Reducing Sultani Figs Losses During Markeeting by Thymol and Chitosan Dipping

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ABSTRACT

The aim of this study was to evaluate the effect of chitosan and thymol postharvest dipping on maintaining fruit quality attributes of Sultani figs. Ripe fig fruits gently picked manually and treated with 0.3 or 0.6 mM thymol and 2.5 or 5 g/L chitosan in addition to water treatment then stored at 0°C and 85-90 % RH. A Samples of stored fruits were taken every week to estimate determine fruit quality and storability. The results of the study showed that chitosan treatments significantly reduced fruit weight loss and shriveling percent up to three weeks as compared with the untreated fruit. Thymol and chitosan treatments decreases the percentage of decay incidence and quantitative losses after one, two or three weeks of cold storage plus two days at room temperature especially at the high concentration. All treatments caused a decrease in the percentage of quantitative losses after two or three weeks of storage as compared to control and 0.3 mM thymol. Chitosan significantly maintained fruit firmness, SSC, total and non-reducing sugars up to 3 weeks. In addition, thymol and chitosan treatments had higher phenolic content than control after 1 or two weeks.

Keywords: Fig- safe agrochemicals -postharvest - quality.

INTRODUCTION

The common fruit figs (*Ficus carica* L.), are one of the highest nutritious fruits, rich in sugars, potassium, calcium, iron and dietary fiber. It is also important source of vitamins, amino acids and antioxidants, in addition it is sodium, fat and cholesterol free (Slavin, 2006 and Veberic et al., 2008). Egypt are the second major producer of figs after Turkey, with cultivated area 28,617 ha and annual production 177, 135 tonnes (FAO, 2017). Shelf-life of fresh fig is extremely short, lasting 1–2 day at 20 °C (Morton, 2000). Fresh ripe figs are soft, delicate, easily bruised and very susceptible to decay. Postharvest phyto-pathological diseases severely limited the storagability. Thus, it commonly consumed near to the production area. So, the reduction of postharvest losses and prolong the storage life will led to developing global marketing.

The major fig diseases are alternaria rot caused by (*Alternaria* spp.), gray mold (*Botrytis cinerea*), fig endosepsis (*Fusarium* spp.) and sour rot (Doster et al., 1996; Doster and Michailides, 2007; Coviello et al., 2009). Several postharvest practices of fresh figs were applied to control decay development during storage and marketing. Controlled atmosphere (CA) at 5%–10% O_2 and 15%–20% CO_2 is useful for reduction of figs rot and increase postharvest life. But long storage in CA led to a loss of figs flavor (Crisosto and Kader, 2007). Also acetaldehyde increased of'Mission' figstreated with high CO_2 during the first week, followed by a slight increase of ethanol content which result in developing off-flavor (Colelli et al., 1991). Moreover, the postharvest use of SO_2 before or during cold storage showed a significant reduce of

decay percent of fresh figs during shelf-life. On the other hand, many restrictions face continues use of SO_2 due to higher residual level, in addition to its bleaching effect on fruit color (Crisosto et al. 2007).

For thus, an efficient safe alternativeis seriously needed to control postharvest decay development on fresh figs. Biological practices against postharvest pathogens of fruit include the use of microbial antagonists, natural compounds, or inducers of resistance active on the host (Spadaro and Gullino, 2014). Postharvest dipping treatments in hot water and sodium carbonate can be used to reduce decay percent for 1 or 2 weeks maximum (Molinu *et al.*, 2006). Also, essential oils are natural antioxidants, well known for their antimicrobial and biodegradable properties, safe/low toxic and non-residual compound for humans and the environment (Kalemba and Kunicka, 2003). The potential of using essential oils and their derivatives to control the postharvest diseases has been investigated in many fresh fruits. Thymol as essential oil from thyme is listed by U.S. Food and Drug Administration as food for human, and it has been used as food preservative, additives and medicinal drug (Jain, 1985; Mansour et al., 1986). Liu et al. (2002) reported that postharvest thymol treatment markedly reduced the germination of *Monilinia fructicola* conidia to 2% compared with 98% on untreated apricot fruit. Also, thymol was highly efficient in controlling gray mold on sweet cherries (Chu et al., 1999) and strawberry (Geransayeh et al., 2015).

