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Mechanical Properties of Two Varieties of Melon (*Colocynthis citrullus)*

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Abstract: The study of the mechanical properties of biomaterials gives the significant knowledge in quality evaluations and control of mechanical damage in size reduction, this study aimed at determining the mechanical properties of two selected varieties (*Bara* and *Sewere*) of melon. The strength properties of the two varieties were determined using a Universal Testing Machine (Testometric Machine) with a 25 KN compression load cell and Integrator. The properties determined include deformation, force, strain, stress, time to failure, time to peak and young modulus, they were determined in two loading orientations (laterally and longitudinally). The data obtained were statistically analysed and difference of means were tested at 95% level of confidence. the deformation, compressive force, strain and stress at the limit of proportionality ranges between 0.74-0.90mm, 9.13-11.13N, 4.63-5.65% and 0.06-0.07N/mm^2 respectively for longitudinal orientation of *Bara* and 1.48-2.51mm, 8.22-14.15N, 9.24-15.6%, 0.05-0.09N/mm^2 respectively for transverse orientation of *Bara* while for *Sewere*, the deformation, compressive force, strain and stress ranges between 1.28-1.69mm, 5.40-6.57N, 8.03-10.55% and 0.03-0.04N/mm^2 respectively for longitudinal orientation and 1.20-1.58mm, 5.47-8.37N, 7.51-9.85%, 0,03-0.05N/mm^2 respectively for transverse orientation. There exists a significant difference in the force required to attain the yield point between the longitudinal and transverse orientation for *Bara* while there is no significant difference between longitudinal and transverse orientation in *Sewere* but *Bara* in transverse orientation is significantly higher that of *Sewere* and *Bara* in longitudinal orientation is significantly higher than that of *Sewere*. The deformation, compressive force, strain and stress at peak point ranges between 1.57-.65mm, 35.43-44.91N, 9.81-10.29% and 0.22-0.28N/mm^2 respectively for longitudinal orientation of *Bara* and 2.20-3.02mm, 22.68-30.35N, 13.77-18.89%, 0.14-0.19N/mm^2 respectively for transverse orientation of *Bara* while for *Sewere* the deformation, compressive force, strain and stress ranges between 3.90-5.79mm, 13.22-23.50N, 24.39-36.25% and 0.08-0.15N/mm^2 respectively for longitudinal orientation and 2.42-3.08mm, 18.17-22.72N, 15.11-19.22%, 0.11-0.14N/mm^2 respectively for transverse orientation.
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Keywords: Melon varieties, mechanical properties, machine design, strength characteristics

1. Introduction

Melon (*Colocynthis citrullus* L.) is an extensively cultivated and consumed oil seed crop in Nigeria and West Africa (Bankole, 2010). It is the fourth most important crop in the world in terms of production (18 metric tons), after orange, banana and grape (Aguayo, 2004). These seeds are vastly nutritious, furnishing the human diet with good quality protein (Ogbonna, 2007). It contains about 41.51% essential amino acids and other essential nutrients (Sabo *et al*., 2015). Melon seed is also a good source of minerals, vitamins, oil and energy in form of carbohydrates (Olaniyi, 2008). The seed contains 0.6 proteins, 4.6g carbohydrates, 33 mg vitamin C, 0.6 g crude fiber, 230 mg K, 16 mg P, 17 g Ca per 100 g edible seeds and unsaturated fatty acids.

Egusi seed are small and flat one end of the seed is rounded and the other is tapered (Bankole, 2010) thus making it more tasking to design its post harvest equipment. Egbe *et al*. (2015) stated that oil can be extracted mechanically by using hydraulic or screw press to press out the oil from melon seed. According to Odigboh (1999), it can also be extracted by using solvent like ethanol. The oil extracted from melon seed can be used for cooking and the residue left after extraction of the oil is high in protein which can be incorporated into baby food and local food such as “Igbalo” or “Jogi” which are mostly fried. All these are taken along with pap and also used for making soap, melon cake are used for livestock feed. According to Ojeih *et al.* (2015), melon seed can provide valuable sources of oil used for both home, consumption and for export.

