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EFFECT OF MODIFIED ATMOSPHERE PACKAGING ON QUALITY AND SHELF LIFE OF MINIMAL PROCESSED POMEGRANATE (*Punica granatum* L.)

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ABSTRACT

The objective of this study was to monitor composition, quality parameters and extend the shelf life of ready-to-eat "Manfalouty" pomegranate arils packaged under modified atmospheres. Minimally processed pomegranate arils were packed in polypropylene PP and polyester/polyethylene (PET/PE) under 4 atmospheres. Packaged pomegranate arils were stored at 5±1°C and 70-75% RH for 15 days. As a general trend, significant change was detected in chemical, physical and microbial attributes of pomegranate arils treatments during cold storage. Stored pomegranate arils packaged in PET/PE were much better than those packaged in PP. On the other hand, the arils stored in (10%O_2+20%CO_2+70% N_2) and (5%O_2+15%CO_2+80%N_2) had the best overall appearance and most physical and chemical properties for 15 days of storage.

I INTRODUCTION

The pomegranate (*Punica granatum* L.), cultivated extensively in tropical and subtropical countries, is widely recognized as one of the oldest fruit crops known to human. Pomegranate is generally consumed fresh or after processing into juice, syrup, jams, or wine. Studies showed that pomegranate has chemo preventive properties such as antimutagenicity, antihypertension, antioxidative potential, and reduction of liver injury due to its high anthocyanin content [1]. Recently, the production and consumption of pomegranate fruit especially minimally processed "ready-to-eat" pomegranate are in increase rapidly in the world, mainly due to greater awareness of its nutritive and medicinal attributes. Pomegranates are rich sources of polyphenols, including ellagitannins, gallotannins, ellagic acids, gallagic acids, catechins, anthocyanins, ferulic acids, and quercetins. These polyphenols exhibit various biological activities, such as eliminating free radicals, inhibiting oxidation and microbial growth, and decreasing the risk of cardio and cerebrovascular diseases as well as some types of cancers [2]. Most of the studies on pomegranates dealt with chemical composition, the changes during ripening shelf life at different storage conditions [3,4]. However, there are few studies on the preservation of pomegranate arils (seeds) using modified atmosphere packaging and different plastic materials [5]. Fresh-cuts or minimally processed produce are highly susceptible to microbial growth enzymatic disorders and physiological response, which limit the shelf-life [6]. Minimal processing of pomegranate mainly consists of washing with sanitizing agents, pH modifications, use of antioxidants, modified atmosphere packaging, and temperature control [7].

Modified atmosphere packaging (MAP) occupied an important place since the principal objective of it is to produce a product with minimal processing and fresh characteristics similar to those at harvest. It also aims to extend the shelf-life of the fruit and reduce the microbial hazards [8]. MAP technology has prolonged the storage period of fruits and vegetables by creating higher CO_2 and lower O_2 concentrations in the surrounding atmosphere of the commodities, decay, respiration rate, ethylene production, and enzymatic activity can be controlled, resulting in an increase postharvest quality [9]. MAP may also prevent weight loss and fruit shriveling [10]. It has been suggested to extend the shelf life of minimally processed arils and minimally processed pomegranate for 14 days at 4°C ± 0.5 with the use of semipermeable film [5]. MAP combined with low storage temperature has been successfully used in general to prolong the shelf life of fresh fruit and vegetables [11,12]. [13] reported a 12.92% decrease in the total anthocyanin content of pomegranate arils after 7 days of storage at 4°C and under an atmospheric composition of 13.5%O_2+7.5%CO_2 using polypropylene baskets. MAP of pomegranate arils at 4°C and under the 7% O_2+15% CO_2 with semi-permeable polymer cannot significantly prolong the shelf-life of minimally processed arils [14]. [15] studied the effect of various gas compositions in active-MAP on the shelf-life and overall quality of minimally processed pomegranate arils stored at 5°C. They observed no significant change in the physicochemical attributes of arils, while aerobic mesophilic bacteria were in the range of 2.30-4.51 log CFU/g.