In addition, the postharvest treatments with chitosan has been suggested due to its antimicrobial effect on several plant diseases, it is also conceded as safe edible coating material and environment safe

(Tripathi and Dubey, 2004). A semi-permeable film can be formed on fruit treated with chitosan, which might be modify the internal atmosphere, as well as to decrease water losses and maintain the quality of the fruits (Olivasand Barbosa-Ca´novas, 2005). Chitosan has broad-spectrum antimicrobial ctivity, which has been well documented (AitBarka, et al., 2004). Application of chitosan has been shown to be effective for control of postharvest diseases and prolonged the storage lifein various fruit such as table grapes, strawberry and jujube fruits without negative effect on fruit quality (El Ghaough et al.,1992; Romanazzi et al.,2002; Meng et al., 2008; Wang et al., 2014).

From the previous studies which refers to the significant effect of thymol as an essential oil and chitosan on reduction of postharvest diseases, they may be promising to manage the decay incidence and losses of fresh figs. The objective of this study was to investigate the effects of postharvest dipping treatments with thymol and chitosan on fruit quality, postharvest life and quantitative losses during cold storage of at 0°C and 85-90% RH.

MATERIALS AND METHODS

1. Plant materials, treatments and statistical design

This experiment was conducted during2017 and 2018 seasons on Sultani fig (*Ficus carica* L.). Fresh fig fruits were manually harvested at ripe stage from 8-year-old trees, grown in a private orchard in Sedi Abdel-rahman, Matrouh governorate, Egypt. Harvested Figs gently packed in carton boxes (2 kg) in two layers, and directly transported to the postharvest laboratory at Faculty of Agriculture, Alexandria University.

The fruits carefully sorted to get rid of unsuitable fruits (mechanical injured, over-ripe, unripe, deformed), uniform fruits ripe stage, size, color and shape were selected to conduct this experiment. The selected fruits were divided into sixty experimental units (5 treatments x 3 replicates x 4 sampling times). Each experimental unitconsisted of 3 kg fruits. Twelve experimental units were randomly selected and subjected for one of the following dipping treatments for one minutes; untreated fruit (control), 0.3 or 0.6 mM thymol and 2.5 or 5 g/L chitosan, then air dried. Fruits of each treatment packed in perforated punnets (500 g), each 6 punnets were packed in one plastic box (40 cm X 25 cm X 15cm) as a replicate. The treatments were arranged in a randomized complete block design (RCBD) in a cold storage room at 0°C and 85-90 % RH for one month. Ten fruits per replicate were taken before storage to determine the initial fruit quality. Samples of 3 replicates per treatment were taken weekly intervals to follow up the fruit quality and storability attributes after 2 days at room temperature as shelf-life.

2. Fruit physical and chemical quality attributes

Fruit firmness was determined using a fruit texture analyzer (Texturepro CT V1.2, Brookfield) with 2.5 cm flat tip at a speed of 2 mm/S. The fruit was compressed to a depth of 5 mm and compression force was expressed in Newtons (N). For soluble solids content (SSC), the flesh of five figs was pressed through cheesecloth with a hand press to obtain a composite juice sample (Crisosto et al., 2010). The juice was used for determination of SSC with a digital refractometer (ATAGO, mod. N-1E, Japan) and expressed as percentages. The sugar extraction was carried out by using ten grams of well mixed fruit flesh tissues, using distilled water according to Loomis and Shull (1937). Reducing and total reducing sugars then determined by Fehling's test for reducing sugars and the inversion of the non-reducing sugars were done according to (AOAC, 2000). Non-reducing sugars were calculated by subtracting reducing sugars from total reducing sugars. One gram of fig flesh was homogenized in 25 ml of 80% ethanol for phenolic compounds extraction at 25 ºC for 15 min, then filtered, and determined using Folin-Denis reagent according to Moyo et al., (2010). A standard curve of gallic acid was used for quantifying the total phenolic content, and data expressed as mg/100 g fruit fresh weight according to Singleton and Rossi (1965).

