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

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

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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 ºC. The fruit was divided into four treatments, and then submitted to the application of three concentrations of 1-methylciclopropene (0.1, 0.5 and 1.0µL.L^{-1}) for a period of 12 hours.The fruitwas again then stored at a temperature of 7 ºC. The rate of respiration was determined, together withcoloration 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 orangesunder evaluation, being responsible for the increasein the rate of respiration.Achange 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.

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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 sectorunder focus isthe production of fruitfor fresh consumptionfor both the domesticand external markets. It should however be noted thatin this area, the consumer marketis fairly demanding, which makes it necessary to adoptmeasures 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 (hº) is a measure that is much used for expressing colour variations in plant products. It is represented on a diagram where 0º corresponds to pure red, 90º corresponds to pure yellow, 180º represents pure green and 270º 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 todetermine 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-harvestlife 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 ofthe 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 usefulpost-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-methylcicloprope ne (1-MCP), which has hadpositive results in various fruits and vegetables. However, studies into its effectson 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 ºC 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 fruitwas weighed and divided into lots. The fruit was then treated with 1-methylcicloprope ne, 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 $\mu L.L^{-1}$). The necessary amount of 1-MCP for each concentration was calculated as a function of the box volume and concentration of ingredientsin 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 ºC. The control fruit (without 1-MCP) also remained inside a box for 12 hours. After this time, the fruitwas removed from the boxes and stored in a cool chamber at 7 ºC. 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 analysedevery 15 days during the storage period: A) rate of respiration: determined by quantifying the production of CO_2. 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 CO_2 analyser. The rate of respiration in mL CO_2 kg^{-1} h^{-1} was calculated from the concentration of CO_2 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 0º represents pure red, 90º represents pure yellow, 180º represents pure green and 270º 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 ºBrix. 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, withthe mixture then beingimmediately filtered in a dark room. The supernatant was read for carotenoids by spectrophotometer at 470nm. H) Phenolic compounds: determined based on the Folin-Ciocauteau method in accordance with Bucic-Kojic *et al*. (2007). Readingsweretaken 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 ºC) 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 intoarc.sen $\sqrt{x/100}$ and submitted to analysis of variance (F-Test); the mean valueswere 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 interactionbetween the control fruit and those treated with 1-MCP for each period of analysis. The lowest dose of 1-MCP (0.1 $\mu L.L^{-1}$) resulted in the lowest rate of respiration when compared to the other doses.x

Jomori *et al*. (2003) found a variation from 18.53 to 27.81mL CO_2 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 CO_2 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 intothe 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 reticulate 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$\mu L.L^{-1}$ 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 fruitbeing 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 includedsuch 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 ºC for 45 days

Period of Storage	Treatment 1-MCP (μL 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 ± 2.168*	105.53 ± 0.21*	49.55 ± 0.35*
	0.1	45.139 ± 4.778*	108.98 ± 1.46*	41.29 ± 2.33*
	0.5	67.274 ± 3.500*	109.16 ± 2.02*	40.42 ± 0.89*
	1.0	68.162 ± 5.196*	106.79 ± 0.42*	41.28 ± 2.61*
30 DAYS	0.0	25.876 ± 2.168*	98.27 ± 1.33*	52.65 ± 5.45*
	0.1	45.139 ± 4.778*	108.89 ± 1.66*	43.12 ± 2.55*
	0.5	67.274 ± 3.500*	108.01 ± 2.84*	42.07 ± 2.88*
	1.0	68.162 ± 5.196*	108.05 ± 2.47*	41.66 ± 2.99*
45 DAYS	0.0	52.792 ± 4.216*	90.88 ± 1.07*	62.34 ± 4.03*
	0.1	44.919 ± 1.505*	100.59 ± 2.76*	39.94 ± 3.36*
	0.5	78.489 ± 15.582*	83.64 ± 4.84*	28.89 ± 2.64*
	1.0	79.193 ± 3.435*	82.76 ± 2.88*	28.94 ± 2.94*

It was possible to see a significant difference between treatmentsfor coloration of the epidermis, when it comes to hue angle and chroma at a temperature of 7 ºC 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 colorationin 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 113.50hº for the control fruit and 117.50º for fruit treated with 1-MCP after 30 days of storage at 10 ºC, with a further 3 days at 20 ºC. The authors concluded that the control fruit showed a greater loss of green coloration, when compared to the other treatments, andthat 1-MCP therefore reduced this lossof 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 tangor.

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 90ºh 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 influencethe SS, TA or ratio for any period when compared to the control treatment.

Pereira *et al*. (2006) reported that theadequate minimum contentfor SS in oranges and tangerines should be around 9.0 and 10.0ºBrix. 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 fruitwas not yet fully ripebecause 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 fruitof the 'Pera' cultivar stored at 7 ºC for 45 days

