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Effect of Moisture Content on Some Physical Properties of *Moringa Oleifera* Seed

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Abstract: *The effect of moisture content on some physical properties of shelled and unshelled Moringa Oleifera seed was investigated at 6.8%, 10%, 15% moisture content (wet basis). The mean values of the physical properties of the seeds were determined as length 8.3 – 8.7 mm and 12.7 – 13.4 mm, width 7.4 – 7.6 mm and 10.3 – 11.0 mm, thickness 6.5 – 7.3 mm and 10.4 – 10.9 mm, geometric mean diameter 133.1 – 160.1 mm and 453.5 – 535.6 mm, sphericity 16.0 – 18.4 mm and 35.7 – 40.0 mm, thousand seed mass 316.8 – 326.7g and 318.3 – 329.3g, bulk density 0.031 – 0.032 g/cm and 0.041 – 0.047 g/cm³, true density 0.221 – 0.632 g/cm³ and 0.300 – 0.289 g/cm³, porosity 85.9 – 94.9% and 86.3 – 83.7%, surface area 3.19 – 2.21 cm³ and 3.56 – 5.32 cm³ for shelled and unshelled seeds respectively. The coefficient of friction as measured on glass was 0.466 – 0.445% and 0.510 – 0.404%, sheet metal 0.425 – 0.466% and 0.481 – 0.547%, plywood 0.740 – 0.597% and 0.525 – 0.594% for shelled and unshelled seeds respectively. The physical properties of the seeds increased with increase in moisture content but porosity however, decreased. This information will provide engineers and designer the relevant data for efficient process handling and equipment design.*
Keywords*: Moisture content, Moringa Oleifera, physical properties, shelled, unshelled*

I. Introduction

Moringa Oleifera is a fast growing, aesthetically pleasing small tree adapted to arid, sandy conditions. The species is characterized by its long, drumstick shaped pods that contain its seeds. Within the first year of growth, *Moringa* has been shown to grow up to 4 meters and can bear fruit within the same first year [1]. Virtually every part of the tree is beneficial in some way, which is of great importance in areas where people have a direct dependence on it for their livelihood. Studies have been carried out on *Moringa Oleifera* in many developed countries of the world such as America, India etc. but it seems that there may be a growing interest in the cultivation possibilities in the more humid tropics, including Central and South America. It can function as windbreaks for erosion control, live fences, as an ornamental or intercropped to provide semi-shade to species requiring less direct sunlight [2].

Moringa Oleifera seeds are large and circular-shaped, and grow inside the lengthy pods of the *Moringa Oleifera* tree. *Moringa* seed pods can reach well over a foot in length and each pod can provide over a dozen large *Moringa* seeds. *Moringa* seeds are dark brown in colour, with 3 papery wings extending from the main kernel of the seeds. These flaps serve as wings to carry the seed away from the mother tree, and with the help of the wind, they move across the ground until they find a resting place to germinate. Unlike the fast-growing leaves of the *Moringa Oleifera* tree, *Moringa* seed pods do not grow back every few months. *Moringa* trees produce seed pods on an annual basis, much like other similar species in the plant kingdom. *Moringa* trees give off incredible volume of seed pods during their reproduction months. An average-sized *Moringa* tree of fifteen to twenty feet in height can produce hundreds or even thousands of seed pods, yielding countless *Moringa* seeds each and every year [2].

a. Uses of *Moringa Oleifera* Seeds

The seeds of the *Moringa Oleifera* plant are among the most nutritious and useful botanical and herbal remedies, as nutritional supplements and for industrial and agricultural purposes. Moringa seeds are edible in both fresh and dried forms and, along with the seed pods that contain them, can be prepared in numerous ways as both food and medicine. The medicinal properties of the moringa seed are well documented in the scientific literature and are further supported by the experiences of generations of traditional Ayurvedic practitioners [3].
While many parts of *Moringa Oleifera* trees are deemed useful, the seeds are especially prized for their medicinal powers. The seeds have valuable properties that enable them to treat a wide array of illnesses and conditions. The National Charity for Organic Growing has studied the efficacy of *Moringa Oleifera* seeds as a medical treatment and found that they provide legitimate relief for many medical problems. These include rheumatism, gout, sexually transmitted diseases, urinary infections, boils, and even epilepsy. When used as medicine, the seeds are pounded and mixed with coconut oil. Often, seed oil derived from the *Moringa Oleifera* seeds will be used in place of the mashed seed [3].

