Physical Properties of the Selected Varieties of Melon (*Citrullus lanatus*)

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Abstract: This study determined some physical properties of two varieties of melon (*Bara* and *Sewere*) using standard methods of evaluation. Properties determined include dimensional, gravimetric and frictional properties. These properties were investigated at 9.83 and 6.73% moisture content wet basis. *Sewere* had the highest axial dimension (14.50, 9, 1.36 mm) for length, width and thickness respectively while *Bara* had 14.08, 8.34 and 1.17 mm respectively. *Bara* has the highest Geometric mean diameter (4.35-6.75mm), while *Sewere* has 4.15-6.62mm. *Sewere* has the highest arithmetic mean diameter which ranged from 6.77-9.47mm while *Sewere* ranged from 6.77-9.07mm. The sphericity of *Bara* and *Sewere* ranged from 0.31-0.49 and 0.29-0.46 respectively while bulk density ranged from 296.65 to 312.81 kg/m3 and 309.16 to 406.94 kg/m^3 respectively. The true density and porosity of *Bara* is higher than that of *Sewere* and it ranged from 1414.08 to 1580.32 kg/m^3 and 79.02 to 80.42% respectively, while the true density and porosity of *Sewere* ranged from 759.15 kg/m^3 to 119.72 kg/m^3 and 47.18 to 65.88% respectively. The highest coefficient of static friction of 0.62 was obtained on plywood followed by glass with a value of 0.42 while stainless steel has the least coefficient of static friction with a value of 0.34 for *Bara*. Similarly, *Sewere* has the highest value of 0.55 on plywood followed by stainless steel with a value of 0.45 while glass has the least coefficient of static friction with a value of 0.40. The angle of repose of *Bara* ranged from 23.02 to 29.09^0 while *Sewere* ranged from 29.28^0 to 37.37^0. The knowledge of physical properties is essential as guide in design and development of various post harvest handling equipment.

Keywords: *Bara, Sewere,* dimensional properties, gravimetric properties and frictional properties

1. Introduction

The various varieties of melon include sweet melon, round melon, muskmelon, casaba, cantaloupe and winter melon (Nayar and Singh, 1998; Robinson and Decker-Walters, 1997). Melon was first described by Linné 1753 in Species planetarum. It is a member of the family Cucurbitaceae represented by some 118 genera and 825 species (Jeffrey, 1990). The family includes pumpkins, squashes, gourds, watermelon, loofah and several weeds. Melon is divided into two subspecies, C. melo ssp. agrestis and C. melo ssp. melo, differentiated by the pubescence on the female hypanthium. Ssp. melo has spreading hairs, and ssp. agrestis appressed hairs (Kirkbride, 1993). *Cucumis melo* includes a wide range of cultivars. Although crosses outside the species are sterile, intraspecific crosses are generally fertile, resulting in a confusing range of variation (Purseglove, 1968). Early taxonomic work including melon was made by Naudin (1859) and Coignaux (1881). The taxonomy of the cultivars is complex and has only recently been reviewed and clarified by Pitrat *et al.* (2000).

Kirkbride classified wild Cucumis in his monograph, 1993.

Melon (*Citrullus lanatus*) is mainly grown for its oily seed, the seeds are prepared for consumption by parching and pounding to free the kernels of the seed coat. The kernels are milled into a whitish paste which is used in soups and stews. The seeds (including seed coat) are also roasted and served as a snack. The oil is suitable for cooking, making of soap and illumination and can also it can readily be refined into superior products for table use. It is of better quality and higher value than cotton seed oil. The melon agronomic and other agricultural management practices adopted by producers in Nigeria do not differ from those for a seed crop. Following harvest, the more robust and good looking seeds are selected and reserved for the next planting season. Processing and storage practices are often inadequate resulting in poor germination and seedling vigour. Therefore, farmers usually prefer high seed rates melons, followed with thinning where seedling emergence is impressive, a practice that is

not only laborious but also wasteful (Egunjobi and Adebisi, 2004).

