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THE IMPACT OF NANO CHITOSAN AND NANO SILICON COATINGS ON THE QUALITY OF CANINO APRICOT FRUITS DURING COLD STORAGE

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ABSTRACT: This work was carried out during 2016 and 2017 seasons in post-harvest Lab. Pomology Dept. Cairo University, Egypt. The quality and internal (physical and chemical) changes in apricot fruits (*Prunus armeniaca* L.) coated with different treatments of Nano chitosan and Nano silicon were studied after different storage periods of cold storage at 1°C and 90-95% (RH). Nano chitosan was prepared with 0.5% concentration and Nano silicon was prepared with 2% concentration, each of them was tested individually or in combination with Thiabendazole (TBZ). The changes in fruit firmness, weight loss, discarded fruit percentage, fruit panel, total acidity (TA), total soluble solids (TSS), and ascorbic content (Vitamin C) at intervals were estimated during 7 weeks. The results of the two successive seasons indicated that the application of Nano chitosan and silicon coatings maintained fruit firmness compared with the control (dipped in TBZ) without significant differences. The application with 0.5% Nano chitosan + TBZ treatment maintained higher firmness values. On the other hand, Nano-chitosan coating + TBZ treatment maintained fruit acidity, fruit panel test and Vitamin C content more than the uncoated control and other treatments without significant differences. While, all coating treatments increased TSS values and discarded fruit percentage compared with the control without significant differences. The lowest value for each of TSS and fresh weight loss percentage was achieved by Nano chitosan 0.5% + TBZ treatment. Similarly, that treatment significantly decreased fresh weight loss percentage compared with the other treatments.

Key words: Chitosan coating, silicon coating, apricot, cold storage, physical and chemical properties.

INTRODUCTION

The apricot tree (*Prunus armeniaca*) is one of the most important fruit species grown in Egypt. The total apricot cultivation area in the world is 536072 ha and total apricot production is 4.3 million tones **(FAO, 2017)**. Apricot is climacteric fruit with a limited postharvest storage life due to acceleration of quality loss, affecting some properties such as fruit firmness, texture, total soluble solids and titratable acidity **(Davarynejad *et al*., 2013**). Deterioration is associated with skin desiccation, colour loss and disease development; however it can be delayed by low temperature storage **(Kader and Arpaia, 1992).** And other supplemented treatments as atmosphere modifications and coatings… *etc*.

Traditionally, antimicrobial agents are added directly to the foods, but their activity may be inhibited by many substances in the food itself, diminishing their efficiency. In such cases, the use of antimicrobial films or coatings can be more efficient than adding antimicrobial agents directly to the food since these may selectively and gradually migrate from the package onto the surface of the food, thereby high concentrations being maintained when most necessary **(Ali, 2015).**

Consumers require fresh and minimally processed foods that are exempt from chemically synthesized substances, and search for those enriched with natural substances that bring health benefits and maintain nutritional and sensory characteristics **(Falguera *et al*.,**

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2011). Therefore, in recent times the efforts of researchers have been focused on searching for new naturally occurring substances that act as possible alternative sources of antioxidants and antimicrobials **(Ponce *et al*., 2008).**

Nanomaterials, because of their tiny size, show unique characteristics. For example, they can change physio-chemical properties compared to bulk materials. They have greater surface area than bulk materials, and due to this larger surface area, their solubility and surface reactivity tend to be higher **(Ruffini and Cremonini, 2009).**

Chitosan is a polysaccharide composed of β-1.4-D-glucosamine linked to N-acetyl-glucosamine residues and is naturally present in fungi cell walls or can be extracted by the deacetylation of chitin (**Berger *et al*., 2014**). As well as, it had the effectiveness on controlling blue mold decay of apples and it can be a promising alternative in controlling postharvest diseases (**Li *et al*., 2015**). Chitosan also was able to reduce the changes of total anthocyanin degradation and to prevent colour deterioration during cold storage (**Varasteh *et al*., 2012**).

Silicon dioxide has a relatively high food safety, is quite stable, and cannot be digested by the digestive tract. This compound has been approved as a food additive **(U.S. Food and Drug Administration, 2011).** At present, nano-silicon dioxide was strict in application of food field in some area. For example, if nanomaterial was used in food processing or preservation, related information must be marked in label according to novel food regulations of EU **(Yu *et al*., 2012).** Furthermore, **Thippeshappa *et al*. (2014)** suggested that silicon sources as potassium silicate significantly increased fruit weight and dimensions, the shelf life period and TSS content of sapota fruits.

