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Research Article
Application of Nano-coating and Chitosan Combination Films on Cantaloupe Preservation

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Abstract

Background and Objective: Fresh-cut cantaloupe faces several quality challenges as an increase of decay rate, browning, respiration and other changes which can reduce the shelf life. Nano-coating combination films as chitosan-nano-silicon dioxide and chitosan-nano-titanium dioxide can extend the shelf life of cantaloupe pieces. **Materials and Methods:** Cantaloupes were classified into four sets, Control (C), Chitosan (CTSN), Chitosan-Nano-Silicon Dioxides (CTSN/NSD) and Chitosan-Nano-titanium Dioxide (CTSN/NTD). **Results:** Coated cantaloupe pieces had the best browning activity of polyphenol oxidase (PPO) (0.26 U/min/g) and the lowest water activity (Aw) (0.89) by chitosan-nano-silicon dioxide films. Chitosan-nano-titanium dioxide films could maintain weight loss (0.93%) and color pigments for L* value. It worked effectively against lipid peroxidation (MDA) (0.15 nmol g^{-1}), Peroxidase Activity (POD) (3.92 U/min/g) and microbial contaminations (6.44 log CFU g^{-1}). **Conclusion:** Both nano-coating films improved some chemical parameters as Titratable Acidity (TA), Soluble Solid Content (SSC) and pH. Nano-coatings films techniques were recommended for cantaloupes preservation methods.

Key words: Chitosan, nano-silicon dioxide, nano-titanium dioxide, shelf life, cantaloupe

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Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Public concern on fresh fruits safety and microbiological contaminations[1]. Fresh-cut fruits specially too large sizes as melon, cantaloupe and pineapple face several quality challenges during washing, cutting, slicing, packaging and storing such as; changing fruit tissue metabolic process, substrates and enzymes resulted in an increase of decay rate, browning, respiration and other changes which can reduce the shelf life[2]. Several applications for preservation techniques are essential for enhancing the cut cantaloupes safety such as packaging with ultraviolet light, gamma radiation, edible coatings and nano-coatings[3,6]. Chen *et al.*[7] offered the combination of chitosan and allyl isothiocyanate for cantaloupe coating due to its film properties and highly antimicrobial activity. Amaro *et al.*[8] studied the oxygen effect on fresh-cut cantaloupes aroma and quality. Sangsuwan *et al.*[9] considered chitosan and methyl cellulose films on cantaloupe microbiological contaminations. Koh *et al.*[10] studied the effect of pulsed light while, Koh *et al.*[11] mentioned the importance of alginate and pulsed light for fresh-cut cantaloupes at 4°C of storage. Treviño-Garza *et al.*[12] used linseed mucilage as an edible coating with chitosan for fresh-cut cantaloupes. Martinon *et al.*[13] approved the importance of chitosan coatings and some antimicrobial agents. Zhang *et al.*[14] mentioned the coating combination of soybean and cinnamon bark oils with alginate for preservation cantaloupes from microbiological contaminations.

Shi *et al.*[15] and Kou *et al.*[16] applied the nano-silica and chitosan combination to improve longan and jujube fruit qualities. Nano-materials such as; gold, silver, zinc oxide, silicon and titanium dioxide have been used for safety coatings. The FDA recommended nano-materials with low concentrations as non-toxic which could be used in drugs, cosmetics and human foods[17].

Therefore, the present work aims to study the effect of chitosan (1%) combination with nano-silica and nano-titanium dioxide coating films on cantaloupe quality during chilling.

MATERIALS AND METHODS

Materials: Cantaloupes were procured at a local grocery store in Taif, Saudi Arabia and transported to laboratory of Food Science and Nutrition Department, College of Sciences, Taif University, Saudi Arabia without any sign of obvious microbial growth or even physical damage. Chitosan (85% deacetylation) glycerol and acetic acid were purchased from Sigma (Louis, USA). Nano-silicon and titanium dioxide with particle size (15 nm) were procured (Shanghai, China).

