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RESEARCH ARTICLE

Effects chitosan, calcium chloride, and paraffin wax on storage and quality of "Ewaise" mango fruits

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Abstract

Two consecutive seasons (2022 and 2023) were used to evaluate the impact of edible coating with calcium chloride**,** chitosan, and paraffin wax on the storability of mango fruit varietal "Ewaise." Fruits were picked and brought straight to the lab where they were cleaned, dried, and processed. The fruits were coated with chitosan, calcium chloride, and paraffin wax. Moreover, water is used as control treatment. For 40 days, the treated fruits were kept in carton boxes at 85–90% relative humidity (RH) and 13°C. To assess fruit quality and storability, fruit samples were withdrawn at harvest and ten-day intervals during cold storage. Fruits that were coated with any of the treatments had far less physical and chemical degradation as well as significantly improved fruit storability contrastingly with untreated fruits (control). This study indicated that coating either chitosan, calcium chloride, or paraffin wax are a promising technique for retaining postharvest quality and boosting the storability of mangoes cv. 'Ewaise' up to 40 days.

Keywords: Storage; shelf life; coating; calcium chloride; paraffin wax; mango chitosan.

1. Introduction

The mango (*Mangifera indica* L.), is a popular and economically significant tropical fruit that is grown throughout the world, including in Egypt. According to Statistics from the Ministry of Agriculture and Land Reclamation (M.A.L.R 2022), there are 326626 feddans of mango orchards in Egypt, with an amount of 1280310 tons produced annually. Texture, sweetness, acidity, taste, volatiles, fragrance, nutritional value, chemical makeup, and flesh color appearance, and shelf life are among the many characteristics of mango fruit quality that are thought to be important factors in producing a fresh mango of superior quality as well as in the acceptability of customers. Mangos are climacteric fruits with a short shelf life and ripen quickly after harvest, which significantly affects ripe fruit loss and makes them more vulnerable to infections by pathogens because of the decrease inside peel impedance and the increase in sugars, water availability, and pulp softening (Wongkhot *et al.*, 2012). Fruit degradation after harvest is being decreased by using natural ingredients instead of chemical ripening agents. (Tripathi & Dubey, 2004).

The use of natural, secure, and environmentally friendly coatings extended the shelf life and collapse of fresh produce, decreased postharvest deterioration, and preserved fruit quality. In addition to modifying the internal atmosphere (producing high CO_2 and low O_2) and reducing water loss, Fruit and the surrounding atmosphere's gas exchange is reduced by the edible coatings acting as a barrier. (Baldwin *et al.*, 1999; Jiang & Li, 2001). Fruit quality is maintained postharvest by using edible coatings

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(Zhu *et al*., 2008; Abbasi *et al*., 2009; Elsabee & Abdou, 2013). The edible coating acts as a barrier against gas diffusion, water migration, aroma changes, solute exchange, and respiration rate reduction. It also prevents weight loss, controls ethylene biosynthesis, maintains fruit firmness, and prevents color changes by regulating anthocyanin and carotenoid synthesis. Additionally, it delays the breakdown of soluble solids, minimizes the loss of TA, phenolic compounds, and ascorbic acid, and preserves antioxidant activity. Furthermore, it helps delay or control chilling injury and reduces microbial decay (Arnon *et al*., 2014; Saberi *et al*., 2018; Korge *et al*., 2020). Paraffin oil is a notable edible coating due to its high safety, non-toxicity, biocompatibility, and affordability. It forms a thin, protective layer on the fruit's skin, reducing moisture loss during storage and inhibiting the growth of certain microorganisms like fungi and bacteria. This helps prevent spoilage and extends the fruit's shelf life. Paraffin oil also alters the atmosphere around the fruit's surface during storage by reducing available oxygen and increasing CO_2 levels (Magashi and Bukar, 2006; Tiwary and Singh 2018; Dawood *et al*., 2023).

