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Delaying Ripening of Cantaloupe fruits by Various Treatments During Storage

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This study was conducted for two seasons 2021 and 2022 to investigate the influence of Putrescine (PUT) at 0.1 or 0.2%, Spermine (SPM) at 0.1 or 0.2% and Chitosan (CS) at 1000 or 2000 ppm and in addition untreated control on quality attributes and delaying ripening of cantaloupe fruits (cv. Primal) during storage at 5° C for 28 days. The results indicated that all treatments were effective in reducing weight loss and colour changes and maintained, fruit firmness, TSS, sugar content, total carotenoids and overall appearance of fruits and modified atmosphere (CO_2 %, O_2 % and ethylene ppm) inside the package as compared with untreated control.

The cantaloupe fruits treated with PUT at 0.1 %, SPM at 0.1 % and Chitosan at 1000 ppm were the most effective treatments in maintaining quality and delaying ripening during all storage periods. However, samples treated with SPM at 0.1 % showed the best quality avoided the ripening, retarded the ethylene production and did not exhibit any changes in general appearance till the end of the storage period (28 days of storage at 5° C), while PUT at 0.2%, SPM at 0.2 % and chitosan at 2000 ppm rated good appearance at 21 days of storage.

1. Introduction

Cantaloupes are typically climacteric fruits that exhibit characteristics like a rise in respiration rate and ethylene production during ripening (Kader, 2002). The quality of cantaloupe is rapidly degraded (the most important challenges in Egyptian export market) leading to high metabolic activities respiration and transpiration rates, which continues postharvest, leading to loss of texture and quality attributes during storage (Haffez, 2016). The rapidly ripening and loss of quality are the most important challenges in front of Egyptian export markets. Furthermore, cantaloupe is rather prone to microbial infection and provides potential transmission for foodborne disorder. Consequently, it's necessary to broaden economically viable and particularly efficient techniques to delay ripening, enhance the storage time, maintain fruit quality, extend the shelf life and controls the microbial contamination of cantaloupe in conjunction with low temperature.

Chitosan coating is a semipermeable polymer, which generates a mechanical barrier toward gasses diffu-

sion (O_2, CO_2) that affects the metabolism, preserve firmness, reduces weight loss and preserve the quality of products (Zahedi et al., 2019). Moreover, chitosan is very antimicrobial and is hence active against a wide range of microorganisms that cause disease and damage to products (Dutta et al., 2009). Therefore, coating cantaloupe with chitosan improved storage properties, delayed ripening, reduced colour change and fungal infection during storage (Haffez, 2016).

Polyamines (PA) are plant regulators of growth, which are delayed ripening and preserve quality (Valero et al., 2002). PUT and SPM are the main forms of polyamines, they have a good effect on preserving quality, delay ripening and delay softening (Perez-Vicente et al., 2002). PAs as postharvest treatment reduce respiration rate, slowdown of ethylene, delay colour changes, improve fruit firmness and extend the shelf life (Serrano et al., 2003) for plums and (Davarynejad et al., 2013) for apricot (Koushesh et al., 2012) for mango.

Furthermore, PAs can reduce ethylene biosynthesis, which is a major predisposing factor in the ripening cycle, as it restricts ACC biosynthesis and inhibits of conversion from ACC to ethylene (Koushesh et al., 2012). Another effect of applying PAs is to improve the decomposition chlorophyll breakdown of fruit (Valero et al., 1998) lemon and (Martinez et al., 2002) apricot.

SPM, is a safe non-toxic, cheap and well-known group of naturally occurring aliphatic nitrogen compounds, which plays an important roles in oxidative homeostasis and amino acid biosynthesis to deal with the damage resulting from oxidative stress (Masson et al., 2017) and several physiological processes, i.e. resistance to aging and resistance to stress to environment (Bhagwan et al., 2000). SPM is a natural amino acid and plays an important role in preserving the quality of mushroom and cucumber (Zhang et al., 2009, Jahangir et al., 2011), reduces weight loss, increases cutting force, reduces rust spot formation and reduces rotting of regular bean pods (Tian et al., 2013). From the above, it is clear to us that the use of chitosan coating and polyamines (PUT and SPM) creates a healthy atmosphere and environment around the fruits, which helps them reduce respiration rates and ethylene production, reduces deterioration, and increases their marketing life.

The present study investigates the effect of PUT, SPM and chitosan as postharvest treatment on maintaining quality attributes, delaying ripening, and extending the storage life and increase the marketing window for Egypt of cantaloupe fruits during storage.

2. Materials and methods

Cantaloupe fruits (Cucumis melo L. cv. Primal Galia type) harvested at the yellow-green colour stag (colour stage 3, which is characterized by round shape, netting with white green flesh colour), which is the optimum ripening stage, according to Fallik et al. (2001) on Oct. 12th and 18th in the first and second season respectively from private farm in El-Fayoum Governorate. The fruits transported to the laboratory that was sound, healthy fruits, uniform in size, weight (750 – 800 g) and colour and free from defects. The fruits were divided into seven principal groups to conduct the storage experiment.

The storage experiment was conducted during the two consecutive seasons 2021 and 2022 in vegetable postharvest Dep. Lab., HRI, ARC, Giza, Egypt (the lab include) on the fruit of cantaloupe.

Cantaloupe fruits were sprayed with Chitosan (CS) at 1000 and 2000 ppm, spermine (SPM) at 0.1 and 0.2% and Putrescine (PUT) at 0.1 and 0.2% and untreated control (spraying with distilled water).

Samples were air dried under the fan at room temperature (25 -28° C), placed in a carton box (33x23 cm x 12.5 cm) containing 3 fruits and tightly overwrapped with polypropylene film 30µm thickness. Each box is one experimental unit (EU) (every EU containing three replicates). Fifteen EU were prepared and stored at 5 °C and 95% relative humidity (RH). The EU was evaluated after 7, 14, 21 and 28 days of storage for the following properties:

Weight Loss Percentage (%): the percentage of weight loss was assayed according to the description of Lemoine et al. (2009).

