

## Effect of MAP and Different Atmospheric Conditions on the Sensory Attributes and Shelf life Characteristics of Fresh Pistachio Nuts

Shima Shayanfar<sup>1</sup>, Mahdi Kashaninejad<sup>1,\*</sup>, Morteza Khomeiri<sup>1</sup>, Zahra Emam Djomeh<sup>2</sup>, Younes Mostofi<sup>3</sup>

<sup>1</sup>Department of Food Science and Technology, Gorgan University of Agricultural Sciences and Natural Resources, Beheshti Ave., Gorgan, 49138-15739, Iran

<sup>2</sup>Department of Food Science, Technology and Engineering, Faculty of Agricultural Engineering, Tehran University, Karaj, Iran

<sup>3</sup>Department of Horticulture, Faculty of Agricultural Engineering, Tehran University, Karaj, Iran.

**Abstract:** Modified atmosphere packaging (MAP) was used to increase the shelf life of fresh in hull pistachio nuts (*Pistacia vera* L.), meeting the market demand for fresh high quality products. Fresh in hull pistachio nuts were stored at 5°C and three different gaseous conditions including 10% O<sub>2</sub>, 20% CO<sub>2</sub> and 70% N<sub>2</sub> (MAP1), 100% CO<sub>2</sub> (MAP2) and ambient atmosphere for 42 days. The samples of 300 g of pistachio nuts were packaged in sealed high barrier poly propylene (PP) bags (26×20 cm). The permeability of films for CO<sub>2</sub> was 3910 cm<sup>3</sup>/m<sup>2</sup> dbar at 23°C and 50% RH. The thickness and the surface of the used films were 2.00 mm and 78.90 cm<sup>2</sup>, respectively. External appearance, weight loss, firmness and color attributes and microbial growth were investigated at regular intervals throughout the storage period. Significant differences were found between packaged and unpackaged fresh in hull pistachio nuts in the most of parameters considered. The firmness in the nuts decreased markedly in control samples. This trend was also observed in the nuts stored under 10% O<sub>2</sub>, 20% CO<sub>2</sub> and 70% N<sub>2</sub>. However, the firmness in those nuts stored in 100% CO<sub>2</sub> increased. On the other hand weight loss was quite slighter in the samples stored at MAP comparing to the control ones (p<0.01). MAP had a significant effect (p<0.01) on the storage time, with the external appearance being the limiting factor for shelf-life of pistachio nuts. Storage in 100% CO<sub>2</sub> and 5°C showed the best results among the treatments in terms of retaining physical properties and sensory attributes, increasing the health and extending the shelf-life of fresh in hull pistachio nuts.

**Keywords:** Pistachio nuts; Modified atmospheres packaging; Quality attributes; Firmness.

### INTRODUCTION

Pistachio nut (*Pistacia vera* L.) is one of the popular tree nuts which is grown mainly in Iran, USA, Syria, Turkey, Greece and Italy (Kucukoner and Yurt, 2003). Based on FAO statistics (Razavi *et al.* 2007), Iran produced about 275,000 Mt of pistachio nuts in 2003, which represented approximately 54.7% of the world's pistachio production. Oxygen is necessary for autoxidation of fats and as pistachio nut is an oily nut it should be stored at very low oxygen pressures to minimize the rate of oxidation. Therefore, the removal of atmospheric oxygen from a fat or food product exerts a protective effect (Swern, 1964). A common method of controlling the oxidation reaction is reducing the O<sub>2</sub>

concentration in the storage atmosphere over the food by vacuum or nitrogen filling for dry or intermediate moisture foods (Kacyn *et al.* 1983) or CO<sub>2</sub> filling which acts as a biostat for fresh fruits and vegetable to prevent anaerobic microbial growth and lipid oxidation (Hotchkiss, 1988).

Modified atmosphere packaging alters the normal composition of air to provide an optimum atmosphere for reducing the product respiration rate, which leads to quality preservation and increase in shelf life. This atmosphere can be passively achieved inside a package due to respiration, consuming oxygen and producing mainly carbon dioxide, and gaseous exchange between the atmosphere on the inside and the outside of the package (Farber *et al.*, 1991). However, Brecht

**Corresponding Author** Mahdi Kashaninejad, Department of Food Science and Technology, Gorgan University of Agricultural Sciences and Natural Resources, Beheshti Ave., Gorgan, 49138-15739, Iran. E-mail: [Kashaninejad@yahoo.com](mailto:Kashaninejad@yahoo.com), Tel/fax: 171-4426432

(1980) proposed 0.0% O<sub>2</sub> and 100% CO<sub>2</sub> for tree nuts. Faruk Gamli *et al.* (2005) studied on storing pistachio paste in sealed glass jars and vacuumed (PP) and non-vacuumed (PP) pouches at 4 and 20°C. The samples stored at 4°C were better than those stored at 20°C within all packaging types.

