

Effects of 1-MCP on the post-harvest quality of the orange cv. Pera stored under refrigeration¹

Efeitos da aplicação de 1-MCP na qualidade pós-colheita de laranjas cv. Pera armazenadas sob refrigeração

Cassia Inês Lourenzi Franco Rosa^{2*}, Edmar Clemente², Dalany Menezes Oliveira², Katieli Martins Todisco² and Jose Maria Correia da Costa³

ABSTRACT - The aim of this work was to analyse the effects of 1-MCP upon the post-harvest quality of the orange cv. Pera stored for 45 days at a temperature of 7 °C. The fruit was divided into four treatments, and then submitted to the application of three concentrations of 1-methylcyclopropene (0.1, 0.5 and 1.0 µL.L⁻¹) for a period of 12 hours. The fruit was again then stored at a temperature of 7 °C. The rate of respiration was determined, together with coloration of the epidermis, SS, TA, ratio, vitamin C, total carotenoids, phenolic compounds, total and reducing sugars, weight loss and juice yield. The data were submitted to analysis of variance (F-Test), and the averages were analysed by regression (P ≤ 0.05). According to the results, it could be seen that higher doses of 1-MCP may have caused chemical stress to the oranges under evaluation, being responsible for the increase in the rate of respiration. A change in coloration of the epidermis from green to yellow/orange was delayed by the application of 1-MCP; the application of 1-MCP did not cause any alteration to such chemical characteristics as SS, TA, ratio, carotenoids, phenolic compounds or sugars.

Key words: *Citrus sinensis* L. Osbeck. Chemical characteristics. Antioxidant compounds. Respiration.

RESUMO - o objetivo deste trabalho foi analisar os efeitos do 1-MCP sobre a qualidade pós-colheita de laranjas cv. Pera, armazenadas ao longo de 45 dias à temperatura de 7 °C. Os frutos foram separados em quatro tratamentos e em seguida submetidos à aplicação de 1-metilciclopropeno em três concentrações (0,1; 0,5 e 1,0 µL L⁻¹) por um período de 12 horas e posteriormente armazenados à temperatura de 7 °C. Determinou-se: taxa respiratória, coloração da epiderme, SS, AT, ratio, vitamina C, carotenóides totais, compostos fenólicos, açúcares redutores e totais, perda de massa e rendimento de suco. Os dados foram submetidos à análise de variância (teste F) e as médias estudadas por meio de regressão (P ≤ 0,05). De acordo com os resultados obtidos, observou-se que: as doses mais elevadas de 1-MCP podem ter causado estresse químico nas laranjas analisadas, sendo responsável pela elevação na taxa respiratória; a mudança de coloração da epiderme dos frutos, de verde para amarela/laranja, foi retardada pela aplicação de 1-MCP; a aplicação de 1-MCP não causou alterações nas características químicas como SS, AT, ratio, carotenóides, compostos fenólicos e açúcares.

Palavras-chave: *Citrus sinensis* L. Osbeck. Características químicas. Compostos antioxidantes, Respiração.

* Autor para correspondência

DOI: 10.5935/1806-6690.20160075

¹Recebido para publicação em 03/07/2013; aprovado em 16/11/2015

Parte da Tese de Doutorado em Agronomia da primeira autora, com concessão de bolsa de estudo cedida pelo CNPq

²Programa de Pós-Graduação em Agronomia, Laboratório de Bioquímica de Alimentos, Universidade Estadual de Maringá, Avenida Colombo, 5790, Jardim Universitário, Maringá-PR, Brasil, 87.020-900, cassialourenzi@gmail.com, eclemente@uem.br, dalany5@yahoo.com.br, katielimar@hotmail.com

³Departamento de Engenharia de Alimentos, Centro de Ciências Agrária, Universidade Federal do Ceará, Fortaleza-CE, Brasil, correiacostaufc@gmail.com

INTRODUCTION

Oranges are the main species of citrus grown in Brazil, where domestic production focuses on exporting the juice; because of the constant flow of information about nutritional quality, demand for this product is continually increasing. Another citrus sector under focus is the production of fruit for fresh consumption for both the domestic and external markets. It should however be noted that in this area, the consumer market is fairly demanding, which makes it necessary to adopt measures for maintaining fruit quality (BENDER, 2006; NEVES, 2009).

The post-harvest quality of the fruit can be evaluated according to different variables that are related to external appearance - such as colour and weight loss - or to internal features - such as juice yield, ratio and antioxidant compounds (vitamin C, carotenoids and polyphenols).

Colour is one of the most important features to be considered. The hue angle (h°) is a measure that is much used for expressing colour variations in plant products. It is represented on a diagram where 0° corresponds to pure red, 90° corresponds to pure yellow, 180° represents pure green and 270° represents pure blue. Chroma (C) represents colour intensity, where values close to zero correspond to neutral colours and values close to 60 express vivid colours (MENDONÇA *et al.*, 2003).

The ratio is calculated as that between soluble solids and the titratable acid content; it is one of the main indicators used to determine the maturation stage, through the balance of sweet and acid flavours (COUTO; CANNIATTI-BRAZACA, 2010). Sartori *et al.* (2002) consider fruit that displays an SS/TA ratio of between 8.8 and 15.4 as being adequate for consumption.