Melon is grown and utilized as food source in most parts of Nigeria. Africa is lacking behind in the development and designing of Agricultural machineries to solve her agriculture challenges mainly due to non-availability of information on the engineering of the crops necessary for design and development of machinery. The engineering properties of the crops include physical, mechanical/rheological, thermal, electrical, and optical properties which serve as an information in designing and construction of post harvest machinery (Aremu *et al*., 2014b; Jaiyeoba *et al.,* 2016a and b; Jaiyeoba and Ogunlade, 2017; Ogunlade *et al.,* 2016 and 2018; Oladimeji *et al*., 2019). The physical properties of two varieties of melon (*Bara* and *Sewere*) including dimensional, gravimetric and frictional properties have been reported (Oyerinde *et al.,* 2020) while there is dearth of information on the mechanical properties of these two varieties. The study of the mechanical properties of biomaterials gives the knowledge significant in quality evaluations and control of mechanical damage in size reduction. Mechanical properties of agricultural materials affects their processing, handling storage and consumption and they are important in the design of planters, harvesters and in postharvest operations such as cleaning, conveying and storage (Balasubramanian *et al*., 2012 and Asoegwu *et al*., 2006; Aremu *et al.,* 2014b). Results obtained from the study of the mechanical properties of two varieties of melon would be essential in the designing of equipment for its processing as well as the designing of facilities for its storage and will also predict the behavior of this agricultural material under load, the maximum allowable load and the minimum energy requirement for size reduction. This study therefore aimed at determining the mechanical properties of two selected varieties (*Bara* and *Sewere*) of melon.

2. Material and Methods

2.1 Sample Preparation: Two varieties of melon, namely *Bara* (Variety A) and *Sewere* (Variety B) used in the study were procured from Bodija market at Ibadan, Oyo state, Nigeria. The samples were cleaned to remove foreign materials, and broken or immature seeds.

2.2 Determination of Mechanical Properties

The strength properties of the two varieties were determined using a Universal Testing Machine (Testometric Machine) (Model M500) with a 25 KN compression load cell and Integrator. The properties determined include deformation, force, strain, stress, time to failure, time to peak and young modulus. The properties were determined in two orientations (laterally and longitudinally). The test was based on the force-deformation characteristics of the seeds. The universal testing machine has three main components which are stable up and motion bottom of platform; a driving unit, and a data acquisition system. During a compressive test the melon seed sample with an area of 160.000mm^2 was placed laterally and longitudinally on the stable up platform (Figure 1) and was compressed with a motion probe at a constant speed of 20 mm/min until the specimen fractured, the counter reading was taken immediately the first cracking sound was heard and the mechanical parameters of the test were automatically generated by the machine when programmed to determine the required mechanical properties of the melon seed. The results and the force-deformation curves obtained at each loading orientation were analyzed for the following: Elastic behavior; Limit of proportionality; Yield point; Breaking point; Peak point; Time to failure, time to peak and Young Modulus.

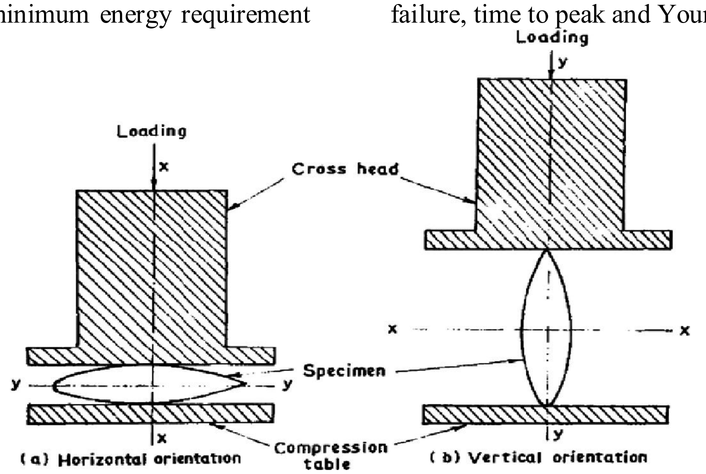

Figure 1: Orientation of African oil bean seed under compressive loading (Aremu *et al.,* 2014)

2.3 Data Analysis

The data acquisition unit of the Testometric machine gave out analysed results however, the raw data obtained were statistically analysed and difference of means were tested using Microsft Excel, 2013 version at 95% level of confidence.

