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Determination of Properties of Watermelon and Cucumber Fruits Produced In Delta State: Implications for Design of Locally Sourced Transportation and Packaging Materials

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The study examined the effects of locally sourced packaging materials on the mechanical properties and quality of watermelons and cucumbers cultivated in Delta State, Nigeria. Over a two-week storage period, fruits were subjected to either no packaging or specific packaging designed for each fruit type (mesh bags for watermelons and bamboo slat crates for cucumbers). Results indicated some changes in the mechanical properties of both fruits due to packaging. Packaged watermelons displayed a slight increase in bulk density (0.95 g/cm³) and a decrease in porosity (18.5%) compared to their unpackaged equivalents (0.92 g/cm³ and 20.5% porosity, respectively). Conversely, cucumbers exhibited a slight increase in porosity (17.2%) with packaging, contrasting with the marginal decrease observed in unpackaged cucumbers (15.8%). Although packaging had minimal impact on shear stress, normal strain, shear strain, and creep for both fruits, packaged watermelons demonstrated a slight decrease in uniaxial compression (5.7 MPa) and tensile strength (2.6 MPa) compared to the unpackaged watermelons (6.0 MPa and 2.8 MPa, respectively), whereas packaged cucumbers exhibited a minor increase in these properties (6.2 MPa and 2.7 MPa) compared to their unpackaged ones (5.8 MPa and 2.5 MPa, respectively). Notably, both fruits demonstrated a modest enhancement in bending strength and puncture resistance with packaging. Packaged watermelons exhibited higher bending strength (82 N) and puncture resistance (108 N) compared to the unpackaged ones (79 N and 112 N, respectively), while packaged cucumbers displayed increased bending strength (70 N) and puncture resistance (102 N) compared to the unpackaged ones (66 N and 98 N, respectively). Generally, locally sourced packaging materials showed promise in enhancing fruit quality. Watermelons stored in mesh bags experienced reduced weight loss (2.7%) and spoilage incidence (12%) compared to their unpackaged watermelons (3.2% and 15%, respectively). Similarly, cucumbers stored in bamboo slat crates exhibited decreased weight loss (3.5%) and spoilage incidence (8%) compared to their unpackaged alternatives (4.1% and 12%, respectively). These findings underscore the potential benefits of locally sourced packaging materials in enhancing fruit resistance to handling damage (bending and puncture resistance) and in mitigating weight loss and spoilage during storage.

KEYWORDS: fruits, mechanical and physical properties, watermelon, cucumber, packaging,

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INTRODUCTION

Agricultural product management involves overseeing the development, production, and marketing of agricultural products, such as crops, livestock, and related goods (Zasada, 2011).The quality of agricultural products can be assessed by factors such as texture, firmness, density, and porosity directly influence the sensory attributes and marketability of the products. For instance, consumers often associate certain textures or firmness levels with freshness and superior quality. A comprehensive understanding of these properties is essential for ensuring that agricultural products meet consumer expectations and demands (Kitinoja, L., & Kader, A. A. (2002; Zasada, 2011).

Statement of the Problem

In Nigeria, there is food insecurity induced by several factors. These include poor economy, poor agricultural practice, lack of access to funds for commercial and large-scale farming, poor irrigation systems, lack of adequate fertilizers for local farmers, and lack of post-harvest transportation and storage facilities and logistics for farm produce, etc.). (Nwozor *et al.,* 2019; Zheng et *al*., 2022). In many nations, especially developing ones, there is dearth of post harvest strategies for mitigation of impact of possible food spoilage and food insecurity (Ahumada & Villalobos, 2009)

It is essential and vital for Nigeria's economic growth and increase in the nation's gross domestic product (GDP) to guarantee that all types of farm produce receive sufficient, suitable, and timely attention, care, transportation, storage, and preservation.