Africa is lacking behind in the development and designing of Agricultural machineries to solve main challenges affecting agricultural development like production of basic post harvest and processing equipment (Aremu *et al.,* 2014; Ogunlade *et al.,* 2016; Jaiyeoba *et al.,* 2016 a and b; Jaiyeoba and Ogunlade, 2017; Ogunlade *et al.,* 2018; Oladimeji *et al.,* 2019). In designing and developing an equipment for the processing of agricultural materials or product which requires handling from the time the product is harvested to the marketing stage, there are some information on physical properties of such crop or produce which serve as an information in designing and construction of farm agricultural machinery. Physical properties of biological material such as melon seeds have unique characteristics which set them apart from other engineering materials. The irregular shape of most biological materials complicates the analysis of their behavior (Bart-Plange *et al.,* 2012). Thus, the main objective of this study was to determine the physical properties of the selected varieties melon.

2. Material and Methods

Sample Preparation: Two varieties of melon, namely *Bara* and *Sewere* used in the study were procured from Bodija market at Ibadan, Oyo state, Nigeria. The samples were cleaned to remove foreign materials, and broken or immature seeds.

Determination of Physical Properties

The physical properties determined include dimensional properties (including length, width, thickness, geometric mean diameter, arithmetic mean diameter, sphericity, surface and Volume), and gravimetric properties (including mass, thousand seed mass, true density, bulk density porosity) and frictional properties (including angle of repose and coefficient of friction)

i. Dimensional Properties: To determine the dimensions of the melon seeds and kernels, 50 seeds and kernels was selected from the bulk sample randomly. For each seed, the three principal dimensions including length (L), width (W) and thickness (T) were measured using image processing technique. Some dimensional properties of seeds and kernels were calculated based on the length, width and thickness which are Geometric mean diameter (D_G),

Arithmetic mean diameter (D_A), Sphericity (φ), Surface (S_A) and Volume (V) were determined using Equations 1 – 5.

$$\text{Geometric mean diameter } (D_G) = \sqrt[3]{LWT} \quad (1)$$

$$\text{Arithmetric mean diameter } (D_A) = \frac{L+W+T}{3} \quad (2)$$

$$\text{Sphericity } (\varphi) = \frac{D_G}{L} \times \frac{100}{1}$$

$$(3)$$

$$\text{Surface area } (S_A) = \pi (D_G)$$

$$(4)$$

$$\text{Volume } (V) = \frac{\pi (D_G)^3}{6}$$

$$(5)$$

ii. Mass and Thousands Seeds Mass: To determine the mass of a single melon seed, kernel and shell, 100 seeds, kernels and shells from the bulk sample were selected. Mass of the selected sample was measured by a digital balance (specified) with an accuracy of 0.001 g. To determine 1000 melon seeds, kernels and shells mass, 50 seeds, kernels and shells were selected; the weight of 200 seeds, kernels and shells was measured. Then the weight of 50 seeds, kernels and then was multiplied by 5 to determine 1000 seeds, kernels and shells mass, which was done with 5 repetitions for the variety to ensure good accuracy, and also the mean and standard deviation was calculated and recorded.

iii. True density: Mass of the samples of melon seeds and kernels was measured by a digital balance (specified) with an accuracy of 0.001 g and volume of the samples of melon seeds and kernels was calculated based on using of the cylinder and distilled water. The difference in weight, in the mass of the seed (melon) and since the volume of beaker is known, the true density was obtained by dividing the weight of the seed by the volume of beaker. This was done with 5 repetitions for the variety to ensure good accuracy and also the mean and standard deviation was calculated and recorded.

iv. Bulk density: The bulk density (ρb) is the ratio of the mass sample of the melon seed to its total volume. It was determined by using a 120cm³ beaker filled with distilled water. The beaker was first weighed empty, the seed was then put poured and fill the beaker to the brim. A flat object (ruler) was used to strike off any melon seed above the beaker's top level; the beaker with its content was weighed. The difference in weight, in the mass of the seed (melon) and since the volume of beaker is known, the bulk density was obtained by dividing the weight of the seed by the volume of beaker. This was done with 5 repetitions for the variety to ensure good accuracy, and also the mean and standard deviation was calculated and recorded.

v. Porosity: Porosity as that fraction of the space in the bulk seed which is not occupied by the melon seed. It is a property of the melon seed, which depends on its bulk and particle density. It was calculated from the percentage average values of bulk and true densities. Measuring cylinder and distilled

water were used and the experiment was done with 5 repetitions for the variety to ensure good accuracy, and also the mean and standard deviation was calculated and recorded.

$$Porosity = 1 - \frac{\rho p}{\rho b} \times 100$$

(6)

Where: ρb is the bulk density of the sample, ρp is the particle density of the sample.