Fruits and films preparations: Some physical, chemical and microbial properties of cantaloupe pieces have been studied after different coatings. Cantaloupes were washed, peeled, cut into square slices and chilled. Chitosan film 1% was prepared by mixing acetic acid and glycerol. The same amount for chitosan solution was mixed with 1% silicon and titanium dioxides to prepare coating films. Cantaloupes were classified into four sets as: (1) Control (deionized water) (C), (2) Chitosan (CTSN), (3) Chitosan-nano-silicon dioxides (CTSN/NSD) and (4) Chitosan-Nano-Titanium Dioxide (CTSN/NTD). The cantaloupe square pieces were dipped into the different films for 10 min then allowed to be drain at room temperature. Cantaloupe pieces were kept in (0.02 mm) polyethylene bags at 4°C for investigations every 2 days of storage.

Weight loss, color determination and texture-profile analysis: Weight loss was calculated as a percentage during the storage period. Surface colour was evaluated using a MiniScan (Reston, VA)[6]. The results were considered as; L*, a*, b* for each treatment at different locations. The Texture-Profile Analysis (TPA) was detected using TA-XT2 (England, U.K.). Settings used were traveling[18] at 1 mm sec^{-1}. Hardness (N), gumminess (N), chewiness (N), springiness, cohesiveness and resilience were determined.

Titratable acidity, soluble solid content and pH: Titratable Acidity (TA) was determined by titration of sodium hydroxide with some modifications[19] and results were intended as a percentage of citric acid. Soluble Solid Contents (SSC) were determined by using a digital refractometer (TS400, NY). The pH value was determined on cantaloupe juice at approximately 28°C with a pH meter (Mettler Co., China) with (4.0 and 7.0) calibration.

Lipid peroxidation and browning activities: Cantaloupes were mixed with 20 mL of 10% Trichloroacetic Acid (TBA) to determine lipid peroxidation (MDA) by producing (MDA-TBA) adduct colorimetrically at OD = 532 nm. The MDA levels can be considered[20] as nmol $well^{-1}$. Polyphenol Oxidase (PPO) was gained by mixing 10 g of cantaloupe with phosphate buffer (pH 7), centrifuging at 4,000 rpm and filtering for pure processing. The 0.3 mL extracts with 2.2 mol L^{-1} phosphate buffer was added to 0.5 mL and 0.175 mol L^{-1} catechol[16]. The absorbance was recorded every 15 sec within 3 min at 420 nm. Peroxidase (POD) was gained by mixing 10 g of cantaloupe with 100 mM with phosphate buffer (pH 7), 10 mM ascorbic acid and 2 mM phenylmethylsulfonyl fluoride. The absorbance was recorded[21] every 20 sec at 460 nm within 6 min.

Detection of water activity and microbiological contamination: Total aerobic plate counts of cantaloupes were determined on 0, 2, 4, 6 and 8 days of storage. About 20 g of each treatment were stomached and incubated using 3 M 212 petrifilms at 37°C for 2 days according to AOAC[22] Twelve colonies were reported as Log CFU g^{-1}. Cantaloupes water activity (Aw) was blended and inserted into a sample cup at room temperature using a water activity meter (Decagon, USA)[10].

Statistical analysis: All the measurements data was performed by using SPSS Version 16.0. (SPSS Inc., USA.). One-way ANOVA was also performed. Significant differences were evaluated by Tokays test software.

RESULTS AND DISCUSSION

Effect of nano-coating films on weight loss, color and TPA: Figure 1 shows the effect of nano-coating on weight loss of cantaloupe pieces stored at 4°C for 0-8 days. Weight loss in the control fruits significantly increased with the storage time and reached 4.78%. Cantaloupes coated with CTSN/NTD had the least weight loss 0.93% than CTSN/NSD and CTSN, which increased regularly during the storage time because of respiration processes and vapor pressure. Weight loss variation can be described by the difference coatings thickness[23]. The same results are in agreement with the previous finding[12].