Due to increasing attention to minimally processed food, high attention is dedicated to fresh consumption of fruits and vegetables. Demand for fresh processed vegetables has led to an increase in the quality and variety of products available to the consumers. Pistachio nuts are traditionally consumed fresh in Iran. As the fresh pistachio nut is a perishable fruit, there should be a way to extend its shelf life. One of the beneficial ways to extend the shelf life of fresh pistachio nuts is to pack them under MAP condition. However the literature review showed that there is no enough published work on the study of MAP on the shelf life of fresh pistachio nut.

The objectives of this study were: (i) to determine the changes of physical, color and sensory attributes in fresh pistachio nuts under different atmospheric conditions, (ii) to extend the storage stability of fresh pistachio nuts (*Pistachia vera L.*) stored at 5°C in the refrigerator and, (iii) to optimize the best gaseous atmosphere for preserving fresh in hull pistachio nuts.

## MATERIALS AND METHODS

**Material:** The “Akbari” variety of pistachio nuts was used for the experiments. The fresh pistachio nuts were received with an average moisture content of 34.21% (wet basis) initially from an orchard in *Damghan*. The samples of 300 g were packaged in sealed high barrier poly propylene (PP) bags (26×20 cm). The permeability of films for CO<sub>2</sub> was 3910 cm<sup>3</sup>/m<sup>2</sup> dbar at 23°C and 50% RH. The thickness and the surface of the used films were 2.00 mm and 78.90 cm<sup>2</sup>, respectively. The packages were filled with two gaseous composition of (1) 100% CO<sub>2</sub> and (2) 10% O<sub>2</sub>, 20% CO<sub>2</sub> and 70% N<sub>2</sub>. The experiment was carried out with three replications. The control samples were also stored under the ambient atmosphere in the refrigerator without packaging. Storage was at 5°C under refrigerator conditions with the relative humidity (RH) of about 65%.

**Weight Loss:** Weight loss was also determined during the storage by monitoring the weight of the contents of the package before and after storage. Weight loss was expressed as the percentage of the loss of weight with respect to the initial weight and was determined in triplicate (Tano *et al.* 2007).

**Firmness:** Pistachio nuts firmness was measured with a Hounsfield-H5KS texture analyzer (THE-500N, UK). The pistachio nuts were placed on the platform. The penetration speed was 5.00 mm/min by a probe of 3.2 mm. The maximum force (*F*<sub>max</sub>) needed to penetrate into the central part of the pistachio nuts over 5.00 mm was used as a firmness measurement.

**Color evaluation:** Color of the pistachio nuts was assessed by tristimulus reflectance colorimetry, using a Minolta Chromameter 5081, with an 11mm aperture (Konica Minolta, Sensing Inc., Osaka). Chromaticity was measured using CIE *L\** (light/dark), *a\** (red/green) and *b\** (yellow/blue) values. Color was also assessed in terms of the browning index (BI) and chroma (*C\**). Chroma represents color saturation which varies from dull (low value) to vivid color (high value):

$$BI = 100 \times (x - 0.31) / 0.17 \quad (1)$$

where  $x = (a - 1.75 \times L) / (5.645 \times L) + (a - (3.012 \times b))$

$$C^* = (a^{*2} + b^{*2})^{1/2} \quad (2)$$

$$h^\circ = \tan^{-1} (b^* / a^*) \quad (3)$$

The colorimeter was standardized using a white reflectance plate (*L\** = 98.9, *a\** = -0.44 and *b\** = -0.30). In each test the two sides of the nuts were measured on the external cap surface. The mean was calculated for each surface type to determine the treatment effects.

**Microbial evaluation:** Mould and yeast counts were determined by pouring 0.1 ml of the diluted sample (10<sup>-2</sup> and 10<sup>-3</sup>) onto potato dextrose agar plates (Nissui, Japan) with 0.1 g/l chloram phenicol. The plates were incubated at 25 °C for 5 days, and the colonies were counted.

**Evaluation of sensory properties:** A trained sensory panel of 10 people used a descriptive test to evaluate the organoleptic properties of the fresh pistachio nuts (hull, shell, nut color, texture, flavor and general acceptance). They were trained in advance with pistachio nut samples at different storage stages and the corresponding scores. General appearance was the main factor to determine the sensory score of the pistachio nuts. The scale was as follows: 5 (excellent fresh), 4 (fresh), 3 (acceptable), 2 (unacceptable), 1 (deteriorated) (Liu and Guo, 2006).

