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ORIGINAL PAPER

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EFFECTS OF PACKAGING AND OZONE TREATMENTS ON QUALITY PRESERVATION IN PURPLE FIGS

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ABSTRACT

The present study was conducted to investigate the effects of different package types and ozone treatments on post-harvest quality of figs. Three different package types (classical-type, modified atmosphere –MAP, consumer-type) and different ozone treatments (0, 5, 10 and 15 minutes) were used in experiments. Purple figs grown in Tekkeköy town of Samsun province were used as the experimental material of the study. Fruits harvested at optimum harvest period were subjected to pre-cooling for a day and then stored in a cold storage at 4°C temperature and 85–90% relative humidity. At the beginning of cold storage and each week of storage, fruits removed from the storage were subjected to weight loss, water soluble dry matter content, titratable acidity, wrinkle, leakage, mold spots, peeling and degustation analyses. Current findings revealed that MAP and 10 or 15-minute ozone treatments had positive impacts on weight loss prevention in figs. While there were not significant differences in other characteristics of treatments, 10 and 15-minute ozone treatments retarded mold spots and leakage in consumer and modified packages.

Key words: *Ficus carica*, MAP, package type, storage

INTRODUCTION

Anatolia is the mother land of figs. History of fig culture in Anatolia is as old as history of humanity. In fig culture, Anatolia is followed respectively by Syria, Palestine, China and India.

World annual fig production was 1 117 452 tons in 2013. Turkey with 298 914 tons is the leading producer worldwide. With regard to production quantities, Turkey is followed respectively by Egypt, Algeria, Morocco and Iran [FAOSTAT 2016]. Fig constitutes about 1,74% of total fruit production of Turkey.

Fig presents a rich variation in natural flora of Black Sea coast line. Turkish fig production was realized as 300 600 tons in 2015 and 11 652 tons of this production comes from Black Sea region and 2 436 tons of regional production comes from Samsun province [TUIK 2016].

Fig (*Ficus carica* L.) is consumed either as table fig (fresh) or as dried [Aksoy et al. 2007]. Besides these consumptions, figs are also used in jams, marmalades, molasses, Turkish delights, ice-creams and cookies.

In agricultural productions, post-harvest processes are also as significant as cultural practices. In horticultural products, about 10–30% post-harvest losses are experienced in some cases [Ozcan 2014]. Since ripening process is not going on after the harvest, fresh figs harvested at edible maturity (as fully ripened) are quite delicate and may get damaged easily. Damaged product has a loss in quality and such a case then result in serious economic losses. Water loss is accelerated in fresh figs as a result of mechanical damages to be experienced in post-harvest period, then increasing

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fruit wrinkling and microorganism activities are experienced. Quality fig fruits should be free of mechanical damages and pest harms.

Improper harvest times, improper packaging materials, improper storage and transportation are among the most significant factors negatively influencing post-harvest quality of figs. There is a need for studies for the development and implementation of technologies to reduce or prevent such quality losses.

The studies toward to reduce yield and quality losses in figs, to serve the products for consumption in a quality fashion, to provide long-duration use of the product as a food stuff, to reduce chemical and pesticide uses have gained a significance during the recent years. Ozone treatments are among these studies.

Ozone is a significant substance and naturally exists in atmosphere. It is also possible to produce ozone artificially. Ozone can partially dissolve in water and has a strong odor. It is among the strongest disinfectants applied to foods. It can be produced either as liquid or gas and used in food industry because of antimicrobial characteristics. Molecular ozone or decomposed ozone products can efficiently and swiftly eliminate microorganisms without leaving any residues.

In agricultural industry, ozone is used in seed industry, seedling industry, in fresh fruit and vegetables, dried fruit and vegetables, frozen or processed products, in cut-flower production, in greenhouses, nutrient solutions of soilless cultures, mushroom production activities and cold storages. Ozone is also an important substance in livestock production and organic farming.