The color index of cantaloupes was depicted in Fig. 2. After storage, the decrease in L* value was observed in all treatments except for CTSN/NTD treatment as Fig. 2a. Falade *et al.*[24] reported that water loss can increase the pigment as β-carotene in watermelon. In addition, the decrease in a* value was observed for nano-coating films treatments as 22.76 and 18.65 for CTSN/NSD and CTSN/NTD that can be a consequence of browning reactions (Fig. 2b). There were no differences were detected for b* values among all coating treatments (Fig. 2c). Zhang *et al.*[14] noticed the same consequences for color determination. The results mentioned that CTSN/NTD coating will maintain the color during storage.

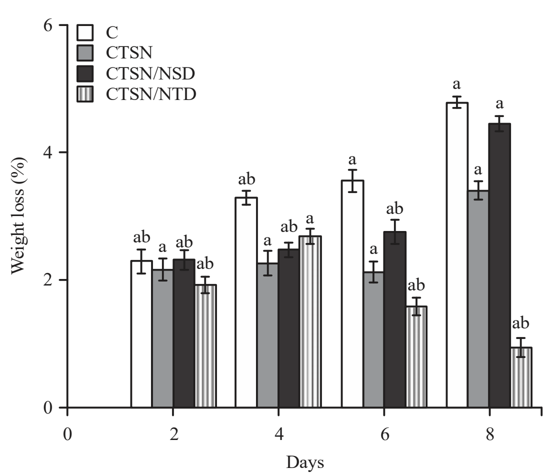

Fig. 1: Effects of different coating on weight loss

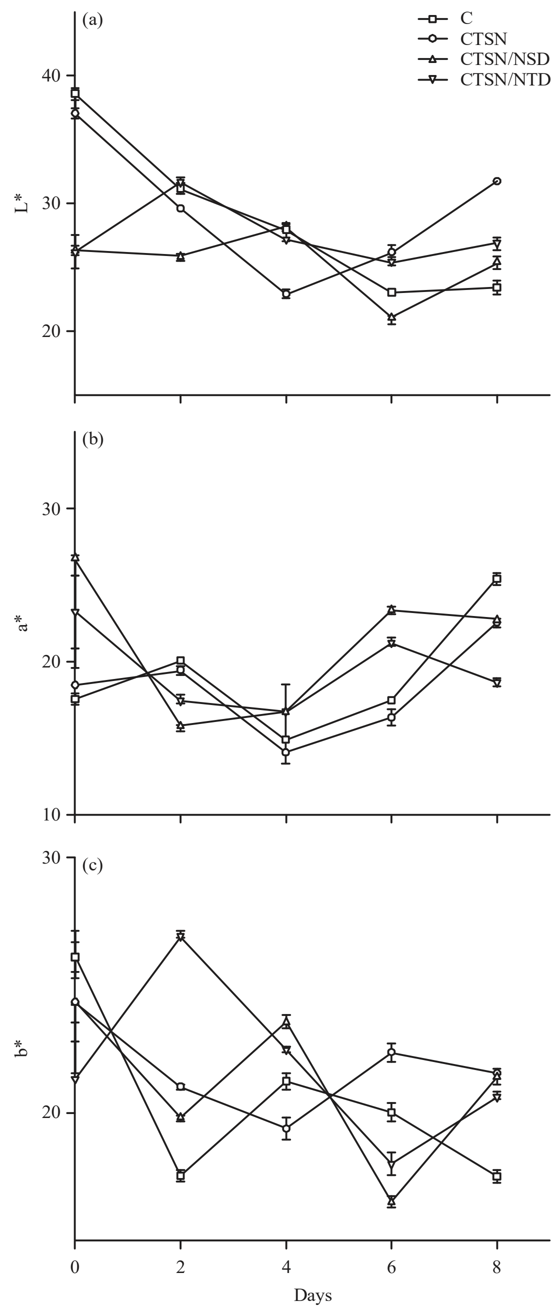

Fig. 2(a-c): Effects of different coating on color index, (a) L*, (b) a* and (c) b*