**Statistical analysis:** The experiment was carried out according to repeated measure design (RMD) with three replications ( $\alpha = 0.05$ ). The statistical elaboration of the results was carried out using the SAS program. The program performed the separated means by LSD test. Results are presented in tables as means ±SD.

## RESULTS AND DISCUSSION

**Weight loss:** The statistical results indicated that the effect of all gaseous treatments, time and the interaction of gaseous treatment and time were significantly meaningful on the weight loss of the nuts ( $p < 0.01$ ). It was also indicated that all 3 treatments have individually significant effect on the weight loss (Table 1) but no significant differences were observed between the 2 gaseous composition ( $P > 0.05$ ). In this study as the samples were in hull, even in the control ones, less weight loss comparing

to what expected was observed. However, the weight loss in the control samples was quite significant comparing with the packed ones ( $p < 0.01$ ). Generally as time goes by the fresh pistachios respire and lose much of their weight in the form of water and carbon dioxide. This fact is also observed in both packed and unpacked samples. Fig. 1 shows that in all 3 samples weight loss increased as the storage time increased. However, as it was anticipated the pistachio nuts which were packed under MAP conditions showed a slighter weight loss than those of the control sample. It could be due to less respiration rate in the modified atmosphere which results in less weight loss of the fresh product. The experiment results indicated the weight loss accelerated immediately after the 7<sup>th</sup> day of storage in the control sample, while this trend was much slower in the packed samples (Fig. 1). It was also observed that the packed samples preserved their quality and freshness during the storage time. Watada and Qi, (1999) suggested that the fresh products are highly susceptible to dehydration and consequently to weight loss; however, the relative humidity generally is so high in film bags or containers overwrapped with film that dehydration is not a common problem. Also in this work, only slight weight was observed and the nuts didn't dehydrate due to the high relative humidity in the packages. In a study that was achieved on tomatoes by Tano *et al.*, (2007) it was indicated that unpackaged tomatoes lost 3.4% of their initial weight, while under MAP even after 35 days of storage, the weight loss was considerably the least. Roy *et al.* (1995) also concluded that the transpiration rate of fresh product increased with water vapor deficit. Additionally it's been proved that the high rate of transpiration accelerates product weight loss. Tano *et al.* (2007) showed that the atmosphere in MAP packaging maintained at

constant temperature was saturated with moisture. Since in this study the samples were kept at the constant temperature, the transpiration was low and the packages were saturated with moisture. Therefore no clues of dehydration were detected. Geuvara *et al.* (2003) pointed out that weight loss was least in cladodes that were packaged in passive MAP with an initial concentration of 20 kPa CO<sub>2</sub> and also there was a close relation between weight loss and the overall quality. Cladodes that were not packaged lost their brilliant green color appearance. Similar results were found in lettuce (Lipton, 1977). Levels of 20 kPa CO<sub>2</sub> can decrease the rate of respiration and transpiration, resulting in low weight loss. Quality deterioration of shredded lettuce, which included the deterioration in texture, color and odor, was delayed in storage at 5 kPa CO<sub>2</sub> (Kakiomenou *et al.*, 1996; Tano *et al.* 2007). Also Koide and Shi (2007) suggested that the weight loss values for green peppers at the end of the 7 days period were  $0.38 \pm 0.1\%$ , and  $1.59 \pm 0.4\%$  for low density poly ethylene (LDPE), and perforated LDPE film packaging, respectively. The green pepper sample in all films showed no sign of shrinkage after 7 days of storage and also showed minimal weight loss and was able to maintain a fresh appearance after 7 days at 10°C. These results agree with the achieved results in this study. Ohta *et al.* (2002) indicated that generally, a weight loss of greater than 5% would cause a reduction in retail value of vegetables and fruits. If we regard the weight loss value as a criterion for the consuming ability of the product, since none of the samples neither the packed samples nor the unpacked ones showed a weight loss greater than 5%, they are still consumable. But as the control samples turned black after the first week of storage they were no good for consumption.

Table 1: Effect of 3 gaseous conditions on the physical properties of fresh in hull pistachio nut stored for 42 days at 5°C.

