Instituto Nacional de Investigación y Tecnología Agraria y Alimentación (INIA)
Available online at www.inia.es/sjar

Spanish Journal of Agricultural Research 2009 7(1), 181-189
ISSN: 1695-971-X

Relationship between sensory and physico-chemical quality parameters of cold-stored 'Clemenules' mandarins coated with two commercial waxes

A. Marcilla[1], M. Martínez[2], J. M. Carot[2], L. Palou[1] and M. A. del Río[1]*

[1] Centro de Tecnología Poscosecha. Instituto Valenciano de Investigaciones Agrarias (IVIA). Ctra. Moncada-Náquera km 4.5; 46113 Moncada (Valencia), Spain.

[2] Departamento de Estadística e Investigación Operativa Aplicadas y Calidad. Universidad Politécnica de Valencia. Camino de Vera, s/n. 46022 Valencia, Spain.

Abstract

The relationship between physico-chemical parameters (weight loss, rind gloss, juice yield, soluble solids content, titratable acidity, maturity index, and ethanol and acetaldehyde content) and sensory attributes (acidity, sensory maturity index, off-flavor and mandarin like-flavor) of 'Clemenules' mandarins was studied in relation to coating treatments and cold storage duration. Fruit were uncoated (control) or treated with two commercial water-based waxes, both with the same wax composition (polyethylene wax and shellac) but two different total solids concentrations (70 and 100 g kg^{-1}). Fruit were stored at 5ºC and 90% relative humidity for 12, 22, 32, 42, 52 or 62 days, plus 7 days at 20ºC to simulate shelf life marketing conditions. Physico-chemical quality was well preserved throughout storage, especially in fruit coated with 70 g kg^{-1} total solids water wax. Fruit from this treatment had the lowest weight loss and the greatest rind gloss. Mandarin-like flavor decreased throughout the storage period, which was highly related with ethanol build-up. Partial least square regression analysis showed that in general the correlation between sensory attributes and instrumental measurements was high.

Additional key words: acetaldehyde, citrus fruit, ethanol, postharvest quality, sensory evaluation.

Resumen

Relación entre la calidad sensorial y físico-química de mandarinas 'Clemenules' recubiertas con dos ceras comerciales y refrigeradas

Se ha estudiado la relación entre los parámetros físico-químicos (pérdida de peso, brillo, rendimiento en zumo, contenido en sólidos solubles, acidez titulable, índice de madurez y contenido en etanol y acetaldehído) y los atributos sensoriales (acidez, índice de madurez sensorial, malos sabores y sabor característico a mandarina) de mandarinas 'Clemenules' tratadas con dos recubrimientos y almacenadas en refrigeración durante distintos periodos. Un grupo de frutos no se recubrió (control), mientras el resto fueron recubiertos con dos ceras al agua comerciales, ambas con la misma composición (polietileno y goma laca) pero con concentraciones distintas de sólidos totales (70 y 100 g kg^{-1}). La fruta fue almacenada a 5ºC y 90% de humedad relativa durante 12, 22, 32, 42, 52 o 62 días seguidos de 7 días a 20ºC simulando la comercialización. Los parámetros físico-químicos se preservaron bien a lo largo del almacenamiento, especialmente en los frutos tratados con el recubrimiento de 70 g kg^{-1} de sólidos totales. Estos frutos mostraron las menores pérdidas de peso y fueron los más brillantes. El sabor característico a mandarina disminuyó a lo largo del almacenamiento, estando relacionado con un aumento del contenido en etanol. Tras una regresión de mínimos cuadrados de los datos obtenidos se observó una elevada correlación entre los atributos sensoriales y las medidas instrumentales.

Palabras claves adicionales: acetaldehído, calidad poscosecha, cítricos, etanol, evaluación sensorial

* Corresponding author: madelrio@ivia.es
Received: 11-02-08. Accepted: 09-12-08.

M. A. del Río is member of the SECH.

Abbreviations used: GU (gloss units), IVIA (Instituto Valenciano de Investigaciones Agrarias), LSD (least significant differences), MI (maturity index), PLRS (partial least-square regression), RH (relative humidity), SSC (soluble solids content), TA (titratable acidity), TFE (teflon).

Introduction

Spain is the fourth leading producer of citrus fruit world-wide and the leading exporter of fresh citrus fruit (www.marm.es). The application of wax coatings to fresh fruit in order to replace the natural waxes that have been removed by washing and brushing procedures is a usual practice by the postharvest fresh citrus industry. The composition of citrus fruit surface coatings is an important factor because it can markedly affects the quality attributes of coated fruit, especially when the fruit are chilled stored for long periods. Selection of the most appropriate coating depends upon several factors such as storage length or export protocols. Typically, different restrictions for export markets are established by national regulations (Llovera *et al.*, 2002).

The most commonly used citrus fruit surface coating formulations are wax emulsions composed of either synthetic or natural waxes dispersed in water or resin solutions. These fruit coatings decrease rind permeability, increase gloss characteristics and reduce water loss (Cuquerella and Martínez-Jávega, 1984). If anaerobic conditions occur, an excessive build-up of volatile compounds such as ethanol and acetaldehyde in the citrus fruit can lead to the production of off-flavors, which are definitely associated with the loss of quality of citrus fruit (Shaw *et al.*, 1991; Del Río *et al.*, 1999). Mandarin fruit are the most susceptible citrus fruit to anaerobic respiration (Cohen *et al.*, 1990).

