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SOME MOISTURE DEPENDENT COMPRESSIVE PROPERTIES OF SHEA KERNEL (*VITELLARIA PARADOXA L*)

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ABSTRACT

The effect of moisture content on some compressive properties of shea kernels was studied so as to provide useful data for the design of appropriate machinery for processing. The effects of moisture content on wet basis (w.b.) and loading on compressive stress, compressive strain, Young's modulus and crushing energy were examined. Compressive stress, compressive strain and Young's modulus decreased with increase in moisture content for shea kernel. Compressive stress and strain decreased linearly from 2.0 to 0.8MPa and 0.0085 to 0.002mm/mm as moisture content increased from 5% to 24% respectively. Young's modulus decreased non-linearly with moisture content from 2000MPa at 5.00% to 100MPa at 24.00%, while crushing energy increased non-linearly from 6 to 135mJ in the moisture content range of 5.00% to 24.00% w.b.

Keywords: Shea kernel, compressive stress, compressive strain, Young's modulus, crushing energy.

INTRODUCTION

Sheanut hails from the *Sapotaceae* family and the commonly known varieties include *Vitellaria paradoxa* (*Butryospermum parkii*) and *Vitellaria nilotica*. Shea nut is obtained from the shea tree, and is grown mostly throughout West and Central Africa in the semi-arid Sahel from Senegal to Ethiopia (Aremu and Nwannewuihe, 2011). Shea nut contains reasonably high amounts of oleic acids from which the shea butter is obtained. Shea butter is one of the basic raw materials for most food, cosmetic, soap as well as the pharmaceutical industries (Boateng, 1992; Thioune *et al*., 2000) and it is sometimes used as a substitute for cocoa butter (Bekure *et al*., 1997). In Ghana, a woman collects nuts from her husband's plots, while wives elsewhere gather shea from trees in fallowed fields (Fobil, 2003). The kernel is obtained from the nut (Fig. 1) by cracking with stones or mortar and pestle. Traditional methods of extraction of shea butter from the kernel involve a series of operations which includes steeping, roasting, pounding or grinding and boiling (Aviara *et al*., 2005). Shea butter is marketed as being effective at treating conditions such as burns, eczema, rashes, severely dry skin, dark spots, skin discoloration, chapped lips, stretch marks, wrinkles and provides natural UV sun protection (Boateng, 1992).

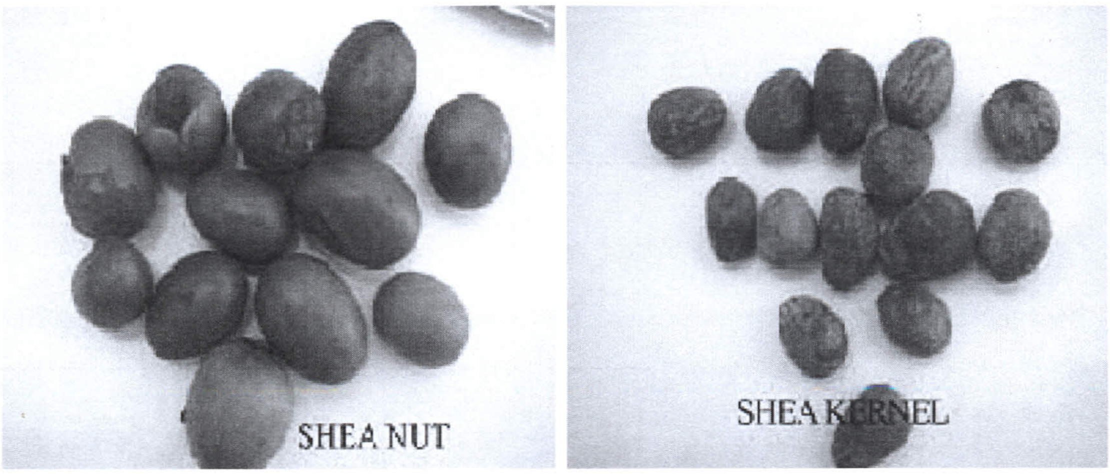

Fig. 1. Shea Nut and Shea Kernel.