vi. Angle of Repose: Angle of repose was determined by using a specially repose box or constructed box with a removable front panel. The box was filled with grain, and the front panel was quickly removed which allows the grains to flow to its natural slope. The slope is a measure of angle of repose, which is calculated by taking the sine of the inclination angle (Tabatabaiefar, 2013). This was done with 5 repetitions for the variety to ensure good accuracy, and the mean, standard deviation, skewness and kurtosis was calculated and recorded.

$$Angle\ of\ Repose = Sin^{-1}(opposite/hypotenuse)$$

(8)

vii. Coefficient of static friction: It is a mechanical properties, the coefficient of static friction of the sample was found with respect to each of five structural materials which are mild steel plate, plastic plate, glass plate, plywood plate and stainless steel plate. A topless and bottomless tin was filled with melon seed and placed on an adjustable tilting plate, faced with the test surface. The cylinder tin was raised so as not to touch the surface. The structural surface with box resting on it was inclined gradually with a screw device until the box just started to slide down and the angle of tilt was read from a graduated scale which is calculated by taking the tangent of the inclination angle. This was replicated 5 times each to ensure good accuracy and the mean, standard deviation, skewness and kurtosis was calculated and recorded.

$$\mu = Tan\ \alpha$$

(9)

Where: μ is the coefficient of static friction and α is the angle of tilt in degrees.

3. Results
Physical Properties of the selected variety of melon (*Bara* and *Sewere*)
i. **Geometric properties of the two varieties of melon:** The geometric properties of the two varieties of melon are presented in Tables 1 and 2; these properties were investigated at 9.83 and 6.73% moisture content wet basis for *Bara* and *Sewere* varieties respectively. The highest axial dimension was observed from variety B (*Sewere*): 14.50, 9.00,1.36mm related to length, width and thickness respectively while variety A (*bara*) had the lowest values of length, width and thickness which are 14.08, 8.34 and 1.17 mm respectively. The dimensions of *Bara* measured at 9.83% wet basis moisture content for length, width and thickness ranges from 12.00 mm to 16.00mm, 6.90mm to 10.00mm and 0.70mm to 3.00mm respectively. The corresponding values of axial dimensions for three varieties of melon seed as reported by Davies (2009) reported mean values of length, width and thickness of three different varieties of melon seeds are 12.81,13.37 and14.50 mm, 7.02,7.22 and 8.47 mm, 2.22, 2.44 and 2.49 mm respectively. The knowledge of axial dimension of any agricultural materials is pertinent in the sense that separation of biomaterial as a unit processing operation is hinged on axial dimensions.

The mean geometric and arithmetic mean diameter, sphericity and surface area and volume were determined, *Bara* has the highest Geometric mean diameter which ranges from 4.35-6.75mm, while that of variety B ranges from 4.15-6.62mm, the corresponding value as reported by Davies (2009), *C. vulgaris* had the highest geometric and arithmetic mean diameters values of 6.25 and 6.31mm respectively. *Sewere* has the highest Arithmetric mean diameter which ranges from 6.77-9.47mm while that of variety A ranges from 6.77-9.07mm. The sphericity of *Bara* and *Sewere* ranges from 0.31-0.49 and 0.29-0.46 respectively. This is almost related to the report of the study carried out by on melon seed, the maximum value was observed for *C. lunatus*, 0.53 followed by *C.edulis*, 0.47. The minimum sphericity was noticed to be *C. vulgaris*, 0.45. Galedar *et al.*, (2008) reported sphericity for pistachio nut at moisture content of 5.83% and kernel at moisture content of 6.03% were 69.34 and 72.59% respectively which is higher than that of melon seed. According to Bal and Mishra (1988), and Garnayak *et al.* (2008) considered any grain, fruit and seed as spherical when the sphericity value is above 80 and 70%, respectively. Therefore, it can be concluded that melon seeds were not spherical based on the sphericty values obtained were less than 0.7-0.8. The surface area and volume ranges from 59.55-144.75mm^2 and 43.21-163.76mm^3 respectively while the surface area and volume of Sewere ranges from 54.12-137.64mm^2 and 37.44 – 151.84mm^3 respectively is less to the investigation made by El-Sayed *et al.*, (2001) and Koocheki *et al.* (2007) for watermelon ranged from 182.96-225.03 mm² and 182.51-220.45mm² respectively.

