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Comparative Study of Different Packaging Materials and its Impact on Guava Fruit Quality under Cold Storage

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Abstract: Climate variables, made us think about sustainability and green practices to reduce future risk and negative environmental impacts, maintain natural resources, and reduce carbon emissions. Nowadays, using reusable, biodegradable, it can also indicate recycling and manufacturing techniques that reduce pollution. Bagasse is an eco-friendly substitute for conventional packaging sources. Communally origin sugarcane fiber attends more benefits packages for the packaging. In this investigation, we tested the effect of bagasse package (T1), mixed bagasse and polyethylene package (T2), a slice of chitosan put in polyethylene package (T3) and control was commercial polyethylene package (T4) on guava fruit under cold storage. All packaging materials are found to have significant effects on physiological weight loss, chilling injury percentage, titrable acidity, vitamin C content, overall acceptability, and marketability of guava fruits under refrigeration temperature.

Key words: Guava, Packaging, Vitamin C, Weight Loss.

1. Introduction

Guava (*Psidium guajava L.*), lays in the family *Myrtaceae* guava is a tropical and subtropical. From the United Nations Food and Agriculture Organization (FAO) which add guava with mangoes and also mangosteen fruits when recording on universal trading statistics guava commercially India produces 42.1% of the world's production followed by Indonesia with 9.9% of world guava production while Egypt's world production is 1.8%. Guava is a delicious and nutritious fruit; it is a very good source of vitamin C containing double times more than oranges and ten times more than tomatoes, however, perishable fruits are most difficult to store for a long time **(Tanveer *et al.*, 2010).** Guava has a tight storage possibility, which leads to overfeeding in the market and low income for the grower, Furthermore, overripe fruit has a shelf life due to a lot of damage and economic losses. So, guava fruits are desired to be achieved appropriately to obtain control market supply. This can be done by using post-harvest treatment wisely and then storing the product at the right temperature and relative moisture.

The guava fruit quality is affected by the cultivar, harvesting time, ripeness stage, packing materials during storage, storage environment, physio-chemical changes under storage, and microbial attack (**Islam, 2008)**. Different attempts to provide quality guava under storage with the use of several chemicals and packaging substances.

Between these, packaging substances have no adverse long-term impacts on human health, using them for storage is always preferable. Plastics have placed serious function as an effective packaging material. Regardless of cost impact, they are saving fruits from microbial pollution, wetness, and loss in weight and also control ethylene condensation in the package (**Ankit and Sonia, 2019**).

The waste of sugarcane fiber After extracting the sugar from the sugarcane is known as Bagasse. In the sugar industry, 3 tons of sugarcane rubbish was remaining from 10 tons of sugarcane. (**Khatri and Pandit, 2022**) If this offal is thrown away, it will cause environmental pollution. Researchers suggested that fiber from sugarcane and leaves trash are wealthy in nutritious minerals such as nitrogen (N), potassium (K), calcium (Ca), phosphorus (P), etc. (**Negrão *et al.*, 2021)** Now in many regions, bagasse has become an exporter of fundamental materials for some products such as food packaging products, paper, textiles, biofuel, and compost. Using bagasse in packing is an eco-friendly substitution for ordinary packaging sources, **(Rahul Vikram *et al.*, 2022).** Bio-plastics are a type of packaging material that consists of polymers produced from natural or renewable resources (**Rudin and Choi, 2013).**

These include for example resumable biomass exporters such as sugarcane, corn, or other forms of cellulose or the use of microbes such as yeast (**Ashter, 2016).** Biodegradable is polylactic acid which is primarily factory from degradable resources such as corn by the fermentation of starch and condensation of lactic acid. For instance, it has found when packaging meat in polylactic acid-based packaging with needs a modified atmosphere environment.

Chitosan (poly β-(1-4) N-acetyl-glucosamine a natural substance known as deacetylated chitin, which is derived from the shells of crustaceans (the crabs, shrimp and crayfish) through biochemical or microbiological operations.