b. *Moringa* Seeds in Traditional Medicine

The seeds of the *moringa* plant have been used in Ayurveda medical practice for centuries to treat a variety of ailments and to improve overall health in patients. The antibiotic properties of *moringa* seeds make them valuable in poultices and topical treatments for bacterial infections and other conditions of the skin. Taken internally, moringa seeds have traditionally been used to reduce the frequency of epileptic fits and to treat arthritis and rheumatoid disorders. *Moringa* seeds are also recommended by traditional practitioners to treat a variety of sexual dysfunctions and to improve sex drive in both men and women [4].

c. Modern Medical Uses

The antibiotic properties of *Moringa* seeds have been proven in laboratory testing. *Moringa* seeds can be used to treat fungal infections as well due to the presence of pterygospermin, a naturally occurring antibiotic present throughout the *Moringa* plant. Additionally, the high protein and iron content of these seeds make them a valuable resource in combating malnutrition and anemia in developing regions of the world [3].

d. Nutritional Value

Moringa Oleifera seeds are eaten like green peas. The seeds offer concentrated nutrients including amino acids, proteins and a wide range of vitamins and minerals, making them an outstanding supplement for stressed and hurried individuals and a solid source of nutrition for undernourished populations around the world. The nuts can be served fresh or dried and often are pressed to remove the oil they contain, which is useful for cooking and can be added to other dishes to boost their nutrient content as well [5].

e. Water Purification

Moringa Oleifera seed powder is particularly effective in purifying water. This is important in many societies, where the only drinking water available may come from a dirty river or lake. The *Moringa Oleifera* seed powder removes dirt by joining with the particles and sinking to the bottom. It also is extremely effective in removing harmful bacteria from bodies of water. *Moringa Oleifera* seed powder is much more economical, and arguably, safer than aluminum sulfate and other chemicals traditionally used in water purification. When crushed and added to turbid water, *moringa* seeds can serve to purify it for drinking and other uses. This cleansing property is the result of the coagulating nature of the *Moringa* seed, which can speed water clarification and allow water to settle and become safe to drink much more quickly. The use of moringa seeds in water purification is expected to provide healthier, safer drinking water for many areas of the world in which technologically advanced methods are not available [1].3

f. Agriculture

Ground and defatted *Moringa* seeds can be used to supplement animal feed or as fertilizer for crops and enrichment of soil, allowing farmers and ranchers to enjoy increased production and improved results from their agricultural endeavors

g. Source for Biofuel

Because *Moringa* seeds are rich in natural oils, they have been considered as a potential source for biofuel materials. Newer extraction techniques may make this even more profitable and prevalent as fossil fuels supplies continue to shrink [6].

In order to design equipment for handling, conveying, separation, drying, aeration, storing, and processing of *Moringa Oleifera* seeds**,** it is necessary to determine their physical properties. The application of physical properties such as shape is an important parameter in developing of sizing and grading machines and for analytical predictions of its drying behaviour [7]. Density, size, and drag coefficient are important in the calculation of terminal velocity of an object in fluid [8]. It has been reported that it is essential to determine the physical properties of oil seeds (for example peanut) for proper design of equipment for handling, conveying, separation, dehulling, drying, aeration and mechanical expression of oil from these seeds. It has been established that moisture content affects the physical properties of seeds appreciably [9, 10].

The problems associated with local processing method, the shortage of processing equipment, and inadequate preservation for *Moringa oleifera* seed, maybe due to the fact that the basic necessary data on the physical properties are limited or not available. Furthermore, most agriculture products are visco-elastic, hence, the determination of the engineering properties of biomaterials are difficult and complicated, since they are apparently affected by comparative moisture content, and the rate of loading [11]. The knowledge of the physical properties of *Moringa Oleifera* seed will be useful for engineers, food scientists, as well as plant and animal breeders, who are involve in the design and fabrication and use of machine necessary for harvesting, processing, and handling and preservation operation of *Moringa Oleifera* seed. The emerging knowledge of the uses and importance of *Moringa Oleifera* seed for different purposes has made the study of the physical properties highly imperative.

