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Original

Sensory profile of 'Douradão' peaches cold stored under controlled atmosphere

Perfil sensorial de pêssegos 'Douradão' armazenados sob refrigeração e atmosfera controlada

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Abstract

The sensory quality of 'Douradão' peaches cold stored in three different conditions of controlled atmosphere (CA1, CA2, CA3 and Control) was studied. After 14, 21 and 28 days of cold storage, samples were withdrawn from CA and kept for 4 days in ambient air for ripening. The sensory profile of the peaches and the descriptive terminology were developed by methodology based on the Quantitative Descriptive Analysis (QDA). The panelists consensually defined the sensory descriptors, their respective reference materials and the descriptive evaluation ballot. Fourteen panelists were selected based on their discrimination capacity and reproducibility. Seven descriptors were generated showing similarities and differences between samples. The data were analyzed by ANOVA, Tukey test and Principal Component Analysis (PCA). Results showed significant differences in the sensory profiles of the peaches. The PCA showed that CA2 and CA3 treatments were more characterized by the fresh peach flavor, fresh peach appearance, juiciness and flesh firmness, and were effective in keeping the good quality of the 'Douradão' peaches during the 28 days of cold storage. The Control and CA1 treatments were characterized by the mealiness and were ineffective for quality maintenance of the fruits during cold storage.

Keywords: *Prunus persica; chilling; woolliness; quantitative descriptive analysis.*

Resumo

A qualidade sensorial de pêssegos 'Douradão' estocados sob refrigeração em três diferentes condições de atmosfera controlada (AC1, AC2, AC3 e Controle) foi estudada. Após 14, 21 e 28 dias de estocagem refrigerada, amostras foram retiradas da AC e mantidas durante 4 dias em ar ambiente para completar o amadurecimento. Os perfis sensoriais dos pêssegos e a terminologia descritiva foram desenvolvidos baseados na Análise Descritiva Quantitativa (ADQ). Os provadores, consensualmente, definiram os descritores sensoriais, seus respectivos materiais de referência e a ficha de avaliação descritiva. Quatorze provadores foram selecionados de acordo com sua capacidade de discriminação e reprodutibilidade. Sete descritores foram gerados, mostrando similaridades e diferenças entre as amostras. Os dados foram analisados por ANOVA, teste de Tukey e Análise de Componentes Principais (ACP). Os resultados mostraram diferenças significativas nos perfis sensoriais dos pêssegos. A ACP mostrou que os tratamentos AC2 e AC3 foram mais caracterizados pelo sabor de pêssego fresco, aparência de pêssego fresco, suculência e firmeza da polpa, e foram efetivos na manutenção da boa qualidade dos pêssegos 'Douradão' durante 28 dias de armazenamento refrigerado. Os tratamentos AC1 e Controle foram caracterizados pela lanosidade e foram ineficientes na manutenção da qualidade dos frutos frigoconservados.

Palavras-chave: *Prunus persica; injúria; lanosidade; análise descritiva quantitativa.*

1 Introduction

Peaches (*Prunus persica* L) are widely appreciated by consumers due to its gustative characteristics such as attractive color, good flavor and juiciness, besides relevant nutritional properties. Brazilians eat approximately 0.85 kg of peach per capita per year (INSTITUTO... 2008). Even though these fruits are seasonal, this value is small in comparison to other fresh fruit consumption such as apples (≈4 kg) and bananas (≈9 kg). Americans eat approximately 2.0 kg of peaches per capita per year. An earlier survey conducted by UC Davis researchers (CRISOSTO, 2006) indicated that hard fruit (unripe), mealiness, lack of taste, and failure to ripen are the main reasons consumers do not eat more stone fruit. The author related that these complaints are a consequence of two main problems: the fact that consumers do not find the ripe fruit ("ready to eat") and the occurrence of chilling injury.

