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ORIGINAL ARTICLE

The effect of oleum myrtle on the fruit quality of strawberries during MAP storage

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Abstract Strawberries are known to be significant source of the nutraceuticals; however, rapid perishable property of this fruit is very important issue. Up to now, extension of this fruit is still the focus of scientific and industrial interest in the worldwide. Therefore, of the known nutraceuticals, myrtle essential oil in this study is intended to use for extending the storage of strawberries. Strawberries were individually immersed in the treatment solutions of 0.1 % myrtle oil, 0.5 % myrtle oil and then placed in Modified Atmosphere Packaging (MAP) for 8 days at 5 °C. The control fruits without myrtle oil treatment were also placed in MAP and stored under the same condition. Treatment of myrtle oil decreased the weight and the fruit firmness loss. Furthermore, titratable acidity (TA), pH and colour value did not display significant changes during storage. Fluctuations were observed in the vitamin C, total soluble solids (TSS), TSS/TA content and microbial growth. The O_2 concentration in MAP decreased from 21 % to around 15 %, whereas, CO_2 concentration varied from 6.0 to 6.9 % in the treatments by the 8th day of storage time. The delay of flesh firmness, weight loss, vitamin C loss and increasing CO_2 concentration in MAP, best sensory quality as well as limiting the growth of microbial parameters in concern was attained through the use of 0.5 % myrtle oil, suggesting that 0.5 % myrtle oil showed more pronounced activity than 0.1 % myrtle oil and control in maintaining the fruit quality and shelf life of fruits during MAP storage.

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Introduction

Fruits offer many health benefits to the mankind, which traced back to the ancient times. These agricultural commodities are highly perishable properties because of their high moisture content (Sagar and Suresh Kumar 2010). Of the delicious fruits, strawberry has a short postharvest life owing to its delicate structure and rapid deterioration. It is mainly susceptible to physical damage, water loss, decay and physiological and microbial deterioration during storage (Bhaskara-Reddy et al. 2000; Shin et al. 2008). To solve this problem, postharvest handling practices have been commonly used in the fruit industry, and enhancing the quality of fruit attained in the field and giving the fruit sufficient shelf life during storage and distribution (Ohlsson and Bengtsson 2000; Fallik 2008; Gil et al. 2009; Artes et al. 2009).

MAP has been elevated to a new degree of importance (Yuan 2003; Fallik 2008). MAP is known to prolong the shelf life of food products and reduce their rates of spoilage while maintaining their safety and general quality (Oorakul 2003; Floras and Matsos 2005; Park and Lee 2008). The basic principle in MAP is that a modified atmosphere can passively or actively be created by using properly permeable packaging materials. The aim is to create an optimal gas balance inside the package, where the respiration activity of a product is as low as possible while ensuring that oxygen concentration and carbon dioxide levels are not detrimental to the product. The selection of film property is very important parameter and changed from fruit to fruit. Due to the complexity of food, many factors influence the type of MAP film to be used, including intrinsic food properties (pH, water activity, and composition) and extrinsic factors (temperature and relative

humidity in processing and storage conditions) (Kader 1995; Perez and Sanz 2001; Yuan 2003; Siro et al. 2006; Allende et al. 2007).

In recent years, various bio-originated compounds have been the focus of scientific and industrial interest in demand for wholesome and natural fresh products (Babalar et al. 2007; Asghari and Aghdam 2010; Diaz-Mula et al. 2011; Sayyari et al. 2011; Jin et al. 2012; Ahlawat and Singh Khatkar 2011; Oz and Ulukanli 2012; Ulukanli et al. 2012; Das et al. 2012).

Of those natural compounds, essential oils are known to be volatile, natural, complex compounds characterized by a strong odour and obtained from plant material (Burt 2004; Bakkali et al. 2008; Serrano et al. 2008). The use of essential oils in preserving fresh fruits has received increasing attention owing to their relatively safe status (Lanciotti et al. 2004; Yadegarinia et al. 2006). The combination of the crude essential oil and/or individual compounds has beneficial effects on the maintenance of the overall quality of various fruits (Serrano et al. 2005; Valero et al. 2006; Tzortzakis 2007; Martinez-Romero et al. 2007).

