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EFFECT OF DRYING METHODS ON THE PHYSICAL PROPERTIES OF TWO VARIETIES OF PERIWINKLE

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Abstract: The effect of cabinet and oven-drying methods on the physical properties of two varieties of periwinkle; *Pachymelania aurita* (spike) and *Tympanotosus fuscatus* (un-spike) was investigated. The selected physical properties of periwinkle were bulk density, moisture content, porosity, sphericity, true density, geometric mean densities, angle of repose, weight, and drying of spike and un-spike periwinkle using cabinet and oven drying methods. Results showed that the geometric properties of the raw samples of *P. aurita* possessed a higher value in the length, width, geometric mean, and sphericity than *T. fuscatus*; also the angle of repose on different materials (plywood, glass, and metal) showed *P. aurita* had a higher value than *T. fuscatus,* respectively. The results showed that the oven-dried samples of *P. aurita* had a higher value in length and geometric mean than *T. fuscatus* while the oven-dried samples of *T. fuscatus* had a higher value in the width and sphericity than *P. aurita*; also the angle of repose for the different materials (plywood, glass, and metal) *T. fuscatus* had a higher value than *P. aurita*, respectively. The cabinet-dried samples of *T. fuscatus* possessed a higher value in the length, width, geometric mean, and sphericity than *P. aurita*; also the angle of repose for the different materials (plywood, glass, and metal) *P. aurita* had a higher value than *T. fuscatus* respectively. Preservation of food by drying is a common practice in different parts of the world and it is used to extend the shelf life of food. Drying allows food to be preserved by removing the moisture in the food, in order to prevent the growth of microorganisms that cause deterioration (Mukhtar, 2009). Reduction in the moisture content as observed, decreases the perishability of these agricultural products, adds value, and extends the shelf life thereby; making them available throughout the year. Also the knowledge of engineering properties (physical properties) of the biomaterial (periwinkle meat) is fundamental because it facilitates the design and development of equipment for harvesting, handling, processing, conveying, cleaning, separation, packing, storing and drying.
Keywords: Oven drying, cabinet drying, periwinkle, physical properties and preservation

1. INTRODUCTION

Periwinkle serves as food in most homes in the south-south geopolitical zone of Nigeria. It is an important ingredient in the preparation of various delicacies especially for the people in the coastal areas where it is found. They are used to cook delicacies such as native soup, afang soup, ekpang nkukwo, ofe nsala, and okra soup [1]. It can be cooked with or without its shell. When cooked with the shell, the mouth is used to draw out the meat from the shell. The meat can also be removed from the shell by using either a toothpick, needle, or nail. Foods prepared with periwinkle provide the body with protein and other essential minerals needed by the body [1]. Periwinkle is economically important as a high source of animal protein, rich in omega-3 fatty acids, and very low in fat. According to the National Nutrient Database for Standard Reference (USDA) raw snails, in general, are about 80% water, 15% protein, and 1.4% fat. It is also a good source of Potassium, Vitamin E (Alpha Tocopherol), Iron, Magnesium, Phosphorus, Copper, and Selenium [2]. Sea foods provide reasonable sources of protein and minerals [1]. Most of the sea foods are consumed by man, as farm food or as plant fertilizers. Some varieties are also used for industrial purposes [3].

