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EVALUATION OF SOME PROPERTIES OF *MORINGA OLEIFERA* SEEDS

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Abstract

A study of some moisture-dependent engineering properties of *Moringa oleifera* seed kernels was carried out in relation to post harvest systems design. The investigation was done at four levels of moisture content:10.0, 17.0, 24.0 and 32.0% wet basis. The properties studied include dynamic angle of repose, angle of internal friction, angle of surface friction, coefficient of static friction at the four selected moisture content. The effect of moisture content on these properties of *Moringa oleifera* seed was investigated. Other properties studied include bio-yield force (80.297N to 44.127), rupture force (110.037N to 60.658), deformation (2.337mm to 1.22N), energy for rupture (257.185J to 72.802J), compressive strength (5.8378N/mm^2 to 3.1864N/mm^2) and modulus of elasticity (140.295N/mm^2 to 94.191N/mm^2). The angle of internal friction measured on plywood was 42.374° – 52.619°, mild steel 36.630° – 48.514°; angle of repose ranged from 17.643° – 23.500°, coefficient of friction as measured on plywood was from 0.570 – 0.749, mild steel 0.480 – 0.674. Both linear and quadratic regression equations established had very high coefficients of determination (R^2 > 0.9), which indicates that they described the relationships reasonably well. The coefficient of static friction of seed was higher on plywood surface and lower on mild steel. This information will provide engineering information for designs of materials handling and postharvest equipment design.

Keywords: *Moringa*, Engineering properties, repose angle, friction, moisture

1.0 Introduction

1.1 Background of the Study

Moringa oleifera belongs to the family Moringaceae and has fourteen species (Morton, 1991). It widely grows in the tropics. It is characterized by scanty foliage, white flowers and long pods, mainly used in the tropics as hedge tree and boundary marks for farms and compounds , especially in the Northern part of Nigeria (Anjorin et al., 2010). In Nigeria, the plant is popularly known as the "miracle tree" or "tree of life" because of its perceived medicinal value. The tree grows both in the South and North and is regarded as a multipurpose tree providing feed, medicine and sometimes used for household water treatment, and a source of revenue to the rural population (Ozumba, 1996; Okafor, 2008). This is an explanation for its choice as a national crop, attracting intensive and widespread attention in research and development. Mature seeds yield 38 – 40% edible oil, which when refined is clear, odourless and resists rancidity. The seed's oil can also be used as a natural source of behenic acid, which has been used as an oil structuring and solidifying agent in margarine and foods containing semi-solid and solid fats, eliminating the need to hydrogenate the oil (Foidl et al., 2001).This is apart from the seed cake remaining after oil extraction being used as a fertilizer (Rashid et al., 2008) and supplement for animal feed formulations. It is believed that insufficient engineering data on moringa has greatly retarded the development of this crop as a commodity even when its potentials as revenue source to the rural populace is well understood. When these data are available, the design and development of machines for the processing and handling will be enhanced. It is therefore the objective of this paper to determine some of the mechanical properties of the seeds of moringa plant, which are relevant to design of storage, handling and processing equipment for the seeds.

2.0 Material and methods

2.1 Sample Preparation

Known quantity of distilled *water was sprinkled on the four sample batches of the Moringa Oleifera* seeds and tied in polyethylene bags. The polyethylene bags were kept in a refrigerator at 5°C for a period of seventy two (72) hours to enable the moisture to distribute uniformly throughout the sample (Sacilik, 2003; Garnayak et al., 2008). On the day of the experiment, the seeds were brought out of the bag and spread on the floor to evaporate the loose moisture and also equilibrate with the ambient conditions of the laboratory. Samples were randomly taken from each sample to determine the initial moisture content of the seed by gravimetric method which involves drying seed samples in a convective oven chamber at 103°C for 24 hours (Ozarslan, 2002). The average initial moisture content obtained from this reconstitution were: 10.0%, 17%db, 24%db, 32% wb.

The quantity of distilled water added to the samples can be used to estimate the expected moisture content of the sample using the following equation 1 (Tabatabaeefar, 2003):

$$W_2 = W_1 \times \left\{\frac{M_2 - M_1}{100 - M_2}\right\} \qquad 1$$

Where, W_2= the mass of distilled water added in grams; W_1=the initial sample mass in grams; M_1 = the initial moisture content of sample in % dry basis, and M_2= the desired moisture content of the sample in % dry basis.

