International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2025: 7.089

Physical Characterisation of Three Nigerian Tomato Varieties (Cobra, Roma, and Owezu): Size and Shape

P. E. Ajayi[1], B. O. Oyefeso[2]

[1]Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Nigeria

[2]Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Nigeria
Corresponding Author Email: *peaceajayi1997[at]yahoo.com*

Abstract: ***Physical properties determine how a fruit behaves during sorting, packaging, and when placed on a conveyor belt. Yet the physical profiles of many Nigerian tomato cultivars remain undocumented. This study characterised the size and shape of three tomato varieties; Cobra, Roma, and Owezu grown at Soilless Farm Lab, Ogun State, Nigeria. The physical characteristics of sixty fruits per variety (180 in total) were determined namely; linear dimensions, mean diameters, projected and surface areas, volume, mass, density, porosity, and sphericity. The results showed Roma was the longest (67.27±7.37 mm) and heaviest (83.31±23.10 g) gravimetrically of the three varieties. Cobra was the most spherical (0.99). Owezu recorded the highest porosity (0.63±0.04). These differences in the properties translate to how each variety is sorted, packed, and transported.***

Keywords: tomato, physical properties, size and shape, post-harvest handling

1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most cultivated and widely consumed vegetables in Africa and Nigeria's commercial production constitutes about 65% of the total tomato production in the West Africa continent [1]. Yet, the nation, Nigeria records approximately 25 to 42% post-harvest losses, mainly due to damage during harvesting, post-harvest handling, as well as during transportation due to poor transportation facilities when moving between farms and markets [2]–[4]. As a result, it is important to design good packaging materials and machines that helps to reduce this rate of loss. Hence, the need to study the physical traits of these fruits

The physical characteristics such as length, width, thickness, mass, volume, density and sphericity are not mere traits, but are the parameters through which the design of agricultural machines are orchestrated and are also used to determine the grading tolerances and the speed at which conveyors move [5]. Sphericity helps to determine the uniformity in shape of a fruit while the density and porosity helps to determine how the fruits are packaged. These properties help in getting the needed data to develop properly fitted locally made machineries.

Only some researchers have studied a few tomato varieties that are actively cultivated in Nigeria separately, however, no comprehensive study have been carried out on the selected species under the same measurement protocol. This study aims at filling that gap. The specific objectives of the study were to; measure the linear dimensions, mean diameters, projected and surface areas, sphericity, aspect ratio, volume, mass, true and bulk density and porosity of Cobra, Roma and Owezu tomato fruits and to find out the level of variation among the three varieties in the above measurements.

2. Materials and Methods

2.1 Sample Collection

The tomato fruits (Cobra, Owezu and Roma) as shown in Figures 1 to 3 were obtained from Soilless Farm Lab, Farm City, Kurere village of Ewekoro Local Government, Ogun State, Nigeria. 180 samples (60 samples per variety) were selected, linear dimension measured and their physical properties obtained and recorded.



Figure 1: Cobra variety



Figure 2: Roma variety



Figure 3: Owezu variety

2.2 Measurement of Physical Properties

The length, width and thickness of the fruits were measured using a digital Vernier calliper (Carrera Precision model CP5912-T 12 Inch Titanium Digital LCD calliper micrometre, China ± 0.150 mm) and the mass of the fruits measured using a digital weighing balance (Adventurer-pro AV 264, model series; 8727164144, Switzerland ± 0.0001 g). The mean diameters which are the arithmetic mean diameter (AMD), geometric mean diameter (GMD), equivalent mean diameter

(EMD) and the projected areas along the length, width and thickness, surface area, true and bulk density, porosity, sphericity, aspect ratio and assumed volume were computed using equations 1 to 15 [5]–[8]. Sample mass to the volume of displaced water was used to estimate the true density, while the mass of the fruit filled to the brim in known volume of container was used to determine bulk density.

