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Modified Atmosphere Packaging for Maintaining Quality and Shelf Life Extension of Persimmon Fruits

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Abstract: The beneficial effects of using Modified Atmosphere Packaging (MAP) of persimmon fruits to extend its availability for export purpose to perform the consumers and markets demands were investigated during two successive seasons of 2007 and 2008. Hachia and Triumph persimmon fruits were harvested at three quarter color stage and enclosed in different packaging materials of Low Density Polyethylene (LDPE) bags at the thickness of 2, 4 and 7 μm LDPE. 100% Nitrogen gas was flushed into the bags for complete replacing of normal air while control fruits were packed with aerobic atmosphere for each thickness. Fruit quality characteristics i.e. fruit firmness, respiration rate, fruit color, Softening as days to eat soft, soluble solid content, total acidity, ascorbic acid content, total phenols and total tannins were assessed periodically after storage periods at 0ºC and after 7 days at 20ºC and 80-85% RH. Packaging fruits at 7 μm Low Density Polyethylene film (LDPE) with N_2 (100%) can be more effective in keeping fruits firm with the least respiration rate during storage and after ripening at 20ºC than 4 and 2 μm LDPE films and control fruits for the two cultivars respectively. Lightness (L*) and Chroma (C*) color parameters had the significant highest values in fruits received (N_2) application and packaged with7 μm LDPE after 90 d storage at 0ºC and 7d ripe. SSC had slight insignificant decrease throughout the storage period at 20ºC due to different polyethylene packaging films and 100% N2 exposure, also untreated fruits showed the same direction. LDPE film at 7 μm thickness recorded the highest content of ascorbic acid but with the least level of acidity and phenols content followed by 4 and 2 μm films throughout storage and ripening periods.Total tannins as indicator of removing fruit astringency were as storage period extend and the thickness of LDPE films increase in packed persimmon fruits in the two cultivars respectively. Moreover, Triumph persimmon fruit had higher content of tannins compared with Hachia variety. These results were suggested that the highest thickness of LDPE film (7 μm) and N_2 (100%) are suitable application for modified atmosphere packaging (MAP) of Hachia and Triumph persimmon fruits as response for long storage under refrigeration with an additional period of time at ambient temperature.

Key words: Fruit quality, Modified Atmosphere Packaging, Nitrogen treatment, persimmon, phenols and tannins

INTRODUCTION

The persimmon (*Diospyros kaki* L.) is an important seasonal fruit often exhibits rapid softening during postharvest distribution, after deastringency, or sometimes on the trees. This is a major problem in the marketing of persimmon (Pang, 2007). Persimmon storage is necessary to extend its availability for transport to distant markets and for extending its availability on local markets. (Ben-Arie and Sonego, 1993). Moreover, Japanese persimmons consist of two groups of cultivars with different degrees of astringency at harvest; one is an astringent type and the other is non-astringent (Thompson, 1998). Removal of astringency from persimmon fruits while avoiding softening is necessary. It has been achieved by different methods, such as keeping the fruit under anaerobic conditions or exposed to products that enhance respiration (Arnal and Del Rio, 2003).

Soluble tannins, which are responsible for persimmon fruit astringency, are polymerized by acetaldehyde under anaerobic conditions to form an insoluble compound which is non astringent (Taira *et al*., 1997; Matsuo and Itoo, 1982). Application of high levels of carbon dioxide or nitrogen gas can be effective in removing astringency from the fruit; however, the duration of treatment depends on the cultivar and temperature (Ben-Arie and Sonego, 1993). It was further observed that nitrogen treated fruits got maximum achieve for appearance and carbon dioxide treated fruits for flavor (Bibi, 2007).

Modified Atmosphere Packaging (MAP) of fresh commodities is a successful technology for maintaining quality for prolonging the shelf-life period during storage

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Table 1: Fruit quality characteristics of Hachia and Triumph persimmon cultivars

Fruit stages	Varieties	Fruit firmness (N)	Respiration rate (ml/kg/h)	SSC (%)	Ascorbic acid (mg/100g)	Total tannins (mg/100g)
At harvest	Hachia	14.50	4.84	22.60	34.92	1.29
	Triumph	16.00	4.18	24.30	32.43	1.37
After ripening	Hachia	12.33	7.15	21.23	29.92	1.03
	Triumph	14.25	6.27	22.72	30.51	1.12

and marketing (Kader, 1986). In this preservation technique the air surrounding the fruit in the package is changed to another composition. If the permeability (for O_2 and CO_2) of the packaging film is adapted to the product respiration, an equilibrium modified atmosphere will establish in the package and the shelf-life of the product will increase (Sandhya, 2010). One of the major benefits of Modified Atmosphere Packaging (MAP) is the prevention or retardation of fruit senescence (ripening) and associated biochemical and physiological changes (Sandhya, 2010). Previously published studies focusing on obtaining good quality fruit during long-term storage using Modified Atmosphere Packaging (MAP), showed that packaging of fruit in low-density polyethylene films resulted in a significant delay of fruit ripening (Ben-Arie *et al.*, 1991).

