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# Using Modified Atmosphere and Different Temperatures for Storing 'Kent' Mango Fruit

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**Abstract:** Mango fruits cv. 'Kent' (*Mangifera indica* L.) as a new and late cultivar were harvested at fully mature-green stage from "Nimos" farm, Giza governorate, Egypt. Fruits were placed in Modified Atmosphere Packages (MAP) at 5% $O_2$ + 5% $CO_2$, 5% $O_2$ + 10% $CO_2$ or 5% $O_2$ + 15% $CO_2$ and control, fruit were stored at 8, 10 or 15°C and 85-90% relative humidity (RH) during the two successive seasons of 2007 and 2008. Fruit quality parameters (texture, skin color, weight loss%, decay%, T.S.S. %, titratable acidity% and ascorbic acid content) were analyzed. As for Modified Atmosphere Packages (MAP), there was a direct relation between fruit texture and Hue angle values and the used concentrations of $CO_2$. While, an inversely relation was observed for fruit weight loss%, T.S.S. % and ascorbic acid content. Modified atmosphere treatments exhibited a significant lower titratable acidity as compared with control fruits under all temperature used, but no significant differences between all modified atmosphere packages were recorded after 6 weeks of storage period. As for the effect of storage temperature, an inversely relation was observed for texture, skin color (Hue angle) values, fruit weight loss% and ascorbic acid content. As respect of total acidity, no significant differences were noticed between all storage temperatures used till the end of the storage period. All used treatments did not give any discarded fruits (decay %) until 2 weeks of cold storage. However after 6 weeks of cold storage, control fruits exhibited the highest value of decay percentage, while the least value was recorded by 5%$O_2$+10%$CO_2$ treatment. Fruit stored at 8°C was distinctive as a short time of cold storage (until 4 week), while fruit stored at 10°C was the best storage temperature for the long time of cold storage (6 weeks). In brief, MAP as a storage technique at level of 5%$O_2$+10%$CO_2$ and stored at 8 and 10 °C and 85-90% RH was the best treatments with "Kent" mango fruits to inhibit the ripening process and maintain the postharvest quality for 4 to 6 weeks.

**Key words:** Mango · Kent · Cold storage · Low temperature · Modified atmosphere packages (MAP)

## INTRODUCTION

In Egypt, mango (*Mangifera indica*, L.) is the sixth most important fruit market after citrus, grapes, olives, apples and banana [1]. International trade of fresh mango still limited due to short season of fruits, short shelf-life and sensitive to storage temperatures below 12°C [2]. Storage is essential for extending the consumption period of mango fruits, regulating their supply to the market and also for long distance transportation. There are many factors which influence mango quality during storage; temperature is one of them. For successful storage it is necessary to efficiently control the temperature throughout the storage period [3]. Visual chilling injury symptoms include uneven ripening, surface pitting, shriveling and scald poor color and flavor, grayish scald-like skin discoloration, increased susceptibility to decay and, in severe cases, flesh browning [4,5]. Modified atmosphere (MA) is referred to as a relationship between product respiration and gas exchange within any form of structural enclosure [3]. Modified atmosphere storage technique can be used to maintain the postharvest quality of different fruits and inhibited the mango ripening process [6-8]. The main factors that retain mango quality in modified atmosphere package (MAP) are increased $CO_2$ levels and decreased $O_2$ levels which reduce respiration rates. Moreover, mango fruit stored in open atmosphere (in air) lost their green color while those stored in control atmosphere remained green and when transferred to air for normal ripening turned yellow but they were still more green than fruit stored continuously in air [9]. This mean that fruit stored at low oxygen

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concentration atmosphere showed decrease in respiration rate, ethylene production, flesh firmness or color losses and the fruit ripening is indicated by changes in respiration rate, flesh firmness and skin color. The delay in ripening, degradation of chlorophyll and retention of green color for a longer period also depend on types of coating [10, 11]. On the other hand, Control Atmosphere (CA) storage of mature green mangoes, "Tommy Atkins", "Haden", "keitt" and "Kent" can be tolerate and benefit from 3-4% $O_2$ plus 25% $CO_2$ for 3 weeks at 12°C, while tree-ripe fruit tolerated and benefited from the same levels of $O_2$ and $CO_2$ for 3 weeks at 8°C or 5% $O_2$ plus 10% $CO_2$ for 3 weeks at 5°C with no evidence of chilling injury [12]. Also, Trindad, *et al.* [13] found that, "Kent" mangoes were stored for 25 days at 13°C in air or in controlled atmospheres (5% $CO_2$ + 5% $O_2$ or 10% $CO_2$ + 5% $O_2$). There were no significant differences among treatments for flesh firmness, physiological weight loss and total soluble solids. However, after 21 days of storage, sensory tests indicated off-odors and off-flavors in samples stored in controlled atmospheres. Moreover, Yantarasri *et al.* [14] found that, film perforation delay softening and can reduce the weight loss of mango cv. "Nam Doc Mai". As respect of total soluble solids, titratable acidity and ascorbic acid content Trindad *et al.* [13] stored "Kent" mangoes for 25 days at 13°C in air or in controlled atmospheres (5% $CO_2$ + 5% $O_2$ or 10% $CO_2$ + 5% $O_2$). Results showed that, there were no significant differences among treatments for SSC and titratable acidity. This work is focused on "Kent" as new introduced mango cultivar. It has highly color and late season fruits. It is aimed to evaluate the effects of low temperatures (8, 13 and 15°C) on fruit quality to alleviate the incidence of chilling injury symptoms and extend storability. Also, desirable quality may be obtained by using some means to regulate the physical and chemical changes that may occur during storage, such as the modified atmosphere treatment.