Table 1: Geometric properties of *Egusi* melon (Bara)

Statistics	Maximum	Minimum	Mean	SD	CV (%)
Length (mm)	16.00	12.00	14.08	0.92	6.52
Width (mm)	10.00	6.90	8.34	0.65	7.80
Thickness (mm)	3.00	0.70	1.17	0.31	26.74
Geometric mean diameter (mm)	6.79	4.35	5.12	0.42	8.19
Arithmetic mean diameter (mm)	9.07	6.77	7.87	0.41	5.21
Sphericity	0.49	0.31	0.36	0.03	8.99
Surface area (mm²)	144.75	59.55	83.05	14.27	17.18
Volume (mm³)	163.76	43.21	71.92	19.53	27.15
Moisture content (% wb)	10.46	9.24	9.83	0.50	5.07
Aspect ratio					
L/T	18.71	4.63	12.61	2.48	19.69
L/W	2.14	1.38	1.70	0.16	9.30
L/M	162.73	122.04	143.24	9.33	6.52

Table 2: Geometric properties of Egusi melon (Sewere)

Statistics	Maximum	Minimum	Mean	SD	CV (%)
Length (mm)	17.00	12.90	14.50	0.92	6.32
Width (mm)	11.00	5.00	9.00	0.82	9.12
Thickness (mm)	2.00	0.90	1.36	0.33	24.61
Geometric mean diameter (mm)	6.62	4.15	5.57	0.49	8.83
Arithmetic mean diameter (mm)	9.47	6.77	8.28	0.47	5.64
Sphericity	0.46	0.29	0.39	0.04	9.26
Surface area (mm²)	137.64	54.12	98.22	17.33	17.64
Volume (mm³)	151.84	37.44	92.59	24.50	26.47
Moisture content (% wb)	7.47	5.84	6.73	0.67	10.02
Aspect ratio					
L/T	17.78	6.45	11.31	2.75	24.29
L/W	2.86	1.32	1.62	0.18	11.34
L/M	252.51	191.61	215.33	13.62	6.32

Gravimetric and Frictional properties of *Bara* and *Sewere* melon seeds: Tables 3 and 4 shows the frictional and gravimetric properties of *Bara* and *Sewere* melon seeds respectively. These properties include bulk density, true density and porosity, 1000 seed mass, angle of repose, angle of static friction, and coefficient of static friction on three structural surface (glass, stainless steel and plywood) and terminal velocity. The bulk density *Sewere* ranged from 309.16 to 406.94 kg/m^3 which was higher than that of *Bara* which ranged from 296.65 to 312.81 kg/m^3. The true density and porosity of *Bara* is higher than that of *Sewere* and it ranged from 1414.08 to 1580.32 kg/m^3 and 79.02 to 80.42% respectively, while the true density and porosity of *Sewere* ranged from 759.15 kg/m^3 to 119.72 kg/m^3 and 47.18 to 65.88% respectively. This is similar to the report on true and bulk densities values of melon seeds, nutmeg and simarouba which were significantly different at 0.05 level (Burubai *et al.*, 2007). El-Sayed *et al.* (2001) reported the mean value of porosity for watermelon, for the three varieties studied; for sarakhey, 51.68%, for kolaleh, 39.14% and for red, 47.80%. The values

obtained for porosity is solely dependent on the true and bulk density. This can be furthered explained from obtained result that aeration through the seeds will be more pronounced in Bara (79.88%) compared to *Sewere* (54.98%). The frictional properties determined were angle of static friction which was conducted using three structural surfaces, it shows that plywood has the highest coefficient of static friction with a value of 0.62 followed by glass with a value of 0.42 while stainless steel has the least coefficient of static friction with a value of 0.34 for Bara, also for Sewere, plywood has the highest value of 0.55 for coefficient of static friction which is followed by stainless steel with a value of 0.45 while glass has the least coefficient of static friction with a value of 0.40. Tabatabaiefa (2003) observed similar trend in the static coefficient of friction of wheat. He recorded lowest static coefficient of friction on glass surface, followed by galvanized iron and lastly plywood. *Bara* has the lowest angle of repose which ranged from 23.02 to 29.09^0 while that of *Sewere* ranges from 29.28^0 to 37.37^0 respectively. The corresponding angle of repose for pistachio nut and kernel were less

than melon seeds (Sirisomboon *et al*., 2007; Galedar *et al*., 2008). The mass of 1000seeds is 96.15g for Bara and 95.10 for Sewere which is slightly similar as the result gotten by (Davies 2009) for the 1000seeds mass of melon for three different varieties which are 94.0g, 110g and 98g. The mean terminal velocity is 4.57 and 4.74 for *Bara* and *Sewere* respectively, this is similar to the investigation made by (Tunde-Akintunde 2007) who recorded the mean value of terminal velocity 4.53m/s at 4.06%(db) and 5.1m/s at 16.81%(db) for *Bara* and *Sewere* seed.

