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# Changes in phenolic compounds and antioxidant capacity of fresh-cut table grape (*Vitis vinifera*) cultivar 'Shahaneh' as influence by fruit preparation methods and packagings

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**Abstract**

The changes in fresh cut grape quality were evaluated over 14 days storage at 5 °C that harvested by two different methods (1-berry and 4-berries cutting), packaged in polyethylene terephthalate (PET) and polyvinylchloride (PVC) bags. The results showed that 4-berries cutting, which packaged in PVC bags showed the lowest weight loss, decay incidence, berry shattering, with the highest acceptability as compared to the other treatments. Total soluble solids (TSS) and TSS/TA were increased during storage in all treatments. The phenolic content in 1-berry cutting increased over the storage time, but its content declined in 4-berries cutting. At almost all of treatments, the flavenoids compositions including catechin, quercetin 3-galactoside and total quercetin decreased significantly at the end of storage. Antioxidant capacity increased up to seven days storage and thereafter decreased at the end of storage. Results showed that fruits packaged in PVC bags had higher total phenolic content, phenolic compositions such as catechin, quercetin 3-galactoside and total quercetin and antioxidant capacity than PET ones.

**Keywords**: Berry quality; Catechin; minimal process; Polyethylene terephthalate; Polyvinylchloride; Quercetin 3-galactoside.
**Abbreviations:** PET-polyethylene terephthalate; PVC-polyvinylchloride; TSS-Total soluble solids; TA-Titratable acidity; FW-Fresh weight; HPLC- High-performance liquid chromatography.

## Introduction

Demand to ready-to-eat fruits with fresh quality is rapidly growing in recent years. It is well-known that minimally processed fruits and vegetables are generally more perishable than the original raw materials (Pittia et al., 1999). Physical damages during the peeling and cutting processes cause to increase in respiration rate, biochemical changes and microbial spoilage, which often result in degradation of color, texture (flaccidity due to loss of water) and flavour of the product (Saltveit, 1997). Nutrient losses may also be accelerated when plant tissues are wounded (Klein, 1987). Little information is available concerning the changes of phenolic compounds and antioxidant capacity in fresh-cut fruits during cold storage. Biochemical changes in vitamin C, sugars and phenolic compounds during storage of fresh-cut fruits are very important, because they are used as primary quantitative parameters of quality (Gorny, 2001). Packaged fresh-cut fruits and vegetables are increasingly becoming popular, because they are convenient and nutritious snack alternatives (Conte et al., 2009). However, fresh-cut products have limited shelf stability due to rapid quality deterioration (Jacxsens et al., 2002). The main limiting factor of packaged fresh-cut grapes is decaying (Holz et al., 2003). Current commercial practices for preparation of fresh-cut grapes are removal of cap stems, but decay incidence and quality loss are primarily caused by tissue injury during stem removal (Kou et al., 2007). Physical damages often stimulate respiration rate (Taiz and Zeiger, 1991), microbial growth, product decay and quality deterioration (Kou et al., 2007). Modified atmosphere packaging (MAP) is the most common manner to preserve the initial color of fresh-cut fruits (Del Nobile et al., 2006). Modified atmosphere (MA) conditions can be done via packaging, which is a passive system, by balancing produced respiration and gas exchange through package materials. There has been an increase in the use of plastic film packaging, such as low density polyethylene (LDPE), polyvinychloride (PVC) and polypropylene (PP) for fresh fruits and vegetables (Lee et al., 1996). These materials are generally transparent, provide a barrier to water vapor transmission, and are very selective in gas permeability to $CO_2$ versus $O_2$ (Lee et al., 1996). Recently, rigid containers offer several advantages over flexible pouches, including serving convenience, protection from mechanical damage and stacking capability. Hence, they are used increasingly in the fresh-cut industry (Chonhenchob et al., 2007). There are only a few publications available regarding to the optimal conditions for maintaining the quality of fresh-cut table grapes. Therefore, the main objectives of the present study were to evaluate the effects of different preparation methods and packaging bags on the quality maintenance and phenolic compounds of fresh-cut table grape.

