

EFFECT OF MOISTURE CONTENT OF TWO VARIETIES OF PALM KERNEL AND SHELL ON THE COEFFICIENT OF SLIDING FRICTION OF A LOCAL FABRIC

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ABSTRACT

The frictional properties of a material are useful in designing equipment for crop processing and storage. The effect of moisture content of two varieties of palm kernel and shell on the coefficient of sliding friction of a local fabric was determined. An oven drying method at 105 °C was used to determine the moisture content according to ASAE Standards. The moisture content of *dura* and *tenera* varieties were 17.4 and 18.2 % (w.b.) which were individually adjusted to 9, 13 and 17 % by adding 76.3, 39.8 and 3.3 g; and 82.3, 46.4 and 10.6 g distilled water respectively. The angle of repose apparatus was used to determine the coefficient of sliding friction of palm kernel and shell of *dura* and *tenera* varieties on the two faces of local fabric. The coefficient of sliding friction for *dura* kernel and shell on the two faces of a local fabric ranged from 0.384-0.655 for 9 %; 0.484-0.706 for 13 %; and 0.462-0.695 for 17 %. The coefficient of sliding friction for *tenera* kernel and shell on the two faces of a local fabric ranged from 0.660-0.947 for 9 %; 0.711-0.852 for 13 % and 0.611-0.902 for 17 %. The moisture contents of *dura* palm kernel, *tenera* palm kernel and *tenera* palm shell had significant effect ($p < 0.05$) on the coefficient of sliding friction on face A and face B of the local fabric but moisture content of *dura* palm shell had no significant effect ($p > 0.05$) on the coefficient of sliding friction.

Keywords: Local fabric, moisture content, coefficient of sliding friction, frictional separation

INTRODUCTION

The high utility of kernel and its products in most Nigeria markets has increased the demand for oil palm kernel nut. These nuts are dried and cracked to obtain the kernel alongside shells which the former is crushed in the mill to obtain palm kernel oil (PKO) and palm kernel cake while the latter are used in the boiler as fuel. The domestic and industrial usage of PKO cannot be overemphasized because it serves as ingredients to many household products, such as but not limited to: soap making, washing powders, margarine, candle, pomade, oil paint, polish, cosmetics and medicine. The palm kernel cake (PKC) found its usage in livestock industries as one of the major ingredients of feed formulation (Emeka & Olomu, 2007; Adepoju *et al.*, 2019).

An effective separation of palm kernel from shell is an important process in the downstream industrial utilization of the components in which the requirements for kernel cleanliness and quality present a major constraint in the palm kernel oil extraction process (Olasumboye & Koya, 2014). There are two methods of separation widely used in Nigeria which are wet and dry methods. The wet methods, clay bath and hydro-cyclones, are used industrially which is a separation done in a liquid medium due to the difference in specific gravity of the components. Nevertheless, it is plagued with some limitations such as large volume of water is required for the separation and the kernel recovered in the wet systems must be sterilized against the growth of moulds and re-dried for 14-16 hours in

silos in order to remove moisture absorbed during the separation process (Akubuo & Eje, 2002; Adepoju, 2019). The dry methods, manual and mechanical, do not require liquid medium for their separation but used one or more of the following principles, which are gravity, coefficient of friction, speed variation, relative motion and shapes of separating materials. Most of these principles of separation had been explored but hampered with some limitations that can be categorized as low separation efficiency except the separation on different canvas materials, different from structural materials, to effect separation according to the surface roughness of the canvas material.

