

# MECHANICAL PROPERTIES OF ZIZIPHUS SPINA-CHRISTI FOR PROCESSING

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## ABSTRACT

*Ziziphus Spina Christi is an important plant whose different parts are used for various kind of medication against bacterial and fungal pathogens. It is used to treat burns, stomach discomfort and urinary infections. The leaves are used for treatment of sores, skin diseases, pulmonary ailments, fever, dysentery and therapeutics of new wounds. The fruits are edible and the leaves are used as fodder crops for animals. The seed also contains oil which could be used for various purposes. However, for large scale processing of ziziphus spina christi there is need to investigate the mechanical properties of the seeds to enable engineers and processors use it for development of processing or oil expression machine. Therefore, this research work investigated the mechanical properties of ziziphus spina christi seed at four moisture levels 10.1, 10.5, 11.9 and 13.4 % mc (w.b). Testometric materials testing machine was used to carry out a compression test on the seeds. The maximum forces at break for the four moisture levels were found to be 927.3N, 1124.2N, 1143.6N and 1233.8N respectively. The maximum deformations at peak for the four moisture levels were 1.858mm, 2.093mm, 4.025mm, and 1.262mm respectively. The maximum strain at break for the four moisture levels were 17.05, 40.25, 20.93 and 20.64 (%) respectively. The maximum energy to break the seed at the four moisture levels was 0.541, 0.852, 1.162, and 0.712 (N.m) respectively. And the maximum rupture energy was 0.95Nm, 2.28Nm, 1.18Nm and 0.86Nm respectively. While hardness ranged from 499.09N/mm, 537.12N/mm, 280.84N/mm and 803.26N/mm respectively. It was found out that the higher the moisture content of the seed the higher the force and energy required for breakage. It was recommended that to break the seeds at minimum force and energy the product should be adequately dried (least moisture content).*

**Keywords:** Mechanical properties, ziziphus spina-christ, processing, compressive

## 1 INTRODUCTION

**M**echanical properties are concerned with the behaviour of agricultural materials under applied forces. The study of mechanical properties is needed for texture analysis and better understanding of product quality. Compressive and other engineering properties are needed in the design of machines and the analysis of the behaviour of the product during unit operations such as drying, cleaning, sorting, crushing and milling [1]. Force-deformation testing of agricultural materials is used to study damage which occurs during harvesting and handling of grains, seeds, fruits and vegetables. Knowledge of the behaviour of a particular agricultural material from test data enhances the chances of having accurate engineering design. Damages done to agricultural materials during harvesting, handling and transportation can reduce their structural integrity [2]. Those damages that are often recorded include bruising and splitting (vegetables and fruits), cracking and chipping (grains, seeds and eggs), and cuts (fruits and seeds) [3]. The amount of force required to produce a given amount of deformation depends on many factors including the rate at which the force is applied, the previous history of loading, moisture content and the composition of the product [4]. These factors play important roles when the qualitative evaluation of the grain's hardness is required during size reduction processes. Several scholars have investigated the mechanical properties of different agricultural materials and food products. Wang [5] reviewed the firmness detection by excitation dynamic characteristics for peach and observed that impact orientation, detected orientation, impact

velocity and impact material did not significantly affect the dominant frequency. Other fruits and vegetables whose mechanical properties have been studied include; cucumber [6], apples and pears [7], apples [8], and garlic [9]. Mohsenin [10] stated that compressive properties of agricultural materials can be determined when a comprehensive force-deformation curve of the product is presented from which modulus of elasticity, toughness, maximum normal contact stress or stress index at low levels of deformation can be obtained. He also said that Hertz's theory of contact stresses can be applied when strains are small, because most agricultural materials are assumed to exhibit extensive elasticity. Olaniyan [11, 17, 19] performed compression tests with the Mansnato Tensiometer universal testing machine to determine the visco-elastic behaviour of shea nut under applied force. The nuts were singly fed onto the machine between the compression plates and loaded to rupture. The force at rupture point and the corresponding deformation for each nut specimen were read from the in-built Force- Deformation curve. However, there was no published work on mechanical properties of ziziphus spina-christ and information on operational parameters like compressive force, hardness and rupture energy, which may be useful for the design of equipment for the mechanical processing or expression of oil from the seed are not handy. Therefore, it calls for a investigation of these parameters.