Recently, using edible coatings can help to preserve fruits and vegetables due to its work as partial barrier for moisture, O_2 and CO_2. Also, they can improve mechanical handling properties, carrying additives, avoiding volatiles loss and even contribute to the production of aroma volatiles (**Olivas and Barbosa-Canovas, 2005**). However, to date, there are few published data on the effects of chitosan and silicon coating on fruit storage **(Yu *et al*. 2012).** Therefore, due to increase in production and export of apricot during the previous years, practical method of packaging and coating are required to improve the postharvest quality and preserve of apricot fruits.

MATERIALS AND METHODS

Nano Chitosan Preparation

The stock solution of chitosan (2% *W/V*) was prepared by dissolving chitosan powder in 2% acetic acid as described by **Park *et al*. (2002)**. Nano chitosan particles were prepared by addition of 1ml aqueous tri polyphosphate solution (0.25%, *W/V*) to 3 ml of chitosan solution under magnetic stirring. The nano chitosan particle size was characterized and described by **Qi *et al.* (2004)**.

Nano Silicon Preparation

The stock solution of silicon (2% *W/V*) was prepared as described by **Haghighi and Pessarakli (2013)**. Silicon was used as a form of silicate and to purify nano-silicon, the synthesized nano-silicon was treated with various methods such as reflux in an acid environment, resulting in nano-silicon bundles with ~ 99% purity. In the next stage, nano-silicon 8–15 nm in diameter and >10 µm long were suspended in water by sonicating the silicon bundles using an ultra-sonicator at 10 mhz for ~30 min resulting in partially homogeneous solution.

Apricot Fruits Preparation and Treatments

This study was carried out during the 2016 and 2017 seasons on apricot fruits cv. Canino. The fruits were harvested in 25/5/2016 and 2017 from a private apricot orchard located in Cairo Alexandria desert road. The ripe fruits were picked manually using small clippers, packed in carton boxes and taken directly to Post-Harvest Lab. in Pomology Dept., Fac. Agric., Cairo Univ., and Egypt. Fruits with any insect infestation or defects. All fruits washed with regular tap water and soap and then rinsed with water then, air dried.

The fruits were packed in PE bags correspond one of the following treatments: 1. Control (dipped in thiabendazole TBZ), 2. Coating with 0.5% nano chitosan: the fruits dipped in nano-chitosan solution (0.5%) for 5 min. 3. Coating with 2% nano silicon: the fruits dipped in nano-silicon solution (2%) for 5 min. 4. Coating with 0.5% nano chitosan + TBZ: the fruits treated with Thiabendazole, dipped in nano-chitosan solution (0.5%) for 5 min. 5. Coating with 2% nano silicon + TBZ: the fruits treated with TBZ, dipped in nano-silicon solution (2%) for 5 min. The fruits were stored for 7 weeks at 1°C and 90-95% relative humidity (RH).

A sample (in average 500g) of each treatment was randomly taken at weekly intervals to evaluate treatments effect during cold storage through the following parameters.

Fruit firmness

Three fruits of each replicate at weekly interval were taken to determine the changes in fruit firmness using the Effegi firmness tester with an 5/16" plunger (Effegi 48011 Alfonsine, Italy). Fruit firmness was expressed (Ib/inch^2).

Discarded fruit percentage (DFP %)

This parameter was calculated as a percentage of the discarded fruits "due to physiological and fungal injuries" to the total number of fruits.

Fruit weight loss percentage (FWL %)

Fruits of each replicate were weighed just before and after cold storage treatments.

FWL (%) = Initial weight – Weight at specific interval / Initial weight × 100

Juice total acidity (%)

It was calculated by titration against 0.1 N sodium hydroxide in presence of phenolphthalein dye according to the method described by **AOAC (2000)**.

Juice total soluble solids content (TSS)

It was determined using a hand refractometer as Brix° using a hand refractometer.

Panel test index (PTI)

Random fruit sample of each replicate was judged by 5 persons to give PTI score according to the following index: 5 = excellent taste; 4 = very good taste; 3 = good taste; 2 = acceptable taste and 1 = bad taste.

Ascorbic Acid (Vitamin. C) Content

Ascorbic acid content was estimated by titration in 2, 6 dichlorophenol-indophenol dye against 2% oxalic acid solution as substrate. Ascorbic acid content was calculated as milligram per 100 ml of fruit juice (**AOAC, 2000**).

Statistical Analysis

The experiment was studied in a completely randomized block design with five treatments, each treatment was divided into three replicates, 60 uniform fruits were chosen at random for each replicate at the first and second season, and the obtained data in both seasons were subjected to analysis of variance (ANOVA) according to **Snedecor and Cochran (1980)**. The interactions effect between treatments and storage period were differentiated using new LSD method at 5% level.

RESULTS

Fruit Firmness (lb/inch^2)

Results in Table 1 clarify the significant decrement of fruit firmness with increasing in cold storage period. Therefore, the lowest fruit firmness was recorded at the end after seven weeks (5.22 and 5.31Ib/inch^2) in the first and second seasons, respectively.