Nonetheless, there are some factors that affect particles motion on an inclined conveyor belt according to Olaoye and Babatunde (2011) which are gravity, crop particle shape, conveyor belt, density, velocity, conveyor belt slope and the coefficient of sliding friction of the crop component on belt material. They also reiterated that belt slope less than the angle of sliding friction of the crop product components, the motion of the particle is hyperbolic, and the belt system behaves as a conveyor but for belt slope greater than the angle of sliding friction of the crop product components, the motion of the particle is sinusoidal, and the belt system behaves as a separator with sufficient belt length. Additionally, Sitkei (1986) mentioned numerous factors that can influence the friction coefficients of agricultural products of which are the moisture content, surface pressure, sliding velocity, nature of the surface and the characteristics of

the environment. All these aforementioned factors could possibly affect the frictional separation of the palm kernels and shells mixture.

Therefore, this research investigated the effect of moisture content on the coefficient of sliding friction of two varieties of palm kernel and shell on the coefficient of sliding friction of a local fabric.

MATERIALS AND METHODS

Materials

The materials used for the determination of moisture content and coefficient of sliding friction of palm kernel and shell were: Digital weighing balance (Scout Pro (SPU2001) electronic balance with accuracy 0.1 g), oven drying machine, desiccator (180 ml), *dura* palm kernel and shell, *tenera* palm kernel and shell, and angle of repose apparatus.

Methodology

Sample collection

Dura nuts were collected from Ogun State Ministry of Agriculture, Eweje, Odeda, Abeokuta, Ogun State while *tenera* nuts were collected from Directorate of University Farms (DUFARM), Federal University of Agriculture, Abeokuta (FUNAAB).

Sample preparation

Dura and *tenera* nuts were cleaned manually from unwanted materials such as cell debris, stones and dirt. The cleaned palm nuts were cracked mechanically using centrifugal cracker into palm kernels and shells. The mixture of the cracked nuts was manually separated into palm kernels and shells in order to know the weight of each component. 1.20 kg of palm kernel and palm shell were weighed individually.

Determination of moisture content

The moisture content determination of *dura* and *tenera* varieties of palm kernel and shell was carried out in the Agricultural and Bio-Resources Engineering Crop Processing Laboratory, College of Engineering, Federal University of Agriculture, Abeokuta (FUNAAB) which is located approximately on latitude 7.2297° N and longitude 3.4392° E, Ogun State, Nigeria.

The initial moisture content of the cracked mixture of palm kernels and shells of the two varieties was determined by oven drying method using ASAE Standards (1998) for oil seeds as used by Orhevba *et al.* (2013). The individual component (1.20 kg) of palm kernels and shells of the two varieties were put in an oven at 105 °C for the first six (6) hours after which it was put in a desiccator to allow them to cool down before measuring the mass of each component and to avoid the component absorbing moisture when out of the oven. Thereafter, the mass of each component was checked at every one (1) hour in order to get a constant mass of the component. Immediately the mass of the component was constant, the final mass of the components was weighed and equation (1) was used to compute the initial moisture content. The component

was divided into three (3) portions each for the two varieties.

$$mc = \frac{w_1 - w_2}{w_1} \quad (1)$$

Where: mc is moisture content, %; w_1 is initial moisture content, kg; w_2 is the final moisture content.

Moisture content adjustment

Calculated amount of distilled water was added to the six (6) samples of the mixture of kernels and shells of the two varieties to bring them to the desired moisture contents of 9, 13 and 17 % w.b. using equation (2) (Olayanju, 2002) and sealed in separate polythene bags. Thereafter, the polythene was kept in refrigerator at 5 °C temperature for at least one week to ensure moisture uniform distribution according to Davies and Zibokere (2011).

$$Q = \frac{A(b - a)}{(100 - b)} \quad (2)$$

Where: A is Initial mass of the sample, g; a is initial moisture content of the sample, % wet basis (w.b.); b is final (desired) moisture content of sample % (w.b.); Q is mass of water added to be added, g.

