Original Article

ACTIVE MODIFIED ATMOSPHERE AND 1-METHYLCYCLOPROPENE DURING SHELF LIFE ON 'FUYU' PERSIMONS

ATMOSFERA MODIFICADA ATIVA E 1-METILCICLOPROPENO DURANTE A VIDA DE PRATELEIRA DE CAQUIS 'FUYU'

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ABSTRACT: The aim of the present study was determine the O_2 and CO_2 levels for active modified atmosphere (MAP), besides evaluate 1-MCP effect about pulp softening delaying and skin browning during shelf life of persimmon fruit after storage in controlled atmosphere (CA) at the temperature -0.5°C. The experiment was carried in factorial arrangement (2x5) with three replications with eight fruit each. After storage plus shelf life was not found significant interaction on pulp softening, but fruit submitted to 1.0 kPa O_2 during shelf life in MAP showed lower softening. However, for skin browning was observed significant interaction. The use of highly CO_2 levels during storage at -0.5°C promotes higher skin browning in all the shelf life MAP conditions, except on fruit of control treatment, after six days of shelf life at 20°C. Partial pressure of 1.0 kPa O_2 during MAP shelf life is the best condition for reduction pulp softening and skin browning of 'Fuyu' persimmon. Partial pressure of 6.0 kPa CO_2 during storage in CA with 0.15 kPa O_2, in cold storage (-0.5°C) keep higher skin browning during MAP shelf life. The use of 1-MCP no brink effect in low O_2 level during MAP shelf life at 20°C.

KEYWORDS: *Diospyrus kaki*. Postharvest. Softening. Browning. Quality.

INTRODUCTION

The state of Rio Grande do Sul (Brazil) stands out on the national production of temperate climate fruit, such as the persimmon, which is one of the most significant fruits cultivated in the country (FAGUNDES et al., 2006). Since the persimmon is a fruit that shows an elevated metabolism, an aspect that confers it a high perishability, the necessity for development of new technologies for reduction of losses and increase of its postharvest life arises, essentially after storage.

Among the storage techniques, the most economical one for postharvest conservation is the temperature reduction of the storage environment (BRACKMANN et al., 2006). Besides temperature reduction, CA can also be used, which, by the reduction of O_2 and the increase of CO_2 in the chambers, significantly reducing the fruit metabolic rate (CHITARRA; CHITARRA, 2005; NAKANO et al., 2003). However, after being stored, either in cold storage or CA, the fruit demonstrated fast pulp softening and skin browning, becoming inappropriate for commercialization (PINTO et al., 2007). Therefore, the development of technologies is necessary in order to maintain the persimmon`s post storage quality.

During storage, the use of ethylene action blinding, such as 1-metilcyclopropene (1-MCP), decreased the softening and maintained flesh firmness (TIBOLA et al., 2005), but its effect during the shelf life, is not clear yet. The 1-MCP is a compound that blinds the ethylene receivers and inhibits the metabolic reaction triggered by ethylene (SISLER; SEREK, 1997). Nevertheless, besides being a chemical product, it showed an elevated cost for storage, this aspect becomes extremely important to the improvement of new procedures for pulp softening control after storage, such as active modified atmosphere (MAP).

The MAP consists in packaging the fruit in semi-permeable packets. This procedure causes changes in the O_2 and CO_2 levels, due to the fruit metabolic activity in passive modified atmosphere (STEFFENS et al., 2007; SEN et al., 2012), already in MAP the changes in O_2 and CO_2 are created by direct gas flushing in the storage container (SEN et al., 2012). The changes in the O_2 and CO_2 levels decrease the respiratory rate, the ethylene production, the transpiration and, consequently, the mass loss (NEVES et al., 2006). However, the correct level of O_2 and CO_2 in the MAP packet has not been stipulated yet, indicating that more studies regarding this subject are needed. With the extreme O_2 reduction and excessive CO_2 increase, the anaerobic metabolism can be initiated (LIU et al., 2004; SONG et al., 2002), triggering the appearance of physiological disorders.