The initial moisture contents of the seed samples were determined by equation 2 (ASAE Standards, 1999):

$$\%\text{ Moisture Content (d.b)} = \frac{\{M_i - M_f\}}{M_f} \times 100 \qquad 2$$

Where, M_i = initial mass of the seeds/kernels in grams and M_f = final mass of the seeds in grams when constant mass is detected.

The shape of the moringa seed is approximately spherical. A graphical description of the shape of the seed and the physical dimensions are presented in figure 1.

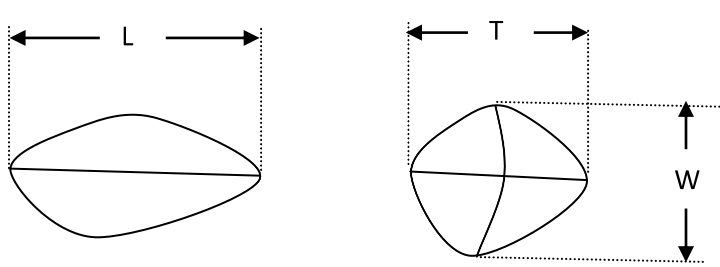

Fig. 1: Dimensions of *Moringa* seed (L, W, T is the length, width and Thickness respectively)

2.2 Angle of repose

The angle of repose indicates the cohesion among the individual units of a material. The higher the cohesion, higher is the angle of repose. The angle of repose of *Moringa* seeds was measured using the discharge method (platform method) to determine the dynamic angle of repose. This method involves the use a bottomless cylinder of 5cm diameter and 10cm height (Taser et al., 2005; Garnayak et al., 2008). A cylinder was placed over a plain surface and *Moringa* seeds were filled in. The cylinder was raised slowly allowing the sample to flow down and form a natural slope. The dynamic angle of repose was calculated from the height and diameter of the pile as:

$$\theta = \tan^{-1}\left\{\frac{2H}{D_p}\right\} \qquad 3$$

Where, θ = angle of repose (^{o}), H = height of pile (cm) and D_p = diameter of the pile (cm) Angle of repose measurements of *Moringa* seeds were replicated 5 times.

2.3 Coefficient of Static Friction

The static coefficient of friction of *Moringa* seeds on two different surfaces namely plywood and mild steel were determined. A plastic cylinder of 100mm, diameter and 50mm height as described by Karaj and Müller, (2010) contained the moringa sample and was placed on the test surface. The plastic cylinder was raised slightly so that its bottom edge does not have contact with inclined surface, thereby letting the moringa seeds to make contact with the surface material. The test surface was attached to a fixed surface of equal dimension by means of two hinges and raised by a screw mechanism. The test surface was raised slowly with screw device until the cylinder holding the kernels started to slide down. At that point, the angle of tilt, which was the angle made with the horizontal, was measured and recorded. The coefficient of friction was calculated using Equation (4).

$$\mu_s = \tan^{-1}(\Phi') \qquad 4$$

Where, μ_s is the coefficient of static friction and Φ' is the tilt angle or angle of friction in degree.

2.4 Angle of Internal Friction

Using equation 5 (Abdel Fattah et al,2006) the angle of internal friction was estimated:

$$\Phi = \frac{\tan^{-1}(\mu_s)}{0.7} \qquad 5$$

Where, μ_s = Static coefficient of friction of seed on any material.

2.5 Rupture Energy.

Energy for rupture, E_R, is the energy needed to rupture the sample, which is the product of rupture force and deformation at rupture. It is mathematically presented as equation 6.

$$E_R\,(J) = \varepsilon F_r \qquad 6$$

Where, E_R *is rupture energy*, ε *is deformation, mm, and* F_r *is rupture force, N*

2.6 Bio-yield Force

From the force-deformation machine graphical output the bio-yield force was determined as the force on the force-deformation curve at which the failure of seed kernels became initiated at cellular level.

2.7 Rupture Force

Rupture force was the point on the force deformation curve at which the kernels completely got broken which was obtained from the machine plotted outputs.

2.8 Poisson Ratio

The determination of the Poisson's ratio of biomaterials is usually very involving. In the absence of adequate instrumentation, it was decided to choose appropriate value of Poisson's ratios for this work considering the values of similar materials reported in literature. Consequently, a Poisson's ratio of 0.35 was used as this falls within 0.25 – 0.49 which is the range of Poisson's ratio for agricultural products (Mohsenin, 1986).