Treatments	Weight Loss (%)	Firmness (N)
G <sub>1</sub>	0.27± 0.03 <sup>b</sup>	48.47±1.24 <sup>a</sup>
G <sub>2</sub>	0.21± 0.03 <sup>b</sup>	27.24±1.62 <sup>b</sup>
G <sub>3</sub>	1.33± 0.03 <sup>a</sup>	25.53±1.62 <sup>b</sup>

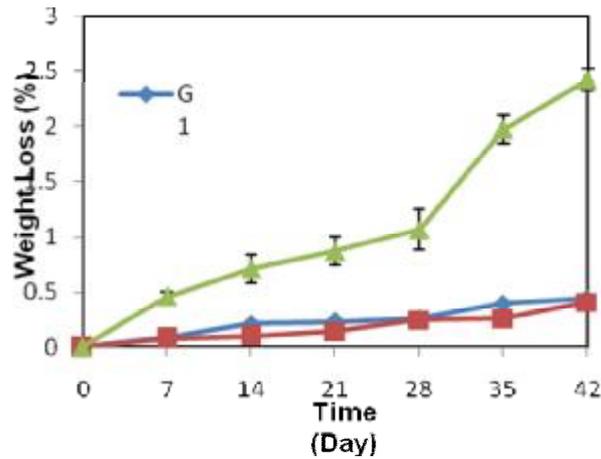


Fig.1: Weight loss during 42 days of storage at 5°C.

**Firmness:** One of the main factors used to determine fruit quality and postharvest shelf-life is the loss of hardness during storage. No matter how the storage condition is, all fresh products lose their firmness during the storage time. As it has been reported in Table 2 generally the firmness of the all the samples decreased during the storage time. O'Connor-Shaw *et al.* (1994) also found that fresh-cut papaya texture declined significantly after 2 days of storage at 13°C. It is important to bear in mind that modified atmosphere storage can also influence the textural quality of fruit and non-fruit vegetables as it was also imparted by Thybo *et al.* (2006). The statistical results disclosed that all the gaseous treatments, time and the interaction of time and gaseous treatment were significantly meaningful on the loss of firmness ( $p < 0.01$ ). Texture of fresh-cut peppers decreased continuously with the storage period in different treatments used. The use of MAP significantly reduced the texture loss of fresh-cut peppers at 5°C (Conesa *et al.* 2007). Tano *et al.* (2007) evaluated the loss of firmness in the unpackaged tomatoes stored at constant temperature was more significant ( $P < 0.05$ ) than the cases of MAP at constant temperature.

Geuvara *et al.*, (2003) pointed out that firmness decreased in all cladodes, but the decrease was faster in those that were maintained without packaging, and the least firmness loss was observed in the passive MAP. All these results are comparable with what was achieved in this work as the most firmness was observed in the unpacked samples.

According to Table 1 no significant difference was observed between the effect of the gaseous composition number 2 and the ambient atmosphere on the firmness of the samples on the last day of the storage ( $P > 0.05$ ). Of course gaseous composition number 1 showed a quite different effect comparing with the other two sample groups on the firmness of the nuts ( $P < 0.01$ ). As it is depicted in Table 2 despite the decreasing trend in the firmness of the samples stored in 10% O<sub>2</sub>, 20% CO<sub>2</sub> and 70% N<sub>2</sub> and the ambient atmosphere, the samples packed under 100% CO<sub>2</sub> showed an increasing trend until the 28<sup>th</sup> day of storage. After the 28<sup>th</sup> day of storage this trend changed into a decreasing trend. Thus, it appears that MAP and the atmosphere of 100% CO<sub>2</sub> can adequately be used to preserve the firmness of fresh in hull pistachio nuts during storage.

Table 2: Firmness changes of fresh in hull pistachio nut stored under different gaseous atmospheres at 5°C.

Time (Day)	Firmness (N)		
	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>
0	31.43±1.55	31.43±1.55	31.43±1.55
7	81.95±2.09	24.38±1.55	26.87±0.50
14	59.43±3.00	24.70±0.50	28.80±2.23
21	58.25±1.68	19.87±1.84	27.89±1.44
28	57.54±2.58	18.90±3.46	24.54±0.64
35	45.74±2.68	26.16±0.46	25.92±1.74
42	22.79±2.13	25.36±1.93	22.20±0.94

Also it seems like out of the tolerance range of CO<sub>2</sub> by the fresh product, softening could be accelerated. Therefore after increasing the firmness of the nuts under gaseous composition number 1 and reaching to the maximum level of the CO<sub>2</sub> tolerable by the nuts, the firmness decreases during the storage time. Hardness is sometimes correlated to weight loss and the degree of injury due to decay or microbial growth. The decrease in firmness during storage could be also related with the development of fungal growth and the increases in the metabolism, which increase the enzymatic activity. It is also possible that the loss in firmness is caused by losses in fiber resulting in the softening of fresh products.