Considering this, the objective of the present study was to determinate the best O_2 and

Received: 28/03/13
Accepted: 03/09/13

CO_2 level for MAP, besides evaluating the 1-MCP effect on pulp softening delaying and skin browning during shelf life of persimmon fruit stored in controlled atmosphere (CA) at a -0.5°C temperature during a 14 week period.

MATERIAL AND METHODS

'Fuyu' persimmons were harvested in a commercial orchard, in the town of Farroupilha, RS, Brazil, in 2012. The fruits were properly selected and homogenized before being stored, therefore only healthy fruit that presented an even color and maturity were used in the experiment. At the harvest, the fruit showed 64.1 N flesh firmness, 0.83 meq $100mL^{-1}$ titratable acidity, 0.0026 µL C_2H_4 kg^{-1} h^{-1} ethylene production, 0.042 µL L^{-1} internal ethylene concentration (IEC), 1.21 mL CO_2 kg^{-1} h^{-1} respiration rate, 14.2 mL CO_2 L^{-1} internal CO_2, skin color: 62.6 luminosity (L), 69.5 chroma (C), 62,9° hue angle (h°).

The fruit were stored at -0.5 °C in two controlled atmosphere (CA) conditions (0.15 kPa O_2 plus 2.0 kPa CO_2 and 0.15 kPa O_2 plus 6.0 kPa CO_2), relative humidity (RH) of 95% (±1%) and ethylene absorption, during 14 weeks. At the end of this period, the fruit were kept during 24 hours in cold storage at -0.5°C. After, were transferred to simulate shelf life at 20 °C, where each CA condition originated five new MAP conditions, in a factorial arrangement 2 x 5 (treatments at -0.5 °C x treatments at 20°C). The MAP treatments evaluated in shelf life were: [1] 1.0 kPa O_2 plus 0.0 kPa CO_2; [2] 20.9 kPa O_2 plus 6.0 kPa CO_2; [3] 1.0 kPa O_2 plus 6.0 kPa CO_2; [4] 1.0 kPa O_2 plus 0.0 kPa CO_2 plus 1-MCP; [5] 20.9 kPa O_2 plus 0.0 kPa CO_2 (CS). At this period, all conditions remained at 99% RH (±1%).

The fruit were stored in hermetically sealed experimental chambers with 0.232 m^3, which were placed inside a cold storage room with 48 m^3 at -0.5°C (±0.1°C) and after at 20.0°C (±0.3°C). Temperature was controlled by thermometers with a 0.1°C resolution inserted in the fruit flesh, being daily accompanied. Partial pressure of O_2 for each treatment was obtained by O_2 dilution in the chamber with injections of N_2 obtained from a pressure swing adsorption (PSA) nitrogen generator (Janus & Pergher, Porto Alegre, RS, Brazil). Partial pressure of CO_2 was obtained by gas injection from a high pressure cylinder. The removal of CO_2 of chambers (treatment 1, 4 and 5) were obtained with hydrated lime, which absorbed this gas. The ethylene absorption was obtained with pellets of potassium permanganate ($KMnO_4$) inside the chamber and the desired partial pressure was maintained by automatic gas control equipment (Siemens®, Berlin, Germany). Corrections were made every time the O_2 and CO_2 partial pressures were inadequate. The O_2 consumed by respiration was replaced by injections of atmospheric air into the chambers, and excessive CO_2 produced by respiration was absorbed with a 40% potassium hydroxide solution.

