EFFECT OF DIFFERENT ATMOSPHERES ON QUALITY CHANGES OF KURDISTAN STRAWBERRY

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A B S T R A C T

The effects of two modified atmosphere packaging conditions (MAP) and a normal atmosphere on quality parameters of Kurdistan strawberry were investigated. For this purpose, tow containers made up of polypropylene were used to package the strawberry under two different initial headspace gas compositions (MAP1: O_2 6%; CO_2 7.2%; N_2 86.8% and MAP2: O_2 0.2%; CO_2 10%; N_2 89.8%), and control where the strawberry samples were stored without packaging in normal atmosphere. Physico-chemical and microbiological properties were monitored during a 7-day storage period at refrigerated temperature (5 °C). Results showed that two MAP packaging conditions significantly prevent product decay and improved the shelf life when compared with the unpackaged product. In this study, the best results were recorded with the MAP1, which assured a shelf life more than 7 days with flavour remaining. MAP, as a technique to extend shelf life, can be used to maintain the quality of Kurdistan strawberry.

Keywords: Kurdistan **s**trawberry, modified atmosphere, quality parameters.

INTRODUCTION

Perishability is an important concern in fruit and vegetable. MAP as "the packaging of a perishable product in an atmosphere which has been modified so that its composition is other than that of air (Hintlian & Hotchkiss, 1986)" has been studied extensively. Physiological changes have profound effects on shelf life and quality of fresh products after harvesting. Fruits and vegetables undergo perhaps the most complicated physiological changes after harvesting. These changes are related to environmental conditions such as gas atmosphere, humidity, temperature, and their physical condition. Changes in concentration of atmosphere gas may cause stressed metabolism in fruits or vegetables, thereby producing undesirable compounds, which affect their flavour. Therefore, MAP must be applied with extreme caution and requires a strict quality control.

After some of the more recent important works include experimenting on the extension of shelf life of cake with MAP (Seiler, 1965); working widely on MAP of different types of bakery products (Ooraikul, 1988); on fruits and vegetables (Kader, 1989); on fresh meats (Gill, 1995); and on meat and poultry products (Hotchkiss & Langton, 1995), MAP has now been commercially applied to practically all fresh produce and processed products (insert the most recent references on MAP for different cultivars of strawberries in other countries). It has been accepted as a notable element in hurdle technology (Leistner & Gorris, 1995).

Strawberry is an important fruit of the Kurdistan region in Iran, production of which is increasing in the last years. Fruit from this region has an excellent flavour but is very sensitive to spoilage, after harvesting, mostly due to high levels of moisture. Iran has produced 38500 tonnes of strawberry in 2007 (FAO, 2009). Kurdistan grows about 80% of the total strawberry production in the Iran. In Kurdistan, the predominant cultivar used in planting and processing is 'Kurdistan strawberry'. The overall production in Kurdistan accounts for 30,000 tonnes. Processed strawberries account for about 4.5 tonnes in Kurdistan.

The strawberry harvest begins in Kurdistan in May and peaks between May and June and continues until July. There is a lack of reports about studies on the quality of Kurdistan strawberry under different atmospheres.

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Therefore, the objective of this work was to study physico-chemical, microbiological, and sensory score of Kurdistan strawberry cultivar under different atmospheres during 7 days of cold storage. The temperature of 5ºC was used as the average temperature of storage for Kurdistan strawberry because it is the temperature usually applied to keep the fruit, when available for the end user.

MATERIALS AND METHODS

Origin of the strawberries: The study was carried out on strawberry cultivar of Kurdistan obtained directly from market. They were transported to the lab in transparent polystyrene containers with a capacity of 500 g and stored at 5ºC. The fruits were carefully selected to be uniform in appearance and free from physical damage and deterioration.

Packaging methods: Polypropylene (PP) packaging containers were used for packaging. In this study three different gas compositions (normal atmosphere; MAP1: O_2 6%; CO_2 7.2%; N_2 86.8% and MAP2: O_2 0.2%; CO_2 10%; N_2 89.8%) were applied. After setting up the experiment, fruits were stored in a cool storage at 5°C, for 7 days.

Quality parameters: Firmness of strawberry was determined with a penetrometer for fruit firmness testing (The Wagner FT 02 Penetrometer - Italy). The maximum force to penetrate the fruit sample was recorded as firmness. Each result was the mean of 10 determinations and was expressed in Newton (N).

After analysing the firmness , strawberries were cut into small pieces and homogenized in a grinder. Total soluble solids percent (%TSS) was measured in the juice of ground strawberries using an Atago RX-2500 digital refractometer (Atago Co. Ltd., Tokyo, Japan) at 20°C. A drop of the juice was placed on the lens and the reading was taken in degree Brix. Calibration was made with deionized water and the lens was carefully rinsed between samples. Total sugar as total reducing sugar was determined according to Iran's Standard based on Lane-Inon measurement (ISIRI, 2007).