Among the antioxidant compounds, ascorbic acid is present in most citrus fruits. This is one of the most important characteristics of quality, since it is a natural antioxidant which plays a part in various reactions that occur during senescence of the fruit, repairing oxidative damage to the cells (FELÍCIO, 2005; KLUGE *et al.*, 2007). Carotenoids are unique compounds in nature; they are present in many plant structures and are responsible for the yellow, orange and red colouration. They are also one of the most important groups of natural pigments due to their wide distribution, structural diversity and many functions (MELÉNDEZ-MARTÍNEZ; VICARIO; HEREDIA, 2007; RIBEIRO; SERAVALLI, 2004). Phenolic compounds display a wide variety of physiological properties, but their main effect is from their antioxidant activity in foods (BALASUNDRAM, SUNDRAM; SAMMAN, 2006).

As well as quality, it is necessary to conserve the useful, post-harvest life of citrus fruits. This is influenced both

by internal factors - such as respiration and the production of ethylene - and external factors, like temperature, relative humidity and the gaseous atmosphere (ROYO *et al.*, 2010). In general, the higher the temperature, the higher the rate of respiration of the fruit, and as a consequence, the shorter the period of conservation. Respiration is therefore a good indicator of fruit metabolism during the post-harvest period, and its control is an efficient way to regulate general metabolism and increase useful post-harvest life. Respiration is also directly related to ethylene production and as a general rule, the greater the production of ethylene, the greater the post-harvest respiration in fruit (CHITARRA; CHITARRA, 2005).

Some ethylene inhibitors have been used, with an aim to increasing the useful, post-harvest life of vegetables. Among them, can be included 1-methylcyclopropene (1-MCP), which has had positive results in various fruits and vegetables. However, studies into its effects on non-climacteric fruits, such as oranges, are scarce.

Given the above, the aim of this work was to analyse the effects of 1-MCP on the post-harvest quality of the orange cv. Pera, stored at 7°C for 45 days.

MATERIAL AND METHODS

Oranges of the 'Pera' cultivar were obtained from CEASA in Maracanaúba, in the State of Ceará, Brazil (CE), and were later transported to the Laboratory of Drying and Quality Control at the Universidade Federal do Ceará (UFC), in Fortaleza, CE. After being selected and washed, the fruit was weighed and divided into lots. The fruit was then treated with 1-methylcyclopropene, a commercial wet table powder from SmartFresh™ (Rohm & Hass Co) containing 0.33% active ingredient. Four treatments were carried out: one control and three concentrations of 1-MCP (0.1, 0.5 and $1.0\ \mu\text{L}\cdot\text{L}^{-1}$). The necessary amount of 1-MCP for each concentration was calculated as a function of the box volume and concentration of ingredients in the commercial product. The product was placed into 30mL glass flasks, which were hermetically sealed with rubber septa. Deionized water at room temperature was later added by means of a syringe. The flasks were agitated vigorously until the product was completely dissolved, and were then opened inside the boxes containing the fruit. The boxes were then immediately closed and left for 12 hours at approximately 20°C . The control fruit (without 1-MCP) also remained inside a box for 12 hours. After this time, the fruit was removed from the boxes and stored in a cool chamber at 7°C . The experiment consisted of 1 cultivar, 4 treatments, 1 temperature, 4 periods of analysis and 4 replications.

After weighing the fruit from each replication, the juice was extracted and later sieved and homogenised. The following were analysed every 15 days during the storage period: A) rate of respiration: determined by quantifying the production of CO₂. The fruit was placed inside hermetically sealed glass containers and a reading taken after two hours. The air inside the glass flasks was circulated through an Agri-datalog®/Schelle® electronic CO₂ analyser. The rate of respiration in mL CO₂ kg⁻¹ h⁻¹ was calculated from the concentration of CO₂ inside the container, the weight of the fruit and the time of closure. B) Coloration of the epidermis: determined with a Minolta model CR310 electronic colorimeter, which uses the CIE L*a*b* or CIELAB colour system. Measurements were expressed as values of L (colour variation from black to white), hue angle (which shows the colour in a diagram, where 0° represents pure red, 90° represents pure yellow, 180° represents pure green and 270° represents pure blue) and chroma (colour intensity or saturation; defined by the distance of the hue angle in a three-dimensional diagram). C) Soluble Solids (SS): obtained by refractometer from the juice of each sample. The values were expressed in °Brix. D) Titratable acidity (TA): determined by potentiometric titration with 0.1M NaOH, using a Digimed® pHmeter. The values were expressed as meq 100mL⁻¹. E) Ratio (SS/TA): calculated as the ratio between soluble solid content and titratable acidity. F) Vitamin C content: neutralisation of ascorbic acid by titration in a solution of 2,6-dichlorobenzeneindophenol, expressed as milligram of ascorbic acid per 100mL of juice. Sample extraction was performed with a 1% solution of oxalic acid. G) Total Carotenoids: this procedure is based on weighing approximately 5mL of the sample, triturating and later adding 45mL of 80% acetone, with the mixture then being immediately filtered in a dark room. The supernatant was read for carotenoids by spectrophotometer at 470nm. H) Phenolic compounds: determined based on the Folin-Ciocalteu method in accordance with Bucic-Kojic *et al.* (2007). Readings were taken by spectrophotometer at 765nm, using gallic acid (GAE) as the standard. I) Total and reduced sugars: determined by the Lane-Eynon method, IAL (2005), employing titration in Fehling's solution A and solution B. J) Weight loss: determined by the difference between initial weight and the weight after storage, using a semi-analytical balance. K) Juice yield: determined by the percentage ratio between the weight of the orange juice and the total weight of the fruit.

