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INFLUENCE OF STORAGE CONDITIONS ON THE QUALITY ATTRIBUTES OF STRAWBERRY

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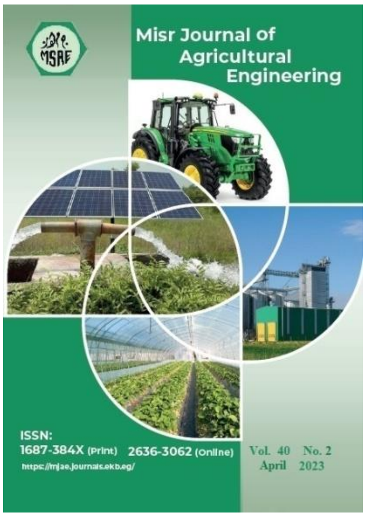

Keywords:
Strawberry; Storage temperatures; Packing; Punnets open-top and Clamshell.

ABSTRACT

The strawberry fruits are highly perishable, has a rapid metabolic rate, and significant levels of substances that are conducive to the growth of pathogenic organisms, including dampness, organic acids, and sugars. The post-harvest shelf-life is shortened as a result of these organisms. Therefore, the present study's objective was to investigate the effects of cold storage on fully ripened strawberry fruit's qualitative characteristics. This experiment was performed in 2020 and 2021 seasons at Badr city, Beheira Governorate. The present study was conducted to assay the influence of the storage conditions on the quality attributes of strawberry fruits. Experiments were carried out with one variety of strawberry (Sensation) fruits, two types of packing punnets (open-top and clamshell) and three temperatures (2, 4 and 6°C). Results indicated that the application of stored at 6°C treatment was the most effective in reducing vitamin C followed by 4°C and no significant effect on mass loss, size and firmness. In other hand, clamshell punnets were the more effective than open-top punnets and interaction 2°C with clamshell. Storage at a temperature of 6°C is better in terms of using less energy and, accordingly, the cost. Therefore, the study recommends any punnets and using packing types as there is no significant difference in it.

1. INTRODUCTION

Strawberry is a non-climacteric fruit and it should be harvested at full or half maturity color to achieve the height quality in relation to flavor and color. The fruits have short shelf life and are highly perishable, with a high rate of respiration, and suffer relatively high post-harvest losses due to fungal development, mechanical injury, physiological deterioration and water loss **(Cordenunsi et al., 2005)**. Egypt is one of the world's strawberry producing and exporting countries and have an export window, the cultivation area of strawberry in 2020 was 15345 ha, 5.71 times higher than that in 2000, whereas the production increased 8.46 times in 2020 to 0.597 million metric tons **(FAOSTAT, 2022)**. Similarly, **(Yang et al., 2020)** indicated that the market share of strawberry which reached $15.9 billion in 2016 is still exploding at the compound annual growth rate of over 5%, and is predicted to reach 10 million metric tons by 2025. Furthermore, around 80% of the strawberry fruits distributed in the market are consumed as fresh, whilst the remaining 20% is utilized for processing in food and/or pharmaceutical industry **(Hong, Yeoung, and Eum, 2018)**. Backing room temperature, however, postharvest senescence, decay and physiological deterioration of strawberry fruits occur very rapidly (due to their high-water percentage ranging from 82 – 88%, and high-metabolic activity), which substantially limit their storage time to only 1–2 days, affecting fruit quality and marketability, and consequently resulting in huge losses **(Ljubica Karakasova, 2017; Zhang et al., 2022)**. To overcome such problems, low temperature (1 – 6°C) and packing are usually used for strawberry during storage, by which the senescence and physiological deteriorations can be delayed. Besides low temperature, packaging in clamshell punnets plays a crucial role for fruit storage, and it was observed to act as a physical barrier that maintains moisture and vapor pressure around the strawberries and consequently minimizes mass loss **(Lan, Zhang, Ahmed, Qin, and Liu, 2019)**. Also, mass loss mainly occurs owing to water loss by transpiration and loss of carbon reserves as a result of respiration. The rate of such loss is dependent on the variation in water pressure between the fruit tissue and the surrounding atmosphere **(Sogvar, Koushesh Saba, Emamifar, and Hallaj, 2016)**, as well as the temperature. Moreover, moisture loss and gaseous exchange from the fruits are usually controlled by the epidermal provided by guard cells and stomata. Mass loss of fruit is mainly due to the water vapor transpiration. Water gets lost from fruit through the entire produce surface, and especially through openings including stomata, wound openings **(Zhe Wang et al., 2014)**. Therefore, the objective of the existing work is setting the fundamental information and technological data regarding the changes in the quality characteristics of strawberry fruits during storage, which can provide the scientific basis for further research in fruit storage.

2. MATERIALS AND METHODS

Two main experiments were conducted at Badr city, Beheira Governorate, Egypt during the two seasons of 2020 and 2021 (February) to assay the influence of the storage conditions on the quality attributes of strawberry fruits. The fruits were stored in two types of packing pannets (open-top and clamshell) under varying temperatures (2, 4 and 6°C) and time (0 – 15 days). To accomplish the main goal of such research, destructive (i.e., mechanical and chemical traits) and non-destructive (i.e., physical characteristics) analyses were comprehensively investigated to quantify the changes in the quality properties of strawberries during storage process.