Certain fungi, such as a species of *Aspergillus niger, Mucorrouxii*, and *Penicillium notatum,* can also create this component. **(Tan *et al.*, 1996).**

According to **Zhelyazkov *et al.* (2014) and Hussein *et al.* (2015)**, chitosan exhibits good biocompatibility, non-toxicity, antioxidant qualities, and great neutrality as a biodegradable. It functions as a superb semi-permeable barrier against moisture, carbon dioxide, and oxygen, minimizing water loss and respiration while averting fruit dehydration and shrinkage (**Petriccione *et al.*, 2015**).

The current study aims to verify the suitability of containers made from bagasse in storing food materials, and whether they are sufficient as package, or is it better to make package by mixing bagasse and polyethylene, and compare this with the commercial polyethylene packages in which guava is stored, and is it possible to add chitosan to commercial polyethylene package to increase the efficiency of storing guava. As the nature of guava is that it is a quickly perishable fruit, so it must be taken care of in terms of choosing the packaging and the degree of cold during storage.

2. Materials and Methods

Fresh and mature Baldy guava (*Psidium guajava* L.) was collected from the private farm in the last week of March 2023 and 2024 seasons on 3% in green fruit and TSS > 10% in ripe fruit, and the TA from 0.2 to 1.5% according to (**Paull and Ching 2014**) with uniform sizes, shapes, colors, and maturity, and without any signs of mechanical damage or fungal decay and transferred to the Laboratory of the Horticulture Research Station at Mansoura. Fruits were washed and kept under a fan for surface drying. After surface drying, all fruits were weighed.

A total of four groups of guava fruits each group with 48 fruits (the first group of fruits was packed in a bagasse package (T_1), the second group was packed in mix bagasse and polyethylene package (T_2), the third treatment fruits were put in polyethylene package with chitosan made as slices (T_3), and the fourth treatment, fruits were put in commercial polyethylene package as the control (T_4) as demonstrated in Fig (1). All packages are perforated on all sides at 2 - 5% of the package size. Bagasse packages, mix bagasse and polyethylene package and chitosan sheets were manufactured in the laboratories of the Faculty of Engineering, Nile University by Prof. Irene Fahim and her assistant team.

All treatments were stored in a fridge at (7 ±1ºC, 80±5% RH). Three replicates of 4 fruits per pack (~600 g) were taken for each treatment. The observations were recorded during storage every 4 days for 20 days storage.

Figure (1). Different packages used in guava storage

Physiological loss in weight percentage (PLW %)

Before treatment, fruits were weighed taken placed on a digital weight balance using the unit gram. Physiological loss in weight was calculated on a weight basis at four days' intervals and expressed in percent (%) **(Sahoo *et al.*, 2015)**

$$\text{PLW \%} = \frac{\text{Fresh weight (g)} - \text{Final weight (g)}}{\text{Fresh weight (g)}} \times 100$$

Decay percentage

Decayed and fruit rotting were measured at intervals every 4 days through all storage period. Rotted fruit which has dark brown or blackish irregular spots were observed on the surface of diseased fruits in general. **(Amina *et al.*, 2022).**

$$\textbf{Decay \%} = \frac{\text{Fresh weight (g)} - \text{Rotting fruit (g)}}{\text{Fresh weight (g)}} \times 100$$

Fruit firmness

It was measured at two orbital sites in three guava fruits for every replicate to determine the breakthrough strength by using a hand-held firmness tester fruits (FT-327, Italy) prepared by 8 mm cylinder stainless-steel press tip **(Harker *et al.*, 1996**) and data were calculated as (kg/ cm^2).

Total soluble solids (TSS)

The total soluble solids of guava juice were measured by a digital refractometer and measured T.S.S °B according to **AOAC (2005)**

Titratable acidity (%)

Titratable acidity was established as a percentage of citric acid according to **AOAC (2005).** Fruit sample was taken from 3 places (shoulder, middle, and apex portion) and juice was extracted from the samples. The 10 ml. extract was diluted with distilled water and made a volume of 100 ml. out of 100 ml extract again 10 ml of extract was taken for analysis. An Aliquot of diluted juice was titrated against a standard alkali solution of 0.1 NaOH using phenolphthalein as an indicator. The reading was expressed as a percentage (%).