3.0 Results and Discussions

3.1. Angle of Repose ($\emptyset_r$):

Table 1 shows the result of the angle of repose, angle of internal friction, coefficient of friction of *Moringa* seed on plywood and mild steel, at the test moisture content. From the table, the angle of repose increases as the moisture content increases. It shows a linear relationship with moisture content as shown in Figure 2.

Table 1: Mean seed frictional property

Moisture content (%db)	Angle of Repose, $\emptyset_r$ (^{o})	Angle of Internal Friction, $\emptyset_i$ (^{o})	Static Coefficient of Friction	
			Plywood	Mild Steel
10	*17.643 ± 472 [a]	42.374 ± 0.131 [a]	0.570 ± 0.002 [a]	0.480 ± 0.001 [e]
17	19.386 ± 0.474 [b]	44.831 ± 0.844 [b]	0.610 ± 0.014 [b]	0.569 ± 0.001 [f]
24	21.271 ± 0.711 [c]	48.402 ± 0.120 [c]	0.672 ± 0.002 [c]	0.636 ± 0.006 [g]
32	23.500 ± 0.432 [d]	52.619 ± 0.074 [d]	0.749 ± 0.001 [d]	0.674 ± 0.005 [h]

*Means in rows with the same superscript are not significantly different at $p \leq 0.05$ using Duncan's Multiple Range Test mean comparison technique

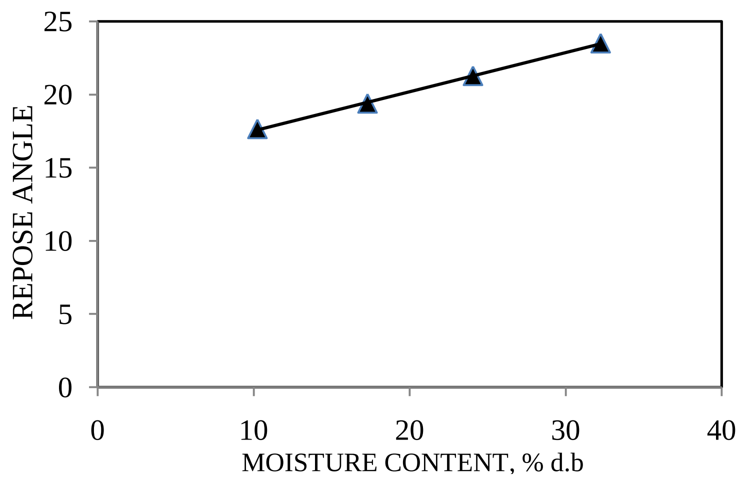

Fig. 2: Effect of moisture content on repose angle of *Moringa oleifera* seed.

The regression equation is given in equation 1, with coefficient of determination, $R^2 = 0.999$.

$$\emptyset_r = 0.267 * M + 14.84 \quad 7$$

Where, M is moisture content in %wb.

3.2 Seed Coefficient of Friction (μ)

Table 3 shows the result of the frictional properties of the seed on two structural surfaces, namely, plywood and mild steel. From the experimental data there is a linear relationship between coefficient of friction, μ, and moisture content for the two surfaces as shown figure 2 and the regression equation with high coefficient of determination. This shows that angle of repose is strongly dependent on moisture content.

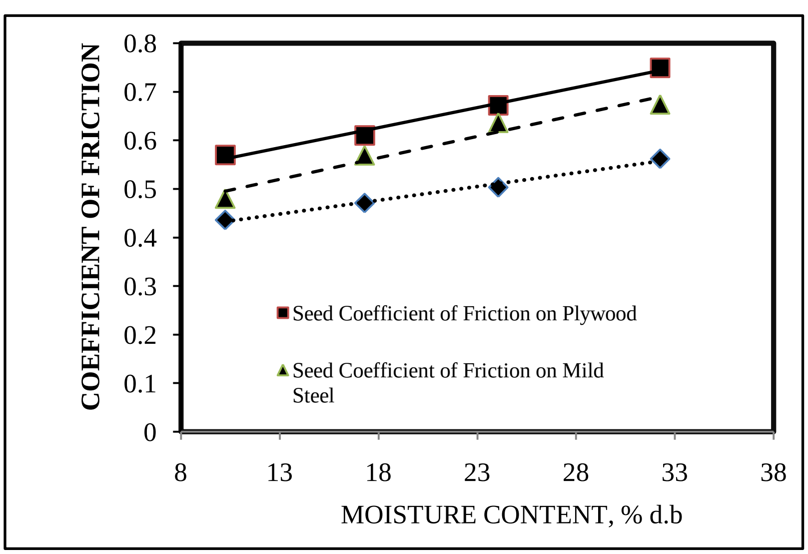

Fig. 3: moisture content against coefficient of friction

The mechanical properties of the moringa seeds investigate are presented in table 2 and compared at different moisture content using Domkert Multiple Range Test (DMRT). The test revealed that means are significantly different at different moisture content. The properties are plotted against moisture content and presented as figures 4 to 8.