Langlais et al. [1991] reported that ozone treatments prevented pathogen (mold, bacteria and virus) development throughout the storage of fruits and vegetables, oxidized ethylene and thus prolonged the storage life of the products; Xu [1999] applied ozone gas at 2–3 ppm in couple hour intervals to a storage containing strawberry, raspberry and grapes and indicated that such treatments doubled the shelf life of the fruits; Barth et al. [1995] reported that 0.3 ppm ozone treatments for 12 days to a storage at 2°C prevented mold development in blackberries and there were not any damages over treated fruits; Çagatay [2006] reported that 0,5 and 1 ppm ozone doses incorporated into pre-cooling water of cherries allowed well storage of the fruits for 5–6 weeks at 0°C temperature and 85–90% relative humidity and indicated that the fruits with ozone treated pre-cooling water had better outcomes with regard to appearance, fruit flesh firmness and microbiological characteristics than the untreated control fruits; Karaca [2010] reported that 950 ±12 ppm ozone treatments for 20 minutes reduced *E. coli* and *L. innocua* microorganism counts in parsley.

The present study was conducted to investigate the effects of different packaging and ozone treatments on quality preservation of fresh figs grown under ecological conditions of Samsun province.

MATERIALS AND METHODS

The present study was conducted in 2013 at cold storage and laboratory of Horticulture Department of Ondokuz Mayıs University Agricultural Faculty. Purple figs sampled at harvest maturity from a producer orchard in Tekkeköy town of Samsun province were used as the experimental material of this study. Experimental fruit samples were taken on 22 August 2013.

In purple figs, average fruit weights vary between 11.35–58.00 g, fruit widths between 3.10–5.25 cm, fruit lengths between 2.20–6.20 cm, pH values between 4.20–5.30, water soluble dry matter (WSDM) contents between 16.6–20.0% and acidity between 0.11–0.30% [Koyuncu 1998]. Fruit colors range from dark purple to light purple and they commonly consumed as fresh and in jams.

Three different packages (classical, consumer and passive modified) were used in experiments. Foam plastic plates (225 × 135 × 27 mm) were used as classical packaging. Consumer packages (120 × 190 × 80 mm) were composed of transparent plastic containers. Polyethylene packs (PE 120-Danisco) (60 × 100 cm) were used for modified packages and technical properties are provided [Akbulut and Ozcan 2005]. Fruits were placed vertically (ostiole down) to packaging containers. Fruits were subjected to pre-cooling for a day in individual cooling units (at 4°C temperature and 85–90% relative humidity). Then packed fruits were preserved at 4°C temperature and 85–90% relative humidity in a cold storage with individual cooling units.

Fruits were placed in packages in 3 replications with 10 fruits in each replication. Fruits were then divided into two groups as control and ozone treatments. Packages were closed after ozone treatments while placing them into the cold storage. A portable ozone generator able to generate ozone gas was used as the ozone source. The generator has a capacity of 6 g/h. Ozone treatments were implemented at 4 different durations: 0 (control), 5, 10 and 15 minutes.

At the beginning of cold storage and each week of storage, fruits removed from the storage were subjected to weight loss, water soluble dry matter content, titratable acidity, wrinkle, leakage, mold spots, peeling and degustation analyses.

The difference between initial weight and sampling weight was considered as percent weight loss. Water soluble dry matter (WSDM) content was determined in fruit juice with a refractometer and expressed in %. Acid content was determined with titration method and expressed in % citric acid.

The wrinkles over the fruits because of moisture loss were visually assessed over a relative scale of 1–5. The least wrinkling (wrinkle of less than 1 cm^2) was expressed as 1 and the greatest wrinkling (wrinkle of over 5 cm^2) was expressed as 5.

The intense, sticky and sweet liquid from the ostiole section of the fruit is defined as leakage. Again a relative scoring over 1–5 points was carried out to compare leakage quantities. The least leakage (the wetted section after leakage is less than 1 cm^2) was expressed as 1, the greatest leakage (the wetted section after leakage is more than 5 cm^2) was expressed as 5.