The pH was recorded by pH meter (pH-526; WTW Measurement Systems, Wissenschaftlich-Technische Werkstätten GmbH, Wellhelm, Germany). In the case of titratable acidity, six grams of ground strawberry was suspended in 100 mL of distilled water and then filtered. The filtrate titrated against 0.1 N NaOH up to pH 8.3 and expressed as citric acid. Anthocyanin content of strawberries was determined using a spectrophotometric method. 2 g of ground strawberry sample mixed with 20 ml of acidified methanol (1% HCl) using a homogenizer and then centrifuged at 2000 g for 15 min. Anthocyanin content was estimated as pelargonidin 3-glucoside at 510 nm, using a molar absorptivity of 36000 $L.cm^{-1}.mol^{-1}$.

The HPLC analysis was carried out to determine the vitamin C on a Shimadzu class LC VP HPLC system with class LC-VP software, a pump (LC-6AD), and a UV-VIS detector (SPD-10AV VP). The column used for measuring vitamin C was SGE (250 mm x 4.6 mm I.D., 5 μm). The mobile phase was water adjusted to pH 3 with phosphoric acid (vitamin C). Separation was carried out by isocratic elution with a flow rate of 0.4 ml min-1 and column temperature was ambient. The UV detector was set at 254 nm. Quantization was based on the peak area measurement.

Sample (10 g) was extracted in 10 ml water adjusted to pH 1.5 with 10 ml phosphoric acid-water (2%, v/v) for vitamin C. The extracts were filtered through filter paper. Then, 1.5 ml buffer (0.01 M KH_2PO_4, pH 8.0) was added to 1.5 ml sample extract. From this, 1.5 ml (organic acids) and 1 ml (vitamin C) of these mixtures were loaded on to C18 cartridges. After loading, 3 ml water adjusted to pH 1.5 with 2 ml phosphoric acid-water (2%, v/v) for vitamin C was passed through the cartridges. For HPLC, 20 μl of the eluents were injected.

For mould enumeration, strawberry samples of 10 g each were stomachered in a 1:10 dilution of sterile ringer (Seward Limited, London, UK). Ten-fold dilution series were made in as needed for pour plating. 1mL of the appropriate sample dilution was pour-plated on YGC agar (YGC, Merck, Germany) incubated at 30 ◦C for 5 days for moulds. Mould counts were expressed as cfu g^{-1}.

Sensory scores of strawberry samples were evaluated by ten trained staff members of the Kurdistan General Department of Standards and Industrial Research. The panelists were asked to evaluate the flavour. A twenty point scale was used where 20= excellent and 1= extremely poor. Accuracy and precision were statistically analyzed.

Data analysis: The results were analyzed using one-way analyses of variance (ANOVA) with the statistical software of SPSS (SPSS Inc., Chicago, IL, USA). Differences between means were studied with Duncan's test and differences at $p < 0.05$ were considered to be significant.

RESULTS AND DISCUSSION

Texture: Changes in texture over the storage time are showed in Figure. 1. As it is clear from the Figureure, the firmness of strawberries under MAP1, compared to MAP2, increased slightly. Strawberries with air packaging changed drastically in terms of texture after 5th day of storage. It has been reported that strawberries treated with CO_2-enriched atmospheres were firmer than air-stored fruit (Wszelaki & Mitcham, 2000; Van der Steen *et al.,* 2002; Pelayo *et al.,* 2003). This phenomenon has been usually linked to the accumulation of CO_2 in the packages. As a result of CO_2-enriched treatments, it was reported that cell-to-cell adhesion increased by 60% due to changes in the pH of the appoplast, with the subsequent precipitation of soluble pectins (Harker *et al.,* 2000).