Therefore, the highest significant (8.98 and 9.24 lb/inch^2) fruit firmness values were recorded after one and seven weeks of cold storage in the first and second seasons, respectively.

All coating treatments maintained higher fruit firmness than the control. The least fruit firmness values were recorded for the control in the first and second seasons (7.01 and 7.27, respectively). Also, the Coating 0.5% nano chitosan + TBZ treatment maintained higher firmness value (7.28 and 7.52 lb/inch^2) compared with the other treatments in the first and second seasons, respectively.

The interaction between cold storage period and treatments clarified that the highest fruit firmness from the interaction between 0.5% nano chitosan + TBZ treatment and 0.5 % nano chitosan in the first and second season, respectively in the first week, while the lowest values was from the control treatment in the last week in both seasons.

Table 1. Effect of chitosan/nano-silicon coating treatments on fruit firmness (lb/inch²) of Canino apricot fruits during cold storage in 2016 and 2017 seasons

Treatment (T)	Fruit firmness (lb/inch²) Cold storage period (SP) (week)								Mean (T)
	0	1	2	3	4	5	6	7	
				2016 Season					
Control (dipped in TBZ)	9.76	9.10	8.16	6.10	6.00	5.90	5.66	4.36	**7.01**
0.5% nano chitosan + TBZ	9.40	9.30	8.20	7.50	6.90	6.46	5.67	4.80	**7.28**
0.5% nano chitosan	9.16	8.53	7.63	6.76	6.46	6.23	6.20	5.96	**7.12**
2% nano silicon + TBZ	9.56	9.10	8.06	7.60	6.67	6.20	5.86	4.43	**7.18**
2% nano silicon	9.43	8.90	7.86	7.10	6.30	5.80	5.70	5.53	**7.08**
Mean (SP)	**9.46**	**8.98**	**7.98**	**7.01**	**6.46**	**6.12**	**5.82**	**5.22**	
New LSD at 0.05 %	T = NS			SP = 0.30			T × SP = 0.68		
				2017 Season					
Control (dipped in TBZ)	9.76	9.33	7.86	7.20	6.60	6.20	5.80	4.36	**7.27**
0.5% nano chitosan + TBZ	9.67	8.26	8.10	7.46	7.20	6.50	6.90	6.06	**7.52**
0.5% nano chitosan	9.80	9.67	8.23	7.80	6.80	6.13	5.83	4.90	**7.39**
2% nano silicon + TBZ	9.67	9.43	8.10	7.73	6.76	6.26	5.73	4.60	**7.29**
2% nano silicon	10.20	9.53	7.87	7.06	6.40	6.30	6.03	5.63	**7.38**
Mean (SP)	**9.82**	**9.24**	**8.03**	**7.45**	**6.75**	**6.28**	**6.06**	**5.31**	
New LSD at 0.05%	T = 0.19			SP = 0.20			T × SP = 0.43		

Discarded Fruit Percentage (DFP %)

It is clear from Table 2 that fruit decay percentage was significantly increased with the advance in cold storage period in both seasons. After three weeks of cold storage, no discarded fruits found under all tested treatments. Fruits of all treatments started to discard at the beginning of the 4th week, and the highest significant fruit decay was observed in the last week of cold storage (47.11 and 44.89 %) in the first and second seasons, respectively.

No significant differences were obtained between all treatments in both seasons. The interactions of control (dipped in TBZ) × 7 weeks storage period and nano silicon × 7 weeks recorded high (51.11 + 46.67 and 48.89 + 46.67) values of DFP% in the two seasons compared with other interactions.

No discarded fruits resulted from the interaction between different periods and all treatments until the third week, and then it increased gradually to be the highest in the control treatment in the last week.

Fruit Weight Losses Percentage (FWL %)

Results in Table 3 indicate that fruit weight loss (FWL) percentage was markedly increased as cold storage period increased, so the highest significant values (13.30 and 13.64%) were recorded after seven weeks (the end of storage period) in the both studied seasons, respectively.

As for the tested treatments, the highest FWL percentage was significantly induced by the control as compared with other treatments (7.47 and 8.83%) without significant differences with 2% nano silicon treatment in both seasons. Coating treatment 0.5% nano chitosan + TBZ significantly decreased FWL percentage compared with the other treatments, with values (4.41 and 6.41%).