Among the numerous methods used for food preservation, drying is unquestionably the most ancient but still very much used nowadays. It is a process by which water is removed from the food, by vaporization or sublimation, thus reducing the water available for degradation reactions of a chemical, enzymatic, or microbial nature [4]. Preservation of food by drying is a common practice in different parts of the world and it is used to extend the shelf life of food. Drying allows food to be preserved by removing the moisture in the food, to prevent the growth of micro-organisms that cause deterioration [5]. The main objectives of drying include preserving food and increasing its shelf life by reducing the water content and water activity; avoiding the need for the use of refrigeration systems for transport and storage which is expensive; reducing space requirements for storage and transport; diversifying the supply of foods with different flavors and textures, thus offering the consumers a great choice when buying foods [4]. The knowledge of the engineering properties of periwinkle is fundamental because it facilitates the design and development of equipment for harvesting, handling, processing, conveying, cleaning, delivering, separation, packing, storing, drying, and mechanical oil extraction. Despite the enormous potential of periwinkles, there is limited literature on the physical properties of dried periwinkles. Assessment of the length-weight relationship and condition factors of periwinkles and the mechanical and chemical properties of selected mollusc shells in Nigeria are some of the past research works undertaken on periwinkles [6 and 7].

This dearth of information about the physical properties of periwinkle meat hinders the efficient mechanization of periwinkle processing. However, the need to bridge these gaps forms the thrust of this work, hence, this study aims to determine the effect of cabinet and oven-drying on the physical properties of periwinkles concerning the variety for the efficient design of processing machine.

2. MATERIALS AND METHODS

Samples collection and preparations

The spike and the un-spike periwinkles were procured from a farm at Itu waterfront market in Akwa Ibom State, Nigeria. The spike and un-spike periwinkle were kept in a bag each and stored in a cool environment with shields and sandy soils, which were water sprayed morning and evening to avoid dehydration of the snails. The periwinkle was washed with clean water to remove traces of the moldy particles. The washed periwinkle was sorted manually to remove dirt and other extraneous materials, and it was then blanched in hot water (100ºC for 10 minutes), using a sterilized needle to de-shell. The de-shelled meat was washed thoroughly with clean water to remove all traces of slimy jelly-like substances in which the meat was embedded. The wholesome de-shelled periwinkle meat was allowed to drain to remove excess water from its surface for further processing and to obtain the initial physical properties of the periwinkle meat. Afterward, the periwinkle meat was dried using the cabinet-drying method at 60ºC and also the oven-drying method at 105ºC for three hours to achieve a constant moisture content and for further processing to obtain the final physical properties.

Cabinet-Drying Method

An existing cabinet dryer (*Fig* 1) in the Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture Umudike, was used in performing this experiment. The cabinet dryer was designed and fabricated with galvanized sheet metals (length 105cm, width 65cm, and depth 85cm). It consists of flat metal trays (length 100cm, width 60cm, and depth 10cm), a drying cabinet for drying agricultural materials, and a heat exchanger. The blower circulates heat in the chambers. It also has an exit vent. The cabinet dryers` primary source of heat was a cooking gas to regulate its burning temperature. The maximum temperature range of the dryer is 60ºC and the rate of the drying was checked with the time interval of two hours for each species sample until the constant moisture content was achieved.

Figure 1: Cabinet dryer

Oven-Drying Method

The oven drying of the de-shelled periwinkle meat sample was done using an electric conventional oven drier, located at the Department of Agricultural and Bioresources Engineering, Umudike at a constant temperature of 105ºC for about three hours [8]. Also, the rate of drying was checked with a time interval of one hour for each species sample until the constant moisture content was achieved.

Determination of Physical Properties of Periwinkle

The 80 periwinkles were selected at random from the bulk samples to determine the geometrical and gravimetric properties of the two periwinkle varieties used in the study. Three replications were performed for each treatment.

Geometrical properties of the periwinkle meat sample

(i) The determination of the periwinkle meat length and width at uniform moisture contents was measured using a vernier caliper with an accuracy of 0.01 mm. The geometric mean diameter was calculated using the relationship given by [9].

$$Dg = LW^{\frac{1}{2}} \tag{1}$$

where; D_g= Geometric mean diameter (mm), L= Length (mm), W= Width (mm)

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(ii) Determination of the sphericity of the periwinkle meat. The sphericity of the periwinkle meat is an index of its roundness. The degree of sphericity (Sp), was used to calculate the sphericity of the two periwinkle varieties.

$$Sp = \frac{Dg}{L} * 100. \quad (2)$$

where; S_p= Sphericity, D_g= Geometric mean diameter (mm), L= Length (mm)

(iii) Determination of the angle of repose of the periwinkle meat. Three structural surfaces, plywood, glass, and metal, were used on an inclined plane. The plane will be gently raised and the angle of inclination at which the sample starts sliding will be recorded from a graduated protractor attached to the equipment and the angle of repose recorded.