The influence of different coatings on the physicochemical parameters of citrus fruit has been widely studied (Hagenmaier and Baker, 1996; Hagenmaier and Shaw, 2002; Hagenmaier *et al.*, 2002; Pérez-Gago *et al.*, 2002; Navarro and Pérez-Gago, 2006). However, there is a lack of information about the effect of such coatings on organoleptic characteristics. Few studies have attempted to relate postharvest treatments and conditions with fruit sensory quality (Hagenmaier and Baker, 1994; Mannheim and Soffer, 1996; Biolatto *et al.*, 2005; Shi *et al.*, 2005; Marcilla and del Río, 2006).

The objective of sensory quality tests is usually to define or control the organoleptic quality of the produce by comparison to a previously selected reference (Sidel *et al.*, 1981). In the case of citrus fruit, the poor knowledge on the attributes that define fruit quality and the difficulty of working with unaltered reference fruits during the time needed to perform the tests are additional handicaps (Costell, 1992).

Objectives of the present work were 1) to study the effect of commercial coating treatments on the fruit quality of cv. Clemenules mandarins stored at 5ºC up to 62 days plus 7 days at 20ºC and 90% RH and 2) to determine the relationship between the instrumental and sensory attributes.

Material and methods

Fruit

Clementine mandarins (*Citrus reticulata* Blanco) cv. 'Clemenules' were harvested at commercial maturity (the maturity index –MI, calculated as SSC/TA ratio, was 8.8) from a commercial orchard in Valencia citrus growing area. After harvest, 30 lots of 50 randomly selected uniform fruit were dipped for 1.5 min in an aqueous fungicide mixture of imazalil (2,500 mg L^{-1}) and guazatine (800 mg L^{-1}). Subsequently, the fruit were subjected to the coating treatments and stored at 5ºC for different periods of time.

Postharvest treatments

The postharvest treatments were as follows: 1) non coated fruits (T1); 2) commercial water wax A with 100 g kg^{-1} total solids (total solids) of polyethylene wax and shellac (T2); 3) diluted commercial water wax A with 70 g kg^{-1} total solids (T3); 4) commercial water wax B with 100 g kg^{-1} total solids of polyethylene wax and shellac (T4), and 5) diluted commercial water wax B with 70 g kg^{-1} total solids (T5).

Treated fruit were cold-stored at 5ºC and 90% RH for 12, 22, 32, 42, 52 or 62 days. After each storage period, fruit were kept at 20ºC for 7 days to simulate shelf-life. Fruit were then subjected to physico-chemical and sensory analyses.

Physico-chemical analyses

For each treatment and storage period, 30 fruit were used to determine percent weight loss. Weight loss was referred to initial fruit weight (g) and expressed as percentage. Rind gloss was measured at 60º from a line normal to the fruit surface with a glossmeter (micro-gloss BYK Gardner Inc, Silver Spring, MD, USA). Reported values were means of 5 readings of 10 fruit per treatment and expressed as gloss units (GU).

For each treatment and storage period, the juice from 3 replicates of 10 fruit was extracted with a rotatory citrus fruit squeezer (Lomi, Model 4) and filtered through a 0.8 mm diameter sieve for the analyses of juice yield, soluble solids content (SSC), titratable acidity (TA), MI, and ethanol and acetaldehyde content. Juice yield was expressed as percentage of juice volume (mL) per fruit weight (g). SSC was determined with a digital refractometer (Atago, Model PR1) and results were expressed as percentage. TA was determined by titrating 5 mL of juice with 0.1 N NaOH to pH 8.1 and results were given as mg citric acid per L of juice (AOAC, 2000). Ethanol and acetaldehyde concentration in the juice was determined by headspace gas chromatography as follows: 5 mL of juice were transferred to 10 mL vials with crimp-top caps and TFE/silicone septum seals and kept at –18ºC until analysis (Hagenmaier and Baker, 1994). A 1-mL sample of the head space was withdrawn from vials previously equilibrated in a water bath at 20ºC for 1 h, followed by 10 min at 30ºC, to reach equilibrium in the head-space, and injected in a gas chromatograph with a flame ionization detector and a 1.2 m × 0.32 cm Poropack QS 80/100 stainless column. The injector was set at 175ºC, the column at 150ºC, the detector at 200ºC, and the carrier gas (He) at 62.7 kPa. Ethanol and acetaldehyde content were identified and quantified by comparison of retention times with standards. Results were expressed as mg per L of juice.