The aim of this study is to evaluate some physical properties of *Moringa oleifera* seed at various moisture contents. This is with the view of creating a database for basic information necessary for the design of processing and handling equipment for *Moringa oleifera* seed. The objective of this study is to determine some physical properties of shelled and unshelled *moringa oleifera* seeds at three moisture content.

II. Methods

One kilogram (1kg) of dried *Moringa Oleifera* seeds was obtained at Kure modern Market in Minna, Niger State of Nigeria. The seeds were cleaned manually to remove all foreign matter such as dust, dirt, stones and chaff as well as immature and broken seeds. The initial moisture content of the seeds was determined by oven drying at 105±1°C for 24 h [12]. The seed sample were divided into six (6) parts; A, B, C, D, E and F. Sample A, B and C will be shelled while D, E, F were unshelled. Samples A and D were used as control for the shelled and unshelled sample respectively. Calculated amount of water was added to samples B, C, E and F to attain a moisture content of 10% (wb) and 15% (wb) for the shelled and unshelled samples respectively and it was wrapped in a foil paper and was kept in a refrigerator for seven days to attain the desire moisture content. The desired moisture contents for the samples were attained by adding calculated amount of distilled water as calculated using equation 3.1 [13]:

$$Q = W_i \frac{(M_{f} - M_i)}{(100 - M_f)} \qquad (1)$$

Where;

Q = the quantity of water added

W_i = initial mass of the sample (grams)

M_f = the final moisture content

M_i = the initial moisture content of sample in (%) dry basis

2.1 Measurement of Length, Width and Thickness

One hundred *Moringa Oleifera* (shelled and unshelled) seeds were randomly selected for each of the moisture content considered and labeled for easy identification. The three principal dimensions namely the length, width and thickness were measured with a micrometer manufactured by Mitutoyo Corporation, Japan, to an accuracy of 0.001 mm [14].

2.2 Determination of Geometric Mean Diameter

The geometric mean diameter (D_g) of the seeds was evaluated using the relationship given as [14]:

$$D_g = (LWT)^{1/3} \qquad (2)$$

Where;

D_g = geometric mean diameter

L = length

W = width

T = thickness

2.3 Determination of Sphericity

The degree of sphericity was determined with equation 3 [14]:

$$\emptyset = \frac{D_g}{L} = \frac{(LWT)^{1/3}}{L} \qquad (3)$$

Where;

$\emptyset$ = degree of sphericity

D_g = geometric mean diameter

L = length

W = width

T = thickness

2.4 Thousand Seed Mass Determination

Thousand seed weight was obtained by using the digital weighing balance of 0.01 g accuracy

2.5 Measurement of Volume and True Density

The seed volume (V_s) and true density (P_t), as a function of moisture content, were determined by toluene displacement method [14]. The amount of displaced toluene was determined by hanging a bunch of thirty seeds in a graduated measuring cylinder. The ratio of weight of seeds to the volume of displaced toluene is the true density.

2.6 Bulk Density Determination

The bulk density (P_b) of these seeds was determined by pouring the seeds into a container of 500ml from a height of 15cm and the excess seeds were removed by a strike-off stick. The content was weighed with a digital weighing balance, Model MT 2000 (Gibertini Electonical, Italy) having a sensitivity of 0.01g and divided by the volume of the container [15].