Fruit quality and ripening characteristics were evaluated after fourteen weeks of storage in a CA at-0.5°C plus six days in different MAP conditions at 20.0°C, with aim to simulate the transportation and the commercialization period. The characteristic evaluated were: a) pulp softening: assessed subjectively through the identification of spots with low firmness, according to a scale of 0 – 3: 0 = <25% of the fruit softening; 1 = ≥25% up to 50% of the fruit softening; 2 = ≥50% up to 75% of the fruit softening; 3 = ≥75% of the fruit softening. The average was obtained by the total number of fruit multiplied by their respective softening level, this product was then divided by the total number of fruit in the sample. b) Skin browning: was assessed on a scale of 0 – 3 according to the amount of browning on the fruit surface, where 0 = <25% of darkened surface; 1 = ≥25% up to 50% of darkened surface; 2 = ≥50% up to 75% of the darkened surface; 3 = ≥75% of darkened surface. The mean scale was calculated likewise the softening. c) Flesh firmness: was determined with a penetrometer model FT 327 (Effegi Systems, Milan, Italy), equipped with a 7.9 mm probe and measured on both sides of the fruit equatorial region, from which the skin had been previously removed, the results were expressed in Newtons (N). d) Ethylene production: was determined by the use of approximately 1200 grams of fruit which were placed into containers with a volume of 5000 mL. These containers were hermetically sealed for approximately two hours. Ethylene synthesis, expressed as µL kg^{-1} h^{-1} C_2H_4, measured by gas chromatography, was calculated by taking into account the ethylene concentration, the fruit mass, the free room inside the container and the time. To analyze ethylene concentration, two gas samples of 1 mL, extracted from the headspace of each syringe, were injected in a gas cromatograph, Varian Gas Chromatograph Star CX 3400 model, (Varian, Palo Alto, CA, USA), equipped with a flame ionization detector (FID) and a Porapak N80/100 steel column. The column, the injector and the detector temperatures were 90, 140 and 200°C, respectively. e) Internal ethylene concentration (IEC): was determined with a vacuum

pump, which withdrew internal air of the fruit, with a 565 mm Hg suction pressure. The vacuum pump removes air from the container filled with water in which a fruit was submerged. An inverted funnel, with a septum in its thinner end, was placed on the fruit, allowing the air removed from it to be accumulated. 1 mL samples of this air were injected in the same chromatograph used for ethylene production and the results were expressed in µL C_2H_4 L^{-1} of the fruit air. f) Respiration rate was determined by the volume of CO_2 production. The air from the same container, used to determine ethylene production, was circulated through an electronic CO_2 analyzer, with the infrared gas analyzer (IRGA) system (Agri-datalog, Lana, BZ, Italy). Based on CO_2 concentration, free room inside the container, fruit weight and closure time, the respiration rate was calculated and expressed in mL CO_2 kg^{-1} h^{-1}. g) Internal CO_2: a sample of approximately 5 mL of air extracted from the fruit, removed by the same method used to ascertain the IEC, was diluted in a 800 mL container. This container was connected to the electronic CO_2 analyzer and the results were expressed in mL CO_2 L^{-1} of the fruit air. h) Skin color: was evaluated by a Minolta Colorimeter (Model CR-310, Ramsey, NY, USA), with the three-dimensional color system CIELAB, being expressed in L, C and h°. The L represents luminosity, which goes from zero to 100,zero being entirely black and 100 entirely white; The chroma (C), which represents intensity or color saturation presents a zero value in the center of the three-dimensional scheme and is increased when moved away from it; and the Hue angle (h°), which shows the color location in a diagram, in where the 0° represents red; 90° represents yellow; 180°, green and 270°, blue i) Titratable acidity: determined by titration of a solution containing10mL of juice diluted in 100mL of distillated water, with NaOH 0,1N. The results were expressed in meq $100mL^{-1}$. j) Mass loss: obtained through the difference noticed between the total mass before and after the storage, data was expressed in percentage of total mass loss.

The experimental design was completely randomized, in a factorial arrangement (2x5), with three replicates of eight fruit. A variance analysis (ANOVA) was conducted to each characteristic evaluated, the averages being submitted to the Tukey test with a 5% error probability ($p<0.0.5$). The data expressed in percentage were transformed with the arc.sen $((x/100)^{0,5})$ formula before being submitted to the variance analysis.

RESULTS AND DISCUSSION

No interaction was found between the partial pressure of CO_2 during cold storage and the O_2 and CO_2 levels during shelf life. Nonetheless, we can affirm that the high partial pressure of CO_2 did not reduced the persimmon pulp softening during the shelf life in different MAP, after three and six days of exposure (Table 1). In relation to the gases partial pressures during shelf life, the use of 1.0 kPa O_2 demonstrated lower pulp softening. Therefore, in a low O_2 level, the 1-MCP and the high CO_2 did not cause any additional effect on the pulp softening, in both evaluations periods. These results diverge from several researches that affirmed that 1-MCP application delays pulp softening (KRAMMES et al., 2005; TIBOLA et al., 2005), notwithstanding, these studies were conducted in higher O_2 levels, on which the 1-MCP have a major effect. Stored in cold storage (control treatment) were almost fully softened after three days of shelf life and did not present satisfactory commercialization conditions.