Ascorbic acid

Ascorbic acid was decided by the 2, 6 dichlorophenol indophenol titration method. **(Rangana, 2007).**

Statistical Analysis

The trial was completed in a randomized design (CRD). The results obtained were subjected to analysis of variance (ANOVA) at P< 0.05 level of significance using AGRES software **(Gomez and Gomez, 1984).**

3. Results and Discussion

3.1. Physiological loss in weight percentage (PLW %)

From Table 1 shows the impact of various different packaging on the PLW% of guava in cold storage. After 4 days of storage in two years of study there is significant difference in PLW among all treatments in different storage treatments.

It may be visible that during general, weight losses accelerated appreciably in all of the remedies with the progress of the storage period but control fruits recommended higher PLW through the storage period. While fruits loaded in mixed bagasse and polyethylene recommended minimum PLW during the period of storage.

The PLW increases steadily during the storage period because of the constant transpiration and respiration that occurs during storage and after harvest. The best treatment to decrease PLW % was mixed bagasse and polyethylene (T2) followed by the package which put a slice of chitosan and bagasse package (T3). The rate of PWL is also affected by the storage temperature and gaseous synthesis inside the packet; guava fruits can only be kept at room temperature for 16 days, while at low temperatures i.e. 5±2°C it can be conserved for 32 days. The detention of weight at 5±2°C is caused by low respiration and transpiration that take place at low temperatures (**Monika *et al.*, 2020**) Physiological loss in weight due to a reduction in moisture content of fruit **(Chitravathi *et al*., 2015).**

Packaging in polythene bags may have increased the CO2 concentration and decreased the O2 which in time lowered the respiration rate of the fruits **(Thompson, 2010).** Put a slice of chitosan in a polyethylene packet reduced PLW like coating fruit on chitosan as found by (**Anuradha *et al.*, 2019**) thus fruits coated in chitosan were significantly reduced the PLW as compared to uncoated ones. Not only can chitosan films stamp out minor incisions and prevent water transmission, but they also act as a moisture barrier, preventing fruits from losing weight and becoming dry during storage **(Ribeiro *et al.*, 2007).** Maybe chitosan slices act the same function, adsorption water evaporation from the packet so, reducing PLW.

Table (1). Effect of different packaging materials on PLW % of Guava fruits under cold storage

Physiological loss in weight percentage (PLW %)													
Season 2023								Season 2024					
Storage period in days													
Treatments	**0**	**4**	**8**	**12**	**16**	**20**	**means**	**0**	**4**	**8**	**12**	**16**	**20**	**Means**
T1	0.0	3.7	5.2	8.7	10.0	11.1	6.45 **b**	0.0	3.0	4.8	7.1	8.9	10.7	5.30 **b**
T2	0.0	2.0	2.8	4.5	5.7	7.3	3.71 **c**	0.0	1.8	2.4	4.0	5.8	8.1	3.68 **c**
T3	0.0	3.6	6.8	8.4	9.3	10.5	6.43 **b**	0.0	3.3	5.0	7.1	9.7	11.0	6.01 **a**
T4	0.0	3.4	6.6	8.6	11.7	13.5	7.30 **a**	0.0	2.8	5.6	7.8	10.1	12.3	6.43 **a**
Means	0.0 **f**	3.1 **e**	5.3 **d**	7.5 **c**	9.1 **b**	10.6 **a**		0.0 **f**	2.7 **e**	4.4 **d**	7.1 **c**	8.5 **b**	10.4 **a**	

T_1 = Bagasse package T_2 = mix bagasse and polyethylene package
T_3 = chitosan slice on polyethylene package T_4 = polyethylene package
Means followed by the same letters within each column do not significantly differ using Duncan's Multiple Range Test at the level of 5%.

3.2. Decay percentage

All the treatments in the two seasons of study exerted a significant positive influence in reducing chilling injury percentage which started after 12 days of storage in first season while it started decayed in twelve days in the second season. As evident from Table 2, the maximum decay percentage (8% in the first season and 7.65 in the second one) was observed in the control treatment (T_4) while minimum decay percentage (2.96% in the first season and 2.83 in the second season) was to fruits packed in mixed bagasse and polyethylene (T_2) throughout the storage followed by chitosan slice on polyethylene packet (T_3) and bagasse packet (T_1).