Total sugar: The results from the sugar analyses are presented in Figure. 2. The initial total sugar concentration of strawberry samples was 5%. During the storage, sugar level in all the packaged samples increased slightly. This can be attributed to water loss of strawberry, thereby concentrating total sugar. More fluctuation in sugar level was observed in strawberry with normal atmosphere. At the end of storage time, there was no significant difference between strawberry of MAP1 and MAP2 ($p < 0.05$) and sugar content was 5.94%.
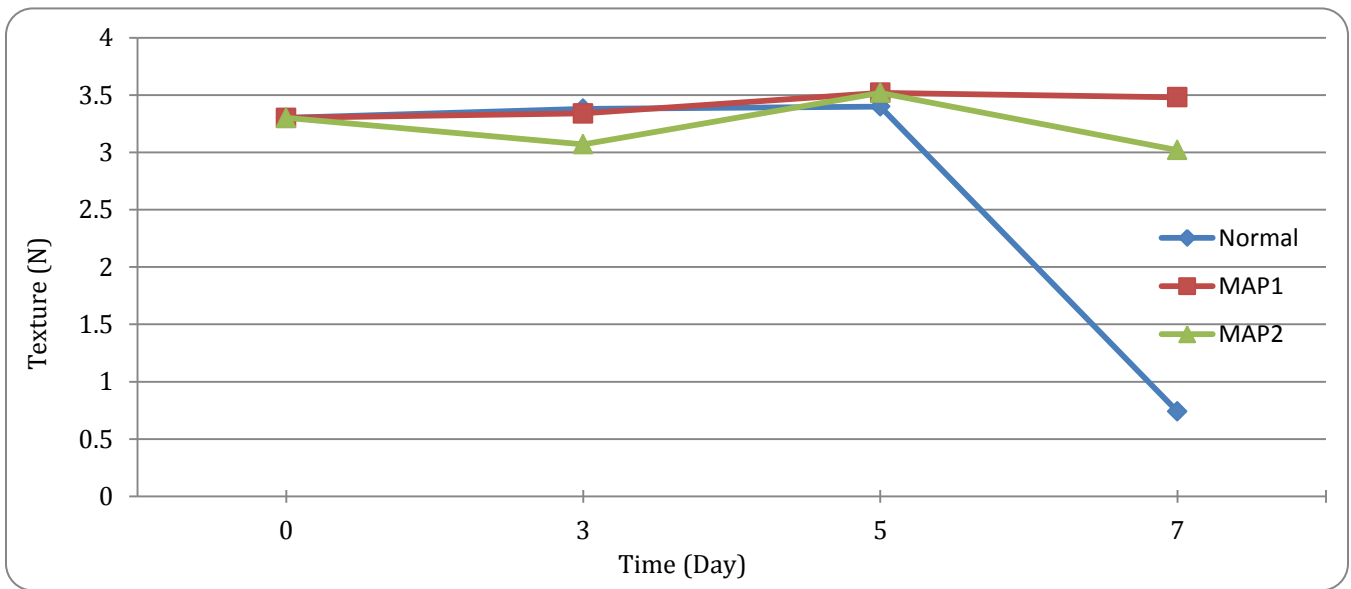

Figure 1. Changes of texture (N) of Kurdistan strawberry at 5°C under different atmospheres.
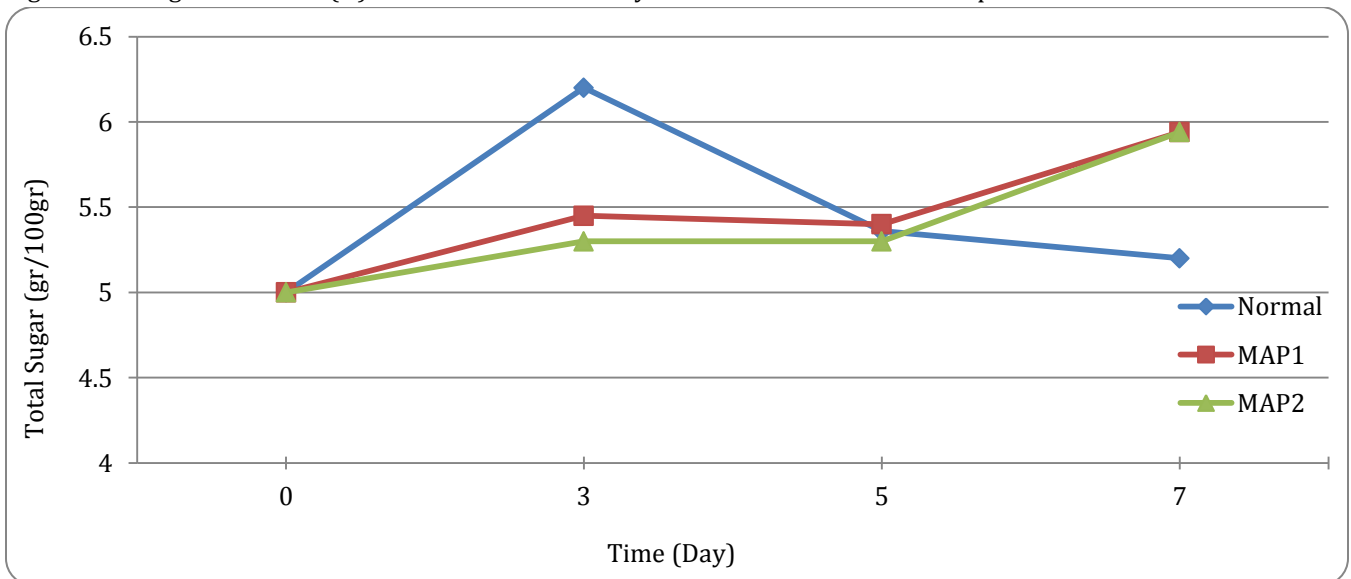

Figure 2. Changes of total sugar (gr/100gr) of Kurdistan strawberry at 5°C under different atmosphere.

