Effects of age on some physical properties of oil palm fruitlets

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Abstract: The effect of age on some physical properties of Dura and Tenera cultivars of oil palm fruitlets were investigated. Fresh fruit bunches of Tenera and Dura were obtained from three different oil palm plantations at different age of cultivations such as 20, 30 and 50 years. Physical properties of their fruitlets were measured at different moisture contents using American Society of Agricultural Engineers (ASAE) standard. As the age increased from 20 to 50 years, mass of Tenera fruitlets increased from 7.25 to 14.89 g, while Dura fruitlets increased from 3.71 to 11.56 g. The sphericity of Dura cultivars increased from 80% to 87%, while that of Tenera fruitlets decreased from 81% to 64%. However, true densities of Dura and Tenera cultivars increased from 978.56 to 1180.32 kg/m^3 and 973.04 to 1160.14 kg/m3 respectively, while bulk densities increased from 720.50 to 882.25 kg/m3 and 680.41 to 865.92 kg/m3 respectively. The effect of age on mass, axial dimension, coefficient of static friction, true and bulk densities for Dura and Tenera cultivars fruitlets were significantly different (p<0.05) within and in-between cultivars except angle of repose and sphericity of Dura cultivar.

Keywords: Oil palm fruitlets, physical properties, Dura and Tenera cultivars, age of cultivation

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1 Introduction

There are fossil, historical and linguistic evidences that oil palm tree (*Elaeis guineensis Jacq)* originated from the tropical rain forests of West Africa (Hartley, 1988; Danyo Gilbert, 2013), and later became domesticated as a cultivated crop across Africa, Asia and America. In Nigeria, three oil palm trees cultivars are cultivated, namely *Dura*, *Tenera and Pisifera*, but most prominent and commercial are two cultivars earlier mentioned above. The *Dura* palm fruitlets cultivar has a thick shell (endocarp) separating the mesocarp (pulp) from the kernel. Its kernel tends to be large, occupying 7% - 20% fruit weight. However, *Tenera* palm fruitlets cultivar has a thin shell (endocarp) in-between mesocarp and kernel. Its kernel is relatively small, comprising 3% - 15% fruit weight, with palm oil content ranges from 24% - 32%. *Pisifera* has no shell and is very frequently female sterile, which cannot enhance commercial planting (Owolarafe et al., 2007a). In Malaysia, new breed of *Tenera* has mesocarp between 80% and 90%, shell about 6%-9% and kernel about 5% (Hai, 2002; Owolarafe, et al., 2007a). The bunch weight varies from 3 kg to about 100 kg, according to age and ecological condition (Hafiz and Shariff, 2011)**.** Naturally, as the oil palm trees of any cultivar increases in age of cultivation, the axial dimension and mass of fresh fruit bunches (FFB) increases, which influences its fruitlets physical properties (Hafiz and Shariff, 2011).

Palm oil, the principal product of the crop, has a great number of uses. About 80% of production is consumed as human food; the remaining is utilized in livestock feed formulation and as industrial raw material (Owolarafe et al., 2007b). Palm oil is the main cooking oil in most countries; and it is a good source of energy, carotenoids (pro-vitamin A) and tocopherol or vitamin E (Owolarafe and Arumughan, 2007). Palm oil has wider

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industrial applications for the manufacturing of confectionaries, paints, cosmetics, soap and detergents. There are nine kilocalories in each gram of all edible oils when it is metabolized, higher than that of carbohydrate which has four kilocalories (FAO, 2007). It also contains a range of fat-soluble vitamins (A, D, E, and K) and essential fatty acids, both of which are necessary for the healthy functioning of the body (O'Brien, 2008; Akinoso and Raji, 2011).

Previous researchers have reported that physical properties of crops are essential parameters in utilization, development of processing methods, and design of equipment (Ogunsina et al., 2008). Akinoso et al., (2009) also established that adequate knowledge on properties include rheological, thermal, optical, electrical, physical and mechanical properties of crop are highly essential for machine design parameters selection and improvement of processing technology that will enhance oil yield and quality. Owolarafe et al. (2007a) reported the physical and mechanical properties of aforementioned prominent palm fruit cultivars as imperatives indices for designing of oil palm processing machines. Likewise physical properties of fruit, nut, and kernel of oil palm were investigated at three levels of moisture content (5%, 8% and11% w.b.) and at sterilization temperature of 40^{o}C, 60^{o}C and 80^{o}C (Akinoso and Raji, 2011). It was reported that moisture content and temperature influences their physical and mechanical properties. Hafiz and Shariff (2011) investigated physical and optical characteristics of *Dura* and *Tenera* cultivars and reported that, there is a correlation between weights and linear dimensions of both cultivars fruitlets. The influence of age on weight and axial dimensions of fruitlets of oil palm trees are yet to be reported by any previous researchers. The variability in physical properties within and in-between *Dura* and *Tenera* fruitlets cultivars was investigated in this work. This factor should be considered while selecting design parameters for oil palm processing machines, most especially screw-press to reduce palm nut breakages during palm oil extraction operation. Hence the main objective of this study was to investigate the effect of age increase on some physical properties of *Dura* and *Tenera* cultivars between the ages of 20 to 50 years of cultivation.

