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Effect of different packaging materials on postharvest quality of cv. Envie2 strawberry

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Abstract

Strawberry fruits require appropriate storage technology to maintain post harvest quality. In order to improve the shelf-life and to reduce the decrease of qualitative and nutraceutical characteristics the effects of different packaging conditions were observed comparing biobased and polypropylene perforated films. Sample units of 0,250 Kg strawberries cv. Envie2 flowpacked have been stored under two different conditions: in cool room at +2°C for 96 hours (like in an ideal supply chain) and in a cool room at +2°C for 48 h followed by storage at room temperature (+20°C) up to 96 hours from start. Fruits packed with biobased film and stored at +2°C showed the better results to preserve the qualitative traits maintaining the best headspace composition (%) for all the storage time.

Introduction

Strawberry is a non-climacteric fruit and it must be harvested at full maturity to achieve the maximum quality in relation to flavour and color. The fruits have short shelf life and are highly perishable, with a high rate of respiration, and suffer relatively high post-harvest losses due to fungal development, mechanical injury, physiological deterioration and water loss (Cordenunsi *et al*., 2005). In the recent past, flavour and appearance were the most important attributes of fruits and other fresh vegetables, but nowadays consumers are more concerned about food safety and nutritional value. The main characteristics related to the quality of ripe strawberry fruit are texture, flavour (soluble sugars and organic acids) and color (anthocyanin content). Change in texture is a consequence of the natural process of senescence and also of the atmosphere in which the fruit is stored. Besides the obvious changes in appearance, mold contamination can also promote undesirable changes in texture and contribute to reduced strawberry shelf-life. The increasing demand for dietary compounds with antioxidant action has focused interest on fruits as natural sources of these compounds. In this respect, strawberry is a good source of ascorbic acid (AA) and flavonoid compounds (Wang *et al*., 1996). Since fruits are no longer only ‘‘attractive foods’’, more effort should be made to understand the effects of treatments to increase shelf-life and improve nutritional value. Several research works have aimed to find the best compromise between extended shelf-life and maintenance of nutritional value. Modified atmosphere, which can be produced by increasing CO_2 level while reducing O_2, has yielded good results regarding strawberry preservation. Effective control of fruit decay in fresh Chinese bayberry, strawberry and blueberry has been obtained by cold storage in combination with carbon dioxide-enriched atmospheres (10–20% CO_2) (Ceponis and Cappelini, 1983; Li and Kader, 1989; Gil *et al*., 1997; Shen and Huang, 2003). Besides the control of O_2 and CO_2 levels inside the cool rooms also other methods are used to extend the shelf life period and among them the detection of new food packaging techniques is gaining many importance, following the increasing interest of the large scale retail trade about the fruits and vegetables packaging, useful to preserve products by external contaminations, to facilitate their handling and overall helpful to retard the senescence processes. Many studies have been aimed to find the best kind of food packaging optimizing the O_2 and CO_2 concentrations inside the packages to maintain fruit and vegetable quality for long time (Gomes et al., 2010). Moreover actually the trend in the food packaging leads to the development and diffusion of biobased films to solve the problem of the packaging waste that is causing increasing environmental concerns (Davis and Song, 2006). So the continuous increasing of pollution of the environment has recently given rise to demands for new biobased polymers, mainly for applications related to food packaging and agriculture (Arvanitoyannis, 1999). It is important to consider that one of the most important aspects

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of packaging films is to preserve the qualitative characteristics of fruit and vegetables during the storage period. Some studies have compared the effect of biobased laminates and films on the quality of fresh produce (Makino and Hirata, 1997; Del Nobile *et al*., 2006) but until now very few informations are available on the effectiveness of biobased film packaging on microbial and physicochemical quality during storage of vegetables (Koide and Shi, 2007). The objective of our study was to investigate the effects of film packaging and storage temperature on physical and nutritional status of strawberry fruits cv.Envie2 harvested at the red ripe stage of maturity stored for a short time (96 hours).