TSS: TSS of strawberries was found to increase with storage time (Figure. 3). The observed increase in TSS content of the samples is an indication of high respiration rate and ripening (Pal and Roy, 1988). The changes were more considerable in untreated compared to the treated samples. The increase in total solids of samples of MAP was slower and more gradual than the other samples stored under normal condition. The total solid content of strawberries reached to 5.94, 5.94 and 5.2% at 7 d for MAP1, Map2 and normal atmosphere, respectively. This shows that the rate of senescence was the lowest in MAP1 and MAP2. Increase in TSS of modified atmosphere packed commodities over storage have been reported by Jafri

et al. (2013) in mushrooms, Manurakchinakorn *et al.* (2010) in fresh-cut mangosteen, Diaz-Mula *et al.* (2011) in yellow and purple plums, and Magaraj *et al.* (2011) in pears.

pH and Titrtable Acidity: The total titratable acidity (TTA) calculated as citric acid, which is the dominant acid in strawberries, for the different atmospheres are displayed in Figure. 4. The acidity of strawberries under MAP1and MAP2 decreased slightly. Over the storage, no significant difference was observed between the acidity of MAP1 and MAP2. The variation in acidity of samples stored under air atmosphere is associated with growth of microorganisms and consequent production of organic acids (Heard, 2002).
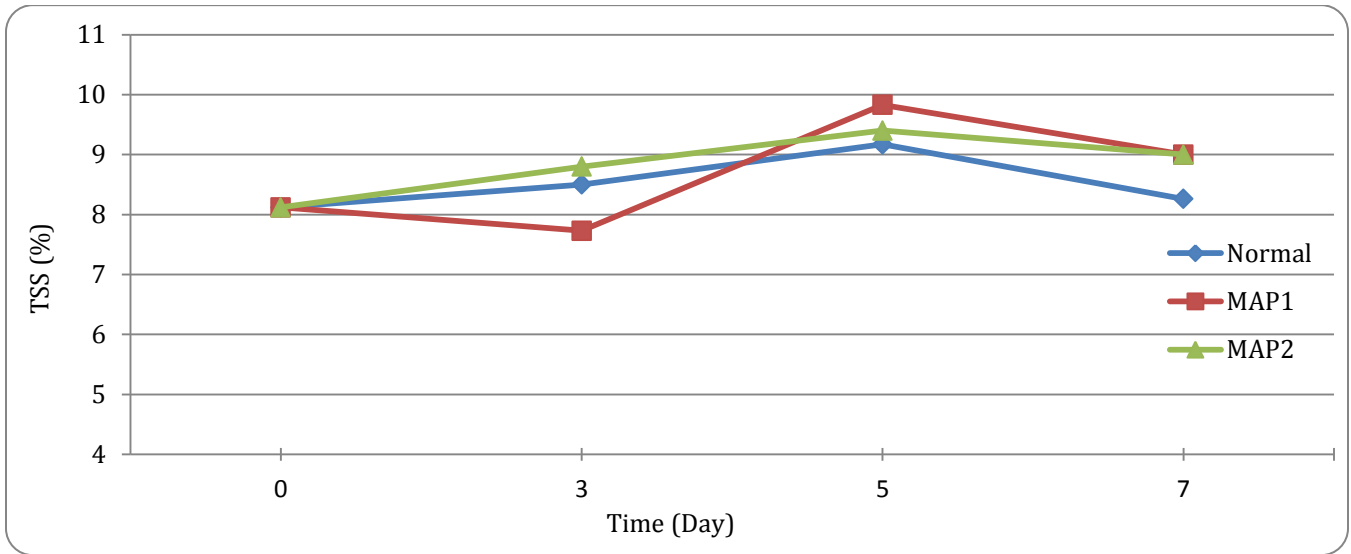

Figure 3. Changes of TSS (%) of Kurdistan strawberry at 5°C under different atmospheres.
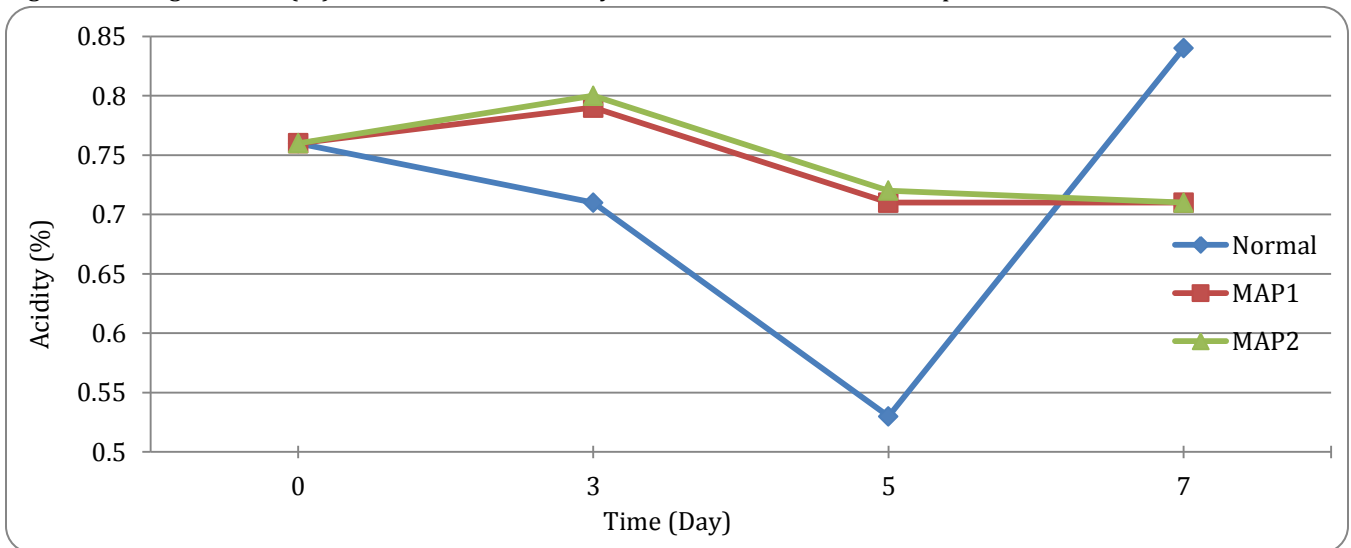

