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Utilization of Modified Atmosphere Packaging to Extend the Shelf-Life of Fresh Figs

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Abstract: The common fig (*Ficus carica*) variety grown in Saudi Arabia is consumed as unpacked with a limited shelf life. This study examined and monitored the quality parameters to determine the shelf life of fresh figs under refrigerated Modified Atmosphere Packaging (MAP) conditions. The treatments evaluated were: MAP1 (80% CO_2, 20%N_2, 0.0% O_2); MAP 2 tray (20% CO_2, 80%N_2, 0.0% O_2); MAP3 tray (20% CO_2, 70% N_2, 10% O_2); control tray treatment (with normal air); and unwrapped cardboard box. The fruit quality attributes such as decay, fruit size, external color, firmness, weight loss, water activity, water content of figs fruits and total soluble solids were measured during storage at 4°C for more than 42 days. Modified atmosphere packaging with 20% CO_2 was successful in reducing the rate of ripening process while the control treatment figs showed signs of ripening development such as significant weight loss and change in figs color. However, the decay incidence was reduced and delayed by all the MAP treatments. The weight loss was less than 1% for all the MAP treatments at the end of storage. The fruit firmness decreased with an increase in weight loss in each treatment after 28 days of storage. There was no significant difference in total soluble solids among the MAP treatments. The shelf life of fresh figs packed in unsealed cardboard box was less than 14 days. In conclusion, MAP resulted in better external appearance and therefore commercial application of MAP in the fresh fig industry should be introduced for fruit preservation.

Key words: *Ficus carica*, modified atmosphere packaging, maturity, shelf life, preservation

INTRODUCTION

The common fig (*Ficus carica* L.) is a traditional fruit in western Asia. Its historical origin is mainly located around southern Arabia (Stover *et al*., 2007) or the eastern part of the Mediterranean Sea or in places with similar weather (Khoshbakht and Hammer, 2006; Irget *et al*., 2008; Doymaz, 2005). Fig cultivation is common in areas near the Mediterranean region. The fig is a nutritious fruit, richer in fiber, potassium, calcium, iron and is free of sodium, fat and cholesterol (Stover *et al*., 2007). Furthermore, figs are an important source of vitamins, amino acids and antioxidants. Fig varieties with dark skin contain high levels of polyphenols, anthocyanin and flavonoids, together with higher antioxidant activity as compared to fig varieties of lighter skin (Solomon *et al*., 2006). However, fig is very sensitive to microbial growth even under cold storage; thus, it is important to consider alternative processes to extend its shelf life. Most commercial production is in dried or otherwise processed forms, since the ripe fruit does not transport well and once picked does not keep well. The ripening stages at harvest and post-harvest preservation conditions have a great influence on the fruits quality (Ayhan and Kara, 2011). Fresh figs are highly perishable which limits their storage for long periods. In order to explore the potential markets, most of the production is used for drying. Figs are climacteric fruits and are slightly sensitive to ethylene action on stimulating softening and decay severity, especially if kept at 5°C or higher temperatures (Gözlekçi *et al*., 2008). In another study, storage in less than 2% oxygen was recommended for better firmness when stored for more than 8 days. Mathooko *et al.* (1993) reported that CO_2 enriched atmosphere inhibited ethylene production, delayed incidence of mold growth and promoted ethanol production. A gas mixture of 80% CO_2+20% O_2 or 100% CO_2 in polyethylene (PE) bags were more effective in mold growth as compared to air or 100% nitrogen. Modified Atmosphere Packaging (MAP) has been suggested to extend the shelf life of fruit and vegetables (Church and Parsons 1995; Church, 1994; Zagory and Kader, 1988; Farber *et al*., 2003; Ayhan and Esturk, 2009). When optimum storage conditions were applied through modified atmospheres, MAP proved to be quite effective in maximizing product shelf life and quality (Farber *et al*., 2003). Potential beneficial effects of MAP include retardation of senescence (including ripening) and associated biochemical and physiological changes i.e., slowing down the rates of respiration, ethylene production, softening and compositional changes (Kader, 2004).

