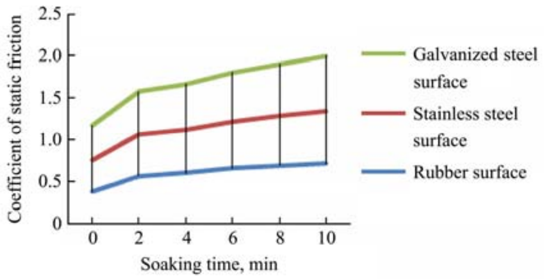

Figure 11 Variation of coefficient of static friction with soaking time for brown beans

3.7 Angle of Repose

Figure 12 shows a plot of average values of angle of repose and soaking time. The figure indicated that angle of repose increased non-linearly from 23.69º to 38.01º for brown pea while for black eye pea increased non-linearly from 22.30º to 34.60º even as the soaking time increased. At 5% level, the samples were found to be significantly different.

An explanation for this increase could be as a result of the increase in surface roughness arising from upsurge in water uptake by the seeds during soaking, thus leading to reduced sliding tendencies between seeds and sliding surface. Consequently, a higher sliding angle was reached before sliding could occur. This result is similar to published literatures by Zewdu and Solomon (2006) for Tef seed, Davies et al. (2011) for three varieties of cowpea, and Nor and Tajul (2010) for N. lappaceum seed.

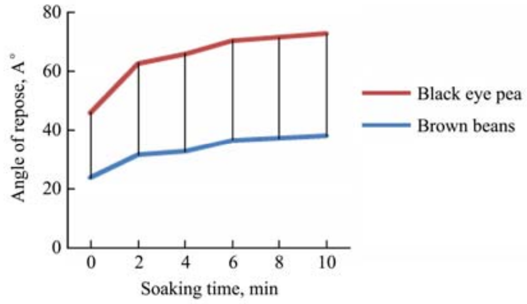

Figure 12 Variation of Angle of Repose with Soaking Time

4 Conclusion

The objective of this research has been to evolve data on the effect of soaking time on some selected engineering properties of two varieties of cowpea seeds. This was necessitated by the fact that there is few available data of the crop in that regard. The study has shown that soaking time considerably affects most of the selected engineering properties of the product and a section of the values of angle of repose and coefficient of static friction recorded after 10 minutes of soaking, thus indicating that the length, width and the thickness are among the most critical element in the design of cleaning, sorting and grading equipment for both varieties of cowpea seed. Also, the high static coefficient of friction observed for rubber material encourages its use as a chute or chamber surface when separation of biomaterial is of importance.

References

Adejumo, B. A., and D. A. Abayomi. 2012. Effect of moisture content on some physical properties of moringaoleifera seed. *Journal of Agriculture and Veterinary Science*, 1(5): 12–21.

Altuntas, E., and H. Demirtola. 2007. Effect of moisture content on physiccal properties of some grain legume seed. *New Zealand Journal of Crop and Horticultural Science*, 35(1): 423–433.

Amin, M. N., M. A. Hossain, and K. C. Roy. 2004. Effects of moisture content on some physical properties of lentil seeds. *Journal of Food Engineering*, 65(1): 83–87.

Bart-Plandge, A., and E. A. Baryeh. 2003. The physical properties of category b cocoa beans. *Journal of Food Engineering*, 60(3): 219–227.

Babatunde, O. O. 1995. Development and performance evaluation of a manually operated cowpea dehulling, machine for soaked cowpea. *Journal of Agricultural Engineering and Technology,* 3(1): 1–7.

Boukar, O., F. Massawe, S. Muranaka, J. Franco, B. M. Dixon, and C. Fatokun. 2010. Evaluation of cowpea germplasm lines for minerals and protein content in grains. In *World Cowpea Research Conference: Improving Livelihoods in the Cowpea Value Chain through Advancement in Science*. Palm Beach Hotel, Saly, Senegal: 27th September-1st October 2010.

Davies, R. M. 2010. Engineering properties of three varieties of melon seeds as potentials for development of melon processing machines. *Advance Journal of Food Science and Technology*, 2(1): 63-66, 2042–4876.