During the storage period continuing, there was a progressive softening of fruits in all the treatments. In the control treatment, most mellowing of fruits was observed facilitating access for decay-causing microbes. Browning has done by dehydration or microbial pollution or the activity of PPO enzymes that are uncontrolled by the harvesting procedure and oxidize phenols into quinines within sub-atomic oxygen. **(Amina *et al.,* 2022).**

Table (2). Effect of different packaging materials on decay % of Guava fruits under cold storage

Decay (%)													
Season 2023								Season 2024					
Storage period in days													
Treatments	**H**	**4**	**8**	**12**	**16**	**20**	**Means**	**H**	**4**	**8**	**12**	**16**	**20**	**Means**
T1	0.0	0.0	0.0	0.0	1.66	4.44	1.01 **b**	0.0	0.0	0.0	0.5	1.45	3.83	0.96 **c**
T2	0.0	0.0	0.0	0.0	1.63	2.96	0.76 **c**	0.0	0.0	0.0	0.8	1.38	2.83	0.83 **c**
T3	0.0	0.0	0.0	0.0	1.00	3.10	0.68 **c**	0.0	0.0	0.0	0.5	1.84	4.12	1.07 **b**
T4	0.0	0.0	0.0	0.0	6.11	8.00	2.35 **a**	0.0	0.0	0.0	1.7	4.23	7.65	2.26 **a**
Means	0.0 **c**	0.0 **c**	0.0 **c**	0.0 **c**	2.60 **b**	4.62 **a**		0.0 **d**	0.0 **d**	0.0 **d**	0.87 **c**	2.22 **b**	4.71 **a**	

T_1 = Bagasse package T_2 = mix bagasse and polyethylene package
T_3 = chitosan slice on polyethylene package T_4 = polyethylene package
Means followed by the same letters within each column do not significantly differ using Duncan's Multiple Range Test at the level of 5%.

3.3. Firmness

Fruit firmness is the more extreme important quality factor for determining shelf-life and the market value of fruit. The maturation of fruits increased gradually resulting in decreased fruit firmness with increasing storage periods (Table 3). Decreases of firmness start slightly after 4 days for all treatments except control which decreases were clear in 12 days is the best day for firmness and lower decay and weight loss percentage.

Guava belongs to climacteric fruit, which means it produces ethylene which arranges fruit ripening by correlating gene expressions that are responsible for various processes, among others; the increasing of cell-breaking enzymes which is a compound inside the fruit, namely, cellulase to break cellulose, pectin, methylesterase (PME), and polygalacturonase (PG) which degrading pectin.

The fruits soften caused of depolymerization and polysaccharide dissolve of cell-wall belonging to pectin, hemicelluloses, and cellulose. Hemicelluloses and pectin are depolymerized and dissolved through the fruit's softening.

Polygalacturonase enzyme hydrolyzes glycosidic linkage in the polygalacturonic acid chain of pectic due to hydrolysis in pectin **(Pua and Davey, 2010).** Fruit softening occurs due to retrogradation in the cell structure, the cell wall texture, and the intracellular materials Firmness of guava can be protected due to fruit treated with chitosan that has antifungal effects and layers of the lenticels and cuticle, along these decreasing respiration and contamination, further ripening developments during storage, (**Scanavaca *et al*., 2007**).

Table (3). Effect of different packaging materials on the firmness of Guava fruits under cold storage