Table 1. Pulp softening (0 – 3) of 'Fuyu' persimmon stored in controlled atmosphere with 0.15 kPa O_2 during 14 weeks in temperature of -0.5°C plus three and six days of shelf life at different levels of active modified atmosphere (MAP). Santa Maria, Brazil, 2012.

MAP conditions at 20°C (kPa O_2 + CO_2)	Days of shelf life in MAP at 20°C					
	3 days of shelf life		Mean	6 days of shelf life		Mean
	2.0 kPa*	6.0 kPa		2.0 kPa	6.0 kPa	
1.0/0.0	0.00	0.00	0.00c***	0.21	0.12	0.16c
20.9/6.0	1.17	1.42	1.29b	2.46	2.37	2.42b
1.0/6.0	0.08	0.04	0.06c	0.29	0.17	0.23c
1.0/0.0**	0.04	0.00	0.02c	0.08	0.16	0.12c
20.9/0.0	2.83	3.00	2.92a	3.00	3.00	3.00a
Mean	0.83A	0.89 A	-	1.21A	1.17A	-

* CO_2 level during controlled atmosphere storage. ** 1-MCP application on the end of cold storage. *** Means followed by equal letters, lowercase in the columns and uppercase in the lines, do not differ by Tukey test, at 5% probability.

Regarding the skin browning, a significant interaction between conditions tested (Table 2) was verified. The 6.0 kPa CO_2 level during cold storage brought higher skin browning in almost all MAP shelf life conditions, ion both evaluation periods. The higher browning can be observed by skin color, where, by the L value, the treatment with 1.0 kPa O_2 + 0.0 kPa CO_2 and 1.0 kPa O_2 + 6.0 kPa CO_2 demonstrated more browning when the fruits were stored in a CA with 6.0 kPa CO_2 during cold storage (Table 4). BRACKMANN et al. (2004) and NEVES et al. (2006) also verified that the increase of CO_2 levels during storage culminated in a higher skin browning of the 'Kyoto' and 'Fuyu' persimmons. Low skin browning was observed in fruits submitted to 1.0 kPa O_2 level during shelf life, the use of 1-MCP at 2.0 kPa CO_2 brought higher browning at the same O_2 level. Another study has demonstrated that 1-MCP does not decrease the skin browning, but maintains flesh firmness (TIBOLA et al., 2005). These results were confirmed by the analysis of skin color, where, by the L value, the high CO_2 level during shelf life in MAP (20.9 kPa O_2 + 6.0 kPa CO_2) showed more skin browning.

Table 2. Skin browning (0 – 3) of 'Fuyu' persimmon stored in controlled atmosphere with 0.15 kPa O_2 during 14 weeks in temperature of -0.5°C plus three and six days of shelf life at different levels of active modified atmosphere (MAP). Santa Maria, Brazil, 2012.

MAP conditions at 20°C (kPa O_2 + CO_2)	Days of shelf life in MAP at 20°C					
	3 days of shelf life		Mean	6 days of shelf life		Mean
	2.0 kPa*	6.0 kPa		2.0 kPa	6.0 kPa	
1.0/0.0	0.79Bbc***	1.71Ac	1.25	0.87Bc	2.29Ab	1.58
20.9/6.0	1.42Bb	2.42Aab	1.92	2.50Ba	2.96Aa	2.73
1.0/6.0	0.71Bc	2.08Abc	1.39	1.07Bbc	2.25Ab	1.66
1.0/0.0**	1.45Ab	1.50Ac	1.47	1.45Bb	1.83Ab	1.64
20.9/0.0	2.80Aa	3.00Aa	2.90	3.00Aa	3.00Aa	3.00
Mean	1.43	2.14	-	1.78	2.47	-

* CO_2 level during controlled atmosphere storage. ** 1-MCP application on the end of cold storage. *** Means followed by equal letters, lowercase in the columns and uppercase in the lines, do not differ by Tukey test, at 5% probability.