General Appearance (GA): GA was evaluated using a scale from (1-9) with 9= excellent, 7= good, 5= fair, 3= poor, 1= unsalable and fruits rating (5) or below were considered unmarketable (the panel tests for general appearance, evaluated by seven researchers at the

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postharvest vegetable lab.)

Surface colour: Determination by Minolta Colorimeter (Model 4100) for the estimation of L*, b* value, as described by McGuire (1992).

Fruit Firmness: Determination by TA-1000 firmness analyser using a penetrating cylinder of 1mm in diameter, to a constant distance (3 and 5 mm) inside the pulp and by a constant speed of 2 mm per sec. (per g/cm2).

Total soluble solid (TSS): It was determined by using a digital refract meter (Abbe Leica Model, Korean).
Total Sugars: Total sugars were determined using Nelson's methods (Malik and Singh, 1980), which determined calorimetrically at wavelength of 520 nm (Sadasivam and Manickam, 2004).

Carotenoids: Total carotenoids content (mg/100g fresh weight) (A.O.A.C. 1990).

Gas composition inside the packages: O_2, CO_2 and ethylene levels were monitored by F-950 Handheld gas analyser (Felix Instruments, USA).

Statistical analysis: For each parameter at each storage time, the measurement was carried out three times. The collected data were submitted for analysis of variance using SPSS (version 11.0). One-way ANOVA was applied to compare the effect of treatments on measured parameters during storage using the least significant difference (LSD) test a 0.05 confidence level.

3. Results

3.1. Weight loss percentage

The data presented in Table (1) showed that the weight loss increased significantly and consistently with the length of the storage periods. Weight loss results from catabolism due to respiration and metabolic processes associated. There are significant differences between

Table 1. Effect of PUT, SPM and chitosan on weight loss (%) of cantaloupe during storage at 5°C in 2021 and 2022 seasons.

			2021			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	0.00 Q	1.26 IJK	2.31 CD	2.98 B	3.85 A	**2.08 A**
CS 1000	0.00 Q	0.72 NO	1.21 J-L	1.57 GH	1.89 EF	**1.08 D**
CS 2000	0.00 Q	1.10 J-M	1.62 F-H	2.10 DE	2.56 C	**1.48 B**
SPM 0.1	0.00 Q	0.33 P	0.88 MN	1.07 K-M	1.13 J-M	**0.68 F**
SPM 0.2	0.00 Q	0.83 MN	1.32 H-K	1.68 FG	2.10 DE	**1.19 CD**
PUT 0.1	0.00 Q	0.52 OP	0.94 L-N	1.19 J-L	1.56 G-I	**0.84 E**
PUT 0.2	0.00 Q	0.95 L-N	1.40 G-J	1.89 EF	2.30 CD	**1.31 C**
Mean	**0.00 E**	**0.82 D**	**1.38 C**	**1.78 B**	**2.20 A**	
			2022			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	0.00 Q	1.23 IJK	2.30 CD	2.96 B	3.82 A	**2.06 A**
CS 1000	0.00 Q	0.70 NO	1.20 I-K	1.55 GH	1.86 EF	**1.06 D**
CS 2000	0.00 Q	1.00 J-N	1.59 F-H	2.00 DE	2.55 C	**1.43 B**
SPM 0.1	0.00 Q	0.31 PQ	0.86 L-N	1.10 I-M	1.23 I-K	**0.70 E**
SPM 0.2	0.00 Q	0.80 M-O	1.30 H-J	1.66 FG	2.00 DE	**1.15 CD**
PUT 0.1	0.00 Q	0.50 OP	0.92 K-N	1.16 I-L	1.55 GH	**0.83 E**
PUT 0.2	0.00 Q	0.92 K-N	1.38 G-I	1.87 EF	2.23 D	**1.28 C**
Mean	**0.00 E**	**0.78 D**	**1.36 C**	**1.76 B**	**2.18 A**	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan‟s multiple rang test.

the tested and control treatments. The treats retained their weight during storage compared to the control. However, low concentrations of Spermine (SPM) at 0.1% and Putrescine (PUT) at 0.1% led to a prominent reduction of the percentage of weight loss with significant differences between them followed by Chitosan (CS) at 1000 ppm and SPM at 0.2% treatments with no significant difference between them, the others treatments were less effective, while control gives the highest value of weight loss. As for the interaction, fruits treated with SPM at 0.1 had significantly reduced weight loss percentage in comparison to other treatments till 28 days of storage at 5° C in the two seasons.

3.2. General appearance (GA) score

The data presented in Table (2) showed a significant difference in the appearance (score) of cantaloupe with the prolongation of storage periods. All treatments had the highest GA score compared to the control, which had the lowest GA score and deteriorated rapidly. However, fruits treated with SPM at 0.1 were the most effective in preserving GA, followed by SPM at 0.2%, PUT at 0.1% and chitosan at 1000 ppm with no significant difference. GA was the worst for control treatment during storage conditions.

During the two seasons, the interaction between post-harvest treatments and the storage period was significant, cantaloupe obtained from SPM at 0.1 treatment showed the best visual quality and no change in this appearance till 21 days of storage and gave a good appearance in final storage conditions (28 days at 5 °C), while fruit rated good appearance due to PUT at 0.1% and chitosan at 1000 ppm treatments after 21 days. The control had a poor appearance and was unsalable in the final storage period.

3.3. L value

The data presented in Table (3) showed that the lightness of cantaloupe fruits significantly decreases with an increased storage period resulting in darker colours. However, the highest L values were obtained from the fruits treated with SPM at 0.1 % and became higher L values resulting in lighter colour during storage, followed by PUT at 0.1% and chitosan (CS) at

Table 2. Effect of PUT, SPM and chitosan on General Appearance of cantaloupe during storage at 5°C in 2021 and 2022 seasons.