There are only few studies on fresh fig preservation using Modified Atmosphere Pressure (MAP). The common fig is an important fruit as it has an economic value for the traditional fresh fruit market in many regions of Saudi Arabia. However, it is consumed and exported as unpacked after harvest with limited shelf life. Modified atmosphere packaging could provide an alternative method of fruit preservation, longer shelf life and added values. Ayhan and Kara (2011) showed that considering the sensory, physical and chemical qualities, the commercial shelf life of fresh figs is 15 days at air and low oxygen applications at 4°C. Enriched oxygen was not suggested for the preservation of fresh figs due to their limited sensorial shelf life.

The aim of this study was to investigate the effects of modified atmosphere packaging to retain the texture and appearance of figs as long as possible during storage.

MATERIALS AND METHODS

Sample preparation and initial testing: Fresh fruit of common figs (*Ficus carioca* L.) was harvested from a commercial orchard in Al-Ahsa oasis, Eastern Region of Saudi Arabia. The fresh fruits were washed after harvesting with potable water, pre-cooled, sorted, prepared, packaged and stored at 0°C into their specific treatment group within a day. All the fig fruits were pre-cooled prior to randomly assigning the treatments. Once pre-cooled, figs were placed into either unsealed cardboard boxes or a single layer of at least 25 fruits in the modified atmosphere packaging trays (37×137×187 mm) obtained from VC999 Packaging Systems AG (Melonenstrasse 2, CH-9100; Herisau, Switzerland). Trays requiring various gas treatments were then actively applied with MAP by introducing the desired gas mixtures to the fig samples using a VC999 TS300N tray sealing machine supplier with packs sealed with a non-permeable film (305 mm PA/PP 65 my).

The experiment consisted of five treatments as listed below:

- Control-unsealed cardboard box
- MAP1 tray pack sealed with normal air
- MAP2 tray pack sealed with (CO_2, 20%; N_2, 80% and O_2, 0.0%)
- MAP3 tray pack sealed with (CO_2, 80%; N_2, 20% and O_2, 0.0%)
- MAP4 tray pack sealed with (CO_2, 20%; N_2, 70% and O_2, 10%)

The target atmospheric concentrations of gas mixtures for treatments were filled from premixed cylinders. Each treatment contained fifty boxes or trays. The gas levels of treatments were measured immediately on the completion of packaging and throughout the storage period prior to quality assessments using an Oxybaby_M+(Witt-Gasetechnik, Witten, Germany). Samples were retained at 4°C for 0, 7, 14, 21, 28, 35 and 42 days of storage. Five containers from each of the five treatments were randomly selected for initial quality assessment. The quality assessment attributes such as decay, fruit size, external color, firmness, weight loss, water activity, water content of figs fruits and Total Soluble Solids (TSS) were measured according to AOAC standard methods of analysis (AOAC, 1992). However, the color measurements, weight loss and firmness were conducted prior to treatment application followed by every week of the storage.

Postharvest storage assessment

Weight loss: The weight of five fruits from each replicate for each treatment was recorded at the initial time (day 0) and then during storage time. The weight loss was expressed as percentage (%).

Firmness: Tests were conducted to determine fruit firmness using a penetrometer (Stanhope-Seta Setamatic Penetrometer, Surrey, UK) with a cone weight of 102.3 g and a 45° cone angle. Measurements were conducted on five individual fruits per replicate. The firmness assessment was conducted prior to treatment application and thereafter on weekly basis.

Total soluble solids (TSS): Fruit pulp (25.0 g) was ground in a mortar and the juice was collected with a plastic pipette. A few drops of the sample were utilized to measure the Total Soluble Solids (TSS) in a Digital Brix Refractometer according to the standard methods of analysis (AOAC, 1992).

Color: The color measurements of fruits were obtained using a Hunterlab Color Quest-45/0 LAV color difference meter (Hunter Associates Laboratory, Inc., Reston, Virginia, USA) standardized with black and green tiles. Measured parameters were the degree of Lightness (L) with L value of 100 representing white and L value of zero representing black, redness (positive 'a' values) and yellowness (positive 'b' values). Measurements were conducted on ten fruits per replicate. The color assessment was taken prior to treatment application and thereafter on weekly basis.

Statistical analysis: The experiment was established as a two-way factorial design with five replicates. There were five packaging treatments and seven periods of storage i.e., 0, 7, 14, 21, 28, 35 and 42 days. Initial measurements were taken without replications and were not analyzed in the factorial design. A Least Significance Difference test (LSD) at the 5% level was used to examine multiple comparisons between means using Statistic 7 software (Analytical Software, Tallahassee, FL, USA).