## 2 MATERIALS AND METHODS

The seeds of ziziphus spina-christ were cleaned manually to remove foreign materials, broken and immature seeds. The initial moisture content was determined by oven drying method at  $105 \pm 1^\circ\text{C}$  for 24 h [12] and was found to be 10.1% (wb). In order to get the rice grains at different moisture levels (10.1, 10.5, 11 and 13.4%) the method reported by [13, 16] was used. After conditioning, the seeds were kept in polyethylene bags and placed in the refrigerator at  $5^\circ\text{C}$  for equilibration to occur. The moisture content of the respective samples were then determined and found to be 10.1%, 10.5%, 11.9% and 13.4 % (wb) respectively for the four groups. Five (5) seeds were selected from each group and their principal dimensions were determined.

### *Compression Test*

Quasi-static compression test using an electronic Universal Material Testing Machine (Testometric, 0500-10080 accuracy 0.01 N) as shown in Plate 1 was used to carry out the test on ziziphus spina-christ seeds. A flat circular plate was used to compress the fruit at a deformation speed of 5.00 mm/min until rupture occurred, as shown in Plate 2. The tests were performed in the Materials Testing Laboratory of the National Centre for Agricultural Mechanization (NCAM) Ilorin, Kwara State. The seeds were loaded individually on the compression machine. The samples were then subjected to compression force by the machine until the biomaterial fails. Thus, the Force - Deformation readings and graph was concurrently plotted. Readings were recorded directly through a computer print-out connected to the machine.



Plate 1. Testometric Universal Material Testing Machine



Plate 2. Compression Test in Progress

The mechanical properties of the ziziphus spina-christ seeds were expressed in terms of the rupture force and hardness, which were calculated using the equations 1 and 2 as stated by [14, 15, 18] respectively.

$$\text{Rupture Energy } E = \frac{1}{2}(F_r D_r) \tag{1}$$

$$\text{Hardness} = \frac{F_r}{D_r} \tag{2}$$

Where,  $F_r$  is force at rupture point (N),  $D_r$  is deformation at rupture point (mm). The maximum rupture energy is 0.95 Nm, while hardness is 803.26 N/mm.

### 3 RESULTS AND DISCUSSION

The results in Tables 1 to 4 shows the compression heights (mm), force at break (N), the deformation at break(mm), strain at break (%),energy at peak (Nm), energy to break (Nm) and energy to yield (Nm). Then the minimum, mean, maximum, standard deviation, coefficient of variation, lower critical limit and upper critical limit of all the values were automatically computed as presented in tables. Figure 1 show plot of force at break verses moisture content with a positive correlation  $r^2$  value of 0.7. This indicates that when the moisture content is high force required to break the seed increases. This is because in the absence of moisture the biomaterial under test is brittle and when moisture is introduced the cell are rewetted with water and the turgor rigidity increases. This can be seen by the regression equation,  $y = -2.2782x^2 + 122.56x$ . Where,  $y$  is force (N) and  $x$  represents moisture content (%). Suggesting that the least force to break the seed can only be obtained the at least moisture content.