$$AMD = \frac{L+W+T}{3} \quad (1)$$

$$GMD = (LWT)^{\frac{1}{3}} \quad (2)$$

$$EMD = \left[L \times \left(\frac{W+T}{2}\right)^2\right]^{\frac{1}{3}} \quad (3)$$

$$PA_L = \frac{\pi \times L \times W}{4} \quad (4)$$

$$PA_W = \frac{\pi \times W \times W}{4} \quad (5)$$

$$PA_T = \frac{\pi \times T \times W}{4} \quad (6)$$

$$S_a = \pi\, GMD^2 \quad (7)$$

$$\rho_b = \frac{m_t - m_c}{V_c} \quad (8)$$

$$\rho_t = \frac{m}{V_d} \quad (9)$$

$$P = \left(1 - \frac{\rho_b}{\rho_t}\right) \quad (10)$$

$$\varphi = \frac{\sqrt[3]{LWT}}{L} \quad (11)$$

$$A_s = \frac{W}{L} \quad (12)$$

$$V_p = 4.19 \times \left(\frac{W}{2}\right)^2 \left(\frac{L}{2}\right) \quad (13)$$

$$V_o = 4.19 \times \left(\frac{L}{2}\right)^2 \left(\frac{W}{2}\right) \quad (14)$$

$$V_e = 4.19 \times \left(\frac{GMD}{2}\right)^3 \quad (15)$$

3. Results and Discussion

The complete data values for the physical properties of Cobra, Roma and Owezu varieties are presented in Tables 1, 2 and 3 respectively, which include dimensional parameters, projected area, surface area, assumed volumes, shape index, mass, densities and porosity. The values stated in the tables have been selected variety-by-variety for a direct comparison on each property as shown in Tables 4 to 6. Both are used in the following discussion.

Table 1: Physical properties of the Cobra tomato variety

Parameter	Mean	SD	Maximum	Minimum	CV (%)
Length (mm)	53.28	5.12	60.84	42.48	9.6
Width (mm)	53.68	4.76	62.8	42.58	8.86
Thickness (mm)	51.54	4.44	59.44	40.15	8.62
AMD (mm)	52.83	4.77	61.02	41.74	9.03
GMD (mm)	52.82	4.76	61.01	41.72	9.02
EMD (mm)	52.83	4.77	61.03	41.73	9.02
PA_L (mm²)	2246.28	19.11	3001.2	1420.81	0.85
PA_W (mm²)	2263.01	17.76	3097.89	1424.16	0.79
PA_T (mm²)	2172.95	16.6	2932.14	1342.89	0.76
Surface area (mm²)	8766.78	71.3	11695.66	5469.19	0.81
Volume, prolate (mm³)	81782.66	18937.12	117290.4	45244.14	23.15
Volume, oblate (mm³)	81283.39	19356.78	117271.05	44653.11	23.81
Volume, ellipsoid (mm³)	78493.69	17978.18	113910.52	43005.87	22.9
Sphericity	0.99	0.93	1	0.98	93.94
Aspect ratio	1.01	0.93	1.03	1	92.28
Fruit mass (g)	82.24	18.52	124.55	45.26	22.51
True density (g/cm³)	1.01	0.56	2.49	0.52	54.99
Bulk density (g/cm³)	0.42	0.04	0.51	0.36	9.94
Porosity	0.52	0.16	0.83	0.21	31.63

Table 2: Physical properties of the Roma tomato variety

Parameter	Mean	SD	Maximum	Minimum	CV (%)
Length (mm)	67.27	7.37	78.98	51.38	10.96
Width (mm)	48.86	4.82	61.96	39.61	9.87
Thickness (mm)	46.71	4.76	59.49	35.6	10.19
AMD (mm)	54.28	5.65	66.81	42.21	10.41
GMD (mm)	53.55	5.53	66.28	41.7	10.33
EMD (mm)	53.55	5.53	66.28	41.74	10.33
PA_L (mm²)	2581.71	27.92	3843.92	1598.62	1.11
PA_W (mm²)	1874.98	18.25	3015.57	1232.41	0.97
PA_T (mm²)	1792.52	18.03	2895.35	1108.89	1.01
Surface area (mm²)	9008.28	96.14	13801.34	5464.67	1.11
Volume, prolate (mm³)	86085.64	24294.51	152330.48	48433.27	28.22
Volume, oblate (mm³)	118750.35	33593.04	186679.26	63117.96	28.28
Volume, ellipsoid (mm³)	82270.68	23202.05	145815.38	43578.94	28.2
Sphericity	0.82	0.75	0.84	0.81	94.26
Aspect ratio	0.73	0.65	0.78	0.77	90.03
Fruit mass (g)	83.31	23.1	150.85	46.78	27.73
True density (g/cm³)	0.97	0.11	1.13	0.8	9.42
Bulk density (g/cm³)	0.43	0.11	0.53	0.34	12.25
Porosity	0.55	0.11	0.64	0.42	14.6