Firmness (Kg / cm^2)													
Season 2023								Season 2024					
Storage period in days													
Treatments	**H**	**4**	**8**	**12**	**16**	**20**	**Means**	**H**	**4**	**8**	**12**	**16**	**20**	**Means**
T1	4.40	4.20	3.66	3.13	2.33	1.73	3.24 **a**	4.35	4.20	3.73	3.08	2.15	1.42	3.15 **a**
T2	4.40	3.93	3.60	2.86	2.00	1.86	2.79 **b**	4.35	3.85	3.48	2.78	2.08	1.63	3.02 **b**
T3	4.40	3.46	2.83	2.20	1.86	1.33	2.68 **b**	4.35	3.54	2.96	2.41	1.48	1.22	2.66 **c**
T4	4.40	3.13	2.93	2.80	2.20	1.66	2.85 **b**	4.35	3.04	2.81	2.67	2.08	1.71	2.77 **c**
Means	4.40 **a**	3.68 **b**	3.25 **b**	2.75 **c**	2.10 **d**	1.64 **e**		4.35 **a**	3.65 **b**	3.24 **b**	2.73 **c**	1.94 **d**	1.49 **e**	

T_1 = Bagasse package　　T_2 = mix bagasse and polyethylene package

T_3 = chitosan slice on polyethylene package　　T_4 = polyethylene package

Means followed by the same letters within each column do not significantly differ using Duncan's Multiple Range Test at the level of 5%.

3.4. Total soluble solids (T.S.S)

Total soluble solids are an essential section reasonable edible quality indicator for any fruits during storage **(Maite *et al.,* 2010).** Data in Table 4 revealed that T.S.S increased with prolongation in storage duration for all treatments with no significant differences among treatments, that is true in the two seasons of study. Temperature during storage was discovered to be a major factor in raising the T.S.S. of guava, although packaging material thickness and gas limitations were not found to be important **(Monika, *et al.,* 2020).** Increasing in T.S.S content during storage could be due to losses in water through respiration and evaporation during storage resulting in the piling up of different solutes in cell vacuoles. Increasing T.S.S content reasons starch hydrolysis into sugars as Guava fruit ripens **(Stover and Simmonds, 1987)**.

3.5. Acidity Percentage

The acidity % is an important character to determine quality and acceptability of fruits. There was no big difference among treatments in acidity (%) all over the storage period in the guava fruits whether in the first season or the second which did not change significantly (Table 5).

The acidity percentage was comparatively high at harvest and then it lowering during ripening which occur as a physical fact. This could be expected to quick imposition of acids in guava fruits in the respiration process as a substrate **(Gupta *et al.,* 1979)**. Similar, **(Ibrahim *et al*., 2014)** suggested that reducing in titratable acids it is possible due to increased catabolism of organic acids into sugars.

Table (4). Effect of different packaging materials on TSS of Guava fruits under cold storage

T.S.S (ºBrix)														
Season 2023								Season 2024						
Storage period in days														
Treatments	**H**	**4**	**8**	**12**	**16**	**20**	**Means**	**H**	**4**	**8**	**12**	**16**	**20**	**Means**
T1	5.5	5.5	5.6	5.7	5.7	5.8	5.63 a	5.3	5.5	5.7	5.7	6.0	6.1	5.71 **a**
T2	5.5	5.8	5.8	5.9	6.0	6.0	5.83 **a**	5.3	5.4	5.5	5.7	5.8	6.0	5.61 **a**
T3	5.5	5.2	5.5	5.6	5.8	6.0	5.60 **a**	5.3	5.5	5.8	5.8	6.0	6.1	5.75 **a**
T4	5.5	5.6	5.8	5.9	5.9	6.0	5.78 **a**	5.3	5.6	5.8	6.0	6.1	6.2	5.83 **a**
Means	5.5 **b**	5.5 **b**	5.6 **a**	5.7 **a**	5.8 **a**	5.9 **a**		5.3 **b**	5.5 **a**	5.7 **a**	5.8 **a**	5.9 **a**	6.1 **a**	

T_1 = Bagasse package T_2 = mix bagasse and polyethylene package
T_3 = chitosan slice on polyethylene package T_4 = polyethylene package
Means followed by the same letters within each column do not significantly differ using Duncan's Multiple Range Test at the level of 5%.

