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Some Physical and Mechanical Properties of Black-Plum

By

Olaoye I.O.
Okegbola O.I.
Ogunrombi I.G.

Research Article

Some Physical and Mechanical Properties of Black-Plum (*Vitex doniana*) Fruits

***Olaoye I.O., Okegbola O.I. and Ogunrombi I.G.**

Department of Agricultural Engineering, The Polytechnic Ibadan, Ibadan. Nigeria

*Corresponding Author's Email: isaacolaoye@yahoo.com, Tel: +2348064796479;

ABSTRACT

Some physical and mechanical properties of *vitex doniana* fruits were studied. The average fruit length, width and thickness were 26.79mm, 24.08mm and 20.16mm respectively. The average fruit mass was 11.12g. The average sphericity and aspect ratio of the fruit were 87.79% and 88.35% respectively. The average true density and bulk density of the fruit bed were 92.87kg/m³ and 47.82kg/m³ respectively. The average porosity of the bed of the fruit was 46.95%. The angle of repose for the fruit on plywood, galvanized sheet and mild steel sheet were 6.0°, 7.0° and 6.0° respectively. Forces at peak for both longitudinal and transverse position were 1450.5N and 1382.2N respectively. Also, the energies at peak for both longitudinal and transverse position were 3.2Nm and 2.7Nm respectively. The stresses at break for both longitudinal and transverse positions were 2.88N/m² and 2.37N/m² respectively. The design of any extraction device for this fruit can utilize these physical and mechanical properties.

Keywords: herbaceous, quadrangle, branch- lets, woodland, savannah region.

INTRODUCTION

Black plum (*vitex doniana*) is a member of verbenaceae family and has been described as woody or herbaceous often with quadrangles or branch- lets. *Vitex* is a large genus and distributed throughout the tropics and sub-tropics. It has rare exceptional leaves which are composite and digitately. In Nigeria this combinations distinguishes it from other genera (Hutchinson *et al.*, 1963). Black plum of the family verbanaceae is a tree crop that grows in open woodland and savannah region of tropical Africa, it is the commonest of the *vitex* species in West Africa, Dalziel *et al.* (1964).

The physical property of *vitex doniana* fruits, like those other fruits are essential for the design of equipment for processing the fruit into juice for human consumption. The properties are affected by numerous factors such as the size, shape, mass, bulk density, density ratio, porosity, angle repose, coefficient of static friction and fracture resistance. Moreover, the knowledge of fracture resistance of the fruit is imperative to design the machine for processing juice for *vitex doniana*. Limited research has been conducted on the physico-chemical properties and sensory evaluation of jam. Ajenifujah-Solebo and Aina (2011).

MATERIALS AND METHODS

Physical Properties

Fresh samples of *vitex doniana* were collected within the metropolis of Saki, Southwest of Nigeria approximately 50 kg fruits. The fruits was divided into smaller samples and analyzed immediately.

Fruit size: In order to determine the size, shape indices and fruit mass, 20 fruits sample each were collected and measurement of each was taken. This measurement was taken five times independently. The parameters determined include length (major diameter) (a), width (minor diameter) (b) and thickness (intermediate) (c) using Vernier caliper. The accuracy of the instrument is 0.01 mm.

Shape: *Vitex doniana* fruit shape was expressed in terms of its sphericity index and aspect ratio. For the sphericity index, S_p , the dimensions obtained for the 100 *vitex doniana* fruits selected at random were used to compute the index using standard method (Mohsenin, 1978) as:

$$S_p = \frac{(abc)^{1/3} \times 100\%}{a} \dots\dots\dots 1$$

Where a = major, b = minor and c = intermediate

For the aspect ratio, 100 *vitex doniana* fruits samples were also selected at random for conducting the experiment. Thus measurement of shape indices was replicated one hundred times. The aspect ratio (R_a) was calculated as recommended by Maduako and Faborode (1990).

$$Ra = b/a \times 100 \dots\dots\dots 2$$

Average Mass: The mass of randomly selected individual fruits were determined using a Mettler Toledo PB 153 electronic balance to an accuracy of 0.001g measurements were determined ten times independently.

