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Fracture Resistance of African Nutmeg *(Monodora myristica)* to Compressive Loading

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Abstract: Fracture resistance of African nutmeg was investigated in the areas of average compressive force, toughness (Strain energy), deformation, failure stress and modulus of elasticity at seed coat rupture as a function of moisture content and loading position. Quasi-static compressive tests were conducted at moisture levels of 8.0, 11.2, 14.0, 17.4 and 28.7 percent d.b in both axial and lateral loading positions. Force required to initiate seed coat rupture decreased as moisture content increased from 8.0 to 28.7 percent. Generally, african nutmegs loaded in the axial position consistently developed seed coat rupture at lower magnitudes of force than those loaded in the lateral positions. Toughness values increased form 0.020.6N.mm to 0.034Nmm for 8.0 and 28.7 percent moistures respectively in the axial loading position. These values of toughness changed from 0.0356 to 1.061Nmm for same levels of moisture, though in the lateral loading position. Modulus of elasticity and failure stress also decreased with increase in moisture content levels in the two loading orientations.

Key words: African nutmeg · compressive force · toughness · deformation · failure stress

INTRODUCTION

African nutmeg (*Monodora myristica*), belonging to the Ananacea family is a climber tree. It is a many-seeded berry that grows well in the evergreen forests of West Africa. The tress is most prevalent in the Southern part of Nigeria [1]. Investigations reveals that almost every part of the tree has economic important [2]. However, the most economically imported parts are the seeds which are embedded in a white sweet-smelling pulp of the sub-spherical fruit Plate 1. It has been observed that an average of 119-122 seeds can be found in one fruit [3]. After harvesting, between April to September every year [4], various unit operations such as fermentation, washing, drying and cracking are performed before consumption or storage. The kernel is a popular condiment used as a souring agent. When ground to powder, the kernel is used to prepare pepper soup as stimulant to relieve constipation and control passive uterine hemorrhage in women immediately after child birth [2,5,6]. This berry also has diuretic properties and used for mild fever and antiseptic [6].

Plate 1: Fruit and seeds of African nutmeg

However, the major challenges encountered in all the unit operations is the cracking of the seed coat to extract the kernel which is still carried out by cracking between stones. This operation is yet to be mechanized to reduce the drudgery associated with it as well as opening the avenue for large scale production. But there is paucity of information on the strength properties of this economically and medically viable crop.

Bilanski [7] applied compressive loads at the rate of 1.27 mm/min to soybeans and measured the force and work required to initiate seed coat rupture. Average force to initiate seed coat rupture dropped from 57.8N at

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1 percent moisture content to 44.4N at 16 percent moisture for a soybean loaded in the horizontal hilium position. Average work increased from 3.8MJ at 1 percent moisture to 31.5MJ at 16 percent moisture. Mamman and Umar [8] studied the effects of moisture content and loading orientation on the mechanical properties of balanites nuts. The six mechanical properties investigated were modulus of elasticity, bioyield point, bioyield stress, compressive strength, rupture strength and modulus of stiffness. Results show that values of the six properties decreased with increase in moisture content.

Shelef and Mohsenm [9] also studied the effects of moisture content on mechanical properties of shelled corn by applying uniaxial compression on individual Kernel of the range of 6.5 to 28 percent moisture content. Results showed that each of the evaluated parameters decreased with increasing moisture content. Several researchers have studied the mechanical properties of different agricultural products [10-13].

Therefore the objective of this study was to determine the average compressive force, deformation failure stress and strain energy of African nutmeg seed coat rupture under quasi-static loading as a function of moisture content and loading position.

MATERIALS AND METHODS

Fresh African nutmeg fruits were collected from the Sabagreia forest, Nigeria, on the 30 July, 2006. The fruits were processed and all foreign matter and damaged seeds were removed. The seeds were then stored at O°C and 90% relative humidity for 48hrs before use.

The seeds were then conditioned to five moisture content levels of 8.0, 11.2, 14.0, 17.4 and 28.7 percent (db) as was used by Oje [14] and Aviara *et al*. [15] in determining the moisture content of thevetia nuts and Shea nuts respectively using the oven method. Upon completion of drying each group of sample was sealed in a polyethylene bag and immediately placed in an insulated box to ensure slow cooling for 12hrs before transferring to refrigerator for storage.

Quasi-static compression tests were performed with an instron universal testing machine equipped with a 50KN compression load cell and an integrator. A deformation rate of 1.0mm/mm was used a recommended by ASAE S368 [16]. Deformation was automatically obtained from the recorder chart.