Sensory analyses

Sessions were established for tasting evaluation of mandarins by a trained sensory panel. Judges were volunteers selected and trained among the staff working in the IVIA, seven women and five men of ages between 21 and 60 year-old. Fifteen mandarins per treatment were sampled after each storage period and shelf life. Each mandarin was peeled and its wedges separated. Three wedges were placed on white pots, identified by a random three-digit code. The order of presentation of the pots was randomized for each judge. For each treatment and storage period ten samples were evaluated, two replicates for each treatment. After assessing the samples for sensory acidity and sensory MI (relationship between sweetness and acidity), panelists recorded their scores by making a mark on a horizontal line of 15-cm length which corresponds to the amount of the perceived stimulus. The left edge (value 0) corresponded to "none" or zero amount of the stimulus while the right edge of the scale (value 15) represented a large amount or very strong level of stimulus. Panelists scored the intensity of off-flavors on a 6-point category scale (0= none, 1= slight, 2= slight-moderate, 3= moderate, 4= moderate-strong, 5= strong) and mandarin like-flavor on a 9-point category scale (1,2,3= bad quality; 4,5,6= acceptable quality; 7,8,9= high quality). All sensory evaluations were conducted in individual booths under white illumination at room temperature. Mineral water was used as palate cleanser between samples (AENOR, 1997).

For visual evaluation, panelists were asked to rank five randomized trays with three mandarins per treatment according to rind gloss intensity (Meilgaard *et al.*, 1999).

Statistical analyses

A multifactor design with storage period and treatment as factors was used to statistically analyse the results. All data, except sensory gloss, were subjected to analyses of variance (ANOVA) using Statgraphics plus 4.1 (Manugest Ks Inc, Rockville, USA). Means were separated by Fisher's Protected least significance difference (LSD) test at $P \leq 0.05$. Ranks of sensory gloss were performed using a Friedman test statistic (AENOR, 1997) which takes the place of the F-statistic in the analyses of ratings.

For multivariate analyses, samples were characterized by the average measurement (instrumental analyses) or by the average score among judges (sensory analyses) for each considered variable. The potential correlation between instrumental and sensory parameters was quantified with partial least-square regression (PLSR) (Geladi and Kowalski, 1986) using Unscrambler 9.0 (Camo AS, Oslo, Norway). Physico-chemical parameters were used as X variables, which were correlated with sensory attributes used as Y variables by PLSR.

Results

Influence of coating treatment and storage period on physico-chemical parameters

Multifactor ANOVA analyses showed that significant interactions between the analyzed factors (coating treatment and storage period) existed for only two (weight loss and rind gloss) out of ten physico-chemical parameters studied. Weight loss increased with storage duration. T3 was the most effective treatment in preventing weight loss and as expected, uncoated fruit lost more weight than coated fruit. Fruit coated with wax with 70 g kg^{-1} total solids (T3 and T5) lost less weight than fruit coated with wax with 100 g kg^{-1} total solids (T2 and T4) (Figure 1). Rind gloss decreased with longer storage periods and significant differences (P< 0.05) were found for storage periods of 32 days or longer. As for weight loss, T3 fruit showed the highest gloss values. Meanwhile, the lowest gloss value was observed for T4-treatment fruit (Figure 1).

Titratable acid decreased with longer storage periods, but was not affected by any treatment. TA was significantly (P< 0.05) lower after cold storage longer than 42 days (Table 1). Significant (P< 0.05) differences in SCC were found between either treatments or storage periods. SSC progressively increased throughout the storage period (Table 1) and the lowest value of SSC was observed on fruit coated with the water wax A (T2, T3; Table 2). According to TA and SSC changes, MI of mandarins increased throughout the storage period and significant (P< 0.05) differences were found after 42 days of cold storage (Table 1). Also, significant (P< 0.05) differences in juice yield were found between different storage periods and postharvest treatments (Table 1, 2).

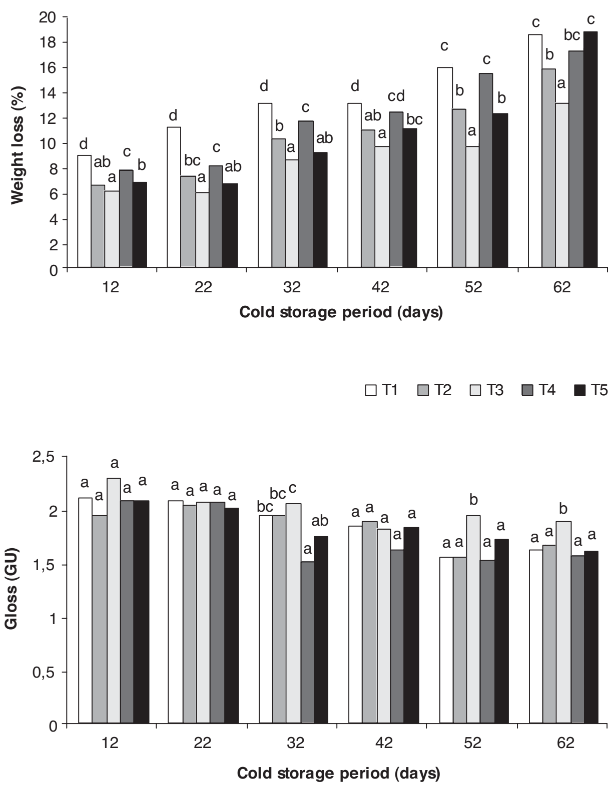

Figure 1. Effect of different storage periods at 5ºC plus 7 days at 20ºC on weight loss and rind gloss of coated 'Clemenules' mandarins. Treatments T1, T2, T3, T4 and T5: see Table 1. For each cold storage period, bars with unlike letters are different according to LSD test at 95% level of significance.