Myrtle oil is an aromatic flavour extracted from the *Myrtus communis* (Myrtaceae) leaves and/or fruits. The myrtle oils are used in food industry, in flavouring meat and sauces, in confectionary and in beverage industry (Chalcat et al. 1998; Aydin and Ozcan 2007). The myrtle extracts and essential oils are known to exert excellent antimicrobial activity (Bouzouita et al. 2003; Sagdic et al. 2003; Yadegarinia et al. 2006) and its efficacy has been tested on lettuce and tomatoes for eliminating Salmonella typhimurium (Gunduz et al. 2009).

To the best of our knowledge, no information is existent on the effects of postharvest myrtle essential oil treatment in combination with MAP on the quality parameters as well as shelf life qualities in strawberries. Hence, the purpose of this study was to investigate to what extent myrtle oil influences the quality and shelf life of strawberries in MAP storage.

Materials and methods

Fruit treatment and storage

Strawberry cultivar 'Selva' fruits were hand-harvested at ripe stage (90 % red colour) from an orchard in Fatih district (Kahramanmaras, Turkey). The fruits were sorted on the basis of uniformity in size and colour, appearance and ripeness, only fruits free of physical damage were included in the present study. The sampled fruits were randomized for essential oil treatment. Essential oil which was obtained from the leaves of *M. communis* through steam distillation was purchased from a commercial seller Talya (Antalya, Turkey). The manufacturers highly recommend the oil for the use as food supplement. *M. communis* oil solutions were prepared by adding essential oil into sterile distilled water (Gunduz et al. 2009).

All strawberries were initially immersed in sterilized distilled water for 5 min and transferred into sterilized sieved trays and then kept at room temperature (20 °C) for 2 h under a laminar flow with the air circulation. The strawberries were divided into three groups. One set of fruits were treated as the control group (I) and then kept in MAP storage at 5 °C with 90 % RH. In the treatment groups, pre-washed and drained strawberry fruits were then immersed in 0.1 % myrtle oil (II), or in 0.5 % myrtle oil (III) for 5 min and transferred into sterilized sieve trays. Treated strawberries were then kept at room temperature (20 °C) for 2 h under a laminar flow with the air circulation. When the excess of immersing solution was completely removed from the fruits, a total of 2.5 kg strawberries from each treatment group were immediately transferred to the modified atmosphere packaging trays (also called polyethylene bulk liner, 30 μ/p-plus antimist, 700×700 in bag size) and then placed in cartoon boxes and stored at 5 °C with 90 % RH. All test groups were examined after storage for 2, 4, 6, and 8 days at 5 °C.

A total of ten replicates (n=10) from each treatment were used for all analyses during storage.

Assessment of quality

Strawberries were weighted before and after the experiment at 5 °C. Weight loss was expressed as a percentage of the initial weight. Fruit flesh firmness was measured on ten fruits per treatment, every 2 days over a period of 8 days at 5 °C. The measurements were made on two opposite sides of each fruit using a FHR-1 (1 kg) firmness tester with cylinder type base diameter with a 5 mm tip (Nippon optical works CO. LTD, Tokyo, Japan). The total soluble solids (TSS) content (%) of juice was measured with a hand held refractometer (Krüss, Germany). The analysis of the titratable acidity was made using the titration method. Briefly, pulp tissue (2 g) was homogenized with 10 ml of distilled water. The mixture was filtered and titrated with 0.1 N NaOH to pH 8.1, and the results were expressed as percentage of citric acid. The pH values of strawberry juice were measured using a Hanna instruments pH meter (HI 2221). The vitamin C content in strawberry juice was determined by direct titration with iodine. Fruit juice (5 ml) was acidified with HCI and then directly titrated with iodine solution. The measurement of vitamin C content of fruit juice was determined on the basis of the vitamin C standard solution. The colour of strawberry was measured by two readings on the two different symmetrical faces of the fruit in each replicate, using a Konica Minolta (CR-400) colorimeter calibrated with a white standard tile. Results of the fruit colour were expressed as described chroma value from $(a^{*2}/b^{*2})½$.

Gas analysis

The changes in headspace O_2 and CO_2 concentration of strawberries were determined using a PBI Dansensor O_2/CO_2 analyzer (Denmark). The volume taken up by the package headspace for gas analysis was about 10 cm^3. The package headspace volume was determined by the difference between the total volume of the packages and the volume of the sample. Each package was used only for a single measurement of the headspace gas composition. Three bags were employed for each measurement (Mastromatteo et al. 2010).

