MODIFIED ATMOSPHERE PACKAGES FOR FRESH SQUASH FRUITS STORAGE

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ABSTRACT

The main aim of this study is to investigate the effect of modified atmosphere (MA) on the quality of squash during storage. Squash fruits were stored at three levels of O_2 concentrations (1, 3 and 5%), three levels of CO_2 concentrations (2, 6 and 10%) under cold storage at 10 °C and 70 % relative humidity as compared with storage in normal air (22C and 70%RH) in perforated and non-perforated packages. CO2, O2 and ethylene inside the packages were recorded. Also, weight loss, hardness and color of fruits were determined. The obtained results indicated that, the concentration CO_2 inside the package of fresh squash during storage ranged from 4.71 to 24.02 % for all treatment. The CO_2 and ethylene concentrations inside the package increases with increasing CO_2 and O_2 levels during storage, while, O_2 concentrations inside the package decreases with increasing CO_2 and O_2 levels during storage. The accumulated weight loss of squash increased from 0 to 2.17, 0 to 2.48 and 0 to 2.80 %, when the storage period increased from 0 to 14 days at 1, 3 and 5% O_2 levels, respectively compared to 35% for normal air (traditional storage). The squash hardness slightly decreased with storage time, the MA storage had slight effect on the hardness. Package perforation obtained a good results in terms of weight loss compared to the traditional storage. The colour (L) of squash decreases with increasing CO_2 level during storage period.*

Keywords: *Squash, Modified atmosphere, Quality, Perforation, shelf life*

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1. INTRODUCTION

Squash fruits are perishable living tissues that continue to respire after harvest. Respiration and transpiration affecting the quality of the stored commodities. Deterioration and spoilage are also affecting the shelf life of it. To prolong the shelf life and keep quality of perishables is by using cooling and maintaining the produce at low temperatures **(Ryall and Lipton, 1979 and Mitchell, 1992)**. Another technique, especially as a complement to temperature management, is modification of the atmosphere surrounding the product to create a new atmosphere that usually has a lower level of O_2 and a higher level of CO_2. At these levels of O_2 and CO_2, the respiration rate of most commodities will decrease, and their shelf-life will be extended **(Geeson, 1990)**.

The modified atmosphere (MA) has a great success in many vegetables. This technique consists of an increase in the partial pressure of the CO_2 and a decrease in the O_2 **(Silveira *et al.*, 2014)**, caused by the gas exchanges of the container with the ambient air. The packaging with low partial pressure of oxygen can reduce the respiration rate and maintain the shelf-life for a longer time or with better quality than the package with normal air. However, the extremely low oxygen content may result, in some cases, in fermentation resulting in an accumulation of unpleasant odors and tastes, reducing the aroma biosynthesis and tissue damage **(Li *et al.*, 2014)**. In this type of atmosphere, the partial pressure of O_2 and CO_2 are not controlled, and vary with time, temperature, type of film and the respiratory rate of the product **(Chitarra and Chitarra, 2005)**.

Several packaging techniques and materials may be used in MAP: polymeric films, rigid plastic trays or preformed pouches closed by heat sealing **(Geeson *et al.*, 1985, Barmore, 1987, Geeson *et al.*, 1988 and Talasila *et al.*, 1995a)** and perforations in otherwise impermeable packages. In the case of polymeric films, the proper atmosphere is obtained by selecting a film with the right gas transmission rate and having the appropriate surface area for the package. For impermeable plastics, the package gas permeability may be achieved by using perforations **(Geeson *et al.*, 1988 and Emond *et al.*, 1991)**. **Emond and Chau (1990)** proposed the use of perforations for products requiring high CO_2 (10 – 20%) with low levels of O_2 (2 – 10%). Because their permeability ratios are close to one, perforation systems can obtain a high CO_2 concentration without reducing the O_2 concentration inside the package below critical levels tolerated by the product.

With whole zucchini squash fruit, a 1% O2 atmosphere at 2.5C (Wang and Ji, 1989) or 5% CO2 at 5C (Mencarelli, 1987) reduced chilling injury and subsequent decay. A 2% O2 at 10C was reported to minimize development of off flavor, which was more pronounced in cooked than in raw fruit (Mencarelli et al., 1983). Slices of zucchini squash may tolerate O2 atmosphere of 1% because they do not have a continuous barrier to gases. The distance of gas diffusion is less in slices than whole fruit, which would result in a smaller gradient of O2. Equally important is the determination of the minimum O2 level that zucchini squash slices could tolerate in MA of film wrapped packages held at 5 to 10 C.

Modified atmosphere packaging (MAP) is a postharvest tool used to preserve quality of various fresh whole and minimally processed fruit and vegetables. MAP relies on the dynamic process of alteration of gaseous composition inside a package determined by permeability of packaging film and produce respiration. However, barrier properties to gases (O_2 and CO_2) and water vapour limit MAP applicability of many commercial polymeric films **(Mangaraj *et al.*, 2009)**. Conventional (passive MAP) that uses high barrier polymeric films are characterized by the generation of unsuitable in package gas composition, condensation of water vapour and subsequent microbial growth causing loss of quality and impaired shelf-life **(Mistriotis *et al.*, 2011)**.

One way to prolong the shelf life and keep quality of perishables is by cooling and maintaining the produce at low temperatures and using the modified atmosphere storage, therefore, the main aim of this study is to investigate the effect of modified atmosphere levels and package perforation on the quality and shelf life of fresh squash fruits during storage.

2. MATERIALS AND METHODS

The experiment was carried out at Agricultural and Bio-Systems Engineering Department Faculty of Agriculture Moshtohor, Benha University, Egypt and Food Technology Research Institute, Agriculture Research Center, during 2018 season.

2.1. Raw Materials:

Squash (*Cucurbita pepo L.*) was brought from the Experimental Research Station at the Faculty of agriculture, Moshtohor, Benha University after harvesting at the same maturity stage. Squash fruits washed and inspected for any damage and infection.

2.2. Methods:

Experiment was divided into two parts, first part was devoted to study the effect of atmospheric modification by raising CO_2 and lowering O_2. Second part was devoted to study the effect of package perforations compared to traditional storage as shown in table (1). Three levels of O_2 and CO_2 were used (1, 3 and 5 % O_2) and (2, 6 and 10 % CO_2). Squash Fruits were placed in package at a rate of 200 g per package. Packages were divided into two groups. One group for gas modification and the others were perforated at a rate 10, 20 and 30 punches packages (0.962, 1.934 and 2.886 mm2 surface areas).