2.1. Strawberry fruits and storage conditions:

Raw materials:

Strawberries (***Fragaria* × *anannasa*** Duch), cv. ‘Sensation’, used for experiment, were hand-harvested [from a commercial farm “modern agriculture company **(PICO)** in February 2020 and 2021 at commercial maturity stage, and transported immediately, under refrigerated conditions (4°C), within 1 h to the laboratory at Bader city where they were processed. The fruits were manually sorted to eliminate physical/ mechanical damage and/or pathological defects. Thereafter, strawberries (after grading process) of uniform size, shape, ripeness and color without visible defects were chosen as experimental materials.

Storage conditions:

The fruits were pooled before packaging into 210 commercial packing punnets (containing approximately 300 g ± 10 g ≈ 12-15 fruit each) distributed as follows: 105 clamshells and 105 open-top punnets). Fruits, after packaging, were precooled at every temperature of study for about an hour to equilibrium to the temperature prior to experiments. The packing punnets (for each- clamshells and open-top) were randomly divided into three groups, placed in trays, and afterward stored at 2, 4 and 6°C [under 95% relative humidity **(Barikloo and Ahmadi, 2018a)**] for 15 days. Each treatment contained five (5) replicates and the entire experiments were repeated twice .The refrigeration chamber used for this research measures 18 meters long, 12 meters wide, and 4.5 meters high. It is made of sandwich panels with a 10 cm thickness, which are integrated roof and wall components and have good insulating properties. These panels are made of two shear-resistant, thin stainless-steel sheet facings that are attached to one another from the internal and external surfaces of an insulated core. These prefabricated panels have insulated polyurethane (40 kg/m^3 density, 0.0205 W/m.K thermal conductivity) injected between them.

Packaging type:

Two common types of commercial packaging materials (including clamshell and open-top punnets) were used to pack 300g ± 10g of strawberries. An open-top punnet as in fig. (1A) can interact with the surrounding environment, whereas a clamshell punnet as in fig. (1B) is a semi-insulated to interact with the surrounding environment Fig. (1) showed packing type of strawberry.

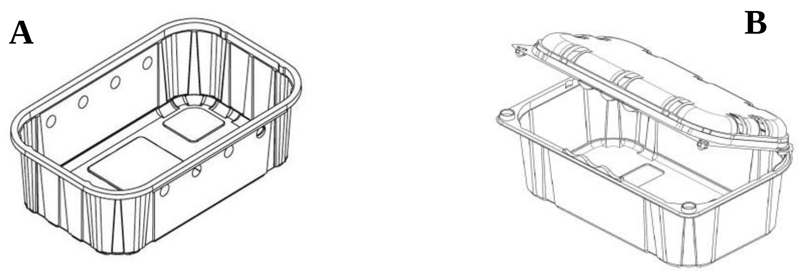

Fig. (1): Packing type of strawberry.

2.2. Quality Evaluations:

In this investigation, the quality attributes of stored fruits at varied experimental conditions were comprehensively assessed. Such properties include physical (i.e., mass, size), mechanical (i.e., firmness), and chemical (i.e., vitamin C) attributes were qualitatively examined to further comprehend the effect of storage conditions on the quality attributes of strawberry fruits.

2.2.1 Physical properties:

2.2.1.1 Mass loss percentage "W_L":

Mass loss (W_L) was evaluated by measuring the mass of fruits in the same package punnet at the beginning (zero day) and during storage period (15 days) at different temperatures. Fruits were weighed using a Digital Electrical Balance (YHC weighing excellence, Wonderscales, China). The mass measured at zero day was set as reference mass. The mass loss was computed as follows**:**

$$\mathbf{WL}\ (\%) = \frac{\mathbf{W_0 - W_t}}{\mathbf{W_0}}\ \mathbf{x\ 100} \qquad \textbf{(1)}$$

where, W_0 is the initial mass (at zero day) of the strawberry fruits in the punnet (g); and W_t (g) represents the mass of fruits at any time during storage period (15 days).

2.2.1.2 Size:

To measure the changes in the size of the strawberries during storage process, the graduated cylinder (500ml) was used. The cylinder was filled with water at a certain volume (V_i). Thereafter, fruit was placed in the cylinder. Volume (V_f) of resultant was then noted. The size of the fruit was quantified during storage period with the aid of the following equation:

$$\textbf{Strawberry volume (ml)} = \boldsymbol{V_f - V_i} \qquad \textbf{(2)}$$

Where, V_i signifies the volume of water (ml); and V_f represents the volume of water and fruit together (ml).