			2021			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	9.00 A	8.33 AB	6.33 CD	3.67 F	3.00 F	**6.07 D**
CS 1000	9.00 A	9.00 A	7.67 A-C	7.00 B-D	6.33 CD	**7.80 B**
CS 2000	9.00 A	9.00 A	7.67 A-C	4.33 EF	3.67 F	**6.73 C**
SPM 0.1	9.00 A	9.00 A	9.00 A	9.00 A	7.67 A-C	**8.73 A**
SPM 0.2	9.00 A	9.00 A	8.33 AB	6.33 CD	5.67 DE	**7.67 B**
PUT 0.1	9.00 A	9.00 A	8.33 AB	7.67 A-C	6.33 CD	**8.07 B**
PUT 0.2	9.00 A	8.33 AB	7.67 A-C	5.67 DE	4.33 EF	**7.00 C**
Mean	**9.00 A**	**8.81 A**	**7.86 B**	**6.24 C**	**5.29 D**	
			2022			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	9.00 A	8.33 AB	6.33 C-E	4.33 FG	3.67 G	**6.33 D**
CS 1000	9.00 A	9.00 A	8.33 AB	7.00 B-D	6.33 C-E	**7.93 B**
CS 2000	9.00 A	9.00 A	8.33 AB	5.00 E-G	4.33 FG	**7.13 C**
SPM 0.1	9.00 A	9.00 A	9.00 A	9.00 A	7.67 A-C	**8.73 A**
SPM 0.2	9.00 A	9.00 A	9.00 A	6.33 C-E	5.67 D-F	**7.80 B**
PUT 0.1	9.00 A	9.00 A	8.33 AB	7.67 A-C	6.33 C-E	**8.07 B**
PUT 0.2	9.00 A	8.33 AB	7.67 A-C	6.33 C-E	4.33 FG	**7.13 C**
Mean	**9.00 A**	**8.81 A**	**8.14 B**	**6.52 C**	**5.48 D**	

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Table 3. Effect of PUT, SPM and chitosan on L value of cantaloupe during storage at 5°C in 2021 and 2022 seasons.

			2021			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	71.32 A	64.38 EF	60.15 GH	52.40 K	47.21 L	**59.09 E**
CS 1000	71.32 A	69.41 B	66.31 CD	61.41 G	60.10 GH	**65.71 B**
CS 2000	71.32 A	66.32 CD	65.31 DE	58.41 I	55.20 J	**63.31 D**
SPM 0.1	71.32 A	70.31 AB	69.24 B	64.32 EF	61.72 G	**67.38 A**
SPM 0.2	71.32 A	67.31 C	65.41 DE	60.31 GH	58.40 I	**64.55 C**
PUT 0.1	71.32 A	69.41 B	67.11 C	63.41 F	59.10 HI	**66.07 B**
PUT 0.2	71.32 A	66.32 CD	63.41 F	59.40 HI	56.32 J	**63.35 D**
Mean	**71.32 A**	**67.64 B**	**65.28 C**	**59.95 D**	**56.86 E**	
			2022			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	71.81 A	64.77 EF	59.36 HI	52.52 L	47.46 M	**59.18 E**
CS 1000	71.81 A	70.17 AB	66.48 C-E	61.53 GH	61.28 H	**66.25 B**
CS 2000	71.81 A	66.50 C-E	65.52 D-F	58.69 IJ	55.35 K	**63.57 D**
SPM 0.1	71.81 A	70.50 AB	68.44 BC	66.52 C-E	63.94 F	**68.24 A**
SPM 0.2	71.81 A	67.50 CD	65.53 D-F	60.51 HI	58.64 IJ	**64.80 C**
PUT 0.1	71.81 A	70.21 AB	64.33 EF	64.00 F	59.80 HI	**66.03 B**
PUT 0.2	71.81 A	66.52 C-E	63.61 FG	59.52 HI	56.52 JK	**63.60 D**
Mean	**71.81 A**	**68.02 B**	**64.75 C**	**60.47 D**	**57.57 E**	

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1000 ppm with no significance between them. However, fruits obtained from sprayed with PUT at 0.2 or CS at 2000 ppm were less effective. While, the lowest L values were obtained from the control resulting in darker colour (lowe L value) during storage periods.

3.4. b value

The parameter b value indicates the degree of colour between blue to yellow (represents yellowness) It has been described as the best reflection of changes in skin tissue during ripening. The data presented in Table (4) showed that significant increase in the b value in cantaloupe fruits with increased storage time. However, the highest b value record in the control treatment, the colour appearance has developed from yellow to completely full orange after 28 days of storage. In contrast, the treatment SPM at 0.1% was most effective in reducing colour changes, and the surface colour in this treatment did not exceed a light yellow colour (low b value) after 28 days of storage followed by PUT at 0.1 % and CS at 1000 ppm treatments with no significant different between them, while the higher concentration of these materials was less effective in this concern.

3.5. Fruits firmness

The data presented in Table (5) showed that significant decrease in firmness of cantaloupe fruits during storage. However, all treatments had significant effects on fruit firmness as compared to control. Moreover, the fruits treated with SPM at 0.1%, PUT at 0.1% and CS at 1000 ppm gave the highest stability value of firmness during storage with no significant difference between them followed by high concentration of these treatments with no significant difference between them. The lowest value of firmness was obtained from control. The interaction between the storage period and post-harvest treatments had a remarkable effect on fruits firmness. Fruits treated with SPM at 0.1% were most effective in keeping the fruits firm until 28 days at 5 °C in the two seasons.

Table 4. Effect of PUT, SPM and chitosan on b value of cantaloupe during storage at 5°C in 2021 and 2022 seasons.

