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# Physical properties of fruit, nut and kernel of oil palm

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A b s t r a c t. Physical properties of Tenera and Dura varieties of palm fruits, nuts and kernels were determined at 3 levels of moisture content (5, 8, 11% w.b.) and temperature (40, 60, 80°C) using standard methods. Obtained data were subjected to regression analysis and ANOVA. The moisture content and temperature effects on mass and force at break point of palm fruit, nut and kernel of the two varieties were significant at $p \leq 0.05$. Sphericity was not significantly ($p \leq 0.05$) dependent on treatment. Studied properties of both varieties showed similar trends but differed in quantity. Shapes of Tenera fruits and Dura nut were close to ovate shape while Dura fruit, kernel and Tenera nut and kernel were close to a sphere in shape. Quantity of energy required to compress a kernel was the highest, followed by mesocarp pressing and cracking of the nuts.

K e y w o r d s: oil palm, fruit, nut, kernel, varieties, physical properties

## INTRODUCTION

Industrial application of vegetable oil is increasing fast. Oil palm is acclaimed to be the richest vegetable oil plant. Harvested palm bunches undergo processing stages of sterilization, striping, digestion and palm oil extraction. Palm nuts and fibres are left as residue. The nuts are dried and cracked into palm kernel and shell. Vegetable oil obtained from oil palm provides double energy as the same quantity of carbohydrate and is therefore considered to be a valuable part of a well balanced diet. 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).

Physical properties of crops are essential parameters in utilization, development of processing methods, and design of equipment (Bagherpour *et al*., 2010; Ogunsina *et al*., 2008). Such properties include rheological, thermal, optical, electrical, physical and mechanical properties. Oil yield and quality have been reported to depend on design parameters (Akinoso *et al*., 2009). Improvement of technology of processing palm fruit, nut and kernel requires accurate information on the physical properties of the crop as affected by primary processing.

This work was carried out to study the effect of moisture content and temperature on some physical and mechanical properties of palm fruit, nut and kernel of two varieties of oil palm tree.

## MATERIALS AND METHODS

Freshly harvested palm fruit of oil palm varieties Tenera and Dura were sourced from Ogun State Ministry of Agriculture and cooperatives (Apoje oil mill), Nigeria. These were processed into nuts and kernel. Their moisture content and temperature were varied using 3x3 factorial experimental design. Levels of moisture content and temperature were 5, 8 and 11% wet basis, and 40, 60 and 80°C, respectively.

Unit mass of the 200 number of each sample used for the analyses were obtained by weighing each sample on a Sartorius 1600 electronic digital weighing balance to an accuracy of 0.001 g. The mean was computed and taken as the unit mass. Spatial dimensions, *viz.* length, thickness and width of 200 units, were measured using digital vernier caliper with 0.01 mm accuracy (Cappera precision, China). These are the dimensions along the longest axis, across the axis perpendicular to the longest in the horizontal direction, and across the third axis perpendicular to both the first and second axis. The average of 200 numbers of samples was determined and recorded as the mean dimension for each of the three dimensions. The sphericity was determined according to Mohsenin (1986).

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Mechanical properties, *viz.* force at break, deformation at break and energy to break was determined using Testometric AX Type DBBMTCL – 2500 kg (Rochdale, England). Testing conditions for the Instron machine were as follows: loading range 0-500 N and crosshead speed 5-30 mm $min^{-1}$. Each sample of palm fruit, nut and kernel was placed between the compression plates of the testing equipment. The sample was compressed at a constant deformation rate of 25.00 mm $min^{-1}$. The procedure was repeated for the 200 replicates. The data logger attached to the machine recorded the listed parameters.

All the experimental procedures were repeated three times for the two varieties. Mean values were recorded as obtained data. Collected data were subjected to regression analysis and ANOVA using SPSS package.