Materials and Methods

Strawberries cv.Envie2 were manually harvested at the red ripe stage of maturity from a commercial orchard (Agrifrutta Soc. Coop. S.R.L. – Italy) at the end of July. The fruits were selected for color and size, individually picked in polyethylene terephthalate (PET) baskets (0,250 Kg) and immediately transferred to the laboratory under cold conditions. The baskets were randomly packed using two different single layer films (biobased film and a polypropylene perforated film) of 25 microns. The different packages (treatment), the film permeability property and the fruits storage conditions are reported in Table I. For the flowpack equipment, an electronic horizontal wrapping machine Taurus 800 (Delphin, Italy) has been used. All fruits were compared with unpackaged samples (control).

The initial gas composition in the package headspace was 20.8% O_2 and 0.03% CO_2. The gases analysis and weight losses were performed daily while other quality control were performed after 72 and 96 hours of storage. For each treatment were used three baskets random (0,750 Kg of strawberry fruits). Headspace composition were measured with a portable gas analyzer (PBI Dansensor, Italy) and expressed as percentages. The same air volume was maintained in the packages across the trial period, as the analyzer introduced the same quantity of air that it removed for the analyses. Calibration was done by using air (Aday and Caner, 2011). Weight loss of each basket was measured as percentage of the initial weight (WL%) using an electronic balance (SE622, WVR Science Education) with an accuracy of 10^{-2}. The total soluble solids content (TSS) (°Brix) and titratable acidity (TA) (meq/l) were measured on juice extracted from a strawberry samples blended at high speed in a tissue homogeniser using respectively a digital refractometer (Atago refractometer model PR-32) and an automatic titrator (Titritino plus 484, Metrohm, Swiss). Organic acids and ascorbic acid were determined with a Merck-Hitachi (Tokyo, Japan.) liquid chromatograph with an L-7455 photodiode detector (DAD) detector, D-7000 system manager, L7200 autosampler and L-7100 pumps (Schirra *et al*., 2008). Simultaneous separation and determination of organic acids and ascorbic acid were achieved according to the procedure described by Yuan and Chen (1999) and by Chinnici *et al.* (2005) using a Bio-Rad cation guard column and a Bio-Rad Aminex HPX-87H Hydrogen form cation exchange resin-based column (300 mm x 7.8 mm i.d.) at 40°C. The mobile phase consisted of 0.005 M sulfuric acid aqueous solution and the samples were isocratically separated at 0.6 mL/min. Peaks of organic acids and ascorbic acid were measured at wavelengths of 210 and 245 nm respectively and were identified by comparing retention times with those of standards and quantification was carried out using external standards. Total phenolic content was analyzed according to the Folin-Ciocalteau colorimetric method (Singleton and Rossi, 1965) and expressed as gallic acid equivalent). Antioxidant activity was assessed using the free radical DPPH, according to Bondet *et al*. (1997). The mixture containing 3 mL of a methanol solution of 0.16 mM DPPH was allowed to react for 15 min in a cuvette. The inhibition percentage of the absorbance at 515 nm of DPPH solution added with sample was calculated using the following equation: Inhibition % = (Abst = 0 – Abst = 15 min)/Abst = 0 x 100. Total anthocyanins content were determined spectrophotometrically using the pH differential method (Rapisarda *et al.*, 2000). Color parameters of juices solution diluted 1/10 with water, were measured in glass cells of 10 mm path length using a Varian Cary 50 spectrophotometer equipped with a Cary Win UV color software. All measurements were done in triplicate. Three measurements were taken on each treatment for each qualitative parametre considered.

All statistics were performed using SPSS for Windows version 17.0. The data obtainend were treated with one-way analysis of variance (ANOVA), and the means were separated using the Tuckey test ($P \leq 0.05$). It was possible to perform parametric tests for the percentages because the sample sizes were identical.