2.2.2 Mechanical properties:

2.2.2.1 Firmness:

Firmness of strawberry was determined using a penetrometer (Fruit Pressure Tester, Model FT 327, Facchini Srl, Alfonsine, Italy) equipped with a flat 3mm-diameter stainless steel cylinder probe. The probe was pressed with a constant force to a depth of 0.5 cm in order to overcome the resistance from skin elasticity, and the mean stress was then recorded. Two different measurements were conducted on two opposite sides of central zone of 5 strawberries. Results (average) of five replicates were then recorded in mg/cm^2.

2.2.3 Chemical properties:

2.2.3.1 Vitamin C assay:

The titration method (with 2, 6- dichlorophenolindophenol (DCPIP)) outlined by **(A.O.A.C., 2000)** was applied to quantify the content of vitamin C (mg/100g fresh mass) using different ascorbic acid concentrations for the standard curve. Titration was done using the standard ascorbic acid and dye solution until a pink colored end point was obtained. Briefly, 50g of strawberries were homogenized using an electric blender (electric blender mod. JB3010 Braun, Germany) after chopping into pieces. Afterward, 10 of the extract was (up to 100mL) using 3% metaphosphoric acid. Five milliliters of diluted solution were filtered (using Whatman (No.1) filter paper), and titrated with DCPIP indicator until an end point of changed color appeared. Computations were done as follows **(Bhat et al., 2016; Sogvar et al., 2016)**:

$$\textbf{Vitamin C (mg/100g)} = \frac{\textbf{(Titer x Dye factor x Concentration x 100)}}{\textbf{(Extract aliquot used for estimation x Volume of sample used for estimation)}} \qquad \textbf{(3)}$$

2.3 Statistical analysis:

Analysis of variance (ANOVA) was performed to assay the impact of the experimental variables (i.e., temperature, time and packing type) on the quality attributes of strawberry fruits during storage process. One-way ANOVA using MINITAB version 18 software (Minitab Inc., Pennsylvania, USA) was performed on the data and the results/outcomes displayed as mean values ± standard deviation of triplicate determinations. Means of statistically significant for the various measured parameters were compared via Tukey's pairwise comparison analysis considering a 5% probability value and alphabetical notations used as superscripts to mark the differences at significant levels.

3. RESULTS AND DISCUSSION

3.1. Effect of Storage Conditions on Physical Properties of Strawberry:

3.1.1. Mass Loss (%):

Mass loss is indicative of the rate of fruit shriveling and moisture loss over storage time. It is mostly ascribed to the thin skin of fruits and the migration of water from their tissues to the environment **(Lan et al., 2019)**.

Table (1) displays the influence of storage temperature, packing type and time as well as their interactions on the mass loss of strawberries. It was observed, from the Table (1), that the mass loss decreased from 2.063 to 1.938% with the increase in storage temperature ($p > 0.05$). The highest value of mass loss was noticed at 2ºC, whereas the lowest value was at 4ºC. These phenomena are possibly linked to the convergence in the temperature range of experiment 2, 4 and 6°C, resulting in the values of mass loss were close and also not significant, which was consistent with the findings reported by **(Guerreiro, Gago, Miguel, and Antunes, 2013)**. However, the mass loss was significantly increased ($p < 0.05$) from 0 to 4.262% during storage (from day 1 to 15, respectively). Further, the mass loss at the end of the storage was 58% greater than that at day 7 ($p < 05$). This is mostly attributable to Strawberry fruits are highly susceptible to rapid water loss which results in fruit shrinkage. Such outcomes were consistent with that observed by **(Ktenioudaki et al., 2019)** who indicated that mass loss of strawberries constantly increased with the prolongation of storage time.

Table (1): Effect of Storage Temperature, Packing type and Storage Period on Mass Loss (%) of Strawberries.

Treatments		Mass Loss (%)			Mean
		D_1	D_2	D_3	
Temperature*Date (T*D)					
2ºC		0 c	1.815 b	4.375 a	2.063 A
4ºC		0 c	1.735 b	4.080 a	1.938 A
6ºC		0 c	1.815 b	4.330 a	2.048 A
Package*Date (P*D)					
P1		0 c	1.780 b	4.283 a	2.021 A
P2		0 c	1.797 b	4.240 a	2.012 A
Temperature* Package*Date (T*P*D)					
2ºC	P1	0 c	1.790 b	4.410 a	2.067 A
	P2	0 c	1.840 b	4.340 a	2.060 A
4ºC	P1	0 c	1.760 b	4.110 a	1.957 A
	P2	0 c	1.710 b	4.050 a	1.920 A
6ºC	P1	0 c	1.790 b	4.330 a	2.040 A
	P2	0 c	1.840 b	4.330 a	2.057 A
Mean (D)		0 C	1.788 B	4.262 A	

D_1: 1st day, D_2: 7th day and D_3: 15th day.

P_1: Open-Top Punnet and P_2: Clamshell Punnet.

Regarding the effect of the packing type on mass loss during the storage period, it was concluded that the mass loss values in P_1 (open-top Punnet) and P_2 (clamshell Punnet) were 2.021% and 2.012%, respectively, with a non-significant difference between them. Nonetheless, the mass loss was considerably increased ($p < 0.05$) from 0 to 4.283% and from 0 to 4.240% for P_1 and P_2, respectively during storage (from day 1 to 15, respectively). Further, the mass loss at the end of the storage was 58.4% and 57.6% higher than that at day 7 for containers P_1 and P_2, respectively, as it turns out that mass loss in P_1 is greater than P_2.