The natural biopolymer molecule Poly-β-(1,4) N-acetyl-D glucoseamine, or chitosan is obtained by the deacetylation of chitin, which is a primary constituent of crustacean shells, including those of crabs, shrimp, and crawfish (Sanford, 2002). Considering that it is biocompatible, biodegradable, non-toxic, and bioactive, chitosan is a viable and environmentally friendly option for managing significant pathogenic bacteria. It has attracted a lot of attention for usage in biotechnology, agriculture, biomedicine, and the food industry (Wu *et al*., 2005; Muzzarelli *et al*., 2012). Chitosan has the physiological capacity to create a coating on fruit and vegetable surfaces, lowering the respiratory rate by modifying the permeability of carbon dioxide and oxygen. This decreases the metabolism of fruit and increases its shelf life (Aider, 2010; Elsabee & Abdou, 2013). Furthermore, fruit surfaces coated with chitosan may provide a barrier that prevents deterioration and triggers a defensive mechanism in the fruit's tissues. (Shibuya & Minami, 2001; Zeng *et al*., 2010). In addition to acting as a preservative and improving fruit quality, chitosan coating can prolong fruit storage life, delay process of ripening, preserve acidity and content of ascorbic acid, increase antioxidant capacity, postpone the browning, control the deterioration, slow down water loss, decrease ripening in mangos, and delay textural changes and slow down the ripening process. (Kittur *et al*., 2001; Wang *et al*., 2007; Zhu *et al*., 2008; Abbasi *et al*., 2009). As a significant component of cultivated tissues, calcium plays a critical role in preserving and regulating a variety of cell functions. By enhancing cell wall strength, membrane stability, and cell-to-cell contact, calcium helps to prevent the deterioration of the middle lamella. (Martin-Diana *et al*., 2007 and Dodd *et al*., 2010). The reason for this is a decline in the activity of 1-aminocyclopropane-1-carboxylic acid oxidase (Guan *et al*., 1991). Regarding this matter, the use of calcium chloride has widely utilized as a firming and preservative in fruits and vegetables. There is a correlation between calcium and fruit ripening, aging, tolerance for stress, and firmness. (Martin-Diana *et al*., 2007). Mango fruits treated with calcium chloride showed improved appearance during storage, delayed ripening, preserved firmness of fruit, delayed skin color, decreased degradation incidence, respiratory rate, and weight loss. (Chitarra *et al*., 2001; Singh *et al*., 2007). Additionally, the percentage of fruit deterioration and rotting was significantly reduced and fruit storability was raised when mango "Totapuri" was dipped in solutions of calcium chloride at a rate of 0.5–4% for duration of 2–5 minutes as a postharvest treatment. (Fatma-Shaaban, 2006; El-Badawy, 2007; Salazar & Serrano, 2013). Ascorbic acid was considerably compared to control fruits, preserved in fully grown green mango and guava fruits as well as throughout storage by pre- and postharvest calcium compound spraying. (Fatma-

Shaaban, 2006; El-Badawy, 2007).

This study's objective was to investigate how calcium chloride, paraffin wax, and chitosan affected the mango fruits after harvest to solve the postharvest problems and improve the storability and shelf life.

2. Materials and methods

This investigation was carried out during two successive seasons (2022 & 2023) on fifteen-year-old, vigorous, fruitful mango trees cv. 'Ewaise' (*Mangifera indica*. L). This investigation was carried out in the Qena Governorate in a private orchard, Egypt. Whenever feasible, uniform fruits those are devoid of bruises, rot, and insect infestation are collected at the physiological maturity stage. Fruits were washed with distilled water, their surfaces treated with a 1% sodium hypochlorite solution and allowed to air dry before being used. Following were the treatments applied to the fruits:

1- Water alone as a control.
2- Chitosan at 0.5%
3- Calcium chloride ($CaCl_2$) at 2%
4- Paraffin wax at 1%

2.1. Preparing mango coating:

The chitosan (Sigma- Aldrich) solution was prepared at a concentration of 0.5 % (w/v) based on the method described by Jiang and Li (2001). Glacial acetic acid 0.5% (v/v) was used to dissolve 5 grams of chitosan under continuous stirring. The pH of the solution was adjusted to pH 5.6 using 1 N NaOH and filled up to 1 L with distilled water.

Calcium chloride (2%) was prepared by 20 grams of calcium chloride in one liter of distilled water. Prepare paraffin wax by melting it on the stove into liquid paraffin wax. The fruits are dipped in melted paraffin wax coat for about a second. The paraffin solidifies immediately on fruit's surface after it is removed from wax bath (Muthuselvi *et al.,* 2020). Fruits that had been handled were stored in carton boxes at 13°C and 85–90% relative humidity. Fruit samples were taken out at harvest time and ten days apart during the storage period in order to assess how coating treatments affected the quality and storability of the fruit. Measurements of fruit's physical and chemical characteristics, as follows:

Weight loss percentage: The following formula was used [(initial fruit weight - fruit weight at examination date) / (initial fruit weight)] × 100.

The percentage of spoiled fruit was ascertained as follows: [(number of decayed fruits at examination date) / (initial number of fruits)] ×100.

Marketable fruit percentage was calculated by the following formula [(sound fruit weight at examination date) / (initial fruit weight)] ×100.

Fruit firmness of the flesh (penetration testing) was recorded by using a texture analyzer Instrument. The force required to penetrate 1 cm inside the fruit using a needle probe diameter of 5 mm was measured. The machine's maximum mode and speed were set to 0.3 mm/sec. Three sites throughout the equatorial area of the whole fruit were used to take readings, and the findings were reported as the resistance force to the piercing tester in units of pressure (g/cm^2), (Watkins & Harman, 1981).

The pulp of each fruit was crushed to extract the juice, which was then strained through a muslin cloth. The clear juice extract was used to measure the inside quality of the fruit as follow:

Total soluble solids (TSS) fruit content was measured by hand refractometer, 0-32 scale (ATAGO N-1E, Japan), and expressed in °Brix.

The percentages of total and reducing sugars were calculated according to A.O.A.C. (2000) using the volumetric method described by Lane and Eynon.