Gravimetric properties of periwinkle meat sample

(iv) Determination of the moisture content of the periwinkle meat. The weight of the sample was taken and recorded, then an empty can was also weighed, the can and the sample were also weighed and then oven-dried at a temperature of about 105^0C for 3 hours and cabinet-dried at a temperature of about 60^0C for 10 hours. Then the dried sample was weighed and the moisture content of the periwinkle meat was determined using the relationship in eqn. 3.

$$MC(wb)\% = \frac{Ww - Wd}{Ww} * 100 \quad (3)$$

where; W_w = weight of wet sample (g); W_d = weight of dried sample (g), wb = wet bases (g)

(v) Determination of the weight of periwinkle meat. This was determined using an electronic weighing balance.

(vi) Determination of the bulk density of periwinkle meat. Archimedes' principle was used. A known volume of a cylinder was used, the weight of the periwinkle meat sample was taken and recorded and the density was determined using the expression.

$$Db = \frac{W_s}{V_b} \quad (4)$$

where; Db = Bulk density of the periwinkle meat sample (g/cm^3), W_s = Weight of the periwinkle meat sample (g), V_b = Volume occupied by periwinkle meat sample (cm^3).

(vii) Determination of the true/solid density of periwinkle meat. This was determined using water displacement. The sample was weighed with mass M_a and emptied into a graduated cylinder containing water. The average volume of the water displaced by the periwinkle meat was recorded as V_w by using the weighing and modified water displacement method as described by [10 and 11]. This was repeated three times and the average value was found. The true/solid was calculated using this expression;

$$Ds = \frac{M_a}{V_v} \quad (5)$$

where; Ds = Solid density of periwinkle meat sample (g/cm^3), M_a = Mass of sample (g), V_w = Volume of water displaced (cm^3)

(viii) Determination of the porosity of periwinkle meat. Porosity was determined from the average values of bulk density and solid density based on the relationship for porosity by [12] using the expression.

$$P = \frac{1 - Db}{Ds} * 100 \quad (6)$$

where; P = Porosity of periwinkle meat sample; Db = Bulk density of periwinkle meat sample (g/cm^3), Ds = Solid density of periwinkle meat sample (g/cm^3)

Statistical analysis

The data obtained from the experiments were analyzed using an ANOVA two-factor replication test at a significant difference of $P < 0.05$ to check the physical parameters' deviation for the two periwinkle varieties *Pachymelania aurita* (spiked) and *Tympanotosus fuscatus* (un-spiked).

3. RESULTS AND DISCUSSION

Geometric properties

The geometric properties of the raw sample of *P. aurita* showed that it possesses a higher value in length (56.2mm), width (1.03mm), geometric mean (8mm), and sphericity (14%) than the raw sample of *T. fuscatus*; also the angle of repose for the different materials plywood (39º), glass (31º) and metal (33º). *P. aurita* had a higher value than *T. fuscatus* respectively. It was also observed that the oven-dried sample of *P. aurita* had a higher value in length (13.56mm) and geometric mean (8.35mm) than the oven-dried sample of *T. fuscatus*. While the oven-dried sample of *T. fuscatus* had a higher value in width (5.14mm) and sphericity (67.31%) than the oven-dried sample of *P. aurita*; also the angle of repose for the different materials plywood (28°), glass (26.5°) and metal (26°) *T. fuscatus* had a higher value than *P. aurita* respectively. For the cabinet-dried sample *T. fuscatus* possessed a higher value in length (15.57mm), width (4.58mm), geometric mean (8.44mm), and sphericity (54.21%) than the cabinet-dried sample of *P. aurita*; also the angle of repose for the different materials plywood (26°), glass (25.5°) and metal (26°) *P. aurita* had a higher value than *T. fuscatus* respectively. Summarized charts of the geometric (physical) properties of *Pachymelania aurita* (spiked) and *Tympanotosus fuscatus* (un-spiked) periwinkle types between the raw, oven-dried, and cabinet-dried samples are given in (figures 2 and 3).