3. Fruit storability:

Fruit storability was expressed as the percentage of fruit weight loss and decay incidence as well as fruit shriveling. Initial weight of 3 punnets per replicate was recoded then reweighted periodically at fruit sampling dates throughout the experiment period. Weight loss percentage was calculated as follow: Weight loss (%) = $[(W_0-W_1)/W_0] \times 100$ (where W_0 is the initial weight and W_1 is the weight measured at sampling date). The decay and shriveling were determined by calculating the weight of decayed or shriveled figs at the sampling date and expressed as a percentage of total figsweight.

$$\text{Decay or shriveling } (\%) = \frac{\text{weight of decayed or shriveled figs}}{\text{Total figs weight}} \times 100$$

Fruit decay was determined as percentage of decay incidence and transformed, using arcsine transformation to fit for analysis of variance. Total quantitative losses of fig fruits was calculated by summation the percentages of the unmarketable figs (decay and shriveling) + weight loss percent. The treatment ended when the total quantitative losses reached up to 25-30 %.

4. Statistical analysis

The treatments were arrangedin a randomized complete block design (RCBD), data were statistically analyzed and means were compared using LSD procedure at 5% level of probability according to Gomez and Gomez (1984). The

statistical analysis was done using SAS ver. 9.3, 2007.

RESULTS AND DISCUSSION

1. Fruit physical and chemical quality attributes

Results presented in Table (1), showed that, chitosan treatments at 2.5 or 5 g/L significantly maintained fruit firmness, as they recorded higher significant compress force than control in both seasons and thymol at 0.3 mM in the second season, after 1 week of cold storage + 2 days at room temperature. The differences among thymol concentrations and control on compress force were not significant in 2018 year. After 2 weeks cod cold storage, the higher compress force was found with figs treated by chitosan at both levels, while fruit treated with chitosan at 5 g/L was markedly firmer than thymol at both levels in both seasons (Table 2). The same result was noticed after 3 weeks of storage in 2017 year, however no significant differences were observed among all treatments in 2018 season (Table 3).

Postharvest chitosan and thymol treated figs had significantly higher SSC than those of control after 1 week of cold storage + 2 days at room temperature in both seasons, except with thymol at 0.3 mM in 2018 year (Table1). Results also revealed that chitosan at 2.5 or 5 g/L significantly maintain the higher SSC percent than thymol at 0.3 mM up to three weeks of cold storage in 2017 year, and with both thymol levels in the second season (Tables 2 and 3).

Concerning the effect of postharvest thymol and chitosan treatments on fruit total phenolic content, results in Table 1, refer to thymol and chitosan treatments at both levels significantly maintained higher phenolic content than control after 1 week in both seasons. Figs treated with chitosan at 5 g/L contained higher significant phenolic content than those treated with thymol at 0.3 mM and chitosan at 2.5 g/L in both seasons (Table 2). Meanwhile, no significant differences were noticed among all treatments in both seasons after 3 weeks (Table 3).

Regarding to fruit sugars content,the results in Table (1) Showed that all thymol and chitosan treatments significantly maintained higher total and non-reducing sugars than control after 1 week of cold storage + 2days at room temperature in both seasons, except with thymol treatments in 2018 year. While sugars content after 2 weeks of cold storage. The data in Table (2), revealed that chitosan treatments maintained higher sugars content in both seasons. However, chitosan at 5 g/L had higher significant total sugars than thymol treatments at both levels in the two seasons, and also reducing and non-reducing sugars in 2018 year only. On the other hand, no significant effect was found among all treatments on reducing and non-reducing sugars in 2017 year.

Results in Table (3), represented that both chitosan levels had higher significant total sugars percent in both seasons. Meanwhile, both chitosan levels and thymol at 0.6 mM were significantly higher on reducing sugars than thymol at 0.3 mM in 2017 year. However, figs treated with chitosan at 5 g/L was significantly higher than both thymol treatments on reducing sugars in 2018 year and non-reducing sugars in both seasons.

All in all, chitosan treated fruits had high or maintained the SSC, Compress force, phenolic contents as well as total sugars. These results could be due to reduction of deterioration and degradation reactions by chitosan coating film. These findings are in line with Seehanam et al. (2010) which reported that chitosan significantly slow down the respiration rate of 'Sai Nam Phueng' Tangerine by modifying the fruit internal atmosphere. As will known the postharvest consumption of sugars and organic acids as substrates for respiratory metabolism will reduce as respiration process and oxidative stresses decreased.

2. Fruit storability

Chitosan treatments at 2.5 and 5 g/L significantly reduced fruit weight loss percent throughout the experiment period up to 3 weeks as compared with the rest treatments in both seasons, except between chitosan at 2.5 g/L and both thymol treatments after one week in 2017 year only (Figure 1).