## RESULTS

The average masses of the fruits were 20.7 and 17.4 g for Tenera and Dura variety respectively. At $p \leq 0.05$, the influence of both moisture content and temperature was significant. Coefficients of determination for Tenera and Dura were 0.77 and 0.96, respectively. The sphericity of the fruits was below 75%. The effect of moisture content was non-significant at $p \leq 0.05$ on sphericity of the two varieties, while temperatures significantly affected the fruits shape.

Mechanical properties of the palm fruits under compression load were as presented in Table 1. Dura required higher force and energy in compression. The reverse was experienced in deformation. Both moisture content and temperature significantly affected the force and deformation at break point of the palm fruits at $p \leq 0.05$. Only the energy required to break Dura fruit was significantly influenced by the process parameters.

The masses of the Tenera and Dura nuts were 2.8 and 9.1 g, respectively. It was interesting to note that differences between the palm fruits and nuts mass were 86.5 and 47.7% for Tenera and Dura, respectively. Mass of the palm nuts for the varieties was significantly affected by moisture content and temperature at $p \leq 0.05$. High coefficients of determination were also recorded. Mean sphericity of the Tenera palm nut was 80% while that of Dura was 69%.

Forces required to break the two varieties of palm nuts were significantly influenced by moisture content and temperature at $p \leq 0.05$, while deformation and energy required to break Tenera were not significantly affected. Dura recorded higher values of force and energy to break (Table 2).

Only the Tenera kernel mass was significantly ($p \leq 0.05$) affected by the treatments. Mean mass of 1.4 and 2.6 g were recorded for Tenera and Dura kernel, respectively. Treatments did not affect palm kernel shape of both varieties ($p \leq 0.05$). The sphericity of all the kernels was high.

Deformation, force and energy required to break the kernel were significant at $p \leq 0.05$. From regression analysis, coefficients of the determination were 0.86, 0.93, 0.95 and 0.93, 0.92 and 0.93 for Tenera and Dura deformation, force and energy to break, respectively. Noticeable differences were observed between the mechanical properties of the varieties (Table 3). The force and energy to break Dura palm kernel were 5870.4 N and 11.6 Nm, respectively, while 2791.3 N and 6.1 Nm were required as the force and energy to break Tenera, respectively.

## DISCUSSION

Increase in moisture was an added weight, and this accounted for the observed behaviour. The weight of crops is one of the major determinants in the choice of handling equipment (Mijinyawa, 2007). An expansion of the mesocarp was noticed during heat treatment. Thus, change in shape might occur. The shape and size of material are relevant in design and selection of appropriate cleaning equipment. A low value of calculated sphericity was an indication of non-spherical shape.

**T a b l e 1.** Physical and mechanical properties of Tenera and Dura palm fruits

| Treatments | | Mass (g) | | Sphericity (%) | | Force (N) | | Deformation (mm) | | Energy (Nm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture content (% w.b.) | Temperature (°C) | Tenera | Dura | Tenera | Dura | Tenera | Dura | Tenera | Dura | Tenera | Dura |
| 5 | 40 | 19.1 | 15.9 | 52.9 | 74.7 | 806.1 | 3924.6 | 11.7 | 8.7 | 4.2 | 4.9 |
| 5 | 60 | 19.4 | 15.0 | 70.1 | 63.4 | 763.4 | 3786.1 | 12.4 | 9.5 | 3.7 | 4.8 |
| 5 | 80 | 18.3 | 14.5 | 58.3 | 74.6 | 684.0 | 3412.0 | 13.6 | 9.7 | 3.2 | 4.1 |
| 8 | 40 | 22.8 | 18.3 | 64.0 | 80.9 | 754.2 | 3784.4 | 12.6 | 9.1 | 3.1 | 4.3 |
| 8 | 60 | 21.7 | 17.9 | 61.7 | 66.4 | 716.9 | 3521.1 | 13.1 | 10.1 | 3.0 | 4.2 |
| 8 | 80 | 17.6 | 15.6 | 69.6 | 68.9 | 671.1 | 3449.7 | 13.9 | 10.5 | 2.8 | 3.6 |
| 11 | 40 | 26.6 | 21.9 | 70.3 | 70.3 | 699.7 | 3642.1 | 12.9 | 9.6 | 3.9 | 3.8 |
| 11 | 60 | 22.7 | 20.0 | 59.9 | 71.5 | 683.2 | 3416.4 | 13.2 | 10.5 | 3.5 | 3.6 |
| 11 | 80 | 18.3 | 18.3 | 60.0 | 74.5 | 643.5 | 3321.4 | 14.3 | 10.9 | 2.6 | 3.4 |