Determination of coefficient of sliding friction

Coefficient of sliding friction was determined using procedures described by Sitkei (1986) as used by Adepoju *et al.* (2023). The apparatus used for the determination is shown in the Plate 1. The components of each variety of palm kernels and shells were loaded in turns into a bottomless four-sided cardboard made box of dimension 100 × 50 × 30 mm on the tilting board. In order to allow the free movement of the sample, one of the edges of the box was not fixed in order to allow for the movement of the crop product component on the board surface covered with local fabric material as shown in the Plate 2. An adjustable screw jack is positioned under the apparatus for controlling the angle of inclination. The box was loaded in turns with the two varieties of kernels and shells. The tilt angle at initial sliding of the box was noted for five readings and averaged. The coefficient of sliding friction was calculated with the Equation (3).

$$\mu = \tan\theta \quad (3)$$

Where μ is the coefficient of friction and θ is the angle of inclination (degree).



Plate 1: Coefficient of sliding friction determination apparatus



Plate 2: Local Fabric for the two faces

Experimental Design

The experimental design was $3 \times 2 \times 2 \times 2 \times 5$ factorial experiment where three (3) moisture contents was used for two (2) varieties of two (2) samples (palm kernel and shell) on two (2) faces of local fabric material at five (5) replicates. The total runs for the determination of coefficient of sliding friction was one hundred and twenty (120).

Data Analysis

The coefficient of sliding friction obtained for the three (3) moisture content of two (2) varieties of two (2) samples on two (2) faces of local fabric material at five (5) replicates were analyzed using the analysis of variance (ANOVA) of Minitab 21 statistical software at 5% significant level. Separation of means was carried out by the use of Tukey.

RESULTS AND DISCUSSION

The moisture content of *dura* and *tenera* varieties was determined to be 17.4 and 18.2 % which were adjusted to 9, 13 and 17 % by adding 76.3, 39.8 and 3.3 g; and 82.3, 46.4 and 10.6 g distilled water respectively.

The average values of *dura* kernel and shell coefficient of sliding friction using the two faces of local fabric material are showed in the Table 1. The *dura* kernel coefficients of sliding friction for 9, 13 and 17 % moisture contents (w.b.) for face A and face B were 0.38, 0.484 and 0.462; and 0.479, 0.564 and 0.568 respectively. It was observed that the coefficient of sliding friction increases as the moisture content increases from 9 to 13 % but decreases as the moisture content increases from 13 to 17 % for the face A and the coefficient of sliding friction obtained increases as the moisture content increases from 9 to 17 % for face B. The coefficient of sliding friction of face B was higher than coefficient of sliding friction for face A (Table 1).

The *dura* shell coefficients of sliding friction for 9, 13 and 17 % moisture contents (w.b.) for face A and face B were 0.519, 0.550 and 0.541; and 0.655, 0.706 and 0.695, respectively. It was observed that the coefficient of sliding friction obtained increases as the moisture content increases from 9 to 13 % but decreases as the moisture content increases from 13 to 17 % for the face A and the coefficient of sliding friction obtained

increases as the moisture content increases from 9 to 13 % but decreases as the moisture content increases from 13 to 17 % for face B. The coefficient of sliding friction of face B was higher than the coefficient of sliding friction for face A (Table 1).

Also, the coefficient of sliding friction of *dura* palm shell on any face of the local fabric was higher than the coefficient of sliding friction of *dura* palm kernel.

Table 1: Average values of *dura* kernel and shell coefficient of sliding friction on local fabric material at different moisture content

Moisture content (%)	<i>Dura</i> palm kernel			
	Face A		Face B	
	θ°	μ	θ°	μ
9	21.0±1.58	0.384±0.03	25.6±0.89	0.479±0.02
13	25.8±1.10	0.484±0.02	29.4±1.95	0.564±0.04
17	24.8±0.84	0.462±0.02	29.6±1.14	0.568±0.03
For <i>Dura</i> palm shell				
9	27.4±1.82	0.519±0.04	33.2±1.79	0.655±0.05
13	28.8±1.30	0.550±0.03	35.2±1.79	0.706±0.05
17	28.4±1.82	0.541±0.04	34.8±0.48	0.695±0.01