**Color Assessment**

**Chroma:** The statistical analysis showed that just time had significant effect on the chroma in the nuts (p<0.01) while the gaseous treatment and the interaction of time and treatment showed no effect on chroma (p>0.05). A similar constant trend was observed in all 3 samples but after the 28<sup>th</sup> day of storage the samples showed a quite decreasing trend. Table 3 summarizes changes in color over the

storage period. It is interesting to note that during the storage time similar trend was observed in all 3 samples. The behavior of color from the first to the last day of storage didn't clearly differ for the various gas treatments, though to a less extent. This may be because of the barrier effect of the hull on the fresh pistachio nuts. Globally, no color changes compared with the color in first day of storage were obtained in all samples, suggesting that none of the gaseous composition can be harmful to pistachio nut color. It may be due to the protective effect of the hull on the pistachio nuts. In a study performed by Ang'os *et al.* (2008) it was concluded that the parameters hue and chroma did not exhibit any statistical differences between the gas treatment batches and the control treatment (synthetic air). Additionally Thompson (1998) revealed that for the CO<sub>2</sub> effect, higher CO<sub>2</sub> atmospheres did not inhibit the color development of tomato fruit, unless the atmospheres were 9.1 kPa or more. Also Sayed Ali *et al.* (2004) marked that CO<sub>2</sub> had no effect on the color development of cherry tomatoes in the films.

Table 3: Changes in color attributes of fresh in hull pistachio nut under different gaseous atmospheres on MAP throughout 42 days at 5°C.

Time (Day)	Chroma			Hue Angle		
	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>
0	16.91	16.91	16.91	0.62	0.62	0.62
	±0.49	±0.49	±0.49	±0.0	±0.0	±0.0
				3	3	3
7	19.45	20.73	20.16	0.92	0.88	0.83
	±0.32	±2.58	±2.39	±0.1	±1.2	±0.2
				6	7	7
14	19.89	19.47	19.56	0.99	1.10	1.09
	±1.10	±1.59	±0.65	±0.3	±0.1	±0.2
				2	8	8
21	20.49±1.36	20.13±2.74	20.25±2.33	0.83±0.17	0.93±0.37	0.87±0.30
28	20.86±0.70	19.81±2.03	19.44±2.45	0.73±0.15	0.69±0.08	0.79±0.06
35	20.80±1.30	19.59±1.97	15.39±3.09	0.86±0.34	0.68±0.34	0.95±0.09
42	21.19±1.14	20.46±1.51	16.96±1.97	0.63	0.46	0.98
				±0.2	±0.1	±0.1
				1	9	0

As shown in Table 3, chroma did not change remarkably with storage time in all treatments. These results on color stability indicated that the product would still be marketable if color was the primary quality indicator.

**Hue:** The statistical analysis showed that only time had significant effect on the hue angle in the nuts ( $P < 0.01$ ) while the gaseous treatment and the interaction of time and treatment showed no effect on hue angle ( $P > 0.05$ ). Of course the constant trend was similar in all the samples, after the 28<sup>th</sup> day of storage the blank samples increased in hue angle contrary to the packed samples. This result was also achieved by Ang'os *et al.* (2008).

**Browning index:** Enzymatic browning is often associated with cell membrane damage in outer tissues, which is in turn associated with very high CO<sub>2</sub> concentrations. Once membrane integrity is

lost, phenolic compounds normally present in cellular compartments are exposed to O<sub>2</sub> and oxidized by the catalyzing activity of polyphenol oxidase liberated by the degrading membrane. The resulting compounds then polymerize to form brown pigments (Tano *et al.*, 2007). This fact was also put into practice by Kader (1980) and could reduce the enzymatic browning by the use of low amounts of O<sub>2</sub>. The statistical analysis showed that time ( $P < 0.01$ ) and the interaction of time and treatment ( $P < 0.05$ ) had significant effect on the browning index in the nuts, while the gaseous treatment showed no effect on the browning index ( $P > 0.05$ ). As it is depicted in Fig. 2 the highest browning value is observed in the control samples. Nicoli *et al.* (1994) observed repressed browning of apples slices in 20% CO<sub>2</sub>/80% N<sub>2</sub> atmospheres.