Microbiological analysis

Twenty five gram of strawberry was homogenised with 225 ml of sterile peptone water in a Stomacher for 2 min. Serial dilutions were then prepared with the same diluent and transferred into petri dish and mixed with the appropriate media. The total viable microbial counts (TVC) were determined on Plate Count Agar (30 °C/72 h) and the psychrotrophs were counted on Plate Count Agar (5 °C/240 h). Yeast and moulds were enumerated on acidified Potato Dextrose Agar (25 °C/120 h). Microbial populations were enumerated at the time of 0, and after 2, 4, 6, and 8 days. The results were then reported as log cfu/g (Oz and Ulukanli 2011).

Assessment of the sensory quality

The sensory testing was conducted at room temperature. Five strawberries of each treatment were randomly distributed to panellists and were evaluated on a 5-point scale. Strawberries were rated on a five point hedonic scale from 1 = very bad to 5 = excellent.

Statistical analysis

Experiments were conducted using a completely randomized design with ten replicates. All statistical analyses were performed using SPSS 13.0 software for Windows. The results were analyzed using the GLM univariate procedure and analysis of variance (SPSS 13.0 commercial software, SPSS Inc., Chicago, II). Means were compared by the least significant difference tested at significance levels of ($P<0.05$).

Results and discussion

In the present study, the weight loss was significantly affected by the myrtle oil treatments in comparison to control group throughout the storage time (Fig. 1). Towards the last day of storage time, the control fruits had 6.7 % weight loss, whereas, 0.1 and 0.5 % myrtle oil possessed 4.3 and 3.3 % weight loss, respectively. It appeared that the rate of weight loss found in fruits treated with 0.1 and 0.5 % myrtle oil was almost one and half times lower than that which was observed in control fruits. The weight loss of control was also evidently more than those of the maximum limit for strawberry marketability (6 %) (Robinson et al. 1975). In this study, all myrtle oil treatments clearly maintained the weight loss of fruits throughout the storage; however, the most significant preservation was obtained with 0.5 % myrtle oil treatment. The retardation of weight loss from the myrtle oil applications may be attributed to their additional protective layer on the surfaces of fruit openings and also minimizing the metabolic activity, respiration and transpiration (Shafiee et al. 2010). The interaction between the use of various essential oil components (eugenol, thymol, or menthol) and MAP was shown to be retarding the weight loss of some non climacteric fruits such as cherries and table grapes (Martinez-Romero et al. 2005; Serrano et al. 2005; Valero et al. 2006). Moreover, the crude essential oils of eucalyptus and cinnamon were also found to be reducing the weight loss of strawberry fruits (Tzortzakis 2007). The earlier reports, together with the results herein, revealed that the effect of different essential oil for reducing the weight loss of fruits is noteworthy.

Loss of firmness is one of the main factors limiting quality and the postharvest shelf-life of fruit and vegetables (Fan et al. 2009). With regard to firmness values in concern, there were significant differences among the treatments during storage (Fig. 1). Fruit firmness was 2.23 in control, 2.86 in 0.1 % myrtle oil and 2.7 in 0.5 % myrtle oil treated fruits by the 2nd day of storage. The firmness values reached to 1.2 in control fruits, 1.6 in 0.1 % myrtle oil treatments and 1.8 in 0.5 % myrtle oil treatments in the end (Fig. 1). It appeared that myrtle oil maintained the firmness of strawberries under MAP storage compared to control fruits. These effects might be explained due the covering the fruit surface openings with the essential oil in concern and thereby reducing the infection, respiration and other ripening processes during storage, which sustains fruit firmness (Ali et al. 2011). Moreover, the gas concentration within MAP environment in conjunction with essential oil may have synergistic effects on the retention of firmness (Zhu et al. 2008). The maintenance of the firmness of essential oil treated fruits was also found in several studies. For example, Serrano et al. (2005) observed that different essential oil compounds (thymol, menthol and eugenol) reduced the flesh firmness of cherry fruits during MAP storage. Of those compounds, Serrano et al. (2005) concluded that eugenol was the most effective one. Similarly, Valero et al. (2006) found that the flesh firmness of table grapes was slightly reduced using the eugenol and thymol. The preservation of the firmness was also reported by Tzortzakis (2007) in strawberry fruits treated with cinnamon essential oil.