2.7 Determination of Porosity

Porosity (P_f) of the bulk seed was computed from the values of the true density and bulk density of the seeds by using the relationship shown in equation 4 [14]:

$$P_f = \left(1 - \frac{P_b}{P_t}\right) \times 100 \qquad (4)$$

Where;

P_f = porosity

P_b = bulk density

P_t = true density

2.8 Determination of Angle of Repose

The dynamic angle of repose was evaluated by using a specially constructed topless and bottomless box made of plywood, 450×450×450 mm with a removable front panel [16]. The box filled with *Moringa Oleifera* (shelled and unshelled) seeds were placed on the floor and the front panel was then quickly removed allowing the seeds to slide down and assume natural slope. The angle of repose was calculated from the measurements of the height (x) of the free surface of the seeds and diameter (y) of the heap formed outside the box using the following relationship:

$$\tan^{-1}\frac{x}{y} = \qquad (5)$$

Where;

x = the height of the free surface of the seeds

y = diameter of the heap formed outside the box

2.9 Determination of Static Coefficient of Friction

Static coefficient of friction of the *Moringa Oleifera* (shelled and unshelled) seed was determined with respect to each of the following three structural materials, namely, mild steel, plywood with grains parallel to the direction of motion and glass. A four sided plywood container with dimensions of $150 \times 100 \times 40$ mm open at both the top and bottom was filled with the seeds and placed on an adjustable tilting surface. The structural surface with the box on its top was gradually raised by means of a screw device until the box just started to slide down. The angle of inclination was read from a graduated scale and the coefficient of friction was taken as the tangent of this angle [17, 18]. The same procedure was repeated for other materials.

$$\mu = \tan\beta \qquad (6)$$

Where;

μ = static coefficient of friction

β = angle of inclination

2.10 Determination of the Surface Area

The surface area was determined by first coating the surface of the seed with paint and coupled with printing on a light flexible paper. The surface edge was traced out with a very sharp thin pencil on a graph paper. The surface area was measured by counting the number of squares within the traced marks [19].

2.11 Determination of Specific Gravity

The specific gravity was determined as a function of moisture content by using a void meter manufactured by Jecons Scientific Limited, Bedfordshire, England. *Moringa Oleifera* (shelled and unshelled) seed was placed in the sample jar and water was added to determine the percentage void content by reading value from the scale on the tube. After this, the material was weighed and the mass recorded. The percentage void content of the sample was computed on the basis of the mass of the sample in the sample jar which was subtracted from the mass of the sample in the jar. The value obtained was used to divide the weight of the sample to obtain the specific gravity [17, 18].

III. Results and Methods

3.1 Presentation of Results

The results of the effect of moisture content on some physical properties of shelled and unshelled *Moringa Oleifera* seeds are as presented in Table 1. The physical properties were determined at 6.8%, 10%, and 15% for shelled and unshelled seeds respectively.

Table 1 Effect of Moisture Content on some Physical Properties of Shelled and Unshelled M*oringa Oleifera* Seeds

	Shelled *moringa oleifera* seed			Unshelled *moringa oleifera* seed		
Parameters	**SampleA (6.8%)**	**SampleB (10%)**	**SampleC (15%)**	**SampleD (6.4%)**	**SampleE (10%)**	**SampleF (15%)**
Length (mm)	8.3	8.4	8.7	12.7	12.8	13.4
Width (mm)	7.4	7.5	7.6	10.3	10.4	11.0
Thickness(mm)	6.5	6.7	7.3	10.4	10.6	10.9
Geometric mean diameter(mm)	133.1	140.7	160.1	453.5	470.4	535.6
Sphericity(mm)	16.0	16.8	18.4	35.7	36.8	40.0
Thousand seed mass (grams)	316.8	319.3	326.7	318.0	323.9	329.3
Bulk density(g/cm³)	0.031	0.032	0.032	0.041	0.043	0.047
True density(g/cm³)	0.221	0.262	0.632	0.300	0.299	0.289
Porosity (%)	85.9	87.7	94.9	86.3	85.6	83.7
Angle of repose(degree)	29.8	28	27.5	26.7	27.5	29.7
Coefficient of friction (%)						
Glass (%)	0.466	0.456	0.445	0.510	0.481	0.404
Sheet metal (%)	0.425	0.446	0.466	0.481	0.510	0.547
Wood (%)	0.740	0.601	0.597	0.525	0.532	0.594
Surface area(cm³)	3.19	2.63	2.21	3.56	3.85	5.32
Specific gravity(grams)	3.986	4.932	5.402	3.898	8.076	9.320

3.3 Discussion of Results

The mean values for the length, width and thickness of shelled and unshelled *Moringa Oleifera* seeds measured at 6.8%, 10% and 15% (w.b) moisture content are presented in Fig 1, 2 and 3 respectively.

