Benha Journal of Applied Sciences (BJAS) **print: ISSN 2356–9751**
Vol. (10) Issue (6) (2025), (77-82) **online: ISSN 2356–976x**

http://bjas.bu.edu.eg
Applied Agriculture Science

Physical, Mechanical and Chemical Properties of Pomegranate Fruits

Wesal M.Abd El-Aziz[1], El-Sayed G.Khater[1], Adel H.Bahnasawy [1]and Mohamed M.El Kholy[2]
[1] Agriculture Engineering Dept., Faculty of Agriculture, Benha University, Egypt
[2] Researcher Head, Agriculture Engineering Res. Inst., Agric. Res. Center, Egypt
E-mail: wesalabdelrahman@gmail.com

Abstract

This work focuses on studying the physical, mechanical, and chemical characteristics of pomegranate fruits (Manfaloty and Wonderful varieties). Results from this study can to be used in the design and development of specific machine. The length, width and thickness of pomegranate fruits were 7.31 and 7.53, 6.85 and 7.20 and 6.67 and 6.20 cm, respectively, for Manfaloty and Wonderful varieties. The geometric mean diameter and arithmetic mean diameter of the pomegranate fruits were 6.92 and 6.94 and 7.21 and 7.22 cm, respectively, for both Manfaloty and Wonderful varieties. The pomegranate fruits mass was 279.55 and 306.01 g for Manfaloty and Wonderful varieties, respectively. The volume of fruits was 276.1 2 and 288.51 cm^3 for Manfaloty and Wonderful varieties, respectively. The true and bulk densities of the pomegranate fruits were 1012.42 and 921.51 and 1060.66 and 927.08 kg m^{-3} for Manfaloty and Wonderful varieties, respectively. The moisture content of pomegranate fruit was 84.37 and 86.01 % for Manfaloty and Wonderful varieties, respectively. The repose angle of pomegranate fruits was 41.33 and 43.07º for Manfaloty and Wonderful varieties, respectively. The cutting force and crushing force of pomegranate fruits were 23.72 and 27.26 and 25.80 and 26.64 kg for Manfaloty and Wonderful varieties, respectively. The firmness of pomegranate fruits was 46.45 and 47.99% for Manfaloty and Wonderful varieties, respectively. The total soluble solids (TSS) of pomegranate fruits were 15.17 and 16.09 % for Manfaloty and Wonderful varieties, respectively.

Keywords: Pomegranate, physical characteristics, mechanical characteristics, dimensions, surface area, volume, density, TSS

1. Introduction

Pomegranate (*Punica granatum L.*) is grown in many countries and regions since ancient time. Several good genotypes were discovered since that. Pomegranate, fruits, leaves, flowers and roots are used in several medical purposes **[22]**. The fruits are the edible part in the pomegranate plant because it contains sugars, vitamins, polysaccharides, polyphenols, and minerals **[13] and [4]**. Pomegranate has a high capacity of antioxidant which is very beneficial for human health. Also, it has high concentration of phenolic compounds and antimicrobial **[24], [32] and [16]**. The total area that is cultivated with pomegranate in Egypt is 85415 feddan (35589.6 ha) with production of 269070 tons **[7]**.

Physical and chemical properties of pomegranate fruits are very important for understanding the behavior necessary for the design of equipment's for harvesting, processing, transportation, separating and packing. Keeping all above facts in view, the present project work was planned to study the physical properties of pomegranate and to study the chemical properties of pomegranate In this study some physical and chemical properties such as moisture content, weight of fruit, weight of arils and peels, volume of fruit, specific gravity, overall dimensions (length, width and thickness), consumable matter, inconsumable matter and TSS, pH value, ascorbic acid etc. was determined and results are78.95%, 204.54 gm, 129.12 gm and 75.38 gm, 242 cm3, 0.844 gm/cm^3,7.07 cm, 6.79 cm and 6.75 cm, 63.10%, 38.8%, 15.7o Brix, 3.5, 11.4 respectively **[10]**.