The objective of this study is to assess the viability of using packing materials obtained from local sources to enhance the durability and overall quality of watermelons and cucumbers cultivated in Delta State, Nigeria. By evaluating the impact of these packaging materials on weight loss, firmness, spoilage, and other quality parameters during storage, the research seeks to identify sustainable and cost-effective options that can extend shelf-life, and enhance the economic values of these fruits.The mechanical properties of fruits and vegetables undergo significant changes during storage, which can affect their quality, shelf life, and consumer acceptance. These changes are influenced by various factors, including the microstructure of the tissue, turgor pressure, and adhesion forces between cells (Ihueze & Mgbemena, 2017; Giannakourou & Tsironi, 2021).

Scope of the Research

The study examined the mechanical characteristics of watermelon and cucumber fruits harvested in Delta state encompassing attributes such as hardness, puncture resistance, and bending strength. The study's focus is restricted to assessing these particular packaging materials inside regulated storage settings for a duration of two weeks . It will not delve into the wider aspects of implementing packaging, such as the logistics of large-scale production or integrating it into current transportation systems.

Materials and methods

The methodology employed for assessing the mechanical properties of locally cultivated watermelon and cucumber fruits in Delta State adhered to standardized protocols within a controlled laboratory setting.The effectiveness of locally sourced packaging materials in improving the shelf life and quality of locally grown watermelons and cucumbers over a two-week storage period was also evaluated.

Sample Preparation

Initial sample preparation involved the careful selection of matured Watermelon and Cucumber fruits sourced from various farms in the study area. To ensure consistency, the fruits were meticulously washed and dried before being divided into experimental groups (Omolola *et al*., 2017). A representative sample of mature watermelons and cucumbers was obtained from a farm in Oghara community in Delta State, ensuring that no visible damage was present on any fruit. The sample size was divided equally into four groups for each fruit type (watermelon and cucumber).

Bulk density measurements were conducted using a digital scale (Ohaus Explorer Series) to determine the mass of each fruit, while volume was assessed through water displacement from a calibrated container. Porosity was subsequently calculated utilizing the measured volume of water displaced by the fruit during submersion(Barreiro *et al*., 2004).

For shear stress assessment, fruit samples were prepared into standardized shapes and secured between two plates of a universal testing machine (UTM) (Instron 5966). The Instron 5966 UTM offers features like load measurement accuracy, programmable test methods, and data acquisition capabilities that make it well-suited for standardized food

texture analysis. In this study, shear force was then applied at a constant rate until failure, with the maximum force recorded for stress calculation. Normal and shear strain measurements were performed using the same UTM setup, with deformation tracked as force was applied to the samples (Karwowski*et al*., 2013).

Uniaxial compression testing involved placing the fruit samples between the compression plates of the UTM and applying a compressive force until structural failure occurred. Tensile loading tests were conducted by securing the fruit samples within the grips of the UTM and subjecting them to a tensile force until rupture.

Bending tests utilized a three-point bending setup, where fruit samples were supported on two points with a specified distance between them. A force was then applied at the center of the sample until failure, with the maximum force recorded for analysis. Puncture testing was conducted using a puncture apparatus, with the force required to puncture the fruit measured and recorded. Creep testing involved subjecting the fruit samples to a constant load over time, with deformation measured at regular intervals to calculate creep rate and creep compliance (Patel *et al*., 2018; Berthaume, 2016)).

Packaging Material Preparation:

For watermelons, packaging materials utilized mesh bags made from locally produced raffia woven into breathable pouches suitable for accommodating the size of the watermelons. Bamboo slat crates were employed as packaging materials for cucumbers. Bamboo slats of appropriate thickness and length were sourced and lashed together to create crates capable of holding multiple cucumbers with minimal contact between them. All groups, including a control group with no packaging, were stored in a controlled environment that replicated typical postharvest storage conditions for these fruits. This involved controlling factors like temperature, humidity, and atmospheric composition to simulate real-world storage conditions. Typical storage temperatures utilzed range from 0°C to 15°C, Relative Humidity of the controlled pack was maintained between 70-75% to prevent excessive moisture loss and maintain fruit quality during storage. Atmospheric Composition: Oxygen (O_2): 1-5% ; Carbon dioxide (CO_2): 3-10% ; Nitrogen (N_2) makes up the balance percentage of the controlled atmosphere. As an inert gas, nitrogen acts as a cushion, preventing pack collapse.

