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Research Article

# Effect of Moisture Content on the Mechanical Properties of Watermelon Seed Varieties

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## ABSTRACT

The effect of moisture content on the mechanical properties of agricultural material is essential during design and adjustment of machines used during harvest, cleaning, separation, handling and storage. This study determined some mechanical properties of Black and Brown colored of watermelon seed grown in Nigeria under different moisture contents range of 6.5 to 27.8% (d.b). The results for the mechanical properties obtained ranged from 15.68-29.54 N for compressive force; 1.95-3.40 mm for compressive extension; 0.13-0.33 N mm$^{-2}$ for compressive strength; and 0.17-1.93 kJ for deformation energy at vertical loading position while at horizontal loading position, results obtained ranged from 14.71-38.36 N for compressive force; 1.94-4.20 mm for compressive extension; 0.16-0.32 N mm$^{-2}$ for compressive strength; and 1.47-76.39 kJ for deformation energy for Black colored watermelon seed. The compressive force, compressive extension, compressive strength, deformation energy ranged from 14.18-36.49 N, 1.85-5.20 mm, 0.19 0.76 N mm$^{-2}$, 26.23-189.75 kJ at vertical loading position and 16.47-41.82 N, 1.68-11.08 mm, 0.34- 0.57 N mm$^{-2}$, 27.67-319.99 kJ at horizontal loading position for Brown colored watermelon seed. The correlation between the mechanical properties and moisture content was statistically significant at ($p \leq 0.05$) level. It is also economical to load Black colored in vertical loading position at 27.8% moisture content and Brown colored in vertical loading position at 27.8% moisture content to reduce energy demand when necessary to crack or compress the seed. This research has generated data that are efficiently enough to design and fabricate processing and storage structures for Black and Brown water melon seeds.

**RESEARCH ARTICLE**

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- Seeds varieties,
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## INTRODUCTION

The effect of moisture content on the mechanical characteristics of agricultural material is essential during design and adjustment of machines used during harvest, cleaning, separation, handling and storage. This knowledge of mechanical properties of biomaterials is a prerequisite in the processing of agricultural products into different food products. Many researchers (Ide *et al.*, 2019; Eze and Eze 2017; Aviara *et al.*, 2012; Bart- Plange *et al.*, 2012; Sarpong and Earnest 2016; Altuntas *et al.*, 2005; Baumler *et al.*, 2006; Manuwa and Muhammad 2001; Guner *et al.*, 2003; Vursavus and Ozguven, 2004; Kibar *et al.*, 2010; Koya *et al.*, 2002; Oni and Olaoye, 2001; Sadeghi *et al.*, 2005; Aydın and Özcan 2002; Maduako *et al.*, 2001; Obi *et al.*, 2015; Paksoy *et al.*, 2010; Baumler *et al.*, 2006; Zareiforoush *et al.*, 2010) reported on the mechanical properties of different agricultural products under different treatments. Their results showed that under different treatments, the biomaterial displays different behavior (Ide *et al.*, 2019). Data on these properties are useful for application in designing equipment for milling, handling, storage, transportation, food processing (Aviara *et al.*, 2013; Agu and Oluka, 2013; Singh and Goswani, 1998). The mechanical ruptures on grain and seed as a result of threshing and handling operations causes reduction in germination power and viability of seeds, increases the chances of insect and pest infestation and also affects the quality of the final product (Ide *et al.*, 2019). Therefore, there is a need to understand these damages and bring solutions to it (Ide *et al.*, 2019; Aviara *et al.*, 2013; Amoah *et al.*, 2016).