The internal CO_2 concentration was lower in fruits stored in MAP with 1.0 kPa O_2 + 0.0 kPa CO_2 during the shelf life, either with or without 1-MCP, on both cold storage conditions (Table 3). The respiratory rate, interaction between the conditions tested was not significant. During shelf life in MAP, the use of 1.0 kPa O_2 + 0.0 kPa CO_2, with or without 1-MCP, showed lower respiration rate, this result shows accordance to the literature, which claims that the respiration rate changes conforming to the cultivar, the temperature and the atmosphere condition (STEFFENS et al., 2007). A low respiration rate during shelf life decreases the flesh firmness loss in these treatments (Table 4), because the pulp firmness loss has close relation to the respiratory rate and the ethylene production (HIWASA et al., 2003).

Internal ethylene was lower in fruits submitted to MAP with1.0 kPa O_2 during shelf life, either with 2.0 or 6.0 kPa CO_2, during cold storage in a CA (Table 3). This fact is due to the low O_2 level, since O_2 is necessary for ACC conversion in ethylene by the ACC oxidase enzyme (YANG; HOFFMANN, 1984). In relation to the ethylene production, there was no significant interaction between CO_2 levels during CA storage and shelf life MAP condition. There was no significant difference between the shelf life conditions. However, fruits stored in the lowest CO_2 level during cold storage showed lower ethylene production.

The lowest mass loss was obtained in fruits stored in a CA with 2.0 kPa CO_2 and subsequent shelf life in MAP with 1.0 kPa O_2 + 0.0 kPa CO_2, with or without 1-MCP (Table 3). The mass loss occurs because of two phenomena, the respiration and, predominantly, the loss of water vapor (MAGUIRE et al., 2000). In this case, the low mass loss happened due to the lower respiration rate verified on fruits exposed to MAP with 1.0 kPa O_2 + 0.0 kPa CO_2, with or without 1-MCP, during shelf life (Table 4). NAKANO et al. (2003) also verified lower mass loss on persimmon fruits stored in modified atmosphere. In the highest CO_2 level (6.0 kPa) during CA, only fruit stored in 20.9 kPa O_2 + 0.0 kPa CO_2 demonstrated higher mass loss, but not showed a significant difference from fruit with 1.0 kPa O_2 + 0.0 kPa CO_2 during MAP shelf life.

MAP with 1.0 kPa O_2 + 0.0 kPa CO_2, with or without 1-MCP, after cold storage in a CA with 2.0 kPa CO_2, provided lower titratable acidity consumption (Table 3). Fruit submitted to a CA with 6.0 kPa CO_2 during cold storage and subsequently MAP with 1.0 kPa O_2 + 6.0 kPa CO_2 also demonstrated higher titratable acidity. This

higher acidity has relation with internal CO_2 contents and respiration rate (Table 3) whereas the acidity degradation has close relation with respiratory activity (CHITARRA; CHITARRA, 2005). During a normal maturation process, a decrease in the titratable acidity and an increase of the soluble solids would occur (BASHIR; ABU-GOUKH, 2003).

Table 3. Internal ethylene concentration (IEC), internal CO_2, ethylene production, respiratory rate, mass loss and titratable acidity of 'Fuyu' persimmon stored in controlled atmosphere with 0.15 kPa O_2 during 14 weeks in temperature of -0.5°C plus six days of shelf life at different levels of active modified atmosphere (MAP). Santa Maria, Brazil, 2012.