Individual African nutmeg seeds were loaded between two parallel plates. The effect of loading position was determined by loading the seeds both axially and laterally. Ten African nutmeg seeds were tested at each moisture level, in each loading position.

RESULTS AND DISCUSSION

The force-deformation behaviour of African nutmeg during compressive loading is exhibited in the curves shown in Fig. 1-5.

Compressive force: The compressive force needed to cause a seed coat rupture of African nutmeg decreased as moisture content increased (Fig. 1). This was noticeable in the axial and lateral loading positions. African nutmeg seeds loaded in the axial position needed 53.8N at 8.0 percent moisture content and only 33.1N at 28.7 percent moisture. However, seeds loaded in the lateral position required 629.6N at 8.0 percent moisture content and only 112.3N at 28.7 percent moisture content. It was however, observed that, though a lower force is required to initiate seed coat crack at higher moisture content, it has the attendance effect of Kernel breakage which has a negative effect on product quality. These results agree with that of Cakir and Alayunk [13].

Toughness (Strain energy): Toughness (Strain energy) defined as the energy absorbed by the seeds prior to seed coat rupture per unit of seed volume. Results show that, toughness of seedcoat increased with increase in moisture content (Fig. 2). This was evident in both axial and lateral loading positions. African nutmeg in the axial loading position had toughness only 0.0216N.mm at 8.0 percent moisture, but increase to 0.034 Nmm at 28.7 percent moisture. Whilst toughness in the lateral loading position increased from 0.0356Nmm at 8.0 percent moisture to 1.061 Nmm. at 28.7 percent moisture. These