Table 2: Average values of *tenera* kernel and shell coefficient of sliding friction on local fabric material at different moisture content

Moisture content (%)	<i>Tenera</i> palm kernel			
	Face A		Face B	
	θ°	μ	θ°	μ
9	36.8±1.64	0.749±0.04	33.4±1.14	0.660±0.03
13	35.4±1.34	0.711±0.04	35.8±1.10	0.722±0.03
17	32.0±1.22	0.625±0.03	31.4±1.52	0.611±0.04
For <i>Tenera</i> palm shell				
9	40.8±1.64	0.864±0.05	43.4±1.52	0.947±0.05
13	37.6±1.82	0.771±0.05	40.4±1.67	0.852±0.05
17	42.0±1.87	0.902±0.06	39.6±1.52	0.828±0.05

The average values of *tenera* kernel and shell coefficient of sliding friction using the two faces of local fabric material are showed in the Table 2. The *tenera* kernel coefficients of sliding friction for 9, 13 and 17 % moisture contents (w.b.) for face A and face B were 0.749, 0.711 and 0.625; and 0.660, 0.722 and 0.611, respectively. It was observed that the coefficient of sliding friction decreases as the moisture content increases from 9 to 17 % for the face A while the coefficient of sliding friction obtained increases as the moisture content increases from 9 – 13 % but decreases as the moisture content increases from 13 to 17 % for the face B. The coefficient of sliding friction on face A was higher than coefficient of sliding friction on face B except at moisture content 13 % (Table 2).

The *tenera* shell coefficients of sliding friction for 9, 13 and 17 % moisture contents (w.b.) for face A and face B were 0.864, 0.771 and 0.902; and 0.947, 0.852 and 0.828 respectively. It was observed that the coefficient of sliding friction obtained decreases as the moisture content increases from 9 to 13 % but increases as the moisture content increases from 13 to 17 % for the face A and the coefficient of sliding friction obtained

decreases as the moisture content increases from 9 to 17 % for the face B. The coefficient of sliding friction of face B was higher than the coefficient of sliding friction for the face A except at 17 % moisture content (Table 2).

Also, the coefficient of sliding friction of *tenera* palm shell on any face of the local fabric was higher than the coefficient of sliding friction of *tenera* palm kernel. The coefficients of sliding friction of *tenera* variety of either palm kernel or shell were higher than that of *dura* variety.

The analysis of variance was carried out to determine the effect of moisture content on the coefficient of sliding friction of *dura* kernel on the face A of local fabric material (Table 3). The moisture content had significant effect at $p < 0.05$ on the coefficient of sliding friction of *dura* kernel on face A of the local fabric. This means that the coefficients of sliding friction of at least two moisture contents of *dura* kernel were different from each other on face A of the local fabric material.

Table 3: Analysis of variance of the effect of moisture content of *dura* kernel on coefficient of sliding friction of face A of the local fabric

Source	DF	SS	MS	F-Value	P-Value
Moisture content	2	0.027401	0.013700	21.87	0.000
Error	12	0.007517	0.000626		
Total	14	0.034918			

Table 4: Analysis of variance of the effect of moisture content of *dura* kernel on coefficient of sliding friction of face B of a local fabric

Source	DF	SS	MS	F-Value	P-Value
Moisture content	2	0.02527	0.012637	12.31	0.001
Error	12	0.01232	0.001027		
Total	14	0.03760			

The analysis of variance was carried out to determine the effect of moisture content on the coefficient of sliding friction of *dura* kernel on the face B of local fabric material (Table 4). The moisture content had significant effect at $p < 0.05$ on the coefficient of sliding friction of *dura* kernel on face B of the local fabric. This means that the coefficients of sliding friction of at least two moisture contents of *dura* kernel were different from each other on face B of the local fabric material.