Table 1. Results of compression Test at moisture content 13.4%

Sample A Test	Height (mm)	Force at Break (N)	Deformation at Break (mm)	Strain at Break (%)	Energy at Peak (N.m)	Energy to Break (N.m)	Energy to Yield (N.m)
1	10.45	1233.800	1.536	16.168	0.712	0.712	0.712
2	9.70	878.200	0.795	8.368	0.276	0.276	0.276
3	9.90	920.400	1.62	17.053	0.598	0.598	0.598
4	9.87	560.900	0.954	10.042	0.198	0.201	0.198
5	9.04	788.800	1.536	16.168	0.351	0.351	0.351
Min		560.900	0.795	8.368	0.198	0.201	0.198
Mean		876.420	1.288	13.56	0.427	0.428	0.427
Max		1233.800	1.62	17.053	0.712	0.712	0.712
S.D.		243.356	0.383	4.035	0.219	0.218	0.219
C. of V.		27.767	29.759	29.759	51.187	50.948	51.187
L.C.L.		574.259	0.812	8.55	0.156	0.157	0.156
U.C.L.		1178.581	1.764	18.57	0.698	0.698	0.698

Table 2. Results of compression Test at moisture content 11.9%

Sample B Test	Height (mm)	Force at Break (N)	Deformation at Break (mm)	Strain at Break (%)	Energy to Peak (N.m)	Energy to Break (N.m)	Energy to Yield (N.m)
1	11.39	931.400	4.025	40.250	1.162	1.162	1.162
2	10.17	1130.400	1.522	15.220	0.602	0.606	0.602
3	9.2	818.400	1.143	11.430	0.324	0.324	0.324
4	8.08	634.200	1.035	10.350	0.321	0.321	0.321
5	8.2	759.500	1.234	12.340	0.263	0.266	0.263
Min		634.200	1.035	10.350	0.263	0.266	0.263
Mean		854.780	1.792	17.918	0.535	0.536	0.535
Max		1130.400	4.025	40.250	1.162	1.162	1.162
S.D.		187.679	1.261	12.614	0.375	0.375	0.375
C. of V.		21.956	70.400	70.400	70.13	69.888	70.130
L.C.L.		621.749	0.226	2.256	0.069	0.071	0.069
U.C.L.		1087.811	3.358	33.580	1.000	1.001	1.000

Table 3. Results of compression Test at moisture content 10.5%

Sample C Test	Height (mm)	Force at Break (N)	Deformation at Break (mm)	Strain at Break (%)	Energy to Peak (N.m)	Energy to Break (N.m)	Energy to Yield (N.m)
1	11.99	1124.200	2.093	20.930	0.852	0.852	0.852
2	9.95	943.600	1.159	11.590	0.620	0.620	0.620
3	9.84	682.900	1.026	10.260	0.266	0.266	0.266
4	9.48	784.000	0.815	8.150	0.268	0.268	0.268
5	9.93	956.800	1.369	13.690	0.693	0.693	0.693
Min		682.900	0.815	8.150	0.266	0.266	0.266
Mean		898.300	1.292	12.924	0.540	0.540	0.540
Max		1124.200	2.093	20.930	0.852	0.852	0.852
S.D.		170.269	0.491	4.908	0.263	0.263	0.263
C.of V.		18.955	37.975	37.975	48.731	48.731	48.731
L.C.L.		686.886	0.683	6.830	0.213	0.213	0.213
U.C.L.		1109.714	1.902	19.018	0.866	0.866	0.866

Table 4. Results of compression Test at moisture content 10.1%

Sample D Test	Height (mm)	Force at Break (N)	Deformation at Break (mm)	Strain at Break (%)	Energy to Peak (N.m)	Energy to Break (N.m)	Energy to Yield (N.m)
1	9.5	707.500	1.858	20.644	0.348	0.348	0.310
2	8.51	706.300	0.876	9.733	0.292	0.299	0.292
3	8.95	761.300	1.604	17.822	0.541	0.541	0.541
4	8.1	764.900	1.606	17.844	0.530	0.53	0.530
5	7.62	927.300	0.831	9.233	0.403	0.403	0.403
Min		706.300	0.831	9.233	0.292	0.299	0.292
Mean		773.460	1.355	15.056	0.423	0.424	0.415
Max		927.300	1.858	20.644	0.541	0.541	0.541
S.D.		90.484	0.470	5.218	0.110	0.108	0.118
C.of V.		11.699	34.655	34.655	26.082	25.565	28.361
L.C.L.		661.112	0.772	8.577	0.286	0.289	0.269
U.C.L.		885.808	1.938	21.534	0.560	0.559	0.561