Table2. Effect of chitosan/nano-silicon coating treatments on discarded fruit percentage (DFP%) of Canino apricot fruits during cold storage in 2016 and 2017 seasons

Treatment (T)	Discarded fruit percentage (DFP %)								Mean (T)
	Cold storage period (SP) (week)								
	0	1	2	3	4	5	6	7	
				2016 Season					
Control (dipped in TBZ)	0.00	0.00	0.00	0.00	15.5	22.22	46.67	51.11	**16.94**
0.5% nano chitosan + TBZ	0.00	0.00	0.00	0.00	11.11	13.33	40.00	44.44	**13.61**
0.5% nano chitosan	0.00	0.00	0.00	0.00	13.33	22.22	31.11	44.44	**13.89**
2% nano silicon + TBZ	0.00	0.00	0.00	0.00	11.10	20.00	35.55	46.67	**14.17**
2% nano silicon	0.00	0.00	0.00	0.00	15.55	20.00	33.33	48.89	**14.72**
Mean (SP)	**0.00**	**0.00**	**0.00**	**0.00**	**13.33**	**19.55**	**37.33**	**47.11**	
New LSD at 0.05%		T = NS			SP = 3.25		T × SP = 7.26		
				2017 Season					
Control (dipped in TBZ)	0.00	0.00	0.00	0.00	17.8	20.00	46.67	46.67	**16.39**
0.5% nano chitosan + TBZ	0.00	0.00	0.00	0.00	13.3	22.23	26.67	42.22	**13.06**
0.5% nano chitosan	0.00	0.00	0.00	0.00	15.56	17.7	35.55	44.44	**14.17**
2% nano silicon + TBZ	0.00	0.00	0.00	0.00	8.89	22.22	35.55	44.44	**14.44**
2% nano silicon	0.00	0.00	0.00	0.00	13.3	20.00	40.00	46.67	**15.00**
Mean (SP)	**0.00**	**0.00**	**0.00**	**0.00**	**13.78**	**20.44**	**36.89**	**44.89**	
New LSD at 0.05%		T = NS			SP = 4.00		T × SP = 8.97		

Table 3. Effect of chitosan/nano-silicon coating treatments on fresh weight losses percentage (FWL%) of apricot fruits during cold storage in 2016 and 2017 seasons

Treatment (T)	Fruit weight losses percentage (FWL %)								Mean (T)
	Cold storage period (SP) (week)								
	0	1	2	3	4	5	6	7	
				2016 Season					
Control (dipped in TBZ)	0.00	0.00	4.76	8.34	9.96	11.51	12.19	15.14	**7.74**
0.5% nano chitosan + TBZ	0.00	0.00	3.45	4.11	4.55	5.47	7.16	10.50	**4.41**
0.5% nano chitosan	0.00	0.00	2.94	3.60	4.83	11.83	13.06	14.2	**6.35**
2% nano silicon + TBZ	0.00	0.00	4.92	8.16	8.98	10.50	11.38	11.67	**6.95**
2% nano silicon	0.00	0.00	3.24	7.78	9.39	11.06	14.27	14.98	**7.59**
Mean (SP)	**0.00**	**0.00**	**3.87**	**6.40**	**7.54**	**10.08**	**11.68**	**13.30**	
New LSD at 0.05%		T = 0.67			SP = 0.84		T × SP = 2.15		
				2017 Season					
Control (dipped in TBZ)	0.00	0.00	5.09	10.41	12.05	13.77	13.89	15.39	**8.83**
0.5% nano chitosan + TBZ	0.00	0.00	4.21	4.80	8.06	10.50	11.74	12.13	**6.41**
0.5% nano chitosan	0.00	0.00	4.08	7.50	8.44	10.00	11.26	12.15	**6.72**
2% nano silicon + TBZ	0.00	0.00	5.01	7.90	10.24	11.79	13.08	13.79	**7.73**
2% nano silicon	0.00	0.00	4.58	9.12	11.20	12.25	12.88	14.72	**8.09**
Mean (SP)	**0.00**	**0.00**	**4.62**	**7.95**	**9.98**	**11.67**	**12.57**	**13.64**	
New LSD at 0.05%		T = 0.89			SP = 1.06		T × SP = 2.62		

No FWL occurred due to the interaction between all treatments in the first week of storage, but it started to increase from the second week to record the maximum value in the control treatment fruits in the last week in both seasons.

Total Acidity Percentage (%)

As shown in Table 4, results cleared that total acidity percentage was gradually and significantly decreased with the advance in cold storage period in the two seasons. The least significant values were recorded seven weeks after cold storage in the two seasons (3.58 and 2.17 mg malic acid), while, the highest significant values resulted from zero time cold storage (5.10 and 4.69%).

Control treatment retained lowest acidity percentage (4.22 and 2.98%) compared with other treatments in the first and second seasons, respectively. Coating 0.5% nano chitosan + TBZ treatment retained significantly higher acidity percentage (4.50 and 3.81 mg malic acid in the two seasons, respectively) compared with control without significant differences with 0.5% nano chitosan treatment in both seasons.

The highest values of acidity were obtained in the first week and its interaction with 0.5% nano chitosan in the first season and 0.5% nano chitosan + TBZ in the second season, while the lowest value was from the interaction between the control treatment in the seventh week.