**Table 1.** Quality parameters and methods employed to evaluate table grape quality after storage for 14 days at 5 °C

| Quality parameters | Methods of evaluation and units |
|---|---|
| Berry appearance | Visual index of clusters: excellent, 1; good, 2; slightly dull, 3; <50% brownish and soft berries, 4; >50% brownish and soft berries, 5 |
| Shatter | Number of shattered berries/kg |
| Acceptability | 9=excellent, no defects, 7=Very good, minor defects, 5=fair, moderate defects, 3=poor, major defects, 1=unusable |
| Decay | 1=none, 2=slight (up to 5% surface affected), 3=moderate (5–20% surface affected), 4=moderately severe (20–50% surface affected) and 5=extreme (>50% surface affected) |
| Flavor | Flavor acceptability, using a five-point scale: excellent, 1; good, 2; acceptable, 3; poor, 4; unacceptable, 5 |

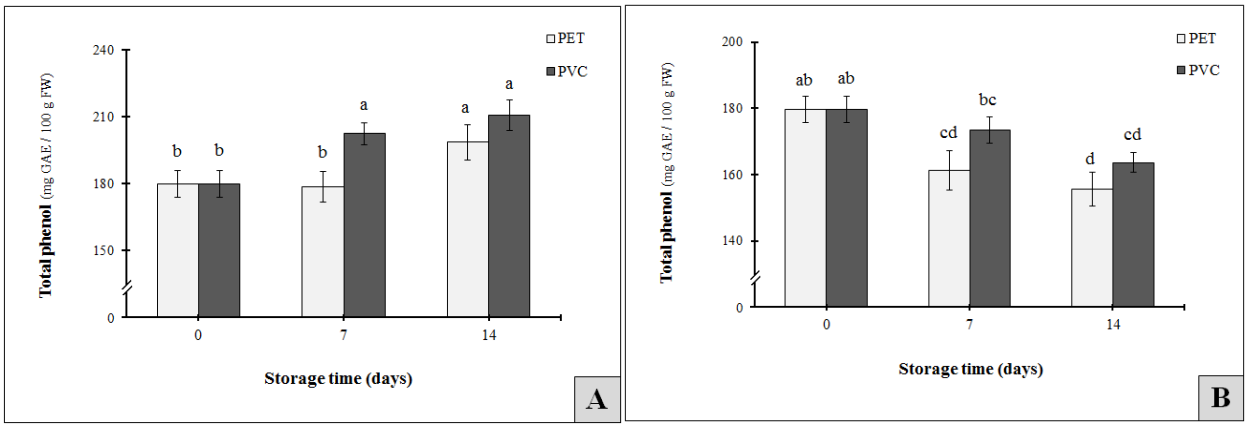


**Fig 1.** Changes in total phenolics of 1-berry cutting (A) and 4-berries cutting (B) grape fresh-cut packaged with PET and PVC during storage at 5 °C. Vertical bars indicate standard error (n=3).

## Results and discussion

### *General quality*

The general quality of fresh-cut berries was decreased during storage (Table 2), because of weight loss, color changes, decay incidence and browning (Crisosto et al., 2002). The grapes without stem (1-berry cutting) indicated more quality declining than 4-berries cutting. Physical damages were occurred during the grape removal (tearing out the stems) and the openings which created after stem removal, have made the grape berries more susceptible to decrease the quality. In addition, berries which packaged in PVC bags could maintain quality and reduce shattering and decay percentage during 14 days storage. The extended shelf-life was observed at 4-berries cutting which packaged in PVC bags may be due to the lower physical damage and respiration rate.

### *Berries weight loss*

All fruits showed a progressively weight loss during the storage period (Table 2). The weight loss is mainly related to respiration rate and moisture evaporation from the fruits. The results showed that 1-berry cutting had higher weight loss than 4-berries cutting both in PET and PVC bags. It may be due to the higher respiration rate of 1-berry, consequence of the damage sustained by the grape tissue when the cap stem is pulled out (Taiz and Zeiger, 1991). This can be explained that packaging of fruits in PVC may cause the better control atmosphere conditions and resulted in the lower respiration rate and weight loss.

### *TSS and TA*

The results showed that TSS was increased significantly throughout entire storage of both 1 and 4-berries cutting (Table 2). Increase in TSS may be due to the higher water loss (Tanada-Palmu and Grosso, 2005). In contrast, TA content was decreased slightly during the storage life (Table 2), which was consistent with fruit quality decline, but there was no significant different between both cutting and packaging treatments. TA is directly related to the concentration of organic acids present in the fruits. The decreasing acidity during storage might be due to the metabolic changes in fruits or due to the use of organic acid in respiratory process which is in agreement with Echeverria and Valich (1989). TSS/TA significantly increased during 14 days storage at 5 °C that was attributed to the decreasing in TA content rather than to an increase in TSS (Table 2).