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Useful data on the mechanical properties of sheanut and kernel are necessary in the mechanization of various unit operations involved in post-harvest processing and also help in the development of optimization parameters for efficient and effective processing equipment (Burubai *et al*., 2007). Compressive and other engineering properties are needed in the design of machines and the analysis of the behaviour of the product during unit operations such as drying, cleaning, sorting, crushing and milling (Akaaimo and Raji, 2006; Irtwange and Igbeka, 2002). The increasing interest in shea butter and its uses in industries and the need for appropriate handling and processing of shea nut and kernel cannot be overemphasised, however, present methods of handling and processing are both laborious and time consuming (Aviara *et al*., 2005). For effective and proper design and manufacture of systems and equipment in handling shea kernel, its engineering properties such as the compressive properties must be available.

Compressive properties including rupture force, compressive strain and stress, Young's modulus and crushing energy are useful information in the design of shea kernel grinding machines. Studies have shown that compressive properties are influenced by a number of factors such as the cultivar, temperature and moisture content of the product under consideration (Delwiche, 2000; Shitanda *et al*., 2002). The rupture force indicates the minimum force required for shelling nuts and grinding kernels (Sirissomboon *et al*., 2007; Galedar *et al*., 2009). The deformation at rupture point can be used for the determination of the gap size between the surfaces to compress the bean for shelling. Several researchers have studied the mechanical properties of various food and biological materials (Shitanda *et al*., 2002) for rough rice; (Khazaei and Mann, 2004) for sea buckthorn berries; (Altuntas and Karadag, 2006) for sainfoin seed; (Isik and Unal, 2007) for white speckled red kidney bean; (Corrêa *et al*., 2007) for rough rice; (Rybiński *et al*., 2009) for pulse seeds; (Galedar *et al*., 2009) for pistachio nuts and kernel; (Khan *et al*., 2010) for industrial hemp stalks and kernel (Kalkan and Kara, 2011) for wheat grains.

Engineering properties of shea kernel is moisture dependent and a range of moisture content exists within which optimum performance of its processing equipment is achieved. Negligible information is available on compressive properties of cash crops grown in Ghana such as shea kernel. Some information exists on the physical and thermal properties of shea nut and kernel (Olajide *et al*., 2000; Aviara *et al*., 2005; Aremu and Nwannewuihe, 2011).

Therefore, the objective of this study was to investigate the effects of moisture content and loading on compressive stress, compressive strain, Young's Modulus and crushing energy of shea kernel that are relevant for the design of processing equipment.

MATERIALS AND METHODS

Preparation of Sample

The samples were cleaned by removing foreign materials and damaged kernels. Shea kernel samples used in the research had all the quality checks performed and ready for local and export market. Samples were conditioned to four moisture content levels of 5.00, 12.00, 18.00 and 24.00% w.b. The samples were sealed in separate polythene bags and kept in a refrigerator at 5°C for five days to ensure uniform moisture distribution. The amount of distilled water added was calculated using equation (1) (Balasubramanian, 2001; Bart-Plange and Baryeh, 2003).

$$M_w = \frac{M_i(m_f - m_i)}{100 - m_f} \quad (1)$$

where:

M_w is the mass of distilled water (g),

M_i is the initial mass of sample (g),

m_f is the final moisture content of sample (%w.b.) and

m_i is the initial moisture content of sample (%w.b.).

Prior to using the kernels they were taken out of the refrigerator and allowed to warm up to room temperature. Similar approaches have been used by Deshpande *et al*. (1993) for soybean, Singh and Goswami (1996) for cumin seed and Aviara *et al*. (1999) for guna seed. After conditioning the samples to the desired moisture levels of 5.00, 12.00, 18.00 and 24.00%w.b., the dimensional properties were determined for four replicates and the mean values calculated.