Total Soluble Solids (TSS as Brix°)

The results in Table 5 show that TSS percentage was gradually increased with the advance in cold storage period in the two seasons. Thus, the highest significantly (13.26 and 13.80° Brix) and the lowest significantly (11.00 and 11.14° Brix) values of TSS were recorded after seven and 0 weeks of storage period in both seasons, respectively.

Control treatment gave the highest TSS (12.25 and 12.62° Brix) in the first and second seasons, respectively. While, coating 0.5 % nano chitosan + TBZ treatment gained significantly the lowest TSS compared with the other tested treatments, with no significant differences in the first season only.

The lowest values of TSS was due to 2% nano silicon + TBZ treatment in the first week, while the same treatment caused the highest TSS in the last week in the first season only and in control in the second season.

Fruit Panel Test Index (FPT)

The results in Table 6 indicate that the fruit panel test (FPT) was significantly gradually decreased with the advance in cold storage period after five weeks of storage. The lowest significant value of FPT were recorded after seven weeks (1.46 and 1.73), while the highest significant (4.60 and 4.20) FPT value were found with the 5th week of cold storage in both studied seasons, respectively.

There were no significant differences between all treatments in FTP in both seasons.

The interactions of all treatments with storage periods 4 or 5 weeks recorded highest values of FPT in the two seasons, as well as, interactions of 3 weeks storage periods and the coating treatments (0.5% nano chitosan + TBZ and 2% nano silicon + TBZ) was significant in the two seasons.

The lowest values of FPT came from the interaction between the first week storage periods and 2% nano silicon treatment in the first season and control in the second season. The highest FPT was from the interaction between the last fifth week and 0.5% nano chitosan + TBZ treatment in the first season while it was between the fourth week and control treatment in the second season then the values decreased again.

Ascorbic Acid Content (mg/100ml juice)

Results in Table 7 show that vitamin C (ascorbic acid) content was significantly decreased with increasing the cold storage period. The lowest significant content (6.74 and 5.93 mg/100ml juice) were found after seven weeks of cold storage period, while the highest significant content (15.13 and 14.20 mg/100ml juice) were recorded at the beginning of cold storage time in both seasons, respectively.

The coating with 0.5% nano chitosan + TBZ and 0.5% nano chitosan treatments maintained significantly the highest ascorbic acid content compared to other treatments in both seasons.

The 0.5% nano chitosan treatment maintained the highest ascorbic acid content in the first season and 0.5% nano chitosan + TBZ treatment in the second season in the first week, while it decreased gradually to be the lowest in the last week in 2% nano silicon in both seasons.

Table 4. Effect of chitosan/nano-silicon coating treatments on total acidity percentage (mg malic acid/100ml juice) of Canino apricot fruits during cold storage in 2016 and 2017 seasons

Treatment (T)	Total acidity percentage (%) Cold storage period (SP) (week)								Mean (T)
	0	1	2	3	4	5	6	7	
				2016 Season					
Control (dipped in TBZ)	4.91	4.68	4.42	4.37	4.14	3.97	3.88	3.43	**4.22**
0.5% nano chitosan + TBZ	5.08	4.97	4.86	4.57	4.44	4.31	4.06	3.65	**4.50**
0.5% nano chitosan	5.44	5.08	4.99	4.68	4.19	4.06	3.88	3.57	**4.49**
2% nano silicon + TBZ	5.08	4.99	4.95	4.55	4.50	4.24	3.88	3.61	**4.47**
2% nano silicon	4.99	4.89	4.77	4.59	4.39	4.20	4.03	3.65	**4.44**
Mean (SP)	**5.10**	**4.92**	**4.92**	**4.55**	**4.33**	**4.15**	**3.94**	**3.58**	
New LSD at 0.05%		T = 0.20			SP = 0.13			T × SP = 0.29	
				2017 Season					
Control (dipped in TBZ)	4.55	4.41	3.92	3.34	2.94	1.74	1.65	1.29	**2.98**
0.5% nano chitosan + TBZ	4.82	4.46	4.19	3.65	3.57	3.44	3.26	3.10	**3.81**
0.5% nano chitosan	4.46	4.19	3.97	3.65	3.48	3.36	3.21	2.85	**3.65**
2% nano silicon + TBZ	4.73	4.24	3.88	3.30	3.03	2.72	2.54	1.96	**3.30**
2% nano silicon	4.91	4.15	3.61	3.25	2.81	2.49	2.09	1.65	**3.12**
Mean (SP)	**4.69**	**4.29**	**3.91**	**3.44**	**3.17**	**2.75**	**2.55**	**2.17**	
New LSD at 0.05%		T = 0.17			SP = 0.16			T × SP = 0.37	

Table 5. Effect of chitosan/nano-silicon coating treatments on total soluble solids (TSS as Brix°) of Canino apricot fruits during cold storage in 2016 and 2017 seasons