MAP conditions at 20°C (kPa O_2 + CO_2)	IEC ($\mu L\ C_2H_4\ L^{-1}$) 2.0 kPa*	6.0 kPa	Mean	Internal CO_2 ($mL\ CO_2\ L^{-1}$) 2.0 kPa	6.0 kPa	Mean
1.0/0.0	488.3Ac***	622.6Abc	555.4	70.6Ac	70.7Ac	70.6
20.9/6.0	1444.6Aa	1674.1Aa	1559.3	236.0Aa	183.7Ba	209.8
1.0/6.0	243.5Ac	403.0Ac	323.3	108.0Bb	130.4Ab	119.2
1.0/0.0**	485.0Bc	915.9Ab	700.5	60.0Ac	53.3Ac	56.6
20.9/0.0	949.8Bb	1607.9Aa	1278.8	210.1Aa	139.9Bb	175.0
Mean	722.32	1044.69	-	136.90	115.60	-
MAP conditions at 20°C (kPa O_2 + CO_2)	Ethylene production ($\mu L\ C_2H_4\ kg^{-1}\ h^{-1}$) 2.0 kPa*	6.0 kPa	Mean	Respiration rate ($mL\ CO_2\ kg^{-1}\ h^{-1}$) 2.0 kPa	6.0 kPa	Mean
1.0/0.0	0.98	1.18	1.08a***	6.08	6.64	6.36c
20.9/6.0	1.05	1.39	1.22a	14.26	14.41	14.33a
1.0/6.0	0.41	1.06	0.74a	12.23	10.82	11.52b
1.0/0.0**	0.79	1.10	0.95a	5.10	5.87	5.48c
20.9/0.0	1.02	1.38	1.20a	10.86	11.49	11.17b
Mean	0.85B	1.22A	-	9.71A	9.85A	-
MAP conditions at 20°C (kPa O_2 + CO_2)	Mass loss (%) 2.0 kPa*	6.0 kPa	Mean	Titratable acidity ($meq\ 100mL^{-1}$) 2.0 kPa	6.0 kPa	Mean
1.0/0.0	0.39Bbc***	0.59Aab	0.49	15.9Aa	15.7Aa	15.8
20.9/6.0	0.53Aab	0.43Ab	0.48	15.1Bb	16.1 Aa	15.6
1.0/6.0	0.52Aab	0.37Ab	0.44	15.2Ab	15.0Ac	15.1
1.0/0.0**	0.19 Bc	0.44Ab	0.31	15.9Aa	16.0 Aa	15.9
20.9/0.0	0.69Aa	0.81Aa	0.75	16.0Aa	15.4Bb	15.7
Mean	0.47	0.53	-	15.6	15.6	-

* CO_2 level during controlled atmosphere storage. ** 1-MCP application on the end of cold storage. *** Means followed by equal letters, lowercase in the columns and uppercase in the lines, do not differ by Tukey test, at 5% probability

Identically to the pulp softening (firmness loss located in parts of the fruit), the flesh firmness was higher on fruit submitted to MAP with 1.0 kPa O_2 during shelf life (Table 4). With a lower concentration of internal ethylene in the fruit submitted to these treatments, a lower cell wall degradation caused by the enzymes that are dependent of this substance occurs, such as poligalacturonases and pectinametilesterases (PAYASI et al., 2009; PRASANA et al., 2007), thereby decreasing the firmness loss and reducing the softening.

Concerning the skin color it was noticed that the interaction was significant for the luminosity and color intensity (Table 4). Fruit exposed to MAP with 1.0 kPa O_2 during shelf life, demonstrated higher color luminosity, associated to 1-MCP or high CO_2 levels. Same behavior was verified on the skin color intensity, when fruit were submitted to CA 2.0 kPa CO_2 in cold storage. These results are valid because chroma values next to 60 represent color with elevated intensity (MENDONÇA et al., 2003). Comparing the two CA (2.0 and 6.0 kPa CO_2), was verified that the luminosity and the intensity were lower in cold storage with CA of 6.0 kPa CO_2, when fruit were exposed to shelf life with MAP 1.0 kPa O_2 with 0.0 kPa CO_2 or 6.0 kPa CO_2. Again, these results confirmed that than higher the CO_2 level (6.0 kPa CO_2) during cold storage, than higher skin browning will be.

Tabela 4. Flesh firmness and skin color of 'Fuyu' persimmon stored in controlled atmosphere with 0.15 kPa O_2 during 14 weeks in temperature of -0.5°C plus six days of shelf life at different levels of active modified atmosphere (MAP). Santa Maria, Brazil, 2012.