2 Materials and methods

Fresh fruit bunches of both cultivars (*Tenera* and *Dura*) were obtained from three different oil palm plantations, namely: Agbongbo village via Obafemi Awolowo University Research and Training Farm, Ile-Ife, Osun state, Elere Adubi Oil Palm Mill, Itori, Ogun State and University of Ibadan Teaching and Research Farm, Ibadan, Oyo State for various ages: 20, 30 and 50 years in Nigeria respectively. Fresh fruit bunches (FFB) obtained were mulched for four days after harvesting, followed by stripping, screening and washing of fruitlets to remove dirt, stones and other extraneous materials. From the population of individual age group for both cultivars, 100 pieces of fruitlets were selected randomly to determine physical properties using standardized procedures.

2.1 Mass

Labeling was done to identify 100 pieces fruitlets of each cultivars (*Dura* and *Tenera*) on age grouping basis (20, 30 and 50 years) prior to weighing. The corresponding mass of each cultivar fruitlets, according to their age group in hundred replicates was determined using electronic digital weighing balance, model: Scout Pro SPU 401.

2.2 Moisture Content

The initial moisture contents (wet-basis) were determined using a standard method reported by Mohsenin, 1986. The initial weight W_1 of labeled fruitlets of 100 pieces from each cultivar in three age groups 20, 30 and 50 years in Nigeria, were measured using electronic digital weighing balance, model: Scout Pro SPU 401 having the least count of 0.1 g. Hence they were subjected to bone drying using electric oven for about six hours at 105°C until the dried weight become constant as W_2. The moisture contents were determined using Equation 1.

$$\text{Moisture Content}_{(w.b)} = \frac{W_1 - W_2}{W_1} \times 100\% \quad (1)$$

2.2 Size and sphericity

The three axial dimensions (major, intermediate and minor diameters, which were denoted as: length, width and thickness respectively) were measured on hundred replicate samples of 20, 30 and 50 years of age on both cultivars using digital micrometer screw gauge, having accuracy level of 0.01 mm. The axial dimensions were taken as demonstrated in Figure 1. The geometrical mean diameter and sphericity of each fruit was calculated using equations 2 and 3 as reported by Moshsenin (1986), and Akinoso et al. (2011).

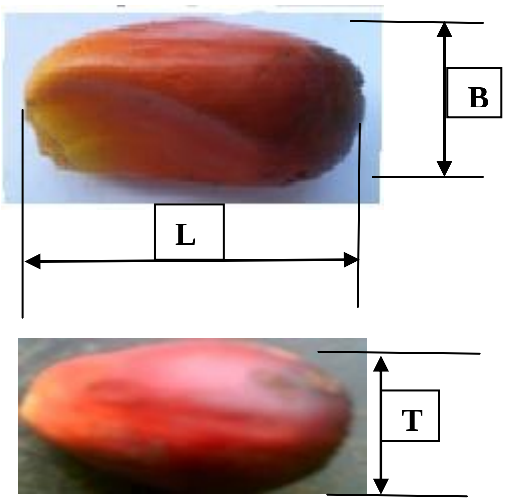


Figure 1 A typical fruitlets linear dimensions
Key: L= length, B= breadth, T= thickness

$$\text{Geometrical mean diameter } G_D = (L.B.T)^{1/3}$$

$$\text{Sphericity, } \Phi = \frac{(L.B.T)1/3}{L}, \quad (3)$$

Where, L = Longest intercept (length) in mm; B = Longest intercept normal to L, (Breadth) in mm; T = Longest intercept normal to L and B (Thickness) in mm.

2.3. The true density

The determination of density of an average fruit size using liquid displacement method was adopted as reported by ASAE (1998).

2.4. Bulk densities

The bulk density was determined by filling a plastic container of 450 cm^3. The initial empty weight of this container was measured, and subsequently its volume was filled to the brim with fruitlets and re-weighed on a Sartorius 1600 electronic digital weighing balance to least count of 0.001 g. This was done in 10 replications using Equation 4 below, the bulk density (ρb) was then calculated for each of the replication on both cultivars (*Dura* and *Tenera*). This procedure was reported by Owolarafe et al. (2007a).

$$\text{Bulk Density } (\rho_b) = \frac{\text{weight of fruitlets (g)}}{\text{volume occupied (cm}^3)} \quad (4)$$

The true density of the palm fruit was determined by the solvent displacement technique (Dutta, et al., 1988; Owolarafe et al., 2007). The true density ρ_t was done in 10 replications, then calculated using equation 4.

2.5 Ratio density

The density ratio for each age and cultivars was estimated using mathematical expression as equation 5 given below:

$$Dr = \frac{\rho_t}{\rho_b} \times 100 \quad (5)$$

2.6 Porosity

The porosity of oil palm fruitlets adopted in this research work was determined using the mathematical expression reported by Mohsenin (1986) shown below as equation 6:

$$\text{Porosity} = (\varepsilon_a) = 1 - \frac{\rho_b}{\rho_t} \times 100 \quad (6)$$