Peaches ripen and deteriorate quickly at ambient temperature. Therefore, cold storage is used to slow down these processes and the decay development. However, one of the factors that contribute greatly to peach quality loss is chilling injury, which limits the storage life of peaches at low temperature to less than two weeks in regular atmosphere. Although the fruits have a good appearance when removed from cold storage, they fail to ripen satisfactorily and evolve excessively to flesh softening, dryness, mealy or woolly texture and flesh browning. This disorder is not externally visible; fruits are often marketed at this stage, leading to decreased consumer acceptance.

In Brazil, peach is one of the commodities with numerous commercial cultivars. The 'Douradão' peach is one of the most important cultivars grown in the State of Sao Paulo, Brazil.

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These fruits have gained the preference of consumers, who have mentioned it as having the best qualitative characteristics such as sweet taste, intense skin color and large size, and of traders and their clients, mainly due to the higher price tendency. However, these fruits are susceptible to chilling injury when cold stored for long periods. It has been reported that the use of controlled atmosphere (CA) with elevated CO_2 and reduced O_2 concentrations delay or prevent the onset of this chilling symptom and the storage life of peaches can be extended (LILL; O'DONAGHUE; KING, 1989; KADER, 2003; LURIE; CRISOSTO, 2005).

To characterize how CA affects product quality, changes can be assessed in terms of sensory characteristics like smell, flavor, texture and appearance, using methodology based on the Quantitative Descriptive Analysis (QDA), which provides a complete description of their sensory properties, being one of the most complete and reliable method for characterization of food attributes (STONE; SIDEL, 1985). The principle of QDA is based on the ability to train panelists to measure specific attributes of a product in a reproducible manner to yield a comprehensive quantitative product description amenable to statistical analyses. In a QDA approach, panelists recruited from the general public work together in a focus group to identify key product attributes and appropriate intensity scales specific to a product. This group of panelists is then trained to reliably identify and score product attributes. QDA results can be analyzed statistically and then represented graphically.

Thus, the objective of this work was to evaluate the influence of controlled atmosphere (CA) and cold storage on the sensory quality and storage life of 'Douradão' peaches using QDA.

2 Materials and Methods

2.1 Material and experimental design

Peaches (*Prunus persica* L) 'Douradão' were harvested from a commercial orchard in Jarinu, Sao Paulo, located in the southeast of Brazil under a sub-tropical climate, they were pre-selected and transported at ambient temperature about 80 km to the Postharvest Laboratory (Food Technology Institute – ITAL, Campinas, Brazil). Fruits were selected according to size and the skin background color (green-yellow), at commercial maturity, and immediately pre-cooled to 5 °C. Before pre-cooling, 72 peaches were randomly sampled and placed in 6 polypropylene (PP) trays (United Plastic Corporation S.A., Santiago, Chile), containing 12 peaches each, which were held in fresh air at 25 ± 1 °C and 90 ± 5% RH for 4 days for ripening. On the 4th day of ripening, 3 trays went to physical and chemical evaluation; the peaches from the other 3 trays were evaluated on sensory characteristics by a trained panel (each tray constituted a replicate).

The experiment was carried out in an entirely randomized design, where fruits were randomly distributed into four lots; each lot containing 72 peaches was placed in hermetically closed 15 L chambers. The CO_2 and O_2 concentrations, inside the chambers, were modified and established with a continuous flow system, the gas mixtures were supplied from high pressure cylinders. The gas concentrations were monitored every two days during cold storage using a gas analyzer (PBI Dansensor, Combi-check 9800-1, Ringsted, Denmark). The following treatments were tested:

(T_1) *Control*: air (0.03 kPa CO_2 and 20.9 kPa O_2);

(T_2) *CA1*: 3.0 kPa CO_2 and 1.5 kPa O_2 (balance N_2);

(T_3) *CA2*: 5.0 kPa CO_2 and 1.5 kPa O_2 (balance N_2); and

(T_4) *CA3*: 10.0 kPa CO_2 and 1.5 kPa O_2 (balance N_2).