Storage period and coating significantly (P< 0.05) affected both acetaldehyde and ethanol contents of 'Clemenules' mandarins. Acetaldehyde content significantly (P< 0.05) increased after 22, 42 and 62 days of cold storage (Table 1). Fruit coated with wax with 70 g kg^{-1} total solids had lower concentration of acetaldehyde than fruit coated with wax with 100 g kg^{-1} total solids (Table 2). As expected, ethanol content also increased during the storage period. Although no significant (P< 0.05) differences were found after 32, 42 and 52 days of cold storage. The highest acetaldehyde (13.31 mg L^{-1}) and ethanol (2167.92 mg L^{-1}) contents were observed after 62 days of storage (Table 1). Fruit coated with the water wax A (T2 and T3) had the lowest concentration of ethanol, these values being significantly (P< 0.05) lower than those for the rest of treatments.

Influence of coating treatment and storage period on sensory attributes

Multifactor ANOVA analyses showed that the interaction between the studied factors (treatment an storage period) was not significant (P< 0.05) for sensory attributes. Panelists found significant (P< 0.05) differences among storage periods for each sensory attribute (Table 3). In contrast, panelists did not find significant (P< 0.05) differences among coating treatments for acidity, sensory MI. Mandarins coated with water wax B with 100 g kg^{-1} total solids were considered as the worst treatment in relation to off-flavors and mandarin-like flavor, they were qualified as of bad quality (Table 4).

The highest value for off-flavors was observed after 32 days of cold storage. After 12 days of cold storage, fruit were scored with the highest value for flavor. This value significantly decreased along the storage period. Flavor were rated as of acceptable quality on fruit stored up to 42 days at 5ºC plus 7 days at 20ºC, and of bad quality on fruit stored for longer periods (Table 3).

In the visual evaluation of rind gloss, panelists found significant differences between treatments (Table 5). T3-treated fruit was the glossiest fruit and T4-treated fruit

Table 1. Effect of different storage periods at 5ºC plus 7 days at 20ºC on chemical quality parameters of coated[1] 'Clemenules' mandarins

Cold storage period (days)	Titratable acidity (mg L^{-1})	Soluble solids content (%)	Maturity index	Juice yield (%)	Acetaldehyde (mg L^{-1})	Ethanol (mg L^{-1})
At harvest	12.30	10.78	8.84	41.00	2.40	97.59
12	9.22c[2]	11.42a	12.45a	38.40c	8.57a	905.67a
22	8.97c	11.96bc	13.43a	39.65c	10.63b	1208.30b
32	8.69c	11.83ab	13.29a	37.74bc	10.93b	1524.06c
42	7.88b	12.37cd	15.75b	35.92ab	12.42c	1544.54c
52	7.33ab	12.50d	17.30c	34.77a	12.48c	1704.38c
62	7.15a	12.65d	17.92c	37.46bc	13.31d	2167.92d

[1] Wax treatments: T1=fruits non-coated, T2=commercial water wax A (100 g kg^{-1} total solids of polyethylene wax and shellac), T3=diluted commercial water wax A with 70 g kg^{-1} total solids, T4=commercial water wax B (100 g kg^{-1} total solids of polyethylene wax and shellac) and T5=diluted commercial water wax B with 70 g kg^{-1} total solids. [2] Means within a column with different letters are significantly different according to LSD test at 95% level of significance.

were less glossy than non-coated fruit or fruit coated with other treatments. This result is in agreement with what was observed with instrumental rind gloss (Figure 1).

Relationship between physico-chemical parameters and sensory attributes

The analysis of correlation coefficients showed that juice yield was the most independent parameter. This parameter correlated poorly with almost all instrumental parameters and sensory attributes. Contrastingly, flavor showed an excellent correlation with all instrumental parameters (Table 6).

A PLS regression model was applied to instrumental parameters and sensory attributes (Figure 2). The loading plot PC1 versus PC2 explained up to 81% of the total variance of the instrumental parameters and 51% of the sensory attributes (Figure 2A). This plot indicated that the variable flavor showed the highest regression coefficient with sensory acidity, in agreement with the high correlation coefficient shown by these two variables (r=0.82) (Table 6). Rind gloss and TA were well correlated with flavor. Off-flavors and sensory MI were highly and positively correlated with SSC, weight loss, ethanol and acetaldehyde. As it was expected these results also showed the negative relation among TA and SSC therefore with MI (Figure 2A).

In general, sensory attributes highly correlated with the corresponding instrumental measurements. Predicted instrumental parameters versus sensory attributes when significant differences between treatments and storage periods were found are shown in Figure 2B. This model revealed two groups. Group labeled I included

Table 2. Effect of different coating treatments on chemical quality parameters of 'Clemenules' mandarins

Treatments[1]	Titratable acidity (mg L^{-1})	Soluble solids content (%)	Maturity index	Juice yield (%)	Acetaldehyde (mg L^{-1})	Ethanol (mg L^{-1})
T1	8.31a[2]	12.46c	15.27a	38.55b	12.20c	1656.38c
T2	7.90a	11.88ab	15.08a	36.82ab	11.50b	1370.91ab
T3	8.13a	11.66a	14.58a	38.26b	10.90ab	1326.63a
T4	8.20a	12.13bc	15.04a	36.83ab	11.40ab	1587.39bc
T5	8.36a	12.48c	15.15a	36.17a	10.70a	1604.41c

[1] See Table 1. Treated fruit were cold-stored for 12, 22, 32, 42, 52 or 62 days plus 7 days at 20ºC. [2] Means within a column with different letters are significantly different according to LSD test at 95% level of significance.