Furthermore, trials carried out by Brackmann *et al.* (1997) on ‘Fuyu’ and ‘Rama Forte’ persimmons demonstrated that fruit packaged in 40 μ low-density polyethylene film retain satisfactory keeping quality for up to 2 months of storage. On the other hand, Cia *et al*., 2003; Cia *et al*., 2006) observed that although LDPE (80 μ) permitted the maintenance of fruit quality, it presented risk of anaerobiosis because acetaldehyde and ethanol accumulated inside the packages. Thus a key of postharvest quality attribute of ‘Fuyu’ is that flesh firmness, since distributors and consumers prefer a firm fruit with crisp texture (Park and Lee, 2005) Most ‘Fuyu’ persimmon fruits are stored and marketed using MAP primarily to retard flesh softening (Lee and Yang, 1997; Park *et al*., 1997). On the other hand, Park (1999) stored ‘Fuyu’ persimmon fruit in controlled atmosphere, air, or in MAP (packaged in 60 μ m polyethylene film) for 28 weeks at 0ºC and observed that the occurrence and severity of the fruit skin blackening increased considerably after 12 weeks of storage and was the highest in the MAP and air treatments.

Hence, the aim of this study was to evaluate the effect of high nitrogen treatment, different packaging thickness and exposure durations on ripening process of Hachia and Triumph persimmon cvs and to attain high quality fruit, firm, and consequently the least losses, which endures more extended storage and marketing life.

MATERIALS AND METHODS

Fruit: Hachia and Triumph persimmon fruits (*Diospyros kaki* L.) were harvested from Nemous orchard located in Katta district, Giza governorate, Egypt. Fruit were harvested at proper maturity stage in October 2007and 2008 in three quarter color stage from eight years old trees grown in sand-loam soil, and were similar in growth and received common horticulture practices. Undamaged fruits, free from visual blemishes, uniform in shape, weight, color and firmness were harvested, graded, packed and transported immediately to the postharvest laboratory of Agricultural Development System (ADS) project in Cairo University. On arrival, fruit were washed, air dried and were received the following Modified Atmosphere packaging and N_2 treatments. The initial quality measurements at harvest and after ripening for 7 days at 20ºC were determined (Table 1).

Modified Atmosphere Packaging (MAP) and N_2 treatments: Fruits of each cultivar were weighed and replicates of six fruit each (average weight of each replicate: 900±30 g) were enclosed in different packaging materials of Low Density Polyethylene (LDPE) bags at the thickness of 2, 4 and 7 μm LDPE. 100% Nitrogen gas from the cylinder was flushed into the bags for complete replacing of normal air while control fruits were packed with aerobic atmosphere condition for each thickness. After treatments the packed fruit were placed in a storage room at (0ºC and 85-90% RH) in corrugated cardboard boxes for a total storage period of 90 days. At every 15 d, three replicates of MAP packages of each treatment were opened, ventilated, and the fruits of treatments were transferred to fiberboard carton boxes and held in a controlled temperature chamber at 20ºC and 80-85% RH during 7 d for ripening. Three replicates for each treatment and sampling time were used and each replicate consists of 6 fruits for each variety. Gases measurements and fruit quality were assessed. Data presented in this paper only were at 30 d intervals.

Fruit quality assessments:

- Fruit firmness was measured using Ametek pressure tester, fitted with an 8 mm hemispherical probe (probe penetration 2 mm), the results calculated as Newton units.
- Total acidity (expressed as malic acid) was determined by titrating 5 mL juice with 0.1N sodium hydroxide using phenolphthalein as an indicator.
- SS content was measured to using a T/C hand refractometer Instrone, Brix-readings 0-30 ranges (Model 10430, Bausch and Lomb Co. Calif., USA).

- Ascorbic acid content was determined using 2, 6 dichlorophenol indophenols' titration methods as described by (AOAC, 1990).