Results and Discussion

The headspace gases concentrations of strawberries stored in the biobased film (treatment A and D) is showed in Table II. The film is able to

Table 1. Different packages and storage conditions of strawberries cv. Envie2

Treatment	Storage conditions	Film packaging	O_2TR (ASTM F2622-08) at 23°C and 50% RH	CO_2TR (ASTM F2476-05) at 23°C and 50% RH
A	+2°C (24, 48, 72, 96 h)	Biobased (from starch corn)	2000	44500
B	+2°C (24, 48, 72, 96 h)e	Perforated (PP with 6 mm holes)	-	-
C	+2°C (24, 48, 72, 96 h)	Control (unpackaged)	-	-
D	+2°C (48 h) +20°C (72, 96 h)	Biobased (from starch corn)	2000	44500
E	+2°C (48h) +20°C (72, 96 h)	Perforated (PP with 6 mm holes)	-	-
F	+2°C (48 h) +20°C (72, 96 h)	Control (unpackaged)	-	-

Table 2. Headspace composition of strawberries cv. Envie2 stored with the biobased film at different temperature

Gas (%)	Treatment	Storage time (hours)			
		24	48	72	96
O_2	A	19.4±0.2	13.7±0.1	18.3±0.2	17.2±0.1
	D	19.0±0.1	13.7±0.1	1.8±0,1	1.0±0.1
CO_2	A	1.8±0.0	3.9±0.1	4.9±0.1	4.5±0.2
	D	1.8±0.0	3.9±0.1	15.0±0.1	18.0±0.1

Average and S.D. s were calculated for 3 replicates

Table 3. WL (%) of strawberries cv. Envie2 stored with different film

Treatment	Storage time (hours)			
	24	48	72	96
A	0.2±0.00	0.2±0.00	0.3±0.00	0.4±0.00
B	0.5±0.00	0.6±0.10	0.9±0.10	1.1±0.10
C	1.0±0.10	1.6±0.20	2.2±0.40	-
D	1.6±0.10	0.1±0.00	0.1±0.00	0.1±0.00
E	1.7±0.20	0.1±0.00	-	-
F	1.4±0.10	0.5±0.05	-	-

create M.A.P. storage condition maintaining along all the storage time gas values different from the normal atmosphere composition (20.8% O_2 and 0.03% CO_2). In correspondence of the temperature change (72 hours) differences in O_2% and CO_2% composition were observed among treatments A and D. Particularly the highest CO_2 concentration (15,0%) was observed for the treatment D and it was due to the rapid respiration rates of strawberries increased by the high temperature (+20°C). The biobased film at low temperature (+2°C) (treatment A) showed best property maintaining the CO_2 concentrations under 5%. Robinson *et al.* (1975) reported that losses of 6% of the initial value of fresh weight in a soft fruit should be considered the limit for marketability. WL % values reported in Table III showed as all treatments didn't affect this qualitative parameter. All treatments showed WL % inferior to 1%. Strawberries are considered mature with approximately 7% of soluble solids (Kader, 1999). Strawberry cv.Envie2 at harvest showed TTS values of 5.4°Brix; for all treatments were observed an increase in the TSS values probably not due to conversion of starch to sugars, since strawberries accumulate very little starch, but due to solubilization of cell wall pectins as showed by the increases in anthocyanin (Table IV). The highest TSS values were observed at 72 hours for the B treatment (6.3°Brix). The TTA was no affected by storage and no differences were observed between treatments; all treatments in fact showed WL% values trascurable (Table III) and this explain the maintenance of TTA values near to harvest (2.42 meq/l).