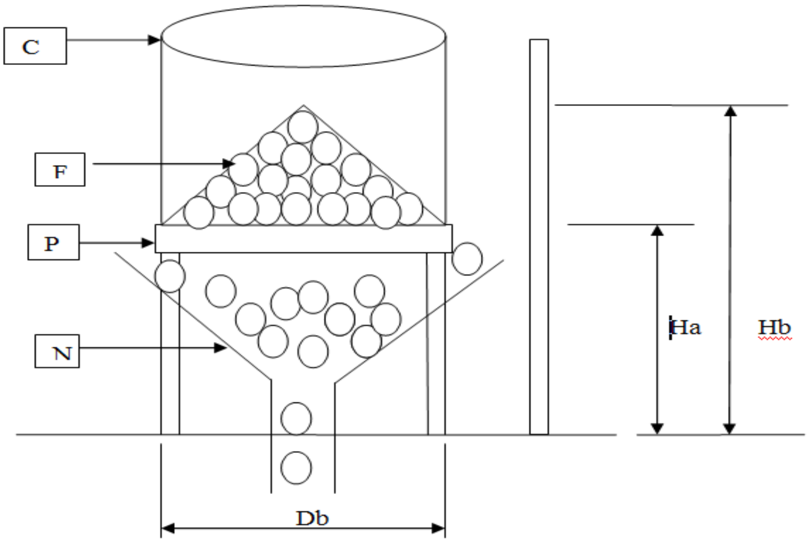
2.7 Angle of repose and coefficient of static friction on fruitlets and nuts

A cylindrical tin container with open ends of 150 mm diameter and vertical height of 200 mm rested on top of wooden table was filled with fruitlets as shown in Figure.2. The cylinder was gradually lifted upward until emptied to form a conical heap. The angle formed at the base of the heap with the corresponding horizontal plane was calculated using mathematical expression below as equation 7. This measurement was done in ten replicates for fruitlets of each cultivar.

$$\text{Angle of Repose } (\phi r) = \tan^{-1}\frac{2\left(H_a - H_b\right)}{D_b} \quad (7)$$

Where, H_a, H_b and D_b are the height of the cone, height and diameter of the cylinder respectively.

fruitlets and nuts of each cultivar was placed one after another to measure their corresponding coefficient of static friction. The tangent of angle ϕ at which the platform was inclined to the horizontal at that moment of



C – Cylinder, F- Palm Fruit, P- Plat-form, N- Funnel.

Figure 2 Apparatus for measuring angle of repose

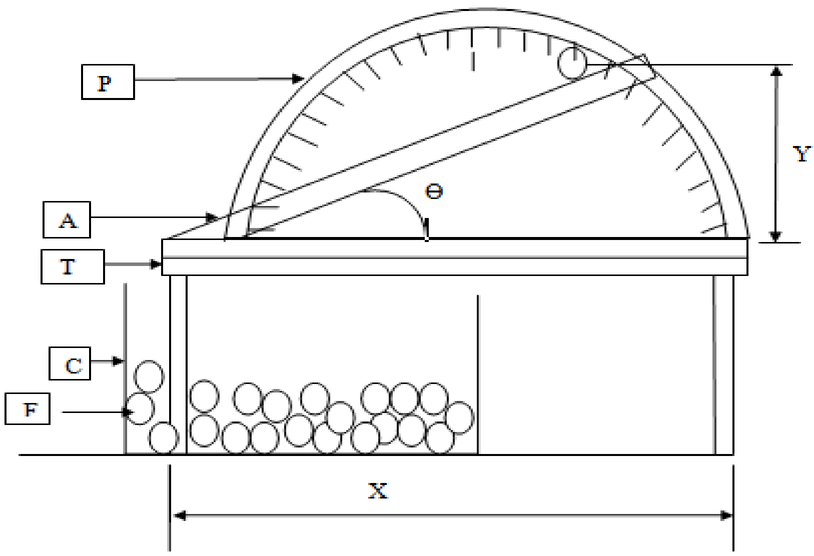


Figure 3 Apparatus arrangement for measuring coefficient of static friction
P- Protractor, A- Inclined Plane Apparatus, T- Table, C- Collector, F-Fruit
θ-Tangent of an angle to the horizontal

The coefficient of static friction (μ) was determined using the inclined plane method as is shown in Figure 3, described by Dutta et al. (1988). The platform was covered at the top with, mild-steel, stainless, and galvanized sheets intermittently while 10 pieces of sliding, indicated by the protractor was obtained as coefficient of static friction.

2.8 Statistical analysis

All experimental data obtained were analyzed using SAS,windows 9.00 (2002) software packages for the

Table 1 Physical properties of *Dura* fruitlets

Age	Mass	Length	Width	Thickness	GMD	Sphericity
Dura 20	3.71c±1.25	23.31c*±3.48	18.77c±2.08	14.65c±2.12	18.52c±2.05	0.80a±0.06
Dura 30	5.76b±1.24	26.57b±3.13	21.29b±2.19	17.35b±1.59	20.85b±1.59	0.79a±0.07
Dura 50	11.60a±2.5	33.28a±3.43	33.28a±2.95	21.36a±2.11	26.32a±2.11	0.80a±0.07

N=100

[a,b,c]*Means of variables on the same column are significantly difference at p<0.05,except in sphericity.*

Table 2 Physical properties of *Tenera* fruitlets

Age	Mass	Length	Width	Thickness	GMD	Sphericity
Tenera 20	8.57b has beed±1.81	30.66c*±3.64	24.00c±2.70	20.21b±3.10	20.79b±2.63	0.81a±0.06
Tenera 30	8.41b±2.46	33.84b±4.93	24.77b±2.95	19.52b±2.89	24.97b±2.16	0.75b±0.09
Tenera 50	14.99a±30.3	42.32a±3.98	27.96a±2.54	23.70a±2.63	29.33a±2.10	0.70c±0.05

N=100

[*a,b,c]*Means of variables on the same column are significantly different at p<0.05*

separation of means by subjecting them to analysis of variance Duncan's Multiple Range Test was employed for the separation of means, while the significant level was at level of $p<0.05$.