			2021			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	40.24 O	44.14 G-K	43.10 KL	50.24 B	55.62 A	**46.67 A**
CS 1000	40.24 O	41.10 NO	43.90 H-L	44.82 E-J	45.92 C-F	**43.20 C**
CS 2000	40.24 O	43.60 I-L	45.20 D-I	46.22 C-E	46.70 CD	**44.39 B**
SPM 0.1	40.24 O	41.20 M-O	42.31 L-N	43.50 J-L	44.31 F-K	**42.31 D**
SPM 0.2	40.24 O	43.80 H-L	43.80 H-L	45.40 C-H	46.80 CD	**44.01 B**
PUT 0.1	40.24 O	42.80 K-M	43.91 H-L	43.92 H-L	44.81 E-J	**43.14 C**
PUT 0.2	40.24 O	43.90 H-L	43.91 H-L	45.60 C-G	46.90 C	**44.11 B**
Mean	**40.24 E**	**42.93 D**	**43.73 C**	**45.67 B**	**47.29 A**	
			2022			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	41.03 G	44.50 D-F	45.75 C-E	50.02 B	55.32 A	**47.32 A**
CS 1000	41.03 G	41.18 G	42.67 FG	44.56 D-F	45.74 C-E	**43.04 C**
CS 2000	41.03 G	44.12 DEF	44.59 D-F	45.94 C-E	47.44 C	**44.62 B**
SPM 0.1	41.03 G	41.05 G	41.06 G	42.26 FG	43.02 FG	**41.68 D**
SPM 0.2	41.03 G	44.46 D-F	44.50 D-F	46.10 CD	47.61 C	**44.74 B**
PUT 0.1	41.03 G	41.20 G	43.65 EF	43.89 D-F	46.26 CD	**43.20 C**
PUT 0.2	41.03 G	44.25 D-F	44.38 D-F	44.32 D-F	45.95 C-E	**43.99 B**
Mean	**41.03 D**	**42.97 C**	**43.80 C**	**45.30 B**	**47.34 A**	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan"s multiple rang test.

Table 5. Effect of PUT, SPM and chitosan on fruit firmness of cantaloupe during storage at 5°C in 2021 and 2022 seasons.

			2021			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	16.58 A	13.81 C-H	12.60 F-J	11.11 J	8.21 K	**12.46 E**
CS 1000	16.58 A	15.50 A-C	14.70 A-E	14.20 B-G	13.00 E-J	**14.80 A-C**
CS 2000	16.58 A	14.70 A-E	13.30 D-I	12.25 G-J	11.00 J	**13.57 D**
SPM 0.1	16.58 A	16.00 AB	15.44 A-C	15.06 A-D	14.32 B-F	**15.48 A**
SPM 0.2	16.58 A	15.10 A-D	14.00 B-G	13.00 E-J	11.90 H-J	**14.12 B-D**
PUT 0.1	16.58 A	15.71 A-C	15.00 A-E	14.50 B-F	13.20 D-I	**15.00 AB**
PUT 0.2	16.58 A	15.57 A-C	13.70 C-H	12.50 F-J	11.60 IJ	**13.99 CD**
Mean	**16.58 A**	**15.20 B**	**14.11 C**	**13.23 D**	**11.89 E**	
			2022			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	17.03 A	14.02 B-G	12.83 E-I	11.40 HI	8.50 J	**12.76 D**
CS 1000	17.03 A	15.83 AB	15.00 A-E	14.50 B-F	13.30 D-I	**15.13 AB**
CS 2000	17.03 A	14.83 A-E	13.50 C-H	12.50 F-I	11.13 I	**13.80 C**
SPM 0.1	17.03 A	16.17 AB	15.70 A-C	15.37 A-D	14.50 B-F	**15.75 A**
SPM 0.2	17.03 A	15.50 A-D	14.30 B-F	13.27 D-I	12.00 G-I	**14.42 BC**
PUT 0.1	17.03 A	15.80 AB	15.30 A-D	14.80 A-E	13.50 C-H	**15.29 AB**
PUT 0.2	17.03 A	15.93 AB	14.00 B-G	12.80 E-I	11.80 G-I	**14.31 BC**
Mean	**17.03 A**	**15.44 B**	**14.38 C**	**13.52 D**	**12.10 E**	

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3.6. Total soluble solids percentage

The data presented in Table (6) showed that significant decrease in TSS % of cantaloupe fruits during storage in both seasons. Cantaloupe fruits treated with SPM at 0.1%, and PUT at 0.1% treatments retained more TSS% without significant difference between them followed by CS at 1000 ppm. Furthermore, other treatments were less effective in this concern. On the other hand, the lowest TSS value percentage resulted from control. In general, the interaction between storage periods and postharvest treatments was significant during storage conditions. After 28 days at 5 °C, fruits treated with SPM at 0.1%, PUT at 0.1% or CS at 1000 ppm resulted in higher TSS % while the control treatment gave the lowest ones.

3.7. Total sugars

The data presented in Table (7) showed that the total sugars content of cantaloupe fruits was affected by the storage period significantly. There is a significant reduction in total sugars in all treatments compared with control. However, fruits treated with low concentrations of SPM at 0.1% and PUT at 0.1% appeared to be the most effective in reducing total sugars loss with no significant difference between them followed by CS at 1000 ppm. The other treatments were less effective. On the other side, control showed the lowest total sugars content during storage.

In general, the interaction between storage periods and postharvest treatments was significant, data revealed that cantaloupe treated with SPM at 0.1 %, Put at 0.1 % and CS at 1000 ppm maintained the highest total sugar contents during all storage periods, while control gave the lowest ones.

Total carotenoid

The data presented in Table (8) showed that there was a significant increase in the total carotenoids content of cantaloupe fruits with time during storage in both seasons. The data of all treatments showed sig-

Table 6. Effect of PUT, SPM and chitosan on total soluble solids of cantaloupe during storage at 5°C in 2021 and 2022 seasons.