## MATERIALS AND METHODS

The present investigation was planned and carried out during the two successive seasons of 2007 and 2008 at Nimos farm, Giza governorate, Egypt. Fifteen years old trees of "Kent" mango cultivar were the plant material used for this study. Fruits were picked at fully mature-green stage (126 days from full blooming in age, 550.20 to 556.40 $cm^3$ in volume, 12.30 to 12.50% in T.S.S. and 0.79 to 0.81% in titratable acidity) from all sides of the tree in the early morning and immediately transferred in refrigerated trucks at 13°C to the laboratory of Horticultural Research Institute at Giza. On arrival, fruits were washed with tap water and 2% boric acid then air dried. Only uniform fruits in size, color and free from any visible blemishes were selected and packed in single layer in carton boxes (approximate 5 Kg). Fruits were then divided into two groups. First group was subjected to Modified Atmosphere Packages (MAP) at three levels of $CO_2$ and the second one hadn't any treatments as a control. Each group was stored at 8 or 10 or 15°C and 85-90% relative humidity (RH). Each treatment had three replicates; each contained 9 carton boxes (9 fruits per box).

**Modified Atmosphere Packages:** Fruits were placed in non-perforated low-density polyethylene sealed bags (25X30 cm in size and 50±5 μ m. in thickness). Bags are coated with a natural mineral which was impregnated into low density polyethylene resin to produce a packaging film. The impregnated mineral is hydroscopic and has known absorptive characteristics e.g. remove ethylene gas as well as anti fog treatment to reduce water formation. Each bag contains one fruit. All bags were subjected to gas-flushed by Gasmixer as the following: 5% $O_2$ + 5% $CO_2$, 5% $O_2$ + 10% $CO_2$ or 5% $O_2$ + 15% $CO_2$ Fruit quality parameters of all group fruits were analyzed at two weeks intervals up to 6 weeks as follows:

**Physical Characteristics**

**Fruit Texture (gm/cm²):** Was determined by using a modern texture analyzer instrument by penetrating cylinder 5 mm diameter to constant distance with a constant speed 1 mm/second. The results were expressed as a resistance force of the skin or flesh (gm/ $cm^2$).

**Skin Color (Hue Angle):** Was determined by using a Hunter colorimeter type (DP-9000) for the estimation of a, b and hue angle (h°). In this system of color representation the values a* and b* describe a uniform two-dimensional color space, where a* is negative for green and positive for red and b* is negative for blue and positive for yellow. From a & b values, a/b were calculated Hue angle (h°= arc tan b*/a*) determines the red, yellow, green, blue, purple, or intermediate colors between adjacent pairs of these basic colors Hue angle (0°= red-purple, 90° = yellow, 180°=bluish-green, 270°= blue), as described by McGuire [15], Fig. (1).

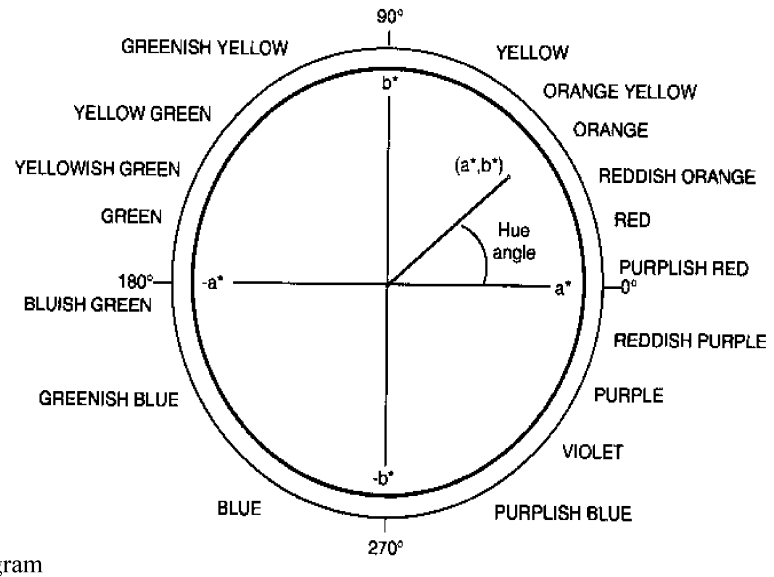


Fig. 1: Hue angle diagram

Weight loss percentage was calculated during storage as the following equation:

$$Weight\ loss\ \% = \frac{A-B}{A} X\ 100$$

Where:

A = The initial weight at start of storage.

B = Weight at inspect date

**Decay Percentage:** Unmarketable fruits including visual chilling injury symptoms were considered as decayed. Decay percentage was calculated according to the following equation.

$$Decay\% = \frac{A}{B} \times 100$$

Where:

A = No of decayed fruits at time of sampling.

B = The initial fruits number.

**Chemical Characteristics:** Total soluble solids percentage (T.S.S. %): T.S.S. percentage of the fruit juice was estimated by Abbe'digital refractometer, according to A.O.A.C. [16].

**Titratable Acidity Percentage:** Acidity percentage of the fruit juice was determined in terms of anhydrous malic acid percentage after titration against 0.1 N. Sodium hydroxide using phenolphthaline as an indicator according to A.O.A.C. [16].

**Ascorbic Acid Content (mg/100gm f. w.):** It was determined in fruit juice by using the dye 2, 6-dichlorophenyl indophenols method described in A.O.A.C., [16]. The results were calculated as mg per 100 gm fresh weight.

**Statistical Analysis Procedure:** All data parameters studied were analyzed as Factorial Completely Randomized Design in factorial arrangement with three replications. All data were subjected to statistical analysis as described by Snedecor and Cochran [17]. The differences between means were differentiated using Duncan multiple range test [18].