2.2.1. Experimental design:

The treatments were arranged in a split plot design in three replications. Table (1) shows the experimental design.

Table (1): The experimental design.

No.	Independent variables	Runs No.	Levels No.	Independent variables levels
1	Gas modification	3	3	Oxygen: 1,3 and 5 %
		3	3	Carbon Dioxide: 2, 6 and 10%
2	Perforation (normal air)	3	3	Numbers: 10, 20 and 30 punches
3	Control	3	1	Traditional stoage
Total runs = 9 Gas modification × 3 runs + 3 Perforations × 3 runs +1 Control × 3 runs = 39 runs.				

2.2.2. Measurements:

O_2, CO_2 and ethylene were measured by Gas Analyzer (Model F-95 - Range 0 to 200±0.1 ppm for ethylene, 0 to 100±0.01% for CO_2 and 0 to 100±0.1% for O_2, USA) within the closed system after the 4, 8, 12 and 14 days period. Before any measurement was taken, the equipment was calibrated. Calculation of the respiration rate was done using the formula below as stated by **Saltveit (2004)**:

$$\textit{respiration}\ \mathrm{rate\,(ml/kg.hr)} = \frac{V_c \times \%CO_2}{W_p \times T \times 100} \quad (1)$$

Where:

V_c is the volume package (L)

W_p is the weight of sample (kg)

T is the time (hr)

Samples were taken after the 4, 8, 12 and 14 days period to determine the moisture loss. Squash samples were weighed by electric digital balance (Model HG – 5000 – Range 0 - 5000 g ± 0.01 g, Japan) before and after drying.

The hardness was measured weekly by Hardness meter (Model GY-1-Range 2-15 kg cm^{-2} ± 0.1 kg cm^{-2}, China). The surface color of squash fruits for each sample was measured with a chroma meter (Model CR-300, Minolta, Japan) and results were expressed as L* and hue angle (arctangent{b*/a*}) values **(Izumi and Watada, 1995)**.

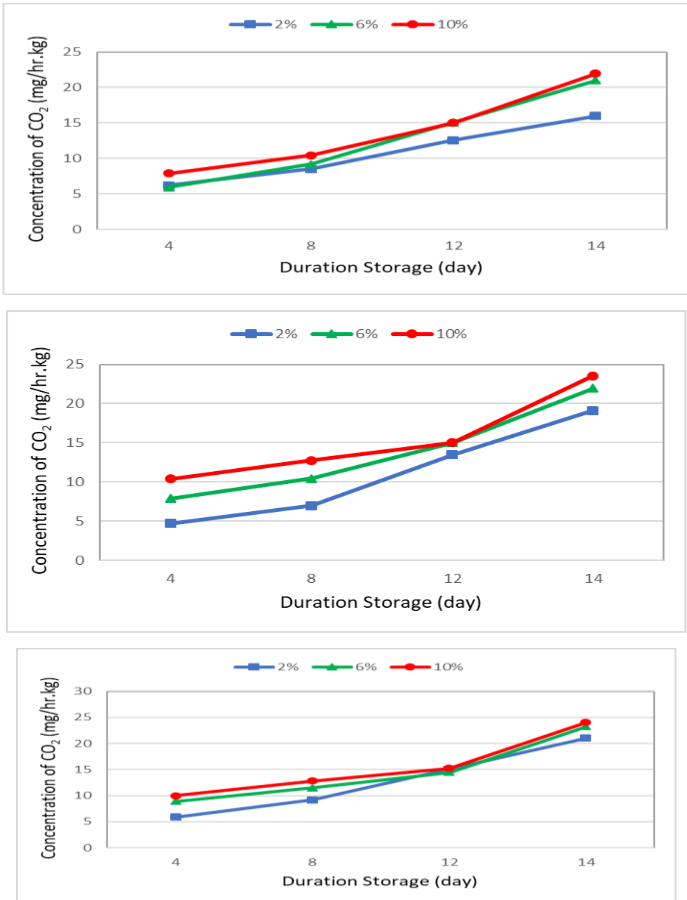
3. RESULTS AND DISCUSSION

3.1. Concentration CO_2 inside the package of squash:

Figures (1 a, b and c) show the effect of modified atmosphere condition (different levels of O_2 and CO_2) on the respiration rate of fresh squash in package. It could be seen that storing squash in different levels of O_2 (1, 3 and 5%) and CO_2 (2, 6 and 10%) in a closed (non-perforation) package caused an accumulation of CO_2 inside the package. CO_2 concentration recorded 15.99% after 14 days storage at 1% O_2 and 2% CO_2 levels, while it reached the highest concentration (24.02%) for the 5% O_2 and 10% CO_2 level treatment after the same period.

The CO_2 concentration inside the package increases with increasing CO_2 and O_2 levels during experimental period, at 1% O_2 concentration, CO_2 concentration inside the package increases from 6.18 to 7.88, 8.49 to 10.43, 12.54 to 15.03 and 15.99 to 21.94 mg/ kg.hr when the CO_2 level increased from 2 to 10% after 4, 8, 12 and 14 days, respectively. At 3% O_2 concentration, CO_2 concentration inside the package changed from 4.71 - 23.55% depending on CO_2 treatment. At 5% O_2, the least CO_2

concentration (5.91%) was recorded at 2% CO_2 in package after 4 days, while the highest CO_2 level (24.02%) was recorded at 10% CO_2 treatment after 14 days.



a

b

c

Figure (1): The effect of modified atmosphere condition (different levels of O_2 and CO_2) on the concentration CO_2 inside the package of fresh squash during storage.

Regarding the effect of perforation the CO_2 concentration inside the package as shown in figure (2), the results indicate that the CO_2% decreased with increasing the perforation, where it was 5.49% for 10 punches after 4 days and decreased to 3.91% for 30 P after the same period. After 14 days storage CO_2 decreased to 3.54 % for the 30 P packages while it was 1.38 % for 10 P package after the same period.

Perforation had lowered the CO_2 accumulation. CO_2 accumulation is depending on perforation surface area. Perforation was drilled through the package. PET plastic container of volume 1250 ml capacity. 10, 20 and 30 holes with diameter of 0.35 mm with area 0.961, 1.92 and 2.88 mm^2 surface areas.