			2021			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	10.20 A	9.80 BC	9.00 G-I	8.20 MN	7.20 O	**8.88 E**
Cs 1000	10.20 A	9.70 B-D	9.40 D-F	9.00 G-I	8.90 H-J	**9.44 B**
Cs 2000	10.20 A	9.20 E-H	9.30 E-G	8.50 K-M	8.10 N	**9.06 D**
Sper. 0.1	10.20 A	10.00 AB	9.80 BC	9.50 C-E	9.30 E-G	**9.76 A**
Sper. 0.2	10.20 A	9.50 C-E	9.20 E-H	8.80 I-K	8.50 K-M	**9.24 C**
Put 0.1	10.20 A	9.80 BC	9.70 B-D	9.40 D-F	9.20 E-H	**9.66 A**
Put 0.2	10.20 A	9.30 E-G	9.10 F-I	8.60 J-L	8.30 L-N	**9.10 CD**
Mean	**10.20 A**	**9.61 B**	**9.36 C**	**8.86 D**	**8.50 E**	
			2022			
Treatment	0	7	14	21	28	**Mean**
Control	10.30 A	9.50 DE	9.13 F-H	8.30 K	7.83 L	**9.01 E**
Cs 1000	10.30 A	9.90 BC	9.60 CD	9.20 E-G	9.07 F-H	**9.61 B**
Cs 2000	10.30 A	9.10 F-H	9.50 DE	8.70 IJ	8.30 K	**9.18 D**
Sper. 0.1	10.30 A	10.00 AB	9.97 AB	9.70 B-D	9.40 D-F	**9.87 A**
Sper. 0.2	10.30 A	9.70 B-D	9.40 D-F	9.00 G-I	8.60 JK	**9.40 C**
Put 0.1	10.30 A	10.00 AB	9.90 BC	9.60 CD	9.40 D-F	**9.84 A**
Put 0.2	10.30 A	9.50 DE	9.20 E-G	8.80 H-J	8.50 JK	**9.26 CD**
Mean	**10.30 A**	**9.67 B**	**9.53 C**	**9.04 D**	**8.73 E**	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan"s multiple rang test.

Table 7. Effect of PUT, SPM and chitosan on total sugars of cantaloupe during storage at 5°C in 2021 and 2022 seasons.

			2021			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	9.48 A	8.86 D-F	8.14 LM	7.08 P	6.11 Q	**7.93 F**
CS 1000	9.48 A	9.25 B	8.81 E-G	8.36 I-K	8.09 LM	**8.80 B**
CS 2000	9.48 A	8.72 FG	8.00 MN	7.52 O	7.23 P	**8.19 E**
SPM 0.1	9.48 A	9.26 B	9.04 CD	8.63 GH	8.23 J-L	**8.93 A**
SPM 0.2	9.48 A	9.00 DE	8.40 IJ	8.00 MN	7.62 O	**8.50 C**
PUT 0.1	9.48 A	9.21 BC	8.89 D-F	8.52 HI	8.11 LM	**8.84 AB**
PUT 0.2	9.48 A	8.90 D-F	8.20 KL	7.83 N	7.61 O	**8.40 D**
Mean	**9.48 A**	**9.03 B**	**8.50 C**	**7.99 D**	**7.57 E**	
			2022			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	9.81 A	8.90 C	8.20 GH	7.16 N	6.17 O	**8.05 E**
CS 1000	9.81 A	9.30 B	9.00 C	8.40 EF	8.17 G-I	**8.94 B**
CS 2000	9.81 A	8.93 C	8.00 IJ	7.59 M	7.30 N	**8.33 D**
SPM 0.1	9.81 A	9.32 B	9.07 C	8.70 D	8.32 FG	**9.04 A**
SPM 0.2	9.81 A	9.02 C	8.54 DE	8.03 H-J	7.81 KL	**8.64 C**
PUT 0.1	9.81 A	9.28 B	9.00 C	8.62 D	8.25 FG	**8.99 AB**
PUT 0.2	9.81 A	9.07 C	8.27 FG	7.97 JK	7.74 LM	**8.57 C**
Mean	**9.81 A**	**9.12 B**	**8.58 C**	**8.07 D**	**7.68 E**	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan"s multiple rang test.

Table 8. Effect of PUT, SPM and chitosan on total carotenoids of cantaloupe during storage at 5°C in 2021 and 2022 seasons.

			2021			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	2.34 P	2.68 G-M	2.88 B-E	3.00 B	3.26 A	**2.83 A**
CS 1000	2.34 P	2.58 J-N	2.60 J-N	2.72 E-K	2.81 C-H	**2.61 CD**
CS 2000	2.34 P	2.62 I-N	2.74 E-J	2.87 B-F	2.97 BC	**2.71 B**
SPM 0.1	2.34 P	2.40 OP	2.47 N-P	2.52 M-O	2.66 H-M	**2.48 E**
SPM 0.2	2.34 P	2.60 J-N	2.67 G-M	2.84 B-G	2.94 B-D	**2.68 BC**
PUT 0.1	2.34 P	2.53 L-O	2.56 K-O	2.68 G-M	2.78 D-I	**2.58 D**
PUT 0.2	2.34 P	2.62 I-N	2.70 F-L	2.86 B-F	2.96 BC	**2.70 B**
Mean	**2.34 E**	**2.58 D**	**2.66 C**	**2.78 B**	**2.91 A**	
			2022			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	2.61 H-K	2.73 F-H	2.90 CD	3.03 B	3.33 A	**2.92 A**
CS 1000	2.61 H-K	2.63 H-K	2.67 G-J	2.80 D-F	2.87 DE	**2.72 C**
CS 2000	2.61 H-K	2.68 F-I	2.78 D-G	2.90 CD	3.09 B	**2.81 B**
SPM 0.1	2.61 H-K	2.53 K	2.55 JK	2.58 I-K	2.73 F-H	**2.60 D**
SPM 0.2	2.61 H-K	2.67 G-J	2.73 F-H	2.90 CD	3.00 BC	**2.78 B**
PUT 0.1	2.61 H-K	2.57 I-K	2.63 H-K	2.73 F-H	2.87 DE	**2.68 C**
PUT 0.2	2.61 H-K	2.67 G-J	2.77 E-G	2.90 CD	3.02 BC	**2.79 B**
Mean	**2.61 D**	**2.64 D**	**2.72 C**	**2.84 B**	**2.99 A**	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan"s multiple rang test.