Table 2: *Moringa* seed Mean mechanical properties comparison table using DMRT at different moisture content for

PROPERTY	MOISTURE CONTENT (% wb)			
	10	17	24	32
BIO-YIELD FORCE (N)	80.297[d] ±4.728	51.022[c] ±7.722	34.666[a] ±4.476	44.127[b] ±0.499
RUPTURE FORCE (N)	110.037[b] ±0.784	59.941[a] ±3.564	60.016[a] ±4.806	60.658[a] ±0.614
DEFORMATION (mm)	2.337[c] ±1.045	1.662[b] ±0.314	0.911[a] ±0.103	1.220[ab] ±0.042
ENERGY FOR RUPTURE (J)	257.185[b] ±115.020	100.101[a] ±22.478	54.444[a] ±5.305	72.802[a] ±3.168
COMPRESSIVE STRENGTH (N/mm^2)	5.8378 [b] ±1.0967	2.6241 [c] ±0.1274	3.7346 [d] ±0.5309	3.1864 [d] ±0.0697
MODULUS OF ELASTICITY (N/mm^2)	140.295 [b] ±74.797	130.503 [c] ±10.963	53.4719 [a] ±11.420	94.191 [d] ±1.720

* Means in rows with the same superscript are not significantly different at $p \leq 0.05$ using Duncan's Multiple Range Test mean comparison technique.

The variation of the studied engineering properties of *Moringa oleifera kernels* with moisture content are presented in Table 3. The general regression equation is presented in equation 8 while the constants and coefficients are presented in table 3.

$$f(M) = a + bM + cM^2 \quad (8)$$

Table 3: Constants and coefficients of regression models of properties of moringa kernel under load

Seed property	Loading orientation	Coefficients			R^2
		a	B	c	
Bioyield force	Horizontal	+159.276	- 9.539	+ 0.184	0.995
Rupture force	Horizontal	+204.964	- 11.908	+ 0.232	0.925
Deformation at rupture	Horizontal	+ 4.550	- 0.259	+ 0.005	0.948
Energy for rupture	Horizontal	+ 612.172	- 43.422	+ 0.829	0.994
Crushing strength	Horizontal	+ 10.480	- 0.609	+ 0.012	0.681
Crushing strain	Horizontal	+ 0.105	- 0.002	+ .00002	0.547
Elastic modulus	Horizontal	+ 264.1	- 13.75	+ 0.255	0.642

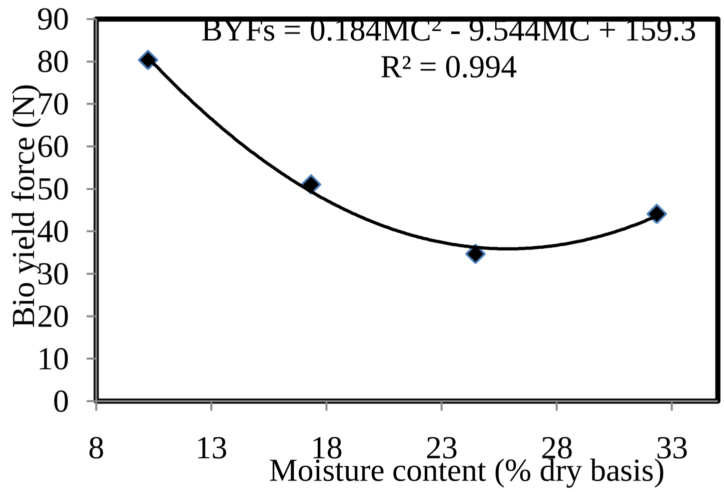

Fig. 4: Effect of moisture content on yield force of *Moringa* seed under compression at the horizontal loading orientations

The bio yield force decreased from 80.297N to a minimum of 35.540N (at 25.935%, d.b) as the moisture content increased from 10.250 to 32.343% (d.b) and thereafter increased with further increase in moisture content under loading condition.