Treatment (T)	Total soluble solids (TSS) (Brix°) Storage period (SP) (week)								Mean (T)
	0	1	2	3	4	5	6	7	
				2016 Season					
Control (dipped in TBZ)	11.16	11.2	11.63	12.13	12.20	12.9	13.33	13.40	**12.25**
0.5% nano chitosan + TBZ	10.83	11.23	11.56	11.96	12.20	12.40	12.83	13.06	**12.01**
0.5% nano chitosan	10.90	11.13	11.53	11.86	12.16	12.56	12.90	13.23	**12.03**
2% nano silicon + TBZ	10.93	11.06	11.76	12.0	12.10	12.86	12.96	13.50	**12.15**
2% nano silicon	11.16	11.50	11.90	11.96	12.30	12.73	12.96	13.10	**12.20**
Mean (SP)	**11.00**	**11.22**	**11.68**	**11.98**	**12.19**	**12.69**	**13.00**	**13.26**	
New LSD at 0.05%		T = NS			SP = 0.15			T × SP = 0.34	
				2017 Season					
Control (dipped in TBZ)	11.26	11.83	12.10	12.40	12.90	13.13	13.40	13.93	**12.62**
0.5% nano chitosan + TBZ	11.00	11.30	11.63	11.90	12.13	12.63	12.93	13.40	**12.11**
0.5% nano chitosan	11.06	11.43	11.46	11.96	12.20	12.73	13.13	13.56	**12.19**
2% nano silicon + TBZ	11.16	11.26	12.00	12.26	12.60	13.03	13.40	14.13	**12.47**
2% nano silicon	11.23	11.43	12.13	12.46	12.66	13.10	13.66	14.10	**12.60**
Mean (SP)	**11.14**	**11.4**	**11.86**	**12.20**	**12.50**	**12.92**	**13.30**	**13.80**	
New LSD at 0.05%		T = 0.34			SP = 0.15			T × SP = 0.35	

Table 6. Effect of chitosan/nano-silicon coating treatments on fruit panel test index (FPT) of Canino apricot fruits during cold storage in 2016 and 2017 seasons

Treatment (T)	Fruit panel test index (FPT) Cold storage period (SP) (week)								Mean (T)
	0	1	2	3	4	5	6	7	
				2016 Season					
Control (dipped in TBZ)	2.00	2.33	2.66	3.00	4.00	4.87	2.66	1.33	**2.87**
0.5% nano chitosan + TBZ	2.33	2.33	3.33	4.00	4.33	5.00	3.33	1.33	**3.25**
0.5% nano chitosan	2.33	2.66	3.66	3.66	4.00	4.33	3.00	1.66	**3.16**
2% nano silicon + TBZ	2.33	2.33	2.66	3.33	4.33	4.33	3.66	1.66	**3.08**
2% nano silicon	2.00	2.00	2.66	4.00	4.00	4.33	3.00	1.33	**2.91**
Mean (SP)	**2.20**	**2.33**	**3.00**	**3.60**	**4.13**	**4.60**	**3.13**	**1.46**	
New LSD at 0.05 %	T = NS			SP = 0.45			T × SP = 1.00		
				2017 Season					
Control (dipped in TBZ)	1.66	2.33	3.00	3.33	4.66	4.00	2.66	1.66	**2.91**
0.5% nano chitosan + TBZ	2.66	2.66	3.66	3.66	4.00	4.34	3.33	1.66	**3.25**
0.5% nano chitosan	2.66	3.00	3.33	3.33	3.66	4.33	3.66	1.66	**3.28**
2% nano silicon + TBZ	2.66	3.00	3.33	3.66	3.66	4.00	3.00	1.66	**3.12**
2% nano silicon	2.00	2.66	2.66	3.00	4.00	4.33	3.33	2.00	**3.00**
Mean (SP)	**2.33**	**2.73**	**3.20**	**3.40**	**4.00**	**4.20**	**3.20**	**1.73**	
New LSD at 0.05 %	T = NS			SP = 0.49			T × SP = 1.09		

(Index 1. very bad / 2.bad / 3. good / 4. very good / 5. excellent taste)

Table 7. Effect of chitosan/nano-silicon coating treatments on ascorbic acid content (mg/ 100 ml juice) of apricot fruits during cold storage in 2016 and 2017 seasons