Figure 4. Changes of acidity (%) of Kurdistan strawberry at 5°C under different atmospheres.

During the storage, pH range was from 3.44 to 3.67. As shown in Figure. 5, pH increased in all samples. pH in MAP2 changed drastically with lesser change in MAP1. These results are in agreement with Siriphanich (1980), who reported that high-CO_2 treatments resulted in higher pH values than those of air control strawberries.

Vitamin C and anthocyanin: Vitamin C content of strawberry fruits was 32.76mg/100g. Over the storage time, the vitamin C level decreased in all samples under different atmospheres (Figure. 6). Vitamin C content in normal and MAP strawberry ranged from 32.76 to 1.42 mg Vit C 100 g^{-1}. Vitamin C, which is thermo-labile, is easily destroyed during processing and storage. At the end of storage period, levels of vitamin C in samples under normal atmosphere were significantly lower than in MAP samples ($P<0.05$). A possible explanation for these differences could be oxidation of vitamin C during storage. It has been reported that storage in CO_2-enriched atmospheres had beneficial effects on vitamin C retention in the first days of storage, but the levels decreased after 10 days of storage (Perez and Sanz, 2001). Our results showed that vitamin C content of strawberries stored under MAP was higher than that of air-stored samples at the end of the storage.
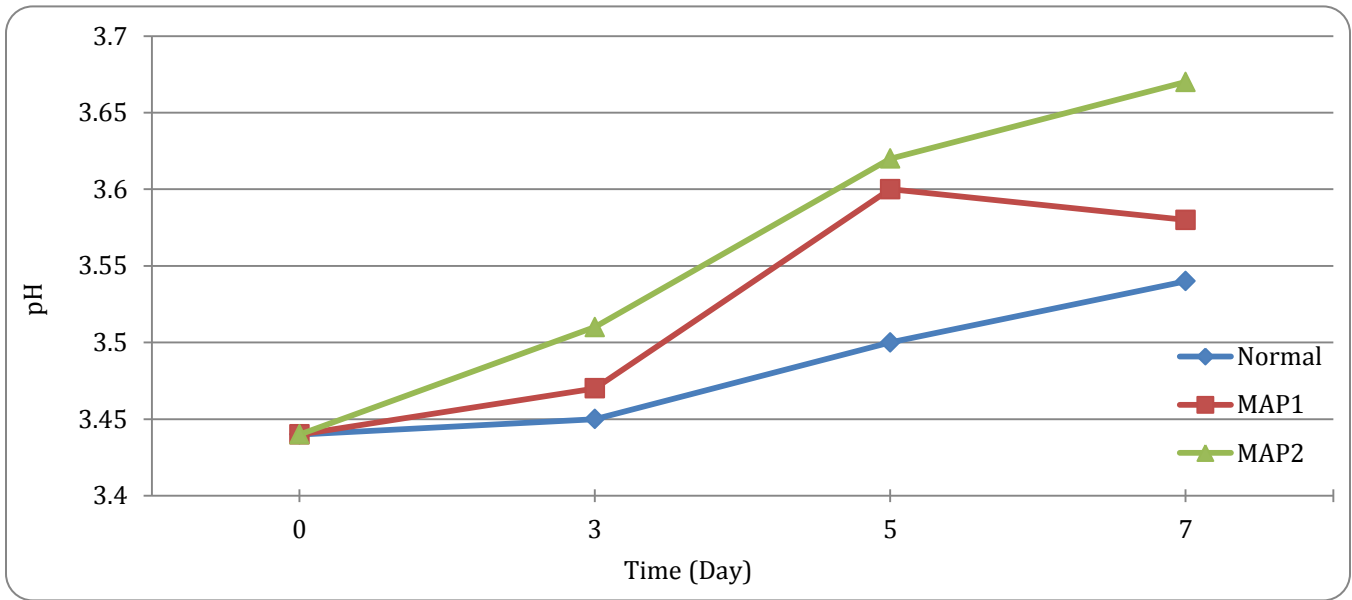