According to Seyed and Elnaz (2006), It is a drought-docile crop which belongs to the Cucurbitaceae family of flowering plants. It is known as Citrullus species and it is known as *Citrullus vulgaris* (Okey and Luky, 2015; Mustafa *et al.*, 2010). According to Mustafa *et al.* (2010), watermelon seed had average value of 31.9%, 4.4%, 57.1%, 8.2%, 6.2%, 130 mg, 456 mg, 7.5 mg for protein, carbohydrate, fat, fiber, ash, calcium, phosphorus and Iron, respectively. Watermelon seeds also contain the vital amino acids such as Leucine, Isoleucine, Tryptophan and Valine (Gladvin *et al.*, 2017). Its essential benefits attracted this research on the mechanical properties in order to develop a method to ensure the mass processing of the watermelon seeds to various food products and exploit the numerous benefits of this underutilized biomaterial. The objective of this research was to experimentally study mechanical properties of watermelon seed and correlation with moisture content. The properties studied were compressive strength, toughness, stiffness, compressive force, compressive extension, deformation energy and moisture content.

## MATERIALS and METHODS

### Source of sample

Watermelon seeds samples used in this experiment were obtained from a local farm in Enugu North Local Government Area of Enugu State, Nigeria at stable moisture content. The two varieties were local varieties dominant in the study area and they were identified by the color of the seeds. These samples were Black and Brown varieties as shown in the Figure 1 below.

Black-coloured Watermelon seeds Brown-coloured watermelon seeds

**Figure 1.** Watermelon seed samples used for the experiment.

**Sample Preparation**

The seeds were properly sorted and cleaned to select viable seeds. After that, the sample were wrapped with polythene bag and covered in plastic containers to avoid change in moisture contents. Then the samples were taken to the laboratory where the mechanical properties were carried out. The apparatus used include Mettler-Toledo Electric digital weighing balance with model number XP204 and 0.001 sensitive, for weighing the samples at intervals OEM Multi- Purpose Oven Dryer with model 0A12ES, drying the sample and 3345-INSTRON Universal Testing Machine (IUTM), of Blue Hill 3 software, and Dell computer system of windows 8 software, for force-deformation characteristics determination. The moisture content of the samples at which the experiments were conducted were varied using the method reported by (Ide *et al.*, 2019) see Equation 5.

**Determination of the Mechanical Properties**

Compression tests were determined the sample at five different moisture levels at two different loading orientations namely horizontal and vertical using INSTRON Universal Testing Machine (IUTM) Model RVA 4500 Newport Scientific Australia controlled by a computer system. The cross-head load of 5 kN $s^{-1}$ was used to compress the samples at speed of 5 mins. As the compression continues, the automated load deformation curve was plotted in relation to the behavior of each sample under compressive test. Fifty (50) randomly selected samples were tested at each loading orientation and at five different moisture contents. The force-deformations curves and its parameters were obtained. The sample were compressed at two different loading positions (horizontal and vertical loading). The samples were placed in the compressive jaws device ensuring that the center of the tool is aligned with the peak of the curvature of the watermelon seed. Force load was applied by clicking start test bottom on the computer system after zeroing the load and extension from the IUTM to avoid errors on the machine and in results. The IUTM compressed the sample until its cracks in the compressing arm of the testing load are noted. At the end of the compression test maximum at load, compressive extension at maximum load, Energy at maximum load and slope at maximum load were tabulated as reported by Ide *et al.*, 2019.

**Figure 2.** 3345-INSTRON Universal Testing Machine (IUTM), of Blue Hill 3 software, and Dell computer system of windows 8 software.

**Compressive force (N):** This is the load or force needed to cause crack on the sample at different moisture content. At this point other properties were determined. Compressive force values were generated in relation to the behavior of each sample under compressive test (Ide, *et al*., 2019).

**Compressive extension (mm):** This is the change in size or shape of a body in response to the applied force. This is known as deformation, which depends on many factors such as rate of applied force, loading position, moisture content and biomaterial composition. Compressive extension values were generated in relation to the behavior of each sample under compressive test (Ide *et al*., 2019).

**Energy at maximum load (J):** This is the maximum energy at maximum load required to crack the sample under compressive test. Energy at maximum values and energy at which the sample ruptured were generated in relation to the behavior of each sample under compressive test (Ide *et al*., 2019).