Respiration rate: Fruits of each sampling date were weighed and placed in 2 L sealed jars at 20ºC. O_2 and CO_2 production samples of the jars headspace were injected into Servomex Inst (Model 1450C-Gas Analyzer). Respiration rate was calculated as mL CO_2/kg/h (Pesis and Ben-Arie, 1984; Lurie and Pesis, 1992).

Fruit color measurement: Skin color was determined and expressed as on the basis of the CIELAB color system ($L*$, $a*$, $b*$) using a Minolta Co., Ltd., Osaka, Japan). Chroma values were calculated from ($a*$, $b*$) using the methods described by (Lopez and Gomez, 2004) Color was longitudinally determined on two points of each fruit.

Softening (the days to eat soft): Determined as the number of days from harvest to a hand pressure corresponding to a firmness of 4-6 N as measured previously and eating ripe according to (Zauberman and Décor, 1995).

Total phenols content: A procedure of folin ciocalteu (AOAC, 1980) was adopted for determination of phenols in methanolic extract of fresh fruit. Total phenols were calculated as mg pyrogallol per 100 g fresh weight.

Total tannins content: were estimated as mg per 100gm fresh weight using potassium permanganate volumetric method according to (Winton and Winton, 1968).

Statistical analysis: All data were subjected to statistical analysis according to the procedures reported by (Snedecor and Cochran, 1980) Treatment means were compared by Duncan's multiple range tests at the 5% level of probability in the two seasons of study.

RESULTS AND DISCUSSION

Fruit firmness: Changes in fruit firmness of Hachia and Triumph persimmon varieties after postharvest treatments of different packages thickness and N_2 application were illustrated in Fig. 1. It is clear to notice that modified atmosphere packaging decreased significantly persimmon fruit firmness gradually towards the end of storage period at 20ºC. Meanwhile, untreated fruits (control) maintained less firm than the other treatments. Packaging fruits at 7 μm of LDPE film with higher concentration of N_2 (100%) can be more effective in keeping fruits firmer after 30 d storage at 0ºC + 7 d at 20ºC recording Newton values (10.10, 13.67) compared with (9.7, 13.33) and (2 9.4, 13.08) in 4 and 2 μm LDPE films for the two cultivars

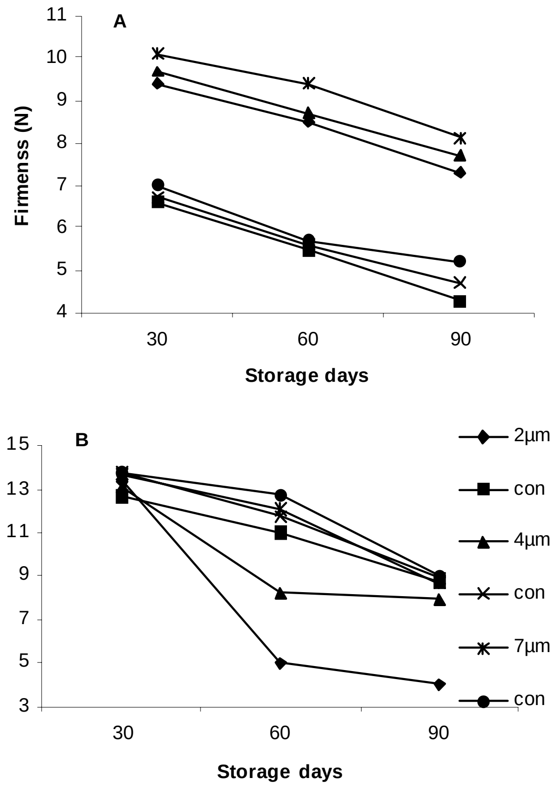

Fig. 1: Flesh firmness (N) of Hachia (A) and Triumph (B) persimmon fruits enclosed in different packaging thickness films and N_2 enriched atmosphere after storage periods at 0ºC + 7d ripening at 20ºC

respectively. Nevertheless, Triumph cv. fruit was best achieved in keeping fruit firmer during ripening at 20ºC. Similar results were obtained by Pesis *et al.* (1986) who observed that persimmon fruits stored under N_2 atmosphere maintained high quality and firmness for 2 weeks and for 3 months at 1ºC. In addition, Fuyu persimmons packed in 60 or 80 μm polyethylene film maintained their firmness levels fairly unchanged for up to 120 d storage at 0ºC (Ben-Arie and Zutkhi, 1992). This delay of softening probably resulted from the retardation of senescence processes due to inhibition of the respiration rate at low O_2 and high CO_2 levels caused by the MA inside the packages of 58 μm PO and 50 μm LDPE films (Cia *et al.*, 2006).