## RESULTS AND DISCUSSION

**Physical Characteristics:** Fruit texture: It is clear from data in Fig. (2) that, all used treatments reduced the rate of texture more than the initial sample as the fruit texture decline was towards the end of storage period. After 6 weeks of cold storage, the highest texture value (211.00 and 217.00 gm/cm$^2$) was obtained by 5%$O_2$+10%$CO_2$ treatment, while control fruits exhibited the lowest value (165.67 and 166.33 gm/cm$^2$) of texture in the first and second season, respectively. Significant differences between all treatments were observed in the two seasons (Fig. 3). On the other hand, fruits stored at 8°C recorded higher values (209.25 and 220.00gm/cm$^2$) of texture than those stored at 10 or 15°C at the end of storage period. Significant differences between all storage temperatures

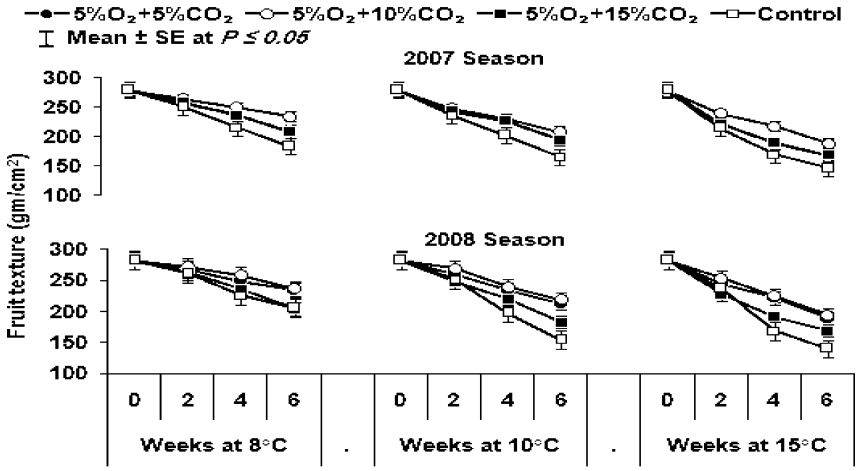


Fig. 2: Effect of modified atmosphere packages on fruit texture (gm/cm$^2$) of "Kent" mango cultiver during stronge at 8, 10 and 15°C in 2007 and 2008 seasons

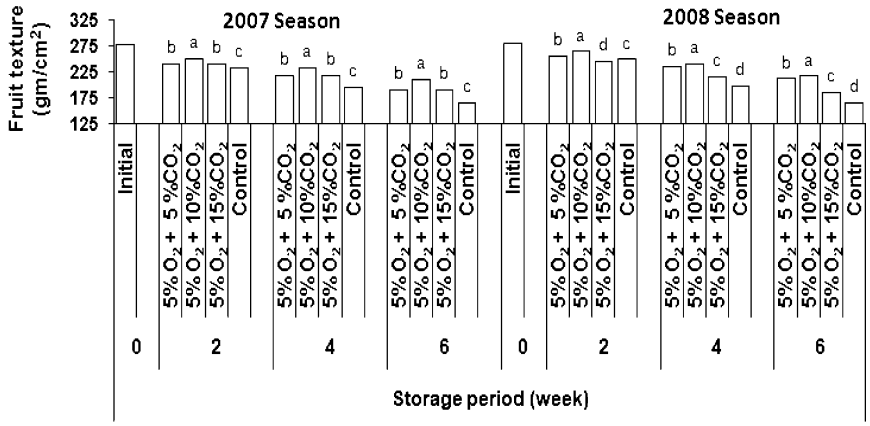


Fig. 3: Specific effect of modified atmosphere packages at different storage period on fruit texture (gm/cm$^2$) of "Kent" mango cultiver in 2007 and 2008 seasons. Mean with the same letter(s) are not significantaly diffrent at $P \leq 0.05$

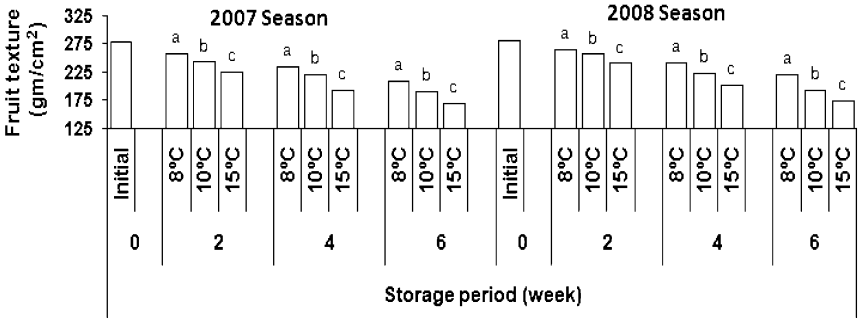


Fig. 4: Specific effect of storage temperature at different storage period on fruit texture (gm/cm$^2$) of "Kent" mango cultiver in 2007 and 2008 seasons. Mean with the same letter(s) are not significantaly diffrent at $P \leq 0.05$

were obtained during storage periods (Fig. 4). The reduction in texture score during storage might be due to the breakdown of insoluble pectic substances to soluble forms by a series of physicochemical changes that were caused by the action of pectic enzymes i.e. Esterase and polygalacturonidase formed in the tissues during

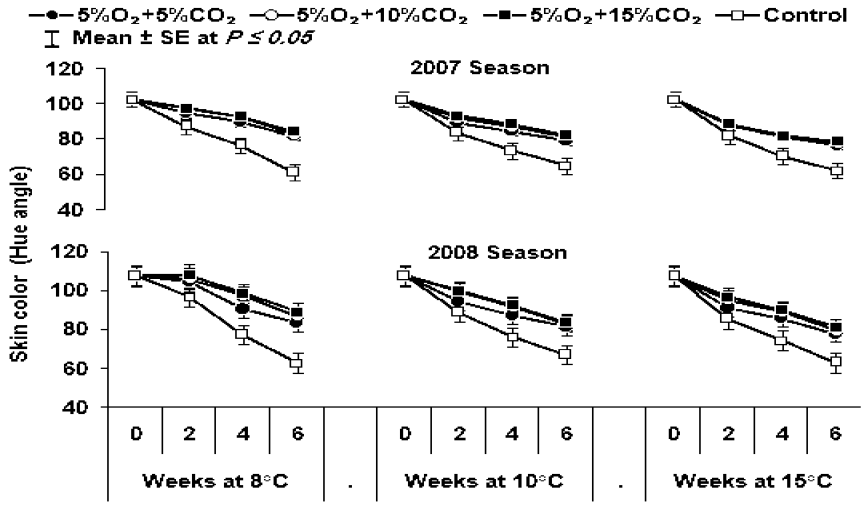


Fig. 5: Effect of modified atmosphere packages on skin color (Hue angle) of "Kent" mango cultiver during stronge at 8, 10 and 15°C in 2007 and 2008 seasons