**Compressive strength (N mm$^{-1}$):** This measures the strength at which each sample under a compressive test will crack. Compressive strength was determined using Equation 1 as recommended by Eze and Eze (2017). It was calculated as the ratio of applied force to the area of the sample, it is denoted as δc.

$$\delta c = \frac{f_c}{A}\left(\frac{N}{mm^2}\right) \quad (1)$$

Where; $\delta c$ is the compressive strength (N mm$^{-2}$); $f_c$ is the maximum load at fracture ($N$); $A$ is the crosssectional area of the sample (mm$^2$).

**Stiffness (N mm$^{-2}$):** Stiffness is rigidity of a material under compression and the extent at which it resists deformation in response to applied load. The stiffness, St, of a material is measure of the resistance offered by an elastic material to deformation. It is given as the ratio of the stress to strain. It was determined using the Equation 2 reported by Ide *et al.*, (2019). ($\delta\,\varepsilon^{-1}$), it is given as

$$S_t = \frac{F}{\delta} \qquad (2)$$

Where $St$ is the stiffness (N mm$^{-2}$); $F$ is the force on the material; $\delta$ is the deformation on the material.

**Toughness (J m$^{-3}$):** This is define as the amount of energy per unit volume that a material under compression can absorb before rupture occurs. It is also defined as a material's resistance to fracture when stressed. It is approximated under the stress–strain curve using the Equation 3 reported by Ide *et al.*, (2019).

$$Toughness = \frac{Rupture\ Energ}{Volume\ of\ the\ material} \qquad (3)$$

**Deformation Energy (N mm$^{-1}$):** This is the total spent energy of a sample under a compressive test at which deformation occurs. It is determined using the Equation 4 reported by Ide *et al.*, (2019).

$$Deformation\ Enery = Rupture\ force\ \chi\ Deformation\ at\ rupture \qquad (4)$$

**Moisture content (MC) %:**

This is the quality of water contains in the sample. The experiment was carried out under the influence of three (3) different moisture contents 6.5, 10.5, 15.4, 18.6 and 27.8% under dry basis. The oven dry method of moisture content determination using a multi-purpose drying oven (OKH – HX – IA) drying oven was used to determine the moisture content (MC) of the samples. The weight of the wet sample and the weight of the dry sample were determined and moisture content is calculated using the Equation 5 reported by Ide *et al.*, (2019).

**Analysis of variance**

The results obtained were submitted to analysis of variance (ANOVA), with the means compared by Duncan's test at 5% of significance. All results were expressed as the mean value standard error (SE). Statistical analyses were performed using SPSS for Windows 8.0.

$$MC = \frac{W_w - W_D}{W_D} X\ 100\% \qquad (5)$$

Where; $MC$ is the moisture content (%); $W_w$ is the weight of wet sample (g); $W_D$ is the weight of dry sample (g).

## RESULTS and DISCUSSION

**Effect of moisture content the mechanical properties of watermelon seed**

Maximum load (N) The Table 1 presented the effect of moisture content on mechanical properties of water melon seeds and Figure 3-7 presented the force-deformation curve of mechanical properties water melon seed as effected by moisture content. It was observed that the maximum force required to crack the sample at horizontal loading position for black and brown watermelon sample ranged from 14.71 – 38.36 N and 16.47 – 41.82 respectively. Black and Brown colored samples had compressive forces at vertical loading position ranging from 1.95 to 3.40 and 1.85 – 5.20 N respectively for moisture content range of 6.5 – 27.8%. It was observed that, as the moisture content of both samples varied, the maximum force required to crack the sample at both horizontal and vertical loading position. The trend of the variation in moisture content and cracking force of the sample were found to be parabolic. It was observed that the sample required higher force at the horizontal loading position than vertical loading position and this could be attributed to structural lining of the sample was at vertical position. This findings gave an insight the maximum load required to crack both samples varies. Therefore it would be implored during the design and fabrication of processing machine for both samples.