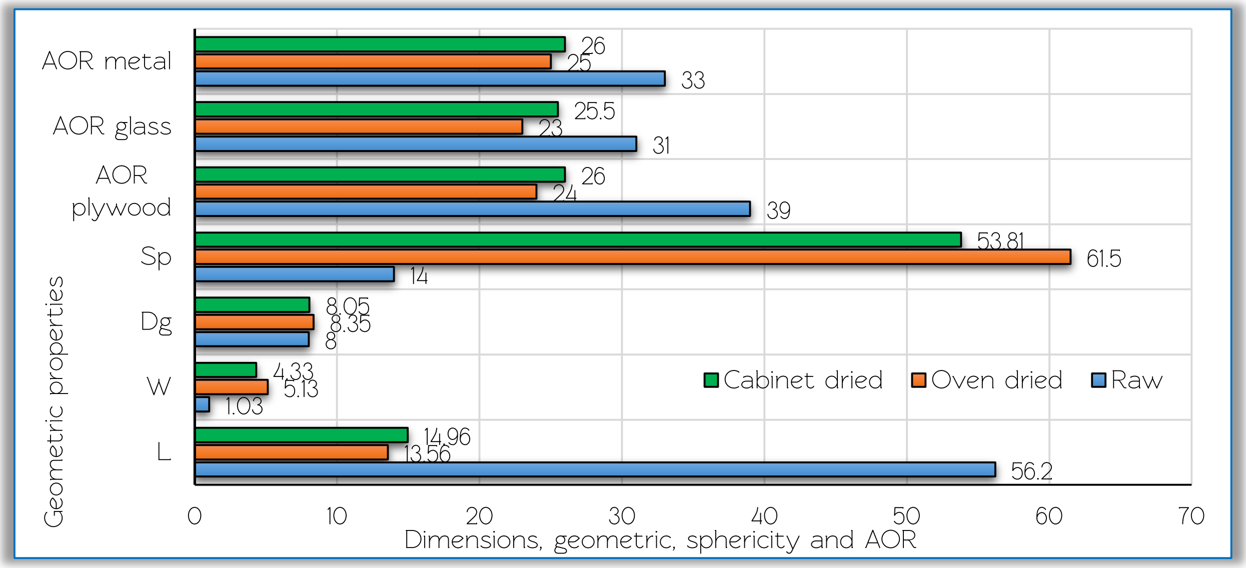

Figure 2. Variation in the length (L), width (W), geometric mean diameter (Dg), and sphericity (Sp) of the raw, oven and cabinet-dried samples of *Pachymelania aurita* (spiked) periwinkle variety. Average of 80 samples and 3 replicates each; AOR – angle of repose (°)