Determination of principal dimensions

The average size was determined based on 100 randomly selected seeds. The three principal dimensions namely length *(a)*, width, *(b)* and thickness *(c)* were measured using a micrometer screw gauge with an accuracy of 0.01mm. The width and thickness were measured perpendicular to the major axis. The geometric mean diameter *(Dg)* or equivalent diameter *(De)* as used by some researchers was calculated using the following relationship (Mohsenin, 1986):

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

The sphericity index (Ø) was calculated using the following formula (Mohsenin, 1986):

$$Ø = \frac{(abc)^{1/3}}{a} \quad (3)$$

Determination of compressive properties

The compression test was conducted on the shea kernel at four moisture content levels (5.00%, 12.00%, 18.00, 24.00% w.b) using the Instron Universal Testing Machine (IUTM) controlled by a micro- computer. Prior to the compression test, the linear dimensions and the sphericity of the shea kernel were measured. During a compressive test, the shea kernel was placed laterally on the platform and was compressed with a motion probe at a constant speed until the specimen fractured. The data acquisition system generated the rupture load and the displacement automatically during the compression. The maximum compressive stress, strain, and crushing energy were determined using the following equations:

$$\sigma_{max} = \frac{P_{max}}{dL} \quad (4)$$

$$\varepsilon_{max} = \frac{\delta l}{l} \quad (5)$$

$$E_c = \frac{P}{2} \times \Delta D \quad (6)$$

Where σ_{max} is the maximum compressive stress in MPa, P_{max} is the maximum load in N, d is the mean diameter in mm, and L is the mean length in mm. ε_{max} is maximum compressive strain in mm/mm, l is the mean width of the specimen in mm, ΔD is the displacement interval in mm and E_c is the crushing energy in J.

An analysis of variance (ANOVA) was performed to examine the effects of experimental factors and their interactions using SPSS 2007. Means of treatments were compared using Fisher's least significant difference. Regression analysis was performed on the data to examine the trends of compressive properties in relation to the kernel moisture content with MS excel. A significant level of probability $p < 0.05$ was used for all analysis and all measurements were replicated four times.

RESULTS AND DISCUSSION

Size and shape dimensions

Table 1 shows the mean major diameter, intermediate diameter, and the minor diameter as well as the effective mean diameter and sphericity of the shea kernel specimen used for the compression test at moisture contents of 4.78 ± 0.28% and 24.17 ± 0.12%. The major diameter, intermediate diameter and the minor diameter had values of 24.17 ± 3.20 mm, 17.55 ± 2.00 mm and 14.95 ± 1.54 mm at moisture content of 4.78 ± 0.28% while at moisture content of 24.17 ± 0.12%, the mean values of the major diameter, intermediate diameter and minor diameter were found to be 24.65 mm, 18.11 mm and 15.46 mm respectively. The geometric mean diameter and sphericity were found to be 18.48 mm and 0.769 at moisture content of 4.78 ± 0.28% and 19.01 mm and 0.775 at 24.17 ± 0.12% moisture content respectively.

Compressive stress

The relationship between stress and moisture content can be found in figure 2. Compressive stress decreased linearly from 2MPa at 5.00% moisture content to 0.8MPa at 24.00% moisture content. The decrease in compressive stress with moisture content may be due to the fact that, as the kernels absorb moisture, they become softer and the forces acting would be minimum leading to reduction in stress. Compressive stress was found to have the following relations with moisture content:

$Y = -0.062x + 2.2897 \qquad R^2 = 0.9958$

Similar decreasing trend was observed with moisture increase in the determination of the strength for barley kernels under uni-axial compression (Bargale *et al.*,1995) three cultivars of whole snap bean (Bay *et al.*, 1996) aegyptiaca nut (Mamman *et al.*, 2005) filbert nut and kernel (Pliestic *et al.*, 2006) African nutmeg (Burubai *et al.*, 2007), barley grains that were quasi-statically loaded in horizontal and vertical orientations (Tavakoli *et al.*, 2009) wheat grains (Gorji *et al.*, 2010) Sc 704 corn variety (Seifi and Alimardani, 2010) and brown rice (Bagheri *et al.*, 2011).