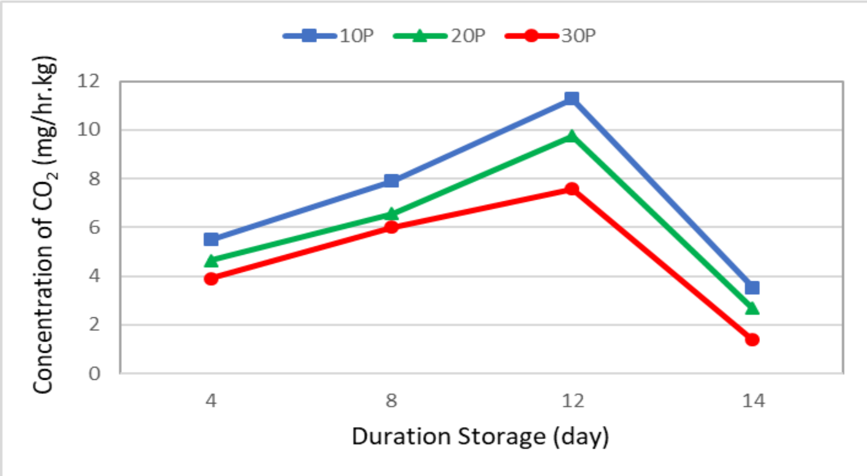


Figure (2): The effect of different perforation surface areas on the concentration CO_2 inside the package of fresh squash during storage.

3.2. Concentration O_2 inside the package:

Figure (3) shows the O_2 concentration inside the squash package during storage as affected by different levels of O_2 and CO_2 concentration. The results show that with increasing the O_2 inside the package. The concentration of O_2 decreased with storage time, where it decreased slightly by increasing CO_2 inside the package. It changed from 1 to 1.63% at 1% O_2 with changing CO_2 from 2-10%, from 1.8 - 3.67% at 3% and 3.53 - 7.5% at 5% O_2.

At 1% O_2, the O_2 inside the package decreased from 1.36 to 1.03% depending on different CO_2 levels from 2-10%. At 3% O_2, the O_2 decreased from 3.67% to 1.8%, meanwhile, it decreased from 7.5 to 3.53% at the higher O_2 level inside the packages. It could be seen from the results that the O_2 depletion increased with time of storage (4 - 14 days) and O_2 level inside the package and decreased by increasing CO_2 level inside the package.

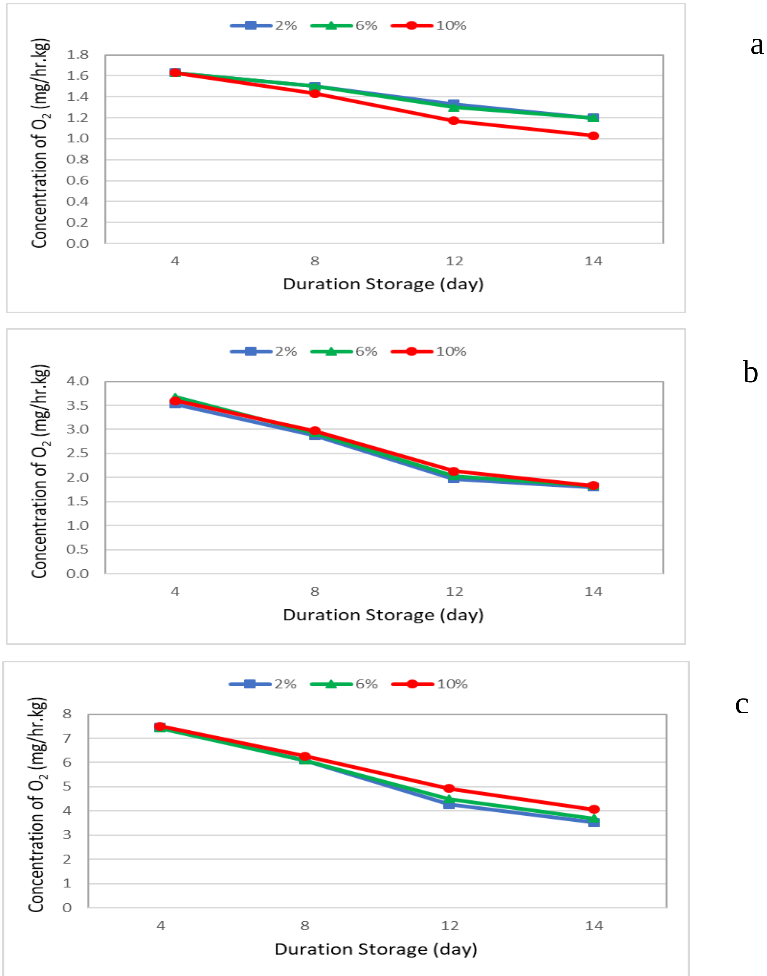


Figure (3): The effect of modified atmosphere condition (different levels of O_2 and CO_2) on the concentration O_2 inside the package of fresh squash during storage.

Regarding the effect of perforation, it could be seen that the perforation has a great effect on the depletion of O_2, where O_2 decreased from 1.63 to 0.57 % for the packages while have 10 P (area 3.85 mm^2), from 1.50 to 0.23% and 1.43 to 0.13 for 20 and 30 P packages, respectively as shown in figure (4).

3.3. Concentration C_2H_4 inside the package:

Figures (5 a, b and c) show the effect of different levels of O_2 (1, 3 and 5%) and CO_2 (2, 6 and 10%) inside the squash packages on the level of producing ethylene during storage. The results indicated that the ethylene concentration inside the package decreases with increasing CO_2 level during storage period. It could be seen that, when the CO_2 concentration increased from 2 to 10%, the ethylene concentration inside the package decreased from 5.27 to 2.35, 22.00 to 14.90, 35.60 to 29.33 and 67.40 to 39.23 % after 4, 8, 12 and 14 days, respectively at 1% O_2 level. At 3% O_2 level, the ethylene concentration inside the package decreased from 8.10 to 6.23, 27.67 to 8.00, 48.97 to 34.80 and 95.33 to 75.57 % after 4, 8, 12 and 14 days, respectively, when the CO_2 concentration increased from 2 to 10%. At 5% O_2 level, the ethylene concentration inside the package decreased from 29.07 to 8.67, 45.27 to 15.53, 62.07 to 50.40 and 150.57 to 107.27 % after 4, 8, 12 and 14 days, respectively, when the CO_2 concentration increased from 2 to 10%. High CO_2 concentration inhibit the generation of C_2H_4 because it can influence the enzyme activity.