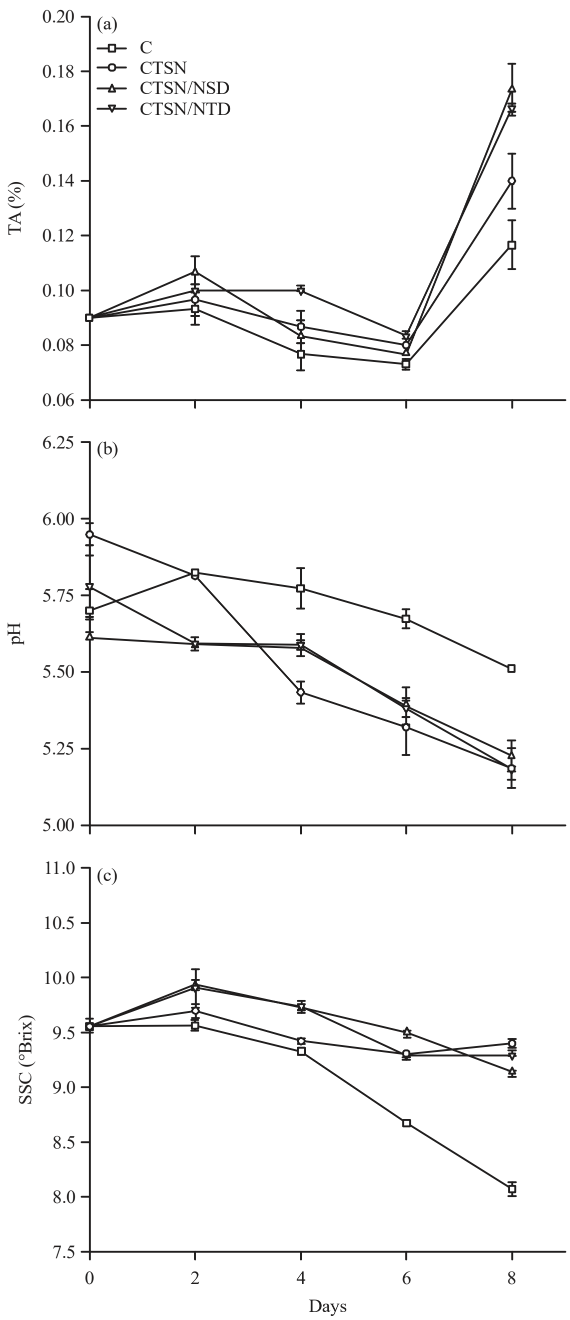

Fig. 3(a-c): Effects of different coating on (a) Titratable acidity, (b) pH and (c) Soluble solid contents (°Brix)

Texture is an essential representative which is highly desirable as customers associate texture with brilliance and freshness. Actually, if customers touch fruits and notice that it is soft, they will reject it immediately[25]. The TPA values of all the coating treatments during storage are shown in Table 1. It was established that the hardness (N), gumminess (N), chewiness (N) and cohesiveness of all the samples increased during the 8 days of storage, while springiness and resilience decreased. From the obtained results, cantaloupes coated with chitosan-nano-silicon dioxide showed the lowest values loss in almost texture analysis compared to other coating treatments, while cantaloupes coated with chitosan-nano-titanium dioxide showed the lowest values loss in springiness only. Munira *et al.*[18] mentioned the reason for the textural changes due to the cutting process that increases the rate of the respiration and packaging and coating processes can dismiss these changes.

Effect of nano-coating films on TA, SSC and pH: Figure 3 shows TA, SSC and pH of cantaloupe pieces as affected by nano-coatings treatments and CTSN. For control samples, the pH decrease and TA increase were more obvious (Fig. 3a, b).

Pintó *et al.*[26] mentioned these changes related to microbial growth and CO_2 concentration which leaded for pH reduction. For CTSN/NTD and CTSN/NSD films coatings detected the same values as 0.17% for TA which can be responsible of ripening delay[26].