True Density: The true density (ρ_t) of the fruit was determined by water displacement method. Fifty randomly selected *vitex doniana* fruits were weighed and lowered into a graduated measuring cylinder containing 1000 ml of water. It was ensured that the fruit was submerged during immersion in water. The increase in volume was noted. The ratio of the mass (kg) of the fruit to the volume (m^3) of water displaced due to the immersed fruit gave the density of the fruit (Amin *et al.*, 2004).

$$\rho_r = \frac{\text{mass}}{\text{volume}} \dots\dots\dots 3$$

Bulk Density: A cylindrical container of known mass and volume was filled with *vitex doniana* and weighed. The mass of the *vitex doniana* was calculated by the difference between the weight of the empty cylinder and the mass after it was filled with the *vitex doniana*. The ratio of the mass of the *vitex doniana* to the volume of the cylindrical container gives the bulk density (ρ_b). The process was repeated 10 times Amin *et al.* (2004).

Density Ratio and Porosity: The porosity (P) was determined as a function of the bulk density and true density of the fruit. The volume fraction occupied by the fruit is given by the ratio of the bulk density ρ_b to the true density ρ_t of the fruit. ($D_t = \rho_b / \rho_t$). The porosity (void fraction) expressed in percent was calculated from average values of bulk and particle densities using equation 4 (Joshi *et al.*, 1993; Deshpande *et al.*, 1993; Suthar and Das, 1996; Jha, 1999; Nelson, 2002).

$$P = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \dots\dots\dots 4$$

The density ratio (D_t) is expressed as a percentage is given by Owolarafe *et al.* (2007)

$$D_t = \frac{\rho_b}{\rho_t} \times 100 \dots\dots\dots 5$$

Determination of mechanical properties

The mechanical properties determined in the study include angle of repose, sliding coefficient of friction and fracture resistance.

Determination of angle of repose: A regular cylindrical container opened at both ends and placed on a galvanized steel surface was filled with the *vitex doniana* fruit to the brim. Afterwards the container was lifted gradually and finally emptied to form a conical heap with the fruits.

The tangent of the angle of inclination to the horizontal ($\tan \emptyset$) was calculated from the height (h) and base radius (r) of the formed heap as Amin *et al.* (2004);

$$\tan \emptyset = \frac{h}{R} \dots\dots\dots 6$$

Where, $\emptyset$ is the angle of repose

This was repeated 5 times for each replicate.

Determination of the coefficient of static friction: Coefficient of static friction is the tangent of the angle of inclination at which a material begins to slide on the surface. Using the method described by Solomon and Zewdu (2009), five *vitex doniana* fruits were placed on an inclined plane apparatus with mild steel. The plane portion of the apparatus was raised. The angle of inclination to the horizontal, as soon as the fruits began to slide, was measured from a protractor attached to the inclined plane. The tangent of the angle of inclination measured gives the coefficient of static friction. This was repeated 10 times.

Determination of fracture resistance: Compression tests were conducted using Universal Compressive Testing Machine (UCTM) controlled by a microcomputer. The fruit was placed between two parallel plates on the machine and compressed till failure occurred Aviara et al. (2007).. Two loading orientations were used (transverse and longitudinal) and twenty-four randomly selected fruits from ripe and unripe were compressed laterally and longitudinally by the UCTM at a compression rate of 5 mm/min. Test results, statistics and graph were automatically generated. The compressive load, compressive stress, compressive strain, stress energy and modulus of elasticity were obtained.

RESULT AND DISCUSSION

The average length, width and thickness for ripe fruit were 26.79, 24.08 and 20.17 mm respectively (Table 1). These measurements are of great value because the dimensions are important in determining aperture size in materials separation (Mohsenin, 1978); Omobuwajo et

Table 1: Physical properties of fresh *vitex doniana* fruit

Length, mm	26.79±2.43	(50)
Width, mm	24.08±2.10	(50)
Thickness, mm	20.16±1.72	(50)
Sphericity, %	87.79±3.69	(50)
Aspect ratio, %	88.35±5.58	(50)
True density, kg/m ³	92.87±14.33	(50)
Bulk density, kg/m ³	47.82±0.32	(50)
Porosity, %	46.95±0.35	(50)
Angle of repose on		
Plywood, °	6.0 ±0.88	(5)
Galvanized sheet, °	7.0 ±0.45	(5)
Mild steel sheet, °	6.0±1.55	(5)

Values in parentheses indicate number of observations

al.(1999) For this type of fruit, these parameters may be useful in determining the size of the components of machine for extracting the fruit juice.