**T a b l e 2.** Physical and mechanical properties of Tenera and Dura palm nuts

| Treatments | | Mass (g) | | Sphericity (%) | | Force (N) | | Deformation (mm) | | Energy (Nm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture content (% w.b.) | Tempe-rature (°C) | Tenera | Dura | Tenera | Dura | Tenera | Dura | Tenera | Dura | Tenera | Dura |
| 5 | 40 | 2.5 | 8.0 | 82.4 | 75.3 | 564.2 | 3327.1 | 8.7 | 3.4 | 0.44 | 2.4 |
| 5 | 60 | 2.3 | 7.9 | 70.6 | 63.4 | 543.7 | 3132.0 | 9.3 | 3.6 | 0.42 | 2.1 |
| 5 | 80 | 1.9 | 7.1 | 93.4 | 76.4 | 513.2 | 3041.9 | 9.5 | 3.6 | 0.41 | 1.6 |
| 8 | 40 | 3.2 | 9.3 | 77.7 | 70.1 | 551.8 | 3222.2 | 8.8 | 3.7 | 0.44 | 2.2 |
| 8 | 60 | 2.7 | 9.1 | 78.3 | 63.4 | 536.0 | 2889.6 | 9.6 | 3.8 | 0.42 | 1.8 |
| 8 | 80 | 2.4 | 8.6 | 71.6 | 59.0 | 501.7 | 2804.1 | 9.7 | 3.6 | 0.40 | 1.6 |
| 11 | 40 | 3.7 | 11.7 | 73.9 | 70.1 | 536.1 | 3006.1 | 8.7 | 3.7 | 0.43 | 2.1 |
| 11 | 60 | 3.6 | 10.8 | 84.2 | 73.4 | 517.9 | 2636.4 | 9.3 | 3.9 | 0.37 | 1.7 |
| 11 | 80 | 3.0 | 9.3 | 86.5 | 66.1 | 492.7 | 2516.1 | 9.4 | 3.7 | 0.37 | 1.4 |

**T a b l e 3.** Physical and mechanical properties of Tenera and Dura palm kernals

| Treatments | | Mass (g) | | Sphericity (%) | | Force (N) | | Deformation (mm) | | Energy (Nm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture content (% w.b.) | Tempe-rature (°C) | Tenera | Dura | Tenera | Dura | Tenera | Dura | Tenera | Dura | Tenera | Dura |
| 5 | 40 | 1.2 | 10 | 88.6 | 71.6 | 3204.4 | 6211.1 | 8.9 | 8.1 | 5.4 | 15.7 |
| 5 | 60 | 1.1 | 1.5 | 90.9 | 80.1 | 3001.9 | 6020.4 | 9.1 | 7.2 | 5.4 | 13.1 |
| 5 | 80 | 1.1 | 1.3 | 73.5 | 60.5 | 2634.6 | 5836.3 | 9.5 | 6.7 | 5.1 | 12.0 |
| 8 | 40 | 1.6 | 2.1 | 77.4 | 67.3 | 3105.2 | 6019.4 | 9.3 | 7.6 | 5.0 | 14.3 |
| 8 | 60 | 1.4 | 1.3 | 83.1 | 63.2 | 2776.3 | 5941.1 | 10.4 | 6.3 | 4.7 | 10.1 |
| 8 | 80 | 1.2 | 1.3 | 90.1 | 76.1 | 2614.0 | 5713.2 | 11.6 | 5.0 | 4.7 | 9.3 |
| 11 | 40 | 1.7 | 2.5 | 87.6 | 77.6 | 2777.4 | 5898.0 | 9.7 | 5.3 | 4.6 | 12.2 |
| 11 | 60 | 1.7 | 2.0 | 93.4 | 80.1 | 2632.9 | 5707.0 | 10.8 | 5.8 | 4.1 | 9.0 |
| 11 | 80 | 1.6 | 1.8 | 77.7 | 61.0 | 2421.5 | 5525.5 | 11.9 | 4.4 | 3.9 | 8.4 |