Table 1: Effect of postharvest chitosan and thymol treatments on SSC, compress force, total phenols, total, reducing and non-reducing sugars of Sultani fig after 1 week of cold storage at 0°C + 2 days at room temperature in 2017 and 2018.

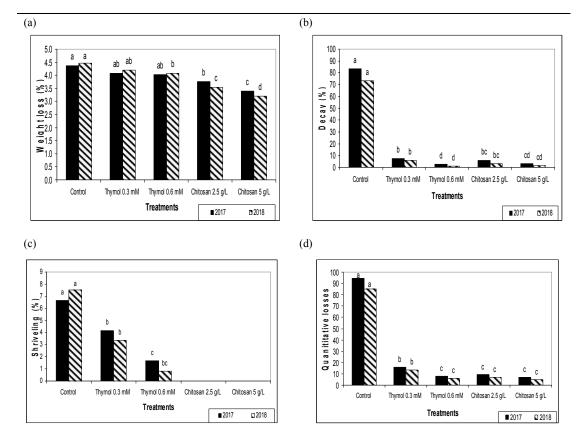| Treatments	SSC (%)		Compress force (N)		Total phenols (mg/100g FW)		Total sugars (%)		Reducing sugars (%)		Non-reducing sugars (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Control	15.20	15.00	0.65	0.75	325.0	303.3	11.22	11.12	10.03	9.84	1.19	1.28
Thymol 0.3 mM	15.47	15.20	0.94	0.81	364.3	343.3	11.88	11.51	9.93	9.83	1.95	1.68
Thymol 0.6 mM	15.60	15.33	0.92	0.87	366.6	380.0	11.83	11.45	9.91	9.99	1.92	1.46
Chitosan 2.5 g/L	15.63	15.47	0.97	0.99	365.4	360.0	11.95	11.79	10.00	9.98	1.95	1.81
Chitosan 5 g/L	15.70	15.67	0.98	0.97	371.5	390.0	12.08	11.82	10.04	9.95	2.04	1.87
L.S.D. at 0.05	0.21	0.27	0.14	0.14	29.5	27.8	0.52	0.47	0.36	0.20	0.47	0.46

(a)

(b)

(c)

(d)

Figure 1: Effect of postharvest thymol and chitosan applications on percent of weight loss, decay, shriveling and total quantitative losses on Sultani fig after 1 week at 0°C + 2d @ RT in 2017 and 2018. Means followed by same letters in the same season are not significantly different at (P < 0.05).

Table 2: Effect of postharvest chitosan and thymol treatments on SSC, compress force, total phenols, total, reducing and non-reducing sugars of Sultani fig after 2 weeks of cold storage at 0°C + 2 days at room temperature in 2017 and 2018.

Treatments	SSC (%)		Compress force (N)		Total phenols (mg/100g FW)		Total sugars (%)		Reducing sugars (%)		Non-reducing sugars (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Thymol 0.3 mM	15.13	15.07	0.74	0.68	249.9	266.7	10.68	10.58	9.48	9.34	1.20	1.23
Thymol 0.6 mM	15.40	15.10	0.75	0.65	264.8	283.3	10.74	10.70	9.53	9.41	1.22	1.29
Chitosan 2.5 g/L	15.47	15.33	0.82	0.80	252.2	260.0	11.26	11.04	9.69	9.59	1.58	1.45
Chitosan 5 g/L	15.60	15.47	0.87	0.82	293.7	303.3	11.59	11.41	9.77	9.63	1.82	1.78
L.S.D. at 0.05	0.24	0.21	0.12	0.14	30.1	29.8	0.61	0.38	0.31	0.22	0.78	0.47

Table 3: Effect of postharvest chitosan and thymol treatments on SSC, compress force, total phenols, total, reducing and non-reducing sugars of Sultani fig after 3 weeks of cold storage at 0°C + 2 days at room temperature in 2017 and 2018.