A relative scoring system over 1–5 was also used for identification of visual mold spots over the fruits. The least mold (total area of mold spots is less than 1 cm^2) was expressed as 1, the greatest mold (total area of mold spots is more than 5 cm^2) was expressed as 5.

Easy peeling of samples taken from each sampling period was assessed by a degustation panel with again a scale of 1–5. The easiest peeled ones were scored as 1 and the hardest peeled ones were scored as 5.

Fruits tastes were assessed by a degustation team of 5 people in each analysis periods. Taste values were scored over a scale of 1–5 (1: terrible, 2: poor, 3: medium, 4: good, 5: elegant).

Color changes (hue angle h^o) over the peels were measured weekly with a CR 300 model Minolta brand color-meter. Decreasing hue angles indicate that color is approaching to red and increasing hue angles indicate that color is moving away from red.

Data were analyzed in accordance with randomized plots factorial experimental design. Sub-groups were identified with Duncan's multiple range test. Data in different statistical groups were coded with different letters and presented in tables.

RESULTS AND DISCUSSION

Weight losses observed throughout the storage duration in different package types and ozone treatments are provided in Table 1. Weight loss was higher in classical packages than modified (MAP) and consumer packages. While the weight loss in classical packages was 17.29%, the value was observed as 9.22% in modified and 5.90 in consumer packages (tab. 1).

With regard to weight losses, packaging × ozone interaction was found to be significant. The greatest weight loss was observed in 5-minute ozone treated classical packages (26,60%) and the least weight loss was observed in 15-minute ozone treated modified packages (0,65%). With regard to effects of ozone treatments, weight loss values varied between 9,61–14,85% with the greatest value in 5-minute ozone treated fruits (14.85%) and the least values in control (9,61%) and 15-minute ozone treated fruits (8,19%) (tabs 1 and 2; fig. 1).

Present findings revealed that packaging had significant effects on reducing weight losses. Demirdoven et al. [2006] reported that 30% weight loss in control treatment decreased to 4% in MAP packages in Demre pepper cultivar; Sabir et al. [2010] reported decreased weight losses in Mirella F1 tomato cultivar with MAP; Basel et al. [2002] indicated prolonged

Table 1. Effects of difference packages and ozone treatments on weight loss of figs throughout the storage duration (%)

Packages	Ozone treatments (min)	Storage duration (week)			
		1	2	average	treatment average
Classical	0	8.89	13.53	11.21bc*	17.29b*
	5	31.93	21.27	26.60d	
	10	10.35	15.74	13.04bc	
	15	9.62	27.02	18.32cd	
MAP	0	9.88	13.80	11.84bc	9.22a
	5	12.13	12.02	12.08bc	
	10	10.66	13.97	12.32bc	
	15	0.30	0.99	0.65a	
Consumer	0	3.25	8.33	5.79ab	5.90a
	5	4.36	7.40	5.88ab	
	10	4.25	8.37	6.31ab	
	15	4.21	7.01	5.61ab	
Average		9.15	12.45		

* P < 0.01

Table 2. Effects of packages and ozone treatments on weight loss of figs (%)

Ozone treatments (min)	Packages			Average
	classical	MAP	consumer	
0	11.21bc*	11.84bc	5.79ab	9.61a*
5	26.60d	12.08bc	5.88ab	14.85b
10	13.04bc	12.32bc	6.31ab	10.55ab
15	18.32cd	0.65a	5.61ab	8.19a
Average	17.29b*	9.22a	5.90a	