The titratable acidity (TA) of fruit content was measured as the procedure of AOAC (2000). The citric acid concentration was measured in grams per 100 milliliters of fruit juice by titrating an aliquot of the juice against 0.1 N NaOH while phenolphthalein was present as an indication of the endpoint. Using the 2, 6-dichlorophenol-indophenol blue dye, the amount of vitamin C in fruit juice was quantified as milligrams of ascorbic acid per 100 milliliters of juice A.O.A.C. (2000). The study used a randomized full block design with three replications (Steel *et al.*, 1997), focusing on two parameters (storage durations and post-harvest treatments). The percentage data were converted to the arcsine of the square root before statistical analysis, and the results display the non-transformed means. Using the MSTAT-C statistical package, an analysis of variance (ANOVA) was performed to examine the effects of coating treatments and cold storage periods on various attributes (M-STAT, 1993). Comparisons between means were done at probability ≤ 0.05.

3. Results

3.1. The percentage of fruit weight loss and fruits damage

Data presented in Figures (1, and 2) showed the effect of chitosan, calcium chloride, and paraffin wax on the weight loss % and fruit damage of “Ewaise” mangoes during cold storage in the 2022 and 2023 seasons. It was clear that the two seasons under study had a similar pattern in the results. Data in current figures clear that fruit weight loss and fruit damage percentage were markedly increased with the advance of the cold storage period. These traits were slightly increased gradually from the beginning of cold storage till the 20 days, then a rapid increase until the 40 days. Weight loss and damage percentage increased during storage, reaching values of (13.3 & 11.5%) and (31.5 & 21.0%) after 40 days. The weight loss was significantly increased and attained (0.0, 3.2, 6.8, 10.6 & 13.3%) and (0.0, 2.0, 4.2, 6.8, & 11.5%) due to storage for 0, 10, 20, 30, and 40 days during the two correspondingly examined seasons. Furthermore, the matching values of damage percentage were attained (0.0, 7.7, 13.7, 18.8, & 31.5%) and (0.0, 1.3, 7.8, 13.1 & 21.0%) respectively.

In response to coating types, it was apparent that all coating treatments significantly decreased the fruit weight loss percentage and undesirable fruit percentage during cold storage compared with control. Using paraffin wax gave the best results, which gave the least percentage of fruit weight loss (1.8, 2.1) and fruit damage (5.3, 3.7 %). The weight loss was attained (11.5, 7.3, 6.5 & 1.8%) and (7.2, 5.1, 5.2 & 2.1%) due to un-coat (control), calcium chloride, chitosan and paraffin wax during the two studied seasons, respectively. The corresponding, damage fruits percentage was attained (24.9, 13.8, 13.3, 5.3) and (19.1, 6.4, 5.4 & 3.7%) respectively. No significant differences in weight loss and fruit damage due to the use of calcium chloride or chitosan. The decrement percentage of weight loss percentage attained (36.52, 43.48 & 84.34%) and (29.17, 27.78 & 70.83 %), as well as damage fruit percentage attained (44.58, 46.59, 78.7%) and (66.49, 71.73, 80.63%) due to use calcium chloride, chitosan and paraffin wax compared to un-coat (control) during the two studied seasons, respectively.

The data also demonstrated that, for weight loss and the proportion of mango fruits that decomposed in both seasons of this study, The treatments and storage times reached showed a substantial connection attained (21.3,14.3, 12.8 & 4.6%) and (16.3,11.8, 12.2 & 5.8%) due to un-coat, calcium chloride, chitosan, and paraffin wax during the two studied seasons, respectively. The corresponding, damage fruits percentage was attained (54.9, 28.8, 29.6, 12.5) and (46.7, 15.3, 12.8 & 9.3%) respectively.

The variation in reduction of fruit loss and fruit damage depends on the coating type used where the use of paraffin wax gave the lowest percentage of fruit weight loss and induced the lowest percentage of decayed fruits compared to the other treatments. The results indicated that using coating treatments proved effective in reducing the percentage of weight loss and fruit damage as well as keeping the mango fruits for a long period.