Compressive strain

The relationship between compressive strain and moisture content is found in figure 2. The compressive strain decreased from 0.0085mm/mm at 5.00% moisture content to 0.002mm/mm at 24.00% moisture content. The relationship between compressive strain and moisture content may be given by:

$Y = -0.0003x + 0.0106 \qquad R^2 = 0.9642$

Young's modulus

Figure 3 indicates the relationship between Young's Modulus and moisture content with a decreasing trend. Young's modulus decreased non-linearly from 2000MPa at 5.00% moisture content to 100MPa at 24.00% moisture content. The relationship between Young's modulus and moisture content may be expressed by the following regression equation:

$Y = -7.308x^2 + 117.72x + 1536.7 \qquad R^2 = 0.9576$

Table 1. Dimensions of kernels used for the compression test at moisture contents of 5 and 24%w.b.

Moisture content (%w.b)	Mean length (mm)	Mean width (mm)	Mean thickness (mm)	Mean equivalent diameter (mm)	Mean sphericity
5	24.17	17.55	14.95	18.48	0.769
24	24.65	18.11	15.46	19.01	0.775

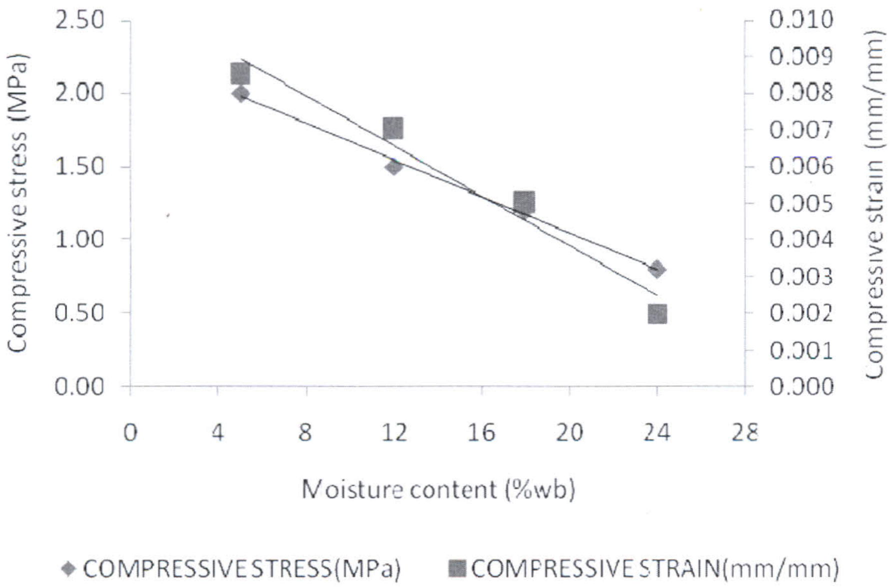

Fig. 2. Relationship between compressive stress, compressive strain and moisture content.

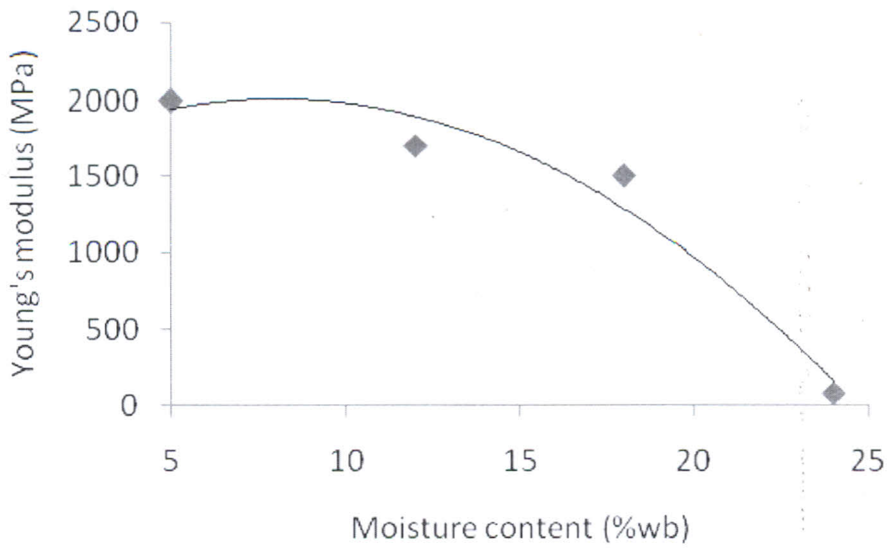

Fig. 3. Relationship between Young's Modulus and moisture content.