The physical properties of the agricultural products are very important in studying the efficiency of the machine that is used in sorting, sizing and grading the biomaterials. Also, to develop these machines, the physical properties are required **[25] and [1]**. Agricultural materials mixing, conveying, fluidization and separation processes required the geometric dimensions of the agricultural materials to determine the performance and capacity of these machines **[14] , [27] and [29]**. Also, hoppers, drying chambers and storage bins required the information about density and specific gravity of the biomaterials that will be handled in them **[21] and [19]**.

[35] studied the weight and volume of the pomegranate fruits, they found that the weight ranged from 103.38 to 505.00 g and the volume ranged from 99.41 to 547.88 cm^3. They also found that the density, peel thickness averaged of 0.91 to 1.04 g cm^{-3} and 1.60 to 6.01 mm, respectively.

Export problems are mainly from the lack of physical and mechanical properties knowledge. Physical, mechanical and chemical properties are

important in many problems associated with the design of machines and the analysis of the behaviour of the product during agricultural processing operations such as handling, planting, harvesting, milling, threshing, cleaning, grading, sorting and drying, therefore, the main aim of this investigation is to study some physical, mechanical and chemical properties of the pomegranate fruits.

2. Materials and methods

Experimental of work was done at Agricultural and Bio-Systems Engineering Department, Faculty of Agriculture, Moshtohor, Benha University, during the period of November and December, 2023.

2.1. Materials

Pomegranate (*Punica granatum L.*) fruits of the Manfaloty and Wonderful varieties were purchased from the local farms at the beginning of the season (Sep., 2024). Pomegranate fruits were used in this study to measure and determine the physical, mechanical and chemical properties.

2.2. Methods

2.2.1. Physical characteristics

For each pomegranate fruit, three principle dimensions; length (L), width (W) and thickness (T) were measured using a digital caliper (Model TESA 1p65- Range 0-150 mm ± 0.01 mm, Swiss) and the average of dimensions was taken.

The geometric mean diameter (Dg) of samples was determined by using the following formula according to **[17]**:

$$D_g = \sqrt[3]{LWT} \quad (1)$$

Where:

L = Length of pomegranate fruit, mm

W = Width of pomegranate fruit, mm

T = Thickness of pomegranate fruit, mm

The arithmetic mean diameter (D_a) was calculated from the three principal dimensions using the following equation **[34]**:

$$D_a = \frac{L + W + T}{3} \quad (2)$$

The fruit surface area (S) was calculated by using the following formula according to **[33]**:

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

The sphericity of the pomegranate fruit (ϕ) was determined by using the following equation **[34]**:

$$\varphi = \frac{D_g}{L} \times 100 \quad (4)$$

The weight of pomegranate fruit was conducted by balance (Model Vibra – Range 0-12000 g ± 0.01 g, Japan). Toluene displacement method was used for measuring the volume (V_m). The true density was a calculated of a pomegranate weight per unit volume. Bulk density was calculated as the ratio of the weight of the fruits to its container volume.

The area of criteria projected (ACP) was conducted as according to **[23]**:

$$APC = \frac{AP_1 + AP_2 + AP_3}{3} \quad (5)$$

Where:

AP_1 is the area projected on the vertical direction L, mm^2

AP_2 is the area projected on the vertical direction T, mm^2

AP_3 is the area projected on the vertical direction W, mm^2

The volume of oblate spheroid (V_{osp}) and ellipsoid (V_{ellip}) shapes were determined as:

$$V_{osp} = \frac{4\pi}{3}\left(\frac{L}{2}\right)\left(\frac{W}{2}\right)^2 \quad (6)$$

$$V_{ellip} = \frac{4\pi}{3}\left(\frac{L}{2}\right)\left(\frac{W}{2}\right)\left(\frac{T}{2}\right) \quad (7)$$

The measurement moisture level of pomegranate is conducted according to **[5]**. Three pomegranate samples (3 samples) were chosen and then weighed using balance. Drying oven (Model 655F Cat. No. 13-245-655, range 50 to 300 ºC, Canada) at 70°C until a constant weight was used to determine the moisture level.

