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Use of Antimicrobial Modified Atmosphere Packages Against Postharvest Diseases in 'Bursa Black' Figs*

'Bursa Siyahi' İncirinde Hasat Sonrası Çürümelerine Karşı Antimikrobiyal Modifiye Atmosfer Paketlerin Kullanımı

Mert Ege TEPELİ[1a*]

Kadir İLHAN[1b]

Mehmet TOPUZ[1c]

Özgür Akgün KARABULUT[1d]

[1]Uludag University, College of Agriculture, Plant Protection Department Görükle, Nilüfer, Bursa

[1a] **Orcid No:** 0000-0002-3155-0035

[1b] **Orcid No:** 0000-0003-1247-9605

[1c] **Orcid No:** 0000-0003-2735-2404

[1d] **Orcid No:** 000-0001-8441-6350

***sorumlu yazar:** Mertegetepeli@gmail.com

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ABSTRACT

Objective: In this investigation was carried out in order to determine the effect of 5 different MAPs, one of which is with antimicrobial (AM) properties. 'Bursa Black' figs whose combinations and unpackaged ones, on the changes in physiological and pathological disorders during storage and shelf life.

Material and Methods: This study was carried out on 3 trials and the products were stored at 3±0.5°C and 90-95% humidity during 32 days and put into the shelf life at 25 ± 0.5°C for 3 days. At the end of the storage, microbiological analysis of the products, gas concentrations, weight loss (%), decayed fruits (%) and decayed fruits at shelf life (%) result were determined.

Result: The packaging of figs during storage has prevented the weight loss that may occur in the products; polyethylene packages (PE) %0,96, AM packages %3,62, control %8,13 (2.trial). At the end of storage, it was observed that AM packages were significantly lower in decayed fruit than in PE package and control, respectively % 2,67, % 48,00, % 16,00 (2.trial).

Conclusion: As a result of the study, it was found that the packages of AM can be used in the commercially or that the PE packages and AM films can be combined.

Keywords:
Bursa Black Fig, Modified Atmosphere Package (MAP), Storage, Antimicrobial MAP

ÖZ

Amaç: Bu çalışma; biri antimikrobiyal (AM) özellikte olan 5 farklı modifiye atmosfer pakete (MAP), bunların kombinasyonlarıyla ve paketsiz (kontrol) olarak koyulan 'Bursa siyahi' incirlerinin muhafaza ve raf ömrü süresince karşılaşılan fizyolojik ve patolojik bozuklukların araştırılması için yürütülmüştür.

Materyal ve Metot: Çalışma 3 tekrarlı olarak yürütülmüş ve meyveler 3±0.5°C ve %90-95 oransal nemde ortalama 32 gün muhafaza edilmiş ardından 3 gün 25±0.5°C'de raf ömrüne bırakılmıştır. Muhafaza sonunda ürünlerin mikrobiyal yükleri, gaz konsantrasyonları, ağırlık kaybı (%), çürük meyve (%) ve raf ömründe oluşan çürük meyve (%) belirlenmiştir.

Bulgular: İncirlerin muhafaza süresince paketlenmesi meyvelerde oluşabilecek ağırlık kaybının önüne geçmiştir, polietilen paket (PE) %0,96, AM paket % 3,62, kontrol % 8,13(2. deneme). Depolama sonunda AM paketlerin, PE ve kontrol grubuna göre meyve çürümesini engellediği bulunmuştur, sırasıyla paketlerin çürüme yüzdeleri % 2,67, % 48,00, % 16,00(2. deneme).

Sonuç: Çalışma sonucunda, AM özelliğe sahip paketlerin, ticari olarak kullanılabileceği ya da PE paketlerle AM filmlerin kombine edilebileceği bulunmuştur.

Anahtar Sözcükler:
Bursa Siyahi İnciri, Modifiye Atmosfer Paket (MAP), Muhafaza, Antimikrobiyal MAP

INTRODUCTION

Fig (*Ficus carica* L.) constitutes an important part of the traditional Mediterranean diet. It originates in the eastern Mediterranean and southern Arabia (Khoshbakht and Hammer, 2006; Stover et al., 2007). The production of fresh fig has been limited due to deficiencies in fruit processing plants. Despite these limitations, the amount of fresh fig production and the market value of the product have increased in recent years. The export value of fresh fig has risen up to $ 2-3 kg^{-1}, and this is one of the highest incomes in Turkey's fresh fruit industry (Bahar and Lichter, 2017).

The rapid decay of the figs is caused by the soft epidermal tissues, and this leads to the susceptibility of the fruit to the fungi (Colelli et al., 1991). The most sensitive part of the figs against fungal decay is the ostiole in the bottom part of the fruit. Ostiol, the natural opening of fig, serves as a channel for the fungal pathogen to enter into the fruit (Karabulut et al., 2004).

Since the skin of fig is thin and sensitive and the fruit becomes soft as it ripes, it cannot be stored commercially. However, it is an advantage for the fig to be stored at low temperatures. Nevertheless, this is not sufficient to prevent decay during storage and at the end of shelf life (Crisosto et al., 1998). Therefore, fig requires complementary technology to prevent ripening and decaying during storage. One of these technologies is the MAP technology. MAP technology depends on the principle of change in the amount of the O_2 and CO_2 based on the respiratory activities of fruits and vegetables in special packages with different gas permeability (Kader, 2002).

It is generally accepted that the storage temperature should be low (0-2° C) and the relative humidity (RH) should be high (Colelli et al., 1991; Gözlekçi et al., 2005). The studies on postharvest technologies in fresh fig are quite limited.

MAPs for fig are not widely used commercially. However, MAPs are widely used in produces such as cherry, pomegranate, cucumber, and zucchini.