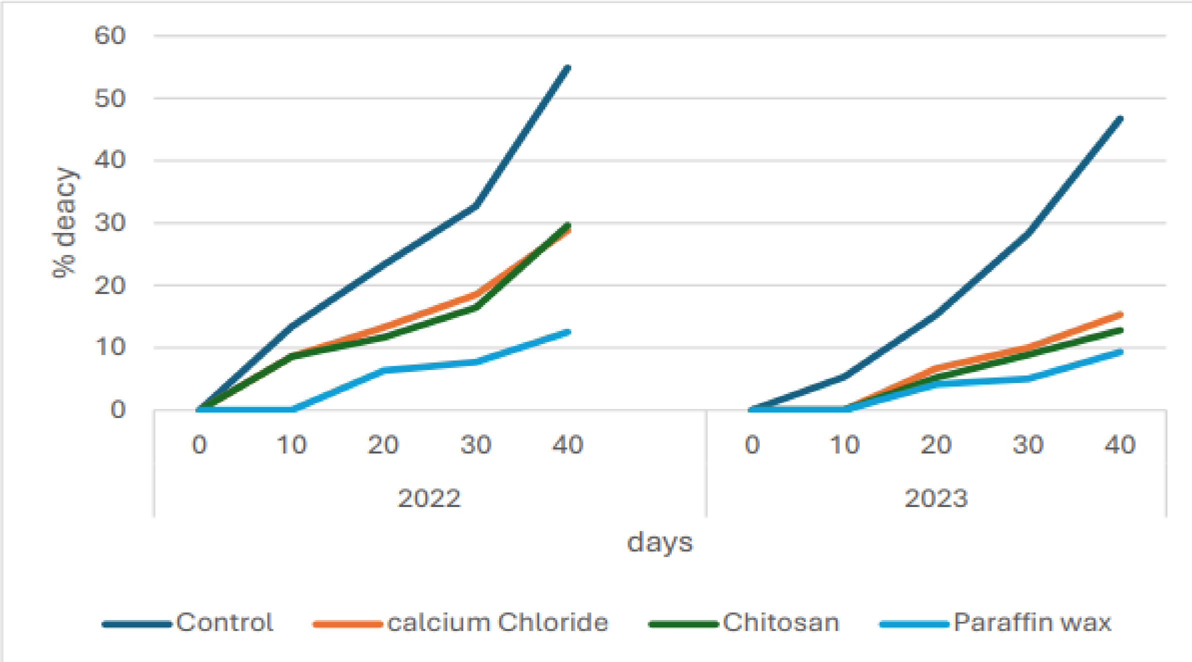

Figure 1. Impact of post-harvest treatments on fruit weight loss (%) of mango cv Ewaise fruits during cold storage in 2022 and 2023 seasons.

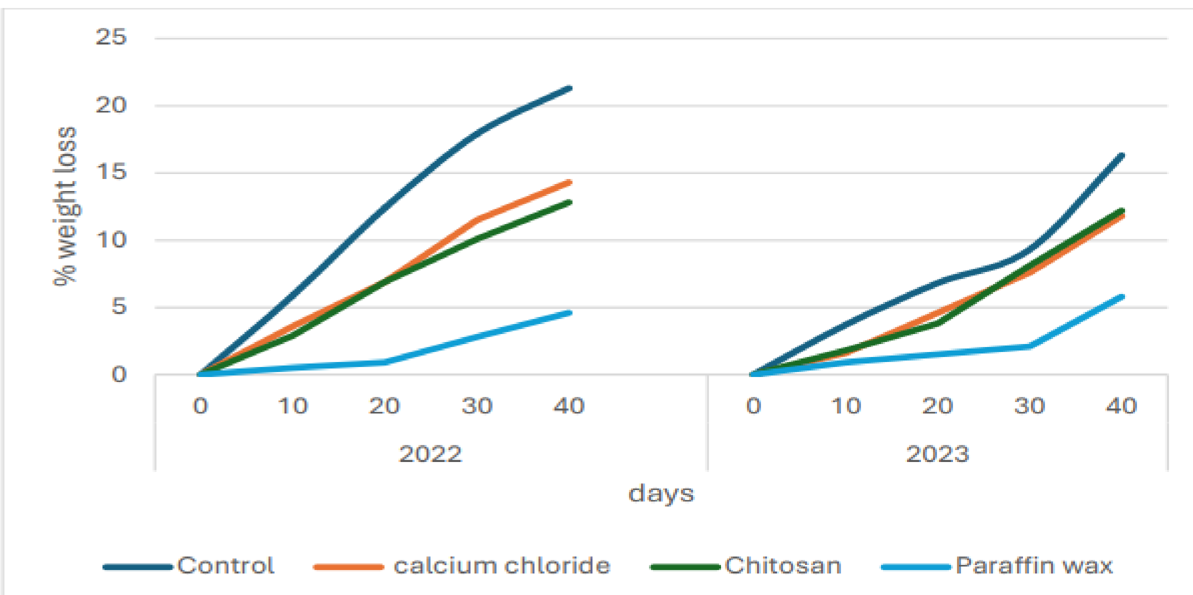

Figure 2. Impact of post-harvest treatments on fruit damage (%) during cold storage in the 2022 and 2023 seasons of mangos cv. Ewaise fruits.

3.2. The firmness and marketable percentage

Data presented in Tables (1, and 2) showed the effect of chitosan, calcium chloride, and paraffin wax on the firmness and marketable percentage of "Ewaise" mangoes during cold storage in the 2022 and 2023 seasons. It was obvious that results took a similar trend during the two studied seasons. Data in the current tables clearly that the firmness and marketable percentage markedly decreased with the advance of the cold storage period. These characteristics gradually decreased starting at the start of cold storage and continued for 20 days, then a rapid decrease until the 40 days. The firmness and marketable percentage decrease during storage, reaching values of (80.6 & 83.2 g/cm²) and (55.3 & 67.5%) after 40 days during the two studied seasons, respectively.