Table 3. Effect of different storage periods at 5ºC plus 7 days at 20ºC on sensory attributes of coated[1] 'Clemenules' mandarins

Cold storage period (days)	Acidity (0-15)	Sensory maturity index (0-15)	Off-flavors (0-5)	Mandarin-like flavor (1-9)
At harvest	5.65	8.38	0.13	7.37
12	5.29d[2]	8.09a	0.70a	5.61d
22	4.15bc	9.08bc	1.00ab	4.50c
32	3.72abc	9.65cd	2.08c	4.73c
42	4.60cd	8.79b	1.41b	4.48c
52	3.66ab	9.37bc	1.92c	3.82b
62	3.11a	10.02d	2.00c	3.28a

[1] See Table 1. [2] Means within a column with different letters are significantly different according to LSD test at 95% level of significance.

cold-stored fruit for 12 and 22 days which had the highest sensory acidity, flavor, TA and gloss. Group labeled II included fruit in the rest of treatments stored for 32, 42, 52 and 62 days. They had the highest SSC, instrumental and sensory MI, ethanol and acetaldehyde contents and off-flavors values. Differences inside groups might have arisen from differences in total solids content of the water wax.

Discussion

Chemical quality parameters were generally well maintained throughout all 62 days of cold storage plus shelf-life and few differences were found among coating treatments.

Whereas some authors did not observe changes in TA and SSC in citrus along their storage (Martínez Jávega *et al.*, 1991; Pozzan *et al.*, 1993; Ben Abda, 1996), other authors observed minimal variations in these parameters (Baldwin *et al.*, 1995; Salvador, 1999) and related such variations with lower fruit dehydration associated with fruit coating.

MI was not affected by the postharvest treatment. This result is in agreement with that obtained by Monterde *et al.* (2003), who did not find differences in MI of 'Clemenules' mandarins between uncoated fruit and fruit coated with a wax with 100 g kg^{-1} total solids after 40 days of storage at 5ºC plus 7 days at 20ºC.

Although significant differences were found in juice yield, these were slight and the values were always higher than the 33% threshold established by the European Union for citrus trade (EUC, 2001).

Only main effects of treatments and storage periods on sensory attributes were detected. Differential effects of coatings were probably due to different shellac contents. Polyethylene wax did not promote modification of internal atmosphere of citrus fruit (Hagenmaier and Baker, 1993) whereas shellac content was the coating ingredient that most affected internal quality of melons (*Cucumis melo* L.) (Fallik *et al.*, 2005). The accumulation of ethanol and ethyl acetate compounds was mainly responsible for large flavor differences in citrus fruits (Hagenmaier and Shaw, 2002) and also in apples (*Malus domestica* Borkh.) (Alleyne and Hagenmaier, 2000). With some exceptions, trained panelists per-

Table 4. Effect of different treatments on the sensory attributes of 'Clemenules' mandarins

Treatments[1]	Acidity (0-15)	Sensory maturity index (0-15)	Off-flavors (0-5)	Mandarin-like flavor (1-9)
T1	3.99a[2]	9.32a	1.64a	4.50b
T2	4.13a	9.14a	1.62a	4.58b
T3	4.36a	9.00a	1.32a	4.48b
T4	3.63a	9.29a	1.69b	3.90a
T5	4.34a	9.09a	1.32a	4.56b

[1] See Table 1. Treated fruit were cold-stored for 12, 22, 32, 42, 52 or 62 days plus 7 days at 20ºC. [2] Means within a column with different letters are significantly different according to LSD test at 95% level of significance.

Table 5. Gloss ranking of treated 'Clemenules' mandarins after 12, 22, 32, 42, 52 and 62 days at 5ºC plus 7 days at 20ºC

Treatments (T)[1]	**12**	**22**	**32**	**42**	**52**	**62**
More glossy	T3a[2]	T3a	T3a	T3a	T3a	T3a
	T1b	T2ab	T1b	T1b	T5b	T2a
	T5bc	T5bc	T2bc	T2bc	T1b	T5a
	T2bc	T4d	T5bc	T5bc	T2b	T4b
Less glossy	T4c	T1d	T4c	T4c	T4c	T1b

[1] See Table 1. [2] Means within a column with different letter are significantly different according to LSD test at 95% level of significance.

ceived slight to moderate off-flavors. In our tests, ethanol content after 62 days of cold storage averaged around 2,200 mg L^{-1}, while the mean for each treatment was not higher than 1,700 mg L^{-1}. Likewise, Cuquerella and Martínez-Jávega (1981) detected off-flavors in 'Valencia' and 'Navel' oranges (*Citrus sinensis* (L.) Osbeck) when juice ethanol content was over 1,400 mg L^{-1}. Hagenmaier (2000) reported that over the range 800-5,000 mg L^{-1}, ethanol content appears to be a good estimate for flavor degradation in 'Valencia' oranges. Also, Hagenmaier (2002) concluded that the flavor of tangerines (*Citrus reticulata* Blanco) was rated as markedly less fresh when juice ethanol values overpassed 1,500 mg L^{-1}. While it seems clear from all these and other research work that increases in ethanol levels in fruit adversely affect the taste, the role of acetaldehyde changes is not clear; it could even improve fruit flavor (Cohen *et al.*, 1990). The decrease in the perception of off-flavors after 42 days of cold storage could be related to an increment of acidity perception because no significant differences between 32 and 42 days of cold storage were found for ethanol content.