The values found in this study is consistent with the results obtained by Afkari-Sayyah and Minaei (2004) who found Young's modulus of wheat kernels to range from 486 to 1631 MPa and to correlate inversely with increasing moisture. According to Afkari-Sayyah and Minaei (2004) a range of 230 to 4100 MPa has been reported by different authors for the modulus of elasticity of food materials with a mean standard error of 172 MPa (Mohsenin, 1978; Arnold and Robert, 1969; Bargale, *et al.*, 1995; Afkari-Sayyah and Minaei, 2004). The results of this study fall within this range. Other researchers such as Mamman *et al.* (2005) for aegyptiaca nut, Burubai *et al.* (2007) for African nutmeg seedcoat, Hemery *et al.* (2010) for wheat bran, Abbaspour-Fard *et al.* (2012) for pumpkin seed also found Young's modulus to decrease with moisture content increase.

Crushing energy

The relationship between crushing energy and moisture content is shown in figure 4. Crushing energy increased non-linearly with moisture content from 6mJ at 5.00% moisture content to 135mJ at 24.00% moisture content.

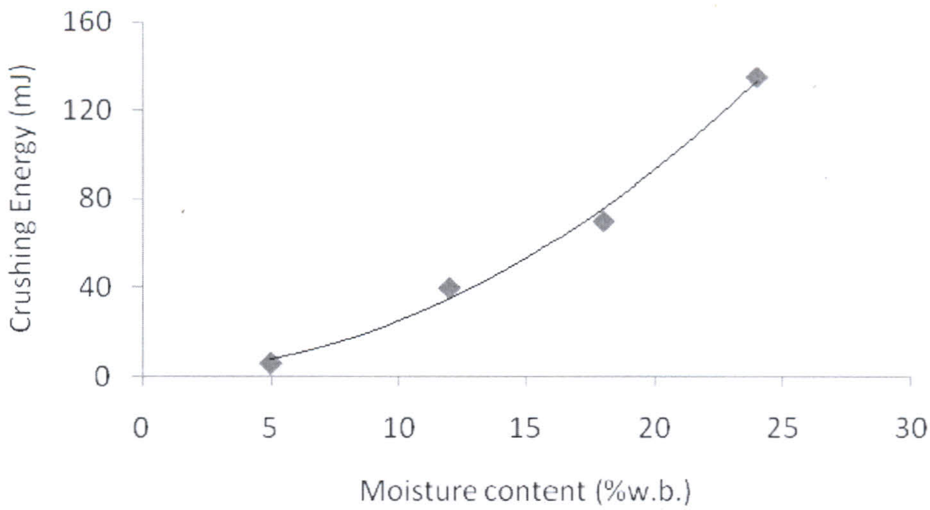

Fig. 4. Relationship between crushing energy and moisture content.

The reason for the increase in crushing energy may be that, as moisture increases, cohesive forces within the kernels increase and as a result, their resistance to cracking also increases. This would reduce compressive efficiency and may lead to increased cost of cracking. The relationship between crushing energy and moisture content may be expressed by the following equation:

$Y = 0.0002x^2 + 0.0001x + 0.0008$ $\quad R^2 = 0.9925$

In a similar research by Tarighi *et al.* (2011) involving corn seeds, rupture energy values were found to increase from 59 to 135 mJ as the moisture content increased from 5.15 to 22.00% d.b.