3. Results

3.1 Elastic behavior of melon seed

The force-deformation diagram of the two varieties of melon with respect to the applied with respect to the load applied. It was observed that variety A had the maximum deformation under applied load in Longitudinal direction while variety B had the lowest in traverse direction.

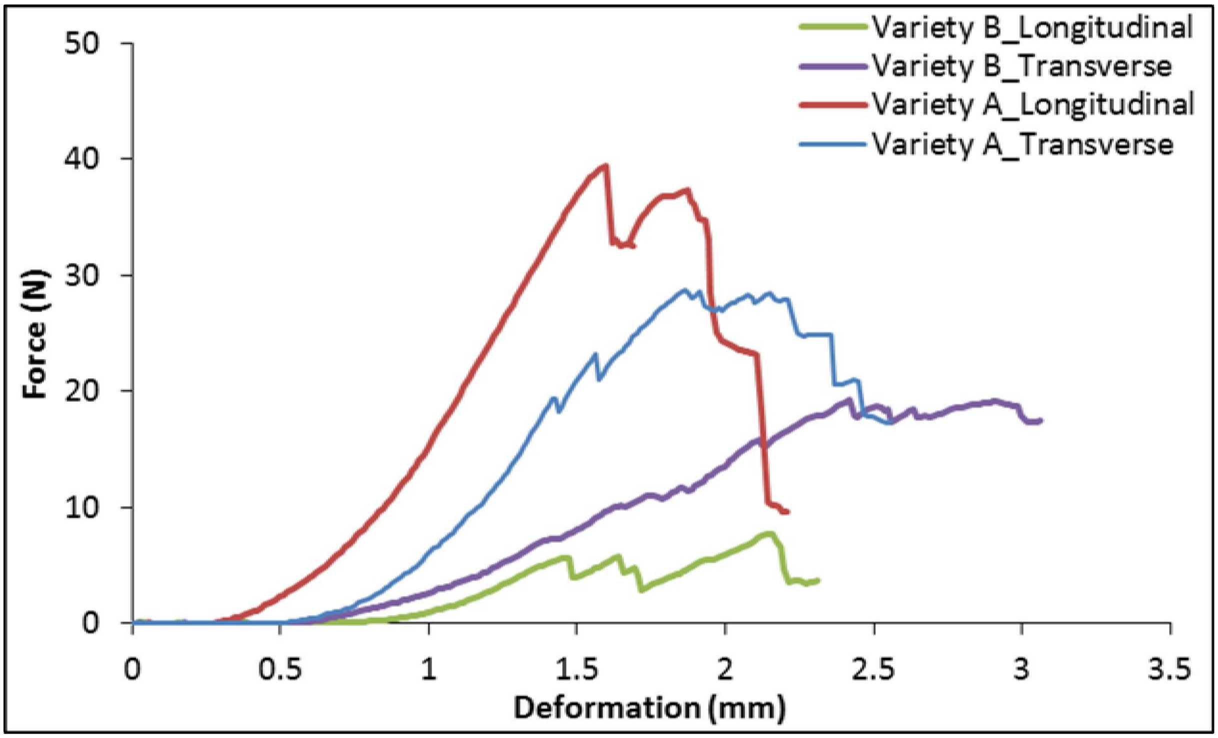

Figure 2: Force vs Deformation of Melon Seed (*Bara* and *Sewere*) in two major orientation

3.2 Mechanical behavior at Limit of Proportionality

The limit of proportionality measures the maximum point to which the melon seed obeys the Newton rule of elasticity that point at the linear relationship between the material deformation and the compressive load applied during compression. It was observed that the limit of proportionality of *Bara* is higher in transverse direction than the longitudinal orientation and vice versa for the *Sewere*. Table 1 shows the statistical summary of the mechanical behavior at the limit of proportionality. The table reveal that there is no significant difference in the force required to attain the limit of proportionality between the longitudinal and transverse orientation for the two variety ($p < 0.05$) but Bara in transverse orientation is significantly higher than that of Sewere.