In response to coating types, it was apparent that all coating treatments significantly increase the firmness and marketable percentage during cold storage compared with control. Using paraffin wax gave the best results, which gave the highest firmness and marketable percentage of (162.9 & 173.9 g/cm²) and the marketable fruit percentage (92.9 & 94.3 %). No significant differences in firmness and marketable fruit percentage as a result of using chitosan or calcium chloride during the two study seasons, respectively.

The fruit firmness was (124.9, 149.7, 151.6 & 162.9) and (115.2, 156.7, 153.1 & 173.9 g/cm²) and marketable fruit percentage was (64.0, 78.9, 80.2 & 92.9) and (73.7, 88.5, 89.4 & 94.3 %) due to use control calcium chloride, chitosan and paraffin during the studied seasons, respectively. The data also demonstrated a strong association between the treatments and storage times for the firmness and marketable percentage of mango fruits in both seasons the firmness was attained (31.3, 88.4, 89.2 & 113.6 g/cm²) and (31.5, 86.5, 81.6 & 133.5 g/cm²) due to un-coat, calcium chloride, chitosan, and paraffin wax for each of the two seasons under study. Achieved was the matching, marketable fruit percentage. (23.8, 56.9, 57.6 & 82.9) and (73.0, 72.9, 75.0 & 84.9) respectively.

The fruit firmness and marketable fruit percentage were significantly decreased and attained (31.3, 88.4, 89.2 & 113.6) and (31.5, 86.5, 81.6 & 133.5 g/cm2), as well as (23.8, 56.9, 57.6 & 82.9) and (37.0, 72.5, 75.0 & 84.9 %) due to use control, calcium chloride, chitosan and paraffin in each seasons under study, respectively.

Table 1. Impact of post-harvest treatments on mango cv. "Ewaise" fruits' firmness (g/cm^2) during cold storage in 2022 and 2023.

	2022						2023					
Treatment	P0	P1	P2	P3	P4	M	P0	P1	P2	P3	P4	M
Control	191.4	169.8	134.3	97.8	31.3	124.9	201.6	163.8	105.4	73.9	31.5	115.2
Calcium chloride	195.3	178.1	158.6	128.2	88.4	149.7	200.6	191.2	158.2	147.2	86.5	156.7
Chitosan	194.6	186.2	163.8	124.3	89.2	151.6	196.8	187.5	161.3	138.3	81.6	153.1
Paraffin wax	193.5	189.6	178.2	139.5	113.6	162.9	202.3	198.9	173.9	161.1	133.5	173.9
M	193.7	180.9	158.7	122.5	80.6		200.3	185.4	149.7	130.1	83.2	
L.S.D at 5%	A: 2.24 B: 2.73 AB: 6.11						A: 2.38 B:2.53 AB: 5.63					

Table 2. Impact of post-harvest treatments on marketable fruit % of mango cv. "Ewaise" fruits in cold storage in 2022 and 2023.

	2022						2023					
Treatment	P0	P1	P2	P3	P4	M	P0	P1	P2	P3	P4	M
Control	100.0	80.7	64.3	51.4	23.8	64.04	100.0	91.0	77.9	62.4	37.0	73.7
Calcium chloride	100.0	87.8	79.8	70.0	56.9	78.9	100.0	98.4	88.7	82.4	72.9	88.5
Chitosan	100.0	88.4	81.4	73.5	57.6	80.2	100.0	98.2	91.0	83.0	75.0	89.4
Paraffin wax	100.0	99.5	92.8	89.5	82.9	92.9	100.0	99.1	94.4	92.9	84.9	94.3
M	100.0	89.1	79.6	71.1	55.3		100.0	96.7	88.0	80.2	67.5	
L.S.D at 5%	A: 3.32 B:3.91 AB: 8.75						A: 3.68 B: 4.10 AB:9.14					

Increment percentage of firmness attained (182.45, 184.98, & 262.94%) and (174.60, 159.05 & 323.81%), as well as marketable fruit percentage attained (139.08, 142.02 & 284.32%) and (97.03,102.7 & 129.46%) due to use calcium chloride, chitosan and paraffin wax compared to un-coat (control) during the two studied seasons, respectively. During the two seasons under study, there were no discernible variations in the proportion of marketable fruit and firmness caused by the application of chitosan or calcium chloride. The difference in the decrease of firmness and marketable fruit percentage depends on the coating type used where the use of paraffin wax gave the highest firmness and marketable proportion of fruits in relation to the other interventions. The results indicated that using coating treatments proved effective in reducing the firmness and marketable fruit percentage, hence, keeping the mango fruits for a long period with the best fruit quality and appearance.

3.3. Fruit characteristics

Tables (3 to 7) display data shown the impact of chitosan, calcium chloride, and paraffin wax on Ewaise mangoes during cold storage in the 2022 and 2023 seasons. It was obvious that results took a similar trend during the two studied seasons. Data in tables (3,4, and 5) clear that total soluble solids (TSS), reducing sugars and total sugars were considerably raised with the progression of the cold storage time. These characteristics steadily grew from the start of cold storage to the 20-day period, then a rapid increase until the 40 days. TSS, total sugars, and reducing increased during storage, obtaining values of (22.9 & 22.0%), (15.0 &14.5 %) and (5.8 & 5.2 %) after 40 days. TSS was significantly increased and attained (16.8, 19.4, 20.6, 22.5 & 22.9%) and (17.4, 20.5, 21.5, 22.2 & 22.0 %) due to storage for 0, 10, 20, 30 and 40 days during the two studied seasons, respectively.