Table 3: Physical properties of the Owezu tomato variety

Parameter	Mean	SD	Maximum	Minimum	CV (%)
Length (mm)	59.87	6.54	73.62	42.72	10.93
Width (mm)	48.29	5.52	58.21	36.87	11.43
Thickness (mm)	46.47	5.24	58.79	36.87	11.29
AMD (mm)	51.55	5.77	63.54	38.82	11.19
GMD (mm)	51.22	5.74	63.15	38.72	11.21
EMD (mm)	51.23	5.74	63.15	38.72	11.1
PA_L (mm²)	2271.51	28.39	3366.19	1237.23	1.25
PA_W (mm²)	1832.36	23.96	2661.59	1067.8	1.3
PA_T (mm²)	1763.31	22.77	2688.11	1067.8	1.29
Surface area (mm²)	8244.24	103.74	12533.45	4711.84	1.25
Volume, prolate (mm³)	75335.47	22432.11	130651.69	35623.17	29.77
Volume, oblate (mm³)	93277.16	27186.62	165239.3	39948	29.14
Volume, ellipsoid (mm³)	72455.32	21534.24	131953.49	33918.62	29.72
Sphericity	0.85	0.87	0.85	0.9	102.63
Aspect ratio	0.81	0.84	0.79	0.86	104.63
Fruit mass (g)	75.03	21.97	141.54	35.71	29.28
True density (g/cm³)	1.03	0.13	1.38	0.91	13.25
Bulk density (g/cm³)	0.37	0.04	0.45	0.31	10.18
Porosity	0.63	0.04	0.71	0.57	6

3.1 Size Characterisation

The variety with the greatest mean length was Roma (67.27±7.37 mm) followed by Owezu (59.87±6.54) while Cobra (53.28±5.12 mm) showed the shortest of the three. However, Cobra had the greatest width (53.68±4.76 mm) and thickness (51.54±4.44 mm) of the three. The values gotten from the dimensions were consistent with shape characteristics with Cobra's near-equal length, width and thickness indicates a rounded fruit while Roma and Owezu showed more elongated shapes [5]. Coefficients of variation (CV) for the dimensional parameters were all in a relatively small range of 8.62–11.43% for all the three varieties, showing that fruit size within each cultivar was consistent and this is desirable for establishing fixed grading tolerances in machine design.

3.2 Shape Characteristics

The varieties were most distinctly separated by sphericity. Cobra had a mean sphericity value of 0.99 (spherical), whereas Roma had the lowest value of 0.82 (elongated) with Owezu at 0.85 given a medium elongated value. Also, the Cobra variety recorded a mean aspect ratio value of 1.01, while Roma recorded a mean value of 0.73 and Owezu, a mean value of 0.81 were even further from a perfect sphere. This shows that the cobra variety is the most spherical of all the three varieties and this helps to ascertain the fruit's orientation during handling and packaging, thus, reducing the amount of void space and the risk of impact damage between fruit [9], [10].

Table 4: Shape indices and assumed-volume estimates for Cobra, Roma, and Owezu, collated side by side from Tables 1–3 for comparison (mean ± SD)

Parameter	Cobra	Roma	Owezu
Sphericity	0.99 ± 0.93	0.82 ± 0.75	0.85 ± 0.87
Aspect ratio	1.01 ± 0.93	0.72 ± 0.65	0.81 ± 0.84
Assumed volume, prolate spheroid (mm³)	81782.66 ± 18937.12	86085.64 ± 24294.51	75335.47 ± 22432.11
Assumed volume, oblate spheroid (mm³)*	81283.39 ± 19356.78	118750.35 ± 33593.04	93277.16 ± 27186.62
Assumed volume, ellipsoid (mm³)	78493.69 ± 17978.18	82270.68 ± 23202.05	72455.32 ± 21534.24