This probably due to that P_2 (clamshell Punnet) act as a physical barrier that maintained moisture and vapor pressure around the strawberries inside the packaging by the holes distributed on both sides of the package, contributing to proper ventilation and providing the ideal atmosphere inside the package and consequently reduced water and mass losses **(Jalali et al., 2019)**. However, in P_1(open-top punnet), strawberry fruits lose water to the atmosphere by transpiration due to heat of respiration and gradient in water potential between produce surface and surrounding because the punnet without cover and therefore water vapor diffuses into the atmosphere, causing an increase of mass loss. Comparable outcomes have been indicated in earlier reports **(Jalali et al., 2019; Lan et al., 2019)**.

Concerning the effect of the interaction between the temperature and packing type during storage period, a significant difference in mass loss was found for all treatments. The mass loss for P_1 at the end of the experiment was 59.4, 57.2 and 58.6% more than that at the day 7 under varied temperatures 2, 4 and 6°C, respectively. Moreover, and the mass loss for P_2 at the end of the storage increased by 57.6, 57.7 and 57.5% in comparison with that at the day 7 under 2, 4 and 6°C, respectively. On the other hand, there are no significant differences between the temperature treatments and the packing type on mass loss. On average, the maximal mass loss (2.067%) was documented for P_1 at 2°C, and the least value was 1.920% for P_2 at 4°C. In addition, the highest and the minimal mass loss were 4.41 and 4.05% at the 15-day storage for P_1 at 2°C and P_2 at 4°C, respectively. Our findings indicated that mass loss is still within the maximum permissible water loss for strawberries before marketability, which is ranged from 2.5 to 6% **(Kelly, Madden, Emond, and do Nascimento Nunes, 2019)**.

3.1.2. Size of strawberry fruits:

The importance of studying the size of strawberry fruits is to determine the optimal methods to handling of strawberries. as well as determining the ideal number of strawberry fruits in the package, without causing damage to it, which contributes to prolonging shelf life of strawberries. Furthermore, it helps in knowing the spaces it occupies, which contributes to choosing the best cooling systems. In addition, we found a strong direct relationship between mass loss and size loss, as they are related to water loss from strawberry fruits.

Concerning data in table (2) indicate that the effect of Storage temperature on the size of strawberry fruits was not significant ($p > 0.05$); moreover, the size loss for strawberry fruits was greater at 4°C than at 2°C at the end of the storage period, It could be seen the size loss decreased from 31.25 to 23.65 and 32 to 24 ml for strawberries stored where it was 24.3% and 25% at 2°C and 4°C, respectively. Also observed that the size loss at the end of the second week was greater than the first week of the experiment, it was 14.9, 13.6 and 14% in the second week at 2, 4 and 6°C, respectively. And it was 11.04, 13.12 and 11.18% in the first week at 2, 4 and 6°C, respectively.

Table (2): Effect of Storage Temperature, Packing type and Storage Period on Size (ml) of Strawberries.

Treatments		Size (ml)			Mean
		D_1	D_2	D_3	
Temperature*Date (T*D)					
2ºC		31.25 a	27.80 b	23.65 c	27.57 A
4ºC		32.00 a	27.80 b	24.00 c	27.93 A
6ºC		31.30 a	27.80 b	23.90 c	27.67 A
Package*Date (P*D)					
P_1		31.43 a	27.93 b	23.67 c	27.68 A
P_2		31.60 a	27.67 b	24.03 c	27.77 A
Temperature* Package*Date (T*P*D)					
2ºC	P_1	31.00 ab	27.90 bc	23.00 d	27.30 A
	P_2	31.50 a	27.70 c	24.30 d	27.83 A
4ºC	P_1	32.00 a	28.00 bc	24.00 d	28.00 A
	P_2	32.00 a	27.60 c	24.00 d	27.87 A
6ºC	P_1	31.30 a	27.90 bc	24.00 d	27.73 A
	P_2	31.30 a	27.70 c	23.80 d	27.60 A
Mean (D)		31.52 A	27.80 B	23.85 C	

D_1: 1st day, D_2: 7th day and D_3: 15th day.

P_1: Open-Top Punnet and P_2: Clamshell Punnet.

As for the effect of the packing type on the size of strawberry fruits, it was found that the size loss in P_1 is greater than in P_2 at the end of the storage period, where size loss was 24.68% and 23.95% for each of P_1 and P_2, respectively, which is clear from it that P_2 was more preserved in the size of strawberry fruits than in P_1, although the difference between them was not significant. Moreover, the size loss at the end of the second week was greater than the first week of the experiment, in P_1 was 15.25% and 11.13%, respectively; in P_2 was 13.15% and 12.4%, respectively.