In response to coating types, it was apparent that all coating treatments significantly decreased the TSS and sugar contents during cold storage compared with control. Using paraffin wax gave the greatest outcomes, with the lowest rate of TSS (18.8 & 19.5%) and total sugar (12.2 & 12.5%). The TSS was attained (22.0, 20.4, 20.4 & 18.8%) and (22.1, 20.9, 20.3 & 19.5%) due to un-coat, calcium chloride, chitosan, and paraffin wax over each of the two study seasons. Following suit, the proportion of total sugars was reached. (14.5, 13.3, 14.4 & 12.2) and (14.7, 13.9, 13.4 & 12.9%) respectively. No significant differences in TSS and total sugars due to the use of calcium chloride or chitosan.

The decrement percentage of TSS attained (7.27, 7.27 & 14.55%) and (5.43, 8.14 & 11.76%), due to the use of calcium chloride, chitosan, and paraffin wax compared to un-coat (control) during the two studied seasons, respectively.

Data also showed that there was a strong interaction among treatments and storage periods for TSS and sugar content percentages of mango fruits in both seasons. The TSS was attained (24.5, 22.8, 23.0 & 1.21%) and (21.6, 21.8, 21.7 & 20.7%) due to un-coat, calcium chloride, chitosan and paraffin wax throughout the two study seasons, respectively. Hence, the decreasing percentage of TSS obtained (6.94, 6.12 & 13.88 %) and (7.62, 8.5 & 12.29%), due to the use of calcium chloride, chitosan, and paraffin wax compared to un-coat (control) during the two studied seasons, respectively.

Also, data in tables (6 and 7) cleared that vitamin C and total acidity were markedly decreased with the advance of the duration of cold storage. These characteristics steadily grew from the start of cold storage to the 20-day period, then a rapid increase until the 40 days. Vitamin C and total acidity decreased during storage, reaching values of (32.9, & 35.4 mg/100ml) and (0.318 & 0.328%) after 40 days. Vitamin C was significantly decreased and attained (38.5, 36.9, 35.9 & 32.9%) and (40.6, 39.1, 38.1, 37.1 & 35.4%) due to storage for 0, 10, 20, 30, and 40 days during the two studied seasons, respectively.

In response of coating types, it was apparent that all coating treatments significantly increased the vitamin C and total acidity during cold storage compared with control. Using paraffin wax gave the best results, which gave the highest vitamin C (36.92 & 38.6 %). The vitamin C was attained (34.2, 35.6, 35.9 & 36.9%) and (37.5, 38.1, 38.0 & 38.6 mg/100 ml) due to un-coat, calcium chloride, chitosan, and paraffin wax in each of the two seasons under investigation. The matching increase % was obtained. (4.09, 4.97 & 7.89) and (1.6, 1.33 & 2.93%) respectively. No significant differences in vitamin C and total acidity due to the use of calcium chloride or chitosan.

The data also showed that, for both seasons' mango fruit acidity percentages and vitamin C content, there was a substantial interaction between treatments and storage times. The two seasons under study yielded the highest levels of vitamin C (30.3, 33.1, 33.5 & 34.8%) and (34.1, 35.5, 35.1 & 36.8 mg/100ml) due to un-coat, calcium chloride, chitosan, and paraffin wax, respectively. Hence, the increment percentage of vitamin C attained (9.24, 10.56 &14.85%) and (4.11, 2.93 & 7.92%), due to the use of calcium chloride, chitosan, and paraffin wax compared to un-coat (control) during the two studied seasons, respectively.

The variation in fruit characteristics depends on the coating type used where the use of paraffin wax gave the least alteration of fruit characteristics compared to the other treatments. The results indicated that using coating treatments proved effective in maintaining the properties and appearance of fruit that kept the mango fruits for a long period.

Table 3. Impact of post-harvest treatments on T.S.S (%) during cold storage in the 2022 and 2023 seasons of mango cv. “Ewaise” fruits.

	2022						2023					
Treatment	P0	P1	P2	P3	P4	M	P0	P1	P2	P3	P4	M
Control	16.8	21.8	22.4	24.6	24.5	22.0	17.4	21.8	23.6	24.2	23.6	22.1
Calcium chloride	16.8	19.8	20.2	22.5	22.8	20.4	17.4	21.0	22.3	22.1	21.8	20.9
Chitosan	16.8	18.6	20.8	22.8	23.0	20.4	17.4	20.1	20.7	21.8	21.7	20.3
Paraffin wax	16.8	17.3	18.8	20.1	21.1	18.8	17.4	19.2	19.5	20.7	20.7	19.5
M	16.8	19.4	20.6	22.5	22.9		17.4	20.5	21.5	22.2	22	
L.S.D at 5%	A:0.46 B:0.51 AB: 1.15						A: 0.48 B: 0.53 AB: 1.18					

Table 4. Impact of post-harvest treatments on the mango cv. “Ewaise” fruits' total sugars (%) during cold storage in the seasons of 2022 and 2023.