Glucose, fructose and sucrose represent the main soluble metabolites (Makinen and Soderling, 1980). Few data are available on changes in sugar content during the ripening of strawberries (Zabetakis and Holden, 1997). Fructose and glucose were present in similar concentrations at harvest (7.09 and 6.69 g/100 ml) while sucrose was present at lower level (3.59 g /100 ml) (Zabetakis and Holden, 1997). After 72 hours of storage the highest fructose and glucose content were found in strawberries stored with the biobased film both at +2°C (treatment A) and at +20 °C (treatment D) while for the sucrose the highest value (3.71 g/100 ml) was found in fruits stored at +2 °C with the perforated film (treatment B). Like sugars, organic acids are important flavour components and can affect the formation of off flavour and the gelling properties of pectin. The highest acid citric values were observed at 72 and 96 hours for fruit maintained with the biobased film at +2°C (treatment A) and +20°C (treatment D) while no differences among treatments were found for the malic acid which maintained values similar to harvest (0.20 mg/100 ml). Ascorbic acid has long been considered an important nutritional component of strawberry fruit (Shin *et al.*, 2007). The mean values of fresh fruits (136.19 mg/100 ml) decreased in the time storage for all samples showing at 72 hours the lowest value for unpackeged fruits stored at low temperature (treatment C). Stored fruits showed a total antioxidant capacity (%) lower than fresh fruits and the high tempertaure (+20°C) affected the values decreases more than low temperature (+2°C). The mechanism by which modified atmosphere storage prevents the increase in total antioxidant activity is not clear, but changment in atmosphere conditions might affect the release of bound phytochemicals that contribute to antioxidant activity. According to Kalt *et al.* (1999) the total anthocyanins on fresh fruits (99.82 mg/100 g) increased with the storage time for all treatments and the highest values (139.98 and 139.48 mg/100 g) were observed at 72 hours respectively for the C and E treatments. According to Holcroft and Kader (1999) the total anthocyanins increase was lower in fruit stored in M.A.P. (treatment A and D) at 72 hours of storage. The accumulation of anthocyanins in strawberries coincides with the induction of phenylalanine ammonia-lyase and uridine diphosphate glucose: flavonoid O_3-glucosyltransferase enzymes (Given *et al.*, 1988). The concentration of total phenolics of strawberry fruit can be maintained or changed during storage (Kalt *et al.*, 1999; Ayala-Zavala *et al.*, 2004). In our study all stored samples showed lower values than fresh fruits according to Cordenunsi *et al.* (2005).

Table 4. Changes in total soluble solids, titratable acidity and total carbohydrates of strawberries cv. Envie2 stored in different conditions

Hours	Treatments	TSS (°Brix)	TTA (meq/l)	Fructose (g/100 ml)	Glucose (g/100 ml)	Sucrose (g/100 ml)
0	Harvest	5.4 ± 0.10	2.42 ± 0.03	7.09 ± 0.03	6.69 ± 0.10	3.59 ± 0.10
72	A	5.5 ± 0.10	2.42 ± 0.02	6.92 ± 0.13	6.57 ± 0.15	3.28 ± 0.07
	B	6.3 ± 0.20	2.39 ± 0.03	6.88 ± 0.13	6.30 ± 0.20	3.71 ± 0.23
	C	5.7 ± 0.10	2.37 ± 0.03	6.97 ± 0.03	5.67 ± 0.03	2.60 ± 0.09
	D	5.1 ± 0.10	2.39 ± 0.02	7.01 ± 0.10	6.35 ± 0.07	3.44 ± 0.06
	E	5.4 ± 0.20	2.31 ± 0.03	6.84 ± 0.05	5.73 ± 0.14	1.86 ± 0.24
	F	- ± -	- ± -	- ± -	- ± -	- ± -
96	A	6.1 ± 0.10	2.36 ± 0.03	6.50 ± 0.04	5.45 ± 0.11	1.60 ± 0.13
	B	5.8 ± 0.20	2.28 ± 0.02	6.52 ± 0.17	5.75 ± 0.17	2.00 ± 0.15
	C	- ± -	- ± -	- ± -	- ± -	- ± -
	D	5.5 ± 0.10	2.41 ± 0.01	6.28 ± 0.11	5.94 ± 0.16	2.61 ± 0.08
	E	- ± -	- ± -	- ± -	- ± -	- ± -
	F	- ± -	- ± -	- ± -	- ± -	- ± -