It was observed that the weight loss in the 'Bursa Black' fig decreases at 0^0C as a result of pre-cooling with strong air flow and that the storage duration of fruit was prolonged between 2 and 4 weeks (Celikel and Karacali, 1998). In another study, 'Brown Turkey' figs were packaged with polyethylene MA films with different gas permeability. It was reported that the respiration rate of figs stored at 0^0C for 21 days decreased at the end of storage period and the shelf life of fruit was prolonged; however, the accumulation of CO_2 was quite low (Bouzo et al., 2012).

There are few studies on antimicrobial package technology for fresh fig.

Villalobos et al., (2015) stored two different types of fig ('Cuello Dama Blanco' and 'Cuello Dama Negro') for 21 days by combining an antimicrobial substance obtained from soybean extracts with two different MAP films (with macro holes, micro holes). They reported that the combination of this natural compound with the macroporous MA film play an important role in maintaining the quality of both types of fig. Yaldız and Şen (2015), in their study was used Sultana grape and they tried three different MAPs. The first one's name is SmartPac MAP (it contains 4.5 g active $Na_2S_2O_5$) and the second one was SO_2 generators placed under and on the top the polyethylene packages. The fruits were stored at -0.5 ± 0.5 °C and 90% relative humidity for 60 days. At the end of 60 days, no decay growth was observed. Cantin et al. (2010), in their study, investigated the effect of SO_2 fumigation and SO_2 generator pads on the decaying of fig at different temperatures. They reported that among different SO_2 concentrations, 25 (μL/L) SO_2 concentration per hour gave the best result for figs and it inhibition postharvest pathogenes such as *Alternaria spp*., *Rhizopus spp*., *Botrytis spp*. and *Penicillium spp*.

In the fig fruit, there was no study regarding AM MAP, AM packaging and AM film technologies.

MATERIAL and METHOD

Material and Method

'Bursa black' figs were harvested in the quality of export from a fig grove in the Gündoğdu Village in Bursa province, which is one of the areas where fig production is made intensively. Only uniformity of size fruit with no external damage figs were chosen among the figs brought to the laboratory on the same day by homogenizing the ones which are solid, in accordance with the 25-fig export viola. It was paid attention that all of the fruits were according to exporting criteria of packinghouses.

The applications in the study were composed of 5 different MAPs, combinations of these MAPs with an antimicrobial film of different sizes and application of antimicrobial film without using MAP (Table 1). In Table 1, applications, application numbers (App. Nu.), abbreviations of applications, information about the application materials and the way in which applications are performed are explained. Control (App.Nu:12) application is also used commercially, consisting only of figs arranged in each part of the viola in the cardboard box. In this application, the bottom parts of fruits (part of the ostiole aperture) do not come into contact with any packaging material except the viola.

In the MAP applications, the fruit viola was placed into the cardboard box and the MAP was placed on the viola. The fruits were put into the MAPs in the way that one fruit would be in each part of the viola (App. Nu: 1,4,7,9,10). In these applications, especially the bottom parts of the fruits were contacted with MAP packages. The combination of AM films with other applications was done in two ways except M-AM (App. Nu:7) packages. In the first combination, unlike MAP packaging's, an AM film ((33.5*42.5 cm-width*length) was put in MAP to cover the top of the viola before the placement of fruits into the MAPs and then the fruits were placed above it (App. Nu: 2,5). The bottom parts of the fruits were contacted with the AM film. In the second combination, unlike the MAP applications, before the placement, AM films in the size of 11x11 (width*length) were put in a way that one film for each parts of the viola (App. Nu: 3,6) and fruits were placed. The bottom parts of the fruits were contacted with the AM film.

M-AM (App. Nu:7) and AM film were used as a combined application (App. Nu:8). In this combined application, like the MAP applications mentioned above, the M-AM (App. Nu: 7) was placed on the viola in the cardboard box and the fruits were placed in M-AM (App. Nu:7) The bottom parts of the fruit were contacted with the M-AM (App. Nu:7). An AM film in the size that covered the viola (33.5*42.5 cm-width*length) was placed on the fruits and the opening of M-AM (App. Nu:7) was closed. In all MAP applications, the pouches of the packages are twisted, doubled and sealed with rubber so that they are air-tight. Besides the MAP applications, AM films were applied without using MAP packages (App. Nu: 11). In this application, each AM film of 11x11 cm (width*length) was placed in a way that one AM film would be in the parts of the viola in the cardboxes. On the AM film, fruits were placed in a way that one fruit would be in each part of the viola. The bottom parts of the fruits were contacted with the AM film.

Table 1. Applications in the study, abbreviations of applications and features of packages Modified Atmosphere Packaging and Storage of Fruits

Çizelge 1. *Çalışmada yapılan uygulamalar, uygulamaların kısaltmaları ve paketlerin özellikleri*

Application Number:(App.Nu:)	Applications	Abbreviations	Application Material and The Way of Application
1	MAP PE	M-PE	Commercially used polyethylene package-Oxygen Gas Permeability (OGP*): 7000 cm^3/m^2 24h
2	MAP PE+Viola AM Film	M-PE+VAM-F	AM film of 33.5x42,5cm (width*length) with an AM effect was placed at the bottom of the fruit in the MAP PE package.
3	MAP PE+Single Fruit AM Film	M-PE+TAM-F	In the MAP PE package, AM films of 11*11 cm (width*length) with the AM effect were placed to contact the bottom of each fruit.
4	MAP TR	M-TR	MAP with trade name TR. OGP: 4200 cm^3/m^2 24s
5	MAP TR+Viola AM Film	M-TR+VAM-F	AM film of 33.5x42,5cm (width*length) with an AM effect was placed at the bottom of the fruit in the MAP PE package.
6	MAP TR+Single Fruit AM Film	M-TR+TAM-F	In the MAP TR package, AM films of 11*11 cm (width*length) with the antimicrobial effect were placed to contact the bottom of each fruit.
7	MAP AM	M-AM	MAP with AM effect. OGP: 1200 cm^3/m^2 24s
8	MAP AM+ Viola AM Film	M-AM+ VAM-F	AM film of 33.5x42,5cm (width*length) with an AM effect was placed at the top of the fruit in the MAP AM package.
9	MAP POINT	M-PO	MAP with trade name POINT. OGP: 3000 cm^3/m^2 24s
10	MAP PREMIER	M-PR	MAP, with trade name PREMIER. OGP: 3500 cm^3/m^2
11	Unwrapped+Single Fruit AM Film	A+TAM-F	The AM film was placed between the bottom part of the fruit and the viola.
12	Unwrapped (Control)	Control	Application without MAP or AM film (Commercial application)