On the other hand, nitrogen (N_2) is a non-reactive gas that is used to exclude more reactive gases from packages and acts as a filler gas to prevent package collapse [16]. Several studies with minimally processed products have explored the use of 100 kPa N_2 atmospheres in MAP. Firmness, colour and chemical properties were maintained and shelf life extended in fruit packaged in 100 kPa N_2 [15,17].

The objective of this study was to determine quality, physical, chemical and microbial changes of ready-to-eat pomegranate arils packaged with different modified atmospheres. For this purpose, pomegranate arils were packaged in PP and PET/PE package under four different atmospheres.

II MATERIALS AND METODES

2.1. Fruit processing and packaging procedures

Pomegranate fruit "Manfalouty" (*Punica granatum* L.) of commercially ripened stage was purchased from local market. The outer skins of fruits were washed in 200 μLL^{-1} chlorine (NaOCl) solution using a brush. Husks were carefully cut at the equatorial zone with sharpened knifes and the arils were manually obtained and mixed to assure uniformity. The samples were dipped in a solution 100 μLL^{-1} chlorinated water [13]. The washed arils were dried for 10 min and weighed as 200 g in two packaging materials tested (PP and PET/PE).

The first package was used a low barrier polypropylene (PP) film (with 50µ thickness, water vapor 1.2 g/m^2d, oxygen permeability 951 CC/m^2d, nitrogen permeability 406 CC/m^2d, carbon dioxide permeability 2210 CC/m^2d and heat sealing at 130°C) was supplied by the Islamic Company for packages in 6th October city, Giza, Egypt. The second package was used a high barrier polyester/ polyethylene (PET/PE) film (with 85 μ thickness, water vapor 1.8 g/m^2d, oxygen permeability 97 CC/m^2d, nitrogen permeability 16 CC/m^2d, carbon dioxide permeability 494 CC/m^2d and heat sealing at 140°C) was supplied by Arabic medical packaging company (flex pack) Cairo, Egypt.

The four different gases compositions were selected as packaging atmospheres: MAP1 (normal atmospheric), MAP2 (100%Nitrogen), MAP3 (5%O_2+10%CO_2+85%N_2) and MAP4 (10%O_2+20%CO_2+70%N_2). Two replicates of each atmosphere were made. Packaged samples were stored at 5±1°C and 70-75% relative humidity for 15 days, and sampling was carried out on 0, 3, 6, 9, 12, and 15 days of storage.

2.2. Physical analyses

2.2.1. Weight Loss was determined following the methods [18].

2.2.2. General appearance: General appearance was tested [19].

2.3. Chemical analysis

2.3.1. Total soluble solid (TSS), pH and total titratable acidity (TTA) were determined following the methods [18].

2.3.2. Total anthocyanin content: Total juice anthocyanin content was determined by method described [20].

2.3.3. Total antioxidant activity: The method used was as reported [21].

2.3.4. Total phenolic content: Total polyphenols were determined by the Folin–Ciocalteu method [22] using gallic acid as the standard. The results were expressed in milligrams of gallic acid equivalents per 1 L of juice.

2.4. Microbial counts

The microbial contents were determined according to methods described in the DIFCO manual [23].

2.5. Statistical analysis

Statistics on a completely randomized design were performed with the analysis of variance (ANOVA) procedure in SPSS (Version 18.0, SPSS Inc.) software. Comparisons among the main treatment means were made using Tukey's H.S.D at ($P = 0.05$) [24].

III RESULTS AND DISCUSSION

3.1. Weight Loss:

The effect of packaging types and modified atmosphere (MAPs) on the pomegranate arils weight loss is presented in "Table" (1). The results revealed that samples packed in PP had low weight loss as compared with those stored in PET/PE. Samples packed under modified atmosphere MAP4 had significantly much better results in weight loss compared with other samples, while samples packed in MAP1 had significantly the highest weight loss during storage that may be related to the modification of atmosphere which reduced respiration rate. Similar results were reported [25].