A clear result from this research is that the best fruit quality of 'Clemenules' mandarins as expressed by both physico-chemical parameters and sensory attributes, was obtained on fruit treated with the coating A with 70 g kg^{-1} total solids of polyethylene wax and shellac (T3). T3-treated fruit reached the best mandarin like-flavor scores, the highest rind gloss values and the lowest weight loss. Furthermore, this treatment caused low increments of SSC and acetaldehyde and ethanol contents after prolonged cold storage. Certainly, under the conditions assayed in this work, the use of wax coatings with 100 g kg^{-1} total solids is unnecessary as compared to 70 g kg^{-1} total solids wax and there are substantial differences between different commercial coatings labeled with the same composition.

Table 6. Correlation coefficients (*r*) between physico-chemical and sensory quality attributes of 'Clemenules' mandarins

	Gloss[1] **(GU)**	**TA**[2] **(mg L**$^{-1}$**)**	**SSC**[3] **(%)**	**MI**[4] **(SSC/TA)**	**Weight lost (%)**	**Juice yield (%)**	**Acetal-dehyde (mg L**$^{-1}$**)**	**Ethanol (mg L**$^{-1}$**)**	**Acidity**	**Sensory MI**	**Off-flavors**	**Flavor**
Gloss (GU)[1]	1.00											
TA (mg L^{-1})[2]	0.59*	1.00	_	_	_	_	_	_	_	_	_	_
SSC (%)[3]	-0.68*	-0.39	1.00	_	_	_	_	_	_	_	_	_
MI (SSC/TA)[4]	-0.70*	-0.94*	0.65*	1.00	_	_	_	_	_	_	_	_
Weight lost (%)	-0.79*	-0.65*	0.72*	0.77*	1.00	_	_	_	_	_	_	_
Juice yield (%)	0.35	0.56*	0.17	-0.50*	-0.23	1.00	_	_	_	_	_	_
Acetaldehyde (mg L^{-1})	-0.69*	-0.76*	0.65*	0.82*	0.84*	-0.27	1.00	_	_	_	_	_
Ethanol (mg L^{-1})	-0.76*	-0.56*	0.74*	0.69*	0.89*	0.10	0.82*	1.00	_	_	_	_
Acidity	0.56*	0.49*	-0.42*	-0.54*	-0.67*	0.18	-0.66*	-0.68*	1.00	_	_	_
Sensory Ml	-0.54*	-0.52*	0.43*	0.56*	0.70*	0.14	0.68*	0.70*	-0.93	1.00	_	_
Off-flavors	-0.49*	-0.43*	0.41*	0.48*	0.61*	0.28	0.55*	0.60*	-0.61	0.66	1.00	_
Flavor	0.69*	0.57*	-0.58*	-0.67*	-0.73*	0.18	-0.73*	-0.75*	0.82	-0.72	-0.52	1.00

*Significant difference values ($p<0.05$). [1] GU (gloss units). [2] TA (titratable acidity). [3] SSC (soluble solids content). [4] MI (maturity index, calculated as SSC/TA ratio).