Crushing energy was found to range from 24mJ to 42.70mJ for horizontal and vertical orientations of paddy rice (Zareiforoush *et al.*, 2010). The increasing trend obtained in this study was similarly observed by other researchers including Singh and Goswami (1998) for cumin seeds, Burubai *et al.* (2007) for African nutmeg, Altuntas and Yildiz (2007) for faba beans, Saiedirad *et al.* (2008) for cumin seeds, Tavakoli *et al.* (2009) for barley grains, Gorji *et al.* (2010) for wheat grains, Seifi and Alimardani (2010) for Sc 704 corn variety and Tarighi *et al.* (2011) for corn grains. However, other researchers have found the crushing energy to decrease with decreasing moisture content (Mamman *et al.*, 2005 for aegyptiaca nut; Unal *et al.*, 2008 for mung beans; Zareiforoush *et al.*, 2010 for two paddy rice varieties; Alhijahani and Khodael, 2011 for strawberry fruit). Bargale *et al.* (1995) in an earlier study found the energy required to cause rupture in the barley kernel to increase initially and then decreased with the moisture content increase which implies that moisture content range is an important consideration.

Engineering implications

In a bid to mechanize the various unit operations involved in the post-harvest processing of shea kernel, information and data on the behaviour of these strength properties as a function of moisture is needed. The utilisation of the data generated would save energy and promote the design and development of appropriate, effective and efficient process machines.

CONCLUSION

In this study, some compressive properties of shea kernel were investigated in the moisture content range of 5.00% to 24.00% (w.b). The following conclusions are drawn from this investigation:

The mean dimensions used for the study ranged from 24.17 to 24.65mm, 17.55 to 18.11mm, 14.95 to 15.46mm, 18.48 to 19.01mm and 0.769 to 0.775 for length, width, thickness, geometric mean diameter and sphericity respectively.

Compressive stress and compressive strain decreased linearly from 2.0 to 0.8MPa and from 0.0085 to 0.002mm/mm with increasing moisture content from 5.00% to 24.00%w.b, respectively. Young's Modulus decreased non-linearly from 2000 to 100MPa as moisture content increase from 5.00%w.b. to 24.00%w.b, while crushing energy increased non-linearly from 6 to 135mJ with a moisture content increase from 5.00% to 24.00% w.b.

REFERENCES

Abbaspour-Fard, MH., Khodabakhshian, R., Emadi, B. and Sadrnia, H. 2012. Evaluation of the Effects of some Relevant Parameters on Elastic Modulus of Pumpkin Seed and its Kernel. International Journal of Biomaterials. Article ID:271650

Afkari Sayyah, AH. and Minaeï, S. 2004. Behavior of Wheat Kernels under quasi-static Loading and its Relation to Grain Hardness. J. Agric. Sci. Technol. 6:11-19.

Akaaimo, DI. and Raji, AO. 2006. Some Physical and Engineering Properties of *prosopis africana* Seed. Journal of Biosystems engineering. 95:197-205.

Alhijahani, HS. and Khodael, J. 2011. Some Physical Properties of Strawberry (Kurdistan variety). World Applied Science Journal. 13(2):206-212.

Altuntas, E. and Karadag, Y. 2006. Some Physical and Mechanical Properties of Sainfoin (*Onobrychis sativa Lam.*), Grasspea (*Lathyrus sativus L.*) and Bitter vetch (*Vicia ervilia L.*) Seeds. Journal of Applied Sciences. 6(6):1373–1379.

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(1):174-183.

Aremu, AK. and Nwannewuihe, HU. 2011. Specific Heat of ground fresh Sheanut Kernel (*Butyrospernum paradoxum*) as Affected by Particle size, Moisture content and Temperature. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS). 2(1):177-183.

Arnold, PC. and Robert A. 1969. Fundamental Aspects of Load Deformation Behaviour of Wheat Grains. Trans. ASAE, 12:104-108.

Aviara, NA., Gwandzang, MI. and Hague, MA. 1999. Physical Properties of Guna Seeds. Journal of Agricultural Engineering Research. 73:105–111.

Aviara, NA., Oluwole FA. and Haque, MA. 2005. Effects of Moisture Content on some Physical Properties of Sheanut (*Butyrospernum paradoxum*). International Agrophysics. 19:193-198.