All treatments were stored during 14, 21 and 28 days at 1 ± 1 °C and 90 ± 5% RH, the room temperature was monitored by an electronic thermostat and fruit temperature by a mercury thermometer (0.1 °C accuracy) inserted in fruit flesh. After 14, 21 and 28 days, chambers were taken from cold storage, the fruits of each treatment were distributed in 6 PP trays and subsequently were held in fresh air at 25 ± 1 °C and 90 ± 5% RH for 4 days for ripening. Physical, chemical and sensory characteristics were evaluated on the 4th day of ripening, as mentioned to the fruits after the harvest. Three replicates per treatment were obtained to each assayed period (each tray containing 12 peaches constituted a replicate).

2.2 Quantitative descriptive analysis

Recruitment, training and selection of assessors

Ethical clearance approval for this work was granted by the Research Ethics Committee, Faculty of Medical Science, University of Campinas (UNICAMP). Fourteen candidates (employees, researchers and students from the Food Technology Institute – ITAL) were pre-screened based on availability, general food habits, their ability to participate in group discussions, as well as ability to discriminate differences between products and to describe their perceptions. These fourteen candidates attended six training sessions over a period of two weeks. Sensory descriptors for odor, texture, flavor and appearance attributes were developed through brainstorming on the similarity and differences between samples of peaches (MOSKOWITZ, 1983). The next step of the training consisted of the development and definition of each descriptive term under supervision of a leader, this step aimed to join similar descriptive terms and to produce reference samples using a round-table consensus (Table 1). The training was finished when the fourteen individuals had no difficulties to evaluate the samples using the descriptive evaluation ballot. In a final session, each sample was evaluated in triplicate by each panelist, using a complete block in the statistical design, and the use of filtered water was recommended for cleansing the palate between samples. Statistical evaluation was performed through analysis of variance (ANOVA), and, for each panelist, the significance levels (p) for the F test (samples and replicates) were calculated. The individuals were selected as panelists using the following criteria: discriminatant power ($p\ F_{samples} < 0.50$), reproducibility ($p\ F_{replicates} \geq 0.05$), according to Damasio and Costell's (1991) methodology.

Table 1. Descriptive terms and reference materials used during panel training sessions and quantitative descriptive analysis sessions.

Attributes	Definitions	Reference materials
Fresh peach smell	Freshness degree of peach.	Low: slices of peach cut 24 h before.
	Smell of fresh newly cut peach.	High: slices of freshly cut peach.
Yellow colour	Shade of yellow colour variable from light yellow to dark yellow.	Light: 10 mL of UHT whole milk (Parmalat, Brazil) plus 10 drops of A.
		Dark: 10 mL of UHT whole milk (Parmalat, Brazil) plus 20 drops of A.
		A = 1 drop of natural urucum coloring (A – 260 – WS) diluted in 5 mL of water.
Fresh peach appearance	Overall impression of the freshness.	Unacceptable: darknes, dry and soft flesh.
		Excellent: yellow shade, juicy and firm flesh.
Fresh peach flavour	Flavour of fresh newly cut peach.	Low: slices of peach cut 24 h before.
		High: slices of freshly cut peach.
Firmness	Force required to bite with the front teeth.	Soft: slices of injury and damaged peach.
		Firm: slices of entire and hard peach.
Juiciness	Amount of juice released on first bite.	Absent: slices of dry peach, without juiciness.
		High: slices of freshly cut peach, vey juicy.
Mealiness	Woolly and dry texture on chewing.	Absent: slices of peach very juicy.
		High: slices of woolly and dry peach.