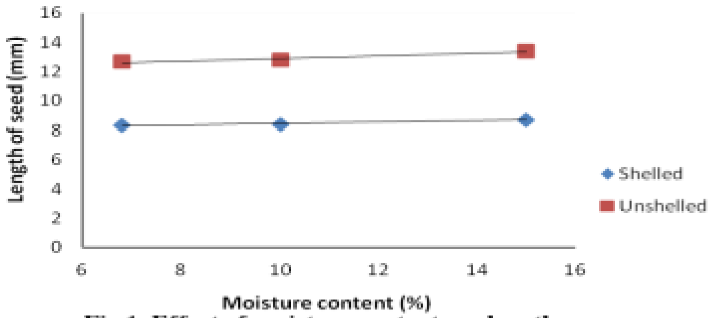

Fig 1 Effect of moisture content on length

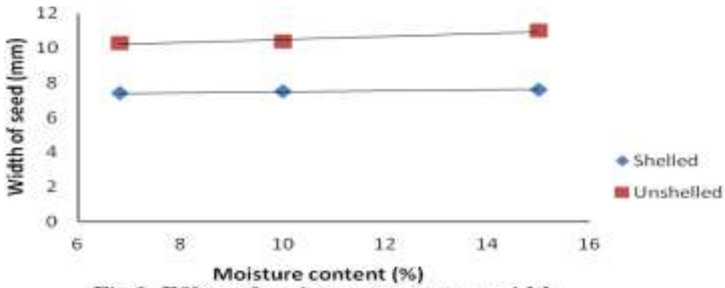

Fig 2 Effect of moisture content on width

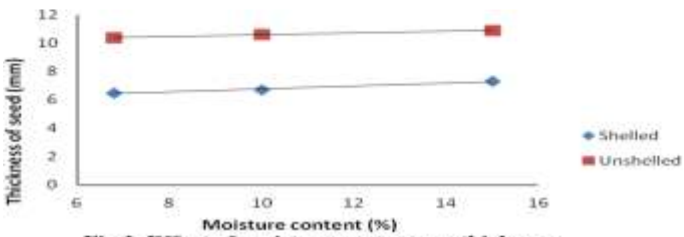

Fig 3 Effect of moisture content on thickness

The results shows that as the moisture content increased, the three linear dimensions also increased due to the swelling of the seeds. This increase in linear dimensions was also observed for millet in which the length increased from 3.522 to 4.163 mm, width 2.735 to 3.211 mm and thickness increased from 2.18 to 2.788 mm for a moisture content increase from 5 – 22.5% (d.b) [20]. An increase was reported in length, width and thickness of soybean from 6.32-6.75 mm, 5.23-5.55 mm and 3.99-4.45 mm respectively [10]. A similar increase was also reported in length, width and thickness of two selected varieties of beniseed from 2.80-3.02 for variety A and 3.025-3.28 for variety B [21].

The geometric mean diameter (*De*) (Fig 4), sphericity (φ) (Fig 5) and surface mass area (*S*) (Fig 6) also increased with increase in moisture content (Table 1). These properties are dependent on the three linear dimensions, which were observed to increase with increase in moisture content. This is probably due to the fact that these properties depend on the three linear dimensions, which increase with increase in moisture content. The sphericity of the seed which ranged from 16.0 – 18.4 is similar to that of sunflower seed but is higher than that of millet, (0.783 - 0.83) and Soybean seeds (0.806- 0.816) [10, 22, 20]. This is because the shape of *moringa* (round at bottom and taper at top) is similar to that of the sunflower seed [22] while that of millet and soybean seed are more spherical [10, 20].