Respiration rate: Modified Atmosphere Packaging (MAP) of persimmon fruits with exposed to N_2 (100%) throughout storage period at 0ºC + 7d ripening at 20ºC were elucidated in (Fig. 2). Respiration rate (CO_2 production) of packaged fruit resulted a noticeable significant increase reaching its peak values up to 60 d storage and then an decrease was observed at the end of storage period. On the other side, the highly thickness

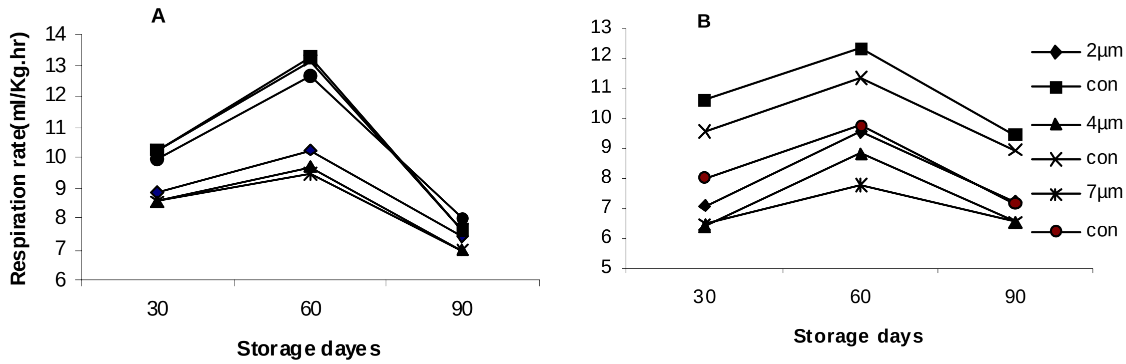

Fig. 2: Respiration rate as ml/kg/h of Hachia (A) and Triumph (B) persimmon fruits enclosed in different packaging thickness films and N_2 enriched atmosphere after storage periods at 0ºC + 7d ripening at 20ºC

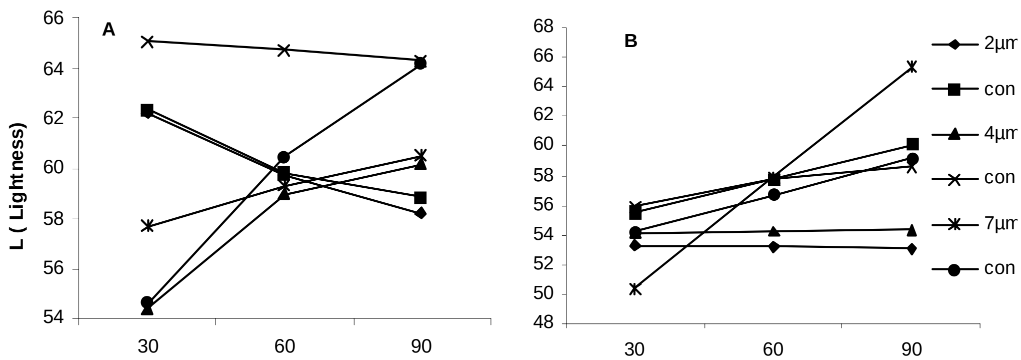

Fig. 3: Skin color (L) of Hachia (A) and Triumph (B) persimmon fruits enclosed in different packaging thickness films and N_2 enriched atmosphere after storage periods at 0ºC + 7d ripening at 20ºC