Alongside the volume measurement using water displacement method, three assumed volumes were derived from the linear dimensions; prolate spheroid, oblate spheroid, and ellipsoid, each treating the fruits as a separate ideal solid. These parameters find its importance in the development of a grading and sorting system where there the outer dimension are used in knowing which shape best fits the system. For Cobra variety, the three estimates converge closely 81,782.66 mm³ (prolate), 81,283.39 mm³ (oblate) and 78,493.69 mm³ (ellipsoid), which is a direct consequence of the sphericity of the cultivar (0.99). Owezu on the other hand showed a wider spread from 72,455.32 mm³ (ellipsoid) to 93,277.16 mm³ (oblate) which is consistent with its intermediate sphericity (0.85). Unlike others, Roma diverges the most; its oblate estimate of 118,750.35 mm³ runs way above the ellipsoid estimate (82,270.68 mm³). This occurs because the oblate formula is heavily dependent of the length of the cultivar and the length (67.27 mm) exceeds the width (48.86 mm). This pattern of great divergence has also been reported for the assumed-volume models for products like Tacca tubers [8], potato tubers [11] and Tannia cormels [12]. These results showed that the dimension-based volume stays more reliable for a more perfectly spherical variety like Cobra but have a great deviation for more elongated variety like Roma and the ellipsoid estimate which draws on all the three axes through the GMD is a good figure to report.

3.3 Gravimetric Properties and Density

Roma had the highest mean mass at 83.31±23.10 g, ahead of Cobra (82.24±18.51 g) and Owezu (75.03±21.97 g). The large standard deviation of Roma on mass (23.1 g) suggests that the cultivar has a higher size variation when compared with the other two cultivars [13]. Bulk density was highest for Roma (0.43±0.11 g/cm³) and lowest for Owezu (0.37±0.04 g/cm³), while true density ranged from 0.52–2.49 g/cm³ for Cobra, 0.80–1.13 g/cm³ for Roma, and 0.91–1.38 g/cm³ for Owezu. The differences in these densities directly reflect the variation in packaging efficiency, storage volume and load optimisation for transport [14].

Table 5: Mass and density of Cobra, Roma, and Owezu tomato fruits, collated side by side for comparison (mean ± SD)

Parameter	Cobra	Roma	Owezu
Fruit mass (g)	82.24 ± 18.52	83.31 ± 23.10	75.03 ± 21.97
True density (g/cm³)	1.01 ± 0.56	0.97 ± 0.11	1.03 ± 0.13
Bulk density (g/cm³)	0.42 ± 0.04	0.43 ± 0.11	0.37 ± 0.04

3.4 Surface Area, Projected Area, and Porosity

Despite Roma being the most elongated variety, it recorded the largest mean surface area (9,008.28±96.14 mm²) whereas Owezu recorded the lowest one (8244.24±103.74 mm²). Unlike the other two, whose projected area in all three orientations differed, the projected area of Cobra along all three orientations was quite uniform, which showed a consistent nature with its near-spherical geometry, while Roma showed the most spread out with its projected area along the length (2,581.71 mm²) significantly greater than the projected area along the width (1,874.98 mm²) and thickness (1,792.52 mm²) showing a similar result for Tannia cormels [12].

Table 6: Surface area, projected area, and porosity of Cobra, Roma, and Owezu tomato fruits, collated side by side for comparison (mean ± SD)

Parameter	Cobra	Roma	Owezu
Surface area (mm²)	8,766.78 ± 71.30	9,008.28 ± 96.14	8,244.24 ± 103.74
Projected area, length axis (mm²)	2,246.28 ± 19.11	2,581.71 ± 27.92	2,271.51 ± 28.39
Projected area, width axis (mm²)	2,263.01 ± 17.76	1,874.98 ± 18.25	1,832.36 ± 23.96
Projected area, thickness axis (mm²)	2,172.95 ± 16.60	1,792.52 ± 18.03	1,763.31 ± 22.77
Porosity	0.52 ± 0.16	0.55 ± 0.11	0.63 ± 0.04

The density followed an inverse order to the porosity: Owezu exhibited the highest value of porosity (0.63±0.04), whereas Roma and Cobra had porosities of 0.55±0.11 and 0.52±0.16, respectively. The higher the porosity the more air-filled and loose the tissue structure of the variety is, causing weaker mechanical resistance of the product to injury when handled [15].