Sensory evaluation of samples

The Quantitative Descriptive Analysis method (STONE; SIDEL, 1985) was used to describe the differences among 'Douradão' peaches samples depending on CA composition and cold storage period. Three series of tests were carried out. In the sensory evaluation, slices of peeled peach (30 g) were used, placed in individual three-digit-coded plastic plates and in sealed 70mL plastic containers, allowing to be saturated with the volatile compounds for odor analysis. All samples were served at room temperature (25 ºC) and they were presented to the panelists in a randomized design, in order to eliminate any serving order effect. The tests were conducted on individual sensory booths of the food sensory analysis laboratory under daylight, the samples were presented one at a time, using a complete block in the statistical design with 3 replicates; the panelists used filtered water as a palate cleanser between samples. On unstructured scales of 9 cm labeled on both ends, with descriptive terms on the left (lower anchor) and on the right (upper anchor), the panelists rated the intensity of each descriptor for each sample, being required to test the attributes in the following order: fresh peach smell (scales labeled low to high presence), yellow color (light to dark), fresh peach appearance (unacceptable to excellent), fresh peach flavor (low to high presence), flesh firmness (soft to firm), juiciness (not juicy to very juicy), mealiness (not mealy to very mealy).

2.3 Physical and chemical analysis

On each day of evaluation, ten fruits were randomly removed from three trays for determination of physical and chemical characteristics. The fruits were cut into two halves and the color was measured from two equidistant points of the equatorial zone of peach, on both sides, using a tristimulus colorimeter (Minolta CR-300, Tokyo, Japan), to obtain the a*, b* and L* parameters. The equipment was calibrated with a white standard RSEX n.6299 (x = 77.46; y = 82.08; z = 88.38). From a* and b*, the Hue angle (H*) was calculated (McGUIRRE, 1992) Equation 1:

$$H^* = \arctan (b^*/a^*) \quad (1)$$

where a* = redness value and b* = yellowness value.

The ratio between soluble solids content and titratable acidity was determined. Segments from each fruit were homogenized using a commercial blender (Philips Walita, R16720, Brazil) and soluble solids content (SSC) at °Brix was measured with a hand refractometer (Atago, model N-1α, Jencons Scientific Ltd., Tokyo, Japan). Titratable acidity (TA) was determined by titrating 10 g of the homogenized pulp with 0.01 N NaOH to an endpoint of pH 8.1 (Micronal Titrator, model B274, Sao Paulo, Brazil), the results were expressed as g of malic acid in 100 g^{-1} sample (ASSOCIATION..., 1995). The pH was determined through direct reading using the same equipment.

2.4 Statistical analysis

Analysis of variance (ANOVA) was performed, the sources of variance being CA composition and storage period for each quality attribute, followed by F test and Tukey MSD (minimum significant difference) multiple comparison of means at $p \leq 0.05$, using the SAS statistical package (STATISTICAL..., 2003). The values at harvest and after each storage period were compared to find significant differences among treatments. Two-way ANOVA with samples and panelists as fixed effects were made on the descriptive profiling. Principal component analysis (PCA) was performed on the averages of subjects and replicates in order to describe the main variation in the sensory data and the correlation matrix was obtained to sensory attributes. For instrumental sensory comparisons, raw data was used to calculate Pearson correlation coefficients (0.05 level of significance).

3 Results and discussion

3.1 Quantitative descriptive analysis

Selection of panelists

The performance of panelists was evaluated by significance scales (p) for the F test (samples and replicates). In this study, fourteen individuals presented p $F_{samples} < 0.30$ and p $F_{replicates} \geq 0.05$, beyond showed individual consensus with the sensory panel (data not shown), they were selected for the samples evaluation.

Sensory evaluation of samples

The quantitative descriptive analysis showed that the sensory properties (appearance, odor, flavor and texture) of the 'Douradão' peaches were affected by the CA composition and cold storage period used in this study. The Figures 1, 2 and 3 present the sensory profiles of each treatment, expressed by graphics, according to the average values of descriptors terms provided by QDA. The zero point in the attribute scale is its centre and the intensity increases from the centre to the end axis. The results showed that the CA2 and CA3 treatments differed significantly from the other treatments, the fruits presented higher intensities of attributes such as fresh peach appearance, fresh peach smell, fresh peach flavor, flesh firmness and juiciness and lower intensity of mealiness. The Control and CA1 treatments increased the intensity of mealiness and decreased the intensity of other attributes along the cold storage period, differing significantly from the CA2 and CA3 treatments, as well as the fruits evaluated immediately after harvest (Tables 2 and 3). After 21 and 28 days of cold storage, all treatments presented lower intensities of yellow color, fresh peach smell and flavor, when compared to the fruit evaluated after harvest. Probably, there was influence of cold temperature

Table 2. Mean values for the appearance, colour, odour and flavour of 'Douradão' peaches after harvest and under CA after cold storage (CS) at 1 ± 1 °C during 14, 21 and 28 days, plus 4 days ripening in air at 25 ± 1 °C.