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Table 1. Effect of packaging materials and modified atmosphere on weight loss (%) of minimally processed pomegranate arils during storage at 5±1°C*.

Treatment		Storage Period (Day)					
Package types	MAPs	0	3	6	9	12	15
PP	MAP1	0.00	0.85^{Cb}	1.97^{Ba}	ND	ND	ND
	MAP2	0.00	0.82^{De}	1.72^{Ed}	2.23^{Dc}	3.17^{Deb}	4.34^{Da}
	MAP3	0.00	0.85^{Ce}	1.61^{Fd}	2.13^{Fc}	3.18^{Db}	4.01^{Ea}
	MAP4	0.00	0.83^{De}	1.54^{Gd}	2.20^{Ec}	3.16^{Eb}	4.00^{Ea}
PET/PE	MAP1	0.00	0.85^{Cb}	2.01^{Aa}	ND	ND	ND
	MAP2	0.00	0.87^{Be}	1.89^{Dd}	2.84^{Ac}	3.54^{Cb}	4.89^{Aa}
	MAP3	0.00	0.89^{Ae}	1.90^{Dd}	2.79^{Bc}	3.64^{Ab}	4.79^{Ba}
	MAP4	0.00	0.85^{Ce}	1.92^{Cd}	2.75^{Cc}	3.61^{Bb}	4.76^{Ca}

PP: polypropylene, PET/PE: polyester/ polyethylene; MAPs: modified atmosphere treatments, MAP1: normal air, MAP2: 100%N_2, MAP3: 5%O_2 +15%CO_2 +80%N_2, MAP4: 10%O_2+20%CO_2+70%N_2; -Averages with different capital letters (due to treatments) and averages with different small letters (due to storage) differed significantly ($P \leq 0.05$). ND: not determined because spoilage.

In this study, all MAPs significantly reduced the water and weight loss of pomegranates during storage period and the lowest weight loss was obtained from the MAP4 and MAP3 treatments. It could be assumed that the packaging materials established a microenvironment with high relative humidity and low O_2 and high CO_2 levels. All these factors were effective in slowing down the respiration and transpiration rates, thereby limiting weight loss. These results are in agreement with previous work on quality of MA-packed pomegranates [26,27]. Weight loss of the fruits significantly increased with storage time in all treatments. Similar results were reported [28].

3.2. Visual quality (general appearance)

The visual quality of pomegranates arils is often the first of many quality attributes judged by the consumer and is therefore, extremely important in overall product acceptance by consumer. "Table" (2) shows the alteration of the pomegranate arils general appearance during the storage period. A significant difference in visual quality was found between all treatments during the storage period, Samples packed in PET/PE significantly had almost higher quality than those packed in PP packages under modified atmosphere. Poor visual quality was observed after 6 days with MAP1 (normal air) in both packaging. PET/PE treatments in MAP4 and MAP3 were the best except that the all treatments achieved visual quality between 6-9. From another point of view, the results revealed that samples packed and stored under modified atmosphere had better visual quality than those stored without modified atmosphere during storage. MAP1 in both packages suffered from excessive loss of visual quality that started from the day 6 of storage. As for other MAPs conserved fruits, in both packaging materials data revealed high significant values of visual quality scores along the storage period. In addition, visual appearance remained relatively unchanged till the 15 days of storage, indicating high maintenance of fruit quality up to the end of the storage period, and ever more scored above the limits of acceptability. Although the differences between the two types of packings lacked of significance, PET/PE often gained slightly higher score than PP. This observation is in accordance [5,29].

Table 2. Effect of packaging materials and modified atmosphere on general appearance of minimally processed pomegranate arils during storage at 5±1°C*.