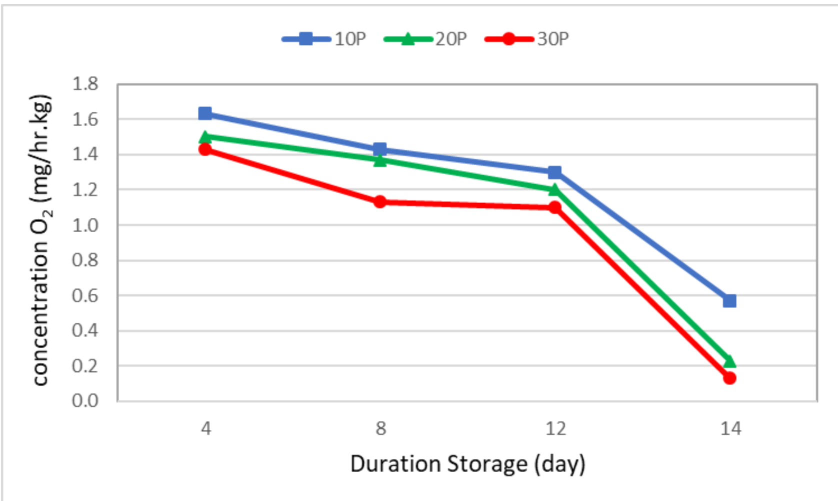


Figure (4): Effect of different perforation surface areas on the concentration O_2 inside the package of fresh squash during storage.

The results indicate that the ethylene concentration inside the package increases with increasing drying period. It could be seen that the ethylene concentration inside the package increased from 4.11 to 51.64, 7.23 to 86.50 and 18.37 to 126.68 %, when the storage period increased from 4 to 14 days at 1, 3 and 5% O_2 levels, respectively.

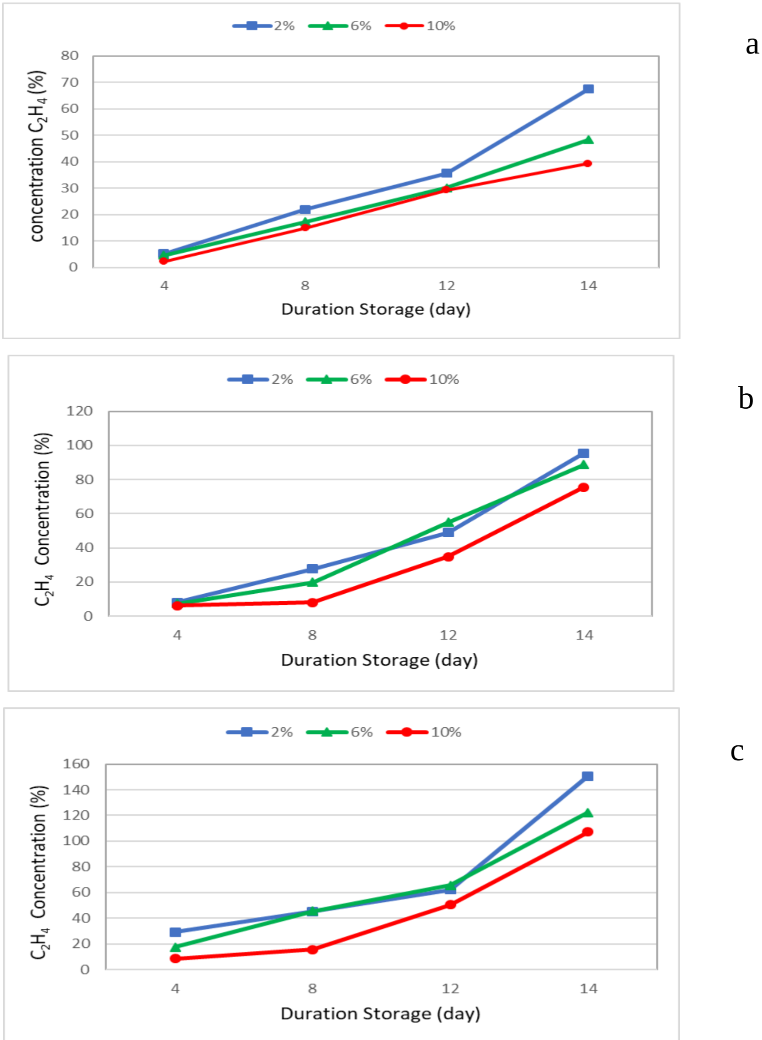


Figure (5): The effect of modified atmosphere condition on the ethylene concentration inside the package of fresh squash during storage.

Regarding the effect of punching the package, the results indicate that, the C_2H_4 level decreases with increasing the number of punches from 10 to 30 p as shown in figure (6). It could be seen that the ethylene concentration inside the package decreased from 9.13 to 3.00, 21.80 to 12.30, 31.43 to 15.93 and 44.93 to 26.23 %, when the perforation level surface area increased from 10 to 30 punches packages after 4, 8, 12 and 14 days, respectively.

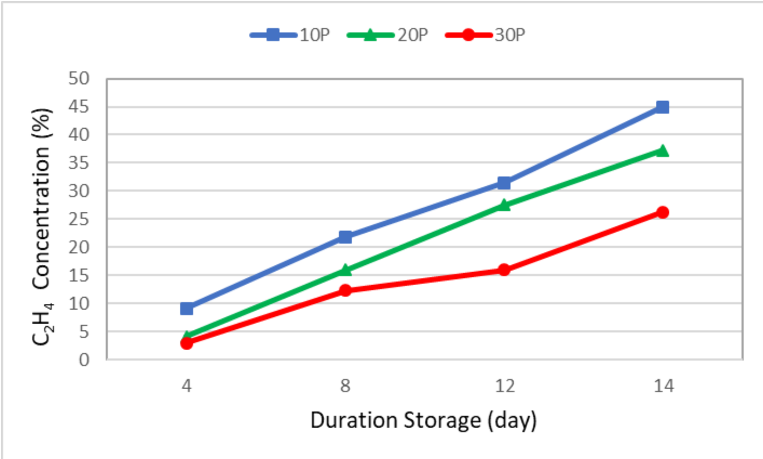


Figure (6): Effect of different perforation level surface area on the concentration C_2H_4 inside the package of fresh squash during storage

3.4. Accumulation weight losses:

Figures (7 a, b and c) show the effect of different O_2 and CO_2 levels on accumulated weight losses inside the package of fresh squash during storage. The results indicated that the accumulated weight losses decrease with increasing CO_2 and O_2 levels during storage period. It could be seen that, when the CO_2 concentration increased from 2 to 10%, the accumulated weight losses decreased from 1.27 to 1.12 and 2.31 to 1.97 % after 7 and 14 days, respectively at 1% O_2 level. At 3% O_2 level, the accumulated weight losses decreased from 1.45 to 1.32 and 2.69 to 2.32 % after 7 and 14 days, respectively, when the CO_2 concentration increased from 2 to 10%. At 5% O_2 level, the accumulated weight losses decreased from 1.99 to 1.76 and 3.40 to 1.97 % after 7 and 14 days, respectively, when the CO_2 concentration increased from 2 to 10%.