TSS content revealed significant differences between control and other treatments with respect to the values in question,

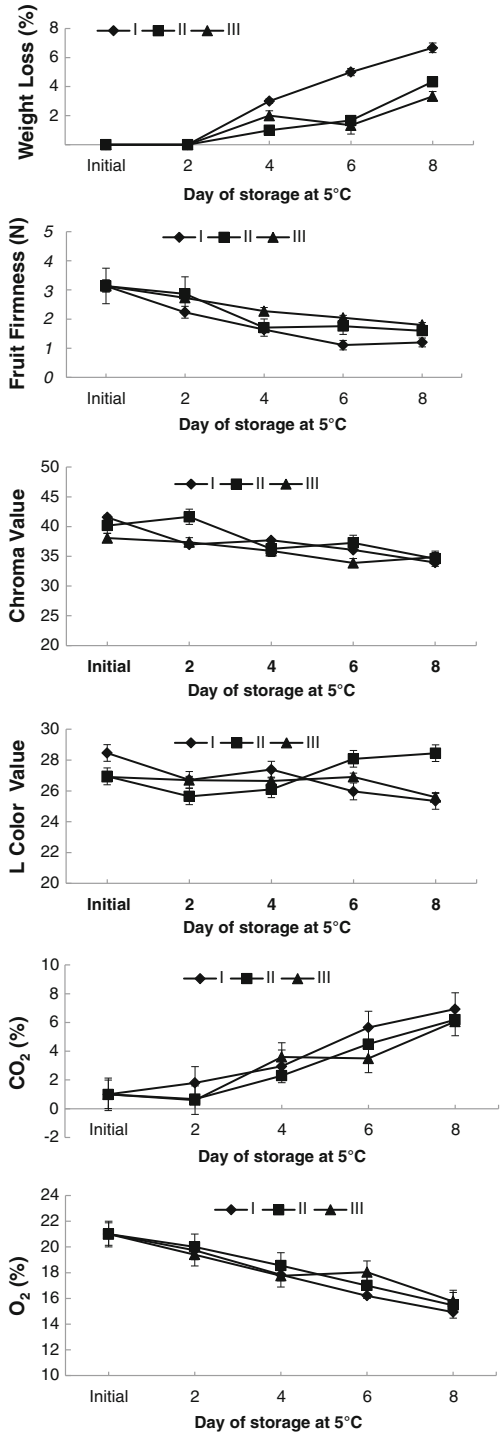

Fig. 1 Effects of myrtle oil treatments (I: control, II: 0.1 % myrtle oil, III: 0.5 % myrtle oil) on physical quality characteristics of strawberries at 5 °C during 8 days Modified Atmosphere Packaging (MAP) storage. Bars indicate ± SE

soon after treatment. The initial TSS value was 8.0 % in control, 6.8 % in 0.1 % myrtle oil and 7.5 % in 0.5 % myrtle oil treatment (Fig. 2). TSS content increased to 8.6 % in control, 7.6 % in 0.1 % myrtle oil and 8.5 % in 0.5 % myrtle oil for the 2 days of storage, afterwards, tended to increased in all treatments. At the end of storage, the highest TSS content was 9 % in both 0.5 % myrtle oil and control fruits followed by 7.4 % in 0.1 % myrtle oil treatment.

The effect of myrtle essential oil on TSS content of strawberry fruits varied depending on the used concentration at the initial time of the experiment, which was in line with the findings of Hassani et al. (2011). These authors applied different concentrations of essential oils on apricot fruits inoculated with *Botrytis cinerea*. In their study, TSS content of control fruits was found to be higher than those of 200 and 400 μl of the essential oils treated apricots towards the end of storage time. TSS content of 200 μl of the essential oils treated apricots was lower than those of 400 μl of the essential oil treated fruits. In the present study, towards the end of storage time, increment in TSS value was also observed in control and 0.5 % myrtle oil when compared to 0.1 % myrtle oil by prolonging the storage time. The present data is well consistent with the findings of Hassani et al. (2011). In other studies, TSS of the essential oil treated cherries did not significantly change from the initial time to the end of storage (Serrano et al. 2005). In contrast, the essential oil vapour treatments on strawberries revealed an increase in their TSS content during exposure (Tzortzakis 2007). The result of the present study appeared to be in agreement with the findings of Tzortzakis (2007). The fluctuating value of TSS content herein and those found by Tzortzakis (2007) may be attributed to the metabolism of carbohydrates during the respiration as well as water loss of fruits.