*OGP: Oxygen Gas Permeability (cm^3/m^2 24h)

MAPs and AM film used in the study were maintained for use in figs from Trendlife® (Istanbul/Turkey). All MAPs are 72*64 cm (width*length). AM films have been reported not only to be contact, but also to have AM effect in the form of gas by the company.

In this study, 3 trials were carried out on different dates in the same harvest season. The dates of the trials were as follows: 1. trial lasted for 30 days between 14.09.2017-14.10.2017, 2. trial, for 32 days between 20.09.2017-22.10.2017 3. trial for 33 days between 28.09.2017-31.10.2017. Fig fruits were stored at 3±0,5^{0}C temperature and 95% relative humidity. At the end of the storage, the fruits are stored shelf life at 20^{0}C for 3 days. The percentages of oxygen and carbon dioxide gases formed by the respiration of fruits were measured in MAP packages on 1st, 3rd and 7th days during the storage period and every 7th day thereafter. Measuring was made by a portable O_2/ CO_2 gas meter device (PBI Dansensor Checkpoint2, Denmark). The study was designed as 3 replications based on the Coincidence Plots Experiment Design and each plastic case was accepted as a replication. There are 25 figs in each case. The net fruit weight of each case is in the range of 1800-1900 g.

Fruit Decay

In the examination of fruits after cold storage, the decayed fruits were counted and the percentage of decayed fruit (%) was determined. After keeping in the cold, figs were storaged the shelf life at 20^{0}C for 3 days after counting the decayed fruits. In addition, the percentage of decayed fruits (%) was determined daily during the shelf life.

Weight Loss

The weight loss of the applications was determined in the study. For this purpose, the applications whose weights were determined before storage were weighed again at the end of the cold storage and their weight loss was determined as percentage (%).

Microbial Analysis

In order to determine the effect of the applications on the microbial load in the fruits used in the experiment, microbial analysis was performed for each application before and after cold storage. The microbial analysis of each application after storage was carried out separately and it was aimed to determine the effect of applications with AM effect on microbial growth. Microbial analysis was performed by taking part from where ostiole (natural aperture) opening is, which is the most sensitive area for decay in whole fruit. 2 fruits were randomly selected from the related application and placed in sterile packages as a whole, 200 ml of sterile distilled water was added in the sterile chamber and it was tightly closed, and then shaken for 15 minutes at 150 rpm in the circular shaker. In addition, 2 more fruits were randomly selected from the same application and the ostiole opening in the lower part was taken as center the round and conical cut in 1 cm diameter by the help of bistoury. The sample taken up was placed in sterile 100 ml glass bottles containing 40 ml of sterile distilled water and then shaken in a circular shaker at 150 rpm for 15 min. At the end of the period, the sterile packages and glass bottles are opened in a sterile chamber, for example, 1000 µl of liquid was taken from the liquid setting and serial decimal (10 times) dilutions were made in sterile eppendorf tubes. From each dilution, 100µl was taken into the related petri plates as example and distributed over nutrient media. Potato Dextrose Agar (PDA, Oxoid) for detection of total microorganism load, PDA containing 100 mgL^{-1} streptomycin sulfate (Oxoid, Sigma-Aldrich) for detection of total yeast and fungal population and Tryptone Soybean Agar (TSA, Difco) petri dishes containing 200 mgL^{-1} cycloheximide (Actidione, Sigma-Aldric USA) for detection of bacterial population were used. Petri dishes were then incubated for 2-3 days for bacterial and yeast growth and 3-5 days for fungus development, at 24^{o}C. At the end of the period, grown colonies were counted and microorganism load (cfu) was determined per whole fruit and part of ostiole.

The study was repeated with two replications and 5 petri dishes were used for the related microorganism group in each replication.

Statistical Analysis

In the experiments, data such as fruit decaying, weight loss and microbial analysis were obtained with 3 replications depending on the coincidence plots experiment design and each plastic case was accepted as a replication. These data were subjected to variance analysis by using JMP statistics program. The differences between the means for each application were determined by the Duncan test ($P \leq 0.05$) (Steel and Torrie, 1980; Yurtsever, 1984).

The data obtained from the determination of the microbial load on the fruits were subjected to the analysis of variance according to the random plot trial design. LSD test was applied to determine differences between applications ($P \leq 0.05$).

Before data analysis, square root transformation was applied (square root of the proportion of affected fruit) to the values.

RESULTS

O_2/CO_2 rates in MAPs

No statistically significant difference was observed between the applications during the storage period (data not shown). It was found that O_2 level was in the range of %13.5-15 and CO_2 was in the range of %1.2-2.6

Weight Loss

In this study, MAPs and their combinations had different effects on weight loss of figs. The weight losses of all trials in the study after the storage are shown in Tables 2, 3 and 4. The least weight loss after cold storage in all trials was seen in M-PE (App.Nu:1) and M-PE film combinations (App.Nu:2,3), while the highest weight loss was in the control group (App. Nu:12) and in A+TAM-F application (App.Nu:11) (Table 2,3,4). At the end of the cold storage in Control (App. Nu: 12) and A+TAM-F (App. Nu: 11) it was observed that there was water loss in the level that will decrease market value on the surface of figs. It was not observed that the fruits in other applications wrapped with MAP lost their market value due to weight loss (Table 2,3,4).

