Storage conditions effect on physic-mechanical properties of Nandini cucumber

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***Abstract*— The aim of this research was the determination of effects of storage duration and conditions on the physical and mechanical properties of cucumber fruit (Nandini cultivar) during shelf life. The three regions of the fruit were separately investigated during a 9-day storage period under two conditions (ambient and refrigerated).The results indicated that storage condition, duration and fruit region had significant effect (P≤0.05) on the failure strength, compressive strength, compressive energy, firmness, toughness, and Young modulus of the fruit. Mechanical properties of cucumber fruits stored under ambient condition decreased rapidly than those stored under refrigerated condition. Failure strength, compressive strength, compressive energy and Young modulus of fruits stored at ambient condition declined by 53.86, 54.01, 65.35, 47.92 % respectively as against 33.35, 30.32, 40.35 and 37.81 % for those stored under refrigerated condition. All investigated physical parameters decreased significantly (P≤0.05) during storage, having lost almost 14 % of their mass, under ambient condition as against 4.8 % mass lost under refrigerated condition.**

***Index Terms*— Nandini, cucumber, physical properties, mechanical properties, storage duration, storage condition.**

I. INTRODUCTION

Cucumber (*Cucumis sativus*) is a member of Cucurbitaceae family that widely cultivated. It is consumed as fresh fruit, slicing, salad and pickling during all seasons. After tomato, onion and cabbage, cucumber had the fourth grade of the area under cultivation among vegetables. China, Iran, Turkey and United States produce about 66% of world cucumber production [1] .Since biological materials are commonly anisotropic, their mechanical properties differ according to the orientation and position in which they are tested. Several factors affect the mechanical properties of agricultural products. The factors include drying temperature, water content, kind of force and grain area the kind of force is applied [2], [3]. Physical properties are important factors in solving problems associated with design of specific machines or analysis of the behavior of the product during agricultural processes such as planting, harvesting, handling, threshing, sorting and drying [4].

Many researchers in literature have investigated how physical and mechanical properties of fruits and vegetables are relevant in the design of sorting, grading, bulk handling, storage and processing systems. Reference [5] investigated some mechanical and nutritional properties of two Iranian apple varieties. Some physico-mechanical properties of pear cultivars were studied by [6], and the result gives the bulk density, rupture force and fruit hardness as 365.84 - 543.12 kgm^{-3}; 23.04 - 39.59 N and 9.87 - 13.74 N/mm for *Santa Maria* and *Deveci* cultivars respectively. According to [7], cutting energy for sweet orange stored in ambient and refrigerated conditions are 3.79 and 4.83 J respectively. Reference [8] examined *viola* cultivar of cucumber, and reports about 38 % decrement in the failure stress of the cucumber fruit during 9 days storage, [9] worked on kiwifruits, and recorded decline in the fruit firmness from 32.6N to 13.4N under ambient and 37.2 N to18.2 N under refrigerated condition, during 16 days storage. Reference [10] investigated some physical properties cucumber and reported the mass of *Green Gold*, *Dharwad* and *Super Dominus* cultivars of cucumber fruits to be 177.7 g, 144.97 g, and 73.15 g respectively.

But the above research result data including the few ones on cucumber (*viola*, *Green Gold*, *Dharwad* and *Super Dominus*) cannot be directly used to design harvesting, handling and processing systems for Nigeria grown *Nandini* cucumber due to Genotype and Environment interaction (GxE). Environment interaction is the change in a cultivar's relative performance over environment, resulting from differential response of cultivar to various edaphic, climatic and biotic factors, [11. According to [12], differences in rainfall pattern and soil properties at different locations were reported to have contributed to variation in tuber yield of cassava. This means the same cultivar of cucumbers planted at different regions (Countries) responded differently in terms of mechanical, chemical and nutritional properties as a result of differences in edaphic, climatic and bioctic factors.

Despite all of these research accounts, and increase in cucumber production in Nigeria, there is still dearth of information on the phyisco-mechanical properties of cucumber (*Nandini)* fruits, which are helpful in modifying and designing handling and processing systems. Therefore, the objectives of this study were to investigate the effect of storage conditions and fruit loading regions (stalk-end, middle and blossom-end) on physico-mechanical properties such as mass lost, shrinkage, firmness, failure strength, compressive strength, compressive energy, toughness, and Young modulus on Nigeria grown *Nandini* cucumber.