**Compressive strength:** The results in Table 1, the compressive strength of Black and Brown coloured samples were 0.16 to 0.32 N $mm^{-2}$ and 0.34–0.57 N $mm^{-2}$ under horizontal loading position while 0.17–1.93 N $mm^{-2}$ and 26.23–189.75 N $mm^{-2}$ for vertical loading position respectively at moisture content range of 6.5–27.8% (db). It implies that the strength of watermelon seeds was found to be higher at vertical loading position than that of horizontal loading position and this may be attributed to the smaller contact that occurred during loading of the sample at vertical loading position. This position has higher resistance of the seed to be cracked. This finding reveals the required strength to process the seed samples and also generated data for strength properties of water melon in the design of handling machine.

**Compressive extension (mm):** The results in Table 1, the compressive extension of Black and Brown samples were 1.94–4.20 mm and 1.68–11.08 mm under horizontal loading position while 0.01–0.07 mm and 0.01–0.03 mm for vertical loading position at moisture content range of 6.5–27.8% (db) respectively. It was observed that as the moisture content varied the compressive extension. The moisture content variation displays parabolic trends for both samples. The compressive extension of a biomaterial under compressive test tells the extent a particular load/force causes deformation at different applied load. This research therefore, reveals that, the Black water melon deforms faster than Brown water melon and this should be considered during the design and fabrication of handling machine.

**Energy:** The maximum energy required to crack the samples were presented in Table 1. The energy ranged from 0.03 to 0.70 J and 0.02–0.14, 0.29 J for Black and Brown coloured samples respectively at the moisture content range of 6.5–27.8% for horizontal loading position.

However, these values ranged from 0.2 to 1.54 J and 0.33–1.22 J respectively at the moisture content range of 6.5–27.8% for vertical loading position. The energy was found to be varied with increase in moisture content at horizontal and vertical loading position but the energy variation with moisture content was not linear but parabolic in nature. It implies that lesser energy is required to crack the sample at vertical loading position than horizontal loading position for both samples across the moisture content tested.

**Toughness (J mm$^{-2}$)**: The toughness of the sample as shown in the Table 1 ranged from 0.60–14.81 J m$^{-2}$ and 0.81–6.97 J m$^{-2}$ at the horizontal loading position for Black and Brown colored sample respectively at 6.5–27.8% moisture range and 0.20–1.54 J m$^{-2}$ and 0.34–1.22 J m$^{-2}$ for Black colored samples and Brown coloured sample in the vertical loading position respectively at moisture range of 6.5–27.8%. It was observed that, as the moisture content increases the toughness of the material also varied at vertical loading position while the variation of moisture content with toughness at horizontal loading position displayed a parabolic trend. The toughness of the samples were found to be higher at horizontal loading position. It was observed that the Black coloured sample is tougher in terms of cracking at horizontal position than vertical loading position.

**Stiffness (N mm$^{-2}$)** Tthe stiffness of the samples at different loading position were presented in the Table 1. As seen the Table 1, at horizontal loading position was recorded as 3.56 to 15.66 N mm$^{-1}$ and 2.61–11.98 N mm$^{-1}$ for Black and Brown coloured samples respectively at 6.5–27.8% moisture content while at vertical loading, stiffness were found to range from 0.17–0.33 N mm$^{-1}$ and 0.26–0.76 N mm$^{-1}$ for Black and Brown coloured samples respectively at 6.5–27.8% moisture content range. This result is similar to what was reported by Eze and Eze (2017) on Mucuna Veracruz. The stiffness of the samples revealed would be helpful during the design and fabrication of its handling equipment.

**Deformation Energy (J)**: The values were presented in Table 1 at 6.5–27.8% moisture content range. The results obtained at horizontal loading position ranged from 0.76–76.39 kJ and 27.67 to 319.9 kJ for Black and Brown colored samples respectively at 6.5–27.8% moisture content respectively while at vertical loading position 0.17–1.93 kJ and 26.23–189.75 kJ for Black and Brown colored samples respectively at 6.5–27.8% moisture content respectively. It was observed that the increase in moisture content of the samples varied the total energy that will cause rupture on the samples. It was noticed that the deformation energy of Brown colored samples on both loading positions was higher than Black colored samples. It implies that, Brown colored sample is stronger at each of the loading positions It was observed that, at different moisture content level the energy required to rupture on the samples varies. It was noticed that the deformation energy of Brown colored sample on both loading positions was higher than Black colored sample. It implies that, Brown colored sample is stronger at each of the loading positions. But for both samples, deformation energy was found to be higher at every vertical loading position.