Fruit Decay

After cold storage and shelf life, significant differences between applications did not emerge in terms of decaying fruit percentage. Fruit decaying after cold storage and the decaying of fruits in the shelf life are given in Table 2, 3 and 4.

In the first trial, the decaying in M-PE (App. Nu: 1) was the highest with 49.33%, while the decaying in the control (App. Nu: 12) and M-TR (App. Nu: 4) had approximate values. The decaying in the applications with AM was observed to be the minimum Table 2.

In the second trial, the decaying in M-PE (App. Nu: 1) was the highest with 48%, while the decaying in the control (App. Nu: 12) was observed with 16%. In the applications of A+TAM-F (App. Nu: 11), M-AM+VAM-F (App. Nu: 8), M-TR+VAM-F (App. Nu: 5) and M-PE+TAM-F (App. Nu:3) no decaying was observed (Table 3).

Table 2. Weight loss (%), fruit decaying after cold storage (%) and fruit decaying during shelf life (%), detected after the cold storage, of 'Bursa black' figs stored for 30 days between 14.09.2017-14.10-2017 at 3^0C in different MAPs (1st trial).

Çizelge 2. *Farklı MAP'larda, 3^0C sıcaklıkta, 14.09.2017-14.10.2017 tarihleri arasında 30 gün muhafaza edilen Bursa Siyah inciri meyvelerinin soğuk muhafazası sonunda tespit edilen ağırlık kaybı (%), soğukta muhafaza sonrası meyve çürümesi (%) ve raf ömrü süresince görülen meyve çürümesi (%) (1. deneme).*

Applications	Weight Loss (%)	After Cold Storage Fruit Decaying (%)	After Shelf Life Fruit Decaying (%)		
			Day 1	Day 2	Day 3
M-PE (App. Nu:1)	0.8 f[x*]	49.3 a	65.3 a	76.9 a	81.2 a
M-PE+V AM-F (App. Nu:2)	0.7 f	14.7 c	24.8 b	30.6 b	36.4 b
M-PE+T AM-F (App. Nu:3)	0.6 f	9.3 cd	15,1 bc	26.7 bc	35,4 bc
M-TR (App. Nu:4)	3.2 d	36.0 b	65.0 a	75.1 a	83.8 a
M-TR+V AM-F (App. Nu:5)	2.6 e	2.7 cd	12.8 bc	17.2 cd	23.0 cd
M-TR+T AM-F (App. Nu:6)	2.4 e	5.3 cd	16.9 bc	21.3 bcd	30.0 bc
M-AM (App. Nu:7)	3.8 c	4.0 cd	15.6 bc	22.8 bcd	28.6 bc
M-AM+V AM-F (App. Nu:8)	2.8 de	4.0 cd	8.4 c	12.7 d	15.6 d
M-PO (App. Nu:9)	4.2 c	8.0 cd	15.3 bc	18.1 bcd	31.2 bc
M-PR (App. Nu:10)	3.8 c	4.0 cd	11.2 bc	19.9 bcd	30.1 bc
A+T AM-F (App. Nu:11)	7.2 b	1.3 d	7.1 c	11.5 d	15.8 d
Control (App. Nu:12)	7.9 a	44.0 ab	59.9 a	68.6 a	81.7 a

[x]LSD Test: (P <0.05) There is no statistically significant difference between the same letters at significance level.
* In each statistical analysis, each column is evaluated according the coincidence plots experiment design.

Table 3. Weight loss (%), fruit decaying after cold storage (%) and fruit decaying during shelf life (%), detected after the cold storage, of 'Bursa black' figs stored for 32 days between 20.09.2017-22.10-2017 at 3^0C in different MAPs (2st trial).

Çizelge 3. *Farklı MAP'larda, 3^0C sıcaklıkta, 20.09.2017-22.10.2017 tarihleri arasında 32 gün muhafaza edilen Bursa Siyah inciri meyvelerinin soğuk muhafazası sonunda tespit edilen ağırlık kaybı (%), soğukta muhafaza sonrası meyve çürümesi (%) ve raf ömrü süresince görülen meyve çürümesi (%) (2. deneme).*

Applications	Weight Loss (%)	After Cold Storage Fruit Decaying (%)	After Shelf Life Fruit Decaying (%)		
			Day 1	Day 2	Day 3
M-PE (App. Nu:1)	0,96 d x*	48,00 a	65,4 a	81,3 a	84,2 a
M-PE+V AM- F (App. Nu :2)	0,90 d	4,00 bcd	12,7 bc	17,0 de	19,9 de
M-PE+T AM- F (App. Nu :3)	0,81 d	0,00 d	2,9 c	10,1 def	14,5 de
M-TR (App. Nu :4)	3,07 bc	13,33 bc	22,0 b	38,0 b	48,1 b
M-TR+V AM- F (App. Nu :5)	2,96 bc	0,00 d	0,0 c	0,0 f	4,3 e
M-TR+T AM- F (App. Nu :6)	3,39 d	1,33 cd	4,2 c	8,6 def	15,8 de
M-AM (App. Nu :7)	3,62 bc	2,67 cd	5,5 c	8,4 def	14,3 de
M-AM+V AM-F (App. Nu :8)	2,39 cd	0,00 d	2,9 c	4,3 def	8,7 de
M-PO (App. Nu :9)	4,15 b	2,67 cd	5,6 c	7,0 def	9,9 de
M-PR (App. Nu :10)	3,68 bc	5,33 bcd	11,1 bc	19,8 cd	27,1 cd
A+T AM-F (App. Nu :11)	7,37 a	0,00 d	1,4 c	1,4 ef	2,9 e
Control (App. Nu :12)	8,13 a	16,00 b	21,8 b	36,3 bc	46,4 bc

[x]LSD Test: (P <0.05) There is no statistically significant difference between the same letters at significance level.
[*] In each statistical analysis, each column is evaluated according the coincidence plots experiment design.