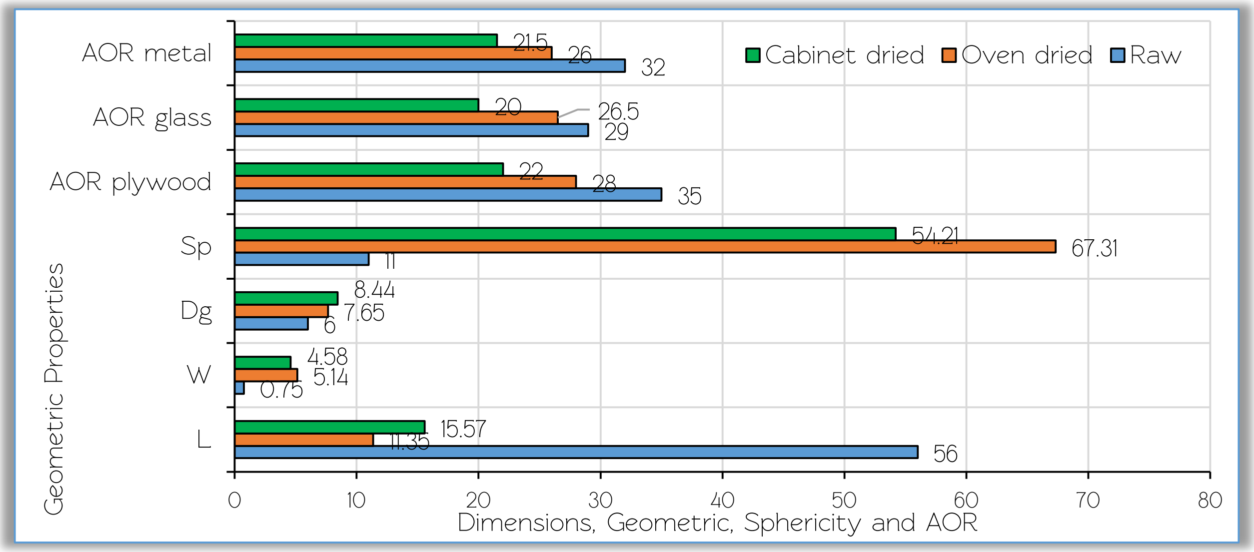

Figure 3. Variation in the length (L), width (W), geometric mean diameter (Dg), and sphericity (Sp) of the raw, oven and cabinet-dried samples of *Tympanotosus fuscatus* (un-spiked) periwinkle variety. Average of 80 samples and 3 replicates each; AOR – angle of repose (°).

Gravimetric properties

The gravimetric properties obtained after drying with the oven and the cabinet dryer include; moisture content, weight, bulk density, solid density, and porosity for the two species of periwinkle *Tympanotonos fuscatus* (spiked) and *Pachymelania aurita* (un-spiked). The raw sample of *P. aurita* had a higher value in moisture content (96.67%) and solid density (0.909g/cm^3) than the raw sample of *T. fuscatus* while the raw sample of *T. fuscatus* had an infinitesimal increase in the weight (32mm), bulk density (0.688g/cm^3) and porosity (47.27%) than the raw sample of *P. aurita*. The oven-dried sample of *P. aurita* had a higher value in porosity (71.4) than an oven-dried sample of *T. fuscatus* while the oven-dried sample of *T.*

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fuscatus had an infinitesimal increase in moisture content (81.23mm) and bulk density (0.315g/cm^3) to *P. aurita* and an equal value in the solid density (1.0g/cm^3) and weight (6mm). The cabinet-dried sample of *P. aurita* had a higher value in weight (7mm) and bulk density (0.359g/cm^3) than the cabinet-dried sample of *T. fuscatus*, also the cabinet-dried sample of *T. fuscatus* had a higher value in moisture content (81.25%) and porosity (70%) than the cabinet-dried sample of *P. aurita* and equal value in the solid density (1.0g/cm^3). *Figs.* 4 and 5 show the summarized charts of the gravimetric (physical) properties of *Pachymelania aurita* (spiked) and *Tympanotosus fuscatus* (un-spiked) periwinkle types between the raw, oven and cabinet-dried samples.