The table also shows that the deformation, compressive force, strain and stress at the limit of proportionality ranges between 0.74-0.90mm, 9.13-11.13N, 4.63-5.65% and 0.06-0.07N/mm^2 respectively for longitudinal orientation of *Bara* and 1.48-2.51mm, 8.22-14.15N, 9.24-15.6%, 0.05-0.09N/mm^2 respectively for transverse orientation of *Bara* while for *Sewere*, the deformation, compressive force, strain and stress ranges between 1.28-1.69mm, 5.40-6.57N, 8.03-10.55% and 0.03-0.04N/mm^2 respectively for longitudinal orientation and 1.20-1.58mm, 5.47-8.37N, 7.51-9.85%, 0,03-0.05N/mm^2 respectively for transverse orientation.

3.3 Mechanical behavior at Yield Point

The yield point measures the stress beyond which a material deforms by relatively large amount for a small increase in the stretching force. It was observed that the deformation and strain of the transverse orientation of *Bara* and *Sewere* is higher than the longitudinal orientation at the yield point also, the force and strength of the longitudinal orientation of *Bara* is higher than the transverse orientation at the yield point and vice versa for *Sewere*.

However, Table 2 shows the statistical summary of mechanical behaviour of melon seed at the yield point. There exists a significant difference in the force required to attain the yield point between the longitudinal and transverse orientation for *Bara* while there is no significant difference between longitudinal and transverse orientation in *Sewere* but *Bara* in transverse orientation is significantly higher that of *Sewere* and *Bara* in longitudinal orientation is significantly higher than that of *Sewere*.

Table 1: The Mechanical Properties of Melon Seed at the Limit of Proportionality

Properties	Statistics	*Bara*		*Sewere*	
		Longitudinal	Transverse	Longitudinal	Transverse
Deformation (mm)	Mean	0.843[bc]	1.856[a]	1.47[ab]	1.432[ab]
	Max	0.904	2.506	1.688	1.576
	Min	0.74	1.478	1.284	1.201
	SD	0.09	0.566	0.204	0.202
	CV (%)	10.641	30.482	13.862	14.099
Force (N)	Mean	10.013[ab]	11.33[a]	6.077[c]	7.04[bc]
	Max	11.13	14.15	6.57	8.37
	Min	9.13	8.22	5.4	5.47
	SD	1.02	2.976	0.606	1.465
	CV (%)	10.189	26.263	9.975	20.807
Strain (%)	Mean	5.269[bc]	11.598[a]	9.19[ab]	8.948[ab]
	Max	5.65	15.663	10.55	9.85
	Min	4.625	9.238	8.025	7.506
	SD	0.561	3.535	1.274	1.262
	CV (%)	10.64	30.482	13.861	14.102
Stress (N/mm^2)	Mean	0.063[ab]	0.071[a]	0.038[c]	0.044[bc]
	Max	0.07	0.088	0.041	0.052
	Min	0.057	0.051	0.034	0.034
	SD	0.007	0.019	0.004	0.009
	CV (%)	10.625	26.335	9.488	20.83

Mean values on the same row with different alphabet are significantly different at $p<0.05$

The table also shows that the deformation, compressive force, strain and stress at yield point ranges between 1.57-1.65mm, 35.43-44.91N, 9.81-10.29% and 0.22-0.28N/mm^2 respectively for longitudinal orientation of Variety A and 1.87-3.02mm, 17.49-28.47N, 11.69-18.89%, 0.11-0.18N/mm^2 respectively for transverse orientation of *Bara* while for *Sewere* the deformation, compressive force, strain and stress ranges between 1.58-2.03mm, 6.09-14.02N, 9.89-12.71% and 0.04-0.09N/mm^2 respectively for longitudinal orientation and 1.38-2.42mm, 9.97-18.17N, 8.64-15.11%, 0.06-0.11N/mm^2 respectively for transverse orientation.