The following factors were studied: One temperature (7 °C) and four concentrations of 1-MCP (0, 0.1, 0.5 and 1.0), evaluated for each period of storage (0, 15, 30 and 45 days), with four replications per treatment and seven pieces of fruit per lot. The data as a percentage were transformed into $\sqrt{x/100}$ and submitted to

analysis of variance (F-Test); the mean values were studied by regression ($P \leq 0.05$), with the aid of the SISVAR statistical software (FERREIRA, 2008).

RESULTS AND DISCUSSION

Table 1 shows the results for rate of respiration and epidermis coloration in fruit of the 'Pera' cultivar.

For the rate of respiration, it was possible to verify that, according to the regression analysis, there was a significant interaction between the control fruit and those treated with 1-MCP for each period of analysis. The lowest dose of 1-MCP (0.1 µL.L⁻¹) resulted in the lowest rate of respiration when compared to the other doses.

Jomori *et al.* (2003) found a variation from 18.53 to 27.81 mL CO₂ kg⁻¹ h⁻¹ in the rate of respiration of the acid lime cv. Tahiti treated with wax, 1-MCP and gibberellin. Chitarra and Chitarra (2005) state that the rate of respiration in oranges is approximately 12 mL CO₂ kg⁻¹ h⁻¹. The results found in the present work were therefore greater than those found in other studies.

When comparing treatments, it can be seen that the rate of respiration increases as the dose of 1-MCP is raised. These results differ from other studies into the application of 1-MCP on non-climacteric fruits, such as the strawberry (TIAN *et al.*, 2000) and the tangor cv. Murcote (TAVARES *et al.*, 2003), where a reduction in respiration rate was seen with the application of 1-MCP.

On the other hand, Edagi *et al.* (2010) found that respiratory activity in the tangor cv. Murcote (*Citrus reticulata* x *Citrus sinensis*), did not vary significantly after treatment with 1-MCP, when compared to the control fruit. Win *et al.* (2006), while studying the acid lime cv. Tahiti, reported that the rate of respiration was not overly influenced by the treatments, there being a slight increase in the respiration rate of fruit treated with 1.0 µL.L⁻¹ 1-MCP. This result corroborates values found in the present work. The increases in respiration seen in the present work may have occurred due to the chemical stress caused by the application of 1-MCP, as the doses may have been prejudicial to the fruit.

There was a great variation in the rate of respiration of the fruit being analysed, and it is important to highlight that in general there may be an influence from a series of factors on respiration. Among them can be included such intrinsic factors as the relation of surface area to volume, the covering surface of the product, and the endogenous production of ethylene, and such extrinsic factors as atmospheric gases, the exogenous application of ethylene and room temperature (CHITARRA; CHITARRA, 2005).

Table 1 - Rate of respiration and epidermis coloration (hue angle and chroma) in fruit of the 'Pera' cultivar stored at 7 °C for 45 days

Period of Storage	Treatment 1-MCP ($\mu\text{L L}^{-1}$)	Rate of Respiration	Epidermis Coloration	
			Colour (Hue)	Chroma
INITIAL	--	31.22 ± 0.779	110.97 ± 0.98	40.02 ± 0.89
15 DAYS	0.0	$25.876 \pm 2.168^*$	$105.53 \pm 0.21^*$	$49.55 \pm 0.35^*$
	0.1	$45.139 \pm 4.778^*$	$108.98 \pm 1.46^*$	$41.29 \pm 2.33^*$
	0.5	$67.274 \pm 3.500^*$	$109.16 \pm 2.02^*$	$40.42 \pm 0.89^*$
	1.0	$68.162 \pm 5.196^*$	$106.79 \pm 0.42^*$	$41.28 \pm 2.61^*$
30 DAYS	0.0	$25.876 \pm 2.168^*$	$98.27 \pm 1.33^*$	$52.65 \pm 5.45^*$
	0.1	$45.139 \pm 4.778^*$	$108.89 \pm 1.66^*$	$43.12 \pm 2.55^*$
	0.5	$67.274 \pm 3.500^*$	$108.01 \pm 2.84^*$	$42.07 \pm 2.88^*$
	1.0	$68.162 \pm 5.196^*$	$108.05 \pm 2.47^*$	$41.66 \pm 2.99^*$
45 DAYS	0.0	$52.792 \pm 4.216^*$	$90.88 \pm 1.07^*$	$62.34 \pm 4.03^*$
	0.1	$44.919 \pm 1.505^*$	$100.59 \pm 2.76^*$	$39.94 \pm 3.36^*$
	0.5	$78.489 \pm 15.582^*$	$83.64 \pm 4.84^*$	$28.89 \pm 2.64^*$
	1.0	$79.193 \pm 3.435^*$	$82.76 \pm 2.88^*$	$28.94 \pm 2.94^*$

It was possible to see a significant difference between treatments for coloration of the epidermis, when it comes to hue angle and chroma at a temperature of 7 °C for all the periods of analysis. These results are similar to those found by Laamim, Ait-oubahou and Benichou (2005), who found that the application of 1-MCP delayed chlorophyll degradation and the consequent development of the orange coloration in tangerines. Similar results (of colour inhibition by 1-MCP) were obtained by Porat *et al.* (1999), when studying oranges of the 'Shamouti' cultivar.