Bargale, PC., Irudayaraj, J. and Marquist, B. 1995. Studies on Rheological Behaviour of Canola and Wheat. Journal of Agric. Engineering Research. 61:267-274.

Bagheri, I. Dehpour, MB., Payman, SH. and Zareiforoush, H. 2011. Rupture Strength of Brown Rice varieties as Affected by Moisture Content and Loading rate. Australian Journal of Crop Science. 5(10):1239-1246.

Balasubramanian, D. 2001. Physical Properties of Raw Cashew Nut. Journal of Agricultural Engineering Research. 78(3):291-297.

Bart-Plange, A. and Baryeh, EA. 2003. The Physical Properties of Category B Cocoa Beans. Journal of Food Engineering. 20(1):219-227.

Bay, APM., Bourne, MC. and Taylor, AG. 1996. Effect of Moisture Content on Compressive Strength of whole Snap bean (*Phaseolus vulgaris* L.) Seeds and Separated Cotyledons. International Journal of Food Science and Technology. 31(4):327-331.

Bekure, Z., Donlan, M., Gordon, Y. and Thomson, J. 1997. "Local to Global. The International market for Shea butter." Presented to United Nations Development Fund for Women.

Boateng, GA. 1992. Production Manual for Improved Shea Butter Processing Technology (Ghana Regional appropriate Technological service, Ghana).

Burubai, W., Ako, AJ., Igoni, AH. and Uyate, YT. 2007. Effects of Temperature and Moisture Content on the Strength Properties of African Nutmeg (*Monodora Myristica*). Bulgarian Journal of Agricultural Science. 13:703-712.

Corrêa, PC., Schwanz da Silva, F., Jaren, C., Afonso Júnior, PC. and Arana, I. 2007. Physical and Mechanical Properties in Rice Processing. Journal of Food Engineering. 79(1):137-142.

Delwiche, SR. 2000. Wheat Endosperm Compressive Strength as Affected by Moisture. Transaction of ASAE. 43(2):365-373.

Deshpande, SD., Bal, S. and Ojha, TP. 1993. Physical Properties of Soybean. Journal of Agricultural Engineering Research. 56:89-98.

Fobil, JN. 2003. "Research and Development of the Shea Tree and Its Products." Horizon International, Yale University Department of Biology <www.solutions-site.org>. Accessed January 2005. In: Canadian Journal of African Studies. 2006. 40:2.

Galedar, MN., Mohtasebi, SS., Tabatabaeefar, A., Jafari, A. and Fadaei, H. 2009. Mechanical Properties of Pistachio Nut and its Kernel under Compression Loading. Journal of Food Engineering. 95:499-504.

Gorji, A., Rajabipour, A. and Tavakoli, H. 2010. Fracture Resistance of Wheat Grain as a Function of Moisture Content, Loading Rate and Grain Orientation. Australian Journal of Crop Science. 4(6):448-452.

Hemery, YM., Mabille, F., Martelli, MR. and Rouau, X. 2010. Influence of Water Content and Negative Temperatures on the Mechanical Properties of Wheat

Bran and its Constitutive Layers. Journal of Food Engineering. 98(3):360-369.

Irtwange, SV. and Igbeka, JC. 2002. Selected Moisture Dependent Friction Properties of two African Yam bean (*sphenostylis stenocarpa*) Accessions. Applied Engineering in Agriculture. 18(5):559-565.

Isik, E. and Unal, H. 2007. Moisture-dependent Physical Properties of white speckled red Kidney Bean grains. Journal of Food Engineering. 82(2):209-216.

Kalkan, F. and Kara, M. 2011. Handling, Frictional and Technological Properties of Wheat as Affected by Moisture and Cultivar. Powder Technology. 213:116-122.

Khan, MMR., Chen, Y., Lague, C., Landry, H., Peng, Q. and Zhong, W. 2010. Compressive Properties of Hemp (*Cannabis sativa L.*) Stalks. Bisostystems Engineering. 106:315-323.

