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Comparative analysis of the physical properties of two varieties of periwinkle relevant to the design of processing equipment

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Abstract: The physical properties of agricultural products are essential in designing machines, equipment, and systems for efficient processing operations. Two periwinkle varieties, *viz Tympanotonus fuscatus* (Linnaeus, 1758) and *Pachymelania aurita* O. F. Müller, 1774, were utilised in this study to investigate and determine their physical properties relevant to the design of efficient processing equipment. The geometric (axial dimensions, mean diameters, surface area, sphericity, aspect ratio) and gravimetric (bulk and true densities, mass, and porosity) properties were measured. The averages for the major diameter, arithmetic mean diameter, geometrical mean diameter, and surface area were highest in the *T. fuscatus* variety. In contrast, the minor diameter, sphericity, and aspect ratio were highest in the *P. aurita* variety. The average bulk and true densities, porosity, and average periwinkle weight for *T. fuscatus* were higher than the *P. aurita* variety. Tukey's pairwise comparison analysis carried out on all the physical properties of the *T. fuscatus,* and *P. aurita* varieties of the periwinkle shells revealed a statistically significant difference at $P < 5\%$.

Keywords: periwinkle varieties; *Tympanotonus fuscatus*; *Pachymelania aurita*; geometric properties; gravimetric properties

Periwinkles are protein-rich univalve invertebrates belonging to the phylum Mollusca, class Gastropoda and sub-class Prosobranchia (Dorit et al. 1991). They are small and characterised by the turreted granular and spiny shell with a tapering end (Onwuteaka et al. 2017). In Nigeria, they occur in lagoons, estuaries, and mangrove swamps and are represented by two genera: *Tympanotonus fuscatus* (Linnaeus, 1758) and *Pachymelania aurita* O. F. Müller, 1774, usually harvested by hand picking (Adebayo-Tayo et al. 2010; Job and Ekanem 2010). Knowledge of the physical properties is highly essential in designing machines, equipment, and systems for efficient processing operations.

Despite the enormous potential of periwinkles, there is limited literature on the physical properties of periwinkles. Assessment of the length-weight relationship and condition factors of periwinkles (Jamabo et al. 2009; Udo 2013; Rasheed and Aderonke 2015; Moruf and Lawal-Are 2015; Solomon et al. 2017) and the mechanical and chemical properties of selected mollusc shells in Nigeria (Ituen 2015) are some of the past research works undertaken on periwinkles. This dearth of information about the physical properties of periwinkles hinders the efficient mechanisation of periwinkle processing.

However, the need to bridge these gaps forms the thrust of this work, hence, this study aims to determine the physical properties of periwinkles with respect to the variety for the efficient design of processing machines.

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MATERIAL AND METHODS

Sample collection and preparation

Fifteen kilograms each of two periwinkle varieties, namely *T. fuscatus* and *P. aurita* (Figures 1 and 2), were purchased from Itu waterfront market in Akwa Ibom State, Nigeria. The periwinkle samples were washed, cleaned, and graded, and then taken to the laboratory for analysis.

Determination of the physical properties of periwinkle

One hundred periwinkles were selected at random from the bulk samples to determine the following physical properties of the two periwinkle varieties used in the study: geometrical, gravimetric, and frictional properties.

Figure 1. *Tympanotonus fuscatus* periwinkle variety (Ekop et al. 2021)

Figure 2. *Pachymelania aurita* periwinkle variety (Ekop et al. 2021)

Geometric properties of the periwinkle samples

Determination of the periwinkle shell size. The periwinkle shell length, width, and thickness at uniform moisture contents were measured using an electronic Vernier calliper (HKFZ, China) with an accuracy of 0.01 mm. The geometric mean diameter, D_g, and arithmetic mean diameter, D_a, of the periwinkle shell was calculated using the relationship in Equations (1 and 2) given by Mohsenin 1986:

$$D_g = (LW)^{\frac{1}{2}} \tag{1}$$

$$D_a = \frac{L+W}{2} \tag{2}$$

where: D_g – the geometric mean; D_a – the arithmetic mean diameters, respectively (mm); L – the length; W – the width of the periwinkles (mm).