Jomori *et al.* (2003), while studying the acid lime, observed hue values of 113.50h° for the control fruit and 117.50° for fruit treated with 1-MCP after 30 days of storage at 10 °C, with a further 3 days at 20 °C. The authors concluded that the control fruit showed a greater loss of green coloration, when compared to the other treatments, and that 1-MCP therefore reduced this loss of coloration. Win *et al.* (2006) found similar results (a reduction in green coloration by 1-MCP) when studying the 'Tahiti' cultivar of the acid lime.

Similar results of a reduction in chlorophyll loss from 1-MCP were also found in climacteric fruits, such as the mango (LIMA *et al.*, 2006) and the sapodilla (MORAIS *et al.*, 2007), among others.

Other studies emphasise the exogenous application of ethylene as a means of speeding up and homogenising coloration of the peel: Mendonça *et al.* (2003) and Jacomino *et al.* (2002), while studying the lemon cultivars 'Siciliano' and 'Felicio' (2005) and the 'Murcote' cultivar of the tangerine.

In the present work, it could be seen that the highest values for hue angle corresponded to the lowest values for chroma, and the greater the hue angle, the greener the epidermis. On the other hand, values close to 90°h represented fruit that was more yellow and orange. It was possible to verify that in general there was an increase in hue value as the doses of 1-MCP were raised.

It can therefore be inferred that 1-MCP is a potential inhibitor of chlorophyll degradation, and that it may help in qualitative procedures prior to the marketing of fruit and vegetables.

Table 2 shows the results for SS, TA, ratio and vitamin C found in fruit of the 'Pera' cultivar.

From the statistical analyses, it was possible to see that the treatments with 1-MCP did not influence the SS, TA or ratio for any period when compared to the control treatment.

Pereira *et al.* (2006) reported that the adequate minimum content for SS in oranges and tangerines should be around 9.0 and 10.0°Brix. Most of the results found in the present work are therefore below that average value. This difference may be due to the period of harvesting, since in the present work, the fruit was not yet fully ripe because of the need to carry out the post-harvest treatments (application of 1-MCP).

On the other hand, values for TA were similar to those observed by Nascimento *et al.* (2005), working with the 'Pera' cultivar, and by Tazima (2010), working with

Table 2 - Values for SS, TA, ratio and vitamin C found in fruit of the 'Pera' cultivar stored at 7 °C for 45 days

Period of Storage	Treatment 1-MCP ($\mu\text{L L}^{-1}$)	Analysis			
		SS ($^{\circ}\text{Brix}$)	TA ($\text{mg } 100\text{mL}^{-1}$)	Ratio	Vitamin C ($\text{mg } 100\text{mL}^{-1}$)
INITIAL	--	9.95 \pm 0.31	1.06 \pm 0.09	9.46 \pm 0.84	52.41 \pm 0.29
15 DAYS	0.0	9.70 \pm 0.96 ^{NS}	0.90 \pm 0.02 ^{NS}	10.81 \pm 0.40 ^{NS}	48.89 \pm 2.40*
	0.1	9.93 \pm 0.33 ^{NS}	1.00 \pm 0.04 ^{NS}	9.90 \pm 0.70 ^{NS}	70.83 \pm 3.19*
	0.5	9.28 \pm 0.45 ^{NS}	0.90 \pm 0.11 ^{NS}	10.44 \pm 1.32 ^{NS}	69.17 \pm 2.46*
	1.0	9.55 \pm 0.77 ^{NS}	0.96 \pm 0.07 ^{NS}	10.01 \pm 0.52 ^{NS}	61.67 \pm 1.43*
30 DAYS	0.0	9.58 \pm 0.73 ^{NS}	0.76 \pm 0.15 ^{NS}	12.93 \pm 2.34 ^{NS}	40.25 \pm 4.99*
	0.1	9.68 \pm 0.22 ^{NS}	0.93 \pm 0.11 ^{NS}	10.52 \pm 1.22 ^{NS}	49.50 \pm 3.11*
	0.5	9.48 \pm 0.39 ^{NS}	0.82 \pm 0.15 ^{NS}	11.72 \pm 1.65 ^{NS}	41.50 \pm 2.38*
	1.0	9.30 \pm 0.32 ^{NS}	0.87 \pm 0.07 ^{NS}	10.74 \pm 0.69 ^{NS}	42.75 \pm 2.50*
45 DAYS	0.0	9.93 \pm 0.44 ^{NS}	0.84 \pm 0.11 ^{NS}	11.85 \pm 1.07 ^{NS}	56.76 \pm 5.84 ^{NS}
	0.1	9.58 \pm 0.31 ^{NS}	0.84 \pm 0.03 ^{NS}	11.36 \pm 0.40 ^{NS}	50.68 \pm 2.81 ^{NS}
	0.5	9.30 \pm 0.24 ^{NS}	0.81 \pm 0.15 ^{NS}	11.79 \pm 2.00 ^{NS}	54.39 \pm 4.46 ^{NS}
	1.0	9.43 \pm 0.46 ^{NS}	0.99 \pm 0.13 ^{NS}	9.61 \pm 1.10 ^{NS}	54.05 \pm 2.47 ^{NS}

the cultivar 'Pera-Bianchi'. Those authors found values of 0.89% and 0.99% respectively.