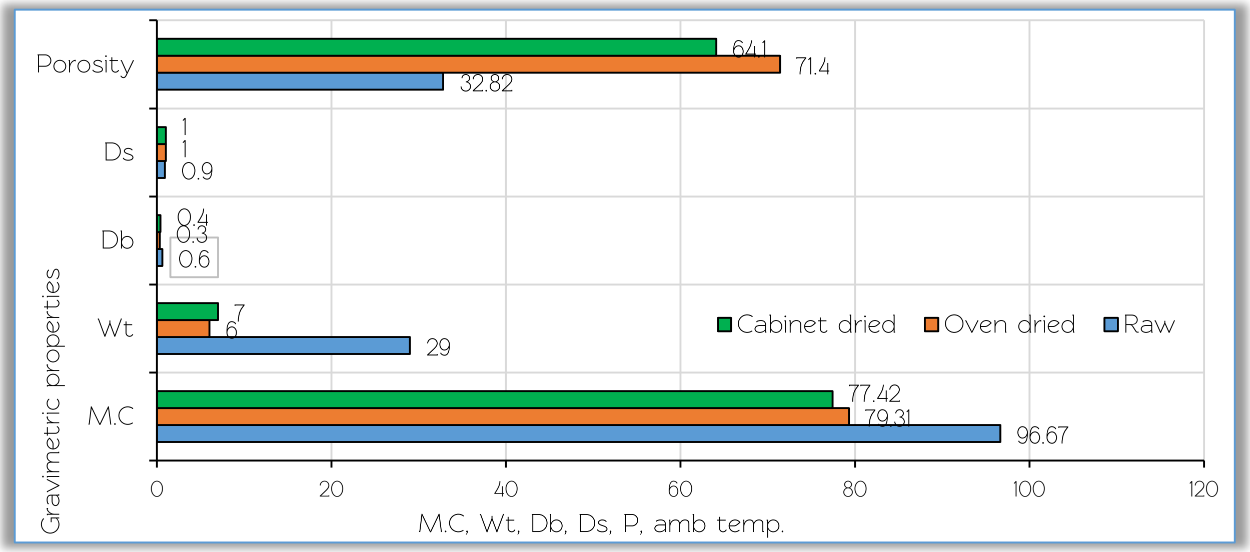

Figure 4. Variation in the moisture content (MC), weight (Wt), bulk density (Db), solid density (Ds), and porosity (P) of the *pachymelania aurita* (spiked) periwinkle variety for the raw, oven, and cabinet-dried samples. Average of 80 samples and 3 replicates each.