Treatment		Storage Period (Day)					
Package types	MAPs	0	3	6	9	12	15
PP	MAP1	9.00^{Aa}	7.76^{Eb}	5.13^{Ec}	ND	ND	ND
	MAP2	9.00^{Aa}	8.50^{Bb}	7.96^{Cc}	7.01^{Ed}	6.74^{Ee}	6.51^{Ff}
	MAP3	9.00^{Aa}	8.52^{Ab}	8.00^{Bc}	7.56^{Dd}	7.11^{CDe}	7.00^{Df}
	MAP4	9.00^{Aa}	8.52^{Ab}	8.00^{Bc}	7.67^{Cd}	7.10^{De}	7.17^{Cf}
PET/PE	MAP1	9.00^{Aa}	7.82^{Db}	5.22^{Dc}	ND	ND	ND
	MAP2	9.00^{Aa}	8.46^{Cb}	8.00^{Bc}	7.56^{Dd}	7.12^{Ce}	6.93^{Ef}
	MAP3	9.00^{Aa}	8.52^{Ab}	8.10^{Ac}	7.80^{Bd}	7.53^{Be}	7.50^{Bf}
	MAP4	9.00^{Aa}	8.50^{Bb}	8.11^{Ac}	7.89^{Ad}	7.62^{Ae}	7.53^{Af}

*See footnotes of Table (1) for details.

3.3. Total soluble solids

The effect of types of packaging materials and modified atmosphere (MAPs) on the TSS pomegranate arils is illustrated in "Table" (3). General gradual decline trend occurred in these contents due to package under modified atmosphere and types of packing materials with storage period. The results revealed significant differences between packaging materials and no significant differences were found between different MAPs treatments in the same package. The initial TSS (°Brix) values of arils were 16.1. After 15 days of storage, the highest level of TSS was observed in stored PP MAP3, MAP4 followed by PET/PP MAP3, MAP4 (14.7 and 14.6, respectively). These results may be related to the modification of atmosphere that reduced respiration rate which depends on the commodity, variety beside the type of film used (permeability and thickness). Similar trend of decrease in TSS of pomegranate arils packaged in MAPs was reported [25].

Table 3. Effect of packaging materials and modified atmosphere on TSS (°Brix) of minimally processed pomegranate arils during storage at 5±1°C*.

Treatment		Storage Period (Day)					
Package types	MAPs	0	3	6	9	12	15
PP	MAP1	16.1^{Aa}	16.0^{Aa}	15.4^{Bb}	ND	ND	ND
	MAP2	16.1^{Aa}	16.0^{Aa}	15.3^{BCb}	15.0^{Ac}	14.6^{Bd}	14.6^{ABd}
	MAP3	16.1^{Aa}	16.0^{Aa}	15.3^{BCb}	15.1^{Ac}	14.6^{Bd}	14.7^{Ad}
	MAP4	16.1^{Aa}	16.0^{Aa}	15.3^{BCb}	15.1^{Ac}	14.6^{Bd}	14.7^{Ad}
PET/PE	MAP1	16.1^{Aa}	15.7^{Bb}	15.6^{Ac}	ND	ND	ND
	MAP2	16.1^{Aa}	15.7^{Bb}	15.4^{Bc}	15.1^{Ad}	14.8^{Ae}	14.5^{Bf}
	MAP3	16.1^{Aa}	15.8^{Bb}	15.3^{BCc}	15.0^{Ad}	14.7^{ABe}	14.6^{ABe}
	MAP4	16.1^{Aa}	15.7^{Bb}	15.2^{Cc}	15.0^{Ad}	14.6^{Be}	14.6^{ABe}

*See footnotes of Table (1) for details.