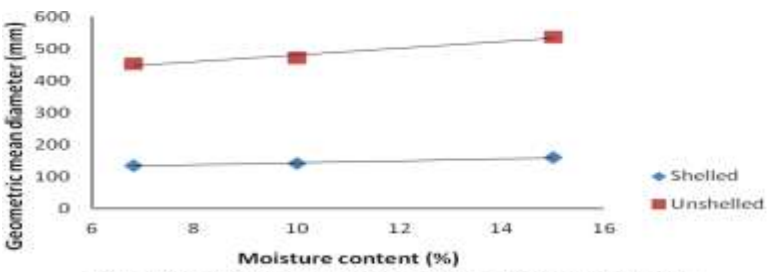

Fig 4 Effect of moisture content on geometric mean diameter

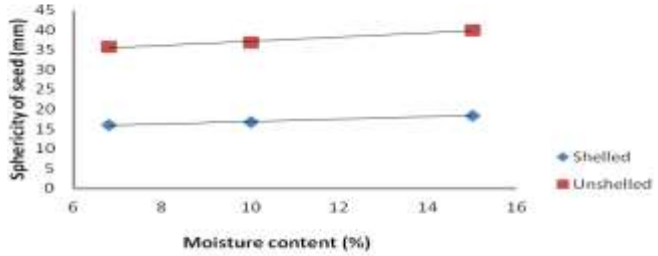

Fig 5 Effect of moisture content on sphericity

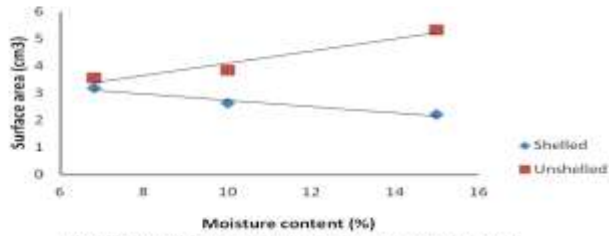

Fig 6: Effect of moisture content on surface area

The thousand seed mass of the seed increased from 316.8 – 326.7g for shelled and 318.0 – 329.3g for unshelled with an increase in moisture content from 6.8% - 15% (wb) for shelled and unshelled *Moringa* seeds (Fig. 7). The bulk density (ρb) of the seed increased from 0.031 – 0.032 g/cm³ for shelled and 0.041 – 0.047 g/cm³ for unshelled with an increase in moisture content from 6.8% – 15% (wb) (Fig 8).

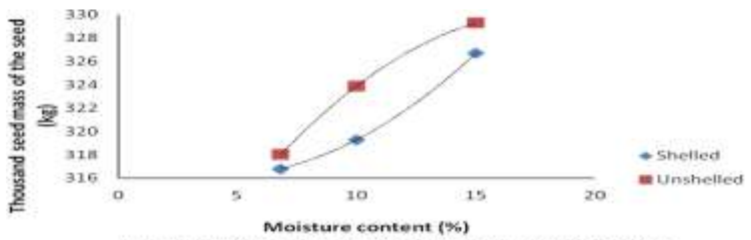

Fig 7: Effect of moisture content on thousand seed mass

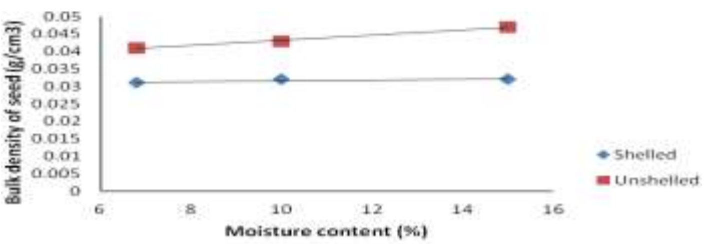

Fig 8: Effect of moisture content on bulk density

The unshelled with larger linear dimensions had a higher bulk density which may be as a result of its higher weight, therefore the bulk density of seeds may be related to the weight of the seed [23]. The true density (ρt) varied from 0.221 – 0.632 g/cm³ for shelled with an increase in moisture content and 0.300 – 0.289 g/cm³ for unshelled with increase in moisture content (Fig 9).