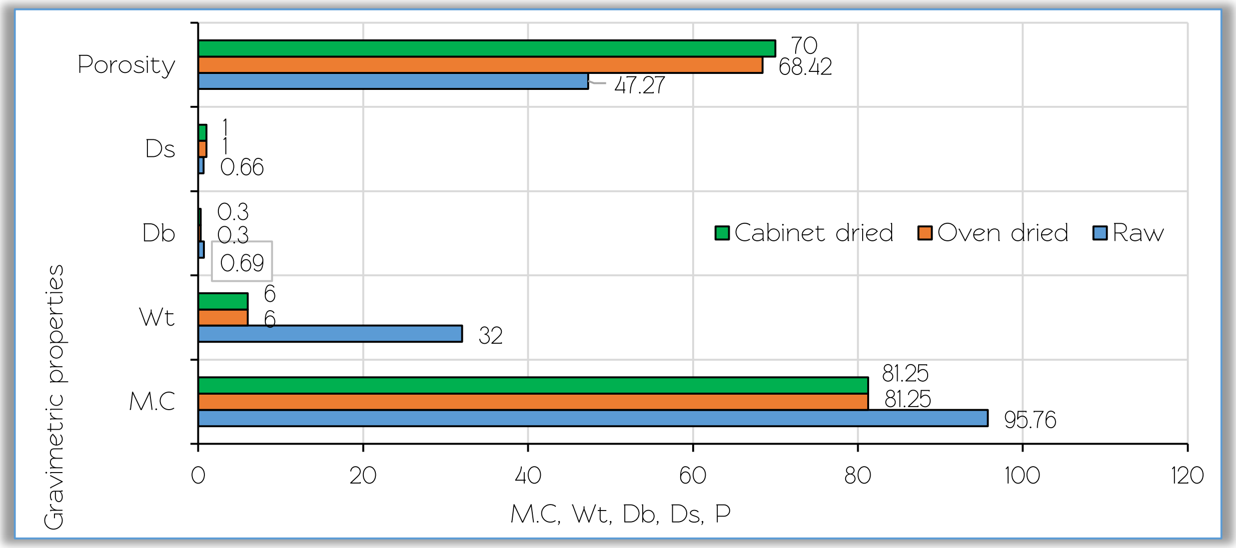

Figure 5. Variation in the moisture content (MC), weight (Wt), bulk density (Db), solid density (Ds), and porosity (P) of the *Tympanotosus fuscatus* (un-spiked) periwinkle variety for the raw, oven and cabinet-dried samples. Average of 80 samples and 3 replicates each.

Table 1. Statistical Analysis for the geometric mean properties of the two species of periwinkle *Pachymelania aurita* (spiked) and *Tympanotosus fuscatus* (un-spiked) for the raw, oven, and cabinet-dried samples. Average of 80 samples and 3 replicates each; AOR – angle of repose (°).

Physical properties	Unit	*P. aurita (spiked)*		*T. fuscatus (un-spiked)*	
		Mean	SD	Mean	SD
Length	(mm)	28.24	13.99	27.64	14.23
Width	(mm)	3.50	1.25	3.49	1.38
Geometric mean diameter	(mm)	8.13	0.11	7.36	0.72
Sphericity	(%)	43.10	14.72	44.17	17.01
AOR plywood	(°)	27.67	2.73	28.33	3.76
AOR glass	(°)	26.5	2.36	25.17	2.68
AOR metal	(°)	30	4.51	26.5	3.04

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Statistically, a significant difference analysis was carried out using a pairwise comparison test at $P < 0.05$ to check the physical parameters' deviation for the two periwinkle varieties. Table 3, shows the geometric mean and standard deviation of the raw, oven, and cabinet-dried periwinkle types; *Pachymelania aurita* (spiked) and *Tympanotosus fuscatus* (un-spiked). It was observed from the data that *P. aurita* has an average higher value in length (28.24mm), width (3.50mm), and geometric mean diameter (8.13mm) than *T. fuscatus*. Whereas *T. fuscatus* possesses a higher value in the sphericity (44.17%). Also, it was observed that *T. fuscatus* had a greater angle of repose with a plywood material (28.33º), whereas *P. aurita* had a greater angle with the metal (26.5º) and glass materials (30º).

Table 2: Statistical Analysis for the gravimetric mean properties of the two species of periwinkle *Pachymelania aurita* (spiked) and *Tympanotosus fuscatus* (un-spiked) for the raw, oven, and cabinet-dried samples. Average of 80 samples and 3 replicates each; AOR – angle of repose (º).

Physical properties	Unit	*P. aurita (spike)*		*T. fuscatus (unspike)*	
		Mean	SD	Mean	SD
Moisture content	(%)	90.38	2.96	93.53	0.2
Weight	(g)	14.0	7.51	14.67	8.67
Bulk density	(g/cm^3)	0.43	0.11	0.43	0.13
Solid density	(g/cm^3)	0.97	0.03	0.89	0.11
Porosity	(%)	58.45	9.55	61.90	7.33

Gravimetric mean properties of the periwinkle types.