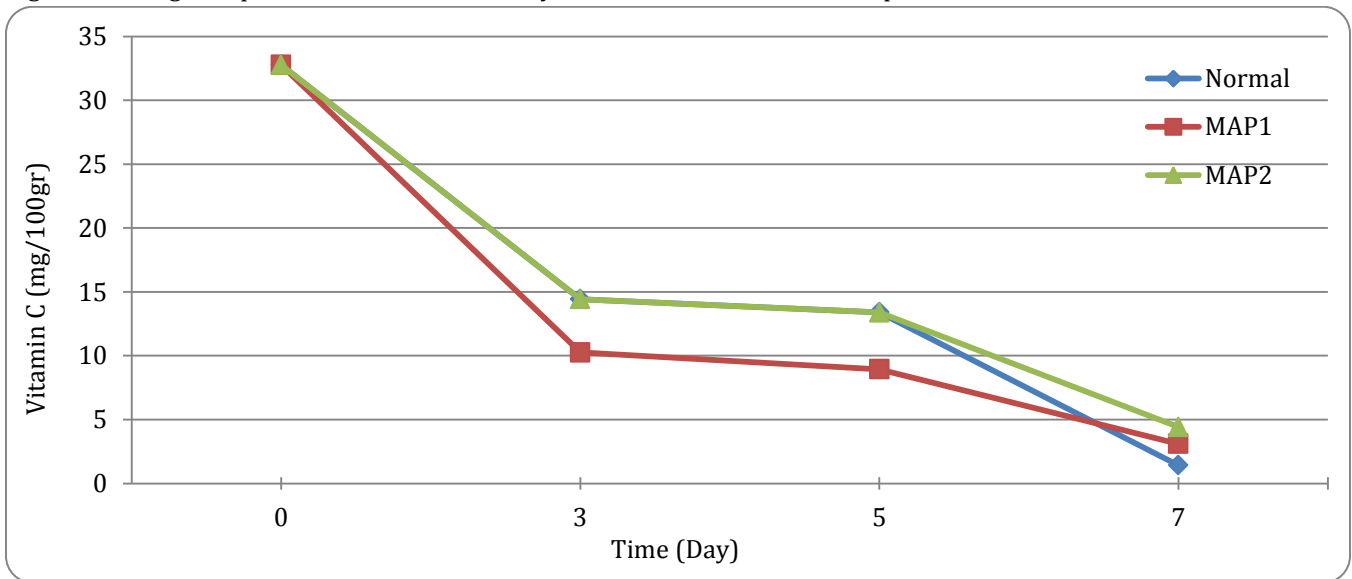Figure 5. Changes of pH of Kurdistan strawberry at 5°C under different atmospheres.

Figure 6. Changes of vitamin C (mg/100gr) of Kurdistan strawberry at 5°C under different atmospheres.

Several authors reported that phenolic contents, particularly anthocyanin, were lower in strawberries treated with atmosphere containing CO_2-enriched atmospheres when compared to air-stored fruit (Perez and Sanz, 2001; Zheng *et al.,* 2007). This phenomenon has been explained as a delay of the fruit ripening process caused by CO_2-enriched atmospheres (Wszelaki & Mitcham, 2000). Our results confirmed that high CO_2 level may reduce anthocyanin content (Figure. 7).

Mould spoilage: The rate of microbial growth is affected by the gas composition of atmosphere. This factor may be applied to a food product to delay or inhibit microbial development, thereby prolonging its shelf life. When applying MAP as a hurdle technique, one must consider the types of microorganisms which may cause spoilage and safety problems to the product.