2.2.2. Mechanical Properties:

2.2.2.1. Repose angle of pomegranate fruits

The repose angle of the product was determined by measuring the angle between the horizontal level and inclined side of the cone that formed by the free fall of the pomegranate fruits.

2.2.2.2. Coefficient of friction

The coefficient of friction between pomegranate fruits and a wall is the ratio of the normal force to the friction force along the wall surface. It is dependent on the tubers stored and the type of surface (Galvanized steel, Plywood and Concrete) in contact with fruits **[6] and [18]**.

2.2.2.3. Total firmness

Taylor pressure and Magness tester determined fruit firmness with a 7/18" plunger.

2.2.3. Chemical characteristics:

2.2.3.1. Total Soluble solids

The total soluble solids (TSS%) was determined by using a refractometer (ATAGO Co.,

LTD., Tokyo, Japan) and the result was expressed as a percentage (%).

2.2.3.2. Total and reducing sugars

Total and reducing sugars were conducted calorimetrically by Nelson arsenate–molybdate colorimetric method **[26]**. Non-reducing sugars were determined by the difference between total sugars and reducing sugars.

3. Results and discussions

3.1. Physical characteristics

Table (1) shows the dimensions of pomegranate fruits, geometric mean diameter, and arithmetic mean diameters of the pomegranate fruits for different pomegranate varieties. The results showed that the length of pomegranate fruits value was 7.31 ± 2.65 and 7.53 ± 2.54 cm for Manfaloty and Wonderful varieties, respectively. The width of pomegranate fruits value was 6.85 ± 2.44 and 7.20 ± 2.41 cm for Manfaloty and Wonderful varieties, respectively, respectively. Also, the thickness of pomegranate fruits value were 6.67 ± 2.07 and 6.20 ± 2.16 cm for Manfaloty and Wonderful varieties, respectively. These dimension data are very important in handling, packing and storage capacity calculation. These results are in agreement previous findings by **[2]**.

The results also indicate that the geometric mean diameter and arithmetic mean diameter of pomegranate fruits were 6.92 ± 1.32 and 6.94 ± 1.45 and 7.21±1.51 and 7.22±1.22 cm, respectively, for Manfaloty and Wonderful varieties. The results indicate that, the peel thickness of pomegranate fruits value was 5.59 ± 1.69 and 5.03 ± 1.70 mm for Manfaloty and Wonderful varieties, respectively. These results are in agreement with **[28]**.

Table (1): Dimensional characteristic of pomegranate fruits for different pomegranate varieties.

Properties	Pomegranate Variety	
	Manfaloty	Wonderful
Length (cm)	7.31±2.65	7.53±2.54
Width (cm)	6.85±2.44	7.20±2.41
Thickness (cm)	6.67±2.07	6.20±2.16
Geometric mean diameter (cm)	6.92±1.32	7.21±1.51
Arithmetic mean diameter (cm)	6.94±1.45	7.22±1.22
Peel thickness (mm)	5.59±1.69	5.03±1.70

Table (2) shows the fruit weight, volume, density, surfac e area, sphericity, moisture content and peel percentage of the pomegranate fruits for different pomegranate varieties. The results showed that the pomegranate fruits weight was 279.55 ± 6.03 and 306.01 ± 5.74 g for Manfaloty and Wonderful varieties, respectively. The volume of fruits was 276.12 ± 4.91 and 288.51 ± 4.99 cm^3 for Manfaloty and Wonderful varieties, respectively. The true and bulk densities of the pomegranate fruits were 1012.42 ± 19.88 and 921.51 ± 13.05 and 1060.66 ± 20.56 and 927.08 ± 13.01 kg m^{-3} for Manfaloty and Wonderful varieties, respectively. The pomegranate fruits surface area was 150.57 ± 4.11 and 163.01 ± 5.55 cm^2 for Manfaloty and Wonderful varieties, respectively. These results are in agreement with **[3]**.