Determination of the surface area, sphericity, aspect ratio, and volume of the periwinkle samples. The surface area, S_a (mm^2), of the periwinkle shell was determined using the geometric mean diameter from the expression in Equation (3):

$$S_a = \pi(D_g)^2 \tag{3}$$

where: S_a – the surface area of the periwinkle shell (mm^2); D_g – the geometric mean diameter (mm).

The sphericity of the periwinkle shell is an index of its roundness. The degree of sphericity, S_p was used to calculate the sphericity of the two periwinkle varieties.

$$S_p = \frac{D_g}{L} \times 100 \tag{4}$$

where: S_p – the sphericity of the periwinkle shell.

The aspect ratio (A_r) was calculated using Equation (5):

$$A_r = \frac{W}{L} \times 100 \tag{5}$$

where: A_r – the aspect ratio of the periwinkle shell.

The average volume of the periwinkle shell and the meat was determined by using the weighing and modified water displacement method, as described by Robert et al. (2019).

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Gravimetric properties of the periwinkle

Determination of the moisture content of the periwinkle meat. The initial moisture content of the periwinkle used for the study was determined in triplicates by the oven drying method specified in the Association of Official Agricultural Chemists (AOAC) (2020) as adopted by Ekop et al. (2020). The samples' moisture content on a wet basis (w.b.) was calculated using Equation (6).

The moisture content (*MC*), was defined based on a wet basis as:

$$MC_{wb}(\%) = \frac{M_W - M_D}{M_W} \times 100 \tag{6}$$

where: MC_{wb} – the moisture content on a wet basis of the periwinkle meat (% w.b.); M_W – the initial weight of the periwinkle meat (g); M_D – the weight of the periwinkle meat after drying (g).

Determination of the periwinkle weight samples. The weight of the periwinkle samples was determined using an electronic weighing balance (Ohaus-Scout Pro, USA) reading to an accuracy of 0.001 g

Determination of the bulk and true density, and the porosity of the periwinkle samples. The bulk and true density and porosity were computed using the relationship in Equations (7–10) given by Mohsenin (1986). There were ten replications.

$$\rho_b = \frac{W_s}{V_b} \tag{7}$$

where: ρ_b – the bulk density of the periwinkle sample (kg·m^{-3}); W_s – the weight of the periwinkle sample (kg); V_b – the volume occupied by periwinkle sample (m^3).

The true density was determined as the ratio between the mass of the periwinkle samples and the true volume of the periwinkle samples using the expression in Equation (8) as:

$$\rho_t = \frac{W_s}{V_t} \tag{8}$$

where: ρ_t – the true density of the periwinkle sample (kg·m^{-3}); W_s – the weight of the periwinkle sample (kg); V_t – the volume of the displaced water (m^3).

The porosity was calculated from the values of the bulk and true densities using the relationship in Equation (9) as:

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \tag{9}$$

where: ε – the porosity, ρ_b – the bulk density of the periwinkle (kg·m^{-3}); ρ_t – the true density of the periwinkle sample (kg·m^{-3}).

Statistical analysis

The data obtained from the experiments were analysed using the SPSS (version 20.0) statistical software package. Statistically, a significant difference analysis was carried out using an ANOVA with Tukey's pairwise comparison test at $P < 0.05$ to check the physical parameters' deviation for the two periwinkle varieties.

RESULTS AND DISCUSSION

Geometric properties of periwinkle samples. The summarised results of the geometric properties of the two periwinkle varieties: *T. fuscatus* and *P. aurita,* are presented in Table 1. It can be observed that *T. fuscatus* possessed a higher average value in the *L* than *P. aurita,* whereas *P. aurita* had a higher value in the *W* than *T. fuscatus,* which can be attributed to the spiky nature of its shells. Also, *T. fuscatus* had higher D_a, D_g and S_a values than *P. aurita* while *P. aurita* had higher S_p and A_r values than *T. fuscatus* (Figure 3). These results showed consistency with published studies (Ituen 2015; Moruf and Lawal-Are 2015; Udo 2013; Solomon et al. 2017). Periwinkle shell dimensions are used to size the clearances of periwinkle cracking rollers, the hopper design and screen aperture sizing for periwinkle shell-meat separations, storage and handling of the periwinkles.