Table 2: Mechanical Properties of Melon Seed at the Yield Point

Properties	Statistics	*Bara*		*Sewere*	
		Longitudinal	Transverse	Longitudinal	Transverse
Deformation (mm)	Mean	1.596[abc]	2.267[a]	1.755[ab]	1.85[ab]
	Max	1.647	3.023	2.033	2.418
	Min	1.57	1.87	1.583	1.383
	SD	0.044	0.655	0.243	0.525
	CV (%)	2.749	28.876	13.862	28.37
Force (N)	Mean	39.553[a]	23.78[b]	9.36[c]	13.33[c]
	Max	44.91	28.47	14.02	18.17
	Min	35.43	17.49	6.09	9.97
	SD	4.859	5.662	4.144	4.296
	CV (%)	12.284	23.811	44.27	32.226
Strain (%)	Mean	9.977[abc]	14.171[a]	10.967[ab]	11.563[ab]
	Max	10.294	18.894	12.706	15.113
	Min	9.813	11.688	9.894	8.644
	SD	0.274	4.092	1.52	3.28
	CV (%)	2.749	28.876	13.859	28.371
Stress (N/mm²)	Mean	0.247[a]	0.149[b]	0.059[c]	0.083[c]
	Max	0.281	0.178	0.088	0.114
	Min	0.221	0.109	0.038	0.062
	SD	0.031	0.036	0.026	0.027
	CV (%)	12.465	23.974	44.493	32.673

Mean values on the same row with different alphabet are significantly different at $p<0.05$

3.4 Mechanical Behavior of Melon at Breaking Point

Breaking point measures the degree of tension or stress at which the material breaks. Figures 3 a-d shows the graphical representation of mechanical behavior at the breaking point which are deformation, force, strain and stress respectively for two varieties of melon seed in two major orientation (longitudinal and transverse). The deformation, compressive force, strain and stress ranges between 1.85±0.31mm, 25.17±13.42N, 11.58±1.94% and 0.16±0.08N/mm^2 respectively for longitudinal orientation of *Bara* and 3.17±0.67mm, 15.67±11.38N, 36.74±5.23%, 0.05±0.02N/mm^2 respectively for transverse orientation of *Bara* while for *Sewere* the deformation, compressive force, strain and stress ranges between 5.88±0.84mm, 8.62±3.39N, 19.84±4.21% and 0.10±0.07N/mm^2 respectively for longitudinal orientation and 3.57±0.46mm, 11.84±1.87N, 22.31±2.87%, Figure 3a shows that the deformation of the transverse orientation of *Bara* is higher than the longitudinal orientation at the breaking point and vice versa in *Sewere*, Figure 3b shows that the force of the longitudinal orientation of *Bara* is higher than the transverse orientation at the breaking point and vice versa for *Sewere* while Fig 3c shows that the strain of the transverse orientation of *Bara* and *Sewere* is higher than the longitudinal orientation at the breaking point and vice versa for strength in Fig 3d. There is no significant difference in the force required to attain the breaking point between the longitudinal and transverse orientation for *Bara* and *Sewere*. 0.07±0.01N/mm^2 respectively for transverse orientation.