### *The changes of total phenolics and flavenoids*

The changes of total phenolic content of fresh-cut grape during storage are shown in the Fig. 1a and 1b. As the results showed, the phenolic content gradually increased during storage in 1 berry cutting in both PET and PVC packaging. In contrast, 4-berries cutting showed a decline in phenolics over 14 days of storage. In both preparation methods, PVC packaging maintained higher phenolic content than PET bags. Phenolic compounds are generally synthesized by the shikimate pathway in which phenylalanine ammonialyase (PAL) is the key enzyme. The physical damage of plant tissue can increase PAL activity, which leads to an increase

**Table 2.** Effect of different packaging (PET and PVC) and fruits preparation methods (1-berry and 4-berry) on some characteristics of fresh-cut grapes during 14 days storage

| Treatment | Storage time | Fruit quality | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Berry appearance | Shattering | Flavor | Decay | Acceptability | Weight loss | TSS | TA | TSS/TA |
| 1-berry | | | | | | | | | | |
| PET | 0 | 1 c | 0.0 c | 1 c | 0.0 d | 9 a | 0.0 c | 15.5 b | 0.6 ns | 28.1 b |
| | 7 | 3 b | 30.5 b | 3 ab | 13.3 c | 3 ab | 9.5 ab | 19.4 a | 0.5 | 38.9 ab |
| | 14 | 5 a | 50.9 a | 4 a | 36.7 a | 1 b | 12.5 a | 19.9 a | 0.4 | 46.4 a |
| PVC | 0 | 1 c | 0.0 c | 1 c | 0.0 d | 9 a | 0.0 c | 15.5 b | 0.6 | 28.1 b |
| | 7 | 3 b | 29.8 b | 2 ab | 11.7 c | 3 ab | 5.8 b | 17.0 ab | 0.5 | 32.1 ab |
| | 14 | 4 ab | 48.3 c | 4 a | 26.7 b | 1 b | 5.9 b | 17.1 ab | 0.4 | 40.0 ab |
| 4-berries | | | | | | | | | | |
| PET | 0 | 1 b | 0.0 c | 1 ns | 0.0 b | 9 a | 0.0 d | 15.5 b | 0.6 ns | 28.1 b |
| | 7 | 2 ab | 16.8 b | 1 | 3.3 b | 7 ab | 8.1 a | 17.0 ab | 0.5 | 30.3 b |
| | 14 | 3 a | 28.8 a | 2 | 16.7 a | 5 b | 8.9 a | 18.0 a | 0.4 | 40.3 a |
| PVC | 0 | 1 b | 0.0 c | 1 | 0.0 b | 9 a | 0.0 d | 15.5 b | 0.6 | 28.1 b |
| | 7 | 1 b | 14.5 b | 1 | 1.7 b | 9 a | 3.1 c | 16.0 b | 0.5 | 32.2 b |
| | 14 | 2 ab | 28.0 a | 1 | 15.0 a | 7 ab | 5.2 b | 17.1 ab | 0.5 | 35.4 ab |

Means of three replicates followed by the same letters were not statistically significant different (P≤0.01). ns = non-significant.
PET: polyethylene terephthalate; PVC-polyvinylchloride