The average sphericity and aspect ratio of the fruit were 87.79% and 88.35% respectively. The high sphericity is an indication of the fruit tending to the shape of a sphere. The other implication of the high sphericity and aspect ratio can also be measured of the ability of the fruit to roll rather than slide on a flat surface. This is very important in design of hoppers for machines. Omobuwajo et al. (2000). The average fruit mass, average true density and bulk density were 11.12 kg, 92.87 kg/m³ and respectively. Interestingly, this result is a reflection of the smaller volume (based on the dimensions) expected from the fruit of *vitex doniana*

The average porosity of a bed of the fruits was 47.0%. The low porosity value observed could explained in term of the high sphericity that is an indication of compact arrangement as reported for *spondias mombin* by Owolarafe et al. (2006);. Both the true and bulk density characteristics are useful in the estimation of load and hence in the design of load shafts for processing machine. The angle of repose for the fruit on plywood, galvanized sheet and mild sheet were 6.0, 7.0 and 6.0° respectively. An explanation for the close value of angle of repose obtained can be given as the smooth surface of the fruit. This is in agreement with results obtained for some other fruits previously studied.

The result of fracture resistance analyses showed on Table 2a and 2b.that the average force at peak for both transverse and longitudinal position were 1382.1 and 1450.5 N respectively. This implies that more forces will be required to extract the juice at the longitudinal position than the transverse position. From the same Table, it also shows that average stress at break at transverse and longitudinal positions were 2.37 and 2.88 N/mm² respectively.

CONCLUSION AND RECOMMENDATION

The following conclusions are drawn from this investigation into physical properties of vitex doniana fruit:

- (i) Physical properties of vitex doniana fruit studied in this work change linearly with an increase in seed moisture content with high correlation.
- (ii) The dimensions of the vitex doniana fruit increased: the major axis by 3.44%, medium axis by 2.35% and minor axis by 6.17%.
- (iii) The sphericity and thousand seed mass varied from 82.1 to 96.9% and 7.39 to 14.41 g, respectively.
- (iv) The bulk and true densities decreased from 59.10 to 40.10 kg/m³ and 117.10 to 51.50 kg/m³, respectively.
- (v) The aspect ratio and porosity increased linearly from 74.8 to 100% and 20.1 to 59.1% respectively.
- (vi) The forces at peak at longitudinal and transverse positions were 1450.5 and 1382.1 N respectively.
- (vii) The energies to peak at longitudinal and transverse positions were 3.30 and 2.05 Nm respectively.
- (viii) The forces at break at longitudinal and transverse positions were 1450.50 and 1382.10 N respectively.
- (ix) The stresses at break at longitudinal and transverse positions were 2.89 and 2.37 N/mm² respectively.
- (x) The energies at break at longitudinal and transverse positions were 3.30 and 2.05 Nm respectively.
- (xi) The Young modules at longitudinal and transverse positions were 17.34 and 14.06 N/mm² respectively.
- (xii) The deformations at peak at longitudinal and transverse positions were 15.04 and 12.36 mm respectively.
- (xiii) The deformations at break at longitudinal and transverse positions were 15.04 and 12.36 mm respectively.

REFERENCES

- Ajenifujah-Solebo SO and Aina, J.O (2011). Physic-chemical properties and sensory evaluation of jam made from Black- Plum fruit (*Vitex doniana*). *African Journal of Food Agricultural, Nutrition and Development*. 11(3): 4772-4784, .
- Amin MN, Hossain KC, Roy (2004). Effects of moisture content on some physical properties of tentil seeds. *Journal of Food Engineering*, 83-87..
- Aviara NA, Shittu SK.and Haque MA(2007). Physical properties of guna fruits relevant in bulk handling and mechanical processing. *International Agro physics*, 21: 7-16. .
- Dalziel JM, Keay RWJ, Onochie CFA and Stanfield DP (Eds) (1964). *Nigerian Trees*. FRIN, Ibadan, Vol. II.
- Deshpande SO, Bal S and Ojha TP (1993). Physical properties of soybean. *Journal of Agricultural Engineering Research*, 56: 89 – 98.
- Jha NS (1999). Physical and hygroscopic properties of makhana. *Journal of Agricultural Engineering Research*: 72: 145 – 150.
- Joshi DC, Das SK. and Mukherjee RK (1993). Physical Properties of pumpkin seeds. *Journal of Agricultural Engineering Research*, 54: 219 – 229.
- Maduako JW and Faborode MO (1990). Some physical properties of cocoa pods in relation to primary processing. *Ife Journal of Technology*, 2: 1-7.
- Moshsein NN (1978). *Physical Properties of animal and plant material*. Gordon and Breach Science Publishers, U.S.A.
- Nelson SO (2002). Dimensional and density data for seeds of cereals grain and other crops. *Transaction of the American Society of Agricultural Engineers*. 45 (1): 165 – 170.
- Omobuwajo TO, Sanni LA and Balami YA (2000). Physical properties of Sorrel Seed. *Journal of Food Engineering*, 45:37 - 41.
- Owolarafe OK, Adeboye OC and Adegbenjo OA (2006). Physical properties and food value of *Spondias mombin* L. an under exploited fruit of Nigeria. *Journal food Science and Technology*, 43 (6): 626 – 629.
- Suthar SH and Das SK (2002). Some physical properties of Karingda (*Citrullus lanatus* Thumb Mansf) seeds. *Journal of Agricultural Engineering Research*, 65:15 – 22.
- Solomon WK and Zewdu AD (2009). Moisture-dependent physical properties of niger (*Guizotia abyssinica* Cass.) seed. *Food Science and Postharvest Technology*, 29 165-170.