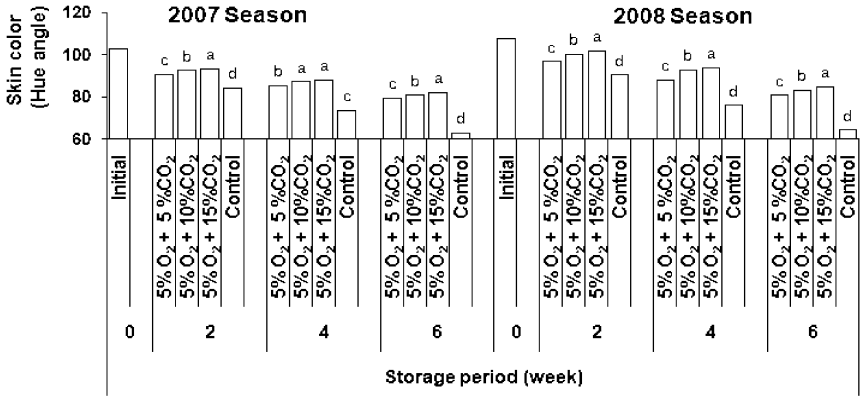


Fig. 6: Specific effect of modified atmosphere packages at different storage period on skin color (Hue angle) of "Kent" mango cultiver in 2007 and 2008 seasons. Mean with the same letter(s) are not significantaly diffrent at $P \leq 0.05$

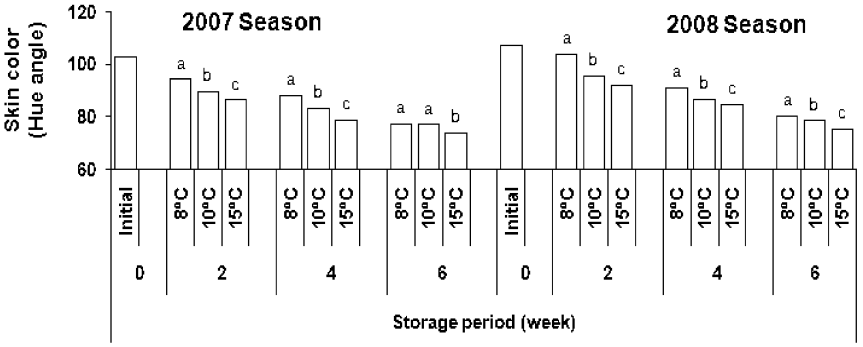


Fig. 7: Specific effect of storage temperature at different storage period on skin color (Hue angle) of "Kent" mango cultiver in 2007 and 2008 seasons. Mean with the same letter(s) are not significantaly diffrent at $P \leq 0.05$

ripening [19]. The faster reduction in texture score in control sample might also be due to accelerated ripening process in free atmospheric conditions of storage temperature etc. These results are in line with those obtained by Yantarasri *et al*., [14]. Authors found that film perforation delay softening and can reduce the weight loss of mango cv. "Nam Doc Mai".

**Fruit Skin Color (Hue Angle):** Results in Fig (5) cleared an evident decrease in skin color (Hue angle) with the advance in storage period in all used treatments. Modified atmosphere package exhibited significantly higher of Hue angle as compared with control fruits (Fig 6). The direct relation between $CO_2$ concentrations and hue angle values was observed. Control fruit treatment exhibited the least values of Hue angle (62.77 and 64.13) for skin color in the two seasons, respectively at the end of storage period. In the same time, there were inversely relation between storage temperatures and hue angle values (Fig 7). This mean that fruit stored at high $CO_2$ concentration atmosphere showed decrease in respiration rate, ethylene production, flesh firmness or color losses. These results are in agreement with those obtained on mango fruits by Manzano, *et al*., [10] and Kittur, *et al*., [11]. In this respect, Yahia and Hernandez [9] mentioned that the main factors that retain mango quality in modified atmosphere package (MAP) are increasing $CO_2$ levels and decreasing $O_2$ levels which reduce respiration rates. Moreover, mango fruit stored in open atmosphere (in air) lost their green color while those stored in control atmosphere remained green and when transferred to air for normal ripening turned yellow but they were still more green than fruit stored continuously in air.

**Weight Loss Percentage:** Results in Table (1) indicated that, a gradual increase in weight loss was shown towards the end of the storage period (6 weeks). Moreover, there were inversely relation between $CO_2$ concentrations and fruit weight loss percentage. The least weight loss percentage (7.86 and 8.71%) was recorded by $5\%O_2+15\%CO_2$ treatment in the first and second seasons, respectively after 6 weeks of cold storage.

On the other hand, there was a significant increase in fruit weight loss at high storage temperature (15°C) comparing with the other storage temperatures (8 and 10°C). Fruits stored at low temperature (8°C) recorded less weight loss percentage (7.44 and 7.80%) at the end of storage period than those stored at higher temperatures (10, 15°C). A significant difference between the three storage temperatures was observed in both seasons. These packages provide excellent hinder against moisture loss from fruits and slow its transpiration [20]. Allam *et al*. [21] found that, seal-packaging of Washington Navel orange fruits with shrinkable film of polyethylene reduced weight loss. Similar reduction was found by Sindhu and Singhort [22] with lemon fruits.

**Decay Percentage:** Data presented in Table (2) indicated that, all used treatments did not give any discarded fruits (decay percentage) until 2 weeks of storage periods. However after 4 weeks of cold storage, the untreated fruits (Control treatment) exhibited the highest value of decay percentage (27.77% and 30.54%) followed by $5\%O_2+15\%CO_2$ treatment (19.44%), while the least value (8.33% and 11.11%) was recorded by $5\%O_2+10\%CO_2$ treatment in the first and second seasons, respectively. On the other hand, the same pattern was observed after 6 weeks of cold storage, the highest value of decay percentage was recorded by control fruits (47.22 % and 47.23%) and the least value (13.89% and 16.67% ) was recorded by $5\%O_2+10\%CO_2$ treatment in the first and second seasons, respectively. Meanwhile, fruits stored at 15°C exhibited the highest value of decay percentage (20.82%) and (33.34% and 35.42%) after 4 and 6 weeks of cold storage in the first and second season, respectively. Nonetheless, fruit stored at 8°C was distinctive as a short time of cold storage (until 4 week), where recorded the least value of fruit decay (14.58% and 22.92%) in both season, respectively. On the contrary, 10°C was the best storage temperature as a long time of cold storage (6 weeks) and recorded the least value of fruit decay (27.08% and 27.09%) in both season, respectively.