3.4. Total Titratable Acidity (TTA)

The data in "Table" (4) indicated that prior to storage (day zero), the measured TTA was 1.26% expressed of citric acid in pomegranate juice. TTA significantly reduced initially across all the

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treatment. We indicated that PET/PE packaging was significantly the best to maintain of TTA especially under MAP4 followed by MAP3 1.17% and 1.16%, respectively. Significantly PP packaging caused the lowest decrease value in TTA especially under MAP1 (normal air) being 0.95% at the end of storage. This could be related to metabolic activities of pomegranate during storage. However, storage time had significant effect on TTA in all applications. The TA values decrease could be attributed to increase in metabolic activities that due to high O_2 concentrations [30].

Table 4. Effect of packaging materials and modified atmosphere on TTA of minimally processed pomegranate arils during storage at 5 ±1°C (expressed as % citric acid)*.

Treatment		Storage Period (Day)					
Package types	MAPs	0	3	6	9	12	15
PP	MAP1	1.26^{Aa}	1.12^{Cb}	0.92^{Fc}	ND	ND	ND
	MAP2	1.26^{Aa}	1.02^{Dc}	0.96^{Ee}	0.98^{Cd}	1.12^{Cb}	0.95^{De}
	MAP3	1.26^{Aa}	1.11^{Cb}	1.05^{Dc}	1.00^{Cd}	0.98^{Ee}	0.98^{Ce}
	MAP4	1.26^{Aa}	1.11^{Cb}	1.09^{Cc}	1.08^{Bc}	1.00^{Dd}	0.98^{Ce}
PET/PE	MAP1	1.26^{Aa}	1.21^{Bb}	0.97^{Ec}	ND	ND	ND
	MAP2	1.26^{Aa}	1.22^{ABb}	1.18^{Bc}	1.17^{Ac}	1.18^{ABc}	1.12^{Bd}
	MAP3	1.26^{Aa}	1.23^{Ab}	1.20^{Ac}	1.18^{Ad}	1.17^{Bde}	1.16^{Ae}
	MAP4	1.26^{Aa}	1.23^{Ab}	1.21^{Ac}	1.19^{Ad}	1.19^{Ad}	1.17^{Ae}

*See footnotes of Table (1) for details.

3.5. pH

The data in "Table" (5) indicated that in general, pH values slightly decreased during storage and no significant differences were observed between all treatments of almost storage period. The pH decreased from 3.50 to 3.45 at the end of storage of almost all applications. The changes in pH were similar with the results [29].

Table 5. Effect of packaging materials and modified atmosphere on pH of minimally processed pomegranate arils during storage at 5±1°C.

Treatment		Storage Period (Day)					
Package types	MAPs	0	3	6	9	12	15
PP	MAP1	3.50^{Aa}	3.49^{Aa}	3.40^{Cb}	ND	ND	ND
	MAP2	3.50^{Aa}	3.46^{Cab}	3.46^{Abc}	3.44^{Ac}	3.43^{Ac}	3.45^{Ac}
	MAP3	3.50^{Aa}	3.46^{Cb}	3.45^{Abc}	3.44^{Ac}	3.42^{ABd}	3.45^{Abc}
	MAP4	3.50^{Aa}	3.46^{Cb}	3.45^{Ab}	3.43^{Ac}	3.41^{Bd}	3.45^{Ab}
PET/PE	MAP1	3.50^{Aa}	3.48^{ABb}	3.43^{Bc}	ND	ND	ND
	MAP2	3.50^{Aa}	3.48^{ABb}	3.46^{Acd}	3.45^{Ad}	3.43^{Ae}	3.45^{Ad}
	MAP3	3.50^{Aa}	3.47^{BCb}	3.45^{Acd}	3.44^{Ad}	3.43^{Ae}	3.46^{Abc}
	MAP4	3.50^{Aa}	3.47^{BCb}	3.45^{Acd}	3.44^{Ade}	3.43^{Ae}	3.46^{Abc}

*See footnotes of Table (1) for details.