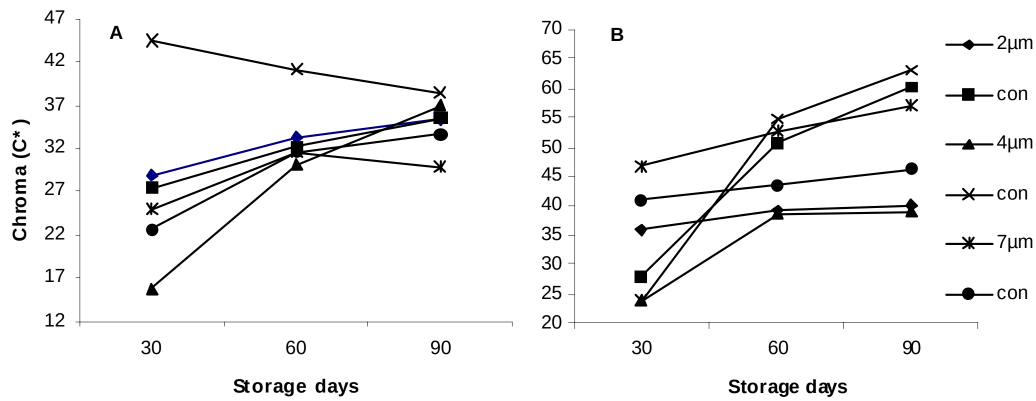

Fig. 4: Skin color (C*) of Hachia (A) and Triumph (B) persimmon fruits enclosed in different packaging thickness films and N_2 enriched atmosphere after storage periods at 0ºC + 7d ripening at 20ºC

(7 µm LDPE film) appeared the least value of respiration rate (9.68, 7.79) followed by (9.68, 8.80), 2 (10.23, 9.56) in 4 and 2 µm films for the two varieties respectively, compared with control fruit which recorded the highest values with expanding storage period. Generally, results may indicate that respiration rate of Triumph persimmon fruits were lower than that in Hachia fruits during storage period. Lee *et al*. (2000) reported that O_2 and CO_2 levels inside the packages may vary according to film thickness and the amount of fruit enclosed in a package. The ability of MA to reduce the respiratory activity inside the packages represents not only a way to control the

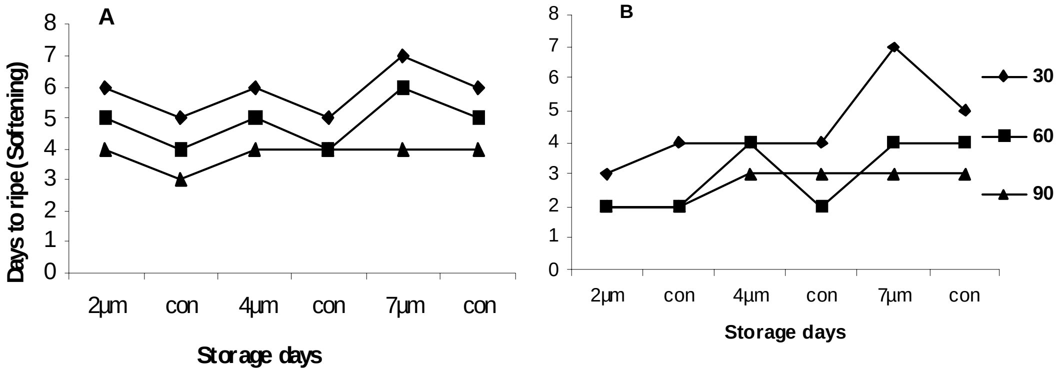

Fig. 5: Softening of Hachia (A) and Triumph (B) persimmon fruits enclosed in different packaging thickness films and N_2 enriched atmosphere after storage periods at 0ºC + 7d ripening at 20ºC

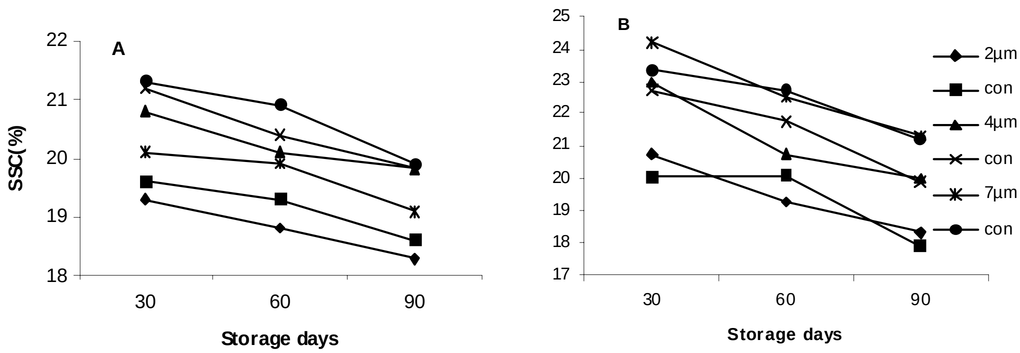

Fig. 6: Soluble solid content (%) of Hachia (A) and Triumph (B) persimmon fruit enclosed in different packaging thickness films and N_2 enriched atmosphere after storage periods at 0ºC + 7d ripening at 20ºC