3 Results and discussion

3.1 Mass of the fruitlet

As shown in Figure 1, the mass of *Dura* cultivar fruitlets increased from 3.71 to 11.56 g, while the mass of *Tenera* cultivars increased from 7.25 to 14.89 g as the age increased from 20 to 50 years. The mean mass of *Tenera* was observed to be higher than that of *Dura* at any corresponding age.

The mass of both *Dura* and *Tenera* cultivars fruitlets increased with age and *Tenera* cultivar fruitlets was observed to be higher than Dura cultivar fruitlets at any corresponding age. This is the major reason why *Tenera* cultivar fruitlets have more oil content than *Dura* cultivar fruitlets (Hafiz and Shariff, 2011). The results are similar to what was obtained by Owolarafe et al. (2007a) and Akinoso and Raji (2011), who reported that the mass of *Tenera* cultivar fruitlets was higher than that of Dura cultivar fruitlets. Hafiz and Shariff (2011) also reported the mean mass of oil palm FFB and fruitlets of three varieties (*PS1 (nigrescens), PS 1 (virescens) and PS 2*) as 20.45, 20.91 and 41.89 kg, 9.03, 11.04 and 11.24 g respectively. The analysis of variance showed that within each cultivar and in-between both cultivars, age of fruitlets had significant effect ($p< 0.05$) on their masses as shown in Tables 1 and 2 respectively.

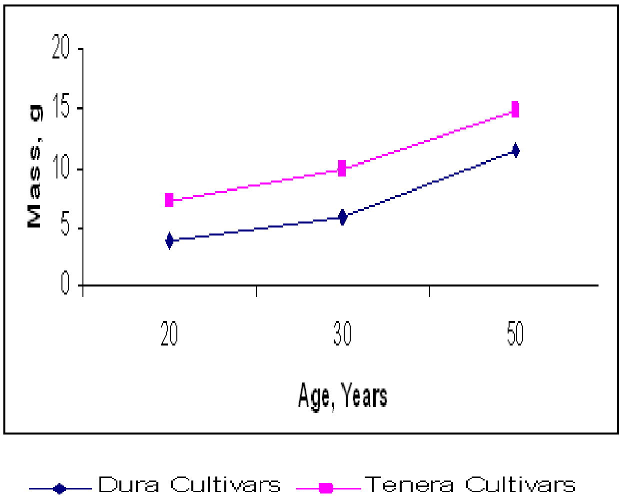


Figure 1 Effect of age on mass of Dura and Tenera

3.2 Axial dimensions

From Figures 2 and 3 the mean axial dimension of fruitlets of *Dura* and *Tenera* cultivars at various moisture contents showed increase with age. . In Figure 2, as the age of *Dura* cultivars increases from 20 to 50 years, length, width and thickness increased from 23.01 to 33.28, 18.78 to 25.96, and 14.64 to 21.37 mm, respectively. The same trend was observed with *Tenera* cultivars as shown in Figure 3. Empirically, *Tenera* cultivar was of higher values in all axial dimensions than *Dura* cultivar when comparing Figures 2 with Figure 3. The variability in axial dimensions of both cultivars of fresh fruitlets of different ages was found to be close to the values reported by previous researchers. Owolarafe et al. (2007a) reported the means of length, width and thickness for *Dura* and *Tenera* cultivars without considering age as: 30.25, 19.95, 15.66 mm; 35.95, 20.15, 17.11 mm, respectively.

These axial dimensions correspond to 30 years of *Dura* and *Tenera* cultivars in Figures 2 and 3.

Oil palm fruitlets varieties (*PS 1(Nigrescens), PS 1(Virescens) and P2*) were reported to have axial dimensions (length, width and thickness) as follows: 34.57, 23.65 mm; 20.95, 38.00, 25.52 mm; and 22.86, 40.64, 27.12 mm, respectively (Hafiz and Shariff, 2011). The disparity in axial dimensions of the fruitlets confirmed differences in their morphology, associated with heterogeneous composition of their cell walls which varies in-between cultivars (Ogunsina, 2009). *Dura* and *Tenera* cultivar fruitlets for 20, 30 and 50 years of age has shown that axial dimensions is significantly different from each other at level of ($p<0.05$), within cultivar and in-between cultivars as is shown in Table 1 and