**Table.1.** Mechanical properties of black and brown colored watermelon seed at different moisture contents and loading orientations.

| **Properties** | | **Moisture content (%)** | | | | |
|---|---|---|---|---|---|---|
| **Black Colour Species** | **Loading position** | **27.8** | **18.6** | **15.4** | **10.5** | **6.5** |
| Compressive force (N) | Vertical | 15.68 | 17.13 | 24.54 | 27.61 | 29.54 |
| | Horizontal | 38.36 | 25.45 | 22.81 | 18.19 | 14.71 |
| Compressive extension (mm) | Vertical | 1.95 | 2.61 | 3.40 | 3.25 | 2.19 |
| | Horizontal | 2.45 | 1.94 | 3.92 | 4.20 | 4.13 |
| Energy at Maximum load (J) | Vertical | 0.02 | 0.01 | 0.07 | 0.07 | 0.02 |
| | Horizontal | 0.06 | 0.03 | 0.70 | 0.20 | 0.10 |
| Toughness (J m$^{-2}$) | Vertical | 0.39 | 0.20 | 1.48 | 1.54 | 0.47 |
| | Horizontal | 1.16 | 0.60 | 14.81 | 4.39 | 2.34 |
| Stiffness (N mm) | Vertical | 59.32 | 6.56 | 7.22 | 8.50 | 13.49 |
| | Horizontal | 15.66 | 13.19 | 5.82 | 4.33 | 3.56 |
| Compressive Strength (N mm$^{-2}$) | Vertical | 0.13 | 0.17 | 0.25 | 0.29 | 0.33 |
| | Horizontal | 0.32 | 0.25 | 0.23 | 0.19 | 0.16 |
| Deformation Energy (kJ) | Vertical | 0.31 | 0.17 | 1.72 | 1.93 | 0.59 |
| | Horizontal | 2.30 | 0.76 | 15.97 | 76.39 | 1.47 |
| **Brown Colour Specie** | | | | | | |
| Compressive force (N) | Vertical | 14.18 | 16.15 | 19.01 | 31.42 | 36.49 |
| | Horizontal | 41.82 | 35.43 | 28.88 | 24.68 | 16.47 |
| Compressive extension (mm) | Vertical | 1.85 | 2.93 | 2.15 | 2.34 | 5.20 |
| | Horizontal | 3.49 | 3.48 | 11.08 | 4.32 | 1.68 |
| Energy at Maximum load (J) | Vertical | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 |
| | Horizontal | 0.03 | 0.04 | 0.02 | 0.02 | 0.14 |
| Toughness (J m$^{-2}$) | Vertical | 0.34 | 0.37 | 1.22 | 0.44 | 0.50 |
| | Horizontal | 1.02 | 1.49 | 0.81 | 0.88 | 6.97 |
| Stiffness (N mm) | Vertical | 7.66 | 5.51 | 8.84 | 13.43 | 7.02 |
| | Horizontal | 11.98 | 10.18 | 2.61 | 5.71 | 9.80 |
| Compressive Strength (N mm$^{-2}$) | Vertical | 0.19 | 0.26 | 0.30 | 0.55 | 0.76 |
| | Horizontal | 0.56 | 0.57 | 0.46 | 0.43 | 0.34 |
| Deformation Energy (kJ) | Vertical | 26.23 | 47.32 | 40.87 | 73.52 | 189.75 |
| | Horizontal | 145.95 | 123.29 | 319.99 | 106.62 | |