Titratable acidity (TA) is directly related to the concentration of organic acid present in fruit, which is an important parameter for maintaining the quality of fruits (El-Anany et al. 2009; Ali et al. 2010). In the present study, initial TA level of control was 0.55 in control, 0.65 in 0.1 % myrtle oil and 0.61 in 0.5 % myrtle oil treated strawberries (Fig. 2). TA level increased to 0.56 in the control fruits, but decreased to 0.60 in 0.1 % myrtle oil treatment, and 0.48 in 0.5 % myrtle oil treated strawberries by the 2nd day of storage. An increasing tendency for control fruits and a decreasing tendency for 0.1 % myrtle oil and 0.5 % myrtle oil treatments were observed in the end, but statistically insignificant. Earlier, TA values of some non climacteric fruits when treated with either essential oil compounds or also whole essential oil varied from fruit to fruit. For example, TA value of menthol and thymol treated cherry fruits decreased slightly, whereas, TA value of eugenol treated cherry fruits decreased significantly (Serrano et al. 2005). The combination of thymol (75 and 150 μl) with MAP decreased the TA value of grapes throughout the storage, whereas, the use of eugenol applications (75 and 150 μl) revealed fluctuations and the upper concentration of this oil increased the TA value of the fruits in concern (Valero et al. 2006). Tzortzakis (2007) reported that TA of essential oil treated strawberries did not differ during vapour exposure and/or following storage to ambient air. Moreover,

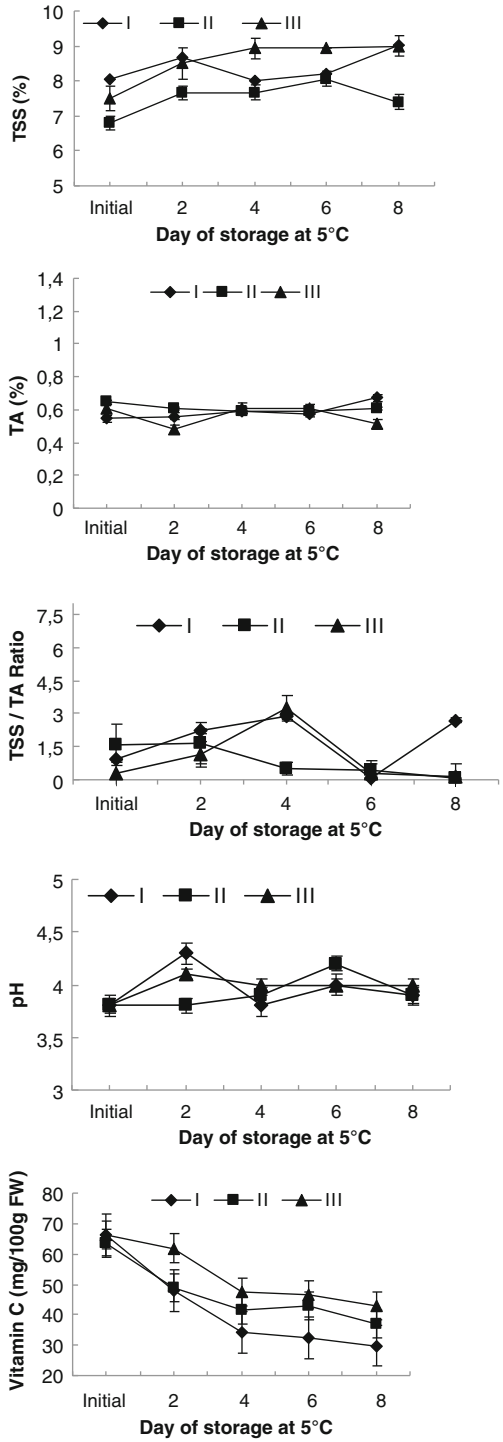

Fig. 2 Effects of myrtle oil treatments (I: control, II: 0.1 % myrtle oil, III: 0.5 % myrtle oil) on chemical quality characteristics of strawberries at 5 °C during 8 days Modified Atmosphere Packaging (MAP) storage. Bars indicate ± SE

Nielsen and Leufven (2008) found that TA value of strawberries unaltered and remained unchanged among the different passive MAP conditions.