MAP conditions at 20°C	Flesh firmness (N)		Mean	Skin color (Luminosity)		Mean
(kPa O_2 + CO_2)	2.0 kPa*	6.0 kPa		2.0 kPa	6.0 kPa	
1.0/0.0	60.7	60.1	60.4a***	56.0Aa	53.1Ba	54.6
20.9/6.0	28.4	29.3	28.8b	44.4Ab	44.8Ab	44.6
1.0/6.0	52.6	59.2	55.9a	55.3Aa	50.9Ba	53.1
1.0/0.0**	62.2	62.4	62.3a	53.4Aa	53.5Aa	53.5
20.9/0.0	0.00	0.00	0.00c	42.3Ab	41.6Ac	42.0
Mean	40.79A	42.18A	-	50.29	48.77	-
MAP conditions at 20°C	Skin color (Chroma)		Mean	Skin color (°Hue)		Mean
(kPa O_2 + CO_2)	2.0 kPa*	6.0 kPa		2.0 kPa	6.0 kPa	
1.0/0.0	56.5Aa***	51.0Bab	53.7	61.7	62.0	61.8a
20.9/6.0	39.7Ab	37.4Ac	38.6	51.0	51.1	51.1b
1.0/6.0	55.6Aa	44.7Bb	50.1	61.3	61.5	61.4a
1.0/0.0**	52.0Aa	52.7Aa	52.2	60.4	61.0	60.7a
20.9/0.0	33.4Ab	31.7Ac	32.6	48.5	48.6	48.6b
Mean	47.45	43.41	-	56.83A	56.57A	-

* CO_2 level during controlled atmosphere storage. ** 1-MCP application on the end of cold storage. *** Means followed by equal letters, lowercase in the columns and uppercase in the lines, do not differ by Tukey test, at 5% probability.

In relation to the hue angle, no significant interaction between the factors was observed (Table 4). It was also verified that the CA in cold storage did not influence this variable. However, fruit submitted to 1.0 kPa O_2 with 1-MCP, 0.0 kPa CO_2 or 6.0 kPa CO_2 during MAP shelf life demonstrated a greener skin color. This finding highlights that the use of low O_2 levels enables the skin color to be greener than fruit submitted to 20.9 kPa O_2 + 0.0 kPa CO_2. BRACKMANN et al. (2004) demonstrated that the use of low O_2 delays the green color loss of 'Kyoto' persimmon fruit.

CONCLUSIONS

The partial pressure of 1.0 kPa O_2 during MAP shelf life is the best level to maintain low pulp softening and skin browning of 'Fuyu' persimmon fruit.

Partial pressure of 6.0 kPa CO_2 during CA storage with 0.15 kPa O_2 at temperature of -0.5°C causes more skin browning during shelf life in MAP.

The uses of 1-MCP have no effect in low O_2 levels during shelf life in MAP.

RESUMO: O objetivo do presente trabalho foi determinar os níveis de O_2 e CO_2 para armazenamento em atmosfera modificada ativa (AMA), além de verificar o efeito do 1-MCP sobre o retardamento do amaciamento da polpa e escurecimento da epiderme durante a vida de prateleira de caquis armazenados em AC na temperatura de -0,5°C durante 14 semanas. O experimento foi conduzido em fatorial (2x5) com três repetições com oito frutos cada. Após o armazenamento mais o período de vida de prateleira não se verificou interação entre os fatores para amaciamento de polpa, sendo que os frutos submetidos a 1,0 kPa de O_2 durante a vida de prateleira em AMA apresentaram menor amaciamento. Para incidência de escurecimento da epiderme ocorreu interação. O uso de alto CO_2 durante o armazenamento a -0,5°C causou maior escurecimento da epiderme em todas as condições de AMA na vida de prateleira, exceto na testemunha, após seis dias de exposição a 20°C. Pressão parcial de 1,0 kPa de O_2 durante a vida de prateleira é a melhor condição de AMA para manter o caqui 'Fuyu' com menor amaciamento e escurecimento da epiderme. Pressão parcial de 6,0 kPa CO_2 durante o armazenamento em AC com 0,15 kPa O_2, na temperatura de -0,5°C causa maior escurecimento da epiderme durante a vida de prateleira. O 1-MCP não tem efeito em baixa concentração de O_2 durante a vida de prateleira em AMA a 20°C.

PALAVRAS-CHAVE: *Diospyrus kak.* Pós-colheita. Amaciamento. Escurecimento. Qualidade.

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