* P < 0.01

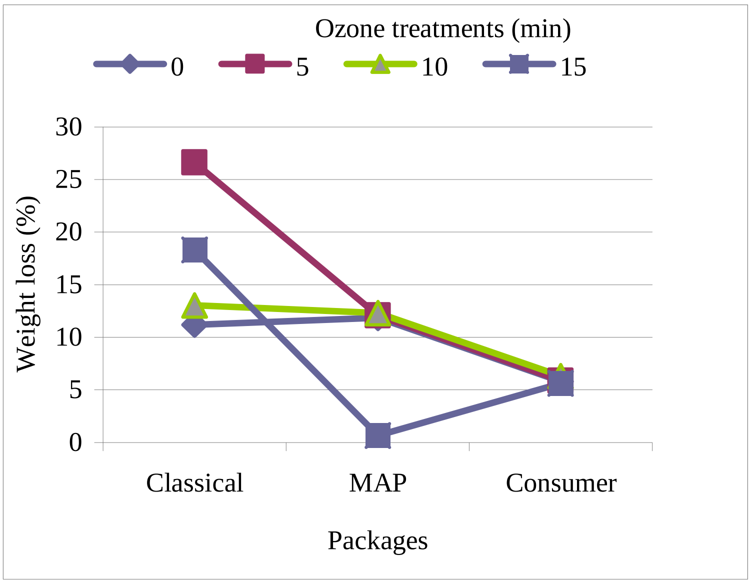

Fig. 1. Effects of packages and ozone treatments on weight loss of figs (%)

shelf life for banana with MAP treatments and Bahar [2006] reported similar prolonged shelf life and almost halved weight loss for nectarine with MAP treatments. In present study, weight loss was 5,90% in consumer and 9,22% in MAP packages, but both treatments were placed in the same statistical group. Thus, current findings comply with those findings provided above.

Ozone treatments had also significant effects in reducing weight losses. With ozone treatments, reduced weight losses and almost doubled shelf lives were reported by Nadas et al. [2003] in strawberry; by Brown et al. [2004] in lettuce, grape, onion, pepper, mushroom, carrot and broccoli; by Xu [1999] in strawberry, raspberry and grape; by Achen and Yousef [2001] in apple, pear and orange; by Palou et al. [2005] in peaches; by Hildebrand et al. [2008] in carrot. In present study, ozone treatments had positive impacts on weight preservation. The least weight loss was observed in 15-minute ozone treatment (8,19%). It was observed in this study that efficiency of ozone treatments varied with the type of packages and the effects were more remarkable in MAP treatments. Akbulut and Ozcan [2005] and Kaynas et al. [2008] reported that storage under modified atmosphere and controlled atmosphere conditions prolonged preservation periods and reduced weight losses significantly. Researchers also indicated reduced water loss, fruit softening and decelerated entire fruit metabolism. Such a case may be resulted from higher relative humidity and higher CO_2 levels within the package than the ambient. Thusly, Sekse [1989] indicated for MAP treatments that increased moisture in internal ambient was effective in reducing weight losses; Sabir et al. [2010] indicated that changes in respiration gas ratios in MAP packages was effective in weight losses of the products.

As compared to initial values, water soluble dry matter (WSDM) contents either increased or decreased throughout the storage duration. Such fluctuation in WSDM were mainly because the fruits used in analyses were not fully uniform and analyses were not able to be repeated over the same fruits (tab. 3).

While WSDM content of the fruits was 14,06% at the beginning of storage, the value increased to 15.08% in classical packages, decreased to 13.89% in consumer packages and 13.23% modified packages at the end of two-week storage. With regard to package × ozone × storage duration interaction, WSDM content reached to the greatest value in classical packages at the second week (16,91%) and the lowest value was observed in MAP of the second week at 5-min ozone treatment (11,35%) (tab. 3).