The fruit sweetness (TSS/TA) provides information on the balance of sugars and acids in the fruit. Therefore, the relationship between TSS and TA along with fruit colour is considered to be the main parameter for determining fruit quality (Kafkas et al. 2007; Voca et al. 2008). In the present assay, treatments appeared to be revealing variable results since significant differences were observed during storage. The ratio of TSS/TA showed a rapid increase with the treatment of 0.5 % myrtle oil by 2nd day and fluctuated onwards (Fig. 2). In the end, higher TSS to TA ratio was observed in 0.5 % myrtle oil treated fruits. A very slight change was observed in other treatment groups up to 6 day of storage and these values remained almost the same both in the control and 0.1 % myrtle oil treated strawberries. However, after 6 day of storage, the ratio observed in other treatments seemed to be fluctuating. The application of essential oil on TSS/TA ratios of fruits seemed to be variable in previous studies. Tzortzakis (2007) found no effect on TSS/TA ratio during passive MAP storage. In the present study, TSS/TA ratio remained almost the same in both the control and 0.1 % myrtle oil treated strawberries, which was consistent with the reports of Tzortzakis (2007). In another study, the ratio of fruit sweetness was reduced by the treatment of essential oils on grapes (Martinez-Romero et al. 2005). The use of thymol was shown to be more effective for delaying the change in maturity index when compared to those obtained by the use of eugenol in grapes. The effectiveness of eugenol on maturity index was found be dose dependent (Valero et al. 2006). The present result with regard to higher concentration of essential oil in concern appeared to be dose dependent effect on strawberry fruits, which was also in agreement with the findings of Valero et al. (2006).

The pH value of all treated strawberries slightly increased in control (3.9), 0.1 % myrtle oil (3.9) and 0.5 % myrtle oil treated fruits (4) up to the 8th days of storage. Throughout the storage time, statistical differences were not observed between the control and treatment groups (Fig. 2). These might be resulted from the increasing/decreasing gas concentration within the MAP storage, as stated by Nunes et al. (2002). Earlier, Serrano et al. (2005) observed that there was a slight increase in pH value in cherry fruits when they were treated with menthol and thymol. It was also noted that pH value revealed a significant increase with the treatment of eugenol (Serrano et al. 2005). It appeared that pH value may vary between fruits and also depend on the use of essential oil in concern.

The ascorbic acid of fruits is one of the most important nutrient quality parameters (Oz 2010).

The significant differences were observed between control and treatments during storage time with respect to vitamin C content (Fig. 2). Losses of vitamin C in control and 0.1 % myrtle oil treated fruits were significantly higher than those of 0.5 % myrtle oil treated fruits by the 2nd day. Concerning the control and treatment groups, the reduction for further storage

continued but was not comparable with the 2nd day. Vitamin C content was 29.8 mg/100 g in control, 36.9 mg/100 g in 0.1 % myrtle oil and 42.9 mg/100 g in 0.5 % myrtle oil treated strawberry fruits in the end. Vitamin C is known to be rapid perishable properties. This undesirable property was also observed in all treatment to some extent. The rapid perishable property of vitamin C in all treatments for further storage might be due to the water loss, cell wall damage, O_2 and/or CO_2 contents in the storage, as stated by other authors (Yaman and Bayindirli 2002; Nunes et al. 2002; Nunes 2008). However, the best preserving application for strawberries was obtained using 0.5 % myrtle oil and 0.1 % myrtle oil treatments, respectively. Likewise, the loss of ascorbic acid was also delayed with the treatment of eugenol and thymol in table grapes (Valero et al. 2006). Furthermore, Tzortzakis (2007) reported that eucalyptus and cinnamon volatile oil compounds maintained fruit quality and organic acids of strawberry fruits.