Average and S.D. s were calculated for 3 replicates

Table 5. Organic acids, antioxidant activity, anthocyanins and total phenolic compounds of strawberries cv. Envie2 stored in different conditions

Variable	Treatment	Stotage time (hours)	
		72	96
Citric acid	Harvest	2.34±0.02	
(g/100 ml)	A	2.25 a[a]	2.04 b
	B	2.09 c	1.92 c
	C	2.03 d	-
	D	2.13 b	2.22 a
	E	1.93 e	-
	F	-	-
Malic acid	Harvest	0.20 ±0.00	
(mg/100 ml)	A	0.19 n.s.	0.17 n.s.
	B	0.19	0.17
	C	0.18	-
	D	0.18	0.17
	E	0.19	-
	F	-	-
Ascorbic acid	Harvest	136.19±0.8	
(mg/100 ml)	A	123.47 c	122.57 b
	B	132.11 a	127.13 a
	C	110.83 d	-
	D	126.97 b	121.25 b
	E	127.84 b	-
	F	-	-
Antioxidants	Harvest	149.36 ± 1.70	
(% inhibition)	A	134.56 a	72.75 c
	B	137.07 a	82.10 b
	C	136.05 a	-
	D	91.91 b	87.98 a
	E	87.71 c	-
	F	-	-
Total anthocyanins	Harvest	99.82 ±1.95	
mg/100 g	A	117.16 b	130.33 a
	B	119.75 b	124.56 c
	C	139.98 a	-
	D	119.60 b	126.9 b
	E	139.48 a	-
	F	-	-
Total phenols	Harvest	549.69±2.87	
(g/100 ml)	A	517.00 a	429.40 c
	B	504.77 a	481.92 a
	C	483.67 bc	-
	D	510.57 a	459.23 b
	E	464.32c	-
	F	-	-

Conclusion

Strawberry represents one of the most important sources of bioactive compounds showing high antioxidant capacity, together with other berries, especially blackcurrants (Kevers *et al.*, 2007; Battino *et al.*, 2009). Several genetic and environmental factors were reported to affect the production and accumulation of bioactive compounds in strawberry (Olsson *et al.*, 2004), and few genotypes were well characterized for these important features (Tulipani *et al.*, 2008). In this study, we have studied, with the same tests, various postharvest parameters than can influence the antioxidant capacity and the phenolic content of strawberry. The precise results revealed the importance of genetic background for the antioxidant capacity and for the content of total phenolics (with up to 3.3-fold variations). Various researchers indicated that the effect of the genotype on strawberry antioxidant capacity and phenolic content is stronger than that of the environmental factors (Capocasa *et al.*, 2008; Crespo *et al.*, 2010). Moreover, in this study, storage temperature and packaging appeared also to be very important, more important than genotype. Regardless of its environmental or physiological drivers, point source variation in fruit phytonutrient contents may be a relevant interest in health-related studies (Cheplick *et al.*, 2010). It may impact the nutritional benefits to consumers and affect the quality advantages associated with direct-marketed fruits. The biobased film is therefore able to replace traditional plastic films, because the quality parameters are very similar to each other. About the qualitative fruits characteristics, nutritional, esthetic and organoleptic quality have been well maintained by the biobased film. Moreover, the biobased film allowed to achieve modified atmospheres in the packed trays with values very similar to those suggested by the literature (10% O_2 e 10% CO_2 Van der Steen *et al.*, 2001) to store strawberries in the medium period. Fruits packed with biobaseds films showed lower weight losses for a lower water vapor transpiration. About other qualitative parameters like TSS and the titratable acidity results of the sample stored with biobased films showed good characteristics. These considerations show the possibility for the biobased

film of replacing the traditional packaging plastic films improving the strawberry shelf life.