Table 4. Weight loss (%), fruit decaying after cold storage (%) and fruit decaying during shelf life (%), detected after the cold storage, of 'Bursa black' figs stored for 33 days between 28.09.2017-31.10-2017 at 3^0C in different MAPs (3st trial).

Çizelge 4. *Farklı MAP'larda, 3^0C sıcaklıkta, 28.09.2017-31.10.2017 tarihleri arasında 33 gün muhafaza edilen Bursa Siyah inciri meyvelerinin soğuk muhafazası sonunda tespit edilen ağırlık kaybı (%), soğukta muhafaza sonrası meyve çürümesi (%) ve raf ömrü süresince görülen meyve çürümesi (%) (3. deneme).*

Applications	Weight Loss (%)	After Cold Storage Fruit Decaying (%)	After Shelf Life Fruit Decaying (%)		
			Day 1	Day 2	Day 3
M-PE (App. Nu :1)	0,90 e x*	45,33 a	56,9 a	68,5 a	78,7 a
M-PE+V AM- F (App. Nu :2)	0,93 e	4,00 cd	9,8 d	12,7 cd	15,6 c
M-PE+T AM- F (App. Nu :3)	0,69 e	1,33 d	2,8 d	4,2 d	14,4 c
M-TR (App. Nu :4)	3,41 d	5,33 bcd	31,4 b	41,6 b	56,1 b
M-TR+V AM- F (App. Nu :5)	3,64 d	5,33 bcd	8,2 d	8,2 cd	12,6 c
M-TR+T AM- F (App. Nu :6)	3,39 d	4,00 cd	8,3 d	15,6 cd	18,5 c
M-AM (App. Nu :7)	4,55 c	5,33 bcd	9,7 d	14,0 cd	16,9 c
M-AM+V AM-F (App. Nu :8)	3,32 d	4,00 cd	5,4 d	5,4 d	9,8 c
M-PO (App. Nu :9)	4,95 c	1,33 d	11,4 cd	23,1 c	26,0 c
M-PR (App. Nu :10)	4,41 c	2,67 d	5,6 d	8,5 cd	11,3 c
A+T AM-F (App. Nu :11)	6,74 b	12,00 b	14,9 cd	17,8 cd	20,7 c
Control (App. Nu :12)	7,46 a	10,67 bc	23,7 bc	46,9 b	54,1 b

[x]LSD Test: (P <0.05) There is no statistically significant difference between the same letters at significance level.
* In each statistical analysis, each column is evaluated according the coincidence plots experiment design.

In the third trial, the decaying in M-PE (App. Nu:1) was the highest with 45.33%, while the decaying in the control (App. Nu: 12) and A+TAM-F (App. Nu: 11) were found to be with 10.67% and 12.00% respectively. The decaying in M-PE+TAM-F (App. Nu: 3), M-PO (App. Nu: 9) and M-PR (App. Nu: 10) was found to be the lowest with 1.33%, 1.33% and 2.67% respectively (Table 4).

According to the decaying in shelf life of the trials, the applications where the decaying was found most in all of three trials are the M-PE (App. Nu: 1), M-TR (App. Nu: 4), control (App. Nu: 12).

During the storage, mainly grey mold (*Botrytis cinerea*) as decaying factor was diagnosed macroscopically. Apart from this factor, the decaying caused by brown spot disease (*Alternaria alternata*) and blue mold (*Penicillium expansum*), and *Rhizopus spp*. decay in the fruits in shelf life was observed macroscopically and microscopically.

Microbiological Analysis

According to the microbial analysis performed in the fruits of 'Bursa black' figs, after the cold storage as the total microorganism (fungus+bacterium+yeast) / fruit, the highest amount of microorganism in the whole of the fruit and in the ostiole part was found to be in M-PE (App. Nu: 1). The applications with the least microorganisms were found to have differences in the fruit and ostiole parts and the results are given in Table 5. According to the microbial analysis of the first trial performed in the fruits of 'Bursa black' figs, after the cold storage as the total microorganism / fruit, the highest amount of microorganism in the whole of the fruit and in the ostiole part was found to be in M-PE (App. Nu: 1). This application is followed by M-TR (App. Nu: 4). The least microorganism is found to be in M-AM (App. Nu: 7) and M-AM+V AM-F (App. Nu: 8) (Table 5).

According to the microbial analysis of the second trial performed in the fruits of 'Bursa black' figs, after the cold storage as the total microorganism / fruit, the highest amount of microorganism in the whole of the fruit and in the ostiole part was found to be in M-PE (App. Nu: 1). This application is followed by M-TR+T AM-F (App. Nu: 6) for the whole fruit and M-PO (App. Nu:9) for the microbial load of the ostiole part. The least microorganism is found to be in M-AM (App. Nu: 7) for the whole fruit and in control (App. Nu:12) for the ostiole part (Table 6).

According to the microbial analysis of the third trial performed in the fruits of 'Bursa black' figs, after the cold storage as the total microorganism/fruit, the highest amount of microorganism in the whole of the fruit and in the ostiole part was found to be in M-PE (App. Nu: 1). This application is followed by M-PE+V AM-F (App. Nu: 2) for the whole fruit and Control (App. Nu: 12) for the microbial load in the ostiole part. The least microorganism is found to be in M-PR (App. Nu: 10) (Table 7).