The surface area information is beneficial in predicting the drying rates and accurate modelling of the heat and mass transfer. In contrast, sphericity is a shape function that determines the rolling ability of agricultural materials during conveying. Thus, the low sphericity of the periwinkle varieties is indicative of the shape not being a sphere (Taser et al. 2005; Garnayak et al. 2008).

A pairwise comparison analysis carried out on the mean values for the geometrical properties of the *T. fuscatus,* and *P. aurita* varieties of periwinkle shells revealed a statistically significant difference at α < 5%.

Gravimetric properties of the periwinkle samples. The summarised results of the gravimetric properties which include the periwinkle weight

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Table 1. Dimensional properties of *Tympanotonus fuscatus* and *Pachymelania aurita*

Physical properties	Unit of measurements	*Tympanotonus fuscatus*		*Pachymelania aurita*	
		mean value	SD	mean value	SD
L	(mm)	43.15	6.17	40.64	2.94
W	(mm)	16.84	2.08	17.24	1.43
D_a	(mm)	30.45	5.16	28.90	1.88
D_g	(mm)	7.73	0.45	7.60	0.25
S_a	(mm^2)	188.46	22.36	181.82	11.77
S_p	(%)	18.13	1.53	18.77	0.82
A_r	(%)	39.58	6.14	42.56	3.66

Average of 100 replicates; L – length (mm); D_a – arithmetic mean diameter (mm); S_a – surface area (mm^2); W – width (mm); D_g – geometric mean diameter (mm); S_p – shpericity; A_r – aspect ratio (%); SD – standard deviation

(M), moisture content (m), bulk density, (ρ_b) and true density (ρ_t) and porosity (for the *T. fuscatus,* and *P. aurita* periwinkles are presented in Table 2. *P. aurita* had an average moisture content (m) higher than *T. fuscatus,* whereas *T. fuscatus* had higher ρ_t, ρ_b M and values than *P. aurita* (Figure 4). These conformed with the gravimetric properties in studies by several authors (Adebayo-tayo et al. 2008; Udo 2013; Moruf, Lawal-Are 2015; Ituen 2015; Solomon et al. 2017). Geometrical properties are useful in designing storage equipment and in the periwinkle shell-meat separation process.

A pairwise comparison analysis carried out on the mean values for the gravimetric properties of the

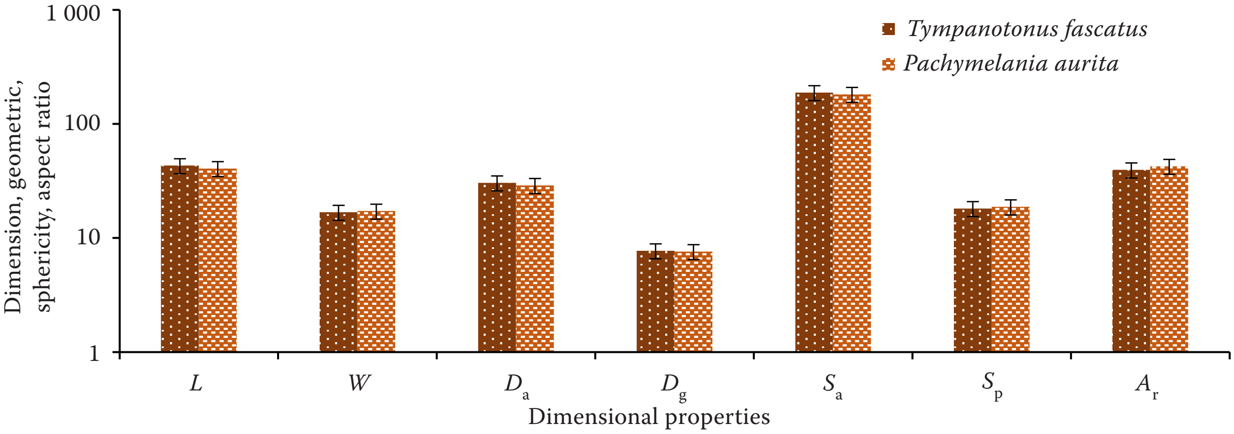

Figure 3. Variation in the dimension, geometric, sphericity, and aspect ratio for the *Tympanotonus fuscatus* and *Pachymelania aurita* periwinkle varieties