Table 3: Gravimetric and frictional properties of *Egusi* melon (Bara)

Statistics	Maximum	Minimum	Mean	SD	CV (%)
Bulk density (kg/m³)	312.81	296.65	303.01	8.61	2.84
True density (kg/m³)	1580.32	1414.08	1508.23	85.28	5.65
Porosity (%)	80.42	79.02	79.88	0.75	0.94
1000seed mass (g)	96.15	96.15	96.15	0.00	0.00
Angle of repose (□)	29.09	23.02	27.01	2.36	8.74
coefficient of internal friction	0.56	0.42	0.51	0.05	9.98
Angle of static friction (□)					
Glass	23.00	18.00	20.60	1.95	9.46
Stainless steel	19.00	16.00	17.80	1.64	9.23
Plywood	32.00	27.00	29.40	1.95	6.63
Coefficient of static friction					
Glass	0.42	0.32	0.38	0.04	10.32
Stainless steel	0.34	0.29	0.32	0.03	9.82
Plywood	0.62	0.51	0.56	0.04	7.96
Terminal velocity (ms⁻¹)	4.97	4.13	4.57	0.90	19.69

Table 4: Gravimetric and frictional properties of *Egusi* melon (Sewere)

Statistics	Maximum	Minimum	Mean	SD	CV (%)
Bulk density (kg/m³)	406.94	390.16	399.37	8.51	2.13
True density (kg/m³)	1192.72	759.15	920.89	236.82	25.72
Porosity (%)	65.88	47.18	54.98	9.73	17.70
1000seed mass (g)	95.10	95.10	95.10	0.00	0.00
Angle of repose (□)	37.37	29.28	32.94	3.45	10.48
coefficient of internal friction	0.76	0.56	0.65	0.09	13.28
Angle of static friction (□)					
Glass	22.00	19.00	20.50	1.22	5.97
Stainless steel	24.00	22.50	23.20	0.57	2.46
Plywood	29.00	25.00	27.00	1.58	5.86
Coefficient of static friction					
Glass	0.40	0.34	0.37	0.02	6.51
Stainless steel	0.45	0.41	0.43	0.01	2.75
Plywood	0.55	0.47	0.51	0.03	6.82
Terminal velocity (m/s)	5.04	4.32	4.74	0.83	17.51

4.0   Conclusions

The following conclusions are drawn from the investigation on the physical properties of two varieties of melon seeds (*Bara* and *Sewere*) at moisture content of 9.83% and 6.73% respectively.

i.   The mean length, width, thickness, arithmetic and geometric mean diameter, sphericity, surface area, volume, 1000unit mass, for *Bara* and *Sewere* of melon respectively are as follows: 14.08mm and 14.50mm, 8.34mm and 9.00mm, 1.17mm and1.36mm, 7.87mm and 8.28mm, 5.12mm and5.57mm, 0.36 and 0.39 83.05mm² and 98.22mm², 71.92mm³ and 92.59mm³.

ii.   The mean porosity, true and bulk densities, angle of repose were investigated, the obtained results were 96.15 and 54.98 kg/m³, 1508.23 and 920.89 kg/m³, 303.01 and 399.37 kg/m³, 32.94, 27.01 º and 29.3-36º for *Bara* and *Sewere* respectively.

iii.   The coefficient of static friction of melon was determined on three different surfaces namely, glass, plywood and stainless steel, plywood was observed to be the highest coefficient of static friction for the two varieties.