The implication of the above observation is that the force needed in the compressive cracking of *Moringa oleifera* seed to initiate the failure of the kernel at the microscopic level is affected by the moisture content.

The variation of the rupture force of *Moringa oleifera* seed with moisture content under compression presented in Figure 5, shows that the rupture force decreased from 110.037N to a minimum of 52.380N as the moisture content increased from 10.25 to 32.34% (d.b) and thereafter increased with further increase in moisture content. The decrease in rupture force can be attributed to the effect of moisture on the intercellular structure of the kernel.

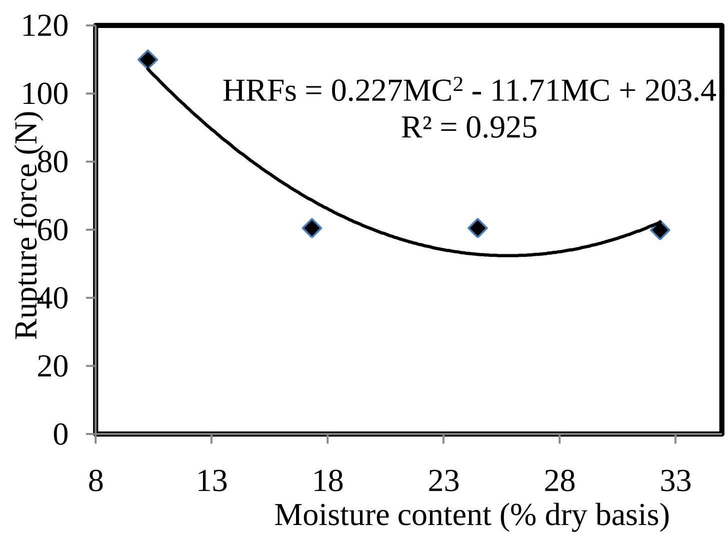

Fig. 5: Effect of moisture content on rupture force of *Moringa* seed under compression

The variation of energy for rupture of *Moringa* seed with moisture content under compression is presented in Figure 7. This shows that the energy for rupture of the seed kernel decreased from 257.185J to a minimum of 54.444J as the moisture content increase from 10.250 to 32.343% (d.b) and thereafter increased with further increase in moisture content under horizontal loading orientation.

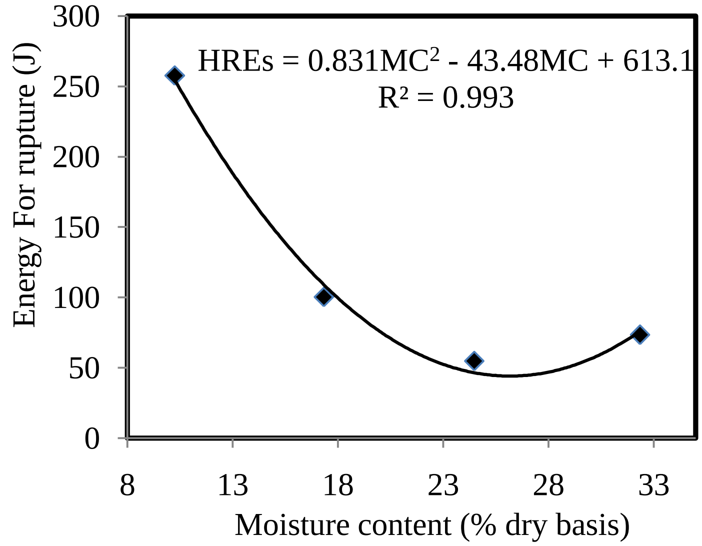

Fig. 6: Effect of moisture content on energy for rupture of *Moringa* seed under compression at the horizontal loading orientations

The variation of *Moringa oleifera* seed compressive (crushing) strength with moisture content under compression is presented in Figure 7. This shows that the crushing strength decreased from 5.499N/mm^2 to a minimum of 2.753N/mm^2 as the moisture content increased from 10.25 to 32.34% (d.b) and thereafter increased with further increase in moisture content when the seed was further compressed.