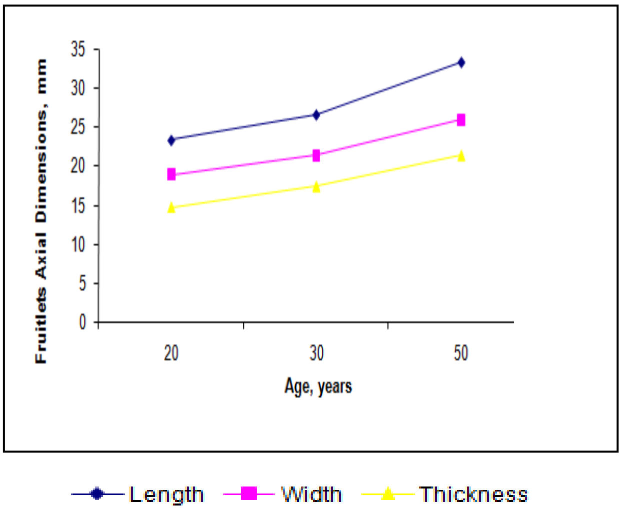


Figure. 2 Effect of age on axial dimensions of Dur

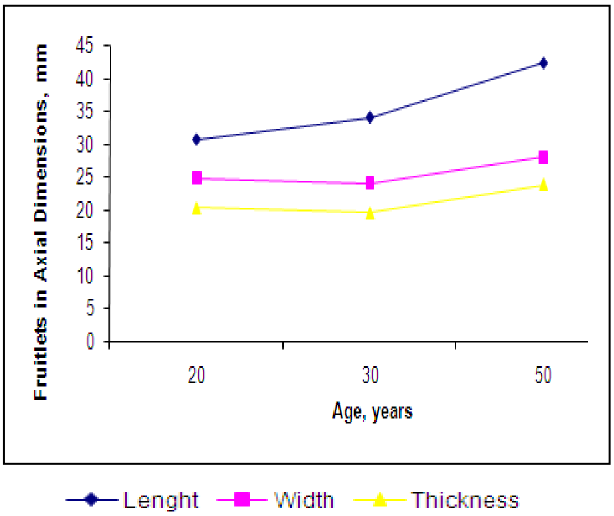


Figure 3 Effect of age on axial dimensions of Tenera

3.3 Sphericity of the fruitlet

In Figure 4, sphericities of fruitlets for Dura and Tenera cultivars were 80, 79; 80%, 81; and 75, 69% at 20, 30 and 50 years respectively. Dura fruitlets cultivar exhibited high tendency to become sphere and can easily roll on any smooth surface than Tenera fruitlet cultivar. These results followed the same trend with other previous researchers' reports. Owolarafe et al. (2007a) reported the mean sphericity of *Dura* and *Tenera* cultivars as 70.67% and 64.23%. Hafiz and Shariff (2011) reported sphericity of three varieties of oil palm FFB and fruitlets (*PS1 (nigrescens), PS 1 (virescens) and PS 2*) as: 80.6%, 84.8% and 76.9%, 74.6%, 75.7% and 81.4%, respectively. Furthermore, Akinoso and Raji (2011) reported sphericity of *Dura* and *Tenera* fruitlets cultivars in the range of 63.4%–80.9% and 52.9%–70.3%, respectively. It was observed that in both cultivars, sphericity values obtained were slightly higher than that of those values reported by other researchers. The age of the oil palm trees that was not considered by other researchers was found to influence the physical properties of fruitlets. In Figure 4, sphericity of both fruitlets cultivars were almost the same from age of 20 to 30 years, as age increased from 30 to 50 years, the sphericity of Dura fruitlets was hihger than that of Tenera fruitlets. The sphericity of both cultivars within each and in between cultivars were significantly different at $p\leq 0.05$ as age increases from 20 to 50 years as is shown in Tables 1 and 2.

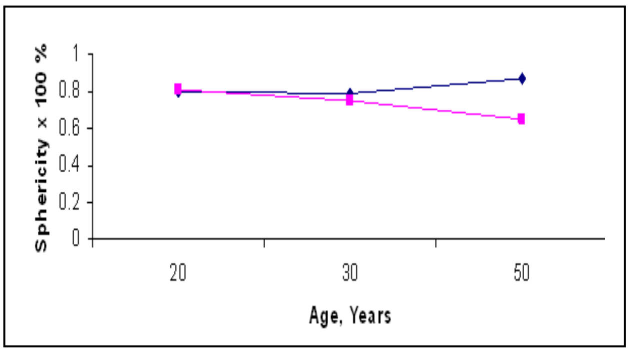


Figure 4 Effect of age on sphericity of Dura and Tenera

3.4 True Density

The result of the effect of age on true density of *Dura* and *Tenera* fruitlets cultivars is shown in Figure 5. The true density of *Dura* and *Tenera* fruitlets cultivars increased from 978.56 to 1180.32 kg/m^3 and 973.04 to 1160.14 kg/m^3, respectively as the age increases. The increase in value could be attributed to the volumetric expansion of fruit tissue walls as age increases which is synonymous to growth. The true density values for both cultivars were within the range obtained by Owolarafe et al. (2007a), Hafiz and Sheriff (2011) on the same cultivars. As shown in Table 3, as the age increases, there was no significant difference in the value of true densities within each cultivar. In Figure 5, there was no disparity between both cultivars in values. However, in-between cultivars, their true densities were insignificantly different ($p < 0.05$) as age increased but there are significant different within the same cultivar as age increases (Table 3).