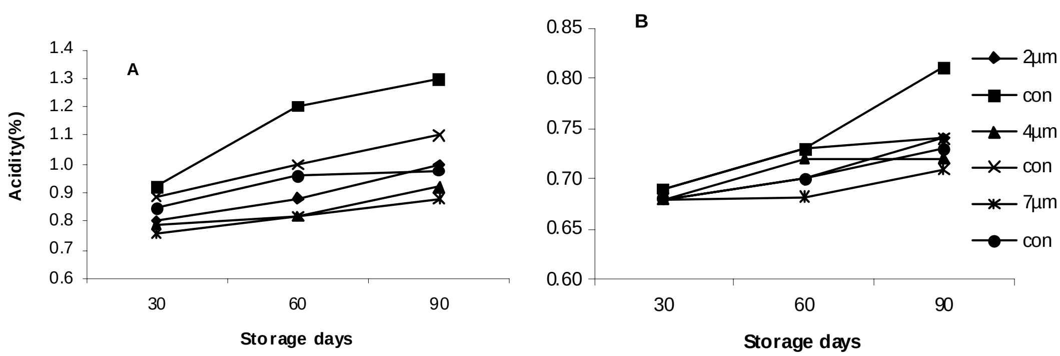

Fig.7: Total acidity (%) of Hachia (A) and Triumph (B) persimmon fruit enclosed in different packaging thickness films and N_2 enriched atmosphere after storage periods at 0ºC + 7d ripening at 20ºC

respiration rate of the fruit, but also a way to decrease of the intensity of catabolic activity and degradation processes (Cia *et al*., 2006; Sandhya, 2010).

Fruit color: The packages have favourable effects on the development of external colour retention of the fruit (Fig. 3, 4). lightness (L*) and Chroma (C*) as colour parameters showed a slight and significant increase of Hachia and Triumph persimmon fruits, with increasing of storage period due to Nitrogen treatment and different packages thickness. Fruits treated with highly thickness film 7 µm LDPE showed the largest lightness (L*) after 90 days of storage at 0ºC + 7d at 20ºC (65.09, 65.31) followed by 4 µm LDPE (64.19, 54.34) and 2 µm (60.5, 53.07) in the two cultivars respectively, while control fruits revealed the least significant lightness at the same date. The Chroma showed a slight increase for all treatments. This pattern is characteristic of more advanced stages of ripening or in other words orange-red color in contrast to yellow-orange, which is indicative of less ripe fruit. Chroma (C*) recorded the highest values at 90 days storage with the package of 7 µm LDPE (38.48, 57.02) followed by 4 µm LDPE (37, 39), meanwhile the least Chroma value was found after 30 d. of storage with 2 µm (29.99, 40.15) in the two cultivars respectively. Our results go in line with those obtained by Moura *et al.* (1997) who reported that "Taubate" persimmon in PVC film had higher chlorophyll levels compared to the control fruit after 72 d of storage at 0ºC. Loss of chlorophyll and biosynthesis of carotenoids are diminished in fruit kept in modified or controlled atmosphere (Kader, 1986).

Softening (days to eat soft): Persimmon fruit softening were assessed in both Hachia and triumph cultivars with high N_2 treatment and different packaging thickness (2, 4 and 7 µm LDPE) after storage periods at 0ºC + 7d ripening at 20ºC and showed a gradual and significant decreased (Fig. 5). Fruit tended to soft ripe when reached 5N (fruit firmness).

Packaging fruit with 7 µm gave the best results for maintaining soft fruit at (7 and 5 days) storage followed by 4 µm (6 and 4 days) and 2 µm (5 and 3 days) for the two cultivars respectively. A similar pattern of softening was observed of untreated fruit (control). Modified Atmosphere Packaging (MAP) showed that persimmon fruit packaged in low-density polyethylene films resulted significant delay of fruit ripening (Ben-Arie *et al*., 1991). Ben-Arie and Zutkhi (1992) found that the rate of softening of "Fuyu" persimmon was considerably reduced in packaging systems during the storage period. Most "Fuyu" persimmon fruits are stored and marketed using MAP primarily to retard flesh softening (Lee and Yang, 1997; Park *et al*., 1997).