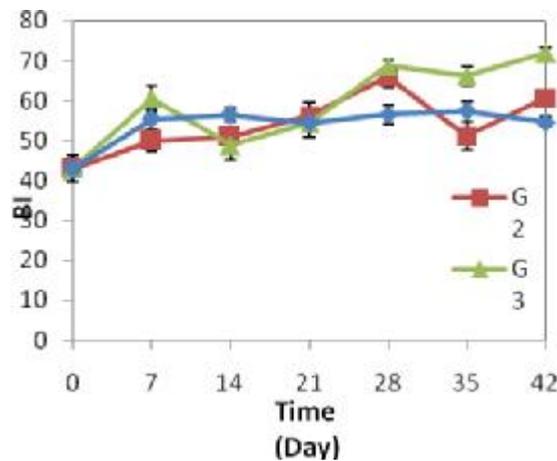


Fig.2: Browning index during 42 days of storage at 5°C.

**Microbial evaluation:** Food deterioration occurs increasingly during storage, and is caused mainly by the activity of microorganisms that thrive in the product. Eventually, the cumulative deterioration effects render the food undesirable to the consumer. Microbial spoilage often limits the shelf lives of many foods. The use of microbial growth parameters can be helpful in describing microbial proliferation characteristics. The growth parameters used to assess spoilage microorganism overgrowth may themselves be affected by the intrinsic properties of the food, extrinsic factors

(temperature, gaseous atmosphere and relative humidity) (McMeekin and Ross, 1996).

In the present study the microbial population started to increase from the 1st days of storage in the control samples (Fig. 3). Also the statistical analysis indicated that time, treatment and time-treatment have significant difference ( $p < 0.01$ ) on mold and yeast population. However as it's illustrated in Table 4 the mold and yeast population in the packed samples were not significantly different ( $P > 0.05$ ) but they were conspicuously different from the control ones ( $P < 0.01$ )

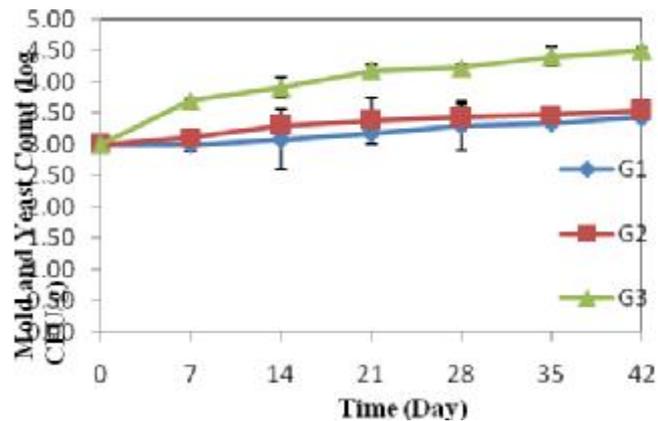


Fig.3: Mold and yeast count during 42 days of storage at 5°C.

In this study the use of MAP could remarkably retard the microbial population in the fresh nuts. This goal was also achieved by Daniels *et al.*, (1985); Babic *et al.* (1996); Blanchard *et al.* (1996) and Guevara *et al.* (2001). It seems like elevated CO<sub>2</sub> concentrations decreases the microbial growth as it was also proved by Gould (1996) who could decrease the microbial growth by 100-fold by the use of elevated concentrations of CO<sub>2</sub>. El-Goorani and Sommer, (1981) deduced that high relative humidity and CO<sub>2</sub> concentrations cause exudation of the contents of broccoli which generally leads to bacterial soft rot. Furthermore, increased temperature and a resultant increase in metabolism of the microorganisms favor decay. The temperature of the storage also affects of the microbial growth as O'Connor-Shaw *et al.* (1994) reported that microorganisms grew more rapidly in fresh-cut fruits stored at temperatures higher than 4°C. Additionally CO<sub>2</sub> was reported to inhibit some types of microorganisms (Hintlian and Hotchkiss, 1986). CO<sub>2</sub> under pressure inhibited bacteria, mold and yeast (Haas *et al.*, 1989). Nguyen-The and Carlin (1994) reported that elevated CO<sub>2</sub> concentrations significantly reduced the development of mesophilic bacteria on chicory leaves at 2 and 6 and 8°C but had no effect at 10 °C. Elevated CO<sub>2</sub> atmospheres

also had an inhibitory effect on the growth of aerobic microorganisms on broccoli kept at 4 °C (Berrang *et al.*, 1990). The bacteriostatic effect of CO<sub>2</sub> is not fully understood, but it could be due to lowering of the pH of growth media, the exclusion of O<sub>2</sub> by replacement of CO<sub>2</sub> or the acidification effect of CO<sub>2</sub> (Daniels *et al.*, 1985), or decreasing the O<sub>2</sub> availability (Babic *et al.*, 1996).