It could be concluded that the reason for the increase in size loss in P_1 (open-top punnet) more than in P_2 (clamshell Punnet) may be due to the strong relationship between mass loss and size loss resulting from the increased water loss from strawberry fruits. Moreover, P_2 was maintained water vapor and relative humidity inside it, which was helped to reduce the rate of decrease in mass loss and thus reduce the rate of size loss, while P_1 lacked it; These results trend agreed with those obtained by **(Jalali et al., 2019; Lan et al., 2019)**.

Regarding the effect of the storage period on size, it was a high significant effect on size loss during the storage period ($p < 0.05$), as the size decreased with increasing storage period, it was 31.52, 27.8 and 23.85 ml on the day 1, day 7 and day 15, respectively, size loss amounted to 24.33%. In addition, the rate of size loss of strawberry fruits in the second week of storage was 14.2% greater than that in the first week, which was 11.8%; it was observed a noticeable decrease of size during the storage period. We can observe that the size loss is directly proportional to the mass loss in strawberry fruits, when the mass loss increases, the size loss increases. Such outcomes were consistent with that observed by **(Barikloo and Ahmadi, 2018b)** who indicated that fruit ripening, respiration and ethylene production during storage lead to increased mass loss, consequently, fruit size decreases and size loss increasing due to softening of texture.

It was observed, the interaction effect between the temperature storage and the packaging type during the storage period, it was found that a significant difference between all treatments during the storage period. It could be seen the highest value of size loss was 25.8%, the size loss decreased from 31 to 23 ml noticed in P_1 at 2ºC then followed by 25% and 23.3% at 4 and 6°C, respectively, whereas the lowest value was 22.8%, the size loss decreased from 31.5 to 24.30 ml in P_2 at 2ºC and then increased 25% and 23.9% at 4 and 6°C, respectively, As it was also clear that the size loss of strawberry fruits increases in the second week of the experiment than in the first week for all treatments, as follow, in P_1 were 10-17.5%, 12.5-14.2% and 10.8-13.9% at 2, 4 and 6°C, respectively. In P_2 were 12-12.27%, 13.75-13% and 11.5-14% at 2, 4 and 6°C, respectively. Whether temperature or packing type over the storage period. Therefore, this is an indicator of the speed of deterioration in the size of strawberry fruits as the storage period increases.

3.2. Effect of Storage Conditions on Mechanical Characteristics:

3.2.1. Firmness "F":

One important fruit feature is how firm the strawberries are. The current research intervention revealed that firmness reduced in relation to storage time **(A. Ali et al., 2011)**. The information in table (3) illustrates how strawberry firmness (measured in mg/cm^2) is affected by storage temperature, packing type, and storage period.

According to Table (3), it was noted that no significant difference for the effect of temperature on firmness, the highest value of firmness was 305 mg/cm^2 at 2°C, and the lowest value of firmness was 302.3 mg/cm^2 at a 6°C. However, firmness was decreased slowly in strawberries stored at 2 and 4ºC i.e. 31.6% to 31.8%, respectively. In comparison, the firmness of strawberries decreased at higher rates at 6ºC, it was 34.4%. Where it recorded the firmness decreased from 361.5 to 247.0, from 361.5 to 246.5 and 357.5 to 244.5 mg/cm^2 for strawberries stored at 2°C, 4°C and 6°C, respectively. Also observed that the firmness loss increased with increasing temperature, meanwhile the firmness loss was greater at the end of the second week than the first week of the experiment, it was 15.2-19.4%, 15.4-19.3% and 14.6-19.8%% at 2, 4 and 6°C, respectively. Furthermore, the firmness had strong inverse correlation with mass loss, demonstrating that the decrease of firmness was closely associated with the effect of temperature and decreased vapor pressure resulted from water transpiration. Additionally, degradation of cell wall polysaccharides (cellulose, hemicelluloses and pectins) also contributed to the fruit softening **(Zhao et al., 2019)**. In contrast, some studies depicted consistency in firmness was maintained, or even increased during storage **(Shin, Liu, Nock, Holliday, and Watkins, 2007)**.

It also notes that the effect of the type of packing type is not significant on firmness, as it was found that the firmness in P_2 is higher than in P_1, where the values were found to be 304.2 and 303.7 mg/cm^2 in P_2 and P_1, respectively, with noted that there was a slight difference in the firmness loss in the two packages, It could be seen the firmness decreased from 360 to 245.3 and 360.3 to 246.7 mg/cm^2 which was 31.8% and 31.5% in P_1 and P_2, respectively. Where it recorded the firmness loss was greater at the end of the second week than the first week of the experiment, it was 15.08-19.75% and 15.15-19.29% in P_1 and P_2, respectively. On other hand, it may be clear that P_2 was better in maintaining the degree of firmness than P_1.

Table (3): Effect of Storage Temperature, Packing type and Storage Period on Firmness (mg/cm²) of Strawberries.