Khazaei, J. and Mann, DD. 2004. Effect of Temperature and Loading Characteristics on Mechanical and Stress Relaxation Properties of sea buckthorn Berries. Agricultural Engineering International. Vol 6.

Mamman, E., Umar, B. and Aviara, N. 2005. Effect of Moisture Content and Loading Orientation on the Mechanical Properties of *Balanites Aegyptiaca* nuts. The CIGR Ejournal Manuscript FP 04015.7:1-5.

Mohsenin, NN. 1978. Physical Properties of Plant and Animal Materials. (1st ed.). Gordon and Breach Publishing Co., New York, USA.

Moshenin, NN. 1986. Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York, USA.

Olajide, JO., Ade-Omowaye, BIO. and Otunola, ET. 2000. Some Physical Properties of Shea Kernel. Journal of Agricultural Engineering Research. 76(4):419-421.

Pliestic, S. Dobricevic, N. Filipovic, D., Gospodaric, Z. 2006. Physical Properties of Filbert Nut and Kernel. Biosystems Engineering. 93(2):173-178.

Rybiñski, W., Szot, B., Rusinek, R. and Bocianowski, J. 2009. Estimation of Geometric and Mechanical Properties of Seeds of Polish cultivars and Lines Representing Selected Species of Pulse Crops, Int. Agrophysics. 23:257-267.

Saiedirad, MH., Tabatabaeefar, A., Borghei, A., Mirsalehi, M., Badii, F. and Ghasemi Varnamkhasti, M. 2008. Effects of Moisture Content, Seed size, Loading Rate and Seed Orientation on Force and Energy Required for Fracturing Cumin Seed (*Cuminum cyminum Linn.*) under quasi-static loading. Journal of Food Engineering. 86:565-572.

Shitanda, D., Nishiyama, Y. and Koide, S. 2002. Compressive Strength Properties of Rough Rice Considering Variation of Contact Area. Journal of Food Engineering. 53:53-58.

Seifi, MR. and Alimardani, R. 2010. The Moisture Content Effect on Some Physical and Mechanical Properties of Corn (Sc 704). Journal of Agricultural Science. 2(4):125-134.

Singh, KK. and Goswani, TK. 1996. Physical Properties of Cumin Seed. Journal of Agricultural Engineering Research. 64:93-98.

Singh, KK. and Goswani, TK. 1998. Mechanical Properties of Cumin Seed (*Cuminum cyminum linn.*) under Compressive Loading. Journal of Food Engineering. 36(3):311-321.

Sirisomboon, P., Kitchaiya, P., Pholpho, T. and Mahuttanyavanitch, W. 2007. Physical and Mechanical Properties of *Jatropha curcas L.* Fruits, Nuts and Kernels. Biosystems Engineering. 97(2):201-207.

Tavakoli, H., Mohtasebi, SS., Rajabipour, A. and Tavakoli, M. 2009. Effects of Moisture Content, Loading Rate and Grain Orientation on Fracture Resistance of Barley Grain. RES. AGR. ENG. 3:85-93.

Tarighi, J., Mahmoudi, A. and Alavi, N. 2011. Some Mechanical and Physical Properties of Corn Seed (Var. DCC 370). African Journal of Agricultural Research. 6(16):3691-3699.

Thioune, O., Ahodikpe, D., Dieng, M., Diop, AB., Ngom, S. and Lo, I. 2000. Inflammatory Ointment from Shea Butter and Hydro Alcoholic Extract of *Khaya sengalensis* Barks (cailcederat) Dakar Med. 45(2):113-6.

Unal, H., Isik, E., Izli, N. and Tekin, Y. 2008. Geometric and Mechanical properties of Mung Bean (*Vigna Radiata* L.) Grain: Effect of Moisture. International Journal of Food Properties. 11(3):585-599.

Zareiforoush, H., Komarizadeh, MH. and Alizadeh. MR. 2010. Mechanical Properties of Paddy Grains under Quasi-static Compressive Loading. New York Science Journal. 2010:3(7):40-46.

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