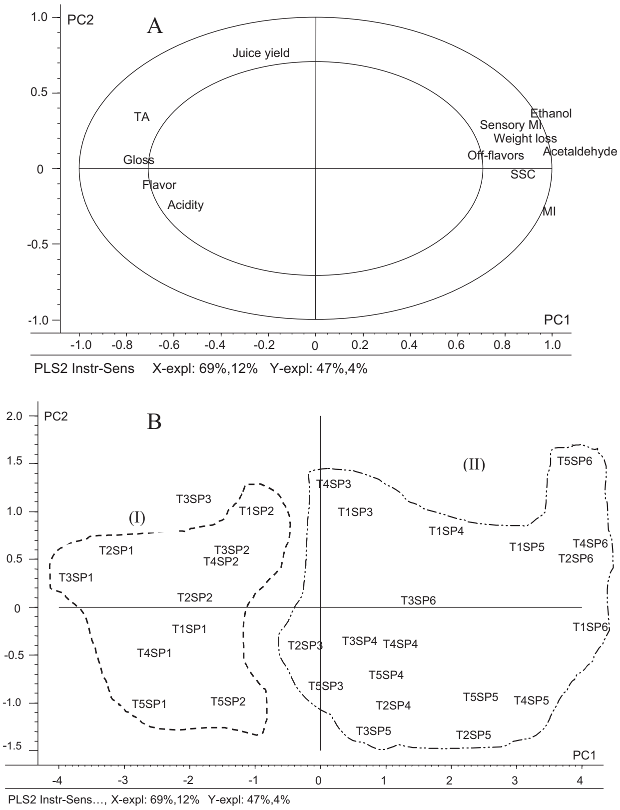

Figure 2. PLS mode: PC1 *vs* PC2. The pattern of co-variation between variables (loading plot A) and samples (score plot B). MI (maturity index). SSC (soluble solids content). TA (titratable acidity). TiSPj, where Ti= treatment 1, 2, 3, 4 or 5 (see Table 1) and SPj= storage period 1, 2, 3, 4, 5 or 6. SP1=12 days at 5ºC plus 7 days at 20ºC, SP2=22 days at 5ºC plus 7 days at 20ºC, SP3=32 days at 5ºC plus 7 days at 20ºC, SP4=42 days at 5ºC plus 7 days at 20ºC, SP5=12 days at 5ºC plus 7 days at 20ºC and SP6=62 days at 5ºC plus 7 days at 20ºC.

The main finding of this work is that there are high correlations between instrumental parameters and sensory attributes. As it was similarly concluded by Marcilla *et al*. (2006), TA was the parameter with the highest positive influence on the taste quality of Clementine mandarins. The increases of weight loss, ethanol and acetaldehyde contents were responsible for the diminution of flavor quality in mandarins.

Acknowledgements

Alicia Marcilla's doctorate program was supported by a grant from The Spanish National Institute for Agricultural and Food Research and Technology (INIA). Madrid. Spain.

References

AENOR, 1997. Análisis sensorial Tomo 1. Alimentación. Recopilación de Normas UNE. Asociación Española de Normalización y Certificación. Madrid, Spain. 253 pp. [In Spanish].

AOAC, 2000. Official methods of analysis. 17th Edition. Washinton, D.C. Association of analyitical chemists international.

ALLEYNE V., HAGENMAIER R., 2000. Candellilla-shellac: an alternative formulation for coating apples. HortScience 35, 691-693.

BALDWIN E.A., NISPEROS-CARRIEDO M., SHAW P.E., BURNS J.K., 1995. Effect of coatings and prolonged storage conditions on fresh orange flavour volatiles, degrees Brix and ascorbic acid levels. J Agric Food Chem 43, 1321-1331. doi:10.1021/jf00053a037.

BEN ABDA J., 1996. Étude de l'effect de quelques cires sur la qualité de trois variétés de mandarines. Master's Thesis. UPV-CIHEAM. [In French].

BIOLATTO A., VAZQUEZ D.E., SANCHO A.M., CARDUZA F.J., PENSEL N.A., 2005. Effect of commercial conditioning and cold quarantine storage treatments on fruit of 'Rouge La Toma' grapefruit (*Citrus paradise* Macf.). Postharvest Biol Technol 35, 167-176. doi:10.1016/j.postharvbio.2004.08.002.

COHEN E., SHALOM Y., ROSENBERGER I., 1990. Postharvest ethanol buildup and off-flavor in 'Murcott' tangerine fruits. J Amer Soc Hort Sci 115, 775-778.

COSTELL E., 1992. Sensory analysis applied to quality of citrus fruits. Rev Esp Cienc Tecnol Aliment 32, 269-281.

CUQUERELLA J., MARTÍNEZ-JÁVEGA J.M., 1981. Some physiological effects of different wax treatments of Spanish citrus fruit during cold storage. Proc Int Soc Citriculture 2, 734-737.

CUQUERELLA J., MARTÍNEZ-JÁVEGA J.M., 1984. Waxing of Spanish citrus fruit. Proc Int Soc Citriculture 1, 494-496.

DEL RÍO M.A., MARTÍNEZ-JÁVEGA J.M., NAVARRO P., CUQUERELLA J., 1999. Recubrimientos para la comercialización de frutos cítricos. Tendencias actuales. Levante Agrícola 348, 301-311. [In Spanish].

EUC, 2001. Regulation 1799/2001 laying down the marketing standard for citrus fruit. European Union Commission, Brussels.

FALLIK E., SHALOM Y., ALKALAI-TUVIA S., LARKOV O., BRANDEIS E., REVID U., 2005. External, internal and sensory traits in Galia-type melon treated with different waxes. Postharvest Biol Technol 36, 69-75. doi:10.1016/j.postharvbio. 2004.11.004.

GELADI P., KOWALSKI B., 1986. Partial least-squares regression: a tutorial. Analytica Chemica Acta 185, 1-32. doi:10.1016/0003-2670(86)80028-9.

HAGENMAIER R.D., 2000. Evaluation of a polyethylene-candelilla coating for ‘Valencia’ oranges. Postharvest Biol Technol 1, 147-154. doi:10.1016/S0925-5214(00)00087-9.

HAGENMAIER R.D., 2002. The flavor of mandarin hybrids with different coatings. Postharvest Biol Technol 24, 79-87. doi:10.1016/S0925-5214(01)00121-1.

HAGENMAIER R.D. BAKER R.A., 1993. Reduction in gas exchange of citrus fruit by wax coatings. J Agric Food Chem 41, 283-287. doi:10.1021/jf00026a029.