	2022						2023					
Treatment	P0	P1	P2	P3	P4	M	P0	P1	P2	P3	P4	M
Control	10.9	14.1	14.7	16.1	16.6	14.5	11.8	14.6	15.5	15.9	15.8	14.7
Calcium chloride	10.9	12.9	13.2	14.7	14.9	13.3	11.8	13.9	14.6	14.8	14.6	13.9
Chitosan	10.9	12.1	14.1	14.9	14.9	13.4	11.8	13.4	13.6	14.2	14.1	13.4
Paraffin wax	10.9	11.2	12.3	13.1	13.6	12.2	11.8	12.8	12.9	13.5	13.6	12.9
M	10.9	12.6	13.6	14.7	15		11.8	13.7	14.2	14.6	14.5	
L.S.D at 5%	A: 0.31 B: 0.35 AB: 0.78						A: 0.36 B: 0.41 AB: 0.91					

Table 5. Impact of post-harvest treatments on the mango cv. “Ewaise” fruits' reducing sugars (%) during cold storage in the seasons of 2022 and 2023.

	2022						2023					
Treatment	P0	P1	P2	P3	P4	M	P0	P1	P2	P3	P4	M
Control	4.2	5.4	5.6	6.2	6.4	5.7	4.4	5.4	5.8	5.9	5.9	5.5
Calcium chloride	4.2	4.9	5.1	5.6	5.7	5.1	4.4	5.1	5.4	5.5	5.6	5.2
Chitosan	4.2	4.7	5.4	5.7	5.8	5.2	4.4	4.9	5.0	5.3	4.1	4.7
Paraffin wax	4.2	4.2	4.7	5.0	5.2	4.7	4.4	4.7	4.8	5.1	5.2	4.8
M	4.2	4.8	5.2	5.6	5.8		4.4	5.0	5.3	5.5	5.2	
L.S.D at 5%	A:0.16 B:0.18 AB: 0.40						A: 0.18 B: 0.20 AB: 0.44					

Table 6. Impact of post-harvest treatments on mango c.v. "Ewaise" fruits' V.C. (mg/100g) during cold storage in the seasons of 2022 and 2023.

	2022						2023					
Treatment	P0	P1	P2	P3	P4	M	P0	P1	P2	P3	P4	M
Control	38.5	36.1	34.3	31.8	30.3	34.2	40.6	38.7	37.5	36.6	34.1	37.5
Calcium chloride	38.5	36.8	35.8	33.7	33.1	35.58	40.6	39.2	38.1	37.3	35.5	38.1
Chitosan	38.5	37.2	35.9	34.2	33.5	35.86	40.6	39.0	38.3	36.9	35.1	38
Paraffin wax	38.5	37.6	37.5	36.2	34.8	36.92	40.6	39.3	38.6	37.6	36.8	38.6
M	38.5	36.9	35.9	34	32.9		40.6	39.1	38.1	37.1	35.4	
L.S.D at 5%	A:0.93 B:1.22 AB: 2.67						A: 1.03 B: 1.36 AB: 3.03					

Table 7. Impact of post-harvest treatments on mango cv. "Ewaise" fruits'total acidity (%). (mg/100g) during cold storage in the seasons of 2022 and 2023.

	2022						2023					
Treatment	P0	P1	P2	P3	P4	M	P0	P1	P2	P3	P4	M
Control	0.361	0.338	0.316	0.298	0.301	.3228	0.375	0.348	0.326	0.309	0.310	0.336
Calcium chloride	0.361	0.343	0.331	0.325	0.313	0.3346	0.375	0.351	0.338	0.334	0.320	0.344
Chitosan	0.361	0.340	0.336	0.325	0.318	0.336	0.375	0.347	0.345	0.345	0.328	0.348
Paraffin wax	0.361	0.350	0.350	0.344	0.340	0.349	0.375	0.360	0.365	0.355	0.355	.0362
M	0.361	0.343	0.333	0.323	0.318		0.375	0.352	0.344	0.336	0.328	
L.S.D at 5%	A: 0.011 B:0.012 AB: 0.025						A: 0.012 B: 0.013 AB:0.027					

4. Discussion

A crucial step in the production and quality of fruit is handling and storage. The longer the storage period, the greater the fresh weight loss and fruit decay percentage. Due to weight loss and shrinkage, fruits can lose a significant amount of water during storage, which can cause damage and deterioration. (Ben-Yehoshua, 2005). The fruit loses weight as a result of its respiration mechanism, humidity transfer, and other internal moisture evaporation processes. (Hassan *et al*., 2014).

Water loss via transpiration and respiration processes is the primary cause of fresh fruit and vegetable weight loss. Increased respiratory metabolism of the fruits and increased water loss from the chitosan coating on the fruit surface might be the cause of the increased weight loss of mango fruits during storage. (Zhu *et al*., 2008; Abbasi *et al*., 2009; Elsabee & Abdou, 2013 ; Wang *et al*., 2014).