The absence of oxygen would inhibit the growth of aerobic microorganisms. Obligatory aerobes such as moulds can be effectively controlled by the removal of oxygen. This was shown by Smith *et al.* (1986), who used an oxygen scavenger to control mould on baked products. An anaerobic atmosphere must be used with extreme caution because this atmosphere favors the growth and toxin production of *C. botulinum* (O'Conner-Shaw & Reyes, 2000). The results showed that decayed strawberry fruit increases with storage time but can be controlled by the use of a suitable atmosphere (Figure. 8).
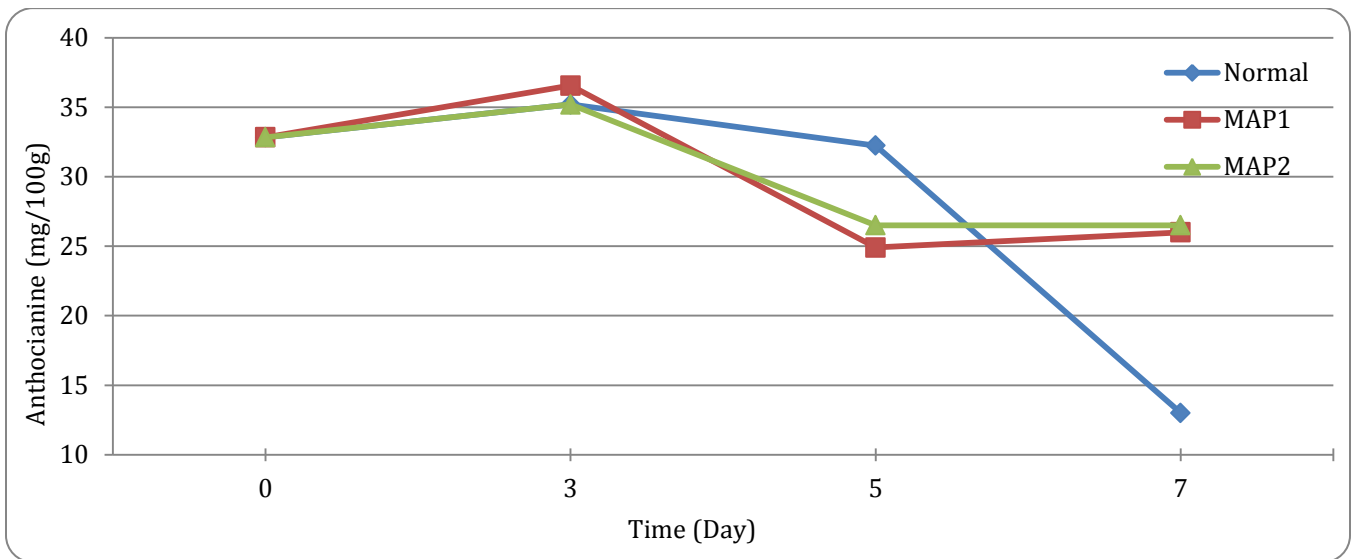

Figure 7. Changes of anthocyanin (mg/100gr) of Kurdistan strawberry at 5°C under different atmospheres.
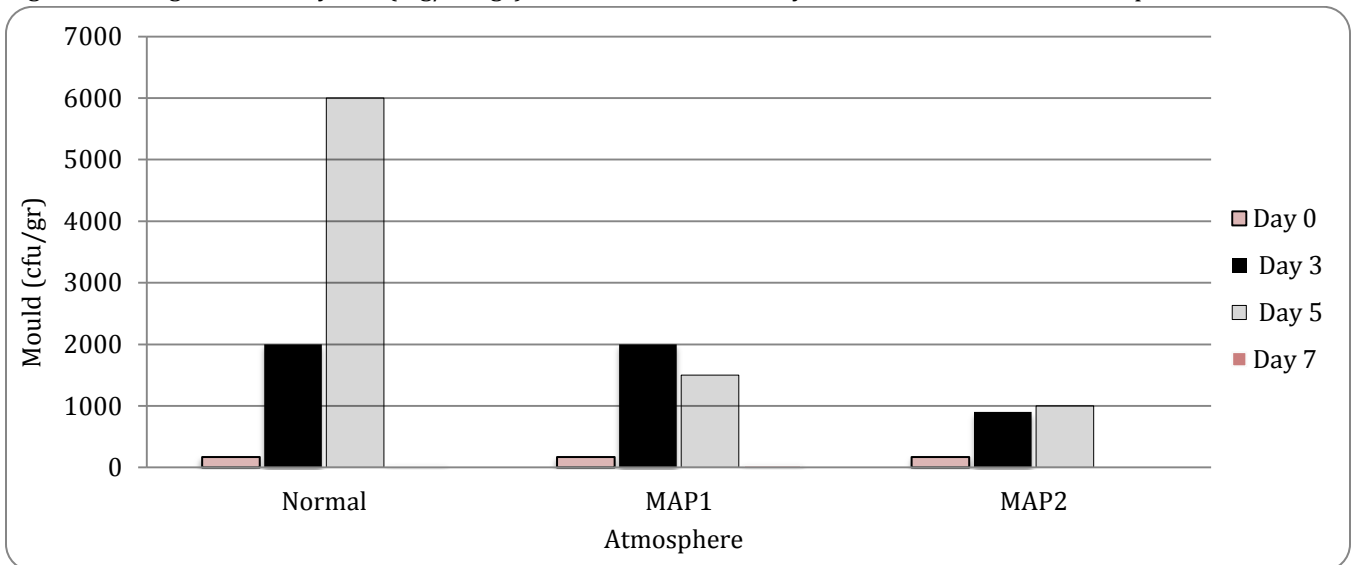

Figure 8. Changes of mould number (cfu/gr) of Kurdistan strawberry at 5°C under different atmospheres.

Thus, the number of moulds in air-stored strawberries was uncountable on 7th day of storage. As shown in Figure. 8, due to O_2 concentration, mould growth was significantly different in MAP1 and MAP2. On 7th day the number for MAP1 and MAP2 was lower than 30 cfu/gr.