3.6. Total anthocyanin content (TAC)

The data in "Table" (6) revealed that there were significant effects of MAPs application and packaging types during storage period on the total anthocyanin content ($P \leq 0.05$). In general, TAC decreased as the storage time increased. It decreased from 12.60 of fruit juice at day zero to 11.50, 11.32 mg cyanidin-3-glucoside equivalent/100ml of fruit juice after 15 days of storage for PET/PE under MAP4, MAP3, respectively. On the other hand, the lowest treatment was pomegranate arils packaged in PP under normal air MAP1. MAP4 samples had higher TAC than the samples packaged in MAP3 or MAP1 during storage. Our results are in agreement [29].

Table 6. Effect of packaging materials and modified atmosphere on anthocyanin of minimally processed pomegranate arils during storage at 5±1°C (mg/100ml)*.

Treatment		Storage Period (Day)					
Package types	MAPs	0	3	6	9	12	15
PP	MAP1	12.60^{Aa}	11.40^{Gb}	8.20^{Gc}	ND	ND	ND
	MAP2	12.60^{Aa}	12.27^{Bb}	11.67^{Ec}	10.89^{Fd}	10.64^{Fe}	10.23^{Ff}
	MAP3	12.60^{Aa}	12.20^{Db}	12.00^{Dc}	11.00^{Ed}	11.00^{Ed}	10.90^{De}
	MAP4	12.60^{Aa}	12.23^{Cb}	12.10^{Cc}	11.06^{De}	11.10^{Dd}	10.99^{Cf}
PET/PE	MAP1	12.60^{Aa}	12.00^{Fb}	9.00^{Fc}	ND	ND	ND
	MAP2	12.60^{Aa}	12.30^{Ab}	12.30^{Ab}	12.11^{Ac}	11.50^{Cd}	10.32^{Ee}
	MAP3	12.60^{Aa}	12.10^{Ec}	12.25^{Bb}	11.23^{Cf}	11.60^{Bd}	11.32^{Be}
	MAP4	12.60^{Aa}	12.20^{Dc}	12.30^{Ab}	11.63^{Be}	11.76^{Ad}	11.50^{Af}

*See footnotes of Table (1) for details.

3.7. Total phenolic content

Data in "Table" (7) revealed that there were significant effects of packaging types and MAPs application on total phenol content that significantly increased during storage period ($P \leq 0.05$). In general, total phenolic content of pomegranate arils increased until the 15 day of storage for all the treatments. This was probably due to changes in total acidity and TSS content, which in return affected the total anthocyanin content and total antioxidant activity. Although there were some differences between all treatments, the lowest increment of total phenolic content was with PET/PE under MAP4 and MAP3 (170.5, 171.0 mg GAE/100gm, respectively) at the end of storage. On the contrary the highest values were registered by PP packaging under MAP1 (174.0 mg GAE/100gm) at the end of storage. These results are in agreement with studies [29, 27].

Table 7. Effect of packaging materials and modified atmosphere on total phenolic content of minimally processed pomegranate arils during storage at 5±1°C (mg GAE/100gm)*.

Treatment		Storage Period (Day)					
Package types	MAPs	0	3	6	9	12	15
PP	MAP1	163.4^{Ac}	174.7^{Ab}	182.7^{Aa}	ND	ND	ND
	MAP2	163.4^{Af}	165.3^{Ee}	167.9^{Dd}	169.9^{Ac}	172.9^{Ab}	174.0^{Aa}
	MAP3	163.4^{Af}	166.9^{Ce}	168.0^{Cd}	169.7^{Cc}	172.8^{Bb}	173.9^{Ba}
	MAP4	163.4^{Af}	166.8^{De}	167.9^{Dd}	169.8^{Bc}	172.3^{Cb}	173.2^{Ca}
PET/PE	MAP1	163.4^{Ac}	170.3^{Bb}	179.1^{Ba}	ND	ND	ND
	MAP2	163.4^{Af}	164.9^{Ge}	167.3^{Ed}	169.5^{Dc}	171.5^{Db}	172.3^{Da}
	MAP3	163.4^{Af}	165.0^{Fe}	167.2^{Fd}	169.0^{Ec}	170.2^{Eb}	171.0^{Ea}
	MAP4	163.4^{Af}	165.7^{De}	166.3^{Gd}	168.1^{Fc}	169.7^{Fb}	170.5^{Fa}

*See footnotes of Table (1) for details.