Treatments		Firmness (mg/cm²)			Mean
		D_1	D_2	D_3	
Temperature*Date (T*D)					
2ºC		361.5 a	306.5 b	247.0 c	305.0 A
4ºC		361.5 a	305.5 b	246.5 c	304.5 A
6ºC		357.5 a	305.0 b	244.5 c	302.3 A
Package*Date (P*D)					
P_1		360.0 a	305.7 b	245.3 c	303.7 A
P_2		360.3 a	305.7 b	246.7 c	304.2 A
Temperature* Package*Date (T*P*D)					
2ºC	P_1	363.0 a	308.0 b	248.0 c	306.3 A
	P_2	360.0 a	305.0 b	246.0 c	303.7 A
4ºC	P_1	361.0 a	306.0 b	244.0 c	303.7 A
	P_2	362.0 a	305.0 b	249.0 c	305.3 A
6ºC	P_1	356.0 a	303.0 b	244.0 c	301.0 A
	P_2	359.0 a	307.0 b	245.0 c	303.7 A
Mean (D)		360.2 A	305.7 B	246.0 C	

D_1: 1st day, D_2: 7th day and D_3: 15th day.

P_1: Open-Top Punnet and P_2: Clamshell Punnet.

It was observed, the effect of the storage period significantly on the firmness, as the firmness decreased with the increase in the storage period, where the values were 360.2, 305.7, 246.0 mg/cm^2 on day 1, day 7 and day15, respectively, with a rate of decrease in the firmness that amounted to 31.7%. Furthermore, the rate of firmness loss of strawberry fruits in the first week of storage was 15.13% less than that in the second week, which was 19.5%. Our result was consistent with the findings reported by **(Lan et al., 2019)** who reported that firmness decreased during storage period, Consistent with their higher mass loss. Moreover, strawberry firmness decreases either during ripening in the field or during storage regardless of the initial ripeness of the fruit.

Concerning the interaction of the temperature storage and packaging type during storage, a significant effect was observed for all interactions, as it was noted that there were no significant differences for packaging type (P_1 and P_2) at the same temperature, the highest value of the firmness was 306.3 mg/cm^2 for the P_1 package at 2°C, and the lowest value of the firmness was 301 mg/cm^2 in package P_1 at 6°C. Where it recorded the highest value of firmness loss rate was 32.4%, the firmness decreased from 361 to 244 mg/cm^2 noticed in P_1 at 4ºC then followed by 31.68% and 31.4% at 2 and 6°C, respectively, whereas the lowest value was 31.21%, the firmness decreased from 362 to 249 mg/cm^2 in P_2 at 4ºC and then increased 31.66% and 31.7% at 2 and 6°C, respectively. It is worthy to mention that the firmness loss rate of strawberry fruits in the first week less than the second week, as follow, in P_1 were 15.15-19.4%, 15.23-20.26% and 14.8-19.4% at 2, 4 and 6°C, respectively. In P_2 were 15.2-19.3%, 15.7-18.36% and 14.4-20.1% at 2, 4 and 6°C, respectively.

This trend was in agreement with the results obtained by **(Barikloo and Ahmadi, 2018a)** who indicated that there was a decreasing trend for firmness under storage conditions compared to an initial day for all treatments. Fruits softening and decreasing firmness not only is related to the conversion of insoluble protopectin into soluble pectin but also is associated with a decrease in hemicellulose. Moreover, the results show a significant difference between treatments of strawberries at various temperature levels, storage period, and packaging types .

3.3. Effect of Storage Conditions on Chemical Properties:

3.3.1. Vitamin C:

Referring to Table (4), it turns out that the effect of temperature on vitamin C was significant, as vitamin C decreases with increasing temperature, the vitamin C loss for strawberry fruits was greater at 6°C than at 2°C and 4°C at the end of the storage period, It could be seen the vitamin C decreased from 40.6 to 33.05, from 40.6 to 31.9 and 40.6 to 30.05 g/ml for strawberries stored where it was 18.59%, 21.42% and 25.98% at 2°C, 4°C and 6°C, respectively. Also observed that the vitamin C loss rate at the end of the first week was less than the second week of the experiment, it was 1.6-17.27%, 2.09-19.74% and 5.92-21.84% at 2, 4 and 6°C, respectively. Furthermore, the vitamin C had strong inverse correlation with mass loss. Our result was consistent with the findings reported by **(Ktenioudaki et al., 2019)** who indicated that the concentration of AA is influenced by environmental factors (including temperature and light intensity), and maturity at harvest. **(Bhat and Stamminger, 2016)** noted a decrease in ascorbic acid content during storage, particularly at temperature higher than 0°C. In addition, ascorbic acid showed high inverse correlation with storage time/ temperature, concentration of oxygen and exposure to light, indicating that ascorbic acid can considerably be affected by storage conditions. In contrast, some studies depicted the ascorbic acid concentrations then declined in fruit stored at 0.5°C and 20°C, but remained unchanged at 10°C **(Shin et al., 2007)**.