Treatments	SSC (%)		Compress force (N)		Total phenols (mg/100g FW)		Total sugars (%)		Reducing sugars (%)		Non-reducing sugars (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Thymol 0.3 mM	14.60	14.47	0.55	0.49	116.8	140.0	9.74	9.63	8.73	8.66	1.01	0.97
Thymol 0.6 mM	14.80	14.53	0.53	0.50	128.4	153.3	10.09	9.81	9.14	9.00	0.95	0.81
Chitosan 2.5 g/L	15.33	14.93	0.67	0.56	118.0	133.3	10.79	10.47	9.36	9.24	1.43	1.23
Chitosan 5 g/L	15.40	15.00	0.72	0.58	129.5	160.0	11.24	10.83	9.47	9.27	1.77	1.56
L.S.D. at 0.05	0.56	0.38	0.11	0.13	14.9	30.8	0.57	0.43	0.34	0.25	0.65	0.54

Figure 2: **Effect of postharvest thymol and chitosan applications on percent of weight loss, decay, shriveling and total quantitative losses on Sultani fig after 2 week at 0°C + 2d @ RT in 2017 and 2018. Means followed by same letters in the same season are not significantly different at (P < 0.05).**
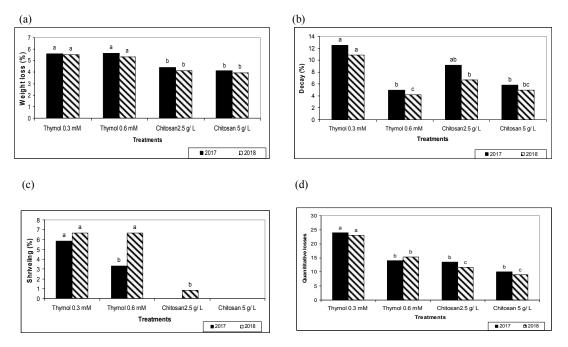

Figure 3: **Effect of postharvest thymol and chitosan applications on percent of weight loss, decay, shriveling and total quantitative losses on Sultani fig after 3 week at 0°C + 2d @ RT in 2017 and 2018. Means followed by same letters in the same season are not significantly different at (P < 0.05).**
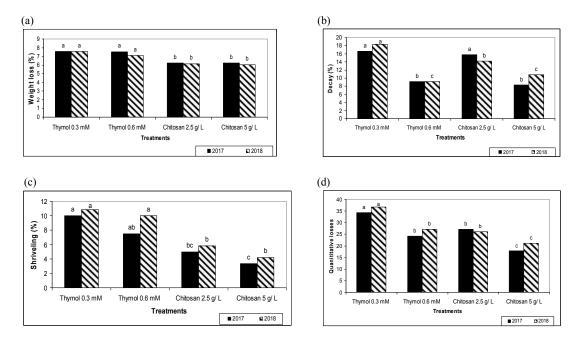
Moreover, the higher concentration of chitosan is more efficient for reduction of weight loss after 1 week of cold storage, while the differences among chitosan or thymol levels were not significant after 2 or 3 weeks of cold storage in both seasons (Figures 2 and 3).

The decay incidence severely reduced by postharvest thymol and chitosan treatments after 1 week under cold storage + 2 days at room temperature in both seasons (Figure 1). No significant differences on decay percent were noticed among thymol and chitosan treatments in both seasons, except with thymol at 0.6 mM, which significantly reduced decay incidence than thymol at 0.3 mM and chitosan at 2.5 g/L in 2017. Results in Figure (2), represented that thymol at 0.6 mM and chitosan at 5 g/L significantly reduced decay percent as compared with thymol at 0.3 mM after storage for 2 weeks in 2017 and 2018 years. Furthermore, the higher levels of both thymol and chitosan had lower significant decay percent than lower levels after cold storage for 3 weeks, in both seasons Figure (3).

Regarding to shriveling percent results reveled thatall treatments significantly reduced shriveling percent as compared with control after 1 week in both seasons (Figure 1). While, the lowest shriveling percent was found with both chitosan levels in both seasons, and thymol at 0.6 mM in 2017 year. Moreover, chitosan treatments recorded the lowest significant shriveling percent up to 3 weeks of cold storage + 2 days at room temperature in both seasons, but the difference among chitosan at 2.5 g/L and thymol at 0.6 mM after 3 weeks was not significant in 2017 year (Figure 3).

Postharvest treatments with chitosan and thymol at both levels significantly reduced the quantitative losses than control after the first week of storage (Figure 1). But the lowest percent of quantitative losses was occurred with chitosan at 2.5 or 5 g/L and thymol at 0.6 mM in both seasons. Moreover, both chitosan levels and thymol at 0.6 mM markedly reduced the quantitative losses as compared with thymol at 0.3 mM after 2 weeks of cold storage (Figure 2). In addition, chitosan at 5 g/L had the lowest significant quantitative losses, followed by chitosan at 2.5 g/L and thymol at 0.6 mM, while thymol at 0.3 mM had the highest percent of postharvest losses in both seasons.