The results for ratio agree with those found by Nascimento *et al.* (2005), who found a value of 11.0; by Couto and Canniati-Brazaca (2010), who found a value of 9.37; and by Tazima (2010), who found values of 10.61, 10.01 and 10.90 for the cultivars 'Pera-Vacinada 3', 'Pera-Bianchi' and 'Pera-Vacinada 4' respectively. However, these values are less than those found by Prudente, Silva and Sobrinho (2004), with values close to 20.4 for fruit from the 'Pera' cultivar grown in Umbaúba, in the State of Sergipe. It is important to point out that the ratio between SS and TA can also be influenced by the soil, climate and time of harvesting. These factors can explain the differences found in the values.

The results obtained in the present work for SS, TA and ratio were similar to those reported by Porat *et al.* (1999), who found no significant differences between the control fruit and doses of 1-MCP applied to oranges of the cultivar 'Shamouti'.

A large variation was seen in the results for vitamin C content. According to the Brazilian Table of Food Composition - TACO (UNICAMP, 2006), the amount of ascorbic acid in oranges of the 'Pera' cultivar is 73.30 mg \cdot 100 mL⁻¹ juice. Couto and Canniati-Brazaca (2010) found values of 62.50 mg \cdot 100 mL⁻¹ in fruit of the same cultivar harvested in Iperó, in the State of São Paulo. Latado *et al.* (2008) found that the concentration of ascorbic acid in blood oranges remained constant, with no significant alterations for almost the entire period of storage.

According to regression analysis, there was no significant interaction between the results, except for after 45 days of storage. However, it is important to point out that the results, which were significantly different between treatments, did not show any tendency towards an increase or decrease in content as a response to the 1-MCP. The data were adjusted by cubic equation with varying values. Nevertheless, it is not possible to affirm that the highest dose of 1-MCP either increased or decreased the amount of ascorbic acid in the fruit.

Jomori *et al.* (2003) did not find any significant differences for vitamin C in the acid lime (cv. Tahiti), when comparing treatments with 1-MCP, gibberellin and wax. The authors justified this result by the product being restricted to the albedo and flavedo of the fruit, with no inner diffusion of the products. This fact can also explain the non-significant results found between treatments in the present work.

In Table 3 are shown the results for total carotenoids and phenolic compounds, and total and reducing sugars in fruit of the 'Pera' cultivar.

The average for total carotenoids in juice from the orange (cv. Pera Rio) found by Sartori *et al.* (2002) was 0.790 mg \cdot 100 mL⁻¹. Duzzioni, Franco and Sylos (2010) found 2.23 mg β -carotene mL⁻¹ in fruit of the cultivar 'Valência'. The values seen in the present work are similar to those cited above.

With the phenolic compounds, it can be seen that the results obtained in the present work are different from results found in the literature. Duzzioni, Franco and Sylos

Table 3 - Total carotenoids, phenolic compounds and total and reducing sugars, in fruit of the 'Pera' cultivar stored at 7 °C for 45 days

Period of Storage	Treatment 1-MCP ($\mu\text{L L}^{-1}$)	Analysis			
		Total Carotenoids ($\text{mg } 100\text{mL}^{-1}$)	Phenolic Compounds ($\text{mg } 100\text{mL}^{-1}$)	Reducing Sugars ($\text{g } 100\text{mL}^{-1}$)	Total Sugars ($\text{g } 100\text{mL}^{-1}$)
INITIAL	--	0.254 ± 0.040	3.542 ± 0.714	4.477 ± 0.155	8.083 ± 0.56
15 DAYS	0.0	$0.374 \pm 0.046^{\text{NS}}$	$3.283 \pm 0.393^{\text{NS}}$	$4.269 \pm 0.177^{\text{NS}}$	$7.893 \pm 0.27^{\text{NS}}$
	0.1	$0.290 \pm 0.088^{\text{NS}}$	$3.617 \pm 0.378^{\text{NS}}$	$4.953 \pm 0.286^{\text{NS}}$	$9.334 \pm 0.41^{\text{NS}}$
	0.5	$0.293 \pm 0.040^{\text{NS}}$	$3.920 \pm 0.388^{\text{NS}}$	$4.697 \pm 0.286^{\text{NS}}$	$8.444 \pm 0.63^{\text{NS}}$
	1.0	$0.322 \pm 0.064^{\text{NS}}$	$3.580 \pm 0.435^{\text{NS}}$	$4.452 \pm 0.063^{\text{NS}}$	$8.896 \pm 0.77^{\text{NS}}$
30 DAYS	0.0	$0.387 \pm 0.085^{\text{NS}}$	$3.712 \pm 0.672^{\text{NS}}$	$4.263 \pm 0.409^{\text{NS}}$	$8.672 \pm 0.23^{\text{NS}}$
	0.1	$0.258 \pm 0.053^{\text{NS}}$	$3.902 \pm 0.473^{\text{NS}}$	$5.287 \pm 0.123^{\text{NS}}$	$8.894 \pm 0.36^{\text{NS}}$
	0.5	$0.320 \pm 0.121^{\text{NS}}$	$3.030 \pm 0.584^{\text{NS}}$	$5.386 \pm 0.443^{\text{NS}}$	$9.970 \pm 0.40^{\text{NS}}$
	1.0	$0.328 \pm 0.073^{\text{NS}}$	$3.561 \pm 0.355^{\text{NS}}$	$5.174 \pm 0.176^{\text{NS}}$	$9.199 \pm 0.40^{\text{NS}}$
45 DAYS	0.0	$0.275 \pm 0.094^{\text{NS}}$	$4.072 \pm 0.435^{\text{NS}}$	$6.071 \pm 1.234^{\text{NS}}$	$8.239 \pm 0.37^{\text{NS}}$
	0.1	$0.252 \pm 0.048^{\text{NS}}$	$3.864 \pm 0.705^{\text{NS}}$	$5.879 \pm 0.406^{\text{NS}}$	$8.911 \pm 1.14^{\text{NS}}$
	0.5	$0.291 \pm 0.083^{\text{NS}}$	$3.883 \pm 1.097^{\text{NS}}$	$5.517 \pm 0.082^{\text{NS}}$	$8.156 \pm 0.11^{\text{NS}}$
	1.0	$0.256 \pm 0.087^{\text{NS}}$	$3.883 \pm 0.32^{\text{NS}}$	$6.291 \pm 0.911^{\text{NS}}$	$9.442 \pm 1.57^{\text{NS}}$