References

Aday, M.S. and Caner, C. 2011. The applications of 'active packaging and chlorine dioxide' for extended shelf life of fresh strawberries. Packaging Technology and Science 24:123–136

Ayala-Zavala, J.F., Wang, S.Y., Wang, C.Y. and Gonzalez-Aguilar, G.A. 2004. Effect of storage temperatures on antioxidant capacity and aroma compounds in strawberry fruit. Leben. Wissenschaft Technol.: Food Science and Technology 37:687–695

Arvanitoyannis, I. S. 1999. Totally and partially biobased polymer blends based on natural and synthetic macromolecules: preparation, physical properties, and potential as food packaging materials. Journal of Macromolecular Science: Reviews in Macromolecular Chemistry and Physics C39: 205–271

Battino, M., J., Beekwilder, B., Denoyes-Rothan, M. Laimer, G.J, McDougall and Mezzetti, B. 2009. Bioactive compounds in berries relevant to human health. Nutrition Review 67: 145–150

Bondet, V., Brand-Williams, W. and Berset, C. 1997. Kinetics and mechanism of antioxidant activity using the DPPH free radical method. Lebensmittel-Wissenschaft und-Technologie 30: 609–615

Capocasa F., Scalzo, J., Mezzetti, B. and Battino, M. 2008. Combining quality and antioxidant attributes in the strawberry: the role of genotype. Food Chemistry111: 872–878

Ceponis, M.J. and Cappelini, R.A. 1983. Control of postharvest decays of blueberries by carbon dioxide-enriched atmospheres. Plant Disease 67: 169–171

Cheplick S., Kwon, Y.I., Bhowmik, P. and Shetty, K. 2010. Phenolic-linked variation in strawberry cultivars for potential dietary management of hyperglycemia and related complications of hypertension. Bioresource Technology101:404–413

Chinnici, F., Spinabell, U., Riponi, C. and Amati, A. 2005. Optimization of the determination of organic acids and sugars in fruit juices by ion–exclusion liquid chromatography. Journal of Food Composition Analysis 18: 121–131

Cordenunsi, B.R., Genovese, M.I., Nascimento, J.R.O., Hassimotto, N.M.A., Santos, R.J. and Lajolo, F.M. 2005. Effects of temperature on the chemical composition and antioxidant activity of three strawberry cultivars. Food Chemistry 91:113–121

Crespo P., Bordonaba, J.G., Terry, L.A. and Carlen, C. 2010. Characterisation of major taste and health-related compounds of four strawberry genotypes grown at different Swiss production sites. Food Chemistry 122: 16–24

Davis, G. and Song, J.H. 2006. Biobased packaging based on raw materials from crops and their impact on waste management. Industrial Crops and Products 23: 147–161

Del Nobile, M.A., Baiano, A., Benedetto, A. and Weightignan, L. 2006. Respiration rate of minimally processed lettuce as affected by packaging. Journal of Food Engineering 74: 60–69

Gil, M.I., Holcroft, D. M. and Kader, A. A. 1997. Changes in strawberry anthocyanins and other polyphenols in response to carbon dioxide treatments. Journal of Agricultural and Food Chemistry 45:1662–1667

Given, N.K., Venis, M.A. and Grierson, D. 1988. Hormonal regulation of ripening in the strawberry, a non-climacteric fruit. Planta 174: 402–406

Gomes, M.H., Beaudry, R.M., Almeida, D.P.F. and Malcata, F.X. 2010. Modelling respiration of packaged fresh cut 'Rocha' pear as affected by oxygen concentration and temperature. Journal of Food Engineering 96: 74–79

Holcroft, D.M. and Kader, A.A. 1999. Controlled atmosphere-induced changes in pH and organic acid metabolism may affect color of stored strawberry fruit. Postharvest Biology and Technology 17: 19–32

Holcroft, D.M. and Kader, A.A. 1999. Carbon dioxide-induced changes in color and anthocyanin synthesis of stored strawberry fruit. HortScience 24: 1244–1248

Kader, A.A. 1999. Fruit maturity, ripening, and quality relationships, Acta Horticulture 485: 203–208

Kalt, W., Forney, C.F., Martin, A. and Prior, R.L. 1999. Antioxidant capacity, vitamin C, phenolics and anthocyanins after fresh storage of small fruits. Journal of Agriculture and Food Chemistry 47: 4638–4644