Treatment (T)	Ascorbic acid content (mg/100 ml juice) Cold storage period (SP) (week)								Mean (T)
	0	1	2	3	4	5	6	7	
				2016 Season					
Control (dipped in TBZ)	14.92	13.87	12.99	11.93	11.34	8.93	7.72	6.94	**11.08**
0.5% nano chitosan+TBZ	15.85	14.68	13.59	13.09	12.57	11.32	8.55	6.71	**11.97**
0.5% nano chitosan	15.64	14.71	14.22	13.30	12.72	9.60	8.42	6.99	**11.95**
2% nano silicon + TBZ	15.01	14.38	13.29	12.49	12.14	11.51	8.82	6.85	**11.81**
2% nano silicon	15.01	14.65	13.65	13.17	11.82	8.97	7.27	6.21	**11.34**
Mean (SP)	**15.13**	**14.46**	**13.55**	**12.79**	**12.12**	**10.07**	**8.15 G**	**6.74 H**	
New LSD at 0.05%	T = 0.58			SP = 0.27			T × SP = 0.60		
				2017 Season					
Control (dipped in TBZ)	13.88	12.71	12.12	11.67	10.65	8.94	6.82	5.65	**10.30**
0.5% nano chitosan + TBZ	14.71	13.64	13.15	12.80	11.78	9.61	7.69	6.39	**11.22**
0.5% nano chitosan	14.48	13.55	12.95	13.01	11.40	9.43	7.64	6.08	**11.07**
2% nano silicon + TBZ	14.06	13.12	12.47	12.15	11.17	9.02	7.20	5.64	**10.60**
2% nano silicon	13.90	12.99	12.23	11.87	11.06	9.09	7.10	5.30	**10.52**
Mean (SP)	**14.20**	**13.20**	**12.58**	**12.30**	**11.21**	**9.22**	**7.29**	**5.93**	
New LSD at 0.05%	T = 0.39			SP = 0.19			T × SP = 0.43		

DISCUSSION

In this study, the effectiveness of different treatments of nano chitosan and nano silicon coatings for increasing the storage life of Canino apricot fruits was investigated. Based on the results, it can be concluded that nano chitosan + TBZ found to be effective to extend the storage life of the fruits.

Nano chitosan and nano silicon coatings delayed changes in weight loss, total soluble solids, titratable acidity and discarded fruit percentage compared to fruits treated with TBZ (control). These findings are corresponding with those of **Gardesh et al., (2016) and Hossain and Iqbal (2016)**.

It was demonstrated that chitosan inhibited the growth of many spoilage and pathogenic bacteria and also yeast and molds **(El Ghaouth *et al.,* 1991; Roller, 2003)**. In this study, treatment with nano chitosan + TBZ coating showed the best treatment which delayed the increase in decay of stored apricot fruits, indicating that the nano chitosan coating reduced pathogen growth in some way. The antimicrobial activity of chitosan is related to its positively charged amino group which interacts with negatively charged microbial cell membrane promoting an increase in their permeability and causing disruptions that lead to cell death (**Ziani *et al*., 2009**). Also, **Aider (2010)** demonstrated that the antimicrobial activity depends on the type of chitosan, degree of acetylation, molecular weight, the target microorganism, the pH of the medium, and presence of other additives or food components. In addition, it was demonstrated that chitosan, antioxidants and their combinations used as postharvest treatments were capable of reducing the deterioration of various physical and chemical characteristics during cold storage and after post- storage shelf life in addition to keeping fruit quality and extending its storability, marketability and shelf life (**Nagy, 2018**).

Similarly, decay incidence of the apricot coated with nano-silicon alone or with TBZ was higher than that of control during storage time. The reason was probably owing to surface effect of nanomaterial. The electrons of outermost layer were unsaturated in surface atoms, and they were not able to interact with other substance **(Hu *et al*., 2007)**. Also, several authors have shown an increased presence of Si in cell walls after Si application which results in increased mechanical cell strength and provide a physical barrier to any pathogen, thereby affects the ability of pathogens hyphae to penetrate the cell wall (**Chérif *et al*., 1992**).

In this study, nano chitosan proved to be an effective coating significantly reducing fresh weight loss compared with control and other treatments. Fruit weight loss is mainly associated with respiration and moisture evaporation through the skin. The rate at which water is lost depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere, and also the storage temperature. They play as barriers, thereby restricting water transfer and protecting fruit skin from mechanical injuries, as well as sealing small wounds and thus delaying dehydration (**Ribeiro *et al*., 2007**). In addition, chitosan coating useful to inhibit pathogen isolates that are resistant to currently used postharvest fungicides **(Chien *et al*. 2007)**.

Nano silicon wasn't effective treatment to reduce weight loss of fruits, that finding isn't agree with **Tesfay *et al*. (2011)**. Who stated that decrease weight loss with Si treatment may be to covers fruit stomata with a Si layer; it reduces fruit respiration and losses of water. Si treatments, therefore, could positively be associated with delaying fruit weight loss by maintaining fruit moisture.

Chitosan coatings have been effective in controlling water loss from other commodities, including apricot fruits (**Ghasemnezhad *et al*., 2010),** peach fruits coated with nano chitosan **(Gad *et al*., 2016**), longan fruit (**Jiang and Li, 2001**), banana and mango (**Kittur *et al*., 2001**) and strawberries (**Ribeiro *et al*., 2007**).