(2010) observed values of around 648.6 in oranges of the 'Valência' cultivar, and $551.9\text{mg}\cdot 100\text{mL}^{-1}$ in 'Murcote' tangerines. Melo *et al.* (2008) had results for total phenolic compounds of 208.10 in oranges of the 'Pera' cultivar, and $146.30 \mu\text{g}\cdot\text{mL}^{-1}$ in oranges of the 'Cravo' cultivar. Couto and Canniatti-Brazaca (2010) found $78.47\text{mg}\cdot 100\text{mL}^{-1}$ in oranges of the 'Valência' cultivar and $21.47\text{mg}\cdot 100\text{mL}^{-1}$ in 'Murcote' tangerines.

According to the regression analysis, there was no significant interaction between carotenoids and phenolic compounds when comparing the control fruit and that treated with 1-MCP. These results differ from other studies, such as that by Morais *et al.* (2007), who studied sapodilla, and found variations in phenolic compounds in fruit treated with 1-MCP. They also found that, during the storage period, the levels of phenolic compounds remained higher in fruit treated with 1-MCP when compared to the control fruit.

No significant interaction was seen for total and reducing sugars between the control fruit and that treated with 1-MCP for any period of analysis.

In Table 4 are shown the results for weight loss and juice yield in fruit of the 'Pera' cultivar.

No significant differences were seen between treatments for weight loss for any period of analysis.

After 45 days of storage, it was possible to verify an increase in weight loss, probably due to water loss and the consequent withering of the fruit (Figure 1).

Assmann *et al.* (2006) also found weight loss during the storage of oranges of the 'Pera' cultivar. After 21 days, there was a reduction of 37.59g in the fruit when compared to the start of the experiment. According to the same authors, this is probably due to an increase in metabolism when the fruit is close to senescence, in addition to a probable increase in ethylene levels because of autocatalysis in the fruit.

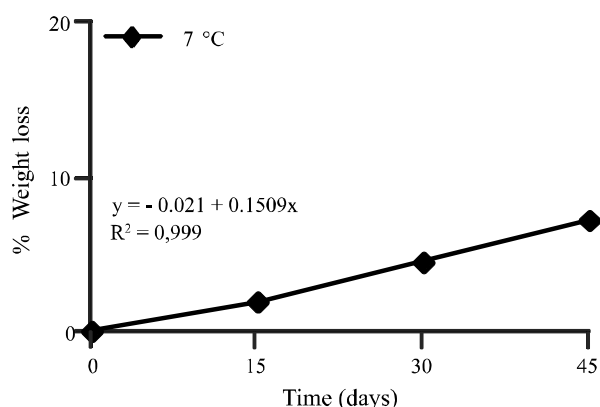
The results found in the present work corroborate those found by Mendonça *et al.* (2003), who observed an increase in weight loss in lemons of the 'Siciliano' cultivar during storage. The authors indicate transpiration as the main process involved in post-harvest weight loss. Similar results were obtained by Felício (2005) while working with the tangor cv. Murcote, and Malgarim, Cantillano and Treptow (2007), while working with 'Navelina' oranges.

As for the influence of 1-MCP on weight loss, some authors report less weight loss in fruits treated with 1-MCP, e.g. the tangerine (LAAMIN; AIT-OUBAHOU; BENICHO, 2005) and mango (LIMA *et al.*, 2006). However, their results differ from those found in the present work, where fruit treated with 1-MCP showed no significant difference when compared to the control fruit.

As already reported, in general the application of 1-MCP did not significantly affect weight loss in the fruit, such loss being due to the period of storage. Porat *et al.* (1999) also reported that weight loss was neither significant, nor due to 1-MCP.