The recorded trend of the mechanical properties suggested that energy input in palm oil recovery processes from Dura fruit will be more substantial than Tenera requirements. Stripping and pressing are important unit operations in palm oil processing. The efficiency recorded in these operations was likely to be influenced by the mechanical behaviour of palm fruits under compression loading since they involved the application of pressure.

The wide difference between fruit and nut mass explained why Tenera produces higher quantity of palm oil. Tenera variety was preferred to Dura (wild grove) due to its greater oil-bearing capacity in the mesocarp (Omoti, 2004). Moisture content of nuts was one of the basic parameters that determine the performance of palm nut cracking machine (Bamgboye and Sadiku, 2003). Therefore, in the design of palm nutcracker, general consideration can be made for moisture content level. High value of sphericity is an indication of the nuts tending to the shape of a sphere. It is also a measure of ability of the nuts to roll rather than slide on a flat surface. This characteristic is very important in the design of hoppers for machines (Burubai *et al*., 2007).

Variation in forces required to break the nuts may be attributed to variation in shell thickness. Tenera and Dura have shell thickness of 2-8 and 0.5-2 mm, respectively (NIFOR, 2000). The wide margin noticed between the values of tenera and Dura revealed that a common palm nutcracker may not be efficient for the two varieties. Tenera required a small force for cracking; application of forces higher than the appropriate will break the kernel. Meanwhile, Akinoso and Igbeka (2007) cautioned that the rate of free fatty acid (a major quality parameter) increase is much faster in broken palm kernels than in whole kernels.

Higher mass of Dura gave it a tendency of having higher quantity of palm kernel oil. High value sphericity showed that their shapes are closed to being spherical. Data on palm kernel spatial dimensions and shape are relevant in the design of vegetable oil expellers. Cognisance must be taken of size and shape of oil-seed in the design of screw pitch, depth of worm, flight width, and helix angle for vegetable oil expellers (Olayanju, 2002).

The dependence of thermodynamic properties of palm kernel on moisture content, reported by Ajibola *et al*. (2005), might account for the significance of treatments. Mechanical oil expression is a process of removing oil from oil-bearing material by the application of pressure using a mechanical device. The importance of application of appropriate pressure in mechanical oil expression has been continuously emphasized (Raji and Favier, 2004).

## CONCLUSIONS

1. Moisture content and temperature affected the mass and force at break of palm fruit, nut and kernel of the two varieties. Studied properties of both varieties showed similar trends but differ in quantity.

2. Tenera fruit is bigger with smaller kernel. This is an advantage in palm oil production. Dura has smaller fruit with bigger kernel. It is an advantage quality characteristic in palm kernel oil production.

3. Shape *viz.* sphericity was not dependent on treatment. Shapes of Tenera fruit and Dura nut were close to ovate shape, while Dura fruit, kernel and Tenera nut and kernel were close to the sphere in shape.

4. Quantity of energy required to compress Dura kernel was the highest, followed by mesocarp pressing and cracking of the nuts, in that order. Very little energy was required to crack Tenera nut (0.4 Nm).

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