Table (5). Effect of different packaging materials on the acidity % of Guava fruits under cold storage

Acidity (%)														
Season 2023								Season 2024						
Period in days														
Treatments	**H**	**4**	**8**	**12**	**16**	**20**	**Means**	**H**	**4**	**8**	**12**	**16**	**20**	**Means**
T1	0.64	0.63	0.61	0.55	0.55	0.55	0.58 **b**	0.63	0.63	0.60	0.58	0.58	0.58	0.60 **a**
T2	0.64	0.64	0.64	0.63	0.57	0.51	0.60 **a**	0.63	0.62	0.60	0.60	0.58	0.55	0.59 **a**
T3	0.64	0.64	0.63	0.59	0.59	0.50	0.59 **b**	0.63	0.63	0.60	0.57	0.55	0.53	0.58 **a**
T4	0.64	0.67	0.67	0.59	0.57	0.57	0.61 **a**	0.63	0.62	0.58	0.58	0.55	0.51	0.57 **a**
Means	0.64 **a**	0.64 **a**	0.63 **a**	0.59 **b**	0.57 **b**	0.53 **b**		0.63 **a**	0.62 **a**	0.59 **b**	0.58 **b**	0.56 **b**	0.54 **c**	

T_1 = Bagasse package T_2 = mix bagasse and polyethylene package
T_3 = chitosan slice on polyethylene package T_4 = polyethylene package
Means followed by the same letters within each column do not significantly differ using Duncan's Multiple Range Test at the level of 5%.

3.6. Ascorbic acid (V.C)

Ascorbic acid is an essential attribute in judging fruit's antioxidant and reducing capacity. The acidity of guava fruits decreased with an increase in the storage period. Decreeing of ascorbic acid started slightly after 4 days as shown in (Table 6). The best treatment for maintaining maximum ascorbic acid content was mixed bagasse and polyethylene (T_2) An initial increase in ascorbic acid could be due to the availability of fruit sugar, a portent of ascorbic acid structure but during later stages, oxidative pulling down of ascorbic acid by oxidase might have contributed to the decrease in ascorbic acid (**Singh *et al*., 2005**).

Table (6). Effect of different packaging materials on Ascorbic acid of Guava fruits under cold storage

Ascorbic acid (mg/100 g)														
	Season 2023							Season 2024						
	Period in days													
Treatments	**H**	**4**	**8**	**12**	**16**	**20**	**Means**	**H**	**4**	**8**	**12**	**16**	**20**	**Means**
T_1	200	200	196	191	186	183	192.6 **a**	220	220	213	204	198	186	206.8 **a**
T_2	200	211	206	198	192	187	199.0 **a**	220	220	214	204	193	184	205.8 **a**
T_3	200	198	195	185	176	165	186.5 **b**	220	218	210	199	191	178	202.6 **a**
T_4	200	195	187	179	167	156	180.6 **c**	220	216	208	197	186	171	199.6 **a**
Means	200 **a**	201 **a**	196 **a**	188 **b**	180 **c**	173 **d**		220 **a**	218.5 **a**	211.2 **a**	201 **b**	192 **b**	178.7 **c**	

T_1 = Bagasse package T_2 = mix bagasse and polyethylene package
T_3 = chitosan slice on polyethylene package T_4 = polyethylene package
Means followed by the same letters within each column do not significantly differ using Duncan's Multiple Range Test at the level of 5%.

4. Conclusion

It is now obvious that using ecologically friendly materials for packaging is it's not just anymore a luxury but rather a necessity placed upon us by life. This necessity arises from the pressing need to reduce pollution, especially residues from the sugar sector, which pose a serious threat to our ecosystems and general well-being. And because the plastic and paper industries resulting from cutting trees increase the environmental burden, and a better study must be continued a formula for the exploitation of reeds of cane and rice straw in the manufacture of containers, as well as a study of different types of fruits.

In contrast to conventional plastic packaging, this study emphasizes the possibilities for using plates made of bagasse and chitosan to package guava fruits. In a previous study for the authors, quality and the tests for permeability were conducted on these plates, which confirmed that they were suitable and of high quality for storing fruits. The outcomes show their beneficial effects on the guava fruits' quality and shelf life. However, more investigation is required to improve the design and manufacturing procedures as well as assess the financial sustainability and scalability of these materials. Nevertheless, this research offers a big step towards environmentally friendly packaging options that can help lower plastic waste and support sustainable business practices in the fruit industry.

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