RESULTS AND DISCUSSION

In this study, for all the five treatments, the percent decay was significantly higher in the control-unsealed and normal air treated fruit than the modified atmosphere packaging trays. The percent decay for the untreated fruits was 100% after 7 days at normal air and after 14 days during storage at 4°C. Corelli *et al.* (1991) reported that atmospheres with 15 or 20% carbon dioxide levels reduced the decay incidence and maintained a bright external appearance.

Weight loss: Fruit weight loss (%) was mainly due to water loss resulting from the difference in vapor pressure between the fruits and the surrounding air (Fig. 1). The wrappers in some treatments are barriers for the movement of water vapor and can help in the maintenance of high relative humidity and fruit turgor (Zagory and Kader, 1988). Weight loss measurements for all the MAP treatments during the trial period were not significant (<1% weight loss) in any treatment. The figs in the control treatment lost weight as these were packaged in cardboard boxes thus allowing moisture loss while the MAP-treated figs were enclosed in packages preventing the water loss. However, the weight loss in the control figs during the trial also influenced the resulting firmness measurements. Although, the principles of Modified Atmosphere Packaging (MAP) of fresh produce are well known, the method (commercial distribution) is limited because of the difficulties in controlling in-package atmosphere and humidity during commercial shipments (Kader *et al*., 1989; Aharoni *et al*., 2008).

Firmness: Data presented in Fig. 2 indicated continuous variations in the fruit firmness. Generally there was no significant difference among the different MAP applications. But the figs under high oxygen (MAP) appeared to have low texture values indicating softer flesh as compared to MAP2 and MAP3. The storage time was significant in its effect on the firmness for passive MAP

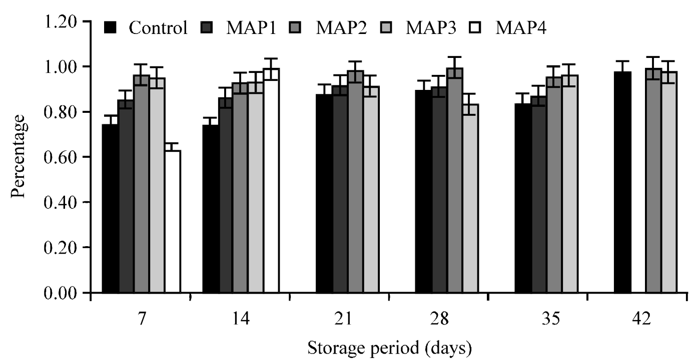

Fig. 1: Figs fruit weight loss (%) during storage period

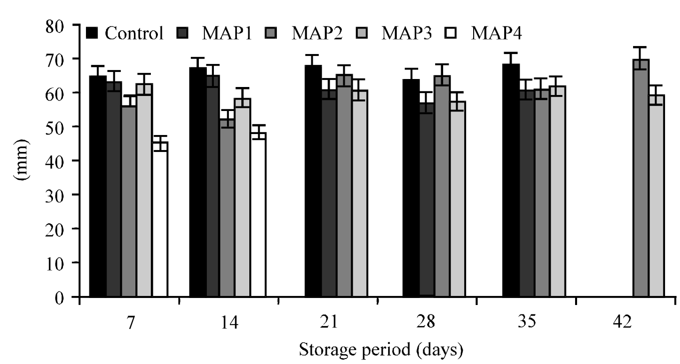

Fig. 2: Firmness (mm) during storage period

applications. In terms of firmness, fruits were acceptable for 20 days under air and low oxygen atmospheres indicating no significant softening during storage. Texture was softer under high oxygen atmosphere when compared to other MAP applications probably due to high metabolic activities under super atmospheric oxygen level. Crisosto *et al.* (2009) stated that there was no significant difference between air and CA treatment on *kadota* figs after storage at 32°F and after one-day shelf life evaluation at 68°F. Corelli and Kader (1994) reported that "*mission*" figs held at 5°C in 20% CO_2-enriched atmosphere lost 25% of the initial quality after 27 days, however, those stored under air deteriorated in less than 2 weeks.

Total soluble solids: Mean values of Total Soluble Solids (TSS) for each treatment are presented in Fig. 3. In general, the Brix values for this variety were similar to those measured by Crisosto *et al.* (2010). Also, lower than the normal range of Brix values in fresh fig were also reported in Italy (Chessa, 1997) and in Turkey (Aksoy *et al.*, 2003; Küden *et al.*, 2008). The lower values of TSS might be due to the difference in location of the commercial orchard as there is low integral radiation in this region than others. Towards the end of the experiment, at day 42, the concentration of TSS in MAP1 was lower than all the other treatments which could be attributed to the absence of a barrier to decrease the respiratory rate of these fruits.