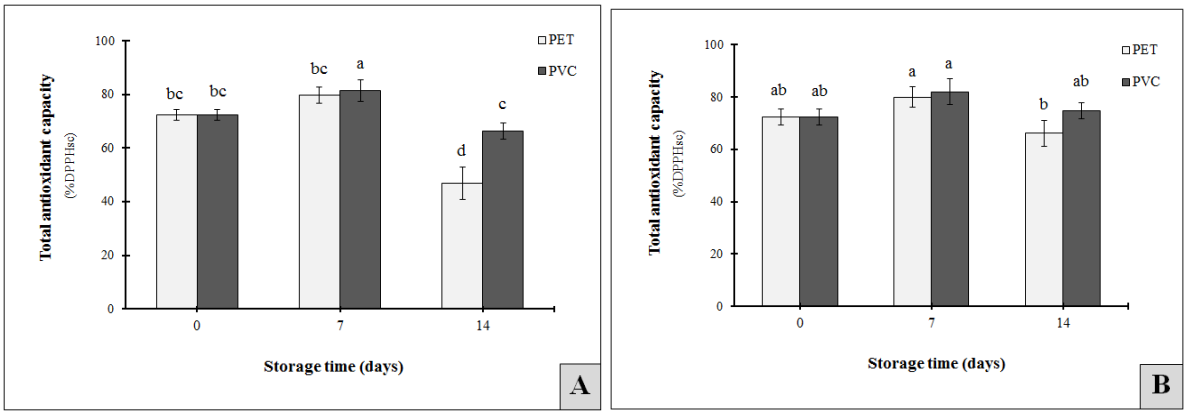


**Fig 2.** Changes in total antioxidant capacity of 1-berry cutting (A) and 4-berries cutting (B) grape fresh-cut packaged with PET and PVC during storage at 5°C. Vertical bars indicate standard error (n=3).

in phenolic compounds (Fan, 2005). Therefore, increasing in phenolic content at 1-berry cutting may be due to a stress in berries during grape removal from the caps. At 4-berries cutting phenolic content decreased during storage that can be related to the postharvest fruit metabolic processes, such as respiration, ethylene production and enzyme activity. Furthermore, the decrease of total phenol content is probably due to the oxidation by polyphenol oxidase (PPO) (Altunkayaand Gökmen, 2008). The changes of flavonoids, including catechin, quercetin 3-galactoside and total quercetin are shown in Table 3. At 1-berry cutting, catechin significantly increased after 14 days storage, but at 4-berry cutting, catechin content decreased during storage. As the results showed, at both 1 and 4-berries cutting, quercetin 3-galactoside and total quercetin content were decreased significantly during storage. This result is in agreement with those of Piretti et al. (1994), who reported that catechin, epicatechin and quercetin glycosides were decreased during storage in 'Granny Smith' apples fruit stored at 0°C. Flavonoids are phenolic derivatives and found in substantial amounts in grape. The decrease in flavonoid is associated with antioxidant capacity during storage (Table 4). Factors that may profoundly differentiate flavonol composition are also those associated with ageing and storage conditions. The flavonoids such as quercetin and catechin are common PPO substrates (Nagai and Suzuki, 2001). It was also reported that quercetin and catechin were oxidized directly by PPO (Jiménez and Garcína-Carmona, 1999). Therefore, the decrease of phenolic composition could be due to the oxidation by PPO (Yamaguchi et al., 2003).

***Antioxidant capacity***

Antioxidant capacity was increased up to seven days storage and thereafter decreased to end of storage in both berry preparation methods. Decrease in antioxidant capacity with prolonged storage may be due to the $O_2$-promoted oxidation of the constitutive phenolic compounds and vitamin C (Stewart et al., 1999). Thus, it could be found that 4-berries cutting maintained higher antioxidant capacity than 1– berry one. In addition, fruits which were packaged in PVC bags had higher antioxidant capacity than PET ones after 14 days of storage at 5 °C (Fig. 2A, B). It seems that both preparation methods could induce a stress in the samples, leading to the release of an additional amount of antioxidants, revealed in the increased antioxidant capacity at the early storage (Plaza

**Table 3.** Effect of different packaging (PET and PVC) and fruit preparation methods (1-berry and 4-berry) on catechin, quercetin 3-galactoside and total quercetin concentration of table grape fresh-cut after 14 days.

| Treatment | Storage time | Phenolic composition | | |
|---|---|---|---|---|
| | | Catechin | Quercetin 3-galactoside | Total quercetin |
| 1-berry | | | | |
| PET | 0 | 73.34 b | 45.25 a | 542.34 a |
| | 14 | 76.33 b | 33.34 c | 464.54 c |
| PVC | 0 | 73.34 b | 45.25 a | 542.34 a |
| | 14 | 96.15 a | 38.74 b | 497.73 b |
| 4-berries | | | | |
| PET | 0 | 73.34 a | 45.25 a | 542.34 a |
| | 14 | 50.67 b | 30.66 c | 509.52 c |
| PVC | 0 | 73.34 a | 45.25 a | 542.34 a |
| | 14 | 68.10 a | 39.48 b | 528.42 b |

Means of three replicates followed by the same letters were not statistically significant different (P≤0.01). ns = non-significant.