Chitosan treatments markedly reduced figs weight loss and shriveling percentages in the two experimental seasons, these results could be due to formation ofchitosan semi-permeable film, modifying the endogenous gases exchange mainly water vapor, CO_2, O_2 and C_2H_4, which reduced water loss, respiration rate and subsequently retard fruit ripening and senescence by (Cosme Silva, *et al.*, 2017).

Both chitosan and thymol treatments controlled postharvest decay incidence. The effect of thymol on reduction of decay may be due to inhibition of conidia germination and mycelial growth. This results are in line with (Luiet al., 2002), they reported that thymol treatment was effective on postharvest decrease of brown rot on apricots as a result of mycelial growth inhibition of *Monlinia fructicola*. Furthermore, thymol changed the morphological and internal structure of *M. fructicola* conidia, casing shrunken shapes and collapsed protoplasts. Moreover, thymol efficiently controlled postharvest gray mold decay on sweet cherries (Chu et al., 1999).

CONCLUSION

From previous findings we can summarize that the postharvest life of fresh Sultani figs can be extended up to 3 weeks and postharvest losses significantly reduced by chitosan and thymol treatments with cold storage at 0°C and 90 % RH. Both chitosan and thymol treatments controlled postharvest decay incidence. Chitosan treatments significantly reduced fruit weight loss and shriveling up to 3 weeks. Thymol and chitosan applications were very effective on controlling decay incidence and quantitative losses after 1 week of cold storage +2d at room temperature. Chitosan treatments markedly maintained higher figs firmness, SSC, phenolic content, total and non-reducing sugars. This results showed that chitosan and thymol are promising safe alternatives to control postharvest diseases and increase marketability of fresh Sultani figs. More experiments are needed to determine the efficiency of wide spectrum of essential oils and their combinations with chitosan.

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الملخص العربى

تقليل الفاقد في ثمار التين السلطاني أثناء التسويق بواسطة الغمس في الثيمول والشيتوزان

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القابلية العالية للتلف وأمراض مابعد الحصاد تحد من تخزين و تسويق ثمار التين الطازجة. الهدف من هـذه الدراسة هو تقييم تأثيرمعاملات الغمس بعد الحصاد بالشيتوزان والثيمول على الأعفان وجودة ثمار التين الـسلطانى. حصدت ثمار التين ناضجة يدويا برفق وأجريت عليها المعاملات التالية، الثيمول بتركيـزى ٠,٣ و ٠,٦ ملليمـول والشيتوزان بتركيزى ٢,٥ و ٥ جم/لتر ومقارنتها بالثمار غير المعاملة (كنترول). وخزنت الثمار على درجة حرارة صفر مئوى ورطوبة نسبية ٨٥−٩٠ %، وأخذت عينات أسبوعيا لقياس خصائص الجودة والقدرة التخزينية للثمـار بعد تركها يومين على درجة حرارة الغرفة. وأوضحت النتائج أن معاملتى الشيتوزان قللت معنويا من النسب المئوية للفقد فى الوزن والكرمشة مقارنتا بباقى المعاملات حتى الأسبوع الثالث. كل معاملات الثيمول والـشيتوزان كانـت فعالة فى الحد من حدوث الأعفان والفاقد الكمى بعد أسبوع. التركيزات الأعلى من كلا المركبين كانت أكثر فاعليـة فى تقليل الأعفان بعد ٢ و٣ أسابيع من التخزين. أنخفضت النسبة المئوية للفاقد الكمى بعـد الحـصاد معنويـا فـى معاملات الثيمول ٠,٦ ملليمول والشيتوزان بتركيزى ٢,٥ و ٥ جم/لتر مقارنتا بالثيمول ٠,٣ ملليمـول بعـد ٢ و٣ أسابيع فى كلا الموسمين. حافظت معاملات الشيتوزان بشكل ملحوظ على الصلابة والمحتوى من المـواد الـصلبة الذائبة والفينولات والسكريات الكلية وغير المختزلة حتى الأسبوع الثالث. وبـذلك يتـضح أن معـاملات الثيمـول والشيتوزان كانت فعالة فى الحد من الأعفان والفاقد بعد الحصاد مما يزيد من العمر التسويقى لثمار التين الطازجـة، إلا أن الشيتوزان كان الأكثر فاعلية.