Colour is one of the most important parameter of quality in the marketing of strawberry. L and chroma value of all treatments slightly reduced in all treatments throughout the storage time. Immediately after treatment, initial L value was 28 in control fruits, 27 in both 0.1 % myrtle oil and 0.5 % myrtle oil treated fruits. The chroma value was 42 in control fruit, 40 in 0.1 % myrtle oil and 38 in 0.5 % myrtle oil treatments at the initial time of treatment. However, there was a slight decrease in L* and Chroma value for all treatment groups towards the end of storage (Fig. 1). But the differences in L* and Chroma value were not found to be significant among the treatments. The present results with regard to colour parameters were in line with the results of Serrano et al. (2005) and Valero et al. (2006). The present result was also well consistent with what was reported by Sacks and Shaw (1993), who observed that strawberries darkened slowly during storage.

Changes in O_2 and CO_2 concentrations in the sampling packages are shown in Fig. 1. Significant differences were observed among the treatments. The initial amount of O_2 concentration was 21 % in all treatment groups. Throughout study, the O_2 concentration decreased gradually and reached to 15 in the control and 0.1 % myrtle oil treated fruits and 16 in 0.5 % myrtle oil treated fruits. Although CO_2 concentration was doubled in control fruits by the 2nd day of storage, 0.4 units was reduced in 0.1 % myrtle oil and 0.5 % myrtle oil treated fruits. The increment in CO_2 concentration was observed in all treatments throughout the storage time. The highest percentage of CO_2 concentration was observed in the control which was followed by 0.1 % myrtle oil and 0.5 % myrtle oil treatments, respectively.

The modification of the internal MAP atmosphere might cause disorders associated with high CO_2 and/or O_2 concentration (Ribeiro et al. 2007). The O_2/CO_2 ratio measured for the control group was similar to those described by Nielsen and Leufven (2008). The high concentration of O_2 was found in 0.5 % myrtle oil and 0.1 % myrtle oil treatments, which might be attributed to the minimizing effect of essential oil on the respiration of fruits or accounted for by a direct consequence of myrtle oil influence over the oxygen diffusion between fruit and environment. Findings suggest that myrtle oil treatment alone inhibited the drastic increases likely to occur in the CO_2 concentration.

The effect of 0.1 % myrtle oil was less pronounced in reducing the growth of total viable microorganisms. Nonetheless, treatment of 0.5 % myrtle oil had a more pronounced activity in limiting the growth of total viable microorganisms, with a reduction of 0.33 and 1.14 log units from the 6th day and onwards (Fig. 3). Chafer et al. (2008) reported that the critical limits for Total Viable Counts (TVC) for fruits are 5×10^7 cfu/g. On the contrary, TVC did not exceed the required limits for consumption of the product in concern. The significant efficacy of 0.5 % myrtle oil was also found in lettuce and tomato with a reduction in *S. typhimurium* population after treatment for 5 min by Gunduz et al. (2009). The present study suggests that the application of myrtle oil on strawberries under MAP storage had a considerable effect in reducing the growth of total viable microorganisms.

Figure 3 illustrates the psychrotrophic counts both in the control group and treatment groups. The significant differences were found across the treatment groups. The psychrotrophic count did not considerably differ between control and 0.1 % myrtle oil treatment groups during storage. The lowest count for the treatment groups was measured in 0.5 % myrtle oil treatment. Psychrotrophic microorganisms are considered to be one of the main causes of food spoilage (Huis in't Veld 1996). During all the storage, psychrotrophic microbial load did not exceed the threshold value recommended for fruits by Chafer et al. (2008), which was dissimilar to the findings of the study carried out by Mastromatteo et al. (2010), who noted that the combination of thymol essential oil and modified atmosphere packaging inhibited the growth of psychrotrophic microorganisms. Differences could be resulted from the essential oil in concern.

Yeast and mould counts of strawberries included in the control and treatment groups are shown in Fig. 3. The significant differences were observed across the treatment groups throughout the storage time. The decrease observed in the number of yeast and moulds in 0.1 % myrtle oil treatment was relatively less than that in the upper concentration of oil. The increasing number of yeast and moulds in the control strawberries might be attributed to the microbial competition rather than fruit's metabolic and physiological state. Or else, it could be explained due to insufficient gas balance inside the packaging system which causes the deterioration the fruits (Meyer et al. 2002; Serrano et al. 2008). Among the treatments, yeast and mould load of 0.5 % myrtle oil treated fruits during storage did not exceed the critical limit of fresh fruits (10^5 cfu/g) (Jacxsens et al. 2002). The interaction between 0.5 % myrtle oil and MAP yielded the best effect in reducing