Chitosan films samples with different nano-coatings significantly lower pH from 5.95-5.18 until the end of the whole storage due to the acetic acid addition in film preparation[27].

The effect of coating on SSC of cantaloupe pieces are shown in Fig. 3c. Coating films have an obvious effect on SSC maintaining, the control pieces value decreased with the storage time and reached 8.07 (°Brix), while coated cantaloupes increased regularly during the storage time under chilling storage[28]. In a word, SSC in CTSN+nano-materials cantaloupes were increased as well as the storage time increase. Koh *et al.*[10] mentioned that the extra fluid loss can concentrate SSC in cantaloupes.

Effect of nano-coating films on MDA, POD and PPO: The MDA content (Lipid peroxidation) is one of the important factors for indicating the of cell consenescence and damage process degrees[29]. As shown in Fig. 4a, the MDA content of cantaloupe pieces increased as well as the storage extension period. The MDA content of the control samples increased obviously more than that of those cantaloupes coated with CTSN+NTD as 1.80 nmol g^{-1} for control and 0.15 nmol g^{-1} after 8 days, respectively.

The POD activity of cantaloupe pieces coated with CTSN+nano-materials increased with the time extension as shown in Fig. 4b. Compared with the untreated and other treated cantaloupes, the POD activity peak value of CTSN/NTD coating film was the lowest (3.92 U/min/g), comparing with the control (7.41 U/min/g).

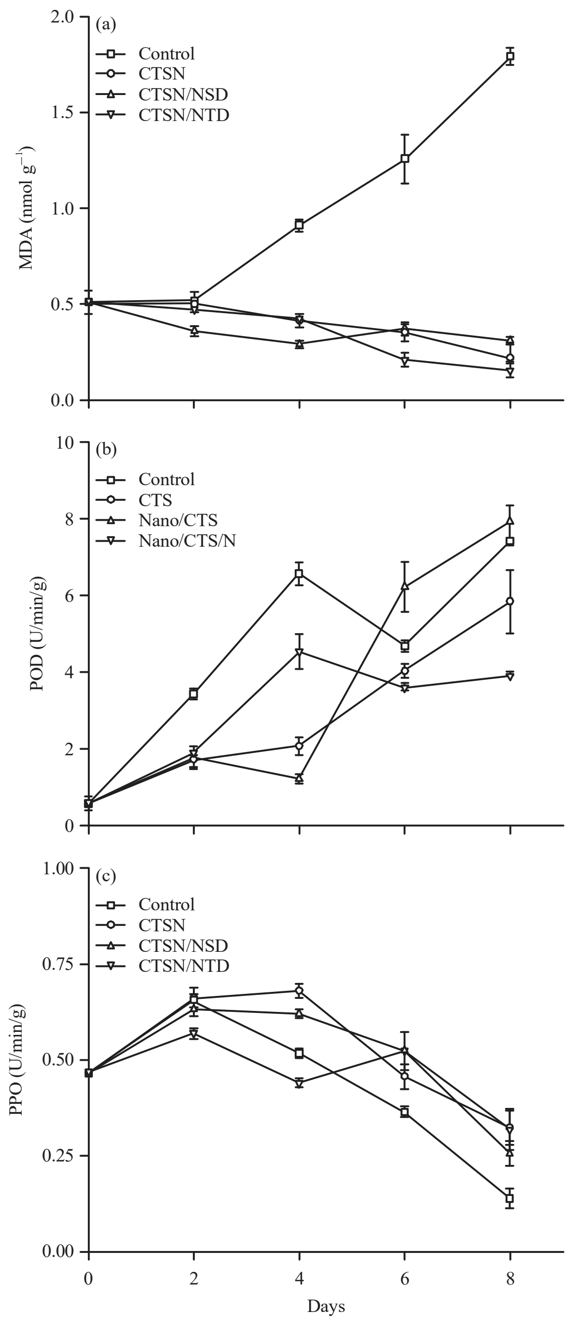

Fig. 4(a-c): Effects of different coating on, (a) Lipid peroxidation, (b) Peroxidase (U/min/g) and (c) Polyphenol oxidase browning activities (U/min/g)