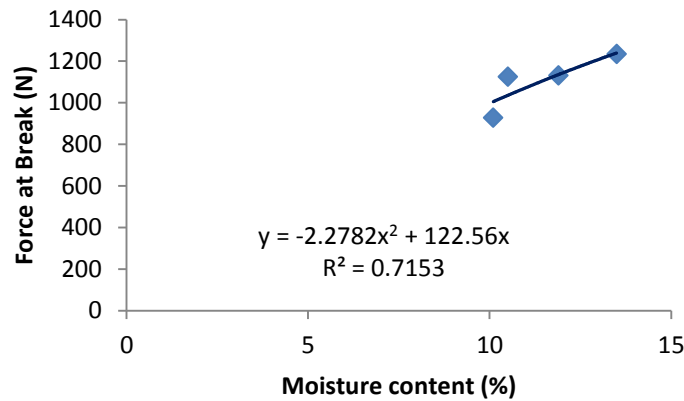


Figure 1. Force at break (N) against Moisture content (%)

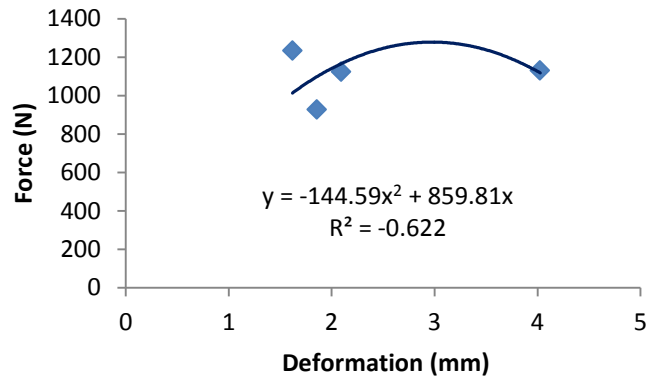


Figure 2. Force at break (N) against Deformation (mm)

Figure 2 shows force at break against deformation with a negative regression coefficient  $r^2$  of (-0.62). The higher the force at break the higher the deformation up to a point when the force begins to decrease and deformation continues to failure. This is in conformity with the load against deformation plot for biological material (bioyield point or rupture point).

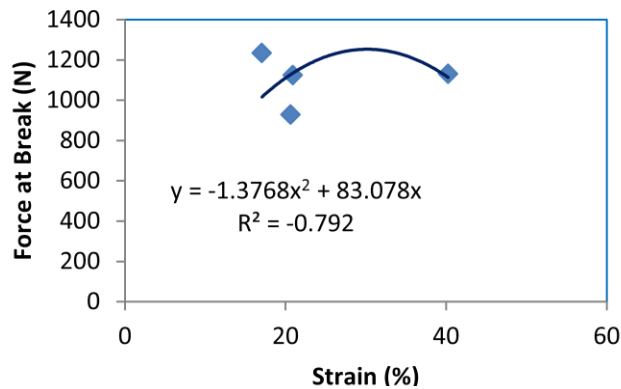


Figure 3. Force at break (N) against strain (%)

The force at break and strain displayed a similar pattern with a negative  $r^2$  value of (-0.79) and a polynomial relation,  $y = -1.3768x^2 + 83.078x$ . Where,  $y$  is force (N) and  $x$  represents strain (%). As the loading continues it will reach the yield point even without further addition of load the failure continues. This is in agreement with Hooke's law for rigid body and the correlation is moderate though negatively.

#### 4 CONCLUSIONS

It can be concluded that the energy required to rupture the seed at any axis would not exceed 2.28Nm and the hardest seed has a hardness of 803.26 N/mm. Cracking the seeds should be done at the least moisture content for storage, this is necessary because addition of moisture reinforces the strength of the seed.

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