The results indicate that the accumulated weight loss of squash fruits increases with increasing drying period. It could be seen that the accumulated weight loss of squash increased from 0 to 2.17, 0 to 2.48 and 0 to 2.80 %, when the storage period increased from 0 to 14 days at 1, 3 and 5% O_2 levels, respectively.

The results also indicted that, the accumulated weight loss as affected by the levels of O_2 and CO_2 inside the package of squash during storage. WL were greatly reduced by reducing O_2 and elevating CO_2 in the packages the highest WL (3.40) recorded when squash stored at 5% O_2 level and 2 % CO_2 level compared to 35.85 % in the conventional storage.

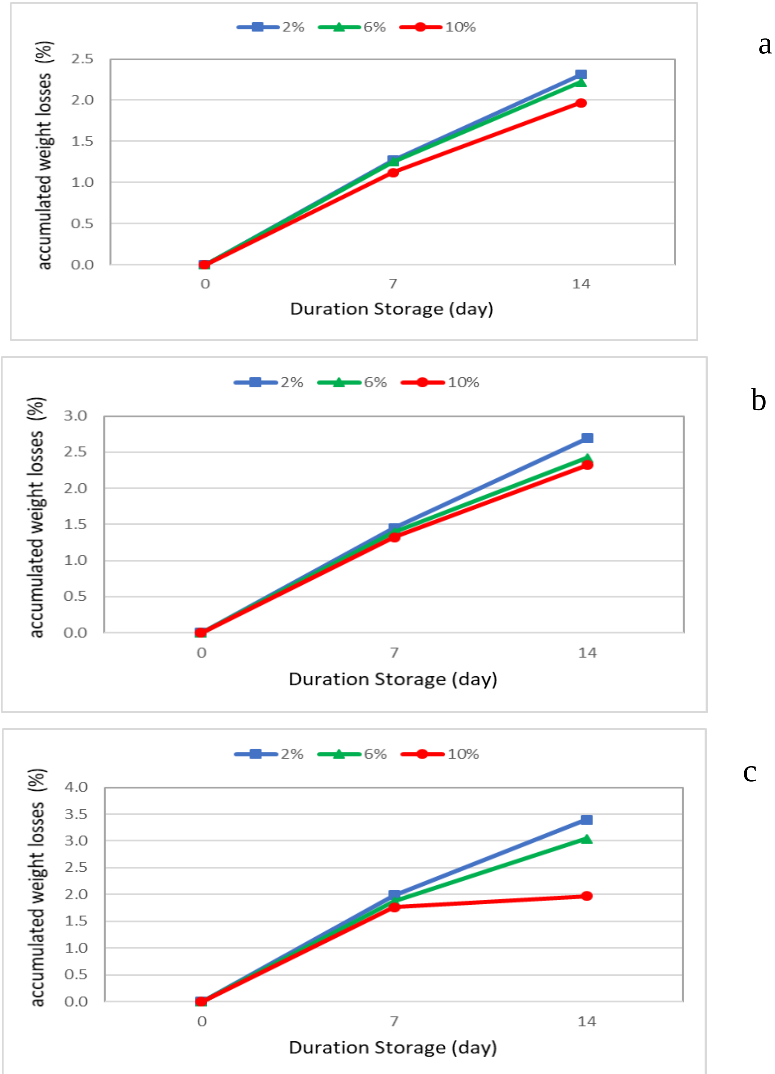


Figure (7): The effect of different O_2 and CO_2 levels on accumulated weight losses inside the package of fresh squash during storage.

Data in figure (8) shows the accumulated weight losses of squash during storage as affected by the perforation levels in package. The results indicated that the accumulated weight losses of squash increases with increasing during storage. It could be seen that the accumulated weight loss of squash increased from 0 to 2.43, 0 to 2.62 and 0 to 3.04 %, when the storage period increased from 0 to 14 days at 10, 20 and 30 punches packages, respectively.

The results also indicated the accumulated weight losses of squash increases with increasing perforation level surface area. It could be seen that the accumulated weight loss of squash increased from 1.36 to 1.73 and 2.43 to 3.04 %, when the perforation level surface area increased from 10 to 30 punches packages after 7 and 14 days, respectively. While it was compared 35% by the end of storage period (14 days) that stored traditionally.

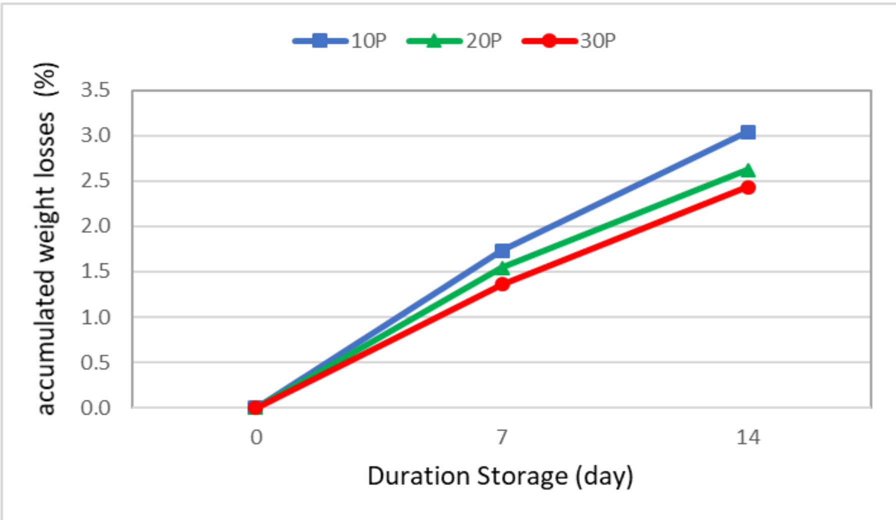


Figure (8): The effect of different perforation level surface area on the accumulated weight losses of squash during storage.

3.5. Hardness of squash:

Figures (9 a, b and c) show the effect of O2 and CO2 level inside the package on the hardness of fresh squash during storage. It could be seen that the squash hardness slightly decreased with storage time, the MA storage had slight effect on the hardness, where it ranged from 6.1 – 5.9 g cm^{-2} depending on the O_2 and CO_2 levels.