II. MATERIAL AND METHODS

A. Material Collection

The cucumber cultivar (*Nandini)* used for this research was sourced from the research farm of National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State, and no fertilizer was applied during the growing period. Three hundred (300) healthy cucumber fruit samples, harvested ten days after anthesis, were selected randomly on the basis of uniformity, washed with the 100 part per million

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concentration of chlorine and dried to eliminate microbial contaminations to prevent infections during storage. The cleaned cucumber fruits were divided into two groups; one was kept in ambient temperature of 29ºC ± 5˚C and 86 -91% humidity and stored for a period of 9 days, while the other portion was stored inside a refrigerator at (5^{o}C and 65 % RH). For each experiment, refrigerated sample was left for 2 hours to equilibrate with room temperature [8], 13]. The physical and mechanical properties of the fruits were determined at the three-days intervals (0, 3, 6 and 9 days) with respect to the fruit's region (stalk, middle and blossom) Figure 1.

B. Physical Properties Determination

Size Determination

For determining size of the cucumber during storage, forty fruits in each experimental lot were numbered and kept in ambient and refrigerated conditions. The major diameter of the cucumber fruit, i.e. middle diameter (D) and length (L) were measured using digital venier caliper, with accuracy of 0.01mm. Equations 1, 2, 3, 4 and 5 were used for computation of geometric mean [14], surface area and sphericity of the fruit [2], shrinkage in length and diameter respectively. The shrinkage in size was expressed as percentage of original fresh size of the fruit.

$$D_g = \sqrt[3]{LD^2} \quad (1)$$

$$S_A = \pi D_g^2 \quad (2)$$

$$\Phi = \frac{\sqrt[3]{LD^2}}{L} \quad (3)$$

$$S_D\,\% = \frac{D_0 - D_i}{D_0} \text{ X } 100 \quad (4)$$

$$S_L\,\% = \frac{L_0 - L_i}{L_0} \text{ X } 100 \quad (5)$$

Where,
L is length (mm)
D is diameter (mm)
D_g is geometric mean diameter (mm)
ϕ is sphericity (%)
S_A is surface area (mm^2)
S_D is the shrinkage in diameter,
S_L is the shrinkage in length,
D_o is the diameter of the fruit on the first day of storage,
D_i is the Diameter of the fruit in the tested day,
L_o is the length of the fruit on the first day of storage,
L_i is the length of the fruit in the tested day.

The shrinkage in size (length and diameter) was expressed as percentage of original fresh size of the tuber (Equations 4 and 5).

Mass Determination

For determining mass, unit mass of the fruit was determined by direct measurement using an electronic digital balance with accuracy of 0.01g.The loss in mass was expressed as percentage of original fresh weight of the fruit. The cumulative losses in mass were calculated as percent of initial mass lost, using equation 6.

$$M_L\% = \frac{M_0 - M_i}{M_0} X\ 100 \quad (6)$$

Where M_L is the mass lost, M_o is the weight on the first day of storage and M_i is the weight in the tested day [15].

Determination of the Mechanical Properties

The quasi-static compression tests on *Nandini* fruits at different storage durations and conditions were performed with a Universal Testing Machine (Testometric model, series 500-532) equipped with a 50 N compression load cell and integrator, with measurement accuracy of 0.001 N. A transverse slices of 20 mm thickness cut from each region of the fruit sample was placed in the machine under the flat compression tool (Plate 1), ensuring that the centre of the tool was in alignment with the cut sample, and compressed at the speed rate of 25 mm/min [6]. Each test was carried out on at 4 replications. The range of storage periods were selected based on literature review and preliminary laboratory tests. As the compression progresses, a load-deformation curve was plotted automatically in relation to the response of each fruit to compression, and the following parameters interpreted by the testometric software.

- Failure strength
- Compressive strength
- Compressive energy
- Firmness
- Young modulus
- Toughness

The American Society of Agricultural Engineers (ASAE, St. Joseph, MI) has established a standard method for the compression testing of food materials of convex shape (ASAE Standard S368.2), [16]. According to [16], bioyield point is related to a failure in the microstructure of the material associated with an initial disruption of cellular structure; and the rupture point of the material, correlates to the macroscopic failure (breaking point) in the sample, the failure strength was taken as the stress at which the sample failed in its internal cellular structure.

Plate 1: Cucumber fruit undergoing quasi compressive test using Universal Testing Machine (Testometricmodel, series 500-532)