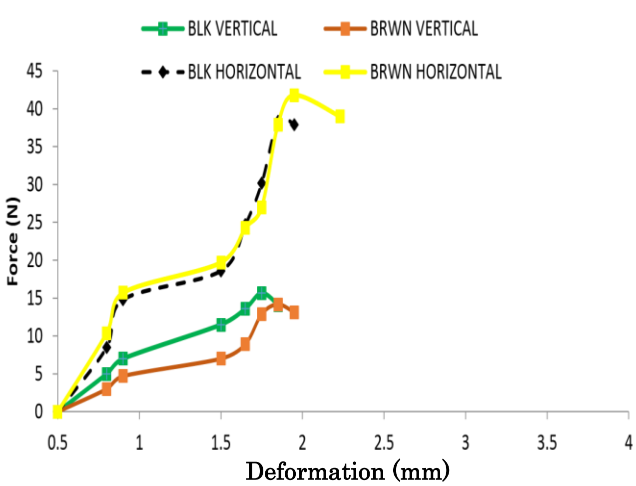


**Figure 3.** Force-Deformation curve of watermelon seed at 27.8% (d.b) under vertical and horizontal loading positions.

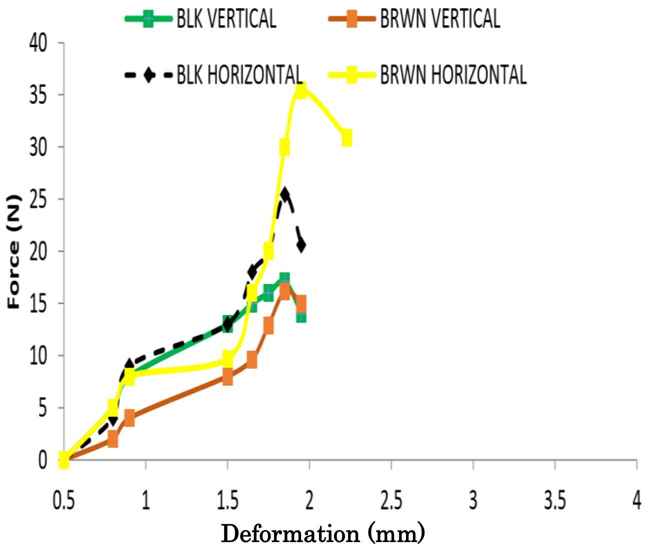


**Figure 4.** Force-Deformation curve of watermelon seed at 18.6% (d.b) under vertical and horizontal loading positions.

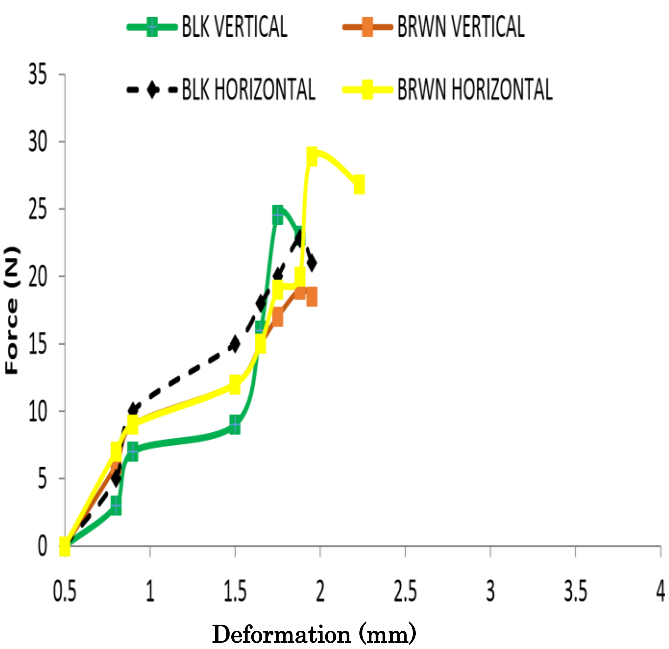


**Figure 5.** Force-Deformation curve of watermelon seed at 15.4% (d.b) under vertical and horizontal loading positions.

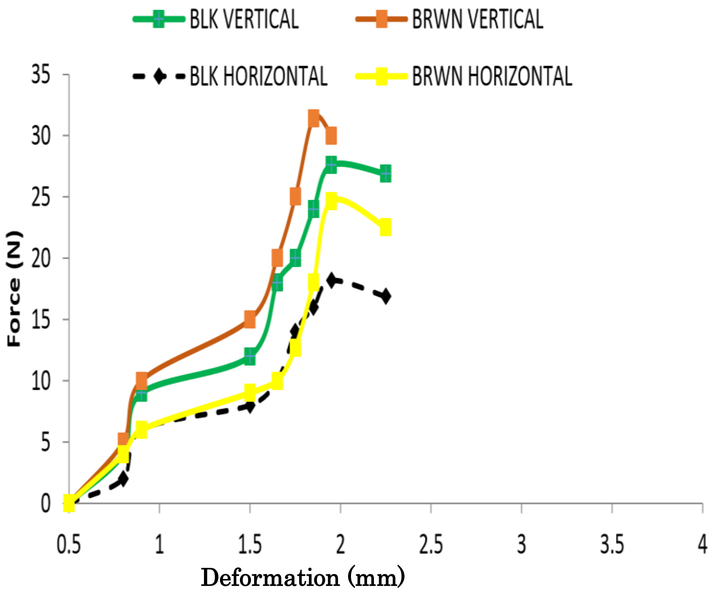


**Figure 6**. Force-Deformation curve of watermelon seed at 10.5% (d.b) under vertical and horizontal loading positions.

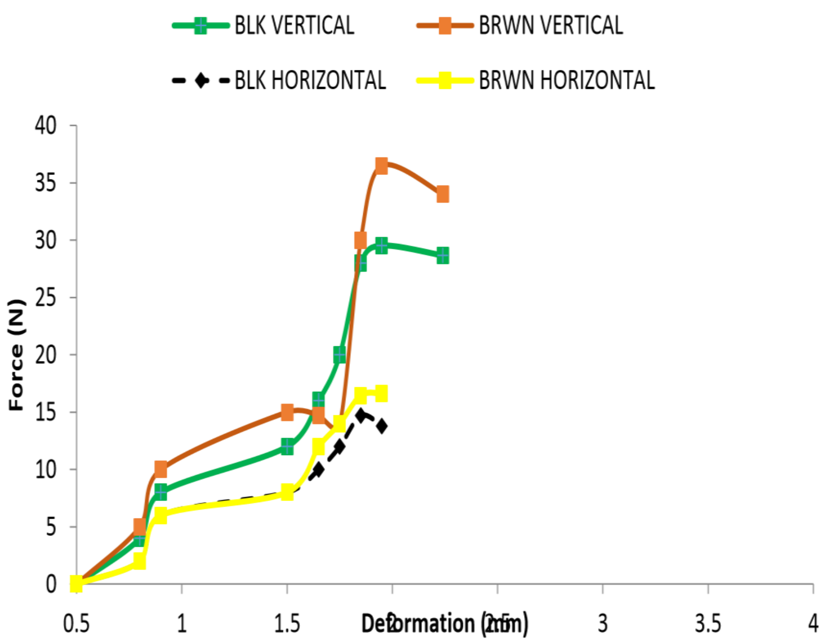


**Figure 7.** Force-Deformation curve of watermelon seed at 6.5% (d.b) under vertical and horizontal loading positions.

The effect of loading position, variety and moisture content on the force deformation characteristics were presented in Tables 2. It can be observed that they exhibited varying relationships with moisture content and loading positions. The $R^2$ values were found to range from 0.848-0.978. It was also observed that the relationship between species, moisture content and the vertical loading position was mainly quadratic in nature with the exception of seed samples at 15.4% (db). Here they exhibited linear (black) and logarithmic (brown) relationships. Similarly for moisture contents 10.5% db and lower the relationship between seed samples and loading position (horizontal) were also quadratic. However, as moisture content increased black seed samples exhibited linear relationship at horizontal loading while brown maintained its quadratic relationship. It can be inferred therefore that the force deformation characteristics of the samples tested showed that loading position, variety and moisture content had a significant effect on the mechanical properties.