Table 2, is the statistical analysis recorded for the gravimetric properties of the *Pachymelania aurita* (spiked) and *Tympanotosus fuscatus* (un-spiked) which includes; moisture content, weight, bulk density, solid density, and porosity. From the table, it is observed that *T. fuscatus* possessed an average higher value of moisture content (93.53mm) and weight (14.67mm) than *P. aurita* whereas *P. aurita* had an equal value in bulk density (0.43g/cm^3) with *T. fuscatus* and an average higher value of solid density (0.97g/cm^3) than *T. fuscatus.*

ANOVA TEST

A comparison analysis was carried out using an ANOVA two-factor replication test on the mean values for the geometric and gravimetric properties of the *T. fuscatus,* and *P. aurita* varieties of periwinkle meat showed a statistically significant difference at $p < 0.05$. SS – the sum of squares, df – degree of freedom, MS – mean square, F – F statistic value of the test, F crit – F critical value of the test. Tests for the three null hypotheses include:

(i) Tests between the samples (*P. aurita* and *T. fuscatus*)

H_1: The means of observations grouped by one factor are the same.

(ii) Tests between the columns of the factors (Raw, Oven-dried, and Cabinet-dried)

H_2: That the means of observations grouped by the other factor are the same.

(iii) Tests for the interaction between the two factors

H_3: There is no interaction between the two factors

Table 3. A summarized result of ANOVA with two-way replication comparison test at $P < 0.05$ to check the geometric physical parameters' deviation for the two periwinkle varieties Pachymelania aurita (spiked) and Tympanotosus fuscatus (un-spiked) of the raw, oven and cabinet-dried samples.

Source of Variation	SS	df	MS	F	P-value	F crit
Sample	4.294402	1	4.294402	4.113165	0.012389	0.911991
Columns	79.76123	2	39.88062	3.259446	0.015054	0.991644
Interaction	27.00795	2	13.50397	3.259446	0.038959	0.961831
Within	12478.48	36	346.6245			
Total	12589.54	41				

Table 4. A summarized result of ANOVA with a two-way replication comparison test at $P < 0.05$ to check the gravimetric physical parameters' deviation for the two periwinkle varieties Pachymelania aurita (spike) and Tympanotosus fuscatus (un-spike) of the raw, oven and cabinet-dried samples.

Source of Variation	SS	df	MS	F	P-value	F crit
Sample	24.28293	1	24.28293	4.072654	0.020114	0.887897
Columns	1556.591	2	778.2955	3.719942	0.029944	0.644682
Interaction	19.85956	2	9.929782	3.219942	0.008225	0.99181
Within	50704.75	42	1207.256			
Total	52305.48	47				

From the ANOVA test results above, having the P-value less than 0.05 for the samples (*P. aurita* and *T. fuscatus*) and the F-critical value less than the F-value we therefore reject the null hypothesis, which then implies that; there is no significant difference between the two samples. Also for the column samples (raw, oven-dried, and cabinet-dried) having the F-value greater than the F-critical value and P-value less than 0.05, we reject the null hypothesis and accept the alternative hypothesis which implies that; there is a significant difference between at least two of the column samples. For the interaction, having the F-value greater than the F-critical value and P-value less than 0.05, we then reject the null hypothesis which implies that; there is an interaction between the entire samples.

4. CONCLUSION

Preservation of food by drying is a common practice in different parts of the world and it is used to extend the shelf life of food. Drying allows food to be preserved by removing the moisture in the food, to prevent the growth of microorganisms that cause deterioration. Drying is capable of removing 80-90% of the moisture content of agricultural products. Reduction in the moisture content as observed, decreased the perishability of these agricultural products, added value, and also extended the shelf life, thereby making them available throughout the year. It was also observed from the ANOVA two-factor replication test result carried out at $P < 0.05$ that, for the samples (*P. aurita* and *T. fuscatus*) there was no significant difference between them; Also for the column samples (*raw, oven-dried,* and *cabinet-dried*) there was a significant difference between them; furthermore, an interaction was observed in the entire data. Hence, the oven-dried and cabinet-dried periwinkle meat samples *Pachymelania aurita* (spike) and *Tympanotosus fuscatus* (un-spike) are nutritionally rich and also has an extended shelf life which helps in solving the challenges of machine design, preservation, processing, handling and storage of the periwinkle product.

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