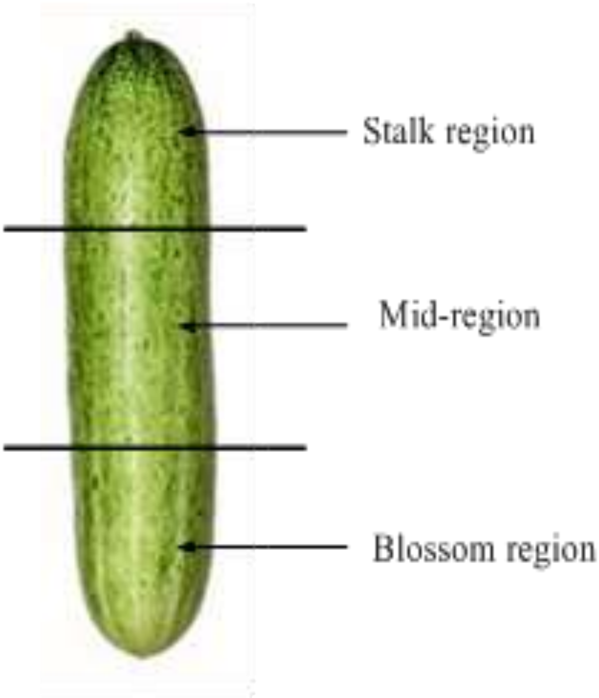

Figure 1: A cucumber fruit showing the three regions.

As the compression progresses, a force-deformation curve was plotted automatically by the machine in relation to the response of the fruit. The results, statistical data and force-deformation curves obtained at each loading were analyzed for bioyield, compressive and rupture points. According to [16], bioyield point is related to a failure in the microstructure of the material associated with an initial disruption of cellular structure; and the rupture point of the material, correlates to the macroscopic failure (breaking point) in the sample, the failure strength was taken as the stress at which the sample failed in its internal cellular structure. The compressive force is the maximum force the sample can withstands, and it is taken as the force at peak of the sample. The toughness is the work (energy) required to cause rupture in a product. It is calculated as the maximum energy divided by the sample volume. The compressive strength was the maximum stress which the sample was able to withstand, before it got completely ruptured. Young modulus was taken as the ratio of the stress to the strain up to the failure point [2], [16], and [17]. The test was replicated six times at each experimental day and the mean of each property under longitudinal loading orientations was obtained.

C Experimental Design and Statistical Analysis

A 4 x 3 x 2 factorial experiment in a Completely Randomized Design (CRD) was employed to study the effects of storage duration, conditions and loading positions on selected physical and mechanical properties of cucumber. Three loading positions, four storage duration and two storage conditions were the considered experimental factors which were replicated four times. The data obtained were subjected to statistical analysis using the using the Statistical Package for Social Statistics (SPSS version 17) and Duncan's Multiple Range Test (DMRT) was used to compare the mean at 95 % confidence level (P< 0.05).

III. RESULTS AND DISCUSSION

A. Physical Properties

Table 1 gives the results of analysis of variance (ANOVA) for the storage duration and storage conditions on the mass lost and size (length and diameter) shrinkage of *Nandini* cultivar of cucumber fruit. As depicted from Table 1, the physical properties were significantly (P<0.05) by storage duration, but storage condition only affects the length and diameter significantly (P<0.05).

Table 1: Analysis of variance of effect of measured physical properties of cucumber fruits (*Nandini*) cultivar with storage conditions and duration

Source	df	Mass loss	Length	Diameter
D	3	0.02095*	7.411E-06*	1.527E-14*
C	1	0.6955^{ns}	0.07368^{ns}	4.542E-05*
D x C	3	0.4311^{ns}	0.1851^{ns}	7.267E-05*

* =Significant on the level of 5%, ns= non-significant
D = Storage duration
C = Storage condition

Cucumber Fruits Mass Loss

Storage duration significantly (P<0.05) affects the mass of the fruits, but storage condition does not significantly (P<0.05) affects it (Table 1). Figure 2 clearly shows that the cumulative mass decreased monotonically with the increasing of storage time in both storage conditions. The higher mass loss (14 %) was observed in cucumber fruits stored at ambient condition followed by the refrigerated fruits (4.8 %). Loss of weight in fresh fruits and vegetables is mainly due to the loss of water caused by transpiration and respiration processes [18].

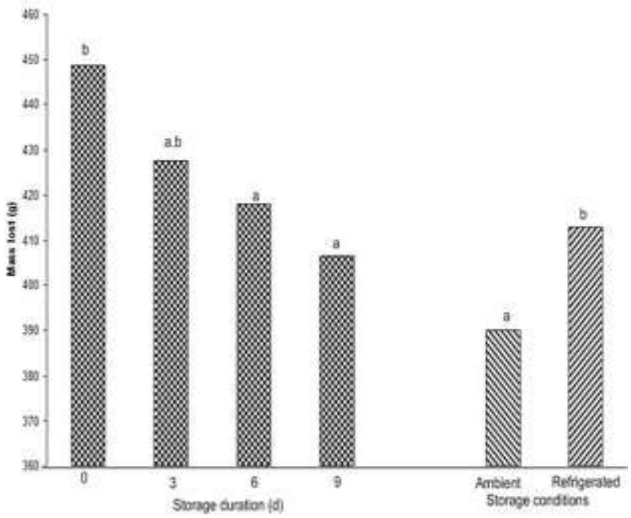

Figure 2: The statistical plot of results of cumulative mass loss during storage under the two storage conditions for nine storage days