Kevers C., Falkowski, M., Tabart, J., Defraigne, J.O., Dommes, J. and Pincemail, J. 2007. Evolution of antioxidant capacity during storage of selected fruits and vegetables. Journal of Agricultural and Food Chemistry 55: 8596–8603

Koide, S. and Shi, J. 2007. Microbial and quality evaluation of green peppers stored in biobased film packaging. Food Control 18: 1121–1125

Li, C. and Kader, A. A. 1989. Residual effects of controlled atmospheres on postharvest physiology and quality of strawberries. Journal of American Society for Horticultural Sciences 114: 405–407

Makinen, K.K. and Soderling, E. 1980. A quantitative study of mannitol, sorbitol, xylitol and xylose in wild berries and commercial fruits. Journal of Food Science 45: 367–371

Makino, Y. and Hirata, T. 1997. Modified atmosphere packaging of fresh produce with a biobased laminate of chitosan-cellulose and polycaprolactone. Postharvest Biology and Technology 8: 179–190.

Olsson M.E., Ekvall, J., Gustavsson, K.E., Nilsson, J., Pillai, D., Sjoholm, I., Svensson, U., Akesson, B and Nyman, M.G.L. 2004. Antioxidants, low molecular weight carbohydrates, and total antioxidant capacity in strawberries (Fragaria x ananassa): effects of cultivar, ripening, and storage. Journal of Agricultural and Food Chemistry 52: 2490–2498

Rapisarda, P., Fanella, F. and Maccarone, E. 2000. Reliability of analytical methods for determining anthocyanins in blood orange juices. Journal of Agriculture and Food Chemistry 48: 2249–2252

Robinson, J.E., Browne, K.M. and Burton, W.G. 1975. Storage characteristics of some vegetables and soft fruits. Annals of Applied Biology 81: 399– 408

Schirra, M., Palma, A., D'Aquino, S., Angioni, A., Minello, E.V. and Cabras, P. 2008. Impact of postharvest hot water and hot air treatments on storage decay and nutritional and functional properties of kumquat (*Fortunella japonica* Lour. Swingle, cv Ovale) fruit. Journal of Agricultural and Food Chemistry 56: 455–460

Shen, L.Q., and Huang, G.R. 2003. Study on modified atmosphere packaging of Myricarubra. Journal of Zhejiang University of Science and Technology 15: 232–235

Shin, Y., Liu, R.H, Nock, J.F., Holliday, D. and Watkins, C.B. 2007. Temperature and relative humidity effects on quality, total ascorbic acid, phenolics and flavonoid concentrations, and antioxidant activity of strawberry. Postharvest Biology and Technology 45: 349–357.

Singleton, V.L. and Rossi, J.A. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American Journal of Enology and Viticulture 16: 144–158

Tulipani S., Mezzetti, B., Capocasa, F., Bompadre, S., Beekwilder, J., de Vos E. Capanoglu., C.H., Bovy, A. and Battino, M. 2008. Antioxidants, phenolic compounds and nutritional quality in different strawberry genotypes. Journal of Agricultural and Food Chemistry 56: 696–704

Van der Steen, C., Jacxsens, L., Devlieghere, F. and Debevere, J. 2001. Combining high oxygen atmospheres with low oxygen modified atmosphere packaging to improve the keeping quality of strawberries and raspberries. Postharvest Biology and Technology 26: 49–58

Wang, H., Cao, G. and Prior, R.L. 1996.Total antioxidant capacity of fruits. Journal of Agricultural and Food Chemistry 44: 701–705

Yuan, J.P. and Chen, F. 1999. Simultaneous separation and determination of sugars, ascorbic acid and furanic compounds by HPLC-dual detection. Food Chemistry 64: 423–427

Zabetakis, I. and Holden, M.A. 1997. Strawberry flavour: analysis and biosynthesis Journal of Science and Food. Agriculture 74: 421– 434