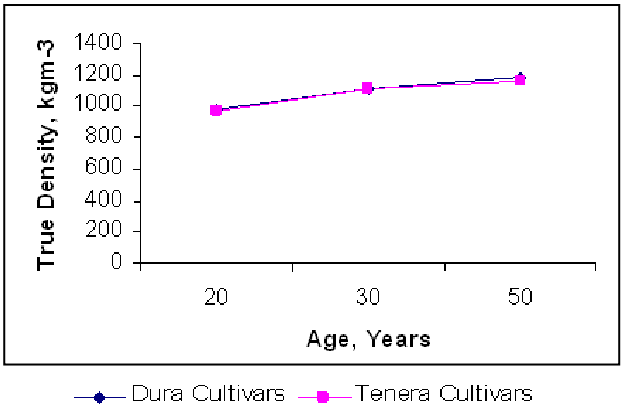


Figure 5 Effect of age on true density for *Dura* and Tenera

3.5 Bulk density

The result obtained for bulk density in respect to the effect of age on Dura and Tenera cultivars fruitlets is shown in Figure 6. The result showed that as age increased from 20 to 50 years for *Dura* and *Tenera* cultivars fruitlets, their corresponding bulk density values increased from 720.50 to 882.25 kg/m^3 and 680.41 to 865.92 kg/m^3 respectively. Averagely, the bulk density of *Dura* cultivar fruitlets is higher than *Tenera* cultivar fruitlets; this may be attributed to higher axial dimension of *Tenera* cultivar fruitlets than *Dura* (Jain and Bal, 1997). Figure 6 shown that as age increased from 20 to 30 years, bulk densities of *Dura* were of higher values than *Tenera* cultivars fruitlets and both cultivars tending towards almost equal value as age increases to 50 years. There was significant difference ($p<0.05$) within and in-between *Dura* and *Tenera* cultivars fruitlets as their age increases from 20 to 50 years as is shown in Table 3.

Table 3 Comparison of true density, bulk density and porosity for *Dura* and *Tenera* cultivars

Code	Cultivars	True Density, kg/m^3	Bulk Density, kg/m^3	Porosity, %
1	*Dura* 20	978.56c ±46.28*	726.50c ±27.34	25.76c ±2.90
2	*Tenera* 20	973.04c ±41.80	680.41d ±36.78	30.05b ±1.86
3	*Dura* 30	1106.50b ±31.87	842.37b ±32.50	24.48c ±2.58
4	*Tenera* 30	1115.46b ±30.60	738.16c ±41.83	33.82a ±3.34
5	*Dura* 50	1180.32a ±37.50	882.26a ±25.47	25.24c ±2.54
6	*Tenera* 50	1160.14a ±46.51	865.92ab ±38.76	25.36c ±2.31

N=5 *^{a,b,c,d}*Means of variables on the same column are significantly difference at p<0.05*

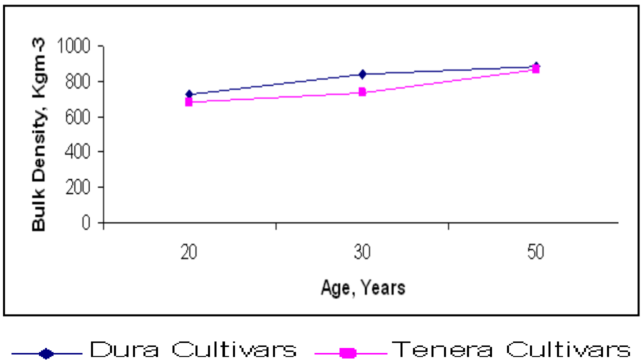


Figure 6 Effect of age on bulk density for *Dura* and *Tenera*

3.6 Porosity

The porosity of *Dura* and *Tenera* cultivars fruitlets ranged from 25.76% to 25.24% and 30.05% to 25.36%, respectively as the age increases from 20 to 50 years (Figure 7). The porosity of *Tenera* was higher than *Dura*. The higher value of porosity exhibited in *Tenera* may be due to their higher value of sphericity and density ratio, which allows for a less compact arrangement of its fruitlets. This could be the main reason why the mean mass for the *Tenera* fruitlets is heavier than *Dura* cultivars. These porosities values were compared favourably with other previous researchers' report on palm oil fruitlets. Owolarafe *et al*. (2007a) reported that *Dura* cultivar fruitlets have porosity value of 40.67%, while *Tenera* cultivars were reported to be 38.55%.

Hafiz and Shariff (2011) also reported the porosities of three varieties of oil palm fruitlets (*PS1 (nigrescens), PS 1 (virescens) and PS 2*) as: 14.48%, 7.05% and 18.72% respectively. The disparities were due to age of palm tree which influences the physical properties of both bunches and fruitlets. In Table 4, the porosity of Dura 20 (25.76%), Tenera 20 (30.05%), Dura 30 (24.48%), Tenera 30 (33.82%) and Dura 50 (25.24%) are significantly different ($p<0.05$) from each other, while the porosity of Dura 20 (25.76%), Dura 30 (24.48%), Tenera 50 (18.98%) and Dura 50 (22.48%) are not significantly different from each other. As is shown in Table 3, porosity increased with age initially and later reduced with age in both cultivars.