Figure (10) shows the hardness of squash stored at different levels of performances (10, 20 and 30p), where, it hangs in changed slightly with storage time from 6.1 to 5.9 g cm^{-2}. Squash stored soundly for 14 days with slight change in hardness.

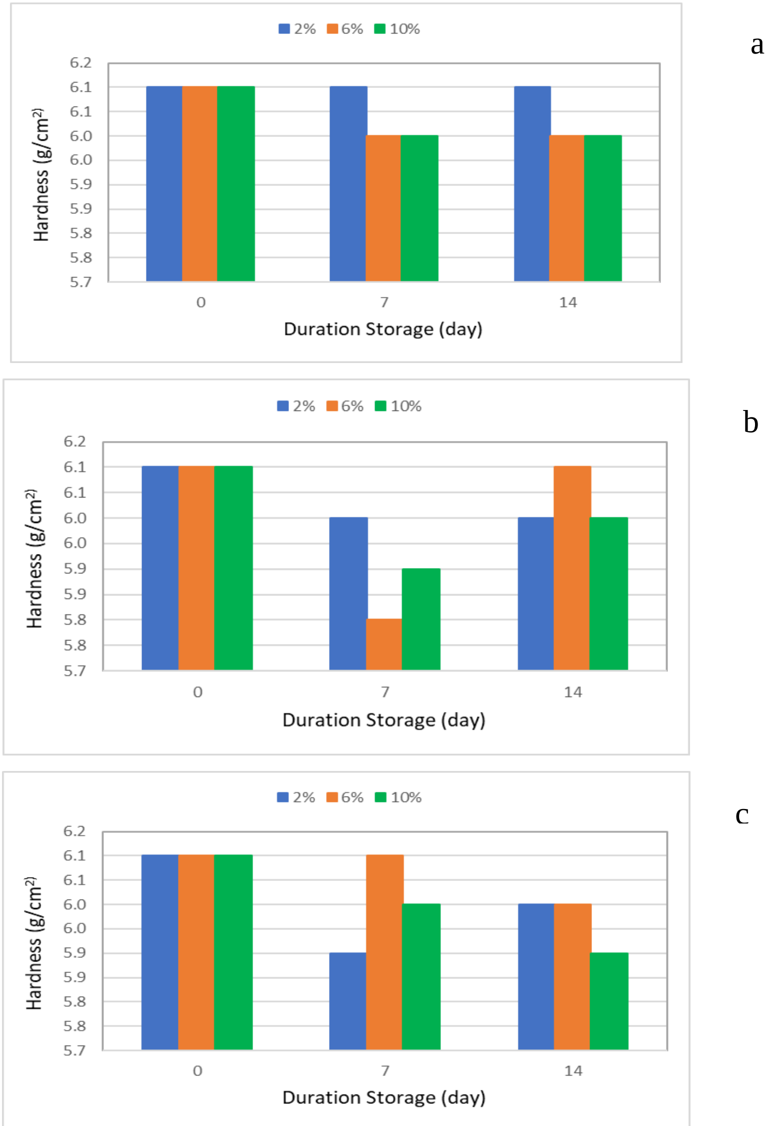


Figure (9): The effect of different O_2 and CO_2 levels on hardness of fresh squash during storage.

3.6. Colour of squash:

Figures (11 a, b and c) show the effect of different O_2 and CO_2 levels on colour (L*) of squash during storage. The results indicated that the colour (L*) of squash decreases with increasing CO_2 level during storage period. It could be seen that, when the CO_2 concentration increased from 2 to

10%, the colour (L*) of squash decreased from 62.18 to 58.11, 62.18 to 58.13 and 62.18 to 62.18 to 57.58 after 7 and 14 days, respectively at 1% O_2 level. At 3% O_2 level, the colour (L*) of squash decreased from 62.18 to 60.17, 62.18 to 58.31 and 62.18 to 58.04 after 7 and 14 days, respectively, when the CO_2 concentration increased from 2 to 10%. At 5% O_2 level, the colour (L*) of squash decreased from 62.28 to 60.01, 62.18 to 56.26 and 62.18 to 56.02 after 7 and 14 days, respectively, when the CO_2 concentration increased from 2 to 10%.

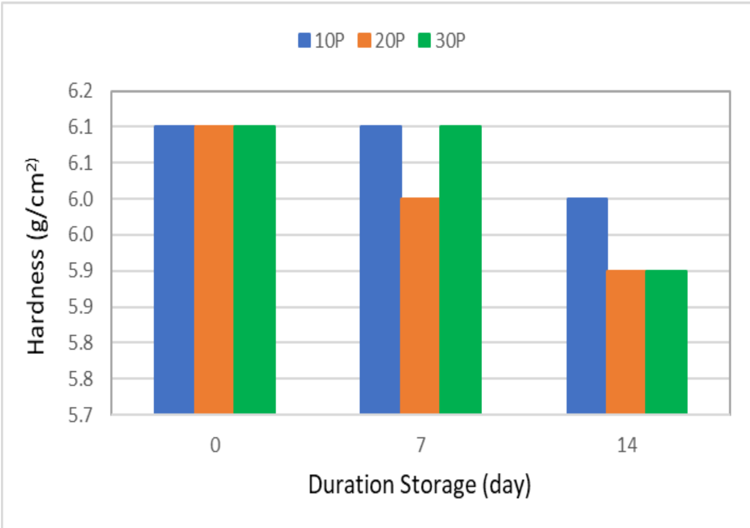
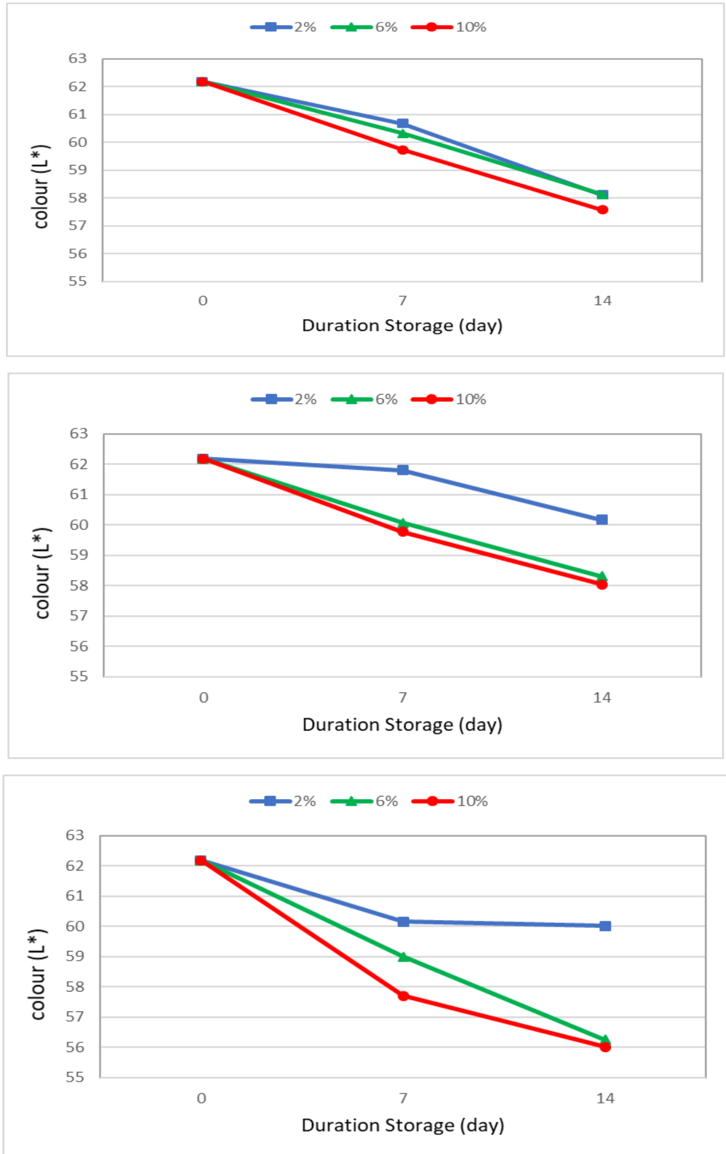