The PPO activity of cantaloupes coated with single CTSN or even CTSN/NSD established an increase on 4th day then decreased until the end of the storage period. CTSN/NSD reported (0.26 U/min/g) compared with other coating films (Fig. 4c). According to the previous results of POD and PPO activities, it recommended to use NSD and NTD coating films for decreasing phenolic activities. Koh *et al.*[11] mentioned the activities reductions were due to the abiotic stress in cantaloupe pieces.

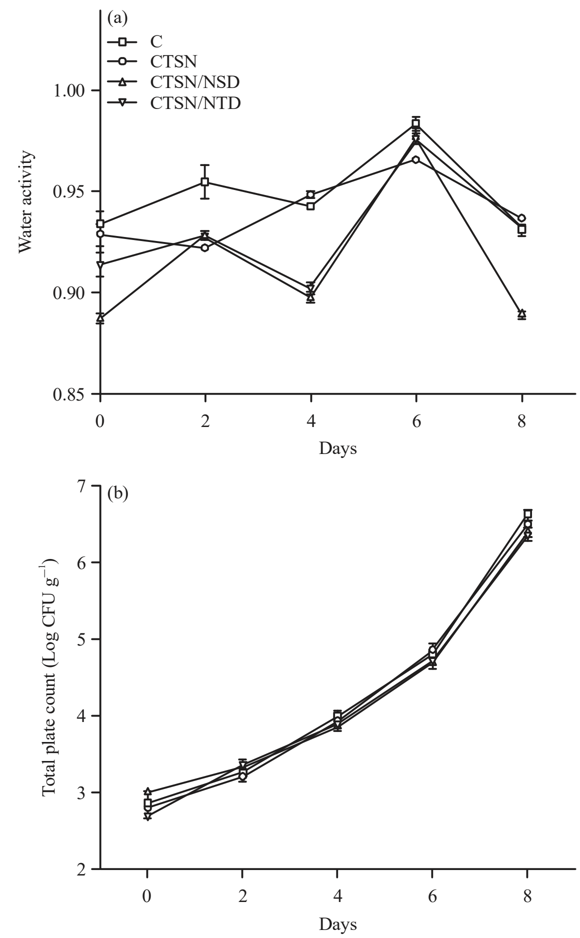

Fig. 5(a-b): Effects of different coating on (a) Water activity and (b) Microbial contamination

Effect of nano-coating films on water activity and microbiological contamination: Water activity values raised considerably in all samples at day 6 of storage that was due to the water holding capacity from the cell wall of the cantaloupe tissues which increases along with the storage time for coated fresh-cut cantaloupes and strawberry samples during chilling[30] at 10°C. The Aw of CTSN/NSD cantaloupes recorded the lowest as 0.89 compared to all the treated cantaloupes as shown as in Fig. 5a.

Figure 5b shows the total population counts during the cantaloupe storage period. The microbiological contamination growth pattern was similar to the previous fresh cut[18]. The total population counts increased during the storage regardless of coating films except for CTSN/NTD. The pH and high sugar contents in the cantaloupe pieces are the main factors for microbial growth promoting[31].

Table 1: Effects of different coating on texture-profile analysis changes of cantaloupe pieces during storage