Modified atmosphere (MA) is referred to as a relationship between product respiration and gas exchange within any form of structural enclosure. MA storage technique can be used to maintain the postharvest quality of different fruits [6]. Moreover, Yantarasri, *et al*. [14] found that film perforation delay softening and can reduce the weight loss of mango cv. "Nam Doc Mai". Principal disorder was chilling injury (CI) when "Kent" mango fruits were subjected to low temperature for long time. The symptoms include grayish scald like discoloration of the skin, skin pitting and uneven ripening. Salunkhe, *et al*. [23] reported that, peroxidase, invertase and cellulase activities in the peel of the mango fruit increased while amylase activity

Table 1: Effect of modified atmosphere packages on fruit weight loss% of Kent mango cultivar during storage at 8, 10 and 15°C in 2007 and 2008 seasons

| | | | | Storage periods (weeks) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2007 Season | | | | | | 2008 Season | | | | | |
| | M.A. Packages (Gas Treatments) | | | 2 | | 4 | | 6 | | 2 | | 4 | | 6 | |
| Storage Temp. | $O_2$ | | $CO_2$ | | | | | | | | | | | | |
| 8°C | 5% | | 5% | 2.66 | i | 5.31 | i | 6.81 | i | 2.84 | h | 5.56 | i | 6.96 | i |
| | | | 10% | 2.56 | j | 5.01 | j | 6.21 | j | 2.50 | i | 4.99 | j | 6.40 | j |
| | | | 15% | 2.13 | k | 4.26 | k | 5.45 | k | 2.48 | j | 4.96 | k | 6.36 | k |
| | | Control | | 5.36 | c | 9.61 | c | 11.30 | d | 5.54 | c | 9.86 | c | 11.50 | d |
| | | Mean | | 3.17 | C | 6.05 | C | 7.44 | C | 3.34 | C | 6.34 | C | 7.80 | C |
| 10°C | 5% | | 5% | 3.73 | f | 7.46 | f | 9.55 | f | 4.08 | f | 8.16 | f | 10.46 | f |
| | | | 10% | 3.63 | g | 7.26 | g | 9.31 | g | 3.90 | f | 7.81 | g | 10.00 | g |
| | | | 15% | 3.34 | h | 6.69 | h | 8.57 | h | 3.63 | g | 7.26 | h | 9.31 | h |
| | | Control | | 6.43 | b | 10.80 | b | 12.10 | b | 6.78 | b | 10.90 | b | 12.00 | b |
| | | Mean | | 4.28 | B | 8.05 | B | 9.88 | B | 4.60 | B | 8.53 | B | 10.44 | B |
| 15°C | 5% | | 5% | 4.43 | d | 8.86 | d | 11.36 | c | 4.59 | d | 9.18 | d | 11.77 | c |
| | | | 10% | 4.27 | e | 8.54 | e | 10.95 | e | 4.29 | e | 8.58 | e | 10.99 | e |
| | | | 15% | 3.73 | f | 7.46 | f | 9.56 | f | 4.08 | f | 8.16 | f | 10.46 | f |
| | | Control | | 7.13 | a | 11.20 | a | 13.50 | a | 7.29 | a | 11.00 | a | 13.30 | a |
| | | Mean | | 4.89 | A | 9.02 | A | 11.34 | A | 5.06 | A | 9.23 | A | 11.63 | A |
| Mean | | $5\%O_2 + 5\% CO_2$ | | 3.61 | B | 7.21 | B | 9.24 | B | 3.84 | B | 7.64 | B | 9.73 | B |
| | | $5\%O_2 + 10\% CO_2$ | | 3.49 | C | 6.94 | C | 8.82 | C | 3.56 | C | 7.13 | C | 9.13 | C |
| | | $5\%O_2 + 15\% CO_2$ | | 3.07 | D | 6.13 | D | 7.86 | D | 3.40 | D | 6.79 | D | 8.71 | D |
| | | Control | | 6.31 | A | 10.54 | A | 12.30 | A | 6.54 | A | 10.59 | A | 12.27 | A |

Values followed by the same letter (s) are not significantly different at $P \leq 0.05$

Table 2: Effect of modified atmosphere packages on fruit decay % of Kent mango cultivar during storage at 8, 10 and 15°C in 2007 and 2008 seasons

| | | | | Storage periods (weeks) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2007 Season | | | | | | 2008 Season | | | | | |
| | M.A. Packages (Gas Treatments) | | | 2 | | 4 | | 6 | | 2 | | 4 | | 6 | |
| Storage Temp. | $O_2$ | | $CO_2$ | | | | | | | | | | | | |
| 8°C | 5% | | 5% | 0.00 | | 8.33 | e | 33.33 | d | 0.00 | | 25.00 | e | 33.33 | d |
| | | | 10% | 0.00 | | 8.33 | e | 16.67 | e | 0.00 | | 16.67 | e | 25.00 | f |
| | | | 15% | 0.00 | | 16.67 | c | 41.70 | d | 0.00 | | 16.67 | c | 33.33 | b |
| | | Control | | 0.00 | | 25.00 | b | 50.00 | a | 0.00 | | 33.33 | b | 50.00 | a |
| | | Mean | | 0.00 | | 14.58 | C | 35.43 | A | 0.00 | | 22.92 | A | 35.42 | A |
| 10°C | 5% | | 5% | 0.00 | | 16.67 | c | 25.00 | e | 0.00 | | 16.67 | c | 25.00 | e |
| | | | 10% | 0.00 | | 8.33 | d | 8.33 | g | 0.00 | | 8.33 | d | 8.33 | g |
| | | | 15% | 0.00 | | 16.67 | c | 33.33 | d | 0.00 | | 16.67 | c | 33.33 | d |
| | | Control | | 0.00 | | 25.00 | b | 41.67 | b | 0.00 | | 25.00 | b | 41.70 | c |
| | | Mean | | 0.00 | | 16.67 | B | 27.08 | B | 0.00 | | 16.67 | C | 27.09 | C |
| 15°C | 5% | | 5% | 0.00 | | 16.67 | c | 25.00 | d | 0.00 | | 16.67 | c | 33.33 | e |
| | | | 10% | 0.00 | | 8.33 | e | 16.67 | f | 0.00 | | 8.33 | e | 16.67 | f |
| | | | 15% | 0.00 | | 25.00 | b | 41.67 | c | 0.00 | | 25.00 | b | 41.67 | c |
| | | Control | | 0.00 | | 33.30 | a | 50.00 | a | 0.00 | | 33.30 | a | 50.00 | a |
| | | Mean | | 0.00 | | 20.82 | A | 33.34 | A | 0.00 | | 20.82 | B | 35.42 | B |
| Mean | | $5\%O_2 + 5\% CO_2$ | | 0.00 | | 13.89 | C | 27.78 | C | 0.00 | | 19.44 | C | 30.56 | C |
| | | $5\%O_2 + 10\% CO_2$ | | 0.00 | | 8.33 | D | 13.89 | D | 0.00 | | 11.11 | D | 16.67 | D |
| | | $5\%O_2 + 15\% CO_2$ | | 0.00 | | 19.44 | B | 38.90 | B | 0.00 | | 19.44 | B | 36.11 | B |
| | | Control | | 0.00 | | 27.77 | A | 47.22 | A | 0.00 | | 30.54 | A | 47.23 | A |