Therefore, high temperature at ambient conditions could be responsible for the observed higher mass loss as such conditions induce high respiration and transpiration in cucumber fruit [19]. In addition, [20] found that storage temperature is the main reason of weight loss for pomegranate fruits. This result clearly suggests the importance of low temperature and relative humidity for cucumber fruit storage and the findings is in accordance with earlier report of [9] in which kiwifruit lost about 14% of weight under ambient condition as against 4.5% under cold storage condition, during 16 days storage. Similar trends for *Bhagwa* and *Ruby* pomegranate fruit and kiwifruits by were reported by [21] and [22].

Fruit Size Shrinkage

From the ANOVA table (Table 1), storage condition and storage duration had significant (P<0.05) effect on the size (length and diameter) of the fruits, while storage condition only had significant (P<0.05) effect on the diameter of the fruits, as there was no significant decrease (p≥0.05) in the length of the cucumber fruits. Figures 3 shows the effect of storage condition on the size of cucumber fruits stored under both conditions, the cucumber fruits size shrunk (decreased) monotonically with increase in storage duration. Decrement of 26.15 % was observed in the diameter of fruits stored under ambient condition as against (8.43 %) recorded for fruits stored under refrigerated condition. It was observed that after six days of storage, storage duration does no longer significantly influenced (p≥0.05) the diameter of the cucumber fruits till the end of the storage period (Figure 3). Decrease in diameter of fruits is usually caused by water loss which is as a result of transpiration and respiration resulting in the shriveling of fruits [23]. Also it was observed that shrinkage in the length of the fruits stored under ambient condition was higher (14.17 %), as compared to (8.12 %) for those stored under refrigerated condition. The result depicts strong relationship between shrinkage and storage days of cucumber fruits under the two storage conditions. This observation agrees with the findings of [24] where the Surface area of the star apple declined by 37.85 % during 25 days storage period. This result is similar to the trends reported by [7] and [8], on oranges and kiwifruits, where the fruit sizes decline consistently during storage. Fruit size is one of the major factors in the design and selection of equipment for primary processing such as separation [25].

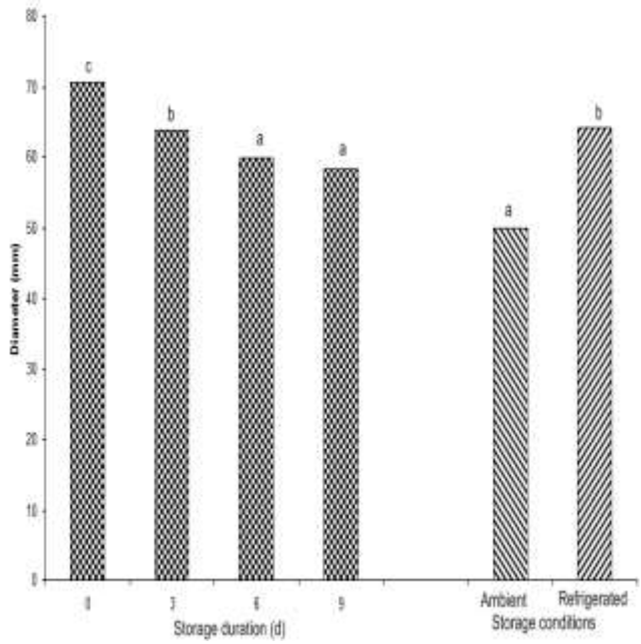

Figure 3: The statistical plot of results shrinkage in diameter size during storage under the two storage conditions for nine storage days

B. *Mechanical Properties*

Table 2 shows results of analysis of variance (ANOVA) of the effect of storage duration, condition, cucumber loading region, and their interactions on the selected six mechanical properties.

Table 2: Analysis of variance of effect of measured mechanical properties of cucumber fruits (*Nandini*) cultivar with storage conditions and duration

Source of variation	df	Failure strength	Compressive strength	Firmness	Compressive Energy	Toughness	Young Modulus
S	3	1.37E-10*	7.85E-13*	1.14E-12*	6.27E-16*	5.04E-16*	1.05E-10*
C	1	1.75E-05*	2.29E-06*	1.37E-06*	3.22E-06*	5.34E-06*	0.01533*
R	2	1.79E-09*	1.18E-10*	5.92E-11*	6.78E-10*	4.85E-10*	6.14E-06*
S x C	3	0.73485^{ns}	0.99688 ^{ns}	0.98173 ^{ns}	0.82078 ^{ns}	0.93112 ^{ns}	0.92595 ^{ns}
S x R	6	0.39919 ^{ns}	0.52805 ^{ns}	0.61481 ^{ns}	0.87764 ^{ns}	0.76495 ^{ns}	0.75832 ^{ns}
C x R	2	0.03818*	0.03765*	0.03788*	0.02317*	0.01648*	0.54132 ^{ns}
S x C x R	6	0.84321 ^{ns}	0.87837 ^{ns}	0.79521 ^{ns}	0.99908 ^{ns}	0.99968 ^{ns}	0.97888 ^{ns}