The sphericity pomegranate fruit was 94.74 ± 4.90 and 95.68 ± 4.81 % for Manfaloty and Wonderful varieties, respectively. These results are in agreement with **[15]**. The moisture content of pomegranate fruit was 84.37±3.73 and 86.01±4.50 % for Manfaloty and Wonderful varieties, respectively. The moisture content of peel was 69.92±4.28 and 82.76±3.71 % for Manfaloty and Wonderful varieties, respectively. The peel percentage of pomegranate fruits value was 39.52 ± 3.21 and 37.61 ± 2.63 % for Manfaloty and Wonderful varieties, respectively.

Table (2): Weight, volume, density, surface area, sphericity, moisture content and peel percentage of the pomegranate fruits for different pomegranate varieties.

Properties	Pomegranate Variety	
	Manfaloty	Wonderful
Weight (g)	279.55±6.03	306.01±5.74
Volume (cm^3)	276.12±4.91	288.51±4.99
True density (kg m^{-3})	1012.42±19.88	1060.66±20.56
Bulk density (kg m^{-3})	921.51±13.05	927.08±13.01
Surface area (cm^2)	150.57±4.11	163.01±5.55
Sphericity (%)	94.74±4.90	95.68±4.81
Moisture content (%, w.b)	84.37±3.73	86.01±4.50
Moisture content of peel (%, w.b)	69.92±4.28	82.76±3.71
Peel Percentage (%)	39.52±3.21	37.61±2.63

Table (3): The projected area, criteria projected area, oblate spheroid volume and ellipsoid shape volume of the pomegranate fruits for different pomegranate varieties.

Properties	Pomegranate Variety	
	Manfaloty	Wonderful
Projected area perpendicular to L direction (cm^2)	50.07±2.17	54.22±3.52
Projected area perpendicular to W direction (cm^2)	48.76±2.09	46.69±2.37
Projected area perpendicular to T direction (cm^2)	45.69±1.64	44.64±2.13
Criteria projected area (cm^2)	48.17±3.11	48.51±3.20
Oblate spheroid volume (cm^3)	179.51±5.28	204.29±6.32
Ellipsoid shape volume (cm^3)	174.79±4.51	175.91±5.07

Table (3) shows the projected area, criteria projected area, oblate spheroid volume and ellipsoid shape volume of the pomegranate fruits for different pomegranate varieties. The results showed that the projected area perpendicular to L direction of pomegranate fruits were 50.07 ± 2.17 and 54.22 ± 3.52 cm^2 for Manfaloty and Wonderful varieties, respectively. The projected area perpendicular to W direction of pomegranate fruits were 48.76 ± 2.09 and 46.69 ± 2.37 cm^2 for Manfaloty and Wonderful varieties, respectively, and the projected area perpendicular to T direction of pomegranate fruits was 45.69 ± 1.64 and 46.69 ± 2.37 cm^2 for Manfaloty and Wonderful varieties, respectively. The results also indicate that, the criteria projected area of pomegranate fruits were 48.17 ± 3.11 and 48.51 ± 3.20 cm^2 for Manfaloty and Wonderful varieties, respectively.

The oblate spheroid volume and ellipsoid shape volume of pomegranate fruits were 179.51±5.28 and 204.29±6.32 and 174.79±4.51 and 175.91±5.07 cm^3 for Manfaloty and Wonderful varieties, respectively

3.2. Mechanical properties:

Table (4) shows repose angle, cutting force, crushing force, firmness and coefficient of static friction of the pomegranate fruits for different pomegranate varieties. The results showed that the repose angle of pomegranate fruits was 41.33 ± 3.06 and 43.07 ± 2.52º for Manfaloty and Wonderful varieties, respectively. The cutting force and crushing force of pomegranate fruits were 23.72 ± 2.64 and 27.26 ± 3.89 and 25.80 ± 3.11 and 26.64 ± 3.74 kg for Manfaloty and Wonderful varieties, respectively. The firmness of pomegranate fruits was 46.45 ± 5.47 and 47.99 ± 4.80 % for Manfaloty and Wonderful varieties, respectively. The results also indicate that the coefficient of static friction for the pomegranate fruits was 0.62± 0.15 and 0.65± 0.13, 0.64± 0.14, 0.68± 0.22 and 0.71± 0.20 and 0.72± 0.18 for Manfaloty and Wonderful varieties, respectively, for galvanized steel, plywood and concrete surfaces.