Values followed by the same letter (s) are not significantly different at $P \leq 0.05$

Table 3: Effect of modified atmosphere packages on T.S.S. % of Kent mango cultivar during storage at 8, 10 and 15°C in 2007 and 2008 seasons

| | | | Storage periods (weeks) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M.A. Packages (Gas Treatments) | | 2007 Season | | | | | | | | 2008 Season | | | | | | | |
| | | | 0 | | 2 | | 4 | | 6 | | 0 | | 2 | | 4 | | 6 | |
| Storage Temp. | $O_2$ | $CO_2$ | | | | | | | | | | | | | | | | |
| 8°C | 5% | 5% | 12.30 | a | 13.82 | fg | 14.97 | h | 19.39 | g | 12.60 | a | 13.52 | h | 14.36 | h | 16.44 | j |
| | | 10% | 12.30 | a | 13.74 | h | 14.94 | i | 19.13 | i | 12.60 | a | 13.52 | h | 14.36 | h | 16.27 | k |
| | | 15% | 12.30 | a | 13.71 | i | 14.58 | k | 18.49 | k | 12.60 | a | 13.35 | i | 14.05 | i | 16.25 | l |
| | Control | | 12.30 | a | 16.52 | b | 19.27 | b | 20.69 | c | 12.60 | a | 16.22 | c | 18.66 | c | 20.74 | c |
| | Mean | | 12.30 | A | 14.45 | B | 15.94 | B | 19.43 | C | 12.60 | A | 14.15 | C | 15.36 | C | 17.42 | C |
| 10°C | 5% | 5% | 12.30 | a | 13.83 | fg | 15.07 | g | 19.67 | e | 12.60 | a | 14.03 | e | 15.29 | e | 17.54 | f |
| | | 10% | 12.30 | a | 13.82 | fg | 14.94 | i | 19.30 | h | 12.60 | a | 13.69 | g | 14.67 | g | 16.98 | h |
| | | 15% | 12.30 | a | 13.81 | g | 14.81 | j | 18.95 | j | 12.60 | a | 13.52 | h | 14.36 | h | 16.79 | i |
| | Control | | 12.30 | a | 16.53 | b | 18.87 | c | 22.47 | b | 12.60 | a | 16.73 | b | 19.09 | b | 21.34 | b |
| | Mean | | 12.30 | A | 14.50 | B | 15.92 | B | 20.10 | B | 12.60 | A | 14.49 | B | 15.85 | B | 18.16 | B |
| 15°C | 5% | 5% | 12.30 | a | 14.12 | c | 15.63 | d | 20.34 | d | 12.60 | a | 14.37 | d | 15.91 | d | 18.27 | d |
| | | 10% | 12.30 | a | 14.09 | d | 15.27 | e | 19.43 | f | 12.60 | a | 14.03 | e | 15.29 | e | 17.71 | e |
| | | 15% | 12.30 | a | 14.01 | e | 15.24 | f | 19.43 | f | 12.60 | a | 13.86 | f | 14.98 | f | 17.52 | g |
| | Control | | 12.30 | a | 16.82 | a | 19.43 | a | 23.14 | a | 12.60 | a | 17.07 | a | 19.71 | a | 22.07 | a |
| | Mean | | 12.30 | A | 14.76 | A | 16.39 | A | 20.59 | A | 12.60 | A | 14.83 | A | 16.47 | A | 18.89 | A |
| Mean | $5\%O_2 + 5\% CO_2$ | | 12.30 | A | 13.92 | B | 15.22 | B | 19.80 | B | 12.60 | A | 13.97 | B | 15.19 | B | 17.41 | B |
| | $5\%O_2 + 10\% CO_2$ | | 12.30 | A | 13.88 | B | 15.05 | B | 19.29 | C | 12.60 | A | 13.75 | B | 14.77 | C | 16.99 | C |
| | $5\%O_2 + 15\% CO_2$ | | 12.30 | A | 13.84 | B | 14.88 | B | 18.96 | C | 12.60 | A | 13.58 | B | 14.46 | C | 16.85 | C |
| | Control | | 12.30 | A | 16.62 | A | 19.19 | A | 22.10 | A | 12.60 | A | 16.67 | A | 19.15 | A | 21.38 | A |

Values followed by the same letter (s) are not significantly different at $P \leq 0.05$