The analysis of variance was carried out to determine the effect of moisture content on the coefficient of sliding friction of *tenera* kernel on the face A of local fabric material (Table 5). The moisture content had significant effect at $p < 0.05$ on the coefficient of sliding friction of *tenera* kernel on face A of the local fabric. This means that the coefficients of sliding friction of at least two moisture contents of *tenera* kernel were different from each other on face A of the local fabric material.

Table 5: Analysis of variance of the effect of moisture content of *tenera* kernel on coefficient of sliding friction of face A of a local fabric

Source	DF	SS	MS	F-Value	P-Value
Moisture content	2	0.04017	0.020084	14.64	0.001
Error	12	0.01646	0.001372		
Total	14	0.05663			

Table 6: Analysis of variance of the effect of moisture content of *tenera* kernel on coefficient of sliding friction of face B of a local fabric

Source	DF	SS	MS	F-Value	P-Value
Moisture content	2	0.03076	0.015381	15.36	0.000
Error	12	0.01202	0.001001		
Total	14	0.04278			

The analysis of variance was carried out to determine the effect of moisture content on the coefficient of sliding friction of *tenera* kernel on the face B of local fabric material (Table 6). The moisture content had significant effect at $p < 0.05$ on the coefficient of sliding friction of *tenera* kernel on face B of the local fabric. This means that the coefficients of sliding friction of at least two moisture contents of *tenera* kernel were different from each other on face B of the local fabric material.

The analysis of variance was carried out to determine the effect of moisture content on the coefficient of sliding friction of *dura* shell on the face A of local fabric material (Table 7). The moisture content had no significant effect at $p > 0.05$ on the coefficient of sliding friction of *dura* shell on face A of the local fabric. This means that the coefficients of sliding friction on face A of the local fabric were significantly the same at any moisture content of the *dura* shell.

Table 7: Analysis of variance of the effect of moisture content of *dura* shell on coefficient of sliding friction of face A of a local fabric

Source	DF	SS	MS	F-Value	P-Value
Moisture content	2	0.002582	0.001291	0.93	0.421
Error	12	0.016657	0.001388		
Total	14	0.019239			

Table 8: Analysis of variance of the effect of moisture content of *dura* shell on coefficient of sliding friction of face B of a local fabric

Source	DF	SS	MS	F-Value	P-Value
Moisture Content	2	0.007224	0.003612	2.45	0.129
Error	12	0.017722	0.001477		
Total	14	0.024946			

The analysis of variance was carried out to determine the effect of moisture content on the coefficient of sliding friction of *dura* shell on the face B of local fabric material (Table 8). The moisture content had no significant effect at $p > 0.05$ on the coefficient of sliding friction of *dura* shell on face B of the local fabric. This means that the coefficients of sliding friction on face B of the local fabric were significantly the same at any moisture content of the *dura* shell.

The analysis of variance was carried out to determine the effect of moisture content on the coefficient of sliding friction of *tenera* shell on the face A of local fabric material (Table 9). The moisture content had significant effect at $p < 0.05$ on the coefficient of sliding friction of *tenera* shell on face A of the local fabric. This means that the coefficients of sliding friction of at least two moisture contents of *tenera* shell were different from each other on face A of the local fabric material.

Table 9: Analysis of variance of the effect of moisture content of *tenera* shell on coefficient of sliding friction of face A of a local fabric

Source	DF	SS	MS	F-Value	P-Value
Moisture content	2	0.04526	0.022631	8.10	0.006
Error	12	0.03354	0.002795		
Total	14	0.07881			

Table 11: Summary of separation of means using Tukey Method for the coefficient of sliding friction on local fabric