* =Significant on the level of 5%, ns= non significant, Storage Duration (S), Storage Condition (C), Cucumber Region (R)

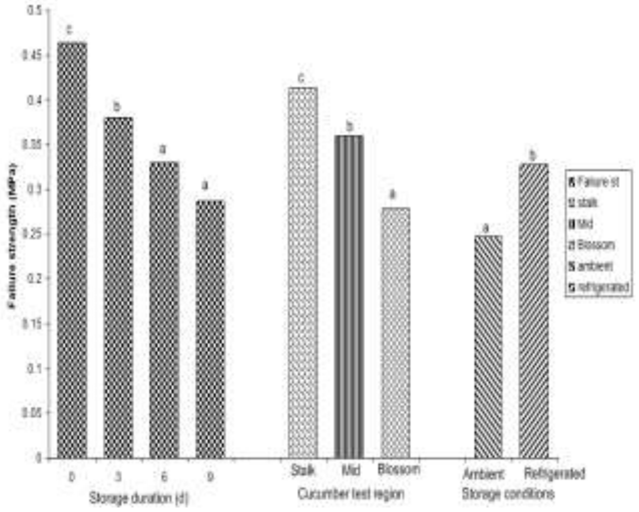

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Figure 4: Effects of storage duration, storage conditions and fruit test position on failure strength of *Nandini* cucumber fruit

Failure Strength

The analysis of variance (Table 2) shows that storage duration and storage condition significantly influence the failure strength at 95 % confidence level. Likewise the fruit region effect on the failure strength is significantly different at 95 % confidence level. The interaction between storage duration, storage condition and fruit region did not significantly influence the failure strength at 95 5 confidence level.

It was observed that the failure strength of the fruit decreased with increase in storage duration, under both storage conditions, across the fruit's three regions as shown in Figure 4, fruit failure strength declined significantly ($P \leq 0.05$) from harvest to day 6 of storage, in both storage conditions, however, further increase in storage time from 6 d to 9 d had no significantly effect on the fruit's failure strength. From the records, it was realized that fruits kept at ambient condition recorded higher firmness lost (54.0 %), than fruits stored under refrigerated condition (30.66 %) at the ninth day of storage. Also, there was significant ($P \leq 0.05$) difference between the fruit regions, as the firmness values decreased from the stalk end across the mid region and the blossom region having the least value.

This finding is in accordance with earlier work of [8] that recorded about 38 % decrease in the failure stress of *Viola* cultivar of cucumber fruits, during 9 days storage period. In addition [9] reported that the failure strength of kiwifruits decreased significantly by 59.2 % for fruits stored under ambient condition and 41.38 % for fruits stored under refrigerated condition for 16 days. The reduction in failure strength demonstrates increased deformability of fruit to compression test as storage period progresses. Similar observations of declined in the failure strength were reported by [7], [24], [26] and [27] for oranges, star apple, pomegranate fruit, and apples and pears respectively.

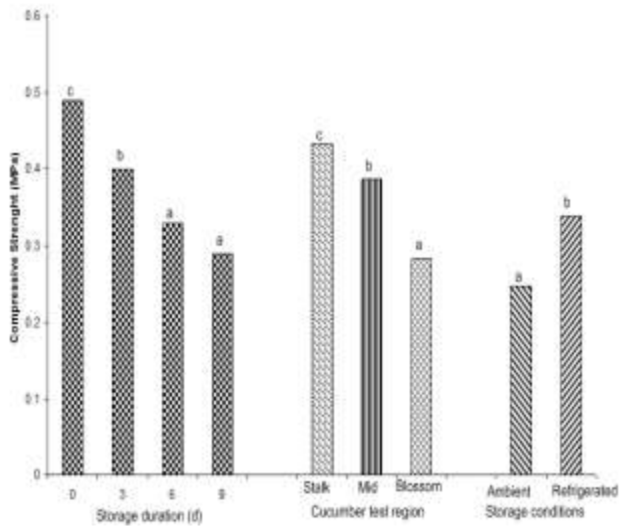

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Figure 5: Effects of storage duration, storage conditions and fruit test position on compressive strength of *Nandini* cucumber fruit