**Table 4.** Correlation coefficients between total phenolics, antioxidant capacity, catechin, quercetin and total quercetin in table grape fresh-cut

| | Total phenolic content | Antioxidant capacity | Catechin | Quercetin 3-galactoside | Total quercetin |
|---|---|---|---|---|---|
| 1-berry cutting | | | | | |
| Total phenolic content | 1 | | | | |
| Antioxidant capacity | 0.05 ns | 1 | | | |
| Catechin | 0.81 ** | 0.04 ns | 1 | | |
| Quercetin 3-galactoside | -0.68 ** | 0.87 ** | -0.27 ns | 1 | |
| Total quercetin | -0.74 ** | 0.91 ** | -0.36 ns | 0.97 ** | 1 |
| 4-berries cutting | | | | | |
| Total phenolic content | 1 | | | | |
| Antioxidant capacity | 0.25 ns | 1 | | | |
| Catechin | 0.73 ** | 0.60 * | 1 | | |
| Quercetin 3-galactoside | 0.65 * | 0.55 * | 0.95 ** | 1 | |
| Total quercetin | 0.61 * | 0.45 ns | 0.86 ** | 0.96 ** | 1 |

** and * Significant difference values P≤0.01and P≤0.05. ns = non-significant.

et al., 2009). Interestingly, there was a significant correlation between antioxidant capacity and flavonoids (Table 4). Beninger and Hosfield (2003) were found a positive correlation between antioxidant activity and flavonoids compositions. Moreover, Pinelo et al. (2004) were reported that antioxidant capacity of flavonoid is in agreement with variations in their antiradical activity.

In conclusion, 4-berries cutting followed by PVC bags packaging could extend storage life and maintain quality of table grape fresh-cuts during low storage temperature

## Materials and methods

### *Plant materials and treatments*

Fruits of the second main table grape (*Vitis vinifera*) cultivar in Iran which is called 'Shahaneh', were obtained from farms during the commercial harvest. Fruits were selected for uniformity in size and color. Blemished, damaged or diseased berries were discarded carefully. Grapes were prepared by two different methods as described by Kou et al. (2007). The grape stems were manually removed so that the grapes were completely stemless (1-berry cutting); and the rachis of the grapes was cut short with a sanitized scissors so that four-berries of each cluster were remained per stem (4-berries cutting). The grapes were then sanitized with 100 mg $L^{-1}$ chlorine solution (NaOCl), adjusted to pH 6.5 with HCl, for 1 min, followed by draining and air drying (Kou et al., 2007). Each 500 g sample of grapes, including 1-berry and 4-berries cutting were randomly packaged in two different ways: 1) rigid polyethylene terephthalate (PET) container (19 × 12.5 × 4 cm) and 2) a polyvinylchloride (PVC) bags (10 × 13 × 3 $cm^3$) with 48 µm thickness and sealed with a 29.2 pmol/s/$m^2$/Pa oxygen transmission rate film. Finally, the fruits were stored at 5 °C for 14 days. Evaluation of berries quality was performed over 14 days with three replications consisting two bags in each replicate.

### *General appearance*

General quality was examined by evaluation of berry appearance, incidence of shattered berries, decay incidence, acceptability and flavor by a panel of five trained judges according to table 1 as describe by Xu et al (2007).

### *Weight loss*

Grapes were weighed at the beginning of the experiment, and thereafter every week during the storage time. Weight loss was expressed as the percentage loss of the initial total weight.

### *Total soluble solids (TSS) and titrable acidity (TA)*

Percentage of TSS as an index of soluble sugar content in fruit was determined by a digital refractometer (CETI-Belgium) at 20 °C. Percentage of TA was determined by titration of 25 ml filtrated juice with adding of 0.1 N NaOH solution to the juice to reach the pH of 8.2.

### *Total phenolic content*

Total phenolics were analyzed spectrophotometrically using the modified Folin–Ciocalteu colorimetric method with some modifications as described by Singleton et al. (1999). Each sample (1g) was extracted with 10 mL acidic methanol and then 250 µL of the methanolic extract were mixed with 250 µL of distilled (DI) water in a test tube followed by addition of 2.5 mL of 10 % Folin–Ciocalteu reagent and allowed to stand for 6 min. Then, 2 mL of 7.5 % sodium carbonate solution were added. Each sample was allowed to stand for 90 min at room temperature in darkness and the absorbance was measured at 760 nm using an UV/Vis spectrophotometer (model PG Instrument +80, Leicester, United Kingdom). Results are expressed as mg gallic acid / 100 g FW.