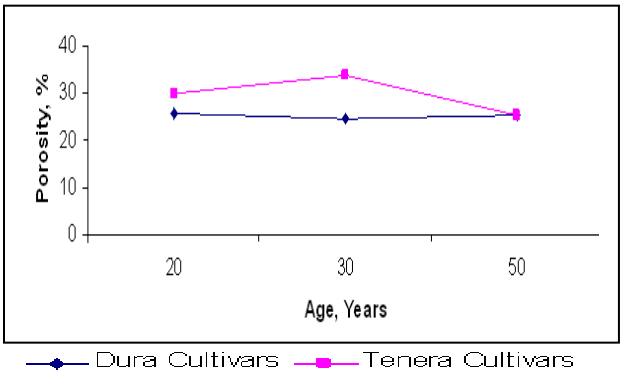


Figure 7 Effect of age on porosity of Dura and Tenera

3.7. Coefficient of static friction

The effect of age on coefficient of friction between five structural materials surfaces with *Dura* and *Tenera* cultivars fruitlets is shown in Figures 8 and 9. The coefficient of static friction for *Dura* cultivars fruitlets on plywood decreased from 0.59 to 0.55, 0.57 to 0.54; 0.53 to 0.51; 0.59 to 0.56 and 0.59 to 0.57 for aluminum, stainless steel, mild steel, and galvanized steel, respectively. The same variation was observed in *Tenera* cultivar fruitlets (Figure 8), but lower in values to *Dura* cultivars fruitlets on the same material. It was observed that as the age of *Dura* and *Tenera* cultivars fruitlets increased, the coefficient of static friction decreased. As shown in Table 5, there is significant difference in all structural material except galvanized sheet. Stainless steel has the lowest coefficient of static friction than any other materials, while values obtained for plywood, aluminum, mild steel and galvanized steel were very close.

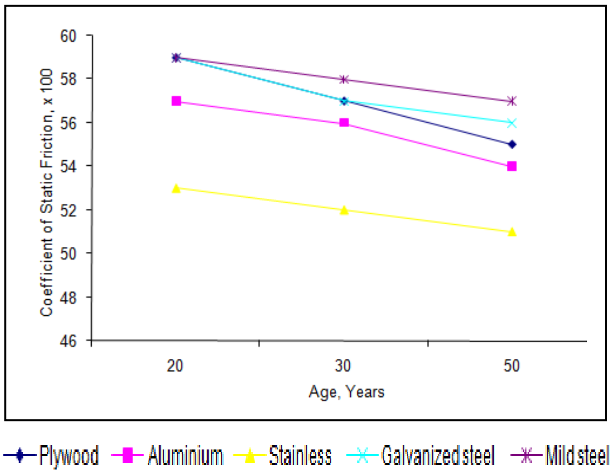
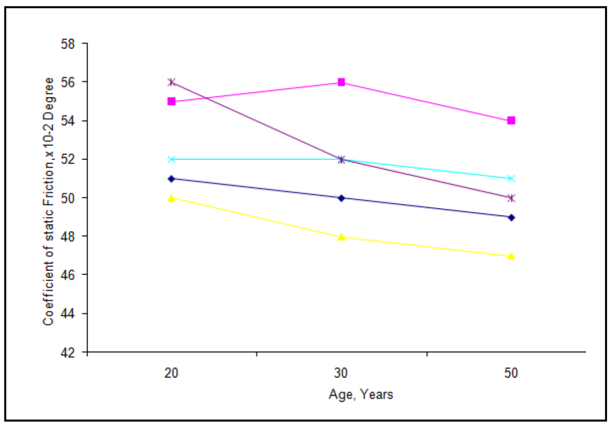


Figure 8 Effect of age on coefficient of static friction for Dura



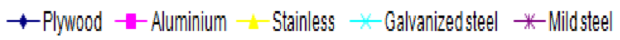


Figure 9 Effect of age on coefficient of static friction for Tenera

aluminum, mild-steel and galvanized steel material surfaces with *Dura* and Tenera cultivars fruitlets. In comparison, from Figures 10 and 11, a sudden increase in the angle of repose values of Dura cultivar fruitlets as

Table 5 Comparison of coefficient of static friction properties on *Dura* and *Tenera* cultivars

Code	Cultivars years	Plywood	Aluminium Sheet	Stainless steel	Mild steel plate	Galvanized steel sheet
1	*Dura* 20	0.59a ±0.02	0.57a ±0.02	0.53a ±0.03	0.59a ±0.03	0.59a ±0.03
2	*Tenera* 20	0.51d ±0.02	0.55c ±0.03	0.50b ±0.03	0.52c ±0.02	0.56a ±0.05
3	*Dura* 30	0.57b ±0.01	0.56b ±0.01	0.52a ±0.03	0.57b ±0.03	0.58a ±0.03
4	*Tenera* 30	0.50d ±0.02	0.56b ±0.03	0.48c ±0.04	0.52c ±0.04	0.52b ±0.03
5	*Dura* 50	0.55c ±0.02	0.54cd ±0.02	0.51b ±0.02	0.56b ±0.02	0.56a ±0.03
6	*Tenera* 50	0.49e* ±0.01	0.54d ±0.03	0.47d ±0.03	0.52c ±0.03	0.50b ±0.03

N=20 *[a,b,c,d,e,] *Means of variables on the same column are significantly difference at* $p<0.05$.

3.8 Angle of repose

The results obtained on the effect of age on angle of repose between five structural materials surfaces with *Dura* and *Tenera* cultivars fruitlets (20, 30 and 50 years) at various moisture contents values were shown in Figure 10. The angle of repose between *Dura* cultivars of 20 to 50 years of age on plywood increases from 23.64 to 41.65°, on aluminum, it increases from 22.21 to 39.20°, on stainless steel, it increases from 18.94 to 33.58°, on mild steel, it increases from 28.95 to 42.58° and on galvanized steel, it increases from 23.82 to 41.42°, respectively. In Figure 11, it was also observed that the angle of repose between *Tenera* cultivars of 20 to 50 years of age on plywood increases from 23.75 to 25.50°, on aluminum, it increases from 19.20 to 19.68°, on stainless steel, it increases from 24.05 to 26.08°, on mild steel, it increase from 0.52 to 0.53° and on galvanized steel, it increases from 24.05 to 24.41°, respectively. As the age increased from 20 to 50 years, the angle of repose of both cultivars fruitlets increased. This may be due to higher proportionate of increase in length than any other axial dimensions, which enhances stability of the fruitlets.