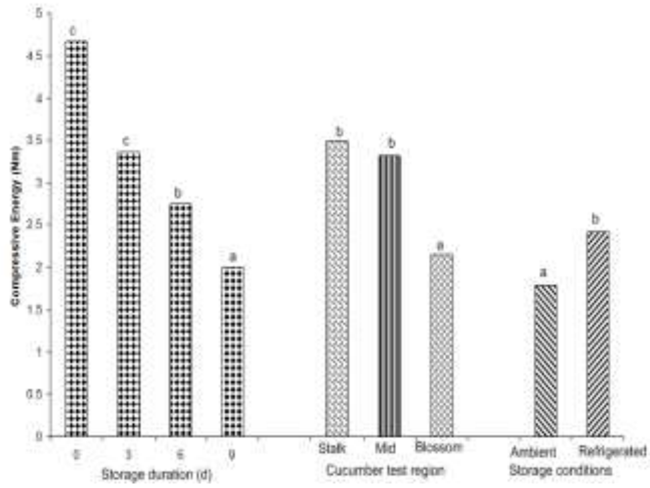

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Figure 6: Effects of storage duration, storage conditions and fruit test position on compressive energy of *Nandini* cucumber fruit.

Compressive Strength

From the ANOVA table (Table 2), storage condition, storage duration and fruit region had significant ($P<0.05$) effect on the compressive strength of the fruits, while the interaction of storage duration and storage condition did not significantly ($P<0.05$) affect the compressive strength of the fruits. The compressive strength of the fruit was significantly related to the fruit's test position

Variation of compressive strength during the storage is shown in Figure 5. It is obvious that the strength decreases over the time of storage, under both storage conditions, in the cucumber's three regions. The compressive strength was higher at the stalk region of the fruit and lowest at the blossom end region (Figure 5). It is also clear from figure 5 that with increasing storage duration from 1 d to 9 d the value of compressive strength decreased significantly ($P<0.05$) by 50.73 % for fruits stored under ambient condition, and 32.70

% for fruits stored under refrigerated condition. Moreover, it can be depicted from figure 4 that samples kept in refrigerated conditions tend to retain their compressive strength than those kept in ambient conditions. A similar result was reported by [24], where the compressive strength of star apples declined significantly by 40 % during 25 storage days. This result shows that *Nandini* cucumber fruits were able to withstand more force at harvest and then lose some strength during storage. This can be attributed that as storage progresses, cucumber fruits become softer and tended to crush easily under load. Reference [27] concluded that the tissue strength of apple and pear decreased during storage duration due to decrease in the thickness of cell wall. The compressive strength behavior observed in this study was similar to that found by [28] for canola pods and [29] for apples.

Compressive Energy

As it can be seen in ANOVA table (Table 2), storage condition, storage duration and fruit region had significantly (P<0.05) influenced the compressive energy of the fruits, while the interaction of storage duration and storage condition did not significantly (P<0.05) influenced the compressive energy of the fruits.

The compressive energy of the cucumber fruits decreased during storage, in both storage conditions (Figure 6). It was realized that, fruits kept at ambient condition recorded higher compressive energy lost (66.05 %) than those fruits stored under refrigerated condition (48.02 %), at the same storage duration. It was also realized that the compressive energy of cucumber fruit was lowest at the blossom region and highest at the stalk region, which implies cucumber fruit absorbed more energy at the stalk region. Therefore, it is important to take into consideration, the fruit's regions of loading while designing crushing and compression machines This result also supported the findings relating to mechanical properties determined by [8] for *Viola* cultivar of cucumber fruits, [24] for star apple, and [27] for apples and pears.

Toughness

The analysis of variances for the storage duration, storage condition, fruit test region, and the interactions between them is shown in Table 2. From the ANOVA table (Table 2), storage condition, storage duration and fruit region had significant (P<0.05) effect on the toughness of the fruits, while the interaction of storage duration and storage condition did not significantly (P<0.05) affect the toughness of the fruits. The *Nandini* cucumber toughness decreased significantly (P<0.05) with storage duration in all the three tested regions in both storage conditions, indicating that the amount of energy to compress the fruit reduces with increasing storage duration. The toughness at the stem end region was significantly (P<0.05) greater than the other two regions, as depicted from Figure 7, the *Nandini* cucumber fruit toughness had the maximum values at the stem end region and the minimum values at the blossom end region. Storage condition also has significant effect (P<0.05) on the toughness of the fruits, as fruits stored under condition declined 65.51 %, as against 48.17 % recorded for those fruits stored under refrigerated condition (Figure 6). Reference [7] reports in their research work that by increasing storage duration, the force and energy needed to cut the orange fruit decreased.