3.8. Total antioxidant activity (TAA)

Data in "Table" (8) indicated that there were significant differences between values of TAA of all treatment. PET/PE packages under MAP4 and MAP3 had values of 46.12 and 46.40%, respectively and were the best in maintaining of antioxidant activity during storage time compared with PP packages which were lower in maintaining TAA than it under all MAPs. TAA of pomegranate arils significantly increased during storage period. There was a positive relationship between antioxidant activity (%) and total phenolic content indicating the effect of polyphenol content on antioxidant activity (Tables 7and 8). These results are in agreement with those [29].

Table 8. Effect of packaging materials and modified atmosphere on total antioxidant activity of minimally processed pomegranate arils during storage at 5±1°C (%)*.

Treatment		Storage Period (Day)					
Package types	MAPs	0	3	6	9	12	15
PP	MAP1	41.43^{Ac}	43.15^{Cb}	47.93^{Aa}	ND	ND	ND
	MAP2	41.43^{Af}	42.31^{Fe}	44.00^{Gd}	45.75^{Dc}	47.90^{Ab}	47.96^{Aa}
	MAP3	41.43^{Af}	43.02^{De}	45.73^{Cd}	46.75^{Bc}	47.80^{Bb}	47.83^{Ba}
	MAP4	41.43^{Ae}	43.35^{Bd}	45.17^{Dc}	46.91^{Ab}	47.21^{Ca}	47.20^{Ca}
PET/PE	MAP1	41.43^{Ac}	43.00^{Eb}	46.16^{Ba}	ND	ND	ND
	MAP2	41.43^{Af}	42.11^{Ge}	44.32^{Ed}	46.63^{Cc}	47.01^{Db}	47.12^{Da}
	MAP3	41.43^{Af}	43.42^{Ae}	44.12^{Fd}	45.67^{Ec}	45.93^{Eb}	46.40^{Ea}
	MAP4	41.43^{Af}	43.03^{De}	44.00^{Gd}	45.12^{Fc}	45.63^{Fb}	46.12^{Fa}

*See footnotes of Table (1) for details.

3.9. Microbiological quality:

Data in "Table" (9) indicated that from the initial day of storage all samples recorded total bacterial count (TBC) <1.0 log CFU/g which increased to a range of 4.4-5.3 log CFU/g across all the treatment by the end of the storage period. Pomegranate arils packaged in PET/PP under MAP4 had 4.4 log CFU/g which was the lowest TBC throughout the storage period compared with the highest count of at PP under 100% nitrogen MAP1 (5.3 log CFU/g) at the end of storage. As well data in "Table" (10) indicated that yeast and mould growth was under the limit of detection for all the treatments and significant differences were found between all treatments during storage. The count was less in PET/PE under MAP4 and MAP3 (3.5 and 3.7 log CFU/g, respectively). This level did not affect the sensory quality of pomegranate arils at the end of the storage time. Even the highest TBC was under 7 log CFU/g, which was established as maximum limit for aerobic bacteria by the Spanish legislation [5]. Generally, microbial count significantly increased with advancing storage period. PET/PE packages were better than PP packages for reducing the microbial count during storage, and MAP4 atmosphere was the best treatment. High levels of O_2 was found to be effective in inhibiting enzymatic discoloration, preventing anaerobic fermentation reactions, and inhibiting aerobic and anaerobic microbial growth. Among the most often used gases in MAP (O_2, CO_2, and N_2), only CO_2 has significant and direct antimicrobial activity due to alteration of cell membrane function including effects on nutrient uptake and absorption, direct inhibition of enzymes, or decreases in the rate of enzyme reactions, penetration of bacterial membranes leading to intracellular pH changes and changes to the physicochemical properties of proteins [31]. The counts of aerobic mesophilic bacteria, and yeast and mould in the present study are similar to those reported [29,5].