Color: The effects of Modified Atmosphere Packaging (MAP) on the change in color of fruits during storage are presented in Table 1. Bouzo *et al.* (2012) indicated that the

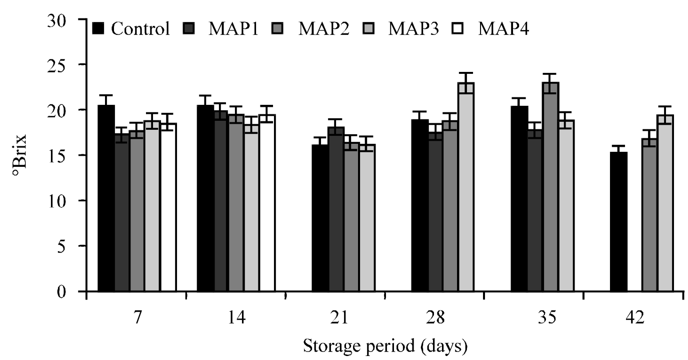

Fig. 3: Total soluble solids during storage period

Table 1: Effect of modified atmosphere packaging (MAP) on color changes during storage period

		The effects of MAP on the color of fresh figs					
		Storage period (days)					
Color characteristics	Treatment	7	14	21	28	35	42
L*	Control	105.01	57.25	0.00	0.00	0.00	0.00
	MAP1	99.51	59.13	52.97	60.68	54.60	56.70
	MAP2	102.01	52.59	59.11	59.53	52.51	0.00
	MAP3	83.86	56.41	51.30	53.42	48.64	57.49
	MAP4	91.94	62.16	61.24	62.31	57.22	58.80
a*	Control	-5.02	0.81	0.00	0.00	0.00	0.00
	MAP1	-5.25	0.58	-0.06	0.08	0.93	-0.75
	MAP2	-2.66	1.64	-1.05	0.64	2.24	0.00
	MAP3	-0.44	-0.08	-1.85	0.16	2.16	0.90
	MAP4	-1.04	-1.33	-3.31	0.41	0.58	0.25
b*	Control	94.13	60.21	0.00	0.00	0.00	0.00
	MAP1	95.23	62.89	62.02	59.11	65.50	61.61
	MAP2	98.33	59.90	62.32	61.16	62.31	0.00
	MAP3	93.23	59.62	54.91	59.79	63.70	60.67
	MAP4	88.76	61.07	61.10	60.29	63.27	64.64

L*: Lightness (Initial color = 59.66), a*: Redness (Initial color = 0.02), b*: Yellowness (Initial color = 56.92), Control: Unsealed cardboard box, MAP1: Tray pack sealed with normal air, MAP2: Tray pack sealed with (80% CO_2, 20% N_2, 0.0% O_2), MAP3: Tray pack sealed with (20% CO_2, 80% N_2, 0.0% O_2), MAP4: Tray pack sealed with (20% CO_2, 70% N_2, 10% O_2)

use of MAP showed some potential to reduce the rate of color change of fig fruits packed and stored at 4°C. Data in Table 1 showed that the modified atmosphere packaging and storage time is significantly affected by the MAP applications. There was no significant difference between MAP 1 and MAP 2 in terms of L* and a* values. However, the L* and a* values at MAP3 were significantly different from MAP1 and MAP2. However, fruits packaged under MAP3 tended to have lower L* and higher a* values than that of MAP1, MAP2 and MAP4 during storage. However, in general, the L* value under MAP1 and MAP2 were significantly higher than those values under MAP3. A general trend demonstrated that the color values did not change much during storage in all the MAP applications.

CONCLUSION

The color and flesh firmness are two important quality characteristics of fresh figs determining the postharvest-life. Fig (*Ficus carica*) fruits can be stored under MAP4 in a tray pack sealed under these conditions (20% CO_2; 70% N_2; 10% O_2) for 28 days based on the physical and chemical properties observed in the study. The shelf life of fresh figs packed in unsealed cardboard box was less than 14 days. The shelf life of figs could be increased by lowering the storage temperature to 0°C as the figs are not sensitive to chilling injury.

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