Soluble Solid Content (SSC): Data presented in Fig. 6 demonstrated that there were a slight and insignificant decrease in soluble solid content of Hachia and Triumph varieties of persimmon fruits throughout the storage period at 0ºC and ripe at 20ºC due to different polyethylene packaging thickness and 100% N_2 treatment. Also untreated fruits showed the same direction. Packaged and untreated fruits gave the lowest level of soluble solid content after 90 d of storage and 7 d to ripe at 20ºC (18.3, 18.6 and 18.60, 17.90) for 2 µm LDPE of Hachia and Triumph cultivars. Meanwhile, Triumph variety had the better content of soluble solid after 30 d of storage and 7 d to ripe at 20ºC for 7 µm thickness compared with the Hachia variety. The results obtained were similar to those mentioned by Turk (1993) who observed that soluble solid content in Fuyu persimmon in 30 µm polyethylene film continuously declined throughout 80 d storage at 1ºC. Little variation in the level of total soluble solid of Fuyu persimmon fruit stored at 7ºC for 42 d in 60 µm polyethylene film reported by Clark and Macfall (1996). While Mohla *et al*. (2000) have reported an increase in SSC for storage intervals, this increase in SSC may be attributed to the packaging of fruit.

Total acidity: The effects of different packaging thickness materials and N2 treatment on the pattern of titratable acidity changes of persimmon fruits during ripening for Hachia and Triumph varieties were shown in (Fig. 7). There is a gradual and non significant increase in acidity of packaged and control fruits during the ripening process for the two varieties respectively. Titratable acidity of Hachia cv. fruits in 2 µm polyethylene film (LDPE) were higher than the other thickness films, while 7 µm polyethylene film gave the least level of acidity for modified packaging (0.76, 0.68%) and untreated fruits (0.85, 0.68%) during storage periods + ripening time. Furthermore, it should be noted that the level of acidity of Triumph fruits have the same trend but less than Hachia cultivars. The same behaviour was also observed by Senter *et al.* (1991) in Fuyu persimmon submitted to analyses at different stages of maturity. Retention of acidity levels caused by 58 µm PO and 50 µm LDPE films may be associated with the effects of simultaneous low O_2 and high CO_2 levels, which may contribute to retarding the metabolism of the fruit. Hussain *et al*. (2004), they also reported negligible difference in pH for fruits during storage.

Ascorbic acid content: According to (Fig. 8) it can be notice that ascorbic acid content (vitamin C) of persimmon fruit (Hachia and Triumph cvs) had a gradual and significant decrease with increasing storage period at 0ºC and 7 d to ripe at 20ºC in all treatments including untreated fruit (control). The LPDE film of 7µm recorded the highest content of ascorbic acid after 30 d of storage at 0ºC and 7 d to ripe at 20ºC (34.77, 26.97) followed by 4 µm (29.78, 25.87) and 2 µm (27.41, 25.41 mg/100 g fresh weight) during ripening period for the two cultivars respectively. Also, control fruits obtained the same trend. There are significant differences between the two cultivars in their content of ascorbic acid while Hachia cv. had the highest values compared with Triumph cv. The results are incompatible with those reported by Abdel-Hafeez (2005) who mentioned that vitamin c content of Costata persimmon fruits was increased.

Total phenols: Persimmon: fruits recorded a noticeable significant decrease in phenols content due to high N_2 (100%) and polyethylene packaging (LDPE) films with increasing of storage period. (Fig. 9) compared with untreated fruit (control). Packaged fruits with highly thickness material 7 µm showed the lower phenols content after 90 d of storage period at 0ºC and 7d to ripe at 20ºC recording (41.63, 2.58) in the two varieties

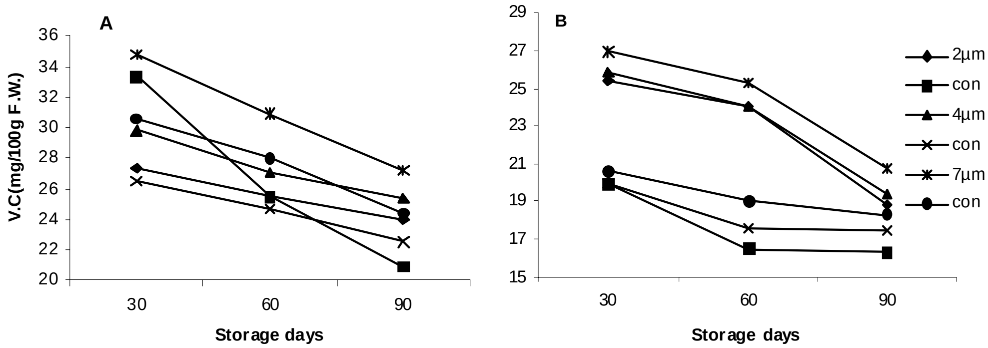

Fig. 8: Ascorbic acid content of Hachia (A) and Triumph (B) persimmon fruit enclosed in different packaging thickness films and N_2 enriched atmosphere after storage periods at 0ºC + 7d ripening at 20ºC