Table 4: Effect of modified atmosphere packages on total acidity % of Kent mango cultivar during storage at 8, 10 and 15°C in 2007 and 2008 seasons

| | | | Storage periods (weeks) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M.A. Packages (Gas Treatments) | | 2007 Season | | | | | | | | 2008 Season | | | | | | | |
| | | | 0 | | 2 | | 4 | | 6 | | 0 | | 2 | | 4 | | 6 | |
| Storage Temp. | $O_2$ | $CO_2$ | | | | | | | | | | | | | | | | |
| 8°C | 5% | 5% | 0.814 | a | 0.626 | c-e | 0.451 | bc | 0.360 | ef | 0.803 | a | 0.640 | bc | 0.487 | c | 0.400 | e |
| | | 10% | 0.814 | a | 0.651 | ab | 0.460 | ab | 0.400 | d | 0.803 | a | 0.668 | a | 0.524 | b | 0.420 | d |
| | | 15% | 0.814 | a | 0.657 | a | 0.470 | a | 0.420 | g | 0.803 | a | 0.677 | a | 0.542 | a | 0.450 | c |
| | Control | | 0.814 | a | 0.606 | fg | 0.411 | e | 0.530 | b | 0.803 | a | 0.620 | de | 0.447 | e | 0.550 | b |
| | Mean | | 0.814 | A | 0.635 | A | 0.448 | A | 0.428 | A | 0.803 | A | 0.651 | A | 0.500 | A | 0.455 | A |
| 10°C | 5% | 5% | 0.814 | a | 0.605 | fg | 0.417 | e | 0.370 | ef | 0.803 | a | 0.610 | ef | 0.468 | d | 0.370 | f |
| | | 10% | 0.814 | a | 0.620 | d-f | 0.422 | de | 0.350 | f | 0.803 | a | 0.626 | c-e | 0.487 | c | 0.380 | f |
| | | 15% | 0.814 | a | 0.641 | a-c | 0.454 | a-c | 0.320 | g | 0.803 | a | 0.645 | b | 0.511 | b | 0.400 | e |
| | Control | | 0.814 | a | 0.585 | hi | 0.377 | f | 0.540 | ab | 0.803 | a | 0.590 | g | 0.428 | f | 0.560 | b |
| | Mean | | 0.814 | A | 0.613 | B | 0.417 | B | 0.395 | A | 0.803 | A | 0.618 | B | 0.473 | B | 0.428 | A |
| 15°C | 5% | 5% | 0.814 | a | 0.596 | gh | 0.404 | e | 0.350 | f | 0.803 | a | 0.590 | g | 0.419 | f | 0.380 | f |
| | | 10% | 0.814 | a | 0.610 | e-g | 0.414 | e | 0.400 | d | 0.803 | a | 0.600 | fg | 0.454 | de | 0.400 | e |
| | | 15% | 0.814 | a | 0.635 | b-d | 0.437 | cd | 0.420 | c | 0.803 | a | 0.631 | b-d | 0.450 | e | 0.420 | d |
| | Control | | 0.814 | a | 0.576 | i | 0.364 | f | 0.550 | a | 0.803 | a | 0.570 | h | 0.379 | g | 0.580 | a |
| | Mean | | 0.814 | A | 0.604 | B | 0.404 | B | 0.430 | A | 0.803 | A | 0.598 | B | 0.425 | C | 0.445 | A |
| Mean | $5\%O_2 + 5\% CO_2$ | | 0.814 | A | 0.609 | C | 0.424 | B | 0.360 | B | 0.803 | A | 0.613 | C | 0.458 | C | 0.383 | B |
| | $5\%O_2 + 10\% CO_2$ | | 0.814 | A | 0.627 | B | 0.432 | B | 0.383 | B | 0.803 | A | 0.631 | B | 0.488 | B | 0.400 | B |
| | $5\%O_2 + 15\% CO_2$ | | 0.814 | A | 0.644 | A | 0.454 | A | 0.387 | B | 0.803 | A | 0.651 | A | 0.501 | A | 0.423 | B |
| | Control | | 0.814 | A | 0.589 | D | 0.384 | C | 0.540 | A | 0.803 | A | 0.593 | D | 0.418 | D | 0.563 | A |

Values followed by the same letter (s) are not significantly different at $P \leq 0.05$

Table 5: Effect of modified atmosphere packages on V.C. content (mg/100 gm f.w.) of Kent mango cultivar during storage at 8, 10 and 15°C in 2007 and 2008 seasons

| | | | Storage periods (weeks) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M.A. Packages (Gas Treatments) | | 2007 Season | | | | | | | | 2008 Season | | | | | | | |
| | | | 0 | | 2 | | 4 | | 6 | | 0 | | 2 | | 4 | | 6 | |
| Storage Temp. | $O_2$ | $CO_2$ | | | | | | | | | | | | | | | | |
| 8°C | 5% | 5% | 22.50 | a | 19.58 | a | 17.14 | a | 14.70 | c | 22.30 | a | 19.97 | a | 18.74 | a | 16.50 | b |
| | | 10% | 22.50 | a | 19.46 | b | 16.93 | b | 15.80 | b | 22.30 | a | 19.85 | b | 17.53 | b | 15.20 | d |
| | | 15% | 22.50 | a | 19.35 | d | 16.73 | d | 14.10 | f | 22.30 | a | 19.74 | d | 17.32 | d | 14.90 | g |
| | Control | | 22.50 | a | 19.33 | e | 16.69 | e | 14.14 | e | 22.30 | a | 19.72 | e | 17.28 | d | 14.94 | f |
| | Mean | | 22.50 | A | 19.43 | A | 16.87 | A | 14.69 | A | 22.30 | A | 19.82 | A | 17.72 | A | 15.39 | A |
| 10°C | 5% | 5% | 22.50 | a | 19.43 | c | 16.86 | c | 14.30 | d | 22.30 | a | 19.81 | c | 17.46 | c | 15.10 | e |
| | | 10% | 22.50 | a | 19.31 | f | 16.66 | f | 16.00 | a | 22.30 | a | 19.70 | f | 17.25 | e | 16.02 | c |
| | | 15% | 22.50 | a | 19.28 | g | 16.59 | g | 13.90 | i | 22.30 | a | 19.66 | g | 17.18 | f | 14.70 | j |
| | Control | | 22.50 | a | 19.26 | h | 16.55 | h | 13.94 | h | 22.30 | a | 19.64 | h | 17.14 | g | 14.74 | i |
| | Mean | | 22.50 | A | 19.32 | B | 16.66 | B | 14.54 | B | 22.30 | A | 19.70 | B | 17.25 | B | 15.14 | B |
| 15°C | 5% | 5% | 22.50 | a | 19.31 | f | 16.66 | f | 14.00 | g | 22.30 | a | 19.69 | f | 17.24 | e | 14.80 | h |
| | | 10% | 22.50 | a | 19.24 | i | 16.52 | i | 15.80 | b | 22.30 | a | 19.62 | i | 17.11 | h | 16.85 | a |
| | | 15% | 22.50 | a | 19.20 | j | 16.45 | j | 13.70 | j | 22.30 | a | 19.58 | j | 17.04 | i | 14.50 | k |
| | Control | | 22.50 | a | 19.18 | j | 16.41 | k | 13.66 | k | 22.30 | a | 19.56 | k | 17.00 | j | 14.46 | l |
| | Mean | | 22.50 | A | 19.23 | C | 16.51 | C | 14.29 | C | 22.30 | A | 19.61 | C | 17.10 | C | 15.15 | B |
| Mean | $5\%O_2 + 5\% CO_2$ | | 22.50 | A | 19.44 | A | 16.89 | A | 14.33 | B | 22.30 | A | 19.82 | A | 17.81 | A | 15.47 | B |
| | $5\%O_2 + 10\% CO_2$ | | 22.50 | A | 19.34 | B | 16.70 | B | 15.87 | A | 22.30 | A | 19.72 | B | 17.29 | B | 16.03 | A |
| | $5\%O_2 + 15\% CO_2$ | | 22.50 | A | 19.28 | C | 16.59 | C | 13.90 | C | 22.30 | A | 19.66 | C | 17.18 | C | 14.70 | C |
| | Control | | 22.50 | A | 19.26 | C | 16.55 | C | 13.92 | C | 22.30 | A | 19.64 | C | 17.14 | C | 14.72 | C |