Figure (10): The effect of different perforation level on hardness of fresh squash during storage.

The results indicate that the colour (L*) of squash fruits decreases with increasing drying period. It could be seen that the colour (L*) of squash decreased from 62.18 to 57.94, 62.18 to 58.04 and 62.18 to 57.43, when the storage period increased from 0 to 14 days at 1, 3 and 5% O_2 levels, respectively.

Figure (12) shows the colour (L*) of squash during storage as affected by the perforation levels in package. The results indicated that the colour (L*) of squash decreases with increasing during storage. It could be seen that the colour (L*) of squash decreased from 62.18 to 59.62, 62.18 to 6020 and 62.18 to 60.93, when the storage period increased from 0 to 14 days at 10, 20 and 30 punches packages, respectively.



a

b

c

Figure (11): The effect of different O_2 and CO_2 levels on colour (L*) of squash during storage.

The results also indicated the colour (L*) of squash increases with increasing perforation level surface area. It could be seen that the colour (L*) of squash increased from 60.39 to 61.53 and 59.62 to 60.93, when the perforation level surface area increased from 10 to 30 punches packages after 7 and 14 days, respectively.

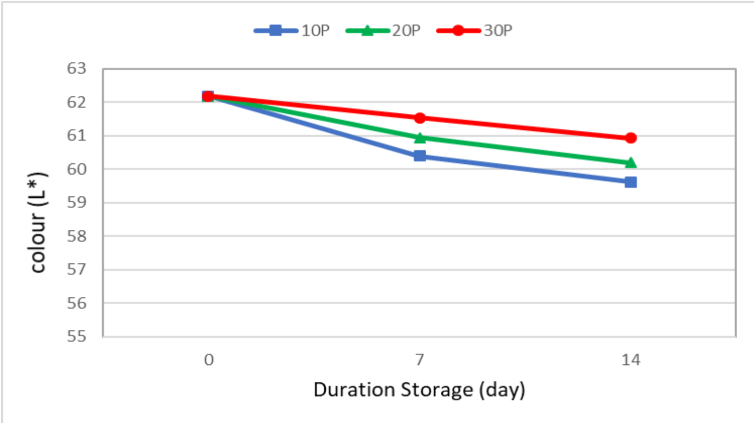


Figure (12): The colour (L*) of squash during storage as affected by the perforation levels in package.

3.7. Hue angle of squash:

Figures (13 a, b and c) show the effect of different O_2 and CO_2 levels on hue angle of squash during storage. The results indicated that the hue angle of squash increases with increasing CO_2 level during storage period. It could be seen that, when the CO_2 concentration increased from 2 to 10%, the hue angle of squash increased from 62.60 to 67.21, 62.60 to 65.47 and 62.60 to 64.52 after 7 and 14 days, respectively at 1% O_2 level. At 3% O_2 level, the hue angle of squash increased from 62.60 to 66.25, 62.60 to 66.20 and 62.60 to 62.61 after 7 and 14 days, respectively, when the CO_2 concentration increased from 2 to 10%. At 5% O_2 level, the hue angle of squash increased from 62.60 to 65.92, 62.60 to 65.47 and 62.60 to 63.88 after 7 and 14 days, respectively, when the CO_2 concentration increased from 2 to 10%.

Figure (14) shows the hue angle of squash during storage as affected by the perforation levels in package. The results indicated that the hue angle of squash increases with increasing during storage. It could be seen that the hue angle of squash increased from 62.18 67.37, 62.18 to 67.56 and 62.18 to 68.31, when the storage period increased from 0 to 14 days at 10, 20 and 30 punches packages, respectively.

The results also indicated the hue angle of squash increases with increasing perforation level surface area. It could be seen that the hue angle of squash increased from 64.99 to 66.57 and 67.37 to 68.31, when the perforation level surface area increased from 10 to 30 punches packages after 7 and 14 days, respectively.