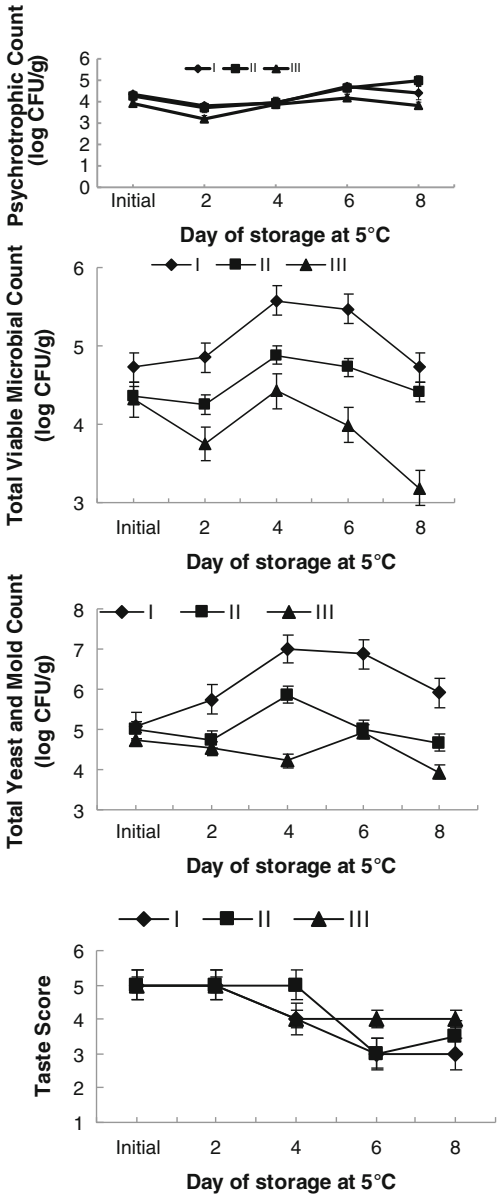

Fig. 3 Effects of myrtle oil treatments (I: control, II: 0.1 % myrtle oil, III: 0.5 % myrtle oil) on microbiological and sensory quality characteristics of strawberries at 5 °C during 8 days Modified Atmosphere Packaging (MAP) storage. Bars indicate ± SE

the number of yeast and moulds, commencing 4.75 log cfu/g and reaching 3.93 log cfu/g by the 8th day of storage. The use of myrtle oil in combination with MAP apparently improves fruit safety extending the shelf life.

Earlier, the use of eugenol, thymol, menthol or eucalyptol reduced the growth of both mesophilic aerobic bacteria and yeast/mould load in cherry fruits (Serrano et al. 2005). The similar effect was also observed with the use of eugenol and thymol in table grapes (Valero et al. 2006). In both study, authors concluded that treatment compounds were more effective for reducing the growth of mould and yeast counts. The results of the microbial parameters in concern herein were to some extent well consistent with what was reported by Serrano et al. (2005) and Valero et al. (2006). The flora of yeast and moulds as well as the aerobic mesophilic microorganisms was not characterised not only in those earlier studies but also in the present study. Differences may be resulted from the type of microbial species in the fruits, type of fruit and treatment in concern or else extrinsic factors.

Significant differences were found across the treatment groups with respect to sensory quality, as illustrated in Fig. 3. However, the present study indicated that the best sensory quality was attained through the use of 0.5 % myrtle oil, which provided good preservation of product by reducing respiration as well as sensory decay (aroma, taste, and appearance). Likewise, Gunduz et al. (2009) also reported that treatments with 500 ppm myrtle oil for 5 min did not produce an adverse effect on sensory quality of lettuce and tomato.

To conclude, improvement of postharvest qualities of strawberries was achieved by the use of myrtle oil treatment. A concentration of 0.5 % myrtle oil in combination with MAP on strawberry fruits appeared to be more effective in maintaining the fruit quality and shelf life throughout storage. Even though the concentration used in this study significantly reduced the population of microorganisms, it was unable to inhibit their growth completely. A higher concentration might be required for inhibiting the growth of microorganisms; however, the use of strong flavour essential oil is likely to result in undesirable sensory qualities during storage. Therefore, the individual testing of the main constituents of the essential oil rather than crude oil or essential oil vapour in combination with passive or active MAP could be suggested for improving the treatment efficiency and for reducing flavour compounds.

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