**Table 2.** Relationships between mechanical properties of black and brown colored watermelon seeds at different moisture contents.

| Sample | Effect of moisture content on force-deformation curves of watermelon seeds at 27.8% (db) | | | |
|---|---|---|---|---|
| | Horizontal | | Vertical | |
| Black | $F = 24.04\, d_f - 11.12$ | $R^2 = 0.921$ | $F = -4.833\, d_f^2 + 22.07\, d_f - 9.579$ | $R^2 = 0.978$ |
| Brown | $F = -3.891\, d_f^2 + 32.08\, d_f - 13.68$ | $R^2 = 0.886$ | $F = 2.438\, d_f^2 + 3.083\, d_f - 1.399$ | $R^2 = 0.933$ |
| | Effect of moisture content on force-deformation curves of watermelon seeds at 18.6 % (db) | | | |
| | Horizontal | | Vertical | |
| Black | $F = 15.55\, d_f - 7.442$ | $R^2 = 0.931$ | $F = -7.542\, d_f^2 + 29.31\, d_f - 12.93$ | $R^2 = 0.97$ |
| Brown | $F = 0.203\, d_f^2 + 17.60\, d_f - 9.414$ | $R^2 = 0.817$ | $F = 4.798\, d_f^2 - 1.200\, d_f - 0.081$ | $R^2 = 0.962$ |
| | Effect of moisture content on force-deformation curves of watermelon Seeds at 15.4% (db) | | | |
| | Horizontal | | Vertical | |
| Black | $F = -3.124\, d_f^2 + 22.40\, d_f - 9.966$ | $R^2 = 0.972$ | $F = 16.51\, d_f - 9.400$ | $R^2 = 0.863$ |
| Brown | $F = 14.01\, d_f - 5.530$ | $R^2 = 0.884$ | $F = 13.22\ln(d_f) + 9.182$ | $R^2 = 0.964$ |
| | Effect of moisture content on force-deformation curves of watermelon seeds at 10.5 % (db) | | | |
| | Horizontal | | Vertical | |
| Black | $F = -1.868\, d_f^2 + 15.22\, d_f - 7.700$ | $R^2 = 0.897$ | $F = -2.367\, d_f^2 + 21.99\, d_f - 10.86$ | $R^2 = 0.925$ |
| Brown | $F = 1.123\, d_f^2 + 9.095\, d_f - 4.483$ | $R^2 = 0.848$ | $F = 8.005\, d_f^2 + 0.535\, d_f - 0.648$ | $R^2 = 0.952$ |
| | Effect of moisture content on force-deformation curves of watermelon seeds at 6.5 % (db) | | | |
| | Horizontal | | Vertical | |
| Black | $F = 1.379 d_f^2 + 6.057 d_f - 2.867$ | $R^2 = 0.942$ | $F = -1.317\, d_f^2 + 20.38\, d_f - 10.62$ | $R^2 = 0.891$ |
| Brown | $F = 3.803 d_f^2 + 1.877 d_f - 1.238$ | $R^2 = 0.953$ | $F = 2.069\, d_f^2 + 12.49\, d_f - 6.127$ | $R^2 = 0.803$ |

## CONCLUSION

It was concluded that the data generated from mechanical properties of Black colored watermelon seed cannot be used in designing of food processing, handling and storage systems for Brown coloured watermelon seed as mechanical properties of both species tested varied with moisture content. This research work have solved a big problem as it revealed the variations existed between Black and Brown water melon seeds. It also generated data which aids the design and fabrication of handling equipment. The results of the force-performance properties of the Watermelon seed were observed to be moisture content dependent (6.5-27.8% db). The correlation that existed between moisture content and the force-deformation properties was statistically significant at ($p<0.05$) level. It is economical to crack the Black and Brown samples at vertical loading position and at 27.85% moisture content in order to reduce energy and strength demand when necessary to crack and compress the samples properly.

## DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest.

## CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declare the contributions to the manuscript such as the sections
**Paul Chukwuka EZE** decleared methodology, conceptualization and review.
**Chikaodili Nkechi EZE** decleared validation and visualization.
**Patrick Ejike IDE** decleared investigation, formal analysis, data curation, writing, original draft and editing.

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