Also as shown in Figure 7, there was no significant difference between the toughness at the stalk end and mid region of the cucumber fruit region, however, significant difference (P<0.05) exist between the blossom end and the other two regions of the fruit. This finding is in accordance with that of [26], who reported 53.56 % decreased in the toughness of pomegranate fruits stored for 5 months in cold storage, and [29] who recorded 66.57 % drop in the toughness of *Golden Delicious* cultivar of apples six months during storage period at ambient condition. The decline in the fruit toughness during storage may be as a result of the fruit's texture becoming softer with increasing storage duration.

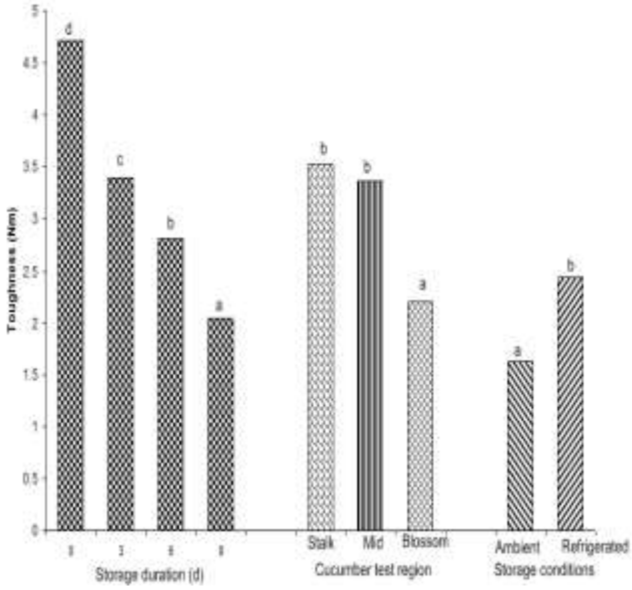

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Figure 7: Effects of storage duration, storage conditions and fruit test position on Toughness of *Nandini* cucumber fruit

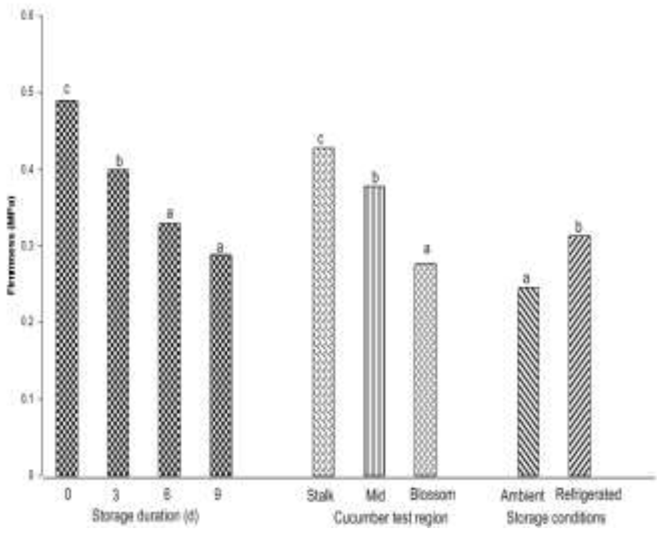

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Figure 8: Effects of storage duration, storage conditions and fruit test position on Firmness of *Nandini* cucumber fruit

Firmness

From the study, fruit region, storage duration and storage conditions significantly influenced ($P<0.05$) the firmness of the *Nandini* cucumber fruits (Table 2). As shown in Figure 8, fruit firmness declined significantly ($P \leq 0.05$) from harvest to day 6 of storage, in both storage conditions. However, further increase in storage time from 6 d to 9 d had no significantly effect on the fruit firmness. It was realized that fruits kept at ambient condition recorded higher firmness lost (54.0 %), than fruits stored under refrigerated condition (30.66 %) at the ninth day of storage. Also, there was significant ($P \leq 0.05$) difference between the fruit regions, as the firmness values decreased from the stalk end across the mid region and the blossom region having the least value. Pervious researchers, [8], [30] and [31] reported that the most firmed part of cucumber fruit was near the stalk (stem) end region; these previous results validate our research results.

The declined in the fruit firmness as storage duration increases may be due to the loss in cell wall integrity of the cucumber fruits, and increase in evaporation, transpiration and metabolic activity of fruits kept in room conditions. According to [32] and [33] declined in fruit firmness resulted in softer texture due to the cellular water loss and disintegration of the cell wall structure composition. This trend of a consistent decrease in *Nandini* fruit firmness with increases in storage duration is in agreement with earlier reports of [24] who reported declined of 40 % in firmness of star apple after 25 days of storage; [9] reported kiwifruit firmness declined by 59 % for ambient and 51 % at cold conditions after 16 days of storage; [8] recorded about 33 % decrease in the firmness of *Viola* cultivar of cucumber fruits, during 9 days storage period; and [34] [35] for cantaloupe fruit, and for two Iranian pomegranate cultivars '*Hondos-e-Yalabad'* and '*Malas-e-Saveh'*.