Table 4 - Weight loss (%) and juice yield (%) in fruit of the 'Pera' cultivar stored at 7 °C for 45 days

Period of Storage	Treatment 1-MCP ($\mu\text{L L}^{-1}$)	Analysis	
		Weight loss (%)	Juice yield (%)
INITIAL	--	0.00	46.38 \pm 2.28 ^{NS}
15 DAYS	0.0	2.58 \pm 0.17 ^{NS}	57.79 \pm 1.20 ^{NS}
	0.1	2.20 \pm 0.05 ^{NS}	55.36 \pm 2.58 ^{NS}
	0.5	1.90 \pm 0.81 ^{NS}	56.87 \pm 1.77 ^{NS}
	1.0	2.22 \pm 0.14 ^{NS}	57.97 \pm 4.05 ^{NS}
30 DAYS	0.0	4.26 \pm 1.23 ^{NS}	54.66 \pm 3.12 ^{NS}
	0.1	4.50 \pm 0.13 ^{NS}	57.66 \pm 2.15 ^{NS}
	0.5	4.49 \pm 0.17 ^{NS}	56.53 \pm 2.47 ^{NS}
	1.0	4.72 \pm 0.49 ^{NS}	55.99 \pm 2.04 ^{NS}
45 DAYS	0.0	6.07 \pm 2.91 ^{NS}	34.46 \pm 7.27 ^{NS}
	0.1	6.65 \pm 0.56 ^{NS}	40.91 \pm 4.34 ^{NS}
	0.5	7.15 \pm 0.47 ^{NS}	35.10 \pm 5.83 ^{NS}
	1.0	6.93 \pm 0.74 ^{NS}	32.48 \pm 5.57 ^{NS}

Figure 1 - Weight loss in oranges of the 'Pera' cultivar during the 45 days of storage at 7 °C

For juice yield, the results were similar to the results reported by Tazima *et al.* (2010) when studying clones of oranges of the 'Pera' cultivar, where they obtained an average of 51% juice. Sartori *et al.* (2002), working with different orange cultivars (including 'Folha Murcha' and 'Valência'), found a variation of between 50 and 60% in fruit kept in a cold chamber at 4-7 °C for from 1 to 5 days.

Comparing the treatments with 1-MCP and the control, no statistical difference was seen in juice yield for any period of analysis.

CONCLUSIONS

1. The change in coloration of the epidermis from green to yellow/orange was delayed by the application of 1-MCP;
2. The application of 1-MCP caused no alterations in the chemical characteristics of SS, TA, ratio, carotenoids, phenolic compounds or sugars;
3. Higher doses of 1-MCP may have caused chemical stress to the oranges, which heightened the increase in the rate of respiration.

ACKNOWLEDGEMENT

The authors wish to thank CNPq for the scholarship granted to the lead author. The authors further wish to thank Rohm and Hass® Química do Brasil for providing the 1-MCP, and the Laboratory of Drying and Quality Control of UFC for their collaboration during the experiment.

REFERENCES

- ASSMANN, A. P. *et al.* Armazenamento de caqui cv. Fuyu e laranja cv. Pera em atmosfera modificada sob diferentes temperaturas. *Synergismus scyentifica*, v. 1, p. 133-143, 2006.
- BALASUNDRAM, N.; SUNDRAM, K.; SAMMAN, S. Phenolic compounds in plants and agri-industrial by-products: antioxidant