Table (4): Some mechanical properties of the pomegranate fruits for different pomegranate varieties.

Properties		Pomegranate Variety	
		Manfaloty	Wonderful
Repose angle (º)		41.33± 3.06	43.07± 2.52
Cutting force (kg)		23.72±2.64	27.26±3.89
Crushing force (kg)		25.80±3.11	26.64±3.74
Firmness (%)		46.45±5.47	47.99±4.80
Coefficient of static friction	Galvanized steel	0.62± 0.15	0.65± 0.13
	Plywood	0.64± 0.14	0.68± 0.22
	Concrete	0.71± 0.20	0.72± 0.18

3.3. Chemical properties:

Table (5) shows total soluble solids, dry matter, total sugar, reducing sugar and non-reducing sugar of the pomegranate fruits for different pomegranate varieties. It could be seen that the total soluble solids (TSS) of pomegranate fruits were 15.17 ± 2.74 and 16.09 ± 3.03 % for Manfaloty and Wonderful varieties, respectively. The dry matter of pomegranate fruits was 32.15 ± 4.66 and 33.99 ± 3.61 % for Manfaloty and Wonderful varieties, respectively. The total sugar of pomegranate fruits was 13.94 ± 2.54 and 14.01 ± 3.08 % for Manfaloty and Wonderful varieties, respectively. These results are in agreement with **[30]**.

The reducing sugar of pomegranate fruits was 10.33 ± 2.67 and 10.26 ± 2.44 % for Manfaloty and Wonderful varieties, respectively. The non-reducing sugar of pomegranate fruits was 3.61±1.05 and 3.75±0.94 % for Manfaloty and Wonderful varieties, respectively.

Table (5): Some chemical properties of the pomegranate fruits for different pomegranate varieties.

Properties	Pomegranate Variety	
	Manfaloty	Wonderful
Total soluble solids (TSS), %	15.17± 2.74	16.09± 3.03
Dry matter, %	32.15±4.66	33.99±3.61
Total sugar, %	13.94±2.54	14.01±3.08
Reducing sugar, %	10.33±2.67	10.26±2.44
Non-Reducing sugar, %	3.61±1.05	3.75±0.94

4. Conclusions

An experimental study was carried out successively to determine the physical, mechanical, and chemical properties of the pomegranate fruits for different pomegranate varieties. The obtained results can be summarized as follows:

The length, width and thickness of pomegranate fruits were 7.31 and 7.53, 6.85 and 7.20 and 6.67 and 6.20 cm, respectively, for Manfaloty and Wonderful varieties. The geometric mean diameter and arithmetic mean diameter of the pomegranate fruits were 6.92 and 6.94 and 7.21 and 7.22 cm, respectively, for Manfaloty and Wonderful varieties. The pomegranate fruits mass was 279.55 and 306.01 g for Manfaloty and Wonderful varieties, respectively. The volume of fruits was 276.12 and 288.51 cm^3 for Manfaloty and Wonderful varieties, respectively. The true and bulk densities of the pomegranate fruits were 1012.42 and 921.51 and 1060.66 and 927.08 kg m^{-3} for Manfaloty and Wonderful varieties, respectively. The moisture content of pomegranate fruit was 84.37 and 86.01 % for Manfaloty and Wonderful varieties, respectively. The repose angle of pomegranate fruits was 41.33 and 43.07 for Manfaloty and Wonderful varieties, respectively. The cutting force and crushing force of pomegranate fruits were 23.72 and 27.26 and 25.80 and 26.64 kg for Manfaloty and Wonderful varieties, respectively. The firmness of pomegranate fruits was 46.45 and 47.99% for Manfaloty and Wonderful varieties, respectively. The total soluble solids (TSS) of pomegranate fruits were 15.17 and 16.09 % for Manfaloty and Wonderful varieties, respectively.