There were insignificant differences observed in fruit firmness between coated fruits with nano chitosan and nano silicon and the control in both seasons. Where, all coating treatments kept higher fruit firmness than the control. These findings are in agreement with the results of several reports which indicating that the treated fruit come out firmer at the end of the storage period (**Li and Yu, 2000; Ardakani *et al*., 2010; Shao *et al*., 2012; Gardesh *et al*., 2016).**

The estimation of amounts of TA, and TSS in the coated fruits and the control during storage showed that coatings with nano chitosan and silicon lead to increase the amount of TA and decrease the amount of TSS in the fruits in both seasons. The same trend was noticed by **Plácido *et al.* (2016)** in tangerines coated with chitosan. **Scalon *et al.* (2012)** explained the compounds responsible for acidity (organic acids) in fruits release hydrogen ions, contributing to increased acidity, and showing the senescence stage progress. Similarly, lower TSS than in control fruits were reported for mangoes and bananas coated with chitosan while higher values reported for treated peaches **(Du *et al.*, 1997; Srinivasa *et al.*, 2002)**. On the other hand, **Shi *et al.* (2013)** mentioned to the decreases in the contents of total soluble solids, and titratable acidity due to chitosan/nano-silica films during storage time.

In this study, the nano chitosan and silicon coatings led to increased content of vitamin C, possibly because the coating reduces the gas exchange rate with the environment, inhibiting the ascorbic acid exposure to O_2 and concentrating it in the fruit. This finding is in agreement with **Han *et al.* (2014)** who reported delayed degradation of vitamin C in chitosan-coated luffa fruits (*Luffa cylindrica*). On contrast, the results revealed by **Shi *et al.* (2013)** stated that there was clear decline in Vitamin C value of the coated fruit with nano chitosan along with the storage period.

It worth to mention that all coating treatments were improved the quality of fruits compared with control by mixing them with TBZ. That is because of postharvest TBZ treatment reduce chilling injury, a physiological disorder that reduces the quality of stored fruits (**Eckert and Eaks, 1989**)

We suggest that the application of nano chitosan coating could be beneficial in extending postharvest life and maintaining quality and, to some extent, controlling decay of apricot fruits. However, for longer storage, chitosan coating to control decay and improve physiochemical properties of apricot fruit, in combination with the partial use thiabendazole, could be better.

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تأثير التغطية بالنانو شيتوزان والنانو سيلكون على جودة ثمار المشمش الكانينو أثناء التخزين المبرد

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أجري هذا العمل خلال موسمي ٢٠١٦-٢٠١٧ في معمل تخزين الحاصلات البستانية بقسم الفاكهة في كلية الزراعة جامعة القاهرة، مصر، تم دراسة تغييرات الجودة والتغييرات الداخلية (الطبيعية والكيميائية) في ثمار المشمش الكانينو والتي تم تغطيتها بمعاملات مختلفة من النانو شيتوزان والنانو سيلكون، وذلك بعد فترات مختلفة من التخزين المبرد على درجة واحد مئوية و٩٠-٩٥% رطوبة نسبية، تم تجهيز النانو شيتوزان بتركيز ٠,٥% والنانو سيلكون ٢%، وتم اختبارهما بصورة فردية أو بخلطهما مع Thiabendazole (TBZ)، تم تقدير التغيرات في صلابة الثمار، الفقد بالوزن، معدل التلف، اختبار التذوق، الحموضة الكلية، المواد الصلبة الذائبة الكلية ومحتوى فيتامين C على فترات خلال ٧ أسابيع، أظهرت النتائج والتي تم اجرائها في موسمين متتاليين أن المعاملة بالنانو شيتوزان والنانو سيلكون حافظت على صلابة الثمار بالمقارنة بالكونترول بدون اختلافات معنوية، أدت التغطية ب ٠,٥% نانو شيتوزان+TBZ حافظت على قيم مرتفعة للصلابة، على الجانب الآخر أدت التغطية بالنانو شيتوزان + TBZ إلى المحافظة على قيم الحموضة، اختبار التذوق ومحتوى فيتامين C أكثر من ثمار الكنترول غير المغطاة والمعاملات الأخرى بدون فروق معنوية في كلا الموسمين، بينما أدت جميع معاملات التغطية إلى ارتفاع قيم المواد الصلبة الذائبة الكلية ونسبة الثمار المستبعدة بالمقارنة بالكنترول بدون فروق معنوية، تحققت أقل القيم عند المعاملة بالنانو شيتوزان + TBZ وبالمثل فإن نفس المعاملة أدت إلى تقليل نسبة الفقد بالوزن معنوياً بالمقارنة بالمعاملات الأخرى.

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