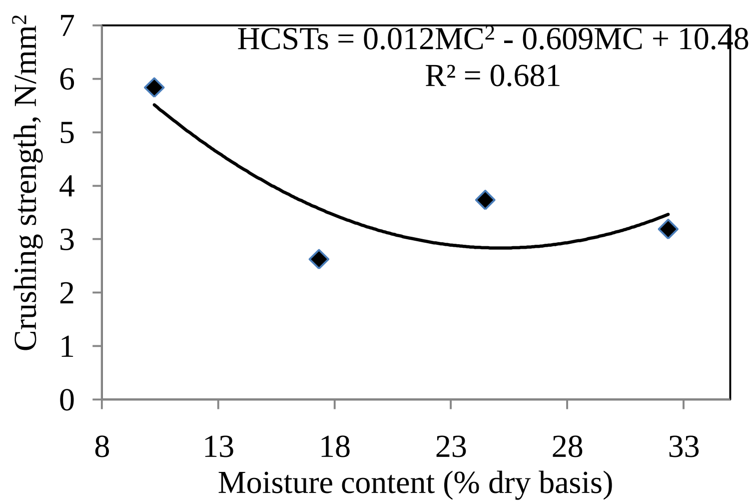

Fig. 7: Effect of moisture content on crushing (compressive) strength of *Moringa* seed under compression at the horizontal loading orientations

The variation of elastic modulus of *Moringa* seed with moisture content when subjected to compressive load under horizontal vertical orientation is presented in Figure 8. The Figure shows that the modulus of elasticity of the seed decreased from 125.776N/mm^2 to a minimum of 78.745N/mm^2 (at 26.961% d.b) as the moisture content increased from 10.250 to 32.343% d.b and thereafter increased with further increase in moisture content under horizontal loading orientation.

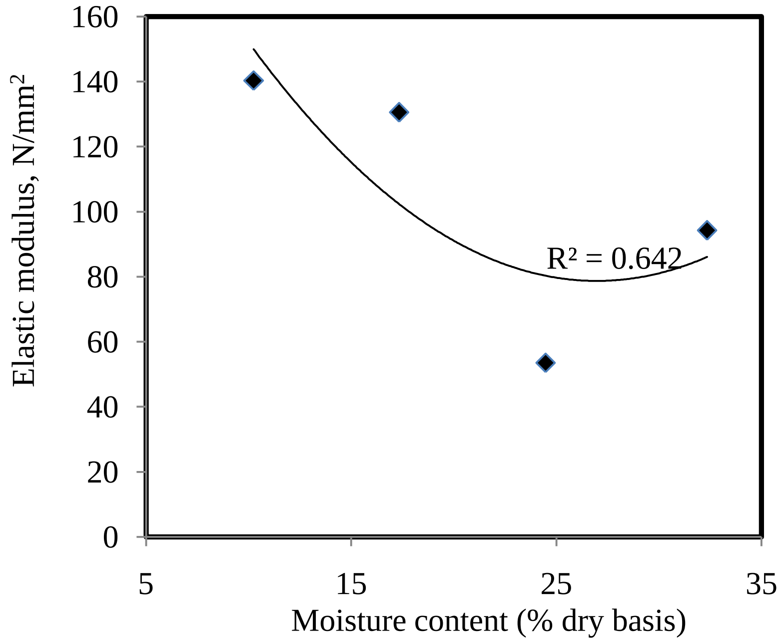

Fig. 8: Effect of moisture content on modulus of elasticity of *Moringa* seed under compression at the horizontal orientation

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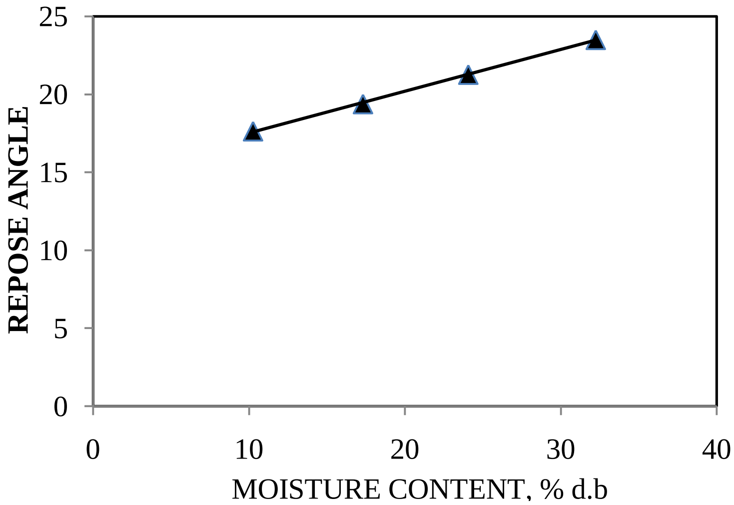