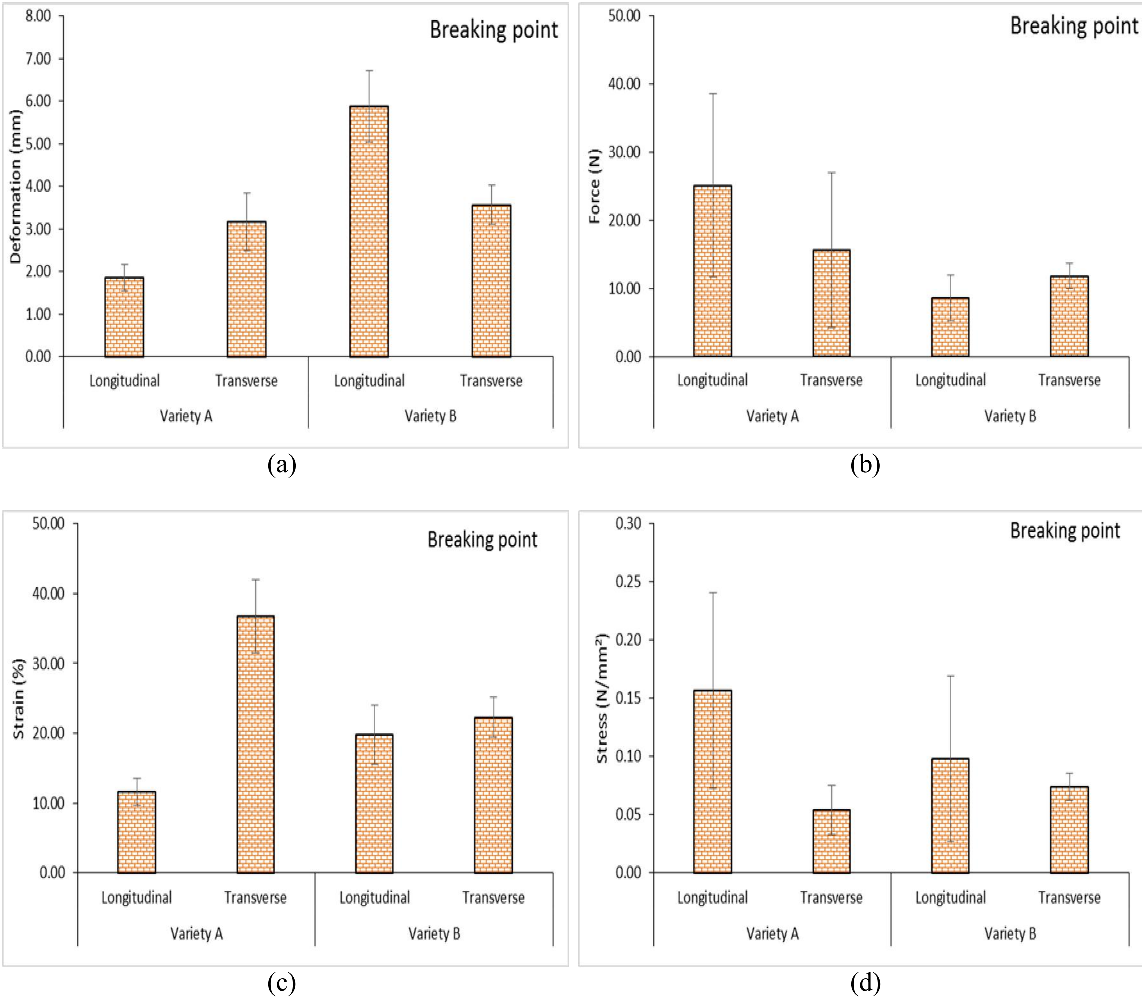

Figure 3: (a) – Deformation, (b) – Force, (c) – Strain, (d) – Stress the melon seeds at breaking point

3.5 Mechanical behavior of Melon at Peak Point under loading

The deformation, compressive force, strain and stress at peak point ranges between 1.57-.65mm, 35.43-44.91N, 9.81-10.29% and 0.22-0.28N/mm^2 respectively for longitudinal orientation of *Bara* and 2.20-3.02mm, 22.68-30.35N, 13.77-18.89%, 0.14-0.19N/mm^2 respectively for transverse orientation of *Bara* while for *Sewere* the deformation, compressive force, strain and stress ranges between 3.90-5.79mm, 13.22-23.50N, 24.39-36.25% and 0.08-0.15N/mm^2 respectively for longitudinal orientation and 2.42-3.08mm, 18.17-22.72N, 15.11-19.22%, 0.11-0.14N/mm^2 respectively for transverse orientation. It was observed that the deformation and strain of *Bara* in transverse orientation is higher than the longitudinal orientation at the peak point, and vice versa in *Sewere*; also, the force and strength of *Bara* in longitudinal orientation is higher than the transverse orientation at the peak point and vice versa for *Sewere*. Table 3 shows the statistical summary of mechanical behaviour of melon seed at peak point. The table reveals that there is significant difference in the force required to attain the yield point between the longitudinal and transverse orientation for *Bara* while there is no significant difference between longitudinal and transverse orientation in *Sewere* but *Bara* in longitudinal orientation is significantly higher than that of *Bara* and *Sewere* in transverse orientation is significantly higher than that of *Sewere*.