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References
1. Adeniran, M. O. and G. F. Wilson (2001). "Seed type classification of egusi Melon in Nigeria" Paper presented at the 6th African Horticultural Symposium, University of Ibadan, 9th – 25th, July.
2. Ahmadi, and Mollazade, K. (2009): Some Physical and Mechanical Properties of Fennel Seed (Floeniculum bulgane) Journal of Agric. Sci., 1(1):66-75.
3. Ajibola, O.O., Eniyemo, S.E., Fasina, O.O. and Adeko K.A. (1990). Mechanical extraction of oil from melon seeds. Journal of Agricultural Research, 45: 1.
4. Aremu, D. O., Babajide, N. A. and Ogunlade, C. A. (2014). Comparison of some Engineering Properties of Common Cereal Grains in Nigeria: *International Journal of Engineering and Science Invention* (IJESI). Vol. 3(4): 10-14. ISSN (online): 2319-6734 and ISSN (print): 2319-6726.
5. Asoegwu, S., Ohanyere, S., Kanu, O., and Iwueke C., (2006). Physical properties of African oil bean seed (Pentclethramacropyll). Agric Eng. Int, The CIGR e-journal Manuscript FP 05006, VIII.
6. Bal, S., and Mishra, H.S., (1988). Engineering properties of soybeans, proceedings of the National seminar and utilization in India, 146-165.
7. Bankole, S.A. (2010). Effect of lemon grass powder and essential oil on mould deterioration and aflatoxin contamination on melon seeds. African Journal of Biotechnology, 3: 52–59.
8. Bart-Plange, A., Mohammed-Kamil A.P., Addo A. and Teye E. (2012): Some Physical and Mechanical Properties of cashew nuts and kernel grown in Ghana. International Journal of Science and Nature. 3(2): 406-415.
9. 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): pp. 63-65.
10. Egbe DE, Mayah TF, Ebot EG, Egbe PA, Abraham JP (2015). Performance evaluation and improvement on a melon seed shelling machine. World Journal of Agricultural Sciences and Engineering 1: 1-10.
11. El-Sayed., et al., (2001). Characteristic attributes of the peanut for its separation. Int. Agrophysics, 15, 225-230 Eng., 97(2): 201-207.
12. Francesca, R. (2013): Melon History, Production and Trade. *ZIPMEC Journal,* 3 (4): 46 – 54.
13. Galedar, M.N., A. Jafari and A. Tabatabaeefa, 2008. Some physical properties of wild pistachio nut and kernel as a function of moisture content. J. Phy. Environ. Agr. Sci., 22: 117-124.
14. Garnayak DK, Pradhan RC, Naik SN, Bhatnager N (2008). Moisture dependent physical properties of Jatropha seeds (Jatropha curcas L). Ind Crops Products; 27: 123-29. http://dx.doi.org/10.1016/j.indcrop.2007.09.001.
15. Jaiyeoba, K. F. and Ogunlade, C. A. (2017). Some Physical Properties of Fermented Locust Bean Produced in Four different locations in Nigeria. *International Journal of Research in Engineering and Applied Sciences (IJREAS).* Vol. 7 Issue 4, April-2017, pp. 38~44. Available online at http://euroasiapub.org/some-physical-properties-of-fermented-locust-bean-produced-in-four-different-locations-in-nigeria/.
16. Jaiyeoba, K. F., Jekayinfa, S. O., Ogunlade, C. A., Oke, A. M. and Apata, M. M. (2016b). Physical and Thermal Properties of Mango (*Mangifera indica)* Seeds. *Science Focus* Vol. 21 (1) 2016 pp. 126 – 132. Faculty of Pure and Applies Sciences, LAUTECH, Ogbomosho, Printed in Nigeria.
17. Jaiyeoba, K., Jekayinfa, S. O., Oloyede, C. T., Ogunlade, C. A. and Oke, A. M. (2016a). Moisture-dependent physical properties of cocoa (*Theobroma cacao*) pods. *International Journal of Organic Agriculture Research & Development,* Volume 13, Sept. (2016): Pp 40 – 46.
18. Jeffrey C. A., (1980): Review of the cucurbitaceae. J Linn Soc; 81: 233-47.
19. John, G.V. (2009): The New Oxford Book of Food plants (Second Edition), Oxford University Press, p. 134 ISBN.0-19-954946-x.
20. Klenin, N.L., Popov I. F and Sukun V.A (1985): Agricultural machine Theory of operation, Computation of controlling parameters and the conditions of operation. A merind publishing Co. PVT. Ltd., New Delhi, Pp 633.
21. Kochhar, A and Hira, C.K. (1997): Nutritional and cooking evaluation of green gram cultivars. Journal of food sciences and Technology, 34(4): 328-330.
22. Koocheki, A., Razavi, S.M., Milani, F., Meghadam, T.M., Abedini, M., Alamatiyan, S. and Izadkhah, S. (2007): Physical properties of watermelon seed as a function of moisture content and variety. Int. Agrophysic., 21 (4): 349.
23. Lgathinathane, K.G. and Hana H. D. (1998): The physical measurement of quality in canned peas.