### *HPLC analysis of flavonoids*

Flavonoids were determined using high-performance liquid chromatography (HPLC) as described by Bakhshi and Arakawa (2006). For polyphenols extraction, 2 mL of solvent (methanol/acetic acid, 85:15, v/v) was added to 1 g of berry powder. The samples were kept in a refrigerator for 24 h and centrifuged for 10 min at 10000 rpm. The supernatant of centrifuged samples were filtered by disposable 0.45µm syringe filter. Fifty microliters of the filtered sample were injected in HPLC_(Waters, 1525, Milford, USA) equipped with a UV-Visible detector (Waters Dual λ Absorbance 2487), C18 column: Waters Symentery C18 5µm 4.6×150 mm (Waters, Dublin, Ireland), at 280 and 350 nm. The flavonoides were identified by comparing their UV spectra and retention times with those of the corresponding standards and by the spiking of samples with the appropriate standard. Catechin standard purchased from Sigma-Aldrich (Canada Ltd) and quercetin 3-galactoside from extrasynthase, France. Querctin and catachin was determined immediately after treatments and the end of 14 days storage.

### *Antioxidant activity*

The antioxidant activity was evaluated by 1, 1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging method according to the procedure of Brand-Williams et al. (1995), with some modifications. Briefly, 1 mL of methanolic extract was added to 2 mL of 0.15 mM solution of DPPH in methanol by vortexing and allowing standing at room temperature in darkness. The absorbance of the samples was measured at 515 nm after 15 min using an UV/Vis spectrophotometer (PG Instrument +80, Leicester, United Kingdom). For each sample, three separate determinations were carried out. The antioxidant activity was expressed as the percentage of decline of the absorbance, relative to the control, corresponding to the percentage of DPPH that was scavenged. The percentage of DPPH, which was scavenged (%DPPHsc), was calculated using

$$\%DPPHsc = [(A_{cont} - A_{samp}) / A_{cont}] \times 100$$

Where $A_{cont}$ is the absorbance of the control, and $A_{samp}$ is the absorbance of the sample.

### *Statistical analysis*

The experiment was conducted using a completely randomized design with three replications. Data were analyzed as a 2-factor linear model using the PROC GLM procedure (SAS software ver. 9.1 2002-2003) with package and storage time as the factors. Significance of the differences was defined as $P < 0.05$.


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### References


Altunkaya A, Gökmen V (2008) Effect of various inhibitors on enzymatic browning, antioxidant activity and total phenol content of fresh lettuce (*Lactuca sativa*). Food Chem 107:1173–1179

Bakhshi D, Arakawa O (2006) Induction of phenolic compound biosynthesis with light irradiation in the flesh of red and yellow apples. J Appl Hortic 8(2):101–104

Beninger CW, Hosfield GL (2003) Antioxidant activity extracts, condensed tannin fractions, and pure flavonoids from *Phaseolus vulgaris* L. seed coat color genotypes. J Agri Food Chem 51:7879–83

Brand-Williams W, Cuvelier ME, Berset C (1995) Use of free radical method to evaluate antioxidant activity. LWT - Food Sci Technol 28(1):25–30

Chonhenchob V, Chantarasomboon Y, Singh SP (2007) Quality Changes of Treated Fresh-cut Tropical Fruits in Rigid Modified Atmosphere Packaging Containers. J Packaging Technol Sci 20:27–37

Conte A, Scrocco C, Brescia I, Del Nobile MA (2009) Different packaging strategies for fresh-cut 'barattiere' melon cultivar (*Cucumis melo* L.). Int J Food Sci Technol 44: 1422–1428

Crisosto CH, Garner D, Crisosto G (2002) Carbon dioxide-enriched atmospheres during cold storage limits losses from *Botrytis* but accelerate rachis browning of 'Redglobe' table grapes. Postharvest Biol Technol 26: 181–189

Del Nobile MA, Baiano A, Benedetto A, Massignan L (2006) Respiration rate of minimally processed lettuce as affected by packaging. J Food Eng 74:60–9

Echeverria E, Valich J (1989) Enzymes of sugar and acid metabolism in stored Valencia organs. J Am Soc Hort Sci 114: 445–449

Fan X (2005) Antioxidant capacity of fresh-cut vegetables exposed to ionizing radiation. J Sci Food Agri 85:995–1000

Gorny JR (2001) A Summary of CA and MA Requirements and Recommendations for Fresh-cut (Minimally Processed) Fruits and Vegetables. Postharvest Horticulture Series No. 22, CD Version.