Young's modulus

The ANOVA results (Table 2), indicated that storage duration, storage conditions, and fruit region significantly influenced ($P<0.05$) *Nandini* Young modulus. The Young modulus decreased significantly ($P<0.05$) with increasing storage duration from harvest day to day 9 (Figure 9). From Figure 9, the Young modulus of *Nandini* cucumber decreased consistently during storage in both conditions, higher under the ambient storage condition than the refrigerated condition. It decreased about 47.92 % for fruits stored under ambient condition, and 37.81 % for fruits stored under ambient condition, signifying that fruits under refrigerated condition tend to retain their strength than those stored under ambient condition. This confirms cucumber fruit can withstand more energy and strength immediately at harvest which deteriorates during storage.

This finding is in accordance with that of [8], the Young modulus of *Viola* cucumber decreases by 39 % during 9 days storage period. Similar trends were also observed by [29] where *Granny Smith* apples stored for six months of storage had 10% reduction on the Young modulus; and [26] where Young modulus of pomegranate fruits decreased by 32.28 % after 5 months in cold storage. According [36] ripeness will reduce the mechanical parameters over time, and it was observed that the cucumber ripened during storage. In addition, [29] said that the modulus of elasticity, failure stress and failure energy of apples decreased with increasing storage duration.

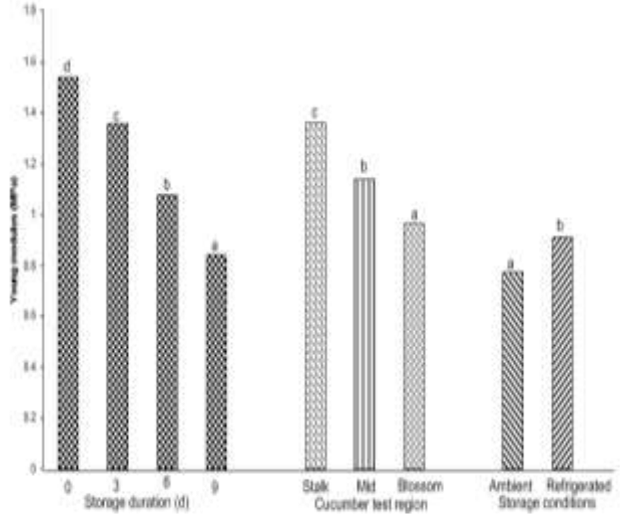

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Figure 8: Effects of storage duration, storage conditions and fruit test position on Young modulus of *Nandini* cucumber fruit

Engineering Applications

Since strength properties play a major role in predicting physical damage to cucumber fruits. Fruits can be packed to higher levels and withstand higher impact and static loads at harvest. Therefore, it is advisable to do most handling, such as packing and transportation, within 4 days of after harvest. Data gotten from this research will help to understand the physical and mechanical characteristics of cucumber and useful in many postharvest processes which help to decrease the effects of unwanted mechanical loading, quantity of energy, force and mass consumption during processing operation like peeling, crushing and chipping. For instance, energy to crush the fruits to produce juice can be greatly reduced, if the fruits were crushed after some days in storage under ambient condition, while packaging and transportation should be done immediately after harvest.

IV. CONCLUSION

The results of this study can be summarized as follows:

i. The physical properties of the cucumber fruits (Cucumis sativus) studied in this work are related to storage time and conditions.

ii. Mass loss and shrinkage were higher in the cucumber fruits stored under ambient conditions, than those stored in refrigerated conditions. Therefore, cucumber fruits should be stored in lower temperature and relative humidity in order to retain their freshness and other physical properties.

iii. The mechanical properties studied were highest at the stalk end, whilst the blossom end has the lowest values, therefore extreme care must be taken when handling the blossom end of cucumber fruits.

iv. The mechanical properties of cucumber fruits stored under ambient condition decreased rapidly than those stored under refrigerated condition.

Consequently, extreme care must be exercised in handling cucumber stored under ambient condition to prevent them from becoming failure and rupturing during the process, especially after 3 days of storage.

v. Cucumber lose their strength over the period of storage It is advisable to do most handling, such as packing, sorting and transportation, within 3 days of harvest.

ACKNOWLEDGMENT

The authors appreciate Mr. G. Akalonu, farm manager, National Center for Agricultural Mechanization (NCAM), Ilorin, Nigeria for his assistance in facilitating the purchase of the cucumber used for the research. Mr. O. M. Odeniyi, a Laboratory technician is acknowledged for his assistance in the course of carrying out the experiments.

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