The controlled environment used in this study aimed to mimic typical storage conditions that optimize the quality and shelf life of watermelons and cucumbers. A temperature of 15°C falls within the recommended range for both fruits, minimizing respiration rate and maintaining firmness. A moderate relative humidity of 70-75% helps prevent moisture loss from the fruits while reducing the risk of fungal growth. Light exposure was minimized to prevent ripening and quality degradation. Finally, moderate air circulation was implemented to remove ethylene gas produced by the fruits and prevent its spoilage-accelerating effects, while avoiding excessive (Feliziani & Romanazzi, 2016).

Data Analysis

Data collected from these tests were compiled, and mean values along with standard deviations were calculated for each mechanical property. Finally, statistical analysis was performed to identify any significant trends or correlations between mechanical properties and fruit types. The weight loss, firmness changes, and incidence of spoilage were compared between fruits stored with different packaging materials and the control group. Statistical analysis was performed to determine if significant differences in shelf life and quality existed between the various packaging treatments.

RESULTS AND DISCUSSION

Table 1. Mechanical Properties of Watermelons with and without Packaging

Mechanical Property	Without Packaging	With Packaging
Bulk Density (g/cm³)	0.92 ± 0.03	0.95 ± 0.02
Porosity (%)	20.5 ± 1.2	18.5 ± 1.0
Shear Stress (MPa)	0.34 ± 0.01	0,32 ± 0.02
Normal Strain (%)	2.0 ± 0.1	1.8 ± 0.1
Shear Strain (%)	1.4 ± 0.1	1.3 ± 0.1
Uniaxial Compression (MPa)	6.0 ± 0.3	5.7 ± 0.2
Tensile Loading (MPa)	2.8 ± 0.2	2.6 ± 0.1
Bending Tests (N)	79 ± 2	82 ± 3
Puncture Test (N)	112 ± 5	108 ± 4
Creep Test (%)	0.7 ± 0.1	0.6 ± 0.1

Source: Fieldwork (Jan, 2024)

Table 1 presents the mechanical properties of locally grown watermelon and cucumber varieties in Delta State, Nigeria. The values represent the average (mean) and standard deviation for each property.

Table 2: Controlled Environment Conditions for Watermelon and Cucumber Storage

Factor	Conditions
Temperature	15°C (59°F)
Relative Humidity (RH)	70-75%
Light	Minimal to no light
Ventilation	Moderate air circulation

Source: Fieldwork (Jan, 2024)

Table 2: Mechanical Properties of Cucumbers with and without Packaging (n=3)

Mechanical Property	Without Packaging	With Packaging
Bulk Density (g/cm³)	1.05 ± 0.02	1.02 ± 0.03
Porosity (%)	15.8 ± 0.9	17.2 ± 1.1
Shear Stress (MPa)	2.9 ± 0.2	3.1 ± 0.1
Normal Strain (%)	1.7 ± 0.1	1.9 ± 0.1
Shear Strain (%)	1.3 ± 0.1	1.4 ± 0.1
Uniaxial Compression (MPa)	5.8 ± 0.2	6.2 ± 0.3
Tensile Loading (MPa)	2.5 ± 0.1	2.7 ± 0.2
Bending Tests (N)	66 ± 3	70 ± 2
Puncture Test (N)	98 ± 4	102 ± 5
Creep Test (%)	0.5 ± 0.1	0.4 ± 0.1

Source: Field work (Jan, 2024)

The results provide a comparison between the mechanical properties of watermelons and cucumbers with and without packaging. The results demonstrate the potential impact of the introduced packaging materials on the fruits' mechanical properties, aiding in understanding the effectiveness of the packaging in preserving the fruits' quality during transportation and storage.