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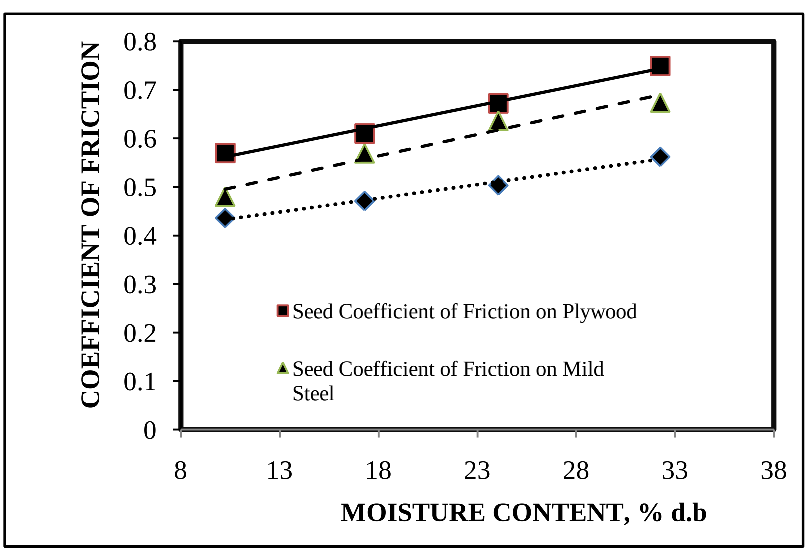

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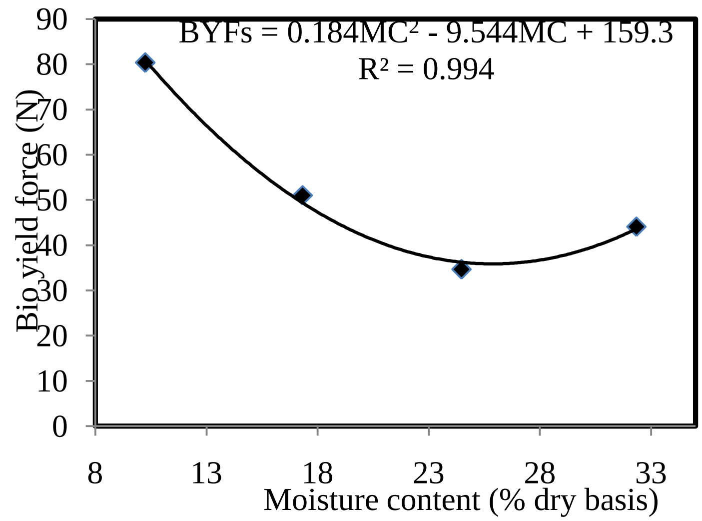

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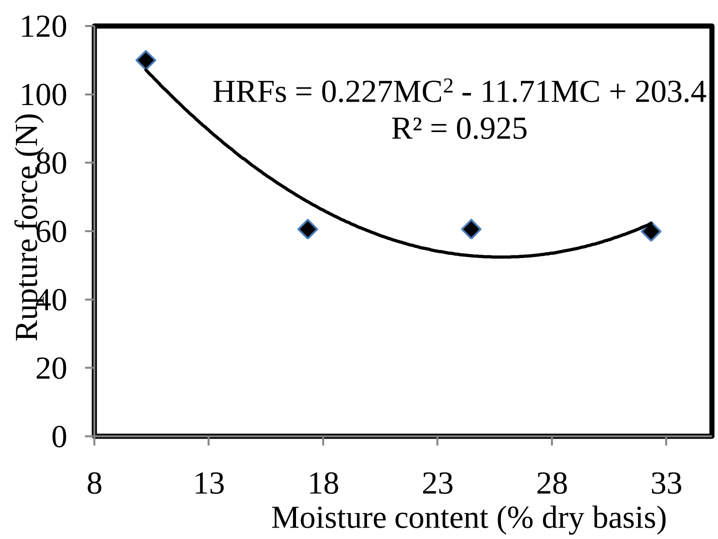