The values of angle of repose obtained are very close to the values as previous researchers reported, on palm oil seed and grains as established by Mohsenin (1986). Owolarafe et al. (2007b) reported the same trend that the average values of angle of repose between plywood,

age increased from 30 to 50 years was observed to be at a faster rate than Tenera cultivar fruitlets. Likewise, the angle of repose of stainless steel was lower than any other materials of construction in *Tenera* cultivars. However, other materials exhibited close values of negligible difference. However, there was not any significant difference within and in-between both cultivars of angle of repose on five structural materials as

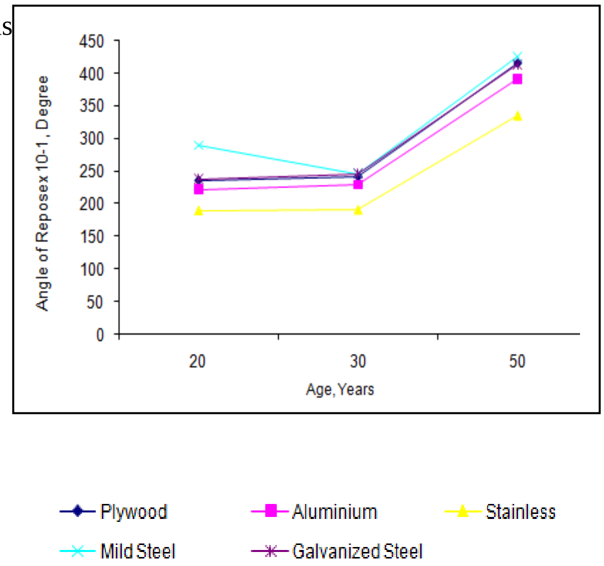
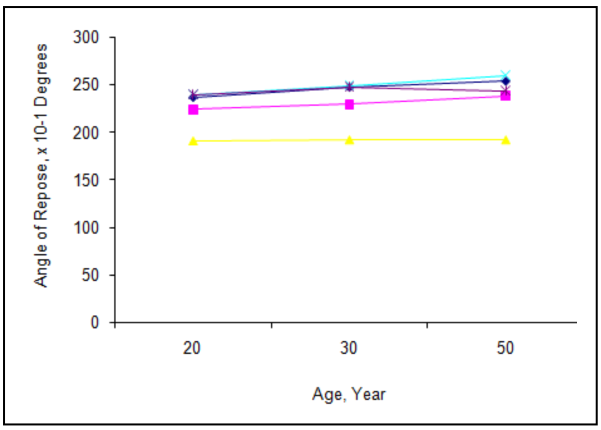


Fig. 10: Effect of Angle of Repose for Dura Cultivar



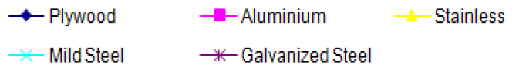


Fig. 11: Effect of Angle of Repose for Tenera Cultivar

Table 6 Comparison of angle of repose of *Dura* and *Tenera* Cultivars fresh fruitlets

Code	Cultivars years	Plywood	Aluminium Sheet	Stainless steel	Mild steel plate	Galvanized steel sheet
1	*Dura* 20	23.64a±1.68	22.08a±1.09	18.83a±1,94	23.95b±2.38	23.80a±2.33
2	*Tenera* 20	23.25a*±1.30	22.50a±1.44	19.03a±2,34	24.05ab±2.24	24.57a±2.31
3	*Dura* 30	24.99a±2.13	23.54a±2.05	19.89a±2.94	24.63ab±2,69	24.70a±2.82
4	*Tenera* 30	23.75a±1.78	22.76a±1.71	19.38a±2.69	24.95ab±2.55	24.90a±2.66
5	*Dura* 50	24.85a±1.29	23.13a±1.45	19.36a±2.35	25.55ab±2.36	24.90a±2.05
6	Tenera 50	25.50a±1.53	23.57a±1.67	19.41a±2.95	26.01a±2.65	24.40a±2.64

N=20 *[a,b]*Means of variables on the same column are significantly difference at p<0.05.*

4 Conclusions

The physical properties such as: mass, axial dimensions and gravimetric dimensions of Dura and Tenera cultivars increased as age of the fruitlets increased from 20 to 50 years of cultivation, except the porosity of Dura cultivars which exhibited decrease as age increased.

The sphericity of Dura cultivars remained constant with age increase, while that of Tenera cultivars decreased proportionally as age increased.

The coefficient of static friction between Dura and Tenera cultivars from 20 to 50 years of age decreased as age increased on plywood, aluminum, stainless steel, mild steel and galvanized steel, while the angle of repose values almost remained constant.

There were significant different (p<0.05) within and in-between some physical properties of both cultivars except sphericity in Dura cultivar as age increased. Also, there were significant different (p<0.05) on coefficient of static friction of both cultivars on five structural materials, but on angle of repose, it was insignificantly different as age of both cultivars increased from 20 to 50 years. Conclusively, the age of oil palm tree cultivation influenced some physical properties of fruitlets of Tenera and Dura cultivars in Nigeria.

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