Table 3: Statistical summary of mechanical property at peak point

Properties	Statistics	*Bara*		*Sewere*	
		Longitudinal	**Transverse**	**Longitudinal**	**Transverse**
Deformation (mm)	Mean	1.596[bc]	2.598[b]	4.979[a]	2.672[b]
	Max	1.647	3.023	5.799	3.075
	Min	1.57	2.203	3.902	2.418
	SD	0.044	0.411	0.974	0.353
	CV (%)	2.749	15.813	19.566	13.209
Force (N)	Mean	39.553[a]	27.167[b]	18.517[c]	20.677[bc]
	Max	44.91	30.35	23.5	22.72
	Min	35.43	22.68	13.22	18.17
	SD	4.859	3.998	5.147	2.31
	CV (%)	12.284	14.715	27.797	11.173
Strain (%)	Mean	9.977[bc]	16.238[b]	31.117[a]	16.7[b]
	Max	10.294	18.894	36.244	19.219
	Min	9.813	13.769	24.388	15.113
	SD	0.274	2.568	6.088	2.206
	CV (%)	2.749	15.813	19.565	13.208
Stress (N/mm²)	Mean	0.247[a]	0.17[b]	0.116[c]	0.129[bc]
	Max	0.281	0.19	0.147	0.142
	Min	0.221	0.142	0.083	0.114
	SD	0.031	0.025	0.032	0.014
	CV (%)	12.465	14.694	27.627	10.971

Mean values on the same row with different alphabet are significantly different at p<0.05

3.6 Time to failure, Time to Peak and Young Modulus

The time to failure, time to peak and young modulus ranges between 4.97-13.88s, 4.76-4.92s, 2.60-3.40N/mm^2 respectively for longitudinal orientation of variety A and 20.18-29.87s, 17.07-27.63s, 1.49-2.03N/mm^2 respectively for transverse orientation of Bara while for Sewere, the time to failure, time to peak and young modulus ranges between 7.79-11.78s, 6.67-9.09s, 3.12-4.43N/mm^2 respectively for longitudinal orientation and 9.22-11.88s, 7.30-9.26s, 0.64-1.97N/mm^2 respectively for transverse orientation. Fig 4 - 6 shows the time to failure, time to peak and young modulus respectively for two varieties of melon seed in two major orientation (longitudinal and transverse). Figure 4 shows that the time to failure of *Bara* and *Sewere* in the transverse orientation is higher than the longitudinal orientations while Figure 5 shows that the time to peak of *Bara* and *Sewere* in transverse orientation is higher than the longitudinal orientation. Figure 6 shows that the young modulus of *Bara* and *Sewere* in longitudinal orientation is higher than its transverse orientation.