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nificantly lowest content of total carotenoids as compared with control which gave the highest value of total carotenoids as intense yellow. On the other hand, cantaloupe fruits treated with SPM at 0.1% were the most effective treatments in reducing the increase of carotenoids content followed by PUT at 1% and CS at 1000 ppm with no significant difference, the other treatments were less effective.

3.8. Gas composition inside the packages.

Data in Tables (9, 10 and 11) indicated that there was a significant decrease in O_2 % and an increase in CO_2% and ethylene concentration in the packages during storage in both seasons. There are statistically significant differences between control and treatments. The gas inside packages treated with SPM at 0.1%, PUT at 0.1% and CS at 1000 ppm had high O_2 %, low CO_2 % and ethylene ppm concentrations with no significant difference between them.

4. Discussion

The results of this study showed that the weight loss % of cantaloupe fruits increased with prolonged storage and these results are consistent with (Atala and El-Gendy, 2020). Weight loss results from catabolism due to respiration and metabolic processes associated with aging (Amarante et al., 2001).

However, all postharvest treatments significantly reduced the weight loss % compared to control. These results are consistent with Razzaqa et al., (2014) in mango and Li et al., (2005) in tomato.

However, SPM at 0.1% and PUT at 0.1% led to a prominent reduction of weight loss % followed by CS at 1000 ppm. This may be due to SPM treatment because; SPM forms linkage throw waxes of the cuticle layer and cell membrane and this linkage forms can preserve cell integrity, cell stabilization and cell consolidation (retarding remove the epicuticular waxes which, decreases the water exchange) (Mirdehgha

Table 9. Effect of PUT, SPM and chitosan on Ethylene concentration (ppm) of cantaloupe during storage at 5°C in 2021 and 2022 seasons.

			2021			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	0.00 L	0.28 D	0.53 C	0.71 B	0.81 A	**0.47 A**
CS 1000	0.00 L	0.00 L	0.02 KL	0.07 G-K	0.10 F-I	**0.04 DE**
CS 2000	0.00 L	0.07 G-K	0.08 G-J	0.14 F	0.20 E	**0.10 B**
SPM 0.1	0.00 L	0.00 L	0.00 L	0.03 J-L	0.06 H-K	**0.02 E**
SPM 0.2	0.00 L	0.05 I-L	0.05 I-L	0.09 F-I	0.11 F-H	**0.06 CD**
PUT 0.1	0.00 L	0.00 L	0.00 L	0.05 I-L	0.08 G-J	**0.03 E**
PUT 0.2	0.00 L	0.06 H-K	0.07 G-K	0.11 F-H	0.12 FG	**0.07 C**
Mean	**0.00 E**	**0.07 D**	**0.11 C**	**0.17 B**	**0.21 A**	
			2022			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	0.00 K	0.26 D	0.51 C	0.68 B	0.78 A	**0.45 A**
CS 1000	0.00 K	0.00 K	0.01 JK	0.06 G-J	0.09 F-H	**0.03 DE**
CS 2000	0.00 K	0.05 G-K	0.07 F-I	0.12 F	0.18 E	**0.08 B**
SPM 0.1	0.00 K	0.00 K	0.00 K	0.02 I-K	0.05 G-K	**0.01 E**
SPM 0.2	0.00 K	0.04 H-K	0.04 H-K	0.07 F-I	0.09 F-H	**0.05 CD**
PUT 0.1	0.00 K	0.00 K	0.00 K	0.04 H-K	0.06 G-J	**0.02 E**
PUT 0.2	0.00 K	0.05 G-K	0.06 G-J	0.10 FG	0.10 FG	**0.06 BC**
Mean	**0.00 E**	**0.06 D**	**0.10 C**	**0.16 B**	**0.19 A**	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan‟s multiple rang test.

Table 10. Effect of PUT, SPM and chitosan on CO_2 % of cantaloupe during storage at 5°C in 2021 and 2022 seasons.

			2021			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	0.03 T	0.16 PQ	1.31 G	2.51 B	3.82 A	**1.57 A**
CS 1000	0.03 T	0.09 RS	0.52 N	0.71 L	1.81 E	**0.63 E**
CS 2000	0.03 T	0.12 QR	0.84 K	1.13 H	2.20 C	**0.86 B**
SPM 0.1	0.03 T	0.05 ST	0.44 O	0.82 K	1.72 F	**0.61 E**
SPM 0.2	0.03 T	0.09 RS	0.62 M	0.94 J	1.80 E	**0.70 D**
PUT 0.1	0.03 T	0.07 R-T	0.51 N	0.70 L	1.80 E	**0.62 E**
PUT 0.2	0.03 T	0.18 P	0.73 L	1.02 I	1.93 D	**0.78 C**
Mean	**0.03 E**	**0.11 D**	**0.71 C**	**1.12 B**	**2.15 A**	
			2022			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	0.03 L	0.60 HI	1.24 E	2.49 B	3.80 A	**1.63 A**
CS 1000	0.03 L	0.08 L	0.50 IJ	0.28 J-L	1.72 D	**0.52 D**
CS 2000	0.03 L	0.11 L	0.81 GH	1.11 EF	2.03 C	**0.82 B**
SPM 0.1	0.03 L	0.07 L	0.36 I-K	0.48 IJ	1.54 D	**0.50 D**
SPM 0.2	0.03 L	0.08 L	0.60 HI	0.83 GH	1.68 D	**0.64 C**
PUT 0.1	0.03 L	0.15 KL	0.49 IJ	0.49 IJ	1.26 E	**0.48 D**
PUT 0.2	0.03 L	0.06 L	0.60 HI	0.93 FG	1.77 D	**0.68 C**
Mean	**0.03 E**	**0.16 D**	**0.66 C**	**0.95 B**	**1.97 A**	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan"s multiple rang test.