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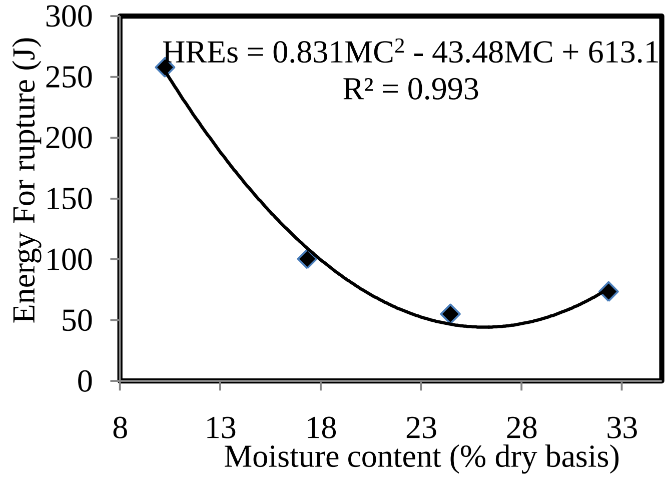

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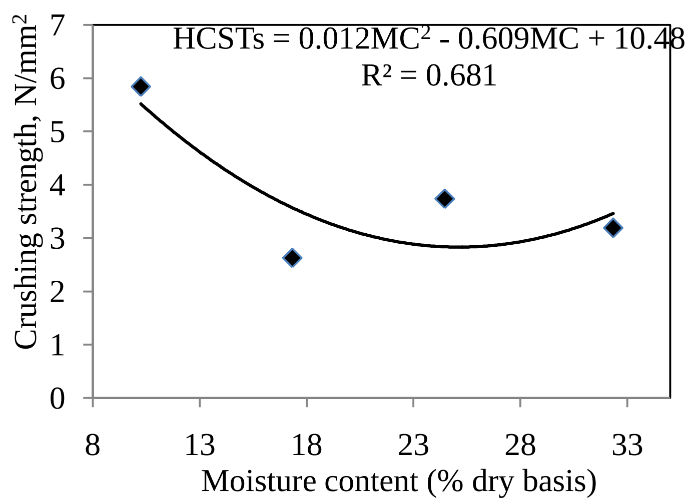

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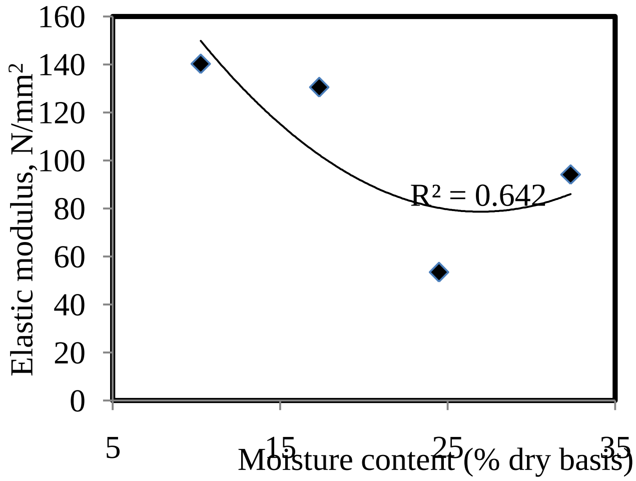

Fig. 8: Effect of moisture content on modulus of elasticity of *Moringa* seed under compression at the horizontal orientation

4.0. Conclusion

This study investigates the behaviour of the properties of the kernels of moringa seeds when subjected to compressive forces at different moisture contents. The results showed that all the investigated properties were significantly affected by moisture content. The angle of repose and surface frictional coefficient of the kernel increase as moisture content increased. The bio yield and rupture force of *Moringa oleifera* seed decreased with increase in moisture content to a certain value and increased with further increase in moisture content. The deformation at rupture and energy for rupture of the *Moringa* seed decreased with increase in moisture content to a minimum value after which it increased with further increase in moisture content. Second order polynomial equations gave the best fit for the relationship existing between the mechanical properties and kernel moisture content under compressive loading. From the determined values, the optimal moisture content for cracking the seed can be taken as 25.375% wb at 2.753N/mm^2 and 32.778% wb at 1.701N/mm^2 when positioned horizontally. The influence of moisture on cracking force was very important as little moisture differences created highly significant increases in the required force..

The modulus of elasticity of the seed was 78.745N/mm^2 at 26.961% wb when placed horizontally. It was generally established that mechanical properties of the *Moringa oleifera* seeds investigated were influenced by moisture content. Similar relationships between moisture content and some mechanical properties have been reported by previous investigators.

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