HAGENMAIER R.D., BAKER R.A., 1994. Internal gases, ethanol content and gloss of citrus coated with polyethylene wax, carnauba wax, shellac or resin at different application levels. Proc Fla State Hort Soc 107, 261-265.

HAGENMAIER R.D., BAKER R.A., 1996. Edible coatings from Candelilla wax microemulsions. J Food Sci 61, 562-565. doi:10.1111/j.1365-2621.1996.tb13158.x.

HAGENMAIER R.D., SHAW P.E., 2002. Changes in volatile components of stored tangerines and other specialty citrus fruit with different coatings. J Food Sci 5, 1742-1745.

HAGENMAIER R.D., GOODNER K., ROUSSEFF R., DOU H., 2002. Storage of ‘Marsh’ grapefruit and ‘Valencia’ oranges with different coatings. Proc Fla State Hort Soc 115, 303-308. doi:10.1111/j.1365-2621.2002.tb08716.x.

LLOVERA A., ORTOLÁ M.D., CHIRALT A., 2002. Recubrimientos utilizados en frutos cítricos. Una revisión. Proc II Congreso Español de Ingeniería de Alimentos. Lleida, Spain. Sept 18-20. p. 12 [In Spanish].

MANNHEIM C.H., SOFFER T., 1996. Permeability of different wax coatings and their effect on citrus fruit quality. J Agric Food Chem 44, 919-923. doi:10.1021/jf950230a.

MARCILLA A., DEL RÍO M.A., 2006. Efecto de distintos recubrimientos en la calidad de mandarinas 'Clemenules', 'Fortune' y naranjas 'Valencia'. Proc VIII Simposio Nacional y V Ibérico de Maduración y Post-recolección, Orihuela, Spain. Sept 27-30, pp. 217-221. [In Spanish].

MARCILLA A., ZARZO M., DEL RÍO M.A., 2006. Effect of storage temperature on the flavour of citrus fruit. Span J Agric Res 4, 336-344.

MARTINEZ-JÁVEGA J.M., CUQUERELLA J., MATEOS M., DEL RÍO M.A., 1991. Coating treatments in postharvest behaviour of oranges. IFF-IIR Commission C2, D1, D2/3. Proc. Technical Innovations in Freezing of Fruit and Vegetables. Davis, California, USA, 9-12 July 1989, pp. 51-55.

MEILGAARD M., CIVILLE G.V., CARR B.T., 1999. Simple ranking test: Friedman analyses- randomized (complete) block design in Sensory evaluation techniques. 2nd ed. CRC Press. Boca Raton, FL, USA. pp. 117-119.

MONTERDE A., SALVADOR A., BEN-ABDA J., MARTÍNEZ-JÁVEGA J.M., 2003. Efecto de la aplicación de recubrimientos de origen natural en la calidad de mandarinas y naranjas. Proc. VI Simposio Nacional y III Ibérico Maduración y Post-Recolección de Frutos y Hortalizas (Merodio C., Escribano I., eds). CSIC-SEFV-SECH, Madrid, 2002. pp. 203-208. [In Spanish].

NAVARRO M.L.L., PÉREZ-GAGO M.B., 2006. Aplicación de recubrimientos comestibles a mandarinas 'Clemenules'. Proc VIII Simposio Nacional y V Ibérico de Maduración y Post-recolección, Orihuela, Spain. Sept 27-30, pp. 405-408. [In Spanish].

PÉREZ-GAGO M.B., ROJAS C., DEL RIO M.A., 2002. Effect of lipid type and amount of edible hydroxypropyl methylcellulose-lipid composite coatings used to protect postharvest quality of mandarins cv. Fortune. J Food Sci 8, 2903-2910. doi:10.1111/ j.1365-2621.2002.tb08836.x.

POZZAN M.A., CUQUERELLA J., NAVARRO P., 1993. Efecto de diferentes recubrimientos en la comercialización directa de naranjas 'Navelina'. Actas Horticultura 9, 614-619. [In Spanish].

SALVADOR A., 1999. Estudio de la aptitud para la desverdización de nuevas variedades 'Clemenpons', 'Loretina' y 'Beatriz'; y el comportamiento en frigoconservación de las mandarinas 'Ellendalle' y 'Ortanique'. Doctoral Thesis. Valencia Politechnic University, Valencia, Spain. [In Spanish].

SHAW P.E., MOSHONAS M.G., PESIS E., 1991. Changes during storage of oranges pretreated with nitrogen, carbon dioxide and acetaldehyde in air. J Food Sci 56, 469-474. doi:10.1111/j.1365-2621.1991.tb05306.x.

SHI J.X., PORAT R., GOREN R., GOLDSCHMIDT E.E., 2005. Physiological responses of 'Murcott' mandarins and 'Star Ruby' grapefruit to anaerobic stress conditions and their relation to fruit taste, quality and emission of off-flavor volatiles. Postharvest Biol Technol 38, 99-105. doi:10.1016/j.postharvbio.2005.06.008.

SIDEL J.L., STONE H., BLOOMQUIST J.J., 1981. Use and misuse of sensory evaluation in research and quality control. J Dairy Sci 64, 2296-2302.