Table 11. Effect of PUT, SPM and chitosan on O_2 % of cantaloupe during storage at 5°C in 2021 and 2022 seasons.

			2021			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	20.80 A	19.00 D-F	17.30 JK	15.40 M	12.51 P	**17.00 D**
CS 1000	20.80 A	20.00 C	19.10 DE	18.75 EF	16.15 L	**18.96 A**
CS 2000	20.80 A	19.80 C	17.60 IJ	16.90 K	14.20 O	**17.86 C**
SPM 0.1	20.80 A	20.24 BC	19.30 D	18.20 GH	16.30 L	**18.97 A**
SPM 0.2	20.80 A	20.50 AB	18.60 FG	17.00 K	14.90 N	**18.36 B**
PUT 0.1	20.80 A	20.65 AB	19.10 DE	18.00 HI	16.00 L	**18.91 A**
PUT 0.2	20.80 A	20.50 AB	18.80 EF	17.00 K	14.60 NO	**18.34 B**
Mean	**20.80 A**	**20.10 B**	**18.54 C**	**17.32 D**	**14.95 E**	
			2022			
Treatment	**0**	**7**	**14**	**21**	**28**	**Mean**
Control	20.80 A	19.70 CD	17.13 HIJ	16.80 J-L	14.23 N	**17.73 D**
CS 1000	20.80 A	20.33 AB	18.60 FG	18.83 E-G	16.37 L	**18.99 A**
CS 2000	20.80 A	20.32 AB	17.63 HI	17.23 H-J	14.87 M	**18.17 C**
SPM 0.1	20.80 A	20.30 A-C	19.73 B-D	18.43 G	16.50 KL	**19.15 A**
SPM 0.2	20.80 A	20.83 A	19.33 DE	17.07 I-K	14.33 MN	**18.47 B**
PUT 0.1	20.80 A	20.68 A	19.20 D-F	17.73 H	16.20 L	**18.92 A**
PUT 0.2	20.80 A	20.57 A	19.27 DE	17.17 H-J	14.87 M	**18.53 B**
Mean	**20.80 A**	**20.39 B**	**18.70 C**	**17.61 D**	**15.34 E**	

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et al., 2007). The rate of respiration and ethylene is decreased by this phenomenon (Shiri et al., 2013 & Champa et al., 2015).
Preventing weight loss % of fruits treated by polyamines is due to decreased respiration rate (Perez-Vicente et al. (2002), Malik and Singh (2005)) and decreased ethylene production during storage (Barman et al. (2011)). SPM at low concentrations may inhibit ethylene production, as well as reduce respiration rate. SPM have four amino groups, this is the most effective scavenger of superoxide radicals (Bouchereau et al., 1999). Chitosan records the lowest weight loss; it can configure a semipermeable film around the surface, modifying the atmosphere internally with limited exchange gas due to the coating barrier. On the other hand, metabolism and enzymatic activity can be affected in the developed respiration, resulting in reduced weight loss (Raymond et al., 2012).

The visual appearance of fresh produce is one of the most important quality factors for marketing and is affected by prolonged storage periods. According to the findings in this study, there was a considerable decrease in the general appearance (GA) score of cantaloupe fruits with increasing storage duration.

These results are consistent with (Atala and El-Gendy, 2020) and it may be caused by slight surface desiccation rather than transparency or macrospore decay (Atress and Attia, 2011).

However, fruit treated with SPM at 0.1% was the most effective treatments in maintaining GA, followed by SPM at 0.2%, PUT at 0.1% and CS at 1000 ppm in both seasons. The results are in agreement with Barman et al. (2011) for PA and Haffez (2016) for chitosan. PAs exogenous can maintain the quality and delay the senescence (enhancing the fruit quality attributes and extending the storage life by delaying the ripening and senescence) in mushrooms and cucumbers (Zhang et al., 2009; Jahangir et al., 2011).

The storage and processing potential of banana fruits has improved with PUT and SPM was observed from the reduction in respiration metabolic rate and ripening delay (Archana and Suresh, 2019). Using chitosan can maintain visual quality and may be a reduction of weight loss, respiration rate, enzymatic degradation, microbial rot and ethylene production (Ansorena et al., 2011).

Colour is one of the main visual quality criteria that influences whether or consumers would accept fresh products. To assess the colour change that happens in fruits across all storage periods, the colour parameters L (Lightness) and b values were measured. With increasing storage time, the L value of cantaloupe fruits declined dramatically, and an evident loss of lightness. A reduction in the L value indicated that the surface is darkening. However, a significant increase in the b value with increasing storage period represented yellowness. The results are consistent with Atala and El-Gendy (2020). Archana and Suresh (2019) showed that a lowering in L value is related to loss of water. The results are consistent with Haffez (2016) for chitosan and Archana and Suresh (2019) for PUT and SPM. The results are consistent with Atala and El-Gendy (2020).

The higher values of b represent fully ripened yellow colour fruit. The fruits became yellow to orange, with the storage time, which may be due to the decomposition of chlorophyll and the synthesis of carotenoids as well, a pigment that contributes to the appearance of the orange colour in the fruits of the cantaloupe (Muharrem et al., 2005). However, restrictive colour changes in fruits treated with SPM and PUT may be due to these materials delaying the degradation of chlorophyll and carotenoid production as well as skin discolouration (Malik & Singh, 2005). SPM coatings prevent production of ethylene, lower the activity of chlorophylls and consequence reduce colour change and chlorophyll degradation and fruits maturity faces delay (Archana and Suresh, 2019).