4. Conclusion

The three varieties vary significantly in size and shape, hence; have to be handled specifically in a different way, rather than a one-size fitness approach. Roma is the longest and the heaviest, with a more elongated form. Cobra variety was the most spherical and well suited to be handled by handling equipment. Owezu is the most porous, a profile that suits a damageable and softer texture. With this study, the physical characteristics provide machine designers and post-harvest handlers in Nigeria with specific information for the various cultivars to design sorting, grading and packing systems.

References

[1] J. Athanasius, "Rate of tomato fruits consumption in Nigeria," Information Guide Nigeria, 2019.
[2] I. K. Arah, H. Amaglo, E. K. Kumah, and H. Ofori, "Pre-harvest and post-harvest factors affecting harvested tomato fruits' quality and shelf life: a mini-review," International Journal of Agronomy, vol. 2015, pp. 1–6, 2015.
[3] M. Qasim, A. U. Samman Liaqat, H. Khan, H. Nasir, M. S. Awan, and K. Akbar, "Postharvest factors affecting shelf life and quality of harvested tomato fruits: a comprehensive review," Scholars Journal of Agriculture and Veterinary Sciences, vol. 9, no. 6, pp. 65–69, 2022.
[4] J. Roy, M. N. Islam, S. Yasmin, and M. S. Mahomud, "Improvement of quality and shelf-life of tomato fruits with aloe vera coatings enriched with tulsi extract," Applied Food Research, vol. 4, no. 2, p. 100449, 2024.
[5] F. Uba, E. O. Esandoh, D. Zogho, and E. G. Anokye, "Physical and mechanical properties of locally cultivated tomato fruits in Sunyani, Ghana," Scientific African, vol. 10, p. e00616, 2020.
[6] M. Moradi, M. Rahmatian, and M. H. Raoufat, "Physical properties of three varieties of tomato, a comparative study," Thai Journal of Agricultural Science, vol. 50, no. 2, pp. 87–95, 2017.
[7] W. A. E. Mahmoud, R. K. Mahmoud, and A. S. Eissa, "Determining some physical and mechanical properties for designing a tomato fruit cutting machine," Agricultural Engineering International: CIGR Journal, vol. 24, no. 4, pp. 131–142, 2022.
[8] B. O. Oyefeso, "Size and shape characterisation of Tacca involucrata tubers," LAUTECH Journal of Engineering and Technology, vol. 15, no. 1, pp. 34–38, 2021.
[9] L. Luo, Y. Tang, Q. Lu, X. Chen, P. Zhang, and X. Zou, "A vision methodology for harvesting robot to detect cutting points on peduncles of double overlapping grape clusters in a vineyard," Computers in Industry, vol. 99, pp. 130–139, 2018.
[10] Y. Tang, M. Chen, C. Wang, L. Luo, J. Li, G. Lian, and X. Zou, "Recognition and localization methods for vision-based fruit picking robots: a review," Frontiers in Plant Science, vol. 11, p. 510, 2020.
[11] A. Tabatabaeefar, "Size and shape of potato tubers," International Agrophysics, vol. 16, no. 4, pp. 301–305, 2002.
[12] B. O. Oyefeso and A. O. Raji, "Physical characteristics and development of mass and volume models for Tannia (Xanthosoma sagittifolium) cormels," Agricultural Engineering International: CIGR Journal, vol. 26, no. 2, pp. 176–183, 2024.
[13] C. E. J. Armstrong, P. Previtali, P. K. Boss, V. Pagay, R. G. V. Bramley, and D. W. Jeffery, "Grape heterogeneity index: assessment of overall grape heterogeneity using an aggregation of multiple indicators," Plants, vol. 12, no. 7, p. 1442, 2023.
[14] U. L. Opara and I. O. Ogra, "Postharvest science and technologies for handling pomegranates (Punica granatum L.)," in Recent Advances in Postharvest Technologies, Volume 2: Postharvest Applications, Berlin/Heidelberg: Springer, 2024, pp. 65–128.
[15] A. Barayman, "Porosity in agriculture: impacts on vegetables and fruits quality," Studocu, 2024.