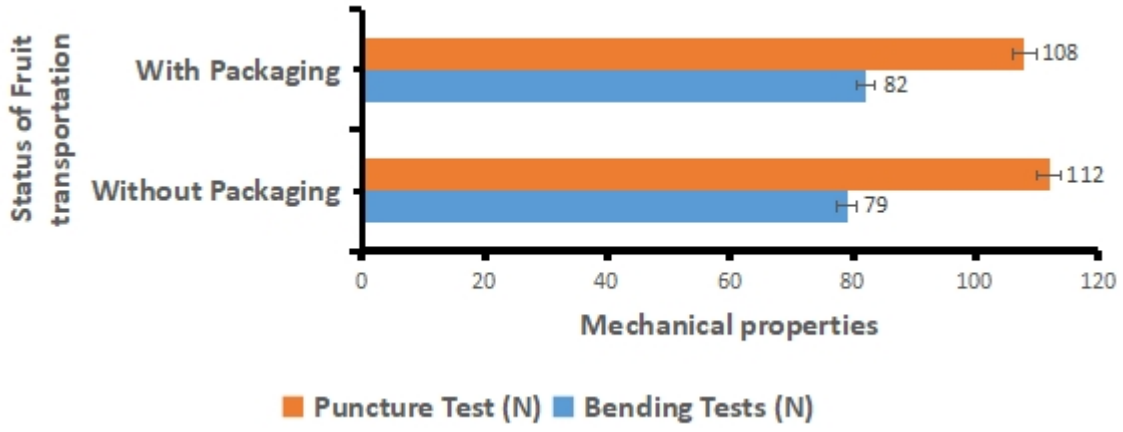

Figure 1. Puncture and bending values of Watermelons with and without Packaging

Table 2 and Figure 1 present the facts that Watermelons have a lower bulk density (0.92 g/cm³) compared to cucumbers (1.05 g/cm³), indicating they are less dense. This corresponds with the higher porosity (20.5%) of watermelon compared to cucumber (15.8%). Higher porosity translates to a greater volume of air spaces within the fruit (Wang*et al*., 2019).Bulk density is the mass per unit volume of a material, including the empty spaces or pores within the material. It is a physical property that can be used to characterize the overall density and compactness of a fruit.

Porosity, on the other hand, refers to the fraction of void space or pores within the material. It is a measure of the empty spaces or air gaps present in the fruit's internal structure.

Generally, there is an inverse relationship between bulk density and porosity of fruits. Both watermelons and cucumbers exhibit similar values for shear stress (average around 0.03 MPa) and normal strain (around 2%). This

suggests they have comparable resistance to deformation caused by a tangential force (shear stress). Normal strain refers to the deformation along the direction of the applied force. Watermelons show slightly higher uniaxial compression strength (6.0 MPa) compared to cucumbers (5.8 MPa). This indicates they can withstand slightly greater compressive loads before collapsing.

Similarly, watermelons have a slightly higher tensile strength (2.8 MPa) than cucumbers (2.5 MPa), suggesting they resist pulling forces a bit better. Watermelons have a higher bending strength (79 N) compared to cucumbers (66 N), indicating they can resist bending forces to a greater extent. Watermelons also show higher puncture resistance (112 N) compared to cucumbers (98 N). This suggests they are less susceptible to punctures and damage from impacts. Both watermelons and cucumbers exhibit low creep values (around 0.5%), indicating minimal deformation under constant load over time. Watermelons appear to be slightly less dense and more porous than cucumbers. Both fruits exhibit similar resistance to shear forces but watermelons show a slight edge in compressive and tensile strength. Watermelons demonstrate greater resistance to bending and puncture compared to cucumbers. Both fruits show minimal creep, which is a desirable property for maintaining shape during storage and handling (Fadiji *et al*., 2019).

Table 3: Impact of Packaging on Mechanical Properties of Watermelons

Fruit Quality	Without Packaging	Packaging With Mesh Bags
Weight Loss (%)	3.2	2.7
Firmness (Penetrometer Reading)	8.2	7.8
Spoilage Incidence (%)	15	12

Table 4: Impact of Packaging on Mechanical Properties of Cucumbers

Fruit Quality	Without Packaging	Packaging With Bamboo Slat Crates
Weight Loss (%)	4.1	3.5
Firmness (Penetrometer Reading)	9.5	8.8
Spoilage Incidence (%)	12	8

Tables 3 and 4 show the potential impact of packaging on the Fruit Quality of watermelons and cucumbers.