Table 3. Effects of different packages and ozone treatments on WSDM contents of figs (%)

Packages	Ozone treatments (min)	Storage duration (week)				
		0	1	2	average	treatment average
Classical	0	14.06b-g*	14.74a-d	16.91a	15.24	15.08a*
	5	14.06b-g	15.76ab	14.60b-d	14.81	
	10	14.06b-g	15.42ab	15.99ab	15.15	
	15	14.06b-g	15.50ab	15.84ab	15.13	
MAP	0	14.06b-g	14.26b-e	11.93f-ı	13.60	13.23c
	5	14.06b-g	11.82g-ı	11.35ı	12.41	
	10	14.06b-g	12.19e-ı	12.40d-ı	12.88	
	15	14.06b-g	14.02b-g	14.00b-g	14.03	
Consumer	0	14.06b-g	14.36b-e	14.67b-d	14.36	13.89b
	5	14.06b-g	13.61b-h	15.02a-c	14.23	
	10	14.06b-g	11.71g-ı	12.83c-ı	12.87	
	15	14.06b-g	14.49b-e	11.60hı	13.38	
Average		14.06	13.99	13.93		

* $P < 0.01$

Table 4. Effects of storage durations and package types on WSDM content of figs (%)

Packages	Storage duration (week)			Average
	0	1	2	
Classical	14.06bc*	15.36a	15.87a	15.08a*
MAP	14.06bc	13.07cd	12.38d	13.23c
Consumer	14.06bc	13.59bc	14.15b	13.89b
Average	14.06	14.01	14.13	

* P < 0.01

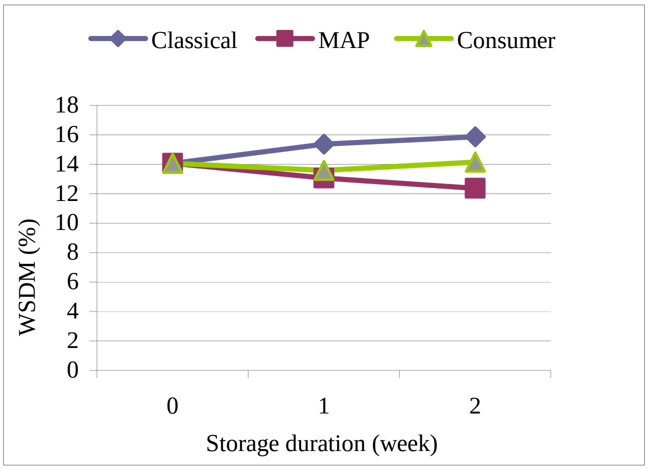

Fig. 2. Effects of storage durations and package types on WSDM content of figs (%)

Effects of package types throughout the storage duration were found to be significant. Values varied between 15,08–13,23% (tab. 4; fig. 2).

With regard to packaging types, while there was an increase in WSDM contents in classical packages, a decrease was observed in modified packages (fig. 2, tab. 4). Higher WSDM contents of classical packages were mainly resulted from higher respiration rates and water loss ratios in these packages. MAP treatments had lower WSDM contents than the classical and consumer packages since respiration slowed down, simple sugars used in respiration decreased and such a decrease then decelerated the changes in WSDM of MAP treatments. The atmosphere in MAP also prevents water losses, thus increase in WSDM is limited because of higher turgor (fig. 2, tab. 4). It was indicated in previous studies that decelerated respiration in MAP better preserved WSDM content of the fruits [Drake and Kupferman 1990, Lurie et al. 1992]. Bostan et al. [1997] reported WSDM content of purple figs as between 15.10–21.00%. Koyuncu [1998] reported WSDM content of purple figs as between 16.60–20.0%. Average WSDM content of present figs throughout the storage duration was identified as 13,99% and such a value was slightly lower than the values reported by Bostan et al. [1997] for fig samples of Black Sea Region. Such differences were mainly resulted from the differences in sampling locations since location of the orchard, ecological conditions, wind, site selection, planting spacing, pruning, fertilization, soil tillage and irrigation may have significant effects on WSDM content of the fruits [Aksoy et al. 2007].

Packaging and ozone treatments had significant effects on titratable acidity (TA) of the fruits throughout the storage duration. As compared to initial values, either increases or decreases were observed in TA values. Such fluctuation in TA values were mainly again because the fruits used in analyses were not fully uniform and analyses were not able to be repeated over the same fruits. With regard to effects of treatments on TA values, effects of package × ozone and package × ozone × storage interactions were found to be significant. While initial TA value at the beginning of storage was 0.195%, the value at the end of two weeks storage increased to 0,209% in classical packages, to 0,203% in consumer packages and decreased to 0,185% in modified packages (tab. 5).