APPENDIX I
Physical properties of *Vitex doniana* (Ripe)

S/N O	Mass (g)	Length (mm) a	Width (mm) b	Thickness (mm) C	Sphericity (%) $\frac{(abc)^{\frac{1}{3}}}{a} \times 100$	Aspect Ratio % b/a x100	Volume m ³ x10 ⁻⁴	True Density Kg/m ³	Bulk Density Kg/m ³	porosity %
1	12.33	28.6	24.4	20.2	84.5	85.3	1.2	102.75	52.25	50.1
2	12.07	28.6	25.6	20.8	86.7	89.5	1.4	86.21	46.10	46.5
3	12.92	28.6	26.4	20.8	87.6	92.3	1.2	107.67	48.20	55.2
4	11.71	28.6	23.8	19.02	82.1	83.2	1.0	117.10	59.10	49.5
5	10.03	26.6	24.4	19.8	88.1	91.7	1.6	62.69	50.12	20.1
6	12.07	27.6	25.4	20.8	88.5	92.0	1.2	100.58	42.00	47.8
7	9.36	23.2	22.2	18.8	91.1	95.7	1.0	93.6	43.10	53.9
8	8.51	27.6	27.4	23.8	95.0	99.3	1.2	70.92	50.75	28.4
9	11.20	23.1	22.1	18.2	91.0	95.7	1.0	112.00	55.10	50.5
10	14.41	29.8	27.6	22.2	83.6	92.6	1.4	102.93	42.10	59.1
11	9.00	25.4	23.2	20.8	90.8	91.3	1.2	75.00	45.21	39.7
12	11.24	27.6	23.2	19.8	84.5	84.1	1.2	93.67	41.11	56.4
13	11.21	24.4	24.2	24.2	96.9	99.1	1.2	93.42	46.25	50.5
14	11.57	25.6	25.1	20.1	91.6	98.0	1.2	96.42	48.26	50.0
15	13.74	26.6	23.2	20.8	88.0	87.2	1.2	114.17	50.75	55.7
16	10.50	29.8	25.4	19.8	82.7	85.2	1.0	105.00	49.10	53.2
17	12.19	28.4	25.2	22.2	88.5	88.7	1.2	101.58	46.00	54.7
18	11.62	28.4	24.4	20.1	84.7	86.0	1.2	96.83	48.10	50.3
19	11.30	28.2	26.1	22.1	89.5	92.6	1.2	94.17	41.45	55.8
20	11.20	27.4	25.6	20.1	88.2	93.4	1.2	93.33	47.25	49.4
21	9.39	24.4	23.2	19.8	91.7	95.1	1.0	93.90	48.12	48.8
22	9.27	25.4	22.2	17.6	84.6	87.4	1.8	51.50	40.10	22.1
23	13.46	30.8	26.6	20.8	83.6	86.4	1.6	84.13	52.22	37.9

APPENDIX I CONTD.