Sealed packaging such as MAP is intended to suppress microbial growth, retard respiration and inhibit oxidative reactions which require free oxygen. In this study the trend of microbial growth in both packed samples was somehow alike. This result was also observed by Koide and Shi (2007) who marked the levels of moulds and yeasts of green pepper during storage period indicated no remarkable changes (<1log CFU/g) among the three packaging treatments. Suparlan and Itoh (2003) reported that the storage of tomatoes in modified atmosphere packaging resulted in high microbial counts due to fruit transpiration and as a consequence, resulting to high relative humidity. It was also reported that the condensation inside the package enhanced microbial spoilage (Koide and Shi, 2007). However as it is depicted in Fig.3 the use of MAP can significantly control the mold and yeast count (P<0.01).

Table 4: Effect of 3 gaseous atmospheres on microbiological properties of fresh in hull pistachio nut throughout 42 days at 5°C.

Treatments	Mold and Yeast (log CFU/g)
G <sub>1</sub>	2.67± 0.15 <sup>b</sup>
G <sub>2</sub>	1.74± 0.15 <sup>c</sup>
G <sub>3</sub>	4.32± 0.15 <sup>a</sup>

**Sensory evaluation:** The sensory scores of the fresh in hull pistachio nuts stored in the different package types at 5°C are illustrated in Table 5. The sensory quality scores considered hull appearance, shell, nut color, nut firmness, flavor and its general acceptance, all of which decreased during storage. During storage, the nuts simultaneously shrunk, lost their acceptable appearance and flavor.

Statistical analysis revealed that time, treatment and time-treatment had a significant (P<0.01) effect on all of the sensory attributes assessed by the group of panelists. As it is shown in Table 5 packaging under MAP condition showed significant difference (P<0.01) between all sensory attributes of packed samples and those subjected to the ambient atmosphere. Of course no significant difference

( $P > 0.05$ ) was observed from those of the samples treated with different gaseous atmospheres. Also Lipton and Harris (1974) reached the same result by pointing out that an atmosphere with reduced  $O_2$  and/or elevated  $CO_2$  reduces respiration rates and the deterioration of the quality of fresh fruit and vegetables. Also it is known that fruits and

vegetables lose their typical fresh appearance and characteristic texture after being held in cold storage for only a short time (Bolin *et al.*, 1989). It is important to realize that storage under MAP will not improve the quality of the product; it will only delay the rate of spoilage.

Table 5: Changes in sensory attributes of fresh in hull pistachio nuts under different gaseous atmospheres on MAP throughout 42 days at 5°C.

Treatment	Hull	Shell	Nut Color	Nut Firmness	Flavor	General Acceptance
G <sub>1</sub>	3.64±0.08 <sup>a</sup>	3.70±0.08 <sup>a</sup>	4.25±0.12 <sup>a</sup>	4.27±0.09 <sup>a</sup>	4.40±0.08 <sup>a</sup>	4.12±0.07 <sup>a</sup>
G <sub>2</sub>	3.84±0.08 <sup>a</sup>	3.67±0.08 <sup>a</sup>	4.25±0.12 <sup>a</sup>	4.18±0.09 <sup>a</sup>	4.31±0.08 <sup>a</sup>	4.12±0.07 <sup>a</sup>
G <sub>3</sub>	1.92±0.08 <sup>b</sup>	2.42±0.08 <sup>b</sup>	2.77±0.12 <sup>b</sup>	2.88±0.09 <sup>b</sup>	2.92±0.08 <sup>b</sup>	2.32±0.07 <sup>b</sup>

During storage of the onions under MAP, they became yellow, slightly translucent, and emitted an unsavory odor. A combination of lower temperature and higher  $CO_2$  levels could improve sensory qualities (Liu *et al.* 2006). Blanchard *et al.* (1996) also concluded that surface microbial development might also alter the visual quality of the onion. The initial discoloration that occurs on the surfaces of prepared product has been defined as enzymatic browning (Mayer, 1987), due to the action of the polyphenoloxidase (PPO). Low  $O_2$  atmospheres developed inside the bags cause a reduction in the enzymatic discoloration because  $O_2$  is a necessary substrate for the enzymatic reaction (Kader, 1980). Also in this study the discoloration of the control samples comparing to the packed samples proved this claim. During the storage of the pistachio nuts, the sensory firmness in all samples decreased. This trend was quite sharper in control samples ( $P < 0.01$ ). Beaudry (1999) pointed out that excessively high levels of  $CO_2$  could induce fermentation and off-odors as well as visible damage in vegetable tissues. Kader (1986) reported that off-flavors could develop in any fresh fruit or vegetable if it is exposed to  $O_2$  and  $CO_2$  levels that result in anaerobic respiration and formation of ethanol and acetaldehyde. However, during the implementation of this study not such a claim was proved until the 28<sup>th</sup> day of storage and the samples stored under 100%  $CO_2$  kept their quality. But after the 28<sup>th</sup> day of storage, a kind of special odor was determinative which was detected as sour by a number of panelists, while pleasant by the others. This odor was detected probably due to the final gas concentrations managed within bags. According with our results, Gil *et al.* (1998) found that off-odors were found at