The error bars represent the standard deviation of the mean; L – length (mm); D_a – arithmetic mean diameter (mm); S_a – surface area (mm^2); W – width (mm); D_g – geometric mean diameter (mm); S_p – shpericity; A_r – aspect ratio (%)

Table 2. Gravimetric properties of *Tympanotonus fuscatus* and *Pachymelania aurita*

Physical properties	Unit of measurements	*Tympanotonus fuscatus*		*Pachymelania aurita*	
		mean value	SD	mean value	SD
m	(%)	74.66	0.032	78.29	0.020
ρ_t	(g·cm^{-3})	1.5158	0.0312	1.43	0.0362
ρ_b	(g·cm^{-3})	0.8168	0.1028	0.793	0.0104
ε	(%)	46.1	0.9392	44.56	0.876
M	(g)	5.4	1.3	4.4	0.8

Average of 100 replicates; m – moisture content (%); ρ_t – the true density of the periwinkle sample (kg·m^{-3}); ρ_b – the bulk density of the periwinkle sample (kg·m^{-3}); ε – the porosity; – mass (g)

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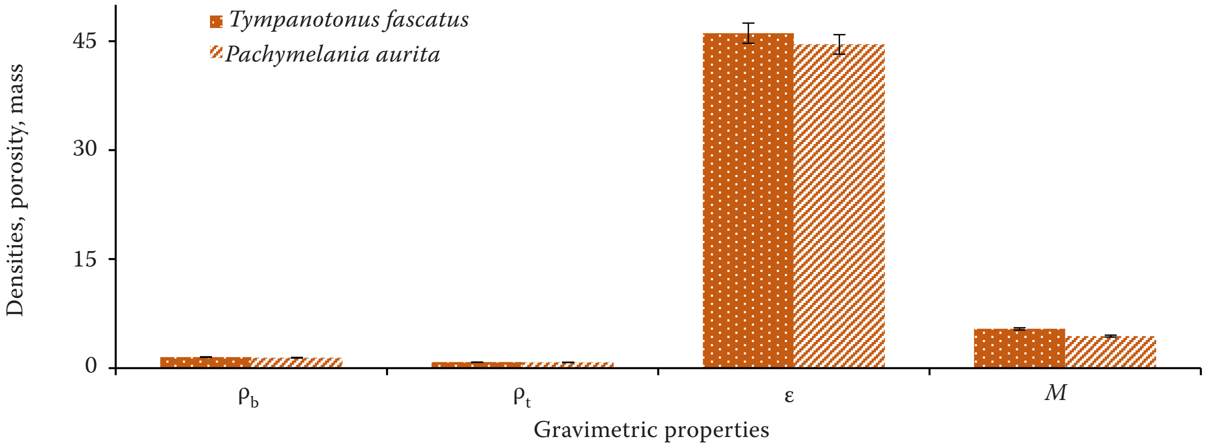

Figure 4. Variation in the densities, porosity, and mass for the *Tympanotonus fuscatus* and *Pachymelania aurita* periwinkle varieties

The error bars represent the standard deviation of the mean; ρ_t – true density (g·cm^{-3}) ρ_b – bulk density (g·cm^{-3}) ε – porosity (%); M – mass (g)

T. fuscatus, and *P. aurita* varieties of periwinkle shells showed a statistically significant difference at α < 5%.

CONCLUSION

This study investigated and determined some of the physical properties of two periwinkle varieties (*T. fuscatus* and *P. aurita*) relevant to the design of efficient processing equipment. It was found that *T. fuscatus* possessed a higher average value in the *L* than *P. aurita,* whereas *P. aurita* had a higher value in the *W* than *T. fuscatus*, which can be attributed to its spikes. Also, *T. fuscatus* had higher D_a, D_g, and S_a values than *P. aurita* while *P. aurita* had higher in S_p and A_r values than *T. fuscatus*. Furthermore, *P. aurita* had *m* value higher than *T. fuscatus,* whereas *T. fuscatus* had higher ρ_t, ρ_b *M* and values than *P. aurita*. The two periwinkle varieties' physical properties were significant on all the parameters investigated at $P < 0.05$. These determined physical properties will be the input parameters for the design of efficient processing equipment for periwinkles.