Holz G, Gutschow M, Coertze S, Calitz F (2003). Occurrence of *Botrytis cinerea* and subsequent disease expression at different positions on leaves and bunches of grape. Plant Dis 87:351–358

Jacxsens L, Devlieghere F, Debevere J (2002) Predictive modeling for packaging design: equilibrium modified atmosphere packages of fresh-cut vegetables subjected to a simulated distribution chain. Intl J Food Microbiol 73:331–41

Jiménez M, García-Carmona F (1999) Oxidation of the flavonols quercetin by polyphenol oxidase. J Agri Food Chem 47:56–60

Klein JD (1987) Relationship of harvest date, storage conditions, and fruit characteristics to bruise susceptibility of apple. J Am Soc Hortic Sci 112–113

Kou L, Luo Y, Wu D, Liu X (2007) Effects of Mild Heat Treatment on Microbial Growth and Product Quality of Packaged Fresh-Cut Table Grapes. J food Sci 72(8): 567–573

Lee L, Arul J, Lencki R, Castaigne F (1996) A review on modified atmosphere packaging and preservation of fresh fruits and vegetables: physiological basis and practical aspects-part 2. Packaging Technol Sci 9:1–17

Nagai T, Suzuki N (2001) Partial purification of polyphenol oxidase from Chinese cabbage *Brassica rapa* L. J Agri Food Chem 49:3922–3926

Pinelo M, Lara M, Maria J, Maria CN. (2004). Interaction among Phenols in Food Fortification: Negative Synergism on Antioxidant Capacity. J Agri Food Chem 52:1177–1180

Piretti MV, Gallerani G, Pratella GC (1994) Polyphenol fate and superficial scald in apple. Postharvest Biol Technol 4:213–224

Pittia P, Nicoli MC, Comi G, Massini R (1999) Shelf-life extension of fresh-like ready to- use pear cubes. J Sci Food Agric 79:955–60

Plaza L, Sánchez-Moreno C, de Pascual-Teresa S, De Ancos B, Cano MP (2009) Fatty Acids, Sterols, and Antioxidant Activity in Minimally Processed Avocados during Refrigerated Storage. J Agric Food Chem 57:3204-3209

Saltveit ME (1997) Physical and physiological changes in minimally processed fruits and vegetables. In: Phytochemistry of Fruits and Vegetables (edited by F.A. Tomas- Barberan & R.J. Robins). Pp. 205–220. Oxford: Claredon Press

Singleton VL, Orthofer R, Lamuela-Raventós RS (1999) Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin- Ciocalteau Reagent. Methods in Enzymol 299:152–178

Stewart D, Oparka J, Johnstone C, Iannetta PPM, Davies HV (1999) Effect of modified packaging (MAP) on soft fruit quality. In Annual report of the Scottish Crop Research Institute for 1999 (pp. 119–124). Invergowrie, Dundee, Scotland: Scottish Crop Research Institute

Tanada-Palmu PS, Grosso CRF (2005). Effect of edible wheat gluten-based films and coatings on refrigerated strawberry (*Fragaria* × *ananassa*) quality. Postharvest Biol Technol 36:199–208

Taiz L, Zeiger E (1991) Respiration and lipid metabolism. In: Brady EB, Donohoe L, editors. Plant physiology. Redwood City, Calif.: Benjamin Cummings. p 282–284

Xu C, Zhao B, Ou Y, Wang X, Yuan X, Wang Y (2007) Elicitor-enhanced syringin production in suspension cultures of *Saussurea medusa*. World J Microbiol Biotechnol 23:965–970

Yamaguchi T, Katsuda M, Oda Y, Terao J, Kanazawa K, Oshima S (2003) Influence of polyphenoloxidase and ascorbate oxidase during cooking process on the radical scavenging activity of vegetables. Food Sci Technol Res 9(1):79–83