Table 5. The effect of different MAPs on the number of microorganisms on the fruit and ostiole on 1st trial (cfu fruit^{-1}, cfu ostiole^{-1})
Çizelge 5. *Farklı MAP'ların 1. denemedeki incir meyvesinin ve ostiolün üzerinde bulunan mikroorganizma sayıları üzerine etkisi (cfu/meyve, cfu/ostiol)*

Applications	Fruit (cfu / fruit)			Ostiole (cfu / ostiole)		
	Total Microorganism	Fungus	Bacteria	Total Microorganism	Fungus	Bacteria
Storage Start	4,00x10^{5}	1,00x10^{5}	3,50x10^{5}	1,88x10^{5}	6,88x10^{4}	5,63x10^{4}
M-PE (App. Nu :1)	5,25x10^{6} a^{x*}	2,25x10^{6} a	1,55x10^{6} a	2,63x10^{5} a	1,25x10^{4} b	2,19x10^{5} a
M-PE+V AM- F (App. Nu :2)	1,39x10^{6} c	1,50x10^{5} bc	1,03x10^{6} bc	1,24x10^{5} c	4,38x10^{3} ef	1,02x10^{5}c
M-PE+T AM- F (App. Nu :3)	4,15x10^{5}e	7,50x10^{4} de	3,50x10^{4} h	1,26x10^{5} c	1,89x10^{4} a	1,06x10^{5}c
M-TR (App. Nu :4)	2,40x10^{6}b	1,45x10^{6} a	1,30x10^{6} ab	1,96x10^{5} b	1,38x10^{4} ab	1,46x10^{5}b
M-TR+V AM- F (App. Nu :5)	9,25x10^{5}d	1,50x10^{4} fg	8,80x10^{5} c	9,25x10^{4} d	1,50x10^{3} g	8,80x10^{4}d
M-TR+T AM- F (App. Nu :6)	4,15x10^{5}e	2,05x10^{5} b	2,05x10^{5} e	7,00x10^{4} e	7,50x10^{3} cd	6,19x10^{4}e
M-AM (App. Nu :7)	1,60x10^{5}g	8,50x10^{4} d	1,10x10^{5} f	2,31x10^{4} h	6,25x10^{3} de	1,63x10^{4}g
M-AM+V AM-F (App. Nu :8)	2,53x10^{4}ı	1,03x10^{4} g	1,00x10^{4} ı	2,53x10^{4} h	1,03x10^{4} bc	1,63x10^{4}g
M-PO (App. Nu :9)	3,53x10^{5}e	2,10x10^{4} f	2,79x10^{5} d	4,75x10^{4} f	7,50x10^{3} cd	3,81x10^{4}f
M-PR (App. Nu :10)	2,58x10^{5}f	5,00x10^{4} e	1,34x10^{5} f	3,63x10^{4} g	3,75x10^{3} f	3,38x10^{4}f
A+T AM-F (App. Nu :11)	1,05x10^{5}h	1,00x10^{4} g	1,63x10^{4} j	3,81x10^{4} g	5,63x10^{3} de	1,31x10^{4}h
Control (App. Nu :12)	1,50x10^{5}g	1,00x10^{5} cd	5,00x10^{4} g	1,96x10^{5} b	1,38x10^{4} ab	1,46x10^{5}b

^{x}LSD Test: (P <0.05) There is no statistically significant difference between the same letters at significance level.
* In each statistical analysis, each column is evaluated according the coincidence plots experiment design.

Table 6. The effect of different MAPs on the number of microorganisms on the fruit and ostiole on 2st trial (cfu fruit^{-1}, cfu ostiole^{-1})
Çizelge 6. *Farklı MAP'ların 2. denemedeki incir meyvesinin ve ostiolün üzerinde bulunan mikroorganizma sayıları üzerine etkisi (cfu/meyve, cfu/ostiol).*

Applications	Fruit (cfu / fruit)			Ostiole (cfu / ostiol)		
	Total Microorganism	Fungus	Bacteria	Total Microorganism	Fungus	Bacteria
Storage Start	7,65x10^{4}	2,65x10^{4}	4,95x10^{4}	1,40x10^{4}	8,44x10^{3}	1,03x10^{4}
M-PE (App. Nu :1)	1,35x10^{6} a^{x*}	7,50x10^{5} a	7,50x10^{5} a	7,35x10^{5}a	1,38x10^{5} ab	6,30x10^{5} a
M-PE+V AM- F (App. Nu :2)	4,05x10^{5} c	8,50x10^{4} ab	2,85x10^{5} bc	3,25x10^{5}e	3,13x10^{3} e	2,39x10^{5} abc
M-PE+T AM- F (App. Nu :3)	4,15x10^{5} c	3,50x10^{4} abc	3,70x10^{5} b	4,81x10^{4}h	1,25x10^{4} c	2,56x10^{4} f
M-TR (App. Nu :4)	3,00x10^{5} cde	1,00x10^{5} ab	1,00x10^{5} efg	6,13x10^{5} bc	9,38x10^{4} b	5,18x10^{5} a
M-TR+V AM- F (App. Nu :5)	2,65x10^{5} de	4,50x10^{4} abc	8,00x10^{4} g	2,57x10^{5} f	1,44x10^{4} c	1,48x10^{5} bcd
M-TR+T AM- F (App. Nu :6)	5,90x10^{5} b	0,00 d	3,45x10^{5} bc	4,38x10^{4} h	6,25x10^{3} d	3,56x10^{4} ef
M-AM (App. Nu :7)	4,00x10^{4} ı	1,00x10^{4} abc	3,00x10^{4} h	5,63x10^{3} ab	1,88x10^{3} ab	4,38x10^{3} a
M-AM+V AM-F (App. Nu :8)	7,00x10^{4} h	5,00x10^{3} cd	6,50x10^{4} g	4,44x10^{4} c	1,25x10^{3} a	1,44x10^{5} ab
M-PO (App. Nu :9)	2,65x10^{5} e	3,00x10^{4} bcd	1,75x10^{5} de	6,81x10^{5} a	9,38x10^{4} ab	5,63x10^{5} a
M-PR (App. Nu :10)	3,70x10^{5} cd	1,20x10^{5} ab	2,20x10^{5} cd	5,44x10^{5} e	8,06x10^{4} e	4,19x10^{5} abc
A+T AM-F (App. Nu :11)	1,00x10^{5} g	1,00x10^{4} abc	8,50x10^{4} fg	1,73x10^{5} h	6,25x10^{3} f	1,11x10^{5} de
Control (App. Nu :12)	1,75x10^{5} f	7,00x10^{4} ab	1,30x10^{5} ef	4,14x10^{5} ı	3,13x10^{3} f	3,04x10^{5} g

^{x}LSD Test: (P <0.05) There is no statistically significant difference between the same letters at significance level.
* In each statistical analysis, each column is evaluated according the coincidence plots experiment design.