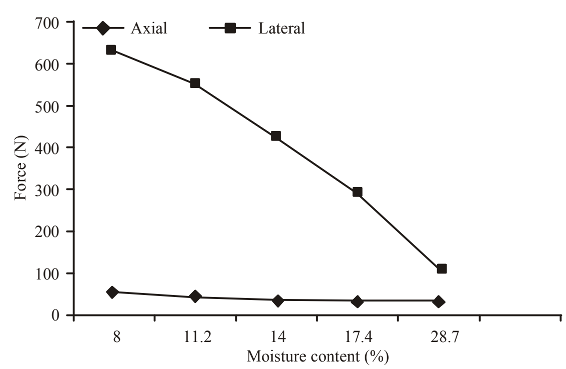

Fig. 1: Force to cause seedcoat rupture as a function of moisture content

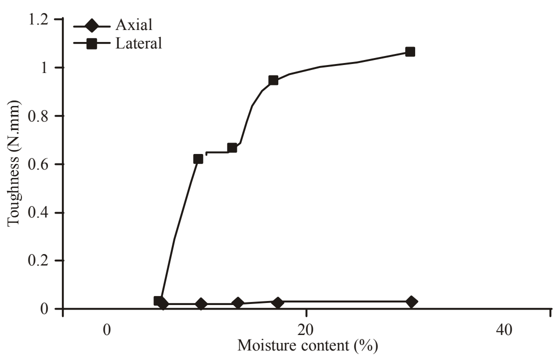

Fig. 2: Toughness at seedcoat rupture as a function of moisture content

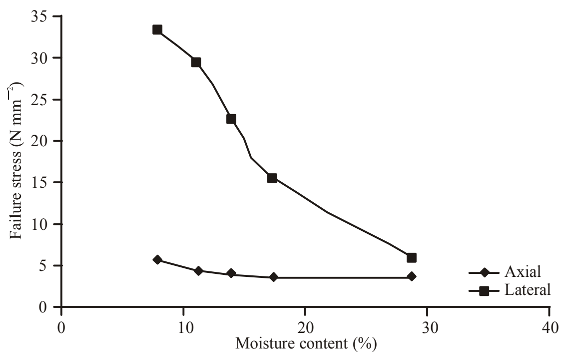

Fig. 3: Failure stress at seedcoat rupture as a function of moisture content

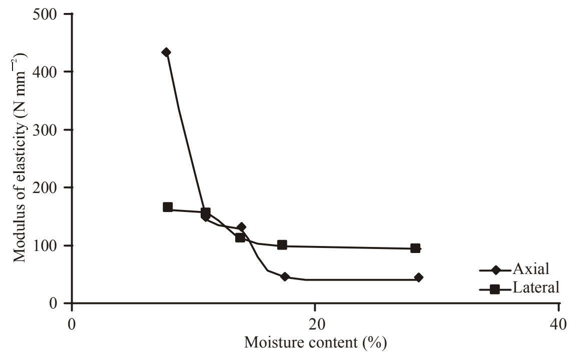

Fig. 4: Modulus of elasticity at seedcoat as a function of moisture content

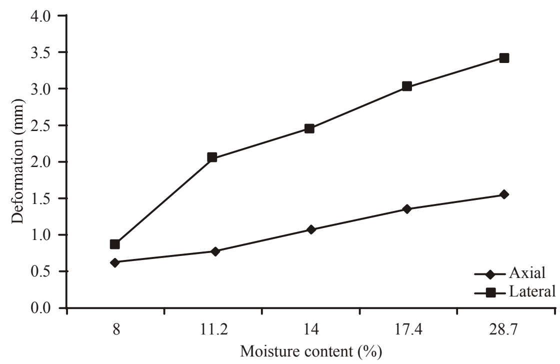

Fig. 5: Deformation at seedcoat rupture as a function of moisture content

results of absorbed energy were all determined from the recorder readings representing the area under the force-deformation curve upto seed coat rupture.

Failure stress: Failure stress otherwise called yield stress is the stress at which the seed coat fails under the action of the applied load. It is calculated as the maximum load on the force-deformation curve divided by the cross sectional area through which the load is applied. Results obtained reveals that failure stress decreased as moisture content increase in both loading orientations. The average failure stress was 5.69 Nmm^2 at 8.0 percent moisture and 3.50 N mm^{-2} at 28.7 percent moisture in the axial loading position. In the lateral loading position, failure stress decreased from 33.21 N mm^{-2} at 8.0 percent moisture to 5.94 N mm^{-2} at 28.7 percent (Fig. 3). Based on results, it is clear to note that more stress is used to initiate seed coat rupture of African nutmeg seed in the lateral loading position than the axial loading geometry. These results are consistent with the findings of Mamman and Umar [8] and Bilanski [7].

Young's modulus: This is a measure of stiffness and rigidity of the specimen or in other words, a measure of how easily the seed coat of African nutmeg can be deformed. Young's modulus readings were obtained from the integrator readings of the slope of the linear portion of the force-deformation curve. Experimental results shows that Young's modulus of African nutmeg seed coat decreased as moisture increased. This was noticeable in the two loading position (Fig. 4). In the axial loading position, Young's modulus was 431.5 N mm^{-2} at 8.0 percent moisture and 41.30 N mm^{-2} at 28.7 percent moisture. Whereas in the lateral position, Young's modulus changed from 161.27 N mm^{-2} at 8.0 percent moisture to 91.84 N mm^{-2} at 28.7 percent moisture. Results obtained herein are in total agreement with the findings of Shelef and Mohsenin [9] and Vincent [17].

Deformation: Deformation at seed coat of African nutmeg was determined from the integrator. Results reveals that deformation at seed coat rupture increased as moisture increase (Fig. 5). Deformation was also observed to be greater in the lateral position than the axial. A deformation of 0.63mm was obtained at 8.0 percent moisture and 1.538mm at 28.7 percent moisture all in the axial loading position. However, in the lateral loading position, values of 0.882 mm at 8.0 percent moisture and 3.413mm at 28.7 percent moisture were obtained as deformations. This implies that more deformation is observable in the lateral loading position, meaning that product damage is eminent. This observation is consistent with the finding of Cenkowski *et al.*[10] and Dhanoa *et al.* [12].

Engineering implications of results: In an attempt to reduce the drudgery associated with the cracking as well as open avenues for large scale production of this valuable crop. Knowledge of this strength properties as a function of moisture content and loading positions must be sort. The decrease in mechanical properties of the seeds with increase in moisture content implies that to save energy, the seeds should be cracked at high moisture content. However, for product quality to be maximized, it is recommended that seeds be cracked axially at low moisture content.

CONCLUSION

Based on the results obtained, the average compressive force required to cause African nutmeg seed coat rupture decreased as moisture content increased from 8.0 to 28.7 percent. African nutmeg seeds loaded in the axial position generally required a lower force to cause seed coat rupture than those loaded laterally.

Modulus of elasticity also showed a negative trend as the sample moisture increase. However, toughness, tend to be positively related to increase in moisture. Deformation at seed coat increased as moisture increased, implying that African nutmeg at higher moistures are softer and more susceptible to bruising.

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