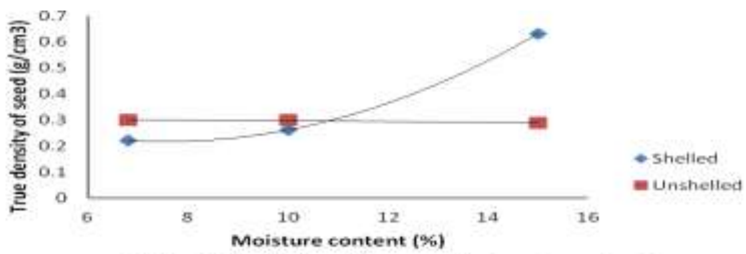

Fig 9: Effect of moisture content on true density

The directly proportional increase in true density with increase in moisture content of shelled seed is similar to that reported for sunflower seed and *karingda* seeds respectively [22] while a decrease in true density of unshelled seed may be as a result of the hardness of the shell which does not permit as much moisture movement as the shelled seed. This same effect was observed in lentil seed and squash seeds [16, 24]. This property is useful in the hydrodynamic separation and transportation of the seeds.

The porosity (*Pt*) calculated from relevant experimental data increased from 85.9 to 94.9 % for shelled while it decreased from 86.3 to 83.7% for unshelled as moisture content increased from 6.8 - 15% (wb) (Fig 10).

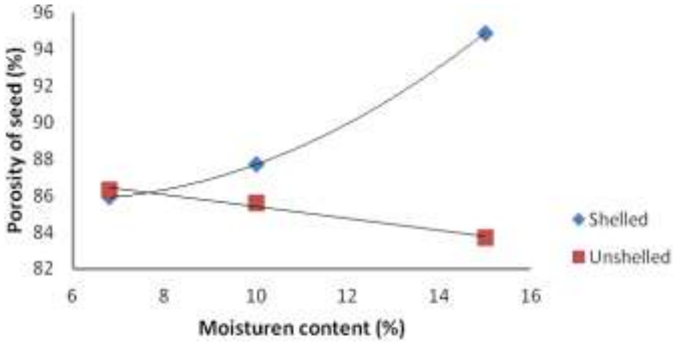

Fig 10: Effect of moisture content on porosity

This decrease in porosity with increase in moisture content was also observed for other grains, for example for pumpkin seed and pigeon pea [25, 26]. The porosity decreases because an increase in moisture content results in a more significant increase/swelling of the linear dimensions, thus reducing the airspaces and giving a more compact arrangement of seeds, invariably reducing the porosity of the grain bulk. The angle of repose (Θ) increased with increase in moisture content 6.8 – 15% (wb) for unshelled seed it increased from 26.7 – 29.7% while a decrease was observed for the shelled seed it reduced from 29.8 to 27.5% as the moisture content increased from 6.4% - 15% (wb) (Fig 11).

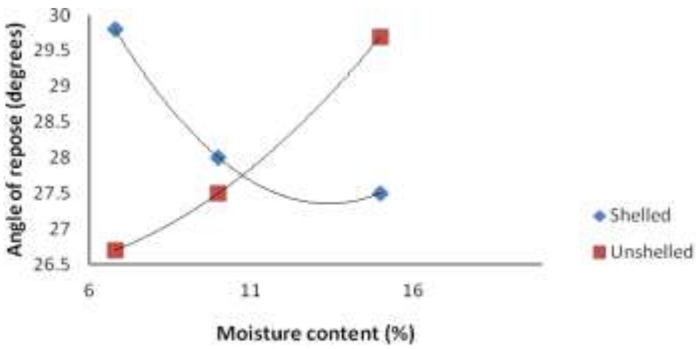

Fig 11: Effect of moisture content on angle of repose

This may be due to the fact that an increase in moisture content increased the cohesion between the seeds, thus increasing the friction the seed experiences during its flow/movement on the selected surfaces. Coefficient of friction of the shelled and unshelled *moringa* seed measured followed a similar pattern; it decreases with increase in moisture content on all the surfaces used. Generally, the maximum friction was experienced with the use of wood surface as reported for *karingda* seeds, while minimum friction occurred with the use of glass as reported for lentil seeds [16]. This difference in coefficient of friction is due to the roughness of the various surfaces. This is because the effect of moisture content is more significant with decrease in roughness of the selected surface since the smoother the surface, the less the friction. Thus the effect of moisture content increase, which is cohesion between the seeds, becomes more pronounced on smoother surfaces since the coefficient of friction on the glass surface is smallest.