In package × ozone × storage interaction, the greatest TA value was observed in control treatment of MAP packages of the second week (0.290%) and the lowest value was observed in 5-minute ozone treated MAP packages of the second week (0.100%). With regard to effects of storage duration, the initial TA value of 0,195% decreased to 0.183 at the end of the first week, then increased to 0.238% at the end of the second week. Such a difference was found to be significant (tab. 5).

Effects of ozone treatments on titratable acidity throughout storage were also found to be significant and the values varied between 0.187–0.215% (tab. 6, fig. 3).

Bostan et al. [1997] reported titratable acidity values of purple figs grown in Black Sea region as between 0.14–0.22% and Koyuncu [1998] reported titratable acidity values of purple figs as between 0.11–0.30%. Current findings comply with those earlier findings. Akbulut and Ozcan [2005] in cherries and Namdar and Ozcan [2007] in kiwifruits, reported lower TA values for MAP and consumer packages

Table 5. Effects of package and ozone treatments on titratable acidity of figs (%)

Packages	Ozone treatments (min)	Storage duration (week)				
		0	1	2	average	treatment average
Classical	0	0.195c-h*	0.180e-h	0.214a-h	0.196bc*	0.209a*
	5	0.195c-h	0.187d-h	0.229a-g	0.204bc	
	10	0.195c-h	0.256a-e	0.289ab	0.247a	
	15	0.195c-h	0.162f-ı	0.237a-f	0.191cd	
MAP	0	0.195c-h	0.180e-h	0.290a	0.198bc	0.185b
	5	0.195c-h	0.155hı	0.100ı	0.150d	
	10	0.195c-h	0.190d-h	0.274a-c	0.220b	
	15	0.195c-h	0.135hı	0.180e-h	0.170cd	
Consumer	0	0.195c-h	0.226a-g	0.217a-h	0.213b	0.203a
	5	0.195c-h	0.211b-h	0.250a-e	0.213b	
	10	0.195c-h	0.146g-ı	0.220a-g	0.179b-d	
	15	0.195c-h	0.202c-h	0.265a-d	0.205b	
Average		0.195b*	0.183b	0.238a		

* P < 0.01

Table 6. Effects of package and ozone treatments on titratable acidity (%)

Ozone treatments (min)	Treatments			Average
	classical	MAP	consumer	
0	0.196bc*	0.198bc	0.213b	0.202ab*
5	0.204bc	0.150d	0.213b	0.189b
10	0.247a	0.220b	0.179b-d	0.215a
15	0.191cd	0.170cd	0.205b	0.187b
Average	0.209a*	0.185b	0.203a	

* P < 0.01

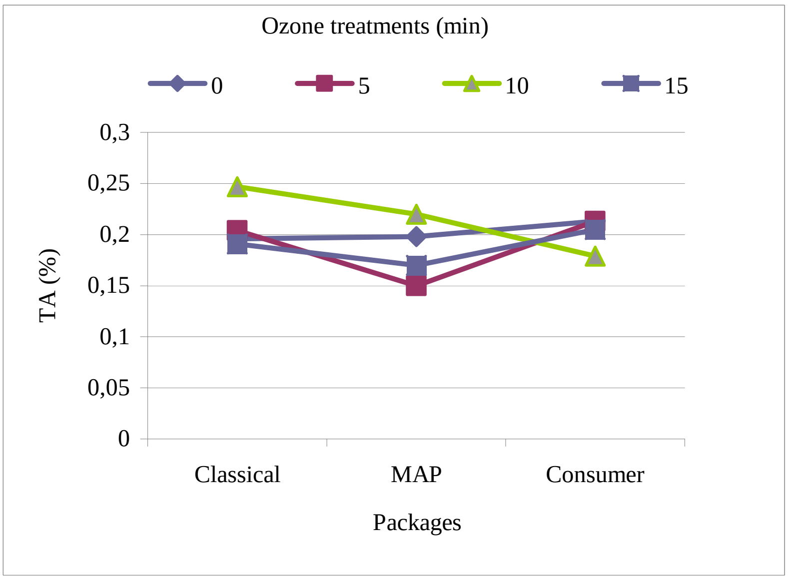

Fig. 3. Effects of package and ozone treatments on titratable acidity (%)