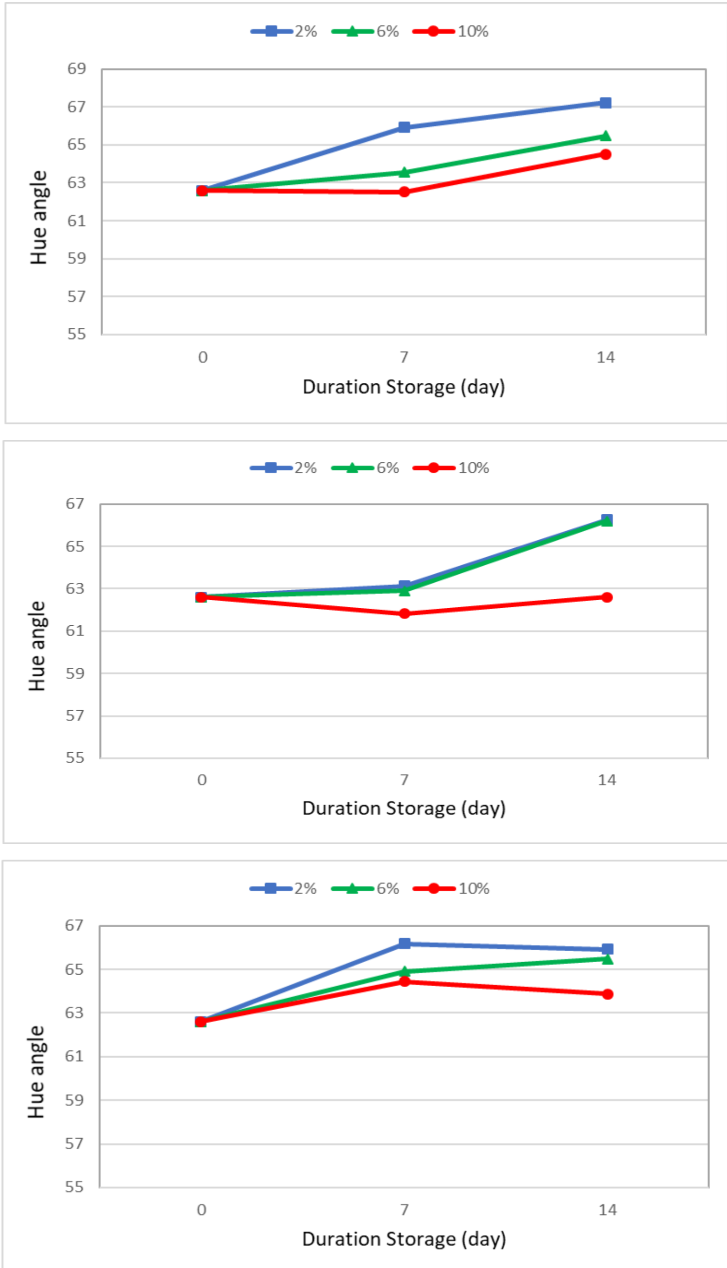


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Figure (13): The effect of different O_2 and CO_2 levels on hue angle of squash during storage.

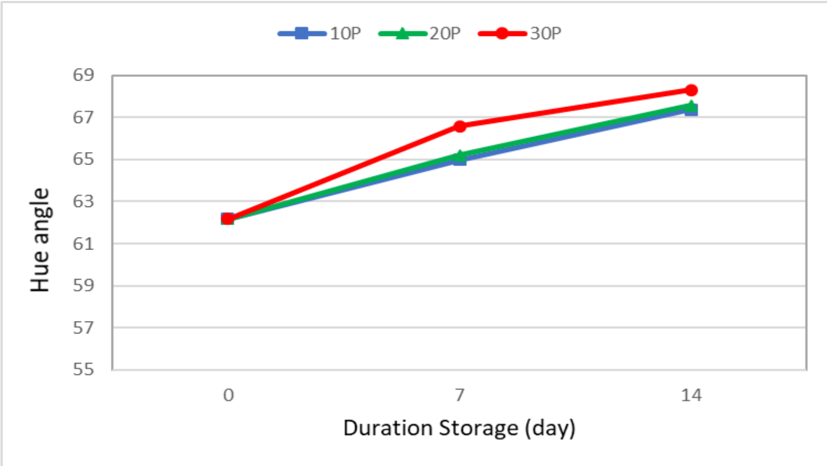

Figure (14): The hue angle of squash during storage as affected by the perforation levels in package.

4.CONCLUSIONS

An experimental study was carried out successively to study the effect of modified atmosphere storage on the quality of squash during storage. Squash fruits were stored at three levels of O_2 concentrations (1, 3 and 5%), three levels of CO_2 concentrations (2, 6 and 10%) and cold storage at 10 °C and 70 % relative humidity as compared with storage in normal air in perforated and non-perforated packages. The obtained results can be summarized as follows:

- The concentration CO_2 inside the package of fresh squash during storage ranged from 4.71 to 24.02 % for all treatment.
- The concentration O_2 changed from 1 to 1.63% at 1% O_2 with changing CO_2 from 2-10%, from 1.8 - 3.67% at 3% and 3.53 - 7.5% at 5% O_2.
- The ethylene concentration inside the package increased from 4.11 to 51.64, 7.23 to 86.50 and 18.37 to 126.68 %, when the storage period increased from 4 to 14 days at 1, 3 and 5% O_2 levels, respectively.
- The accumulated weight loss of squash increased from 0 to 2.17, 0 to 2.48 and 0 to 2.80 %, when the storage period increased from 0 to 14 days at 1, 3 and 5% O_2 levels, respectively.
- The squash hardness slightly decreased with storage time, the MA storage had slight effect on the hardness.

- The colour (L*) of squash decreases with increasing CO_2 level during storage period. While, the hue angle of squash increases with increasing CO_2 level during storage period.

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الملخص العربى.

تخزين ثمار الكوسة الطازجة فى عبوات ذات جو معدل

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تهدف هذه الدراسة الى بحث تأثير التخزين فى الاجواء المعدلة على جودة والعمر التخزينى لثمار الكوسة الطازجة. حيث تم تخزين ثمار الكوسة تحت ثلاث مستويات من تركيز الاكسجين (١ – ٣ – ٥%) وثلاث مستويات من تركيز ثانى اكسيد الكربون (٢ – ٦ – ١٠%) فى الاجواء الباردة على درجة حرارة ١٠ °م ورطوبة نسبية ٧٠% ومقارنتها بالتخزين فى الجو الطبيعى داخل عبوات مثقبة وبدون ثقوب. وكانت اهم النتائج المتحصل عليها كما يلى: تراوح تركيز ثانى اكسيد الكربون داخل العبوة من ٤,٧١ الى ٢٤,٠٢ % لكل المعاملات. وزاد تركيز كلا من ثانى اكسيد الكربون والايثيلين داخل العبوة بزيادة تركيز كلا من ثانى اكسيد الكربون والاكسجين خلال فترة التخزين بينما انخفض تركيز الاكسجين داخل العبوة بزيادة تركيز ثانى اكسيد الكربون وزيادة مدة التخزين. زاد الفاقد فى الوزن التراكمى من ٠ الى ٢,١٧ ومن ٠ الى ٢,٤٨ ومن ٠ الى ٢,٨٠% بزيادة مدة التخزين من ٠ الى ١٤ يوم عند تركيز اكسجين ١ و٣ و٥% على الترتيب مقارنة ٣٥ % للتخزين التقليدى. انخفض صلابة ثمار الكوسة انخفاض بسيط مع التخزين. انخفض لون ثمار الكوسة بزيادة تركيز ثانى اكسيد الكربون خلال مدة التخزين.

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