Days	Coating treatments	Hardness (N)	Gumminess (N)	Chewiness (N)	Springiness	Cohesiveness	Resilience
0	C	15.99±0.18[a]	8.09±1.25[b]	5.48±1.33[a]	0.78±0.01[a]	0.37±0.05[a]	0.37±0.04[a]
	CTSN	8.01±1.39[b]	4.09±0.30[a]	3.09±0.40[b]	0.75±0.06[a]	0.29±0.03[a]	0.40±0.01[a]
	CTSN/NSD	13.13±0.08[b]	3.72±0.14[a]	2.16±0.07[b]	0.78±0.08[a]	0.41±0.04[a]	0.43±0.04[a]
	CTSN/NTD	11.38±2.19[a]	7.32±0.05[b]	4.75±0.05[a]	0.73±0.01[b]	0.36±0.03[b]	0.42±0.06[a]
2	C	19.00±0.62[b]	9.00±0.13[a]	6.39±0.92[a]	0.72±0.11[a]	0.51±0.00[b]	0.36±0.02[ab]
	CTSN	10.04±6.20[b]	5.48±0.35[b]	3.36±0.87[a]	0.72±0.07[a]	0.42±0.07[a]	0.34±0.03[b]
	CTSN/NSD	13.21±2.43[b]	7.79±3.18[a]	5.55±2.41[ab]	0.70±0.02[a]	0.41±0.04[b]	0.40±0.06[a]
	CTSN/NTD	17.47±0.96[a]	7.92±1.86[b]	5.79±1.98[ab]	0.71±0.08[b]	0.49±0.03[ab]	0.35±0.03[a]
4	C	21.07±10.48[a]	11.36±6.47[a]	8.85±5.04[a]	0.71±0.01[a]	0.53±0.06[a]	0.35±0.02[a]
	CTSN	14.01±0.27[ab]	7.93±1.12[a]	5.76±1.39[a]	0.70±0.09[ab]	0.45±0.08[a]	0.37±0.07[a]
	CTSN/NSD	13.85±1.83[ab]	8.64±0.46[ab]	5.91±3.41[a]	0.70±0.01[b]	0.51±0.04[b]	0.35±0.01[b]
	CTSN/NTD	19.05±0.02[a]	9.37±0.50[b]	6.07±0.51[ab]	0.70±0.02[a]	0.51±0.06[a]	0.34±0.04[a]
6	C	27.16±8.40[a]	14.29±2.95[a]	9.58±1.40[a]	0.68±0.04[ab]	0.55±0.05[a]	0.32±0.07[a]
	CTSN	23.39±0.15[a]	10.53±0.72[a]	7.44±1.09[a]	0.67 ±0.04[a]	0.67±0.05[a]	0.34±0.02[a]
	CTSN/NSD	16.97±8.13[a]	9.08±3.86[b]	6.68±2.18[a]	0.61±0.02[b]	0.54±0.16[a]	0.25±0.11[a]
	CTSN/NTD	20.41±10.75[a]	9.37±4.21[b]	6.21±2.11[ab]	0.65±0.09[a]	0.54±0.05[b]	0.28±0.03[a]
8	C	30.25±11.47[a]	15.52±5.00[a]	11.01±3.58[a]	0.67±0.06[a]	0.56±0.03[a]	0.25±0.01[a]
	CTSN	23.76±6.08[a]	13.63±5.22[a]	9.66±4.76[a]	0.61±0.12[a]	0.85±0.49[a]	0.26±0.20[a]
	CTSN/NSD	22.63±2.58[a]	9.32±2.00[ab]	6.79±0.53[a]	0.58±0.12[a]	0.55±0.04[a]	0.23±0.06[a]
	CTSN/NTD	31.37±12.59[ab]	15.56±5.04[b]	11.49±4.06[a]	0.64±0.02[a]	0.69±0.05[b]	0.27±0.02[ab]

Values within a column (lowercase) are significantly different ($p \geq 0.05$), values indicate ±standard deviation

CONCLUSION

Nano-coatings combination as chitosan-nano-silicon dioxide and chitosan-nano-titanium dioxide can extend the shelf life of cantaloupe pieces by maintaining weight loss, color pigments; work effectively against lipid peroxidation, phenolic activities and microbial contaminations.

SIGNIFICANCE STATEMENT

In this study, nano-coatings were efficient for reducing microbial growth, CTSN/NTD and CTSN/NSD reached 6.36-6.44 log CFU g^{-1}, respectively. This study discovered the possible effect of NTD application for improving cantaloupes microbiological quality and other parameters.

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