Period of Storage	Treatment 1-MCP (μL L^{-1})	Analysis			
		SS (°Brix)	TA (mg $100mL^{-1}$)	Ratio	Vitamin C (mg $100mL^{-1}$)
INITIAL	--	9.95 ±0.31	1.06 ±0.09	9.46 ± 0.84	52.41 ±0.29
15 DAYS	0.0	9.70 ± 0.96^{NS}	0.90 ± 0.02^{NS}	10.81 ± 0.40^{NS}	48.89 ± 2.40*
	0.1	9.93 ± 0.33^{NS}	1.00 ± 0.04^{NS}	9.90 ± 0.70^{NS}	70.83 ± 3.19*
	0.5	9.28 ± 0.45^{NS}	0.90 ± 0.11^{NS}	10.44 ± 1.32^{NS}	69.17 ± 2.46*
	1.0	9.55 ± 0.77^{NS}	0.96 ± 0.07^{NS}	10.01 ± 0.52^{NS}	61.67 ± 1.43*
30 DAYS	0.0	9.58 ± 0.73^{NS}	0.76 ± 0.15^{NS}	12.93 ± 2.34^{NS}	40.25 ± 4.99*
	0.1	9.68 ± 0.22^{NS}	0.93 ± 0.11^{NS}	10.52 ± 1.22^{NS}	49.50 ± 3.11*
	0.5	9.48 ± 0.39^{NS}	0.82 ± 0.15^{NS}	11.72 ± 1.65^{NS}	41.50 ± 2.38*
	1.0	9.30 ± 0.32^{NS}	0.87 ± 0.07^{NS}	10.74 ± 0.69^{NS}	42.75 ± 2.50*
45 DAYS	0.0	9.93 ± 0.44^{NS}	0.84 ± 0.11^{NS}	11.85 ± 1.07^{NS}	56.76 ± 5.84^{NS}
	0.1	9.58 ± 0.31^{NS}	0.84 ± 0.03^{NS}	11.36 ± 0.40^{NS}	50.68 ± 2.81^{NS}
	0.5	9.30 ± 0.24^{NS}	0.81 ± 0.15^{NS}	11.79 ± 2.00^{NS}	54.39 ± 4.46^{NS}
	1.0	9.43 ± 0.46^{NS}	0.99 ± 0.13^{NS}	9.61 ± 1.10^{NS}	54.05 ± 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 differencesfound 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 resultsfor vitamin C content. According to the Brazilian Tableof Food Composition - TACO (UNICAMP, 2006), the amount of ascorbic acid in oranges of the 'Pera' cultivar is 73.30mg.$100mL^{-1}$ juice. Couto and Canniatti-Brazaca (2010) found values of 62.50mg.$100mL^{-1}$ in fruitof 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, withno significant alterationsfor almost the entire period of storage.

According to regression analysis, there was no significant interactionbetween 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 decreasein content as a response to the 1-MCP. The data were adjusted by cubic equation with varyingvalues. 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 beingrestricted to the albedo and flavedo of the fruit, with no inner diffusion of the products. Thisfact can also explain the non-significant results found between treatments in the present work.

In Table 3 are shownthe results for total carotenoidsand 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 0.790mg.$100mL^{-1}$. Duzzioni, Franco and Sylos (2010) found 2.23mg.β-carotene mL^{-1} in fruitof 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 ºC for 45 days

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

(2010) observed values of around 648.6 in oranges of the 'Valência' cultivar, and 551.9mg.$100mL^{-1}$ 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 μg.mL^{-1} in oranges of the 'Cravo' cultivar. Couto and Canniatti-Brazaca (2010) found 78.47mg.$100mL^{-1}$ in oranges of the 'Valência' cultivar and 21.47mg.$100mL^{-1}$ 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 fruittreated with 1-MCP when compared to the control fruit.

No significant interaction was seen for total and reducing sugarsbetween 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 lossfor 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 foundweight 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 autocatalysisin 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.

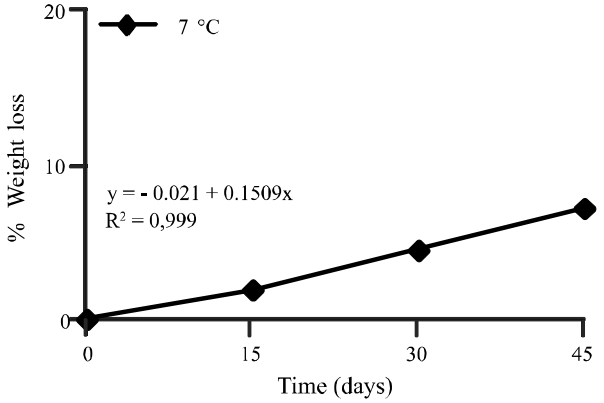
As for the influence of 1-MCP on weight loss, some authors report lessweight loss in fruits treated with 1-MCP, e.g. the tangerine (LAAMIN; AIT-OUBAHOU; BENICHOU, 2005) and mango (LIMA *et al*., 2006). However, their results differ from those found in the present work, where fruittreated with 1-MCP showed 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 ºC for 45 days

Period of Storage	Treatment 1-MCP (µL L-1)	Analysis	
		Weight loss (%)	Juice yield (%)
INITIAL	--	0.00	46.38 ± 2.28^{NS}
15 DAYS	0.0	2.58 ± 0.17^{NS}	57.79 ± 1.20^{NS}
	0.1	2.20 ± 0.05^{NS}	55.36 ± 2.58^{NS}
	0.5	1.90 ± 0.81^{NS}	56.87 ± 1.77^{NS}
	1.0	2.22 ± 0.14^{NS}	57.97 ±4 .05^{NS}
30 DAYS	0.0	4.26 ± 1.23^{NS}	54.66 ± 3.12^{NS}
	0.1	4.50 ± 0.13^{NS}	57.66 ± 2.15^{NS}
	0.5	4.49 ± 0.17^{NS}	56.53 ± 2.47^{NS}
	1.0	4.72 ± 0.49^{NS}	55.99 ± 2.04^{NS}
45 DAYS	0.0	6.07 ± 2.91^{NS}	34.46 ± 7.27^{NS}
	0.1	6.65 ± 0.56^{NS}	40.91 ± 4.34^{NS}
	0.5	7.15 ± 0.47^{NS}	35.10 ± 5.83^{NS}
	1.0	6.93 ± 0.74^{NS}	32.48 ± 5.57^{NS}

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



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 fruitkept in a cold chamber at 4-7 ºC for from 1 to 5 days.

Comparing the treatments with 1-MCP and the control, no statistical difference was seenin juice yieldfor 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 causedno 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.

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