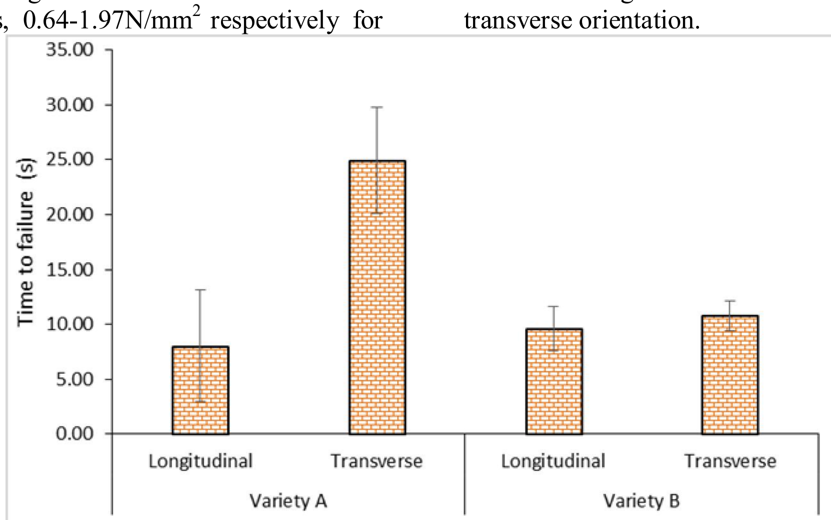

Figure 4: The failure time of the melon seed under compression test

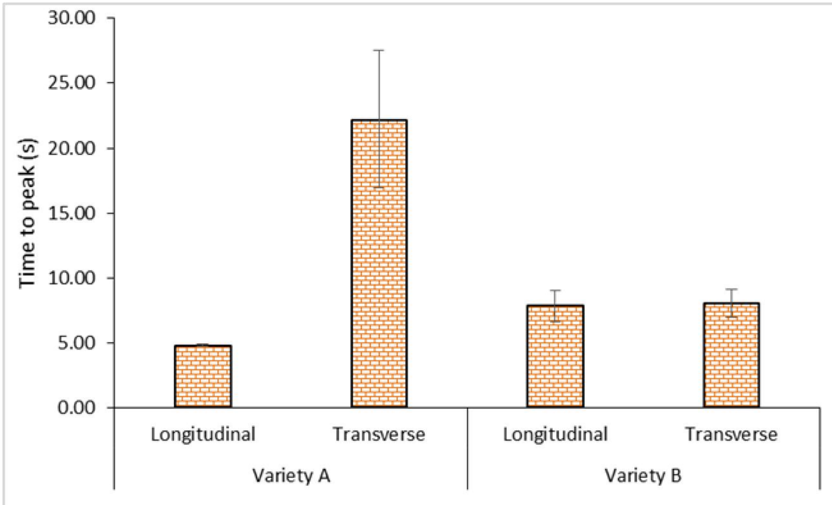

Figure 5: The time taken the melon seed to attain peak point under compression test

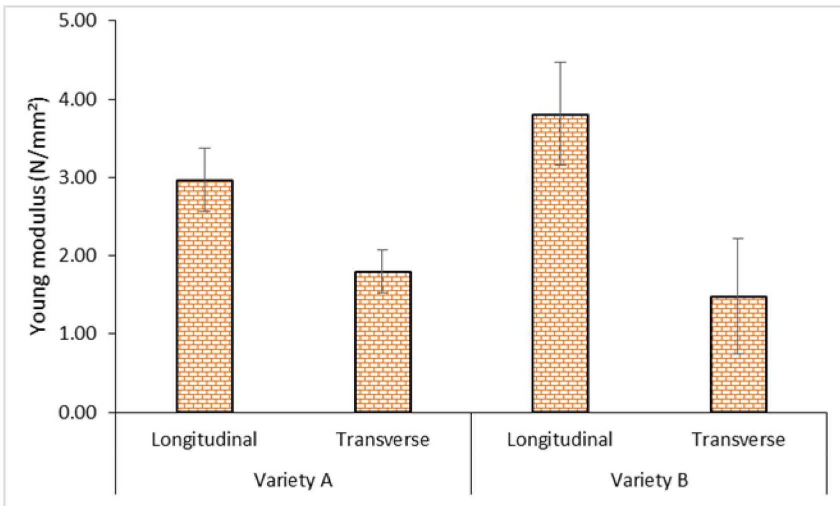

Figure 6: The young modulus of elasticity of melon seeds under compression test

4.0 Conclusions

The mechanical properties of two varieties of melon (*Bara* and *Sewere*) were investigated prior to design of post harvest machine. The mechanical behavior (stress, strain, force and deformation) at limit of proportionality, peak point, breaking point and yield point for two varieties of melon seed in two major orientation (longitudinal and transverse) was determined. There was no significant difference in the force required to attain the limit of proportionality between the longitudinal and transverse orientation for the two variety ($p < 0.05$) but *Bara* in transverse orientation is significantly higher that of *Sewere.* There was significant difference in the force required to attain the yield point between the longitudinal and transverse orientation for *Bara* while there was no significant difference between longitudinal and transverse orientation in *Sewere* but *Bara* in transverse orientation is significantly higher that of *Sewere.* There was no significant difference in the force required to attain breaking point between the longitudinal and transverse orientation for the two varieties while there was a significant difference in the force required to attain the yield point between the longitudinal and transverse orientation for *Bara* and no significant difference for both orientations of *Sewere*. The time to failure of the transverse orientation of *Bara* and *Sewere* is higher than the longitudinal orientations while the time to peak of the transverse orientation of *Bara* and *Sewere* is higher than the longitudinal orientation, also, the young modulus of the longitudinal orientation is higher than the transverse orientation of *Bara* and *Sewere.* The data obtained will be guide for food and agricultural engineers, processors and stakeholders involved in design and development of various post harvest handling equipment and machinery.

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