Concerning the effect of the packaging type on vitamin C, it was clear that it had a significant effect, as the value of vitamin C in P_2 was greater than in P_1, where the value of vitamin C was 37.27, 37.17 mg/100g for P_2 and P_1, respectively, it could be seen the vitamin C decreased from 40.6 to 30.4 and 40.6 to 32.93 mg/100g which was 25.12% and 18.89% in P_1 and P_2, respectively. Where it recorded the vitamin C loss was greater at the end of the second week than the first week of the experiment, it was 0.24-24.93% and 5.73-13.95% in P_1 and P_2, respectively. And thus, P_2 is more conserving vitamin C than package P_1. Considering, water loss may enhance loss of ascorbic acid because of increased oxidation **(Shin et al., 2007)**, where the water loss was lower in P_2 compared with P_1, and therefore P_2 was better in preserving vitamin C than P_1.

Table (4): Effect of Storage Temperature, Packing type and Storage Period on Vitamin C (mg/100g) of Strawberries.

Treatments		Vitamin C (mg/100g)			Mean
		D_1	D_2	D_3	
Temperature*Date (T*D)					
2ºC		40.6 a	39.95 b	33.05 e	37.87 A
4ºC		40.6 a	39.75 c	31.9 f	37.42 B
6ºC		40.6 a	38.45 d	30.05 g	36.37 C
Package*Date (P*D)					
P_1		40.6 a	40.5 b	30.4 e	37.17 B
P_2		40.6 a	38.27 c	32.93 d	37.27 A
Temperature* Package*Date (T*P*D)					
2ºC	P_1	40.6 a	40.5 b	30.7 i	37.27 C
	P_2	40.6 a	39.4 d	35.4 g	38.47 A
4ºC	P_1	40.6 a	40.6 a	30.4 j	37.2 D
	P_2	40.6 a	38.9 e	33.4 h	37.63 B
6ºC	P_1	40.6 a	40.4 c	30.1 k	37.03 E
	P_2	40.6 a	36.5 f	30.0 l	35.7 F
Mean (D)		40.6 A	39.38 B	31.67 C	

D_1: 1^{st} day, D_2: 7^{th} day and D_3: 15^{th} day.

P_1: Open-Top Punnet and P_2: Clamshell Punnet.

The effect of storage period on vitamin C was significant, as the concentration of vitamin C decreased with increasing storage period, where the values of vitamin C were 40.6, 39.38 and 31.67 mg/100g on day 1, day 7 and day15, respectively, with a decrease in vitamin C by the end of storage period 21.99%. Moreover, the rate of vitamin C loss of strawberry fruits in the first week of storage was 3.0% less than that in the second week, which was 19.57%; it was approximately six times the loss in first week. It is worthy to mention that Ascorbic acid, a predominant form of vitamin C, is known to be highly unstable **(Mishra and Kar, 2014)**, therefore, our result was agreement with that observed by **(Wang, Hu, Ding, Ye, and Liu, 2018)** who examined the effect of temperature as a function of time on the AA of strawberries. The outcomes displayed that AA content was decreased with prolongation of storage period. Loss of AA in fresh fruit and vegetables during storage has been attributed to various causes, such as tissue degradation as the product becomes overripe, cell wall damage and enzymatic oxidation caused by bruising, but also due to water loss which can intensify AA oxidation. Many other studies have also reported the loss of AA during storage of strawberries **(Ktenioudaki et al., 2019)**. In contrast, some studies depicted, the total AA content increased at the end of 9 days of storage indicating synthesis of ascorbic acid during storage as reported by **(Mishra and Kar, 2014)**.

As for the interaction of the temperature storage and packing type during the storage period on vitamin C, we found that all treatments are highly significant among themselves. Moreover, it becomes clear that the highest value of vitamin C was 38.47 mg/100g for P_2 at 2°C with the lowest rate decrease was 12.8% (decreased from 40.6 to 35.4 mg/100g) in the end of storage period. And the lowest value of vitamin C was 35.7 mg/100g for P_2 at 6°C, with the highest reduction was 26.1% (decreased from 40.6 to 30.01 mg/100g). Furthermore, for P_1, the rate of vitamin C decrease at the end of storage period was 24.38%, 25.12% and 25.86% at 2, 4 and 6°C, respectively. For P_2, the rate decrease of vitamin C at the end of storage period was 12.8%, 17.73% and 26.1% at 2, 4 and 6°C, respectively. Where it recorded the vitamin C loss rate of strawberry fruits in the first week less than the second week, as follow, in P_1 were 0.24-24.19%, 0.0-25.1% and 0.49-25.49% at 2, 4 and 6°C, respectively. In P_2 were 2.95-10.15%, 4.18-14.13% and 10.09-17.8% at 2, 4 and 6°C, respectively. Where an increase in the rate of vitamin C deficiency for both P_1 and P_2 is evident with an increase in temperature during the storage period, these results trend agreed with those obtained by **(Li, Ye, Jiang, and Luo, 2017; Mishra and Kar, 2014)**.