Common wealth sciences and industry organization (Australia) Bul. 154.

24. Matouk, A.M., Radwan S. M., M.M. El-kholy, and T. R. Ewies (2004): Determination of seeds density and porosity for some cereal crops. Misr. J. Of Agric. Eng., 21(3): 623 -641.

25. Mohsein, N. N. (1986). Physical properties of plant and animal materials. New York: Gordon and Breach Science Publishers.

26. Nalbandi, H., Ghassanizadeh, K. and Selledlor, R.A. (2010). Seed Moisture Dependent on Physical Properties of Turgenia latifolia: Criteria for sorting Journal of Agricultural Technology., 6(1):1-10.

27. Odigboh, E.U. (1999). Impact Egusi Shelling Machine. Transactions of American Society of Engineers (ASAE), Volume 22, Issue 6, pp. 1264-1269.

28. Ogbonna, P.E. and Obi, I.U. (2007). The influence of poultry manure application and plant density on growth and yield of Egusi melon (*Colocynthis citrullus*) on the Nsukka Plains of South eastern Nigeria. Agro-Science, Volume 1, Issue 1, pp. 22-129 .

29. Ogunlade, C. A., Alaka, A. C., Babajide, N. A., Aremu, D. O., Anjorin, S. E. and Akinyele, O. A. (2016). Moisture-dependent physical properties of popcorn. *Journal of Multidisciplinary Engineering Science and Technology.* Vol. 3(2): 4069-4073.

30. Ogunlade, C. A., Jaiyeoba, K. F., Oke, A. M. and Onojah, P. E. (2018). Dimensional Properties of *Garcinia kola* Nuts as Influenced by Moisture Content. International Journal of Research and Reviews, 5 (7): 176 – 181.

31. Ojeih, G. C., Oluba, O. M., Ogunlowo, Y. R., Adebisi, K. E Eidangbe, G. O. and Isiosio, I. O. (2007). Physiochemical Properties and Fatty Acid Composition of *Citrullus lanatus* (Egusi Melon) Seed Oil, Journal of Biological Sciences, 8 (4): 814 – 817.

32. Ojo, A.A., Bello, L.L. and Vange, T. (2002): Evaluation of Egusi melon (*Colocynthis citrullus* L.) Accessions. Tropicat Oil Seed, Journal, Volume 7, pp. 25-29.

33. Oladimeji, S. T., Oyerinde, A. S. and Ogunlade, C. A. 2019. Development and Evaluation of a Melon Shelling Machine. Adeleke University Journal of Engineering and Technology [AUJET] 2 (2): 149-155. http://aujet.adelekeuniversity.edu.ng/index.php/aujet/article/view/77.

34. Olaniyi, J.O. (2008). Growth and seed yield response of egusi melon to nitrogen and phosphorus fertilizers application. American-Eurasian Journal of Sustainable Agriculture 2: 255-260.

35. Sabbah, M. A., S. N. Solimananbd M. O Yehia (1994): Physical properties of Egyptian pady rice related to steeping process Misr. J. Of Agric Engineering,11(1):248 – 260.

36. Sabo H, Sadou H, Amoukou IA, Alma MM, Sidikou RS. (2015): Determination and comparison of the amino acid composition of seventeen *Lagenaria siceraria* varieties and one variety of *Citrullus colocynthis* seed flours. Pakistan Journal of Nutrition 14: 100-106.

37. Sirisomboon, P., P. Kitchaiya, T. Pholpho and W. Mahuttanyara, (2007). Physical and mechanical properties of jatropha fruit, nuts and kernels. Biosys.

38. Sitkei, G. (1987): Mechanics of Agricultural Materials. Developments in Agricultural Engineering 8. ELSEVIER, Amsterdam, Oxford, New York, Tokyo. 294 – 295.

39. Tabatabaiefar (2003): Determination of Angle of Repose. American Society of Agricultural Engineering Technologies, Volume 35 Issue 1, Pp. 93 – 98.

40. Tunde-Akintunde TY, Akintunde BO (2007). Effect of moisture content and variety on selected physical properties of beniseed. Manuscript FP 07 021. Vol IX. November,2007.

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