The static coefficient of friction of shelled and unshelled *Moringa* seed on the selected surfaces is close to that of degree, and karingda seeds, whereas that of pigeon pea is lower [27, 26]. Fig 12, 13 and 14 shows a graphical representation of the static coefficient of friction of shelled and unshelled *Moringa Oleifera* seeds on glass, metal, and wooden surface respectively.

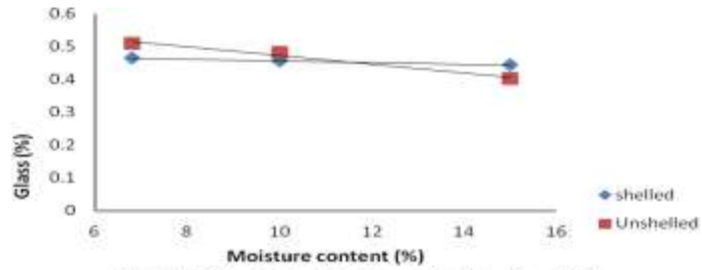

Fig 12: Effect of moisture content on the static coefficient of friction of moringa seeds on a glass surface

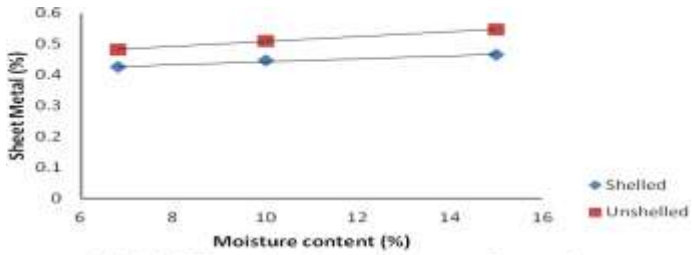

Fig 13: Effect of moisture content on the static coefficient of friction of moringa seed on a metal surface

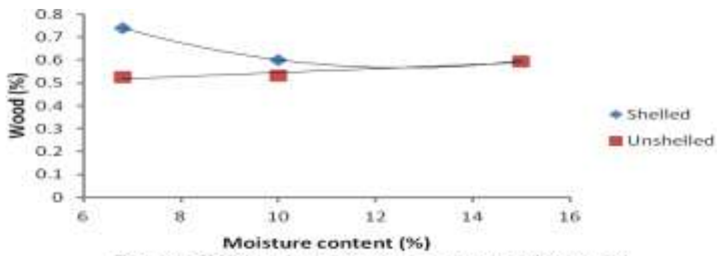

Fig 14: Effect of moisture content on the static coefficient of friction of moringa seed on a wooden surface

The specific gravity of the seed increased from 3.986 – 5.402g for shelled and 3.898 – 9.320g for unshelled with an increase in moisture content from 6.8 – 15% (wb) (Fig 15).

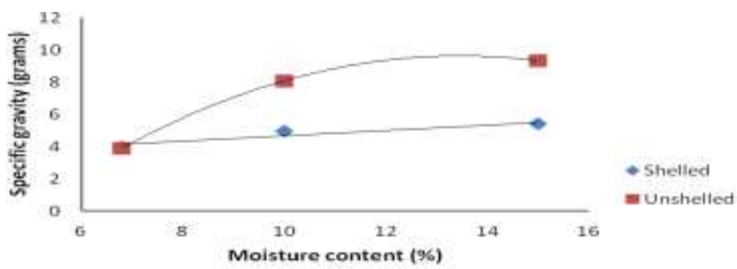

Fig 15: Effect of moisture content on specific gravity

IV. Conclusions

The following conclusions can be made from this work:

1. The physical properties of the seed determined as function of moisture content varied significantly with increase in moisture content.
2. The length, width, thickness, sphericity, geometric mean diameter, thousand seed mass, angle of repose, surface area, true density, and coefficient of friction, showed an ascending linear relationship except, the porosity which has a descending linear relationship on moisture gain. These properties will provide important and essential data for efficient process and equipment design.

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