4. CONCLUSION

The open-top and clamshell packing punnets were used in the experiment to examine how the quality characteristics of strawberry were affected by storage temperatures of 2, 4, and 6°C (i.e. mass loss, size, firmness and Vitamin C). Following is a summary of the outcomes attained:

- The accumulated mass loss the mass loss was significantly increased from 0 to 4.262% during storage (from day 1 to 15, respectively). Further, the mass loss at the end of the storage was 58% greater than that at day 7. While, mass loss values in P_1 (open-top Punnet) and P_2 (clamshell Punnet) were 2.021% and 2.012%, respectively.
- The size decreased with increasing storage period, it was 31.52, 27.8 and 23.85 ml on the day 1, day 7 and day 15, respectively, size loss amounted to 24.33% at the end of storage period. Furthermore, the size loss for strawberry fruits was greater at 4°C than at 2°C at the end of the storage period, it could be seen the size loss decreased from 31.25 to 23.65 and 32 to 24 ml for strawberries stored where it was 24.3% and 25% at 2°C and 4°C, respectively.
- The firmness decreased with the increase in the storage period, where the values were 360.2, 305.7, 246.0 mg/cm^2 on day 1, day 7 and day15, respectively, with a rate of decrease in the firmness that amounted to 31.7%. The highest value of firmness was 305 mg/cm^2 at 2°C, and the lowest value of firmness was 302.3 mg/cm^2 at a 6°C.
- The concentration of vitamin C decreased with increasing storage period, where the values of vitamin C were 40.6, 39.38 and 31.67 mg/100g on day 1, day 7 and day15, respectively, with a decrease in vitamin C by the end of storage period 21.99%. It could be seen the vitamin C decrease was 18.59%, 21.42% and 25.98% at 2°C, 4°C and 6°C, respectively.

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تأثير ظروف التخزين على صفات جودة الفراولة

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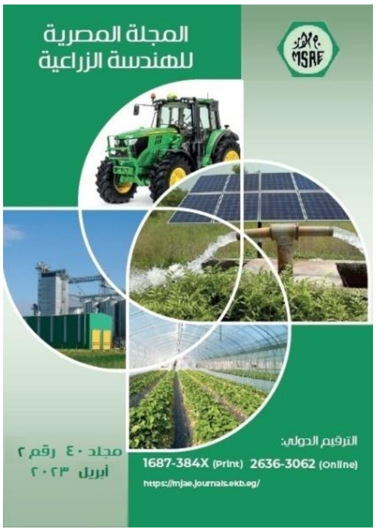

الكلمات المفتاحية:
الفراولة؛ درجات حرارة التخزين؛ التعبئة؛ سلال مفتوحة من أعلى وسلال صدفية.

الملخص العربي

الهدف الرئيسي من هذه الدراسة هو دراسة تأثير درجات حرارة التخزين (٢ و ٤ و ٦°م) ونوعين من سلال التعبئة (مفتوحة القمة والصدفية) على صفات جودة الفراولة (أي فقدان الوزن والحجم والصلابة وفيتامين C). حيث زاد فقد الوزن بشكل معنوي من ٠ إلى ٤,٢٦٢٪ أثناء التخزين (١٥ يوما). علاوة على ذلك ، بينما كانت قيم فقدان الوزن في P_1 (السلال مفتوحة القمة) ٢,٠٦٧ و١,٩٥٧، و٢,٠٤٠٪ عند ٢ و٤ و٦°م على التوالى. وكانت فى P_2 (السلال الصدفية) ٢,٠٦٠، ١,٩٢٠ و٢,٠٥٧٪ عند ٢ و٤ و٦°م على التوالي. انخفض الحجم مع زيادة فترة التخزين فبلغ ٣١,٥٢ و ٢٧,٨ و ٢٣,٨٥ مل في اليوم الأول واليوم السابع واليوم 15 على التوالي، علاوة على ذلك ، انخفض الحجم من ٣١,٢٥ إلى ٢٣,٦٥ ومن ٣٢ إلى ٢٤ مل للفراولة المخزنة حيث كانت. ٢٤,٣٪ و ٢٥٪ عند ٢°م و ٤°م ، على التوالي. وفى الوقت نفسه تناقصت الصلابة مع زيادة فترة التخزين حيث كانت القيم ٣٦٠,٢ و ٣٠٥,٧ و ٢٤٦,٠ مجم/سم^2 في اليوم الأول واليوم السابع واليوم ١٥ على التوالي بمعدل انخفاض في الصلابة بلغ ٣١,٧٪، حيث كانت أعلى قيمة للصلابة ٣٠٥ مجم/سم^2 عند ٢°م ، وأقل قيمة للصلابة كانت ٣٠٢,٣ مجم/سم^2 عند ٦°م. وقد انخفض تركيز فيتامين C مع زيادة فترة التخزين ، حيث كانت قيم فيتامين C كالتالى ٤٠,٦ و ٣٩,٣٨ و ٣١,٦٧ مجم / ١٠٠ جرام في اليوم الأول واليوم السابع واليوم ١٥ على التوالي ، مع انخفاض فيتامين C بنهاية فترة التخزين ٢١,٩٩٪، كما يمكن ملاحظة انخفاض فيتامين C بنسبة ١٨,٥٩٪ و ٢١,٤٢٪ و ٢٥,٩٨٪ عند ٢ و ٤ و ٦°م على التوالي.