REFERENCES

Adebayo-Tayo A.A., Onilude A.A., Ogunjobi A.A., Adejoye, D.O. (2006): Bacteriological and proximate analysis of periwinkle from two different creeks in Nigeria. World Applied Sciences Journal, 1: 87–91.

AOAC (2016): Official methods of analysis of the AOAC, 20th ed. Hotwiz W.H (ed.): Washington, Association of Official Analytical Chemists.

Dorit R.L., Walker W.F., Barnes R.D. (1991): Zoology. Philadelphia, Sounders College Publishing.

Ekop I.E., Simonyan K.J., Onwuka U.N. (2020): Comparative analysis of proximate compositions of two varieties of periwinkle relevant to its processing equipment design. Umudike Journal of Engineering and Technology, 5: 1–4.

Ekop I.E., Simonyan K.J., Onwuka U.N. (2021): Effects of processing factors and conditions on the cracking efficiency of *Tympanotonus fuscatus* and *Pachymelania aurita* periwinkles: Response surface approach. Journal of Agriculture and Food Research, 3: 100094.

Garnayak D.K., Pradhan R.C., Nalk S.N., Bhatnagar N. (2008): Moisture-dependent physical properties of Jatropha seed. Industrial Crops and Products, 27: 127–129.

Ituen E.U.U. (2015): Mechanical and chemical properties of selected mollusk shells in Nigeria. International Journal of Agricultural Policy and Research, 3: 53–59.

Jamabo N.A., Chindah A.C., Alfred-Ockiya J.F. (2009): Length-weight relationship of a mangrove pros branch *Tympanotonus fuscatus* var *fascatus* (Linneaus 1758) from the Bonny Estuary, Niger Delta, Nigeria. World Journal of Agricultural Science, 5: 384–388.

Job B.E., Ekanem A.P. (2010): Nutritional status of two periwinkle species from a tropical creek in Nigeria. African Journal of Environmental Pollution and Health, 8: 41–44.

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

Moruf R.O., Lawal-Are A.O. (2015): Growth pattern, whorl, and girth relationship of the periwinkle, *Tympanotonus fuscatus* var *radula* (Linneaus 1758) from tropical estuaries lagoon, Lagos, Nigeria. International Journal of Fisheries and Aquatic Studies, 3: 111–115.

https://doi.org/10.17221/58/2020-RAE

Onwuteaka J., Ugbomeh A., Onyebuchi O.A. (2017): Aspects of the population dynamics of periwinkle (*Tympanotonus fuscatus*) along the Bonny River, Nigeria. Annual Research and review in biology, 2: 1–13.

Rasheed O.M., Aderonke O.L. (2015): Growth pattern, whorl, and girth relationship of the periwinkle, *Tympanotonus fuscatus* var *radula* (Linneaus, 1758) from a tropical estuarine lagoon, Lagos, Nigeria. International Journal of Fisheries and Aquatic Studies, 3: 111–115.

Robert U.W., Etuk S.E., Ebuka A.O. (2019): Modified water displacement method and its use for determination of bulk density of porous materials. Journal Renewable Energy & Mechanics, 1: 1–16.

Solomon O.O., Ahmed O.O., Kunzmann A. (2017): Assessment of length-weight relationship and condition factor of periwinkle (*Tympanolonus fuscatus*, Linnaeus 1758) from Okrika estuary, Niger-Delta Area of Nigeria. Environmental risk assessment and remediation, 1: 1–6.

Taser O.F., Altuntas E., Ozgoz E. (2005): Physical properties of Hungarian and common Vetch seeds. Journal of Applied Sciences, 5: 323–326.

Udo P.J. (2013): Length-weight (Girth relation and condition factor of the periwinkle *Tympanotonus fuscatus*, carithidae Gastropoda) of the Cross River, Nigeria. International Journal of Fisheries and Aquatic Studies, 1: 26–28.

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