5. References

[1] Abdalgawad, G.A., Khater, E.G., Bahnasawy, A.H. and Mosa, M.M. (2023). Potato tubers quality as affected by modified atmospheric conditions and package type during storage. Misr J. Ag. Eng., 40 (3): 227-242.

[2] Abdel-salam, F.F., Moharram, Y.G. and El-Zalaki E.M. (2018). Physical Properties and Some Bioactive Compounds of Four Pomegranate Cultivars (*Punica granatum* L.) Grown in Egypt. *Alex. J. Fd. Sci. & Technol., 15(1), 77-89*

[3] Al-Maiman, S.A., and Ahmad, D. (2002). Changes in physical and chemical properties during pomegranate (Punica granatum L.) fruit maturation. Food Chemistry, 76, 437–441.

[4] Al-Said, F. A., Opara, L. U., & Al-Yahyai, R. A. (2009). Physico-chemical and textural quality attributes of pomegranate cultivars (Punica granatum L.) grown in the Sultanate of Oman. Journal of Food Engineering, 90, 129–134.

[5] ASAE Standard (1984). ASAE 5352.1.moisture measurement. American Society of Agric. Eng. 2950 Niles Road, St. Joseph, MI 49085-9659.

[6] ASAE Standard (1987). Density, specific gravity, and weight moisture relationships of grain for storage. ASAE Standards 1987: 298-305.

[7] CAPMS (2019). Annual year book for general statistics. Egypt: Central Agency for Public Mobilization and Statistics of ARE.

[8] Chandrasekar, V. and Viswanathan, R. (1999). Physical and thermal properties of coffee. J. Agric. Engng. Res., 73: 227-234.

[9] Dalvand, M.J. (2011). Physical properties of potato tubers cv. analytic cultivated in iran. Vegetable Crops Research Bulletin, 74: 117-128.

[10] Dhake, K. Jawale L.and Kumar A. (2023). Physico-chemical properties of pomegranate fruits. The Pharma Innovation Journal, 12(5): 1775-1778.

[11] Ferrara, G., Giancaspro, A., Mazzeo, A., Giove, S.L., Matarrese, A.M.S., Pacucci, C. (2014). Characterization of pomegranate (Punica granatum L.) genotypes collected in Puglia region, Southeastern Italy. Scientia Horticulturae, 178, 70–78.

[12] Gamea, G.R., Abd El-Maksoud, M.A. and Abd El-Gawad, A.M. (2009). Physical characteristics and chemical properties of potato tubers under different storage systems. Misr J. Ag. Eng., 26(1): 385- 408.

[13] Gil, M.I., Tomas-Barberan, F.A., Hess-Pierce, B., Holcroft. D.M. and Kader, A.A. (2000). Antioxidant activity of pomegranate juice and its relationship with phenolic composition and processing. Journal of Agriculture and Food Chemistry, 48, 4581-4589.

[14] [14], B.Y. and O'Callaghan J.R. (1990). Aerodynamic Properties of Grains/Straw Materials. Journal of Agricultural Engineering Research, 46: 275 – 290.

[15] Jannatizadeh A., Naderi Boldaji M., Fa-tahi1 R., Ghasemi Varnamkhasti M. and Tabatabaeefar A. (2008). Some post-harvest physical properties of Iranian apricot (Prunus armeniaca L.) fruit. International Agrophysics. 22: 125-131.

[16] Jithender, B., Vyas, D.M., Abhisha, S. and Rathod, P.J. (2017). Determination of Physical and Mechanical Properties of Pomegranate (Var. bhagwa) Fruit and Aril. Int. J Curr. Microbiol. App. Sci. 2017;6(10):879-885.

[17] Kacharu, R.P., Gupta R.K. and Alam A. (1994). Physico-Chemical Constituents and Engineering Properties of Food Crops. Scientific Publishers, Jodhpur, India, ISBN: 8172330839.

[18] Khater E.G. and Bahnasawy A.H. (2018). Effect of Storage temperature and Packages Type on The Self life and Quality of Green Beans. The 4th International Conference on Biotechnology Applications in Agriculture (ICBAA), Benha University, Moshtohor and Hurghada, 4-7 April 2018, Egypt, 663 -670.