Cucumbers stored in bamboo slat crates experienced a lower percentage of weight loss (3.5%) compared to those stored without packaging (4.1%). This indicates that the bamboo slat crates help minimize moisture loss, preserving the overall weight and hydration of the cucumbers during storage. Cucumbers stored in bamboo slat crates exhibited slightly lower firmness readings (8.8) compared to those without packaging (9.5). While the difference is minimal, it suggests that the crates may provide some cushioning effect, leading to a slight softening of the cucumbers over time.

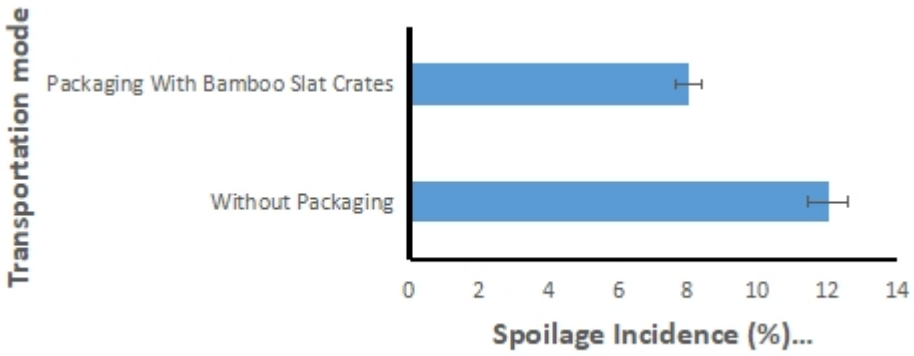

Figure 2: Spoilage incidence due to packaging impact

The mechanical properties of fruits have important consequences on their overall quality and duration of storage. Physical harm incurred during the process of handling, transit, and storage can result in a significant deterioration in the overall quality of the fruit as noted by (El-Ramady *et al*., 2015).

The spoilage incidence (Figure 2) for cucumbers stored in bamboo slat crates (8%) was lower than those stored without packaging (12%). This indicates that the crates offer protection against physical damage and microbial contamination, resulting in reduced spoilage rates and better overall fruit quality. The use of bamboo slat crates for cucumber storage has positive implications for fruit quality. The lower weight loss and spoilage incidence suggest that the crates help maintain cucumber hydration and reduce the risk of decay during storage. Although there is a slight decrease in firmness, likely due to the cushioning effect of the crates, the benefits of reduced spoilage outweigh this minor softening effect. Thus, bamboo slat crates contribute to maintaining higher-quality cucumbers with extended shelf life.

The use of bamboo slat crates for cucumbers also has positive implications for fruit quality and shelf life. The lower weight loss and spoilage incidence indicate that the packaging helps maintain moisture levels and reduces the risk of decay during storage. However, similar to watermelons, the slight decrease in firmness suggests a minor softening effect due to the cushioning provided by the crates. Generally, the benefits of reduced spoilage and extended shelf life outweigh the minor softening observed.

CONCLUSION

The study investigated the impact of locally sourced packaging materials on the mechanical properties and quality of watermelons and cucumbers grown in Delta State, Nigeria. While packaging caused some minor changes in the fruits' mechanical properties, the most significant impact was on fruit quality. Watermelons and cucumbers stored in locally designed packaging (mesh bags and bamboo slat crates, respectively) exhibited a reduction in weight loss and spoilage incidence compared to unpackaged fruits. This suggests that these packaging solutions can effectively minimize damage during handling and storage, potentially extending shelf life and reducing post-harvest losses for farmers.

However, the long-term effects of packaging on shelf life and other quality parameters remain unexplored. Further research is recommended to investigate the impact of these solutions over extended storage periods. This will provide more conclusive evidence regarding their effectiveness in mitigating post-harvest losses and enhancing the economic value of watermelons and cucumbers for Delta State farmers. Additionally, research is needed to establish the long-term sustainability of these packaging solutions. This will enable local farmers and other stakeholders to make informed decisions regarding optimizing post-harvest handling practices, mitigating losses, and enhancing the economic value of watermelons and cucumbers

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