Table 9. Effect of packaging materials and modified atmosphere on total bacterial count of minimally processed pomegranate arils during storage at 5±1°C (log CFU/g)*.

Treatment		**Storage Period (Day)**					
Package types	**MAPs**	**0**	**3**	**6**	**9**	**12**	**15**
PP	MAP1	$<1.0^{Ac}$	2.5^{Ab}	4.7^{Aa}	ND	ND	ND
	MAP2	$<1.0^{Af}$	1.8^{Ce}	2.7^{Cd}	3.9^{Ac}	4.8^{Ab}	5.3^{Aa}
	MAP3	$<1.0^{Af}$	1.4^{Ee}	2.2^{Ed}	3.5^{Bc}	4.1^{Eb}	5.1^{Ba}
	MAP4	$<1.0^{Af}$	1.3^{Fe}	2.0^{Fd}	3.4^{Cc}	4.3^{Cb}	5.1^{Ba}
PET/PE	MAP1	$<1.0^{Ac}$	2.2^{Bb}	4.5^{Ba}	ND	ND	ND
	MAP2	$<1.0^{Af}$	1.5^{De}	2.3^{Dd}	3.5^{Bc}	4.6^{Bb}	5.0^{Ca}
	MAP3	$<1.0^{Af}$	1.0^{Ge}	1.5^{Gd}	3.1^{Ec}	4.2^{Db}	4.8^{Da}
	MAP4	$<1.0^{Af}$	1.0^{Ge}	1.4^{Hd}	3.2^{Dc}	4.0^{Fb}	4.4^{Ea}

*See footnotes of Table (1) for details.

Table 10. Effect of packaging materials and modified atmosphere on yeast and moulds of minimally processed pomegranate arils during storage at 5±1°C (log CFU/g)*.

Treatment		**Storage Period (Day)**					
Package types	**MAPs**	**0**	**3**	**6**	**9**	**12**	**15**
PP	MAP1	$<0.5^{Ac}$	2.6^{Ab}	4.2^{Aa}	ND	ND	ND
	MAP2	$<0.5^{Af}$	1.9^{De}	3.1^{Cd}	3.6^{Ac}	3.7^{Ab}	4.0^{Aa}
	MAP3	$<0.5^{Af}$	2.0^{Ce}	2.9^{Dd}	3.5^{Bc}	3.7^{Ab}	3.9^{Ba}
	MAP4	$<0.5^{Af}$	2.0^{Ce}	2.9^{Dd}	3.4^{Cc}	3.6^{Bb}	3.8^{Ca}
PET/PE	MAP1	$<0.5^{Ac}$	2.3^{Bb}	4.0^{Ba}	ND	ND	ND
	MAP2	$<0.5^{Af}$	1.5^{Fe}	2.9^{Dd}	3.3^{Dc}	3.5^{Cb}	3.8^{Ca}
	MAP3	$<0.5^{Af}$	1.8^{Ee}	2.8^{Ed}	3.1^{Ec}	3.3^{Db}	3.7^{Da}
	MAP4	$<0.5^{Ae}$	1.9^{Dd}	2.4^{Fc}	2.9^{Fb}	3.1^{Eb}	3.5^{Ea}

*See footnotes of Table (1) for details.

V CONCLUSION

Changes in quality attributes of "Manfaloty" pomegranate arils using two types of packages and four types of MAPs were investigated during 15 days cold storage. Results indicated that both of packaging materials PP and PET/PE maintained a quality of arils but significantly PET/PE package was the best for maintaining the physical, chemical, general appearance and microbial attributes. Packaging under modified atmosphere especially10%O_2+20%CO_2+70%N_2 in packages was the most effective this respect.

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