[19] Khater, E.G. and Afify M.T. (2021). Quality characteristics and shelf life of pepper fruits as influenced by storage conditions and pepper varieties. Misr J. Ag. Eng., 38 (4): 349 – 362.

[20] Khater, E.G. and Bahnasawy A.H. (2016). Watermelon fruits properties as affected by storage conditions. Misr J. Agri. Eng., 33 (1): 101 – 122.

[21] Khater, E.G., Bahnasawy A.H. and Ali S.A. (2014). Physical and Mechanical Properties of Fish Feed Pellets. J. Food Process. Technol. 5 (10): 378. doi: 10.4172/2157-7110.1000378

[22] Lansky, E.P. and Newman, R.A. (2007). Punica granatum (pomegranate) and its potential for prevention and treatment of inflammation and cancer. Journal of Ethnopharmacology, 109, 177–206.

[23] Malcolm E.W., Tappan J.H. and Sister F.E. (1986). The size and shape of typical sweet potatoes. Trans. ASAE. 29: 678-682.

[24] Malik, A., Afaq, F., Sarfaraz, S., Adhami, V.M., Syed. D.N. and Mukhtar, H. (2005). Pomegranate fruit juice for chemoprevention and chemotherapy of prostate cancer. Proceedings of the National Academy of Sciences of the United States of America, 102(41), 14813-14818.

[25] Mohsenin, N.N. (1986). Physical properties of plant and animal materials second revised. Gordon and Breach Sci. Publ., New York.

[26] Nielsen, S.S. (2010). Phenol-sulfuric acid method for total carbohydrates, in Food Analysis Laboratory Manual. (Berlin: Springer), 47–53. doi:10.1007/978-1-4419-1463-7-6

[27] Oje, K., Alonge A. F. and Adigun Y. J. (2001). Some Engineering Properties of Shear Nut Relevant to Mechanical Processing. Ife Journal of Technology, 10(2): 17 – 20.

[28] Patel, M.B., Nath A. and Mayani J.M. (2018). A study on physical properties of pomegranate (*Punica granatum* L., Punicaceae) fruits. International Journal of Chemical Studies, 6(5), 1460-1463.

[29] Perez-Alegria, L.R., Ciro H.J. and Abud V. L.C. (2001). Physical and Thermal Properties of Parchment Coffee Bean. Transactions of the American Society of Agricultural Engineers, 44(6):1721-1726.

[30] Piret S.R., Kotkas K., Rosenberg V., Kulp M., Kuhtinskaja M. and Vaher M. (2020). Analysis of Total Phenols, Sugars, and Mineral Elements in Colored Tubers of Solanum tuberosum L. Foods, 9(1862): 1-12.

[31] Razavi S.M.A., Emadzadeh B., Rafe A., Mohammad A.A. (2007). The physical properties of pistachio nut and its kernel as a function of mois-ture content and variety: Part I. Geometrical properties. J. Food Eng., 81: 209-217.

[32] Reddy, M.K., Gupta, S.K., Jacob, M.R., Khan, S.L., and Ferreira, D. (2007). Antioxidant, antimalarial and antimicrobial activities of tannin rich fractions, ellagitannins and phenolic acids from Punica granatum L.. Planta Medica, 73(5), 461–467.

[33] Sacilik, K.A., Öztürk, R. and Keskin, R. (2003). Some physical properties of hemp seed. *Biosystems engineering*, *86*(2):.191-198.

[34] Sunmonu M.O., Iyanda M.O., Odewole M.M and Moshood A.N. (2015). Determination of Some Mechanical Properties of Almond Seed Related to Design of Food Processing Machines. Department of Agricultural and Biosystems Engineering, University of Ilorin, Nigeria. Nigerian J. Technolo. Develo., 12(1): 22-26.

[35] Vahid, A., Khodayar, H. and Mehdi, S. (2009). Physical and chemical properties of pomegranate (*Punica granatum* L.) fruit in maturation stage. *American-Eurasian J. Agric. Environ. Sci*. 6(4): 411-416.