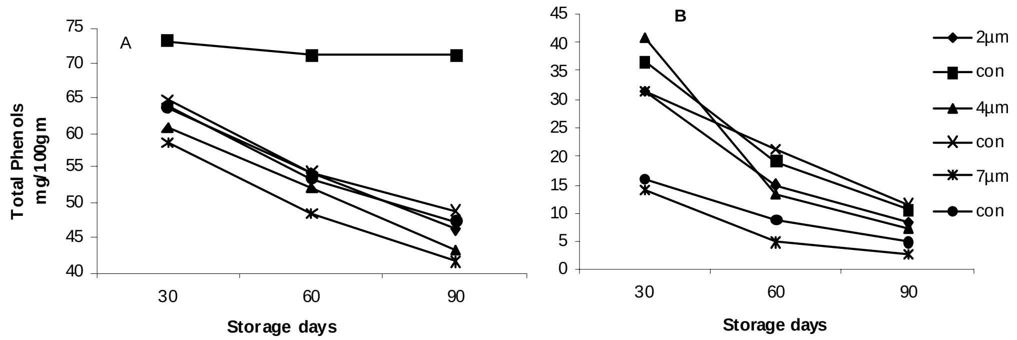

Fig. 9: Total phenols content of Hachia (A) and Triumph (B) persimmon fruit enclosed in different Packaging thickness films and N_2 enriched atmosphere after storage periods at 0ºC + 7d ripening at 20ºC

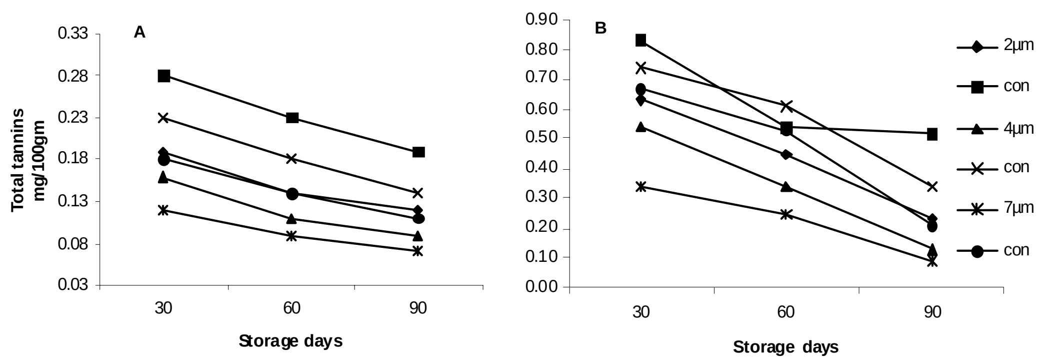

Fig. 10: Total tannins content of Hachia (A) and Triumph (B) persimmon fruit enclosed in different packaging thickness films and N_2 enriched atmosphere after storage periods at 0ºC + 7d ripening at 20ºC

respectively. This decrease of total phenols content was parallel with expanding storage period ,with maintaining persimmon fruit quality but it was less than the occurred in control fruits (47.38, 4.75). Total phenols content decreased considerably with nitrogen and carbon dioxide treatments, also the lowest value were observed for nitrogen treated samples throughout the entire storage period. (Bibi *et al*., 2007).

Total tannins: Tannins content of Hachia and Triumph persimmon fruits showed sharp significant decrease with expanding the storage period up to 90 days of storage at 0ºC and 7 d to ripe at 20ºC due to different packaging thickness and N_2 treatment. (Fig. 10). Packaged fruit at 7 µm LDPE film enhanced the decline of total tannins during storage period (0.07, 0.09) compared with 2 µm (12, 0.23) and 4 µm (0.09, 0.13) of LDPE film thickness.

Control fruits which recorded the highest value of tannins in 2 μm packages thickness after 30d of storage (0.83, 0.23) in the two cultivars respectively. Moreover, Triumph persimmon fruit had higher content of tannins compared with Hachia variety. Bibi (2007) reported that some astringent fruits show reduction in tannins on ripening due to decrease in extractability/polymerization accompanied by loss in fluidity and decrease in astringency. Finally, application of high levels of carbon dioxide or nitrogen gas can be effective in removing astringency from the fruit; however, the duration of treatment depends on the cultivar and temperature (Ben-Arie and Sonego, 1993).

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