- activity, occurrence, and potential uses. **Food Chemistry**, v. 99, n. 1, p. 191-203, 2006.
- BENDER, R. J. Colheita, beneficiamento, embalagem, conservação e comercialização. In: **Citricultura: laranja: tecnologia de produção, pós-colheita, industrialização e comercialização**. Porto Alegre: Cinco Continentes, 2006. 396p.
- BUCIC-KOJIC, A. *et al.* Study of solid-liquid extraction kinetics of total polyphenols from grapes seeds. **Journal of Food Engineering**, v. 81, p. 236-242, 2007.
- CHITARRA, M. I.; CHITARRA, A. B. **Pós-colheita de frutas e hortaliças: fisiologia e manuseio**. 2. ed. rev. e ampl. Lavras: Universidade Federal de Lavras, 2005. 785 p.
- COUTO, M.A.L.; CANNIATTI-BRAZACA, S.G. Quantificação de vitamina C e capacidade antioxidante de variedades cítricas. **Ciência e Tecnologia de Alimentos**, v. 30, p. 15-19, 2010. Suplemento 1.
- DUZZIONI, A. G.; FRANCO, A. G.; SYLOS, C. M. de. Determinação da atividade antioxidante e de constituintes bioativos em frutas cítricas. **Alimentos e Nutrição**, v. 21, n. 4, p. 643-649, 2010.
- EDAGI, F. K. *et al.* Inibição da ação do etileno retarda o desenvolvimento de injúrias de frio em tangor 'Murcott'. **Ciência Rural**, v.40, n.7, p.1530-1536, 2010.
- FELÍCIO, A. H. **Conservação refrigerada de Tangor 'Murcott' tratada termicamente**. 2005. 57 f. Dissertação (Mestrado em Ciências) - Escola Superior de Agricultura 'Luiz de Queiroz', Universidade de São Paulo, Piracicaba, 2005.
- Ferreira, D. F. Sisvar: um programa para análises e ensino de estatística. **Revista Symposium**, v. 6, p. 36-41, 2008.
- INSTITUTO ADOLFO LUTZ. **Métodos físico-químicos para análise de alimentos**. 5. ed. Brasília, 2005. 1018p.
- JACOMINO, A. P., KLUGE, A. R.; BRACKMANN, A.; CASTRO, P. R. C. Amadurecimento e Senescência de Mamão com 1-Metilciclopropeno. **Scientia Agricola**, v.59, n.2, p.303-308, 2002.
- JOMORI, M. L. L. *et al.* Conservação refrigerada de lima ácida 'Tahiti': uso de 1-metilciclopropeno, ácido giberélico e cera. **Revista Brasileira de Fruticultura**, v. 25, n. 3, p. 406-409, 2003.
- KLUGE, R. A. *et al.* Danos de frio e qualidade de frutas cítricas tratadas termicamente e armazenadas sob refrigeração. **Revista Brasileira de Fruticultura**, v. 29, n. 2, p. 233-238, 2007.
- LAAMIM, M.; AIT-OUBAHOU, A.; BENICHO, M. Effect of 1-methylcyclopropene on the quality of clementine mandarin fruit at ambient temperature. **Journal of Food, Agriculture & Environment**, v. 3, n. 1, p. 34-36, 2005.
- LATADO, R. R. *et al.* O acúmulo de antocianinas e características físicas e químicas de frutos de laranjas sanguíneas durante o armazenamento a frio. **Revista Brasileira de Fruticultura**, v. 30, n.3, p. 604-610, 2008.
- LIMA, M. A. C. de; SILVA, A. L.; AZEVEDO, S. S. N.; SANTOS, P. de S. Tratamentos pós-colheita com 1-metilciclopropeno em manga 'Tommy Atkins': efeito de doses e número de aplicações. **Revista Brasileira de Fruticultura**, Jaboticabal, v.28, n.1, p.64-68, 2006.
- MALGARIM, M. B.; CANTILLANO, R. F. F.; TREPTOW, R. O. Armazenamento refrigerado de laranjas cv. Navelina em diferentes concentrações de cera à base de carnaúba. **Acta Scientiarum Agronomy**, v. 29, n. 1, p. 99-105, 2007.
- MELÉNDEZ-MARTÍNEZ, A. J.; VICARIO, I. M.; HEREDIA, F. J. Pigmentos carotenoides: consideraciones estructurales y físico-química. **Archivos Latino americanos de Nutricion**, v. 57, n. 2, 2007.
- MELO, E. A. *et al.* Capacidade antioxidante de frutas. **Brazilian Journal of Pharmaceutical Sciences**, v. 44, n. 2, p. 193-2001, 2008.
- MENDONÇA, K. *et al.* Concentração de etileno e tempo de exposição para o desverdecimento de Limão 'Siciliano'. **Brazilian Journal of Food Technology**, v. 6, n. 2, p. 179-183, 2003.
- MORAIS, P. L. D. de *et al.* Amadurecimento de sapoti (*Manilkara zapota* L.) submetido ao 1-metilciclopropeno. **Revista Brasileira de Fruticultura**, v.28, n. 3, p. 369-373, 2007.
- NASCIMENTO, L. M. do *et al.* Laranja charmute de brotas: promissora variedade tardia. **Revista Laranja**, v. 26, n. 1, p. 69-75, 2005.
- NEVES, L.C. **Manual pós-colheita da fruticultura brasileira**. Londrina: EDUEL, 2009. 494p.
- PEREIRA, M. E. C. *et al.* **Procedimentos Pós-Colheita na Produção Integrada de Citros**. Cruz das Almas, Embrapa Mandioca e Fruticultura Tropical, 2006. 40p.
- PORAT, R. *et al.* Effects of ethylene and 1-methylcyclopropene on the postharvest qualities of 'Shamouti' oranges. **Postharvest Biology and Technology**, v.15, p.155-163, 1999.
- PRUDENTE, R. M., SILVA, L. M. S., CUNHA SOBRINHO, A. P. Comportamento da laranjeira 'Pêra' sobre cinco porta-enxertos em ecossistema de tabuleiros costeiros, Umbaúba-se. **Revista Brasileira de Fruticultura**, v. 26, n. 1, p. 110-112, 2004.
- RIBEIRO, E. A.; SERAVALLI, E. A. G. **Química de Alimentos**. São Paulo: Edgard Blücher, 2004. p.179-181.
- ROYO, C. **Respuesta de los frutos cítricos a las bajas temperaturas: estudio mediante micromatrices**. 2010. 243 f. Tese (Doutorado) - Universidad Politécnica de Valencia, 2010.
- SARTORI, I. A. *et al.* Maturação de frutos de seis cultivares de laranjas-doces na depressão central do rio grande do sul. **Revista Brasileira de Fruticultura**, v. 24, n. 2, p. 364-369, 2002.
- TAVARES, S. *et al.* Qualidade Pós-Colheita em tangor 'Murcott' tratado com biorregulador 1-metilciclopropeno e armazenado sob refrigeração. **Revista Laranja**, v. 24, n. 2, p. 491-506, 2003.

TAZIMA, Z. H. *et al.* Produção e qualidade dos frutos de clones de laranjeira 'Pera' no norte do Paraná. **Revista Brasileira de Fruticultura**, v. 32, n. 1, p. 189-195, 2010.

TIAN, M. S. *et al.* Responses of strawberry fruit to 1-methylcyclopropene (1-MCP) and ethylene. **Plant Growth Regulation**, v. 32, p. 83-90. 2000.

UNIVERSIDADE ESTADUAL DE CAMPINAS. **Tabela Brasileira de Composição de Alimentos: TACO**. 2. ed. Campinas, 2006. Disponível em: <http://www.unicamp.br/nepa/taco/contar/taco_versao2.pdf>. Acesso em: 20 dez. 2012.

WIN, T. O. *et al.* Effects of different concentrations of 1-MCP on the yellowing of West Indian lime (*Citrus aurantifolia*, Swingle) fruit. **Postharvest Biology and Technology**, v. 42, p. 23-30, 2006.