Table 7. The effect of different MAPs on the number of microorganisms on the fruit and ostiole on 3st trial (cfu fruit^{-1}, cfu ostiole^{-1})
Çizelge 7. *Farklı MAP'ların 3. denemedeki incir meyvesinin ve ostiolün üzerinde bulunan mikroorganizma sayıları üzerine etkisi (cfu/meyve, cfu/ostiol).*

Applications	Fruit (cfu / fruit)			Ostiol (cfu / ostiole)		
	Total Microorganism	Fungus	Bacteria	Total Microorganism	Fungus	Bacteria
Storage Start	4,80x10^{4}	9,38x10^{4}	2,50x10^{4}	3,51x10^{5}	9,38x10^{3}	3,37x10^{5}
M-PE (App. Nu :1)	4,85x10^{6} a^{x*}	4,00x10^{5} a	2,25x10^{6} a	2,63x10^{5} a	1,25x10^{4} b	2,19x10^{5} a
M-PE+V AM- F (App. Nu :2)	6,10x10^{5} b	8,50x10^{4} d	3,05x10^{5} b	5,38x10^{4} e	1,06x10^{4} bc	2,94x10^{4} g
M-PE+T AM- F (App. Nu :3)	1,55x10^{5} f	3,00x10$^{4\,f}$	1,15x10^{5} d	7,00x10^{4} d	7,50x10^{3} d	6,19x10^{4} d
M-TR (App. Nu :4)	3,70x10^{5} d	1,05x10^{5} d	2,65x10^{5} b	4,63x10^{4} f	7,50x10^{3} d	3,81x10^{4} e
M-TR+V AM- F (App. Nu :5)	4,55x10^{5} c	2,65x10^{5} b	1,25x10^{5} d	3,94x10^{4} f	2,75x10^{4} d	3,38x10$^{4\,e}$
M-TR+T AM- F (App. Nu :6)	5,45x10^{5} c	1,50x10^{5} c	6,00x10^{4} fg	4,75x10^{4} g	7,50x10^{3} a	3,81x10^{4} f
M-AM (App. Nu :7)	2,00x10^{5} e	4,00x10^{4} ef	1,60x10^{5} c	2,31x10^{4} j	1,25x10^{3} g	2,06x10^{4} ı
M-AM+V AM-F (App. Nu :8)	9,00x10^{4} g	1,50x10^{4} g	7,00x10^{4} f	1,00x10^{4} k	2,50x10^{3} f	8,13x10^{3} j
M-PO (App. Nu :9)	1,35x10^{5} f	2,00x10^{4} g	1,10x10^{5} d	3,63x10^{4} h	3,75x10^{3} e	3,38x10^{4} f
M-PR (App. Nu :10)	9,50x10^{4} h	2,00x10^{4} g	5,50x10^{4} g	2,81x10^{4} ı	8,13x10^{3} cd	2,44x10^{4}
A+T AM-F (App. Nu :11)	1,00x10^{5} g	4,50x10^{4} e	6,00x10$^{4\,f}$g	1,96x10^{5} b	1,38x10^{4} b	1,46x10^{5} b
Control (App. Nu :12)	1,85x10^{5}e	8,50x10^{4}d	9,00x10^{4} e	1,96x10^{5} b	1,38x10^{4} b	1,46x10^{5} b

^{x}LSD Test: (P <0.05) There is no statistically significant difference between the same letters at significance level.
* In each statistical analysis, each column is evaluated according the coincidence plots experiment design.

DISCUSSION

Trials were conducted at the times when the produce was abundant and the unit price decreased, and the produce was simulated in accordance with the aim to put on market when the product started to decrease and the unit price increased. One of the most important problems in fig storage is the preservation of fruit quality. Softening and weight loss plays an important role in the deterioration of fruit quality. In addition, it is an important factor that increases the sensitivity to fungal decay. Respiration and water transpiration rates were defined as the main causes of softening during postharvest storage (Paniagua et al., 2013). The films used in some applications prevent the movement of water vapour in the package and slow the weight loss of the fruit due to the high relative humidity. (Kader and Zagory, 1988). The changing amounts of O_2 and CO_2 during cold storage also show that the gas permeability of the MAPs used is different.

If we compare MA packages and their combinations according to different criteria; in the weight loss criteria generally the most weight loss is found to be in Control (App. Nu: 12) and A+T AM-F (App. Nu: 11). In MAP applications, the maximum weight loss is found to be in M-PO (App. Nu: 9) and M-PR (App. Nu: 10). The least weight loss is observed in M-PE (App. Nu: 1) and its combinations. Bouzo et al. (2012) used MAPs in different structure in the storage of the figs (*Ficus carica L*. 'Brown Turkey') for 21 days. They reported that 13% less weight loss has occurred in the fruits put into the Polyethylene MAP (Xtend® MA / MH, StePac Ltd., Israel) compared to the control application. In this study, in M-PE (App. Nu:1) 7.1% less weight loss was observed compared to the Control (App. Nu:12)

When the average decaying rate of fresh figs after 30 days of cold storage is examined the most decaying is observed for all of three trials in M-PE (App. Nu: 1), which is followed by Control (App. Nu: 12). The reason for the more decaying in M-PE (App. Nu:1) than Control (App. Nu:12) is thought that M-PE (App. Nu: 1) creates a suitable environment for the development of microorganisms by creating excess moisture in the package. In applications involving AM film, the decaying was detected at low levels. This is due to the effect of the AM substance in AM films. The results of microbial load analysis support these results.