Davies, R. M., and D. S. Zibokere. 2011. Effect of moisture content on some physical and mechanical properties of three varieties of cowpea (Vignaunguiculata (L) Walp). *CIGR Journal*, 13(1): manuscript No. 1700.

Gebreselassie, T. R. 2012. Moisture dependent physical properties of cardamom (*Elettaria Cardamomum M.*) seed. *CIGR Journal*: 14(1): 108–115.

Jha, S. N., and S. Prasad. 1993. Physical and thermal properties of gorgon nut. *Journal of Food Process Engineering,* 16(3): 237–245.

Kashaninejad, M., A. Amortazavi, A. Safefekordi, and L. G. Tabil. 2006. Some physical properties of pistachio (*pistaciavera*l.) nut and its kernel. *Journal of Food Engineering*, 72(1): 30–38.

Kurien, P. P., H. S. R. Desikachar, and H. A. B. Parpia. 1972. Processing and utilization of grain legumes in India. *Tropical Agriculture Research Series No. 6*. Tokyo, Japan: pp. 225

Lella, P., M. Asghar, and G. Hossein. 2013. Some physical properties of pistachio nuts. *International Journal of Agriculture and Crop Science*, 5(7): 704–711.

Maduako, J. N., and M. O. Faborode. 1990. Some physical properties of cocoa pods in relation to primary processing. *Ife Journal of Technology*, 2(1): 1–7.

Mahmoud, T., T. Hamed, R. Ali, A. Hojat, and S. Mohammad, and T. G. Zahedi. 2009. Moisture-dependent physical properties of barley grains. *International Journal of Agriculture and Biological Engineering*, 2(4): 84–91.

McCabe, W. L., J. C. Smith, and P. Harriot. 1986. *Unit Operations of Chemical Engineering*. New York, USA: McGraw-Hill Press.

Mohsenin, N. N. 1986. *Physical Properties of Plant and Animal Materials.* 2nd Ed. New York: Gordon and breach Science Publishers.

Nalbandi, H., H. R. Ghassemzadeh, and S. Seiiedlou. 2010. Seed moisture dependent on physical properties of turgenialatifolio: criteria for sorting. *Journal of Agricultural Technology,* 6(1): 1–10.

Nor, S., and A. Y. Tajul. 2010. The physical properties of n. lappaceum seed as a function of moisture content. *Advance Journal of Food Science and Technology*, 4(4): 199–206.

Ogunjimi, L. A. O., N. A. Aviara, and O. A. Aregbesola. 2002. Some engineering properties of locust bean seed. *Journal of Food Engineering*, 55(2): 95–99.

Ogunsina, B. S., and A. I. Bamgboye. 2007. Effect of pre-shelling treatment on the physical properties of cashew nut (*Anacardium occidentale*). *International Agrophysics*, 21(4): 385–389.

Polat, R., C. Aydin, and A. K. B. Erkol. 2007. Some physical and mechanical properties of pistachio nut. *Bulgarian Journal of Agricultural Science*, 13(1): 237–246.

Seyed, M. T. G., M. M. Seyed, M. Ali, T. G. Amin, and M. A. Seyed. 2010. Moisture-dependent engineering properties of black cumin (Nigella Sativa L.) seed. *CIGR Journal*, 12(1): 1–18.

Sirisomboon, P., P. Pornchaloeampong, and T. Romphophak. 2007. Physical properties of green soybean: criteria for sorting. *Journal of Food Engineering*, 79(1): 18–22.

Suther, S. H., and S. K. Das. 1996. Some Physical properties of karinda seeds. *Journal of Agricultural Engineering Research,* 4(65): 15–22.

Tavakoli, H., A. Rajabipour, and S. S. Mohtasebi. 2009. Moisture-dependent some engineering properties of soybean grains. *CIGR Journal*, 11(1): 2–14.

Tunde-Akintunde, T. Y., and B. O. Akintunde. 2007. Effect of moisture content and varietyon selected properties of beniseed: *CIGR Journal*, 9(4): 1–13.

Zewdu, A. D., and W. K. Solomon. 2006. Moisture-dependent physical properties of tef seed. *Biosystems Engineering*, 96(1): 57–63.