Values followed by the same letter (s) are not significantly different at $P \leq 0.05$

decreased during the development of chilling injury (CI). Nonetheless, Trindad, *et al.* [13] noted that the mangoes cv. "Kent" is highly perishable and that their normal useful life after harvest is 14 to 21 days when kept at 10 to 12°C. Controlled atmospheres did not have any benefit over refrigeration in extending the storage life of "Kent" mangoes.

**Chemical Characteristics**

**Total Soluble Solids Percentage:** T.S.S % increased with the advance in cold storage up to 6 weeks (Table 3). The highest percentage of T.S.S (22.1% and 21.38%) was obtained by control treatment at the end of cold storage in the two seasons, respectively. The least percentage was recorded by $5\%O_2$+$15\%CO_2$ and $5\%O_2$+$10\%CO_2$ treatments (18.96% and 19.29) in the first season and (16.85 and 16.99%) in the second season with no significant differences between them in both seasons, respectively. As for the effect of storage temperature, data revealed that a direct proportion between the degree of storage temperature and values of T.S.S. percentage. The highest degree of storage temperature (15°C) recorded the highest value (20.59% and 18.89%) after 6 weeks of storage period in both season, respectively compared to those stored at low temperature (8, 10°C). It may be noticed that the changes in T.S.S. at the storage periods are resultant of three aspects, i.e., respiration, inversion of insoluble compounds to simpler forms and moisture loss by evaporation. So, the tendency of T.S.S. to increase at storage period may be attributed to the quick conversion of insoluble solids to soluble ones beside the high rate of moisture loss. These results were in coinciding with those reported by Bagdady, *et al.* [24] on "Washington" Navel orange fruits. Author's found that, the high-density Polyethylene (HDPE) film or other anti-transpirant treatments caused an increase in total soluble solids of the juice compared with that of untreated fruits after 60 and 90 days of storage. Otherwise, Trindad, *et al.* [13] with "Kent" mangoes, Allam, *et al.* [21] with "Washington" Navel orange and Mansour and El-Oraby [25] with lemon fruits found that, modified atmosphere package had no significant effect on SSC content of fruits under study.

**Titratable Acidity Percentage:** As shown in Table (4), data indicated that total acidity % decreased with the progress in storage period up to 4 weeks, then increased up to the end for control and 15°C of storage temperature.

Modified atmosphere treatments exhibited significantly lower titratable acidity contents as compared with control fruits. At the end of cold storage, there were no significant differences between all modified atmosphere packages. Moreover, control fruit exhibited the highest percentage (0.540 and 0.563) of total acidity in both seasons, respectively. Moreover, no significant differences were recorded between the three storage temperatures in this respect after 6 weeks of storage period. In this respect, Trindad, *et al.* [13] found that no significant differences among controlled atmospheres of stored 'Kent' mangoes at 13°C on titratable acidity.

**Ascorbic Acid Content (mg/100gm f. w.):** Generally, the amounts of Ascorbic acid exhibited a decrease trend with the advance storage period throughout the two seasons (Table 5). After 6 weeks of cold storage, the highest values (15.87 and 16.03 mg/100gm f. w.) were observed in the fruits treated by $5\%O_2 + 10\%CO_2$. The least value were recorded by $5\%O_2+15\%CO_2$ treatment and control (13.90 and 13.92 mg/100gm f. w) in the first season and (14.70 and 14.72 mg/100gm f. w) in the second season with no significant differences between them in the both seasons, respectively. Data also revealed that, an inversely relation between the degree of storage temperature and values of Ascorbic acid. At the end experiment, the least degree of storage temperature (8°C) recorded the highest value (14.69 and 15.39 mg/100gm f. w), in both season, respectively. Similar results were found by Abd El-Hafeez [20] on "Costata" persimmon fruits. Untreated fruits lost more of their vitamin C content than that with shrinkable film due to the oxidation reaction which took place when fruits were directly exposed to normal atmospheres.

## CONCLUSION

Modified atmosphere packages (MAP) as a storage technique at level of $5\%O_2+10\%CO_2$ and stored at 8 and 10°C and 85-90% relative humidity can be used with "Kent" mango fruits to inhibit the ripening process and maintain the postharvest quality for 6 weeks.

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