S/No	Mass(g)	Length (mm)	Width(mm)	Thickne ss(mm)	sphericity	Aspec t Ratio % b/a x100 x10 ⁻⁴ Kg/m ³		True Density Kg/m ³	Bulk Density	%
		a	b	C	$\frac{(abc)^{\frac{1}{3}}}{a}$					
24	10.57	25.4	19.4	19.8	84.1	76.4	1.3	81.31	46.10	48.0
25	9.34	25.4	20.2	18.8	83.8	79.5	1.0	93.40	48.22	48.4
26	11.36	27.2	23.2	20.6	86.4	85.3	1.5	75.73	42.00	48.2
27	11.56	26.2	25.2	21.2	92.0	96.2	1.2	96.33	50.12	48.0
28	10.07	25.4	23.4	19.4	89.0	92.1	1.0	100.7	48.26	50.1
29	11.21	28.6	21.4	19.8	80.3	74.8	1.0	112.10	44.10	60.7
30	8.65	19.4	19.2	15.6	92.7	99.0	0.8	108.13	42.25	60.9
31	12.63	28.6	25.4	20.2	85.6	88.8	2.0	63.15	50.10	20.7
32	11.29	26.6	25.4	19.8	89.2	95.5	1.0	112.90	47.10	58.3
33	8.99	22.2	21.2	18.6	92.8	95.5	1.0	89.90	49.21	45.2
34	9.88	26.6	23.2	19.1	85.6	87.2	1.0	98.80	48.11	51.3
35	13.90	30.8	26.2	20.1	82.2	85.1	1.2	115.83	50.27	56.6
36	12.27	28.6	25.4	22.2	88.3	88.8	1.4	80.50	49.10	44.0
37	14.00	30.9	26.4	22.6	85.5	85.7	1.6	87.50	51.10	41.6
38	13.48	28.4	26.2	22.2	89.7	92.3	2.0	87.40	42.00	38.0
39	9.90	26.6	23.2	19.8	86.6	87.2	1.0	99.00	48.10	51.4
40	13.85	28.6	26.4	23.6	91.3	92.3	1.4	98.93	48.80	50.7
41	7.39	23.2	20.8	17.6	87.9	89.7	1.0	73.90	50.11	32.2
42	10.42	26.4	25.4	20.8	91.2	96.2	1.2	86.83	46.24	47.0
43	10.77	25.4	24.4	20.8	92.3	96.1	1.2	89.75	48.91	45.5
44	10.70	27.6	23.2	18.8	83.0	84.1	1.0	107.00	46.65	56.4
45	10.60	25.4	23.2	17.6	85.6	91.3	1.2	88.33	49.00	45.0
46	10.36	27.6	22.2	19.8	83.3	80.4	1.4	74.00	47.25	36.1
47	7.98	20.8	20.8	15.4	90.5	100	0.8	99.75	49.00	51.0
48	12.07	28.6	25.4	19.8	85.0	88.8	1.2	100.58	52.10	48.2
49	11.73	27.6	25.4	22.2	90.5	92.0	1.4	83.79	53.75	36.0
50	10.55	26.6	25.4	20.8	90.7	95.5	1.2	87.92	51.10	42.0
47.85	11.12	26.79	24.08	20.16	87.79	88.35	1.2	92.87		

APPENDIX II

Table 2a: Fracture Resistance of *Vitex Doniana* Ripe Fruit at Transverse Position

Stress @ Peak N/mm ²	Force @ Peak N	Energy to Peak (N.m)	Force @ Break N	Stress @ Break N/mm ²	Energy to Break (N.m)	Force @ Yield N	Stress @ Yield N/mm ²	Young Modulus N/mm ²	Deform. @ Peak (mm)	Deform. @ Break (mm)
2.489	1565.5	2.365	1565.5	2.489	2.365	-	-	15.43	13.67	13.67
2.736	1452.5	1.623	1452.5	2.736	1.623	-	-	17.66	11.23	11.23
1.908	936.8	1.556	936.8	1.908	1.556	-	-	7.66	11.21	11.21
2.634	1680.6	2.316	1680.6	2.634	2.316	-	-	8.29	13.42	13.41
2.071	1275.3	2.363	1275.3	2.071	2.363	-	-	21.27	12.28	12.28
Average 2.368	1382.1	2.045	1382.1	2.368	2.045	-	-	14.06	12.36	12.36

Table 2b: Fracture Resistance of *Vitex Doniana* Ripe Fruit at Longitudinal Position

Stress @ Peak N/mm ²	Force @ Peak N	Energy to Peak (N.m)	Force @ Break N	Stress @ Break N/mm ²	Energy to Break (N.m)	Force @ Yield N	Stress @ Yield N/mm ²	Young Modulus N/mm ²	Deform. @ Peak (mm)	Deform. @ Break (mm)
3.579	1687.2	2.467	1687.2	3.579	2.467	-	-	19.629	15.822	15.822
2.206	1310.1	3.571	1310.1	2.206	3.571	-	-	18.648	15.411	15.411
3.471	1842.8	3.414	1842.8	3.471	3.414	-	-	32.730	10.676	10.676
2.525	1239.4	2.907	1239.4	2.525	2.907	1239.4	2.525	9.2076	16.973	16.973
2.660	1173.1	4.128	1173.1	2.660	4.128	519.8	1.178	6.4910	16.310	16.310
Average 2.888	1450.5	3.298	1450.5	2.888	3.298	879.6	1.852	17.3411	15.038	15.038