Table 7. Effects of package and ozone treatments of color changes (h°)

Treatments	Ozone treatments (min)	Storage duration (week)				
		0	1	2	average	treatment average
Classical	0	224.23	205.61	175.93	201.92	206.57
	5	224.23	242.63	230.07	232.31	
	10	224.23	151.97	284.34	220.18	
	15	224.23	120.43	171.03	171.89	
MAP	0	224.23	178.29	226.46	209.66	196.00
	5	224.23	217.30	220.76	220.76	
	10	224.23	52.45	138.34	138.34	
	15	224.23	206.26	215.24	215.24	
Consumer	0	224.23	303.97	221.98	250.06	226.54
	5	224.23	149.72	200.60	191.51	
	10	224.23	146.33	277.88	216.14	
	15	224.23	269.92	251.25	248.46	
Average		224.23	187.07	226.61	209.70	

than for classical packages. Current findings were also parallel to those earlier findings. The treatments decelerating respiration are also effective in deceleration of acidity. Titratable acidy was lower in classical and consumer packages than MAP packages of the present study. Variation in ambient atmosphere composition is a significant factor effective in degradation of acidity. MAP treatments decelerate respiration and consequently degradation of acidity based on changes in atmosphere composition. MAP treatments also reduce water loss, thus MAP packages generally have lower TA values than the other packages.

Table 8. Effects of package and ozone treatments on color changes (h^o) (%)

Ozone treatments (min)	Packages			Average
	classical	MAP	consumer	
0	201.92	209.66	250.06	220.55
5	232.31	220.76	191.51	214.86
10	220.18	138.34	216.14	191.55
15	171.89	215.24	248.46	211.86
Average	206.57	196.00	226.54	

With regard to effects of package and ozone treatments on mold spots, leakage, wrinkling and peeling characteristics of the fruits, the differences between the treatments were not found to be significant. There were some spoilage over the fruits throughout the storage and the control fruits had the greatest spoilage in appearance. Ozone treatments had significant impacts on changes in appearance of the fruits. Mold spots and leakage were observed later in 10 and 15-minute ozone treated fruits as compared to untreated control fruits. Current findings were quite similar with the results of Drake and Kupferman [1990] and Koyuncu et al. [2008].

With regard to effects of treatments on hue angle (h^o), initial h^o value of 224.23 was observed at the end of two-week storage as 226.54 in consumer packages, 206.57 in classical packages and 196.00 in MAP packages. With regard to effects of packages, while there were not significant changes in h^o values of classical and consumer packages, the greatest color intensity was observed in consumer packages (tab. 7). Since color transformations and degradations increased in consumer packages, colors more intensely showed up in these packages. Decelerated respiration and other physiological processes in MAP treatments also decelerated changes in color intensity. As compared to control treatment, ozone treatments had lower h^o values. Such a case was resulted from deceleration of physiology by ozone (tab. 8).

CONCLUSION

Package and ozone treatments did not have significant effects on taste. Based on these findings, it can be stated that ozone treatments had positive impacts on fruit consumption.

Considering the entire findings of the present study together, it was concluded that MAP treatments and 10 or 15-minute ozone treatments made a quite significant difference in quality preservation of figs. Spoilage of fruits was observed later in 10 and 15-minute ozone treated consumer and modified packages. In general, MAP and ozone treatments had positive contributions in quality preservation, but further studies are still recommended to be done on quality preservation of figs.

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