the end of the shelf life of ‘Lollo Rosso’ lettuce packaged under MAP. In addition, Nguyen-the and Carlin (1994) concluded that atmospheres containing high  $CO_2$  and low  $O_2$  gas concentrations favored growth of LAB and the accumulation of lactic acid, acetic acid, and ethanol probably due to the lactic heterofermentative metabolism of LAB and consequently, the development of off-odors. However, Pirovani *et al.* (1998) reported that after 8 days, off-odors were not observed in minimally processed lettuce, even in packages with 1.5 kPa  $O_2$  and 12 kPa  $CO_2$ .

General appearance is the most important quality attribute that consumers use to evaluate the quality of fruits and vegetables, as people ‘buy with their eyes’. As it’s depicted in Fig. 4 the packed samples reserved their general acceptance until the 42<sup>nd</sup> day of storage while the control ones continued a sharp decreasing trend in their general acceptance right after the first day of storage and were not suitable for consumption after the 14<sup>th</sup> day of storage. It was indicated that the overall quality of the fresh pistachio nuts as judged subjectively was high in nuts that were packaged in passive MAP while the nuts that were not packaged lost their brilliant color appearance and became dull as the storage period increased and finally turned into black (Fig. 5). Similar results were found in lettuce (Lipton, 1977). According to Fig. 4 it’s clear that after the second week of the storage the control samples are not consumable, while the packed ones are quite acceptable until the last days of storage. It shows that the modified atmosphere packaging has beneficial effects on the storage of the fresh pistachio nut and by the last days of the storage time they are still consumable.

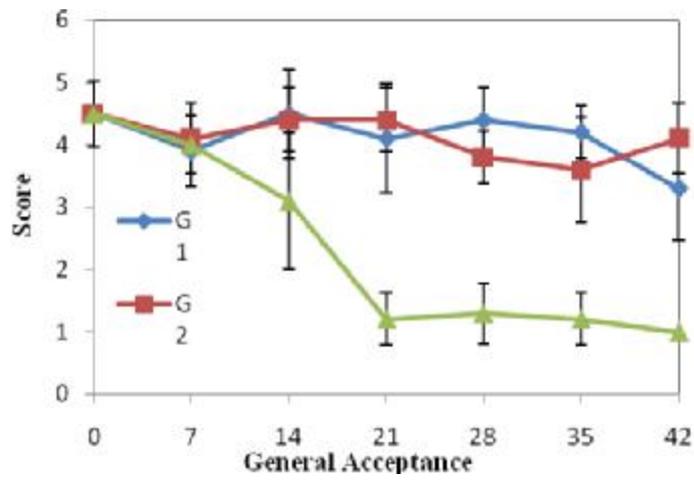


Fig.4: Sensory general acceptance during storage throughout 42 days at 5°C.



Fig. 5: Comparison of the visual appearance of the packed (left) and unpacked (right) pistachio nuts on the last day of the storage.

## CONCLUSION

The decrease of weight loss, softening rate, browning index, mold and yeast count are the main metabolic responses to reduced O<sub>2</sub> and elevated CO<sub>2</sub> atmospheres. The beneficial effects of the use of MAP during the storage of fresh in hull pistachio nut: (i) delayed perish ability and the extended shelf life, (ii) reduced incidence and severity of certain physiological disorders, (iii) reduced fungal growth, (iv) greater colorants retention, (v) delayed nut softening, and (vi) preserving the sensory attributes. Regarding all factors the two gaseous compositions were just different in firmness. Firmness retention was higher in samples packed under 100% CO<sub>2</sub> than that of packed under 10% O<sub>2</sub>, 20% CO<sub>2</sub> and 70% N<sub>2</sub>. Therefore it's concluded that for storing the fresh in hull pistachio nuts the modified atmosphere packaging with 100% CO<sub>2</sub> can be more beneficial and can extend the shelf life of the fresh in hull pistachio nut from 2 weeks until approximately 35 days which is quite an outstanding achievement.

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