Paraffin oil is a notable edible coating due to its high safety, non-toxicity, biocompatibility, and affordability. It forms a thin, protective layer on the fruit's skin, reducing moisture loss during storage and inhibiting the growth of certain microorganisms like fungi and bacteria. This helps prevent spoilage and extends the fruit's shelf life. Paraffin oil also alters the atmosphere around the fruit's surface during storage by reducing available oxygen and increasing CO_2 levels (Magashi and Bukar, 2006; Tiwary and Singh, 2018; Dawood *et al*., 2023).

Losses in firmness as the storage time goes on because mango fruits develop and more enzymes that break down cell walls are active, such as pectatelyases, pectinesterase, polygalacturonase, and pectin methylesterase during ripening and cold storage (Ali *et al*., 2004). Climacteric fruits produce more CO_2 in the cell wall, which enhances the activity of hydrolyzing enzymes. (Zhu *et al*. 2008; Abbasi *et al*., 2009; Medeiros *et al*., 2012; Hong *et al*., 2012; Yu *et al*., 2012; Elsabee & Abdou, 2013; Shi *et al*., 2013). The calcium ions in fruit are linked to firmness and are thought to reinforce the middle lamella and other cell walls by holding the cells together, which slows down the processes of ripening and senescence (Vicente *et al*., 2007). Chitosan coating has significant promise for extending the mango fruit's (cv. White Chaunsa) postharvest storage life. During fruit storage, chitosan coating effectively reduced the rate of postharvest degradation while maintaining the The titratable acidity, hardness, weight loss, peel color, and total soluble solids of the fruit. Mango fruit's high ascorbic acid, total phenolic content, and antioxidant activity were maintained throughout storage thanks to the chitosan coating, which also reduced the rate of respiration and ethylene formation. This implies that coating with chitosan enhances antibacterial qualities and reduces permeability to water and gas exchange. Thus, in addition to decreasing the frequency of decay, chitosan-coating efficiently regulates reduces ethylene synthesis and respiration rate in addition to weight loss, delaying the ripening and senescence of fruit. Thus, it may be said that mango fruit can have its shelf life increased by using chitosan (Kundu *et al*., 2020).

Additionally, chitosan and calcium edible coating modify gas diffusion, which in turn modifies the exchange of CO_2 and O_2 between fruit tissue and the surrounding air. Fruit moisture is preserved, and typical metabolic activity is decreased, which delays textural changes and slows down the ripening process in mangos. (Wang *et al*., 2007; Zhu *et al*., 2008).

The impact of coating procedures on TA preservation and lowering the buildup of TSS in mango fruit was most likely caused by a superior semi-permeable barrier surrounding the fruit, which modifies the interior atmosphereby raising carbon dioxide and decreasing oxygen, slowing respiration, and suppressing metabolic activity and ethylene production rates. Therefore, delaying the process of ripening. (Singh *et al*., 2007; Wang *et al*., 2007; Zhu *et al*., 2008; Abbasi *et al*., 2009; Medeiros *et al*., 2012; Hong *et al*., 2012; Yu *et al*., 2012; Elsabee & Abdou, 2013; Shi *et al*., 2013). Thus, mango fruits treated with coatings of chitosan and calcium chloride, particularly those treated in combination, seemed to inhibit metabolic activities, postponing the decrease in TA content and restricting the rate at which the TSS content of the mango fruits changed during storage. The increased increase in mango fruit content in TSS with time may also be related to the breakdown of carbs into sugars brought on by moisture loss and a drop in acidity. (Golding *et al*., 2005). Furthermore, because citric acid is converted to sugars and then used in the fruit's metabolic process, the acidity of the fruit is reduced. (Doreyappy-Gowda & Huddar, 2001; Rathore *et al*., 2007). These outcomes correspond with those attained by Chitarra *et al*. (2001), Kittur *et al*. (2001), Singh *et al*. (2007), Wang *et al*. (2007), Zhu *et al*. (2008), Abbasi *et al*. (2009) and Hojo *et al*. (2009) on mango fruits. They found that during fruit storage, chitosan and calcium chloride reduced the fruit's TSS and TSS/TA ratio while maintaining the fruit's TA content. Furthermore, they noticed that while the TSS and TSS/TA ratio gradually and significantly increased, the fruit content in TA gradually and dramatically decreased over the course of the cold storage period.

Mango fruits' total soluble solids and sugar contents steadily rose as storage duration increased. Similarly, with date fruits (Afoakwa and Sefa-Dedeh, 2001; Azelmat *et al*., 2005) who observed that the insoluble chemicals present caused a slow rise in TSS and sugar levels over time.

5. Conclusion

According to this study, coating mangoes cv. "Ewaise" with chitosan, calcium chloride, or paraffin wax is a potential method for maintaining postharvest quality and boosting storability for 40 days at 13ºC and 85–90% RH.

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Conflicts of Interest

The authors disclosed no conflict of interest.

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