The reduction in fruit firmness with increasing the storage period may be due to the gradual breakdown of protopectin, especially for small fractions. These fractions are more soluble in water, and this is directly related to the rate of softening and the decrease in firmness of the fruits (Abdel-Sattar et al., 2023). Also, the softening of cantaloupe is due to the breakdown in the structure of the cell and the compositional intracellular wall of the cell (Abdel-Sattar et al., 2023). The application of SPM, PUT and chitosan reduced softening and maintained fruit firmness during storage.

These results are in agreement with (Walters, 2003) for

SPM (Malik et al., 2006 and Malik and singta, 2006) for PUT and (Haffez, 2016) for chitosan.

PAs can modify genes for ethylene biosynthesis that may control or inhibit it, and also controls genes for ethylene perception, cell wall alteration associated with enzymes and polyamine conjugation (Savithri et al., 2008). Valero et al. (2002) reported that regasification of the cell wall is causing fruit persistence; it is caused by the cross-linking of the polyamine-carboxyl group (eCOO) of pecitn materials in the cell wall.

These bindings may inhibit the degradation of cell wall enzymes (pectin methyl esterase, pectin esterase and poly galacturonase) and reduce firmness and preserve the wall rigidity. SPM have four groups of amines which are positively charged at physiological pH to bind to charge negative molecules such as nucleic acids, phospholipids and a lot of proteins which markedly suppress the rate of softening of grape berries during storage (Walters, 2003). The positive effect of chitosan coating may be the reason for maintaining toughness, which may be due to its high antifungal activity and covering the skin of cuticles and lentils, thus it reduces infection and reduces respiration rate and other ripening processes (Hong et al., 2012). The rapid decline in fruit firmness under control is caused by elevated ethylene production, which leads to the deterioration of the middle and intracellular lamina of the cell wall (Watkins and Nock, 2012).

The TSS % of cantaloupe fruits decrease with the prolongation of the storage period confirming results were obtained by Atala and El-Gendy (2020) on cantaloupe. The decrease in dissolved solids content can be explained by the hydrolysis of sucrose, the use of reducing sugars in respiration and the loss of water through transpiration (Abdel-Sattar et al., 2023). Cantaloupe fruits treated with SPM at 0.1%, PUT at 0.1 % and chitosan at 1000 ppm maintained their TSS% during storage. This result is consistent with Zahedi et al. (2019) for chitosan and (Archana and Suresh, 2019) for PUT and SPM. Jongsri et al. (2016) found that mango treated with chitosan had a significant effect on maintaining TSS during storage. PAs also retarded the degradation of TSS (Champa et al., 2014).

The mean of TSS was stable in treated with PUT and SPM (Malik et al., 2006, Malik and Singh, 2005). Maintaining TSS% of cantaloupe fruits by using SPM, PUT and CS may be due to these materials preventing the production of ethylene, which decreases the rate of respiration and physiological changes (Jongsri et al., 2016 & Malik & Singh, 2005) and in turn reduced the loss of TSS (Ali et al., 2011).

The reduction in total sugar content of cantaloupe fruits with increasing the storage period is in agreements with Atala and El-Gendy (2020) and may be due to the consumption of sugars through the process of respiration (Abdel-Sattar et al., 2023). The application of SPM, PUT and CS reduces the loss of total sugar, which may be due to these substances slowing down the rate of respiration, slowing down the metabolism, delaying the ripening process, and modifying the internal atmosphere of the fruit by reducing oxygen and/or increasing carbon dioxide. They also inhibit ethylene production and thus preserve total sugars during storage, these results are consistent with Raymond et al. (2012) for chitosan, (Koushesh et al., 2012) for PUT and Archana and Suresh (2019) for PUT and SPM.

Furthermore, the total carotenoids content of cantaloupe fruits increased with the prolongation of the storage period. These results are consistent with Watkins and Nock (2012) reported that cantaloupes are high ethylene producers; ethylene accelerates the degradation of chlorophyll and accumulation of carotenoids content (the appearance of yellow or orange colours). Ethylene also promotes the ripening of the pulp. However, all the treatments showed significantly the lowest content of total carotenoids content as compared with the control which gave the highest value of total carotenoids as intense yellow.

The colour changes in untreated control may be due to fruits exposure to ethylene production by products can promote yellowing and shorten the storage life (Zahedi et al., 2019). Decreasing ethylene production or inhibition of its action by using SPM, PUT and CS treatments can delay fruit ripening and reduce colour change of cantaloupe fruits. (Koushesh et al. (2012), Valero et al. (2002) for polyamine and Haffez (2016) for chitosan).

Cantaloupe fruits are still active and continue to respire after harvest (Muharrem et al., 2005). It is abso-

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lutely necessary to monitor the gaseous composition inside the packages and to adjust the appropriate proportions of the gases; moreover, analyses of package atmospheres showed that all processors had their own atmosphere modification inside the package.

The results of this study showed that there was a significant decrease in O_2 and an increase in CO_2 and ethylene in the packages during storage. Similar results were obtained by (Atalla and El-Gendy, 2020). These results may be due to O_2 consumption and CO_2 and ethylene production during ripening (Kadar, 2002). The increase in ethylene may be due to cantaloupe fruits are typical climacteric fruits that exhibit characteristics raise in ethylene production during ripening (Kader, 2002). However, the gas inside the packages treated with SPM at 0.1%, PUT at 0.1% and CS at 1000 ppm had high O_2 and low CO_2 and ethylene concentration may be due to these materials preventing ethylene production and action of ethylene, which decreased respiration rate and consequently reduced the consumption of O_2 % and decrease accumulation of CO_2 % and ethylene ppm concentrations inside the package (Liu et al., 2007) for chitosan, (Barman et al., 2011) for PUT and Malik et al. (2006) for SPM.

5. Conclusion

From the previous results it could be concluded that cantaloupe fruits sprayed with SPM at 0.1% treatment was a promising technique for delaying the ripening, maintaining the fruit quality and extending the shelf life of fruits for 28 days of storage at 5° C.

Conflict of Interest

The authors declare no conflict of interest. Besides, the funders had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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