Moisture Content (%)	<i>Dura</i> palm kernel A	<i>Dura</i> kernel B	<i>Tenera</i> kernel A	<i>Tenera</i> kernel B	<i>Tenera</i> shell A	<i>Tenera</i> shell B
9	0.384±0.03 ^a	0.479±0.02 ^a	0.749±0.04 ^a	0.660±0.03 ^a	0.864±0.05 ^a	0.947±0.05 ^a
13	0.484±0.02 ^b	0.564±0.05 ^b	0.711±0.04 ^a	0.722±0.03 ^b	0.771±0.05 ^b	0.852±0.05 ^b
17	0.462±0.02 ^b	0.568±0.03 ^b	0.625±0.03 ^b	0.611±0.04 ^a	0.902±0.06 ^a	0.828±0.05 ^b

Means that do not share a letter are significantly different

For *tenera* palm kernel on the face A of the local fabric, the coefficients of sliding friction at 9 and 13 % moisture contents were significantly the same which were significantly different from the coefficient of sliding friction at 17 % moisture content (Column 4). For *tenera* palm kernel on the face A of the local fabric, the coefficients of sliding friction at 9 and 17 % moisture contents were significantly the same which were significantly different from the coefficient of sliding friction at 13 % moisture content (Column 5). For *tenera* palm shell on the face A of the local fabric, the coefficients of sliding friction at 9 and 17 % moisture contents were significantly the same which were significantly different from the coefficient of sliding friction at 13 % moisture content (Column 6). For *tenera* palm shell on the face B of the local fabric, the coefficient of sliding friction at 9 % moisture content was significantly different from the coefficients of sliding friction at both 13 and 17 % moisture contents that were significantly the same (Column 7).

Table 10: Analysis of variance of the effect of moisture content of *tenera* shell on coefficient of sliding friction of face B of a local fabric

Source	DF	SS	MS	F-Value	P-Value
Moisture content	2	0.03932	0.019658	8.31	0.005
Error	12	0.02840	0.002367		
Total	14	0.06772			

The analysis of variance was carried out to determine the effect of moisture content on the coefficient of sliding friction of *tenera* shell on the face B of local fabric material (Table 10). The moisture content had significant effect at $p < 0.05$ on the coefficient of sliding friction of *tenera* shell on face B of the local fabric. This means that the coefficients of sliding friction of at least two moisture contents of *tenera* shell were different from each other on face B of the local fabric material.

The summary of separation of means for the coefficient of sliding friction on local fabric using Tukey Method is shown in the Table 11. For *dura* palm kernel on the face A and face B of the local fabric, the coefficient of sliding friction at 9 % moisture content was significantly different from the coefficients of sliding friction at both 13 and 17 % moisture contents that were significantly the same (Column 2 and column 3).

CONCLUSIONS

This study obtained values for coefficient of sliding friction as affected by the moisture content of the sample on two faces of local fabric material which are needed to understudy canvas materials for frictional separation. The following conclusions were drawn from the study:

The average values of *dura* kernel and shell coefficient of sliding friction on the two faces of local fabric ranged from 0.380-0.655 for 9 % moisture content; 0.484-0.706 for 13 % moisture content and 0.462-0.695 for 17 % moisture content.

The average values of *tenera* kernel and shell coefficient of sliding friction on the two faces of local fabric ranged from 0.660-0.947 for 9 % moisture content; 0.711-0.852 for 13% moisture content; and 0.611-0.902 for 17 % moisture content.

The coefficient of sliding friction of *tenera* palm shell on any face of the local fabric was higher than the coefficient of sliding friction of *tenera* palm kernel.

The coefficient of sliding friction of *dura* palm shell on any face of the local fabric was higher than the coefficient of sliding friction of *dura* palm kernel.

The coefficients of sliding friction of *tenera* variety of either palm kernel or shell were higher than that of *dura* variety.

The moisture contents of *dura* palm kernel, *tenera* palm kernel and *tenera* palm shell had significant effect ($p < 0.05$) on the coefficient of sliding friction on face A and face B of the local fabric but the moisture content of *dura* palm shell had no significant effect ($p > 0.05$) on the coefficient of sliding friction on face A and face B of the local fabric.

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