Flavour analysis: The flavour analysis was performed to differentiate any flavour between the different packaging conditions during 7 days of storage (Figure. 9). There were significant differences in the flavour of strawberries kept in the different packaging conditions. None of the samples including air-stored and MAP1 showed significant changes after 5 days of storage. However, on 5th day the flavour of strawberries with MAP1 condition changed significantly. After 7 days of storage, the reduction of flavour was more noticeable in control samples when compared to strawberries in MAP1 and MAP2. This negative effect on flavour of strawberry could be stated as the most adverse effect of MAP. Similar trend has been reported by Allende *et al.* (2007). Acetaldehyde is a very volatile intermediate product of anaerobic respiration in fruit and vegetables. In the presence of sufficient O_2, most fruit and vegetables respire aerobically and at low O_2 concentrations, there is a chance of fermentation.However, when there is inadequate NADH to reduce all of the acetaldehyde to ethanol, result the accumulation of acetaldehyde. CO_2-enriched atmosphere has a role in the induction of anaerobic respiration and ethanol production (Kimmerer & Kozlowski, 1982). Kader (1986) stressed that the effects of both low O_2 and high CO_2 concentrations in the induction of anaerobic respiration are additive. Ethanol in the tissue stored under modified atmosphere at constant temperature suggests partial induction of anaerobic respiration when the O_2 concentration dropped below 10% and the CO_2 concentration rises above 5% (Kader, 1987).
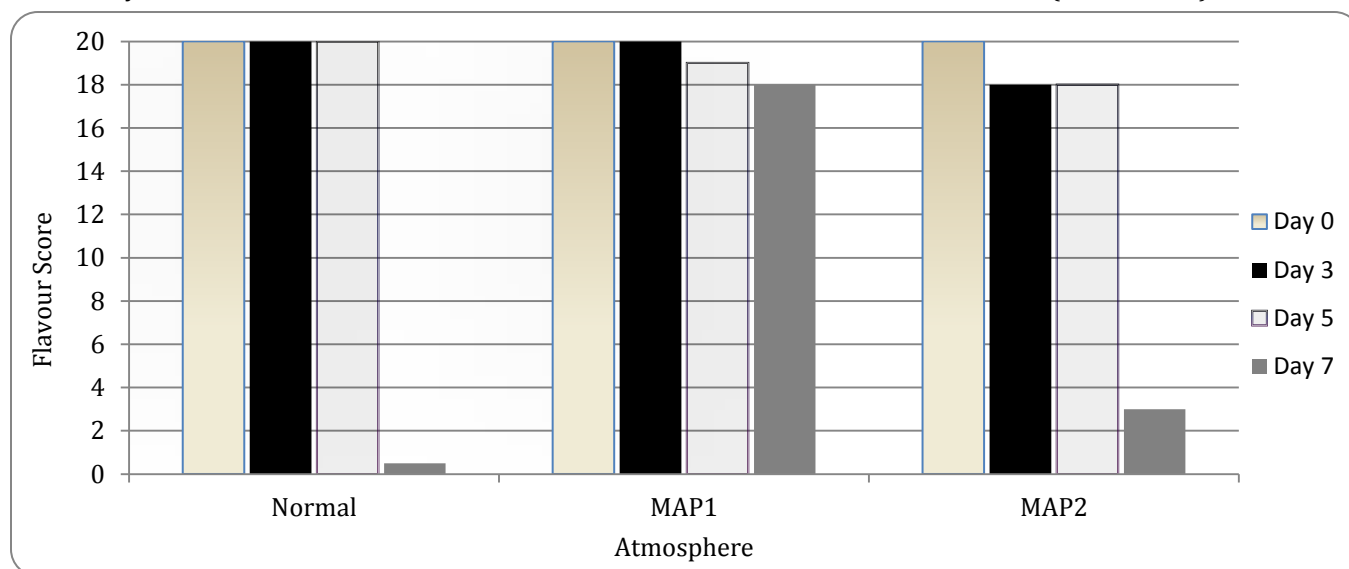

Figure 9. Changes of flavour score of Kurdistan strawberry at 5°C under different atmospheres.

Although high CO_2 atmospheres reduced decay, they increased production of fermentative metabolites that impart negative organoleptic properties to strawberries (Van der Steen et al., 2002; Pelayo *et al.,* 2003). Therefore, in this study, flavour scores of active MAP strawberries were significantly (Probability P<0.05) lower than in air-stored samples after 3rd day of storage.

CONCLUSIONS

The postharvest treatments (name the treatments) tested under the described conditions affected the physico-chemical properties of 'Kurdistan' strawberries. In general, the use of high CO_2 atmospheres significantly reduced anthocyanin content of strawberries after treatment. At the end of storage time, the content of vitamin C under normal atmosphere after 7th day was significantly lower than MAP samples (p<0.05). MAP conditions delayed the fungal growth when compared to air-stored samples (include the temperature = 25°C and RH = 35%). Flavour scores of MAP in Kurdistan strawberries were significantly lower than those of air-stored samples after 3 days of storage.

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