The decaying rates of fresh figs during shelf life were also examined. According to the results, in the general sense, the highest decaying on the first day of the shelf life was detected in M-PE (App. Nu: 1), M-TR (App. Nu: 4). On the second day of shelf life, it was observed in M-PE (App. Nu: 1), M-TR (App. Nu: 4), and Control (App. Nu: 12) and on the third day, in M-PE (App. Nu: 1), M-TR (App. Nu: 4), and Control (App. Nu: 12). According to the results, the least decaying varied depending on the trials.

When the effects of the applications on the number of microorganisms on fruit and ostiole are examined, the application where the most microbial density is in both the fruit and its ostiole part is found to be M-PE (App. Nu:1). The reason for this is thought that the film used in M-PE (App. Nu: 1) has more moisture in the package than other applications. In the combination of M-PE (App. Nu: 1) with AM pads, AM substance is thought to suppress the microorganism population. The applications with the least microbial density were identified as AM-containing packages and their combinations. Antimicrobial packets have been shown to reduce microbial density. Microbial density has been observed to be more in the ostiole part of fruit. The reason for this is thought that the ostiole part has a natural opening, it makes entrance into the fruit easy for microorganism.

CONCLUSION

During the storage, compared to M-PE (App.Nu:1), if 3.5-4% less weight loss is acceptable for the user and the storage duration of 'Bursa black' fig at +3^{0}C is not more than 33 days, M-AM (App. Nu:7), AM film combinations or M-PO (App. Nu: 9) and M-PR (App. can be used instead of M-PE (App. Nu:1). It was observed that M-AM (App. Nu:7) packages and combinations decreased the decaying and microbial load compared to other M-PE (App. Nu:1) packs and control (App. Nu:12) and pressed the pathogens and decreased the loss of product. If M-AM (App.Nu:7) is used commercially, both the weight loss will be thought to be kept in minimum levels and the rates of decaying will decrease.

According to the results, it is thought that MAP applications such as M-AM (App. Nu:7) packs, AM film combinations or M-PO (App. Nu: 9) and M-PR (App. Nu:10) can be used commercially; however, it can be developed for the storage conditions for longer durations.

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REFERENCES

Bahar, A., Lichter, A., 2018. Effect of controlled atmosphere on the storage potential of Ottomanit fig fruit. *Scientia Horticulturae*. 227 (2018) 196-201

Bouzo, C.A., Travadelo, M., Gariglio, N.F., 2012. Effect of different packaging materials on postharvest quality of fresh fig fruit. *International Journal of Agriculture and Biology*, 14, 821–825.

Cantin, C.,M., Palou, L., Bremer, V., Michailides, T., J., Crisosto, C., H., 2010. Evaluation of the use of sulfur dioxide to reduce postharvest losses on dark and green figs. *Postharvest Biology and Technology*, 59 (2011) 150–158.

Celikel, F.G., Karacali, I., 1998. In: Aksoy, U., Ferguson, L., Hepaksoy, S. (Eds.), Effects of Harvest Maturity and Precooling on Fruit Quality and Longevity of 'Bursa Siyahi' Figs (*Ficus Carica L.*), 480 ed. International Society for Horticultural Science (ISHS), Leuven, Belgium, Izmir, Turkey, pp. 283–288.

Colelli, G., Mitchell, F.G., Kader, A.A., 1991. Extension of postharvest life of mission figs by CO_2-enriched atmospheres. *HortScience*, 26, 1193–1195.

Costa, C., Lucera, A., Conte, A., Mastromatte, A., Speranza, B., Antonacci, A., Del Nobile, M.A., 2011. Effects of passive and active modified atmosphere packaging conditions on ready-to-eat table grape. *Journal of Food Engineering*, 102, 115–121

Crisosto, C.H., Mitcham, E.J., Kader, A.A., 1998. Fig: Recommendations for Maintaining Postharvest Quality, Perishable Handling. Postharvest Technology Center, University of California, Davis.

Gözlekçi, S., Erkan, M., Karaşahin, I., Şahin, G., 2005. Effect of 1-methylcyclopropene (1-MCP) on fig (*Ficus carica cv. Bardakci*) storage. III International Symposium on Fig 798 325–330.

Kader, A. A. 2002. Modified atmospheres during transport and storage. p 135-144. In A. Kader (Ed.). Postharvest technology of horticultural crops, University of California Agricultural and Natural Resources, Publication 3311, Oakland, California.

Kader, A.A. and Zagory, D., 1988. Modified atmosphere packaging of fresh produce. *Food Technology.*, 42: 70–77

Karabulut, O. K., Gabler, F. M., Mansour, M., Smilanick, J. L. 2004. Postharvest ethanol and hot water treatments of table grapes to control gray mold. *Postharvest Biology and Technology*. 34: 169-177.

Khoshbakht, K., Hammer, K., 2006. Savadkouh (Iran)–an evolutionary center for fruit trees and shrubs. *Genetic Resources and Crop Evolution*, 53, 641–651.

Paniagua, A.C., East, A.R., Hindmarsh, J.P., Heyes, J.A., 2013. Moisture loss is the major cause of firmness change during postharvest storage of blueberry. *Postharvest Biology and Technology*, 79, 13–19.

Villalobos, M.d.C., Serradilla, M.J., Martín, A., Ruiz- Moyano, S., Pereira, C., Córdoba, M.d.G., 2015. Synergism of defatted soybean meal extract and modified atmosphere packaging to preserve the quality of figs (*Ficus carica L.*). *Postharvest Biology and Technology*, 111 (2016) 264–273

Yaldız, S. and F. Şen. 2015. Research on Efficiency of Different Sulphur Dioxide Generators on Storability of Table Sultana Seedless Grapes. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, 52 (3):297-305