Fresh peach appearance						
After		+ 4 d ripening		+ 4 d ripening		+ 4 d ripening
harvest	6.5[x a]	7.6 [A]	6.5 [a]	7.6 [A]	6.5 [ab]	7.6 [A]
Treatments	After 14 d CS	+ 4 d ripening	After 21 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	4.3 [b]	5.1 [B]	3.8 [b]	4.4 [B]	3.5 [c]	3.6 [C]
CA1	5.0 [b]	5.4 [B]	4.9 [b]	5.0 [B]	4.2 [c]	4.1 [C]
CA2	6.6 [a]	7.3 [A]	6.7 [a]	7.1 [A]	6.7 [a]	6.9 [A]
CA3	6.4 [a]	7.3 [A]	6.5 [a]	6.9 [A]	5.5 [b]	5.7 [B]
Yellow colour						
After		+ 4 d ripening		+ 4 d ripening		+ 4 d ripening
harvest	6.4 [a]	7.4 [A]	6.4 [a]	7.4 [A]	6.4 [a]	7.4 [A]
Treatments	After 14 d CS	+ 4 d ripening	After 21 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	5.6 [a]	7.1 [A]	5.1 [ab]	6.7 [AB]	4.1 [b]	4.8 [C]
CA1	5.8 [a]	7.0 [A]	5.1 [ab]	6.4 [B]	4.0 [b]	5.8 [BC]
CA2	5.4 [a]	6.8 [A]	4.6 [b]	6.3 [B]	4.3 [b]	6.0 [B]
CA3	5.3 [a]	6.7 [A]	4.8 [b]	6.2 [B]	4.1 [b]	5.9 [BC]
Fresh peach smell						
After		+ 4 d ripening		+ 4 d ripening		+ 4 d ripening
harvest	6.8 [a]	7.5 [A]	6.8 [a]	7.5 [A]	6.8 [a]	7.5 [A]
Treatments	After 14 d CS	+ 4 d ripening	After 21 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	3.9 [b]	6.0 [B]	3.7 [b]	5.0 [B]	3.6 [b]	4.9 [C]
CA1	3.9 [b]	6.3 [B]	3.7 [b]	5.1 [B]	3.8 [b]	5.0 [C]
CA2	3.7 [b]	6.9 [AB]	3.7 [b]	5.5 [B]	4.3 [b]	6.0 [B]
CA3	3.6 [b]	6.8 [AB]	3.6 [b]	5.8 [B]	4.5 [b]	5.9 [B]
Fresh peach flavour						
After		+ 4 d ripening		+ 4 d ripening		+ 4 d ripening
harvest	6.6 [a]	7.7 [A]	6.6 [a]	7.7 [A]	6.6 [a]	7.7 [A]
Treatments	After 14 d CS	+ 4 d ripening	After 21 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	3.8 [c]	5.1 [B]	3.8 [c]	4.9 [C]	3.8 [c]	4.0 [C]
CA1	4.1 [bc]	5.8 [B]	4.1 [c]	5.1 [C]	3.9 [c]	4.1 [C]
CA2	5.3 [ab]	7.2 [A]	5.2 [bc]	6.9 [AB]	5.1 [b]	6.4 [B]
CA3	5.5 [a]	7.1 [A]	5.5 [ab]	6.8 [B]	5.3 [b]	6.1 [B]

[x]Average (n = 14). Control = air; CA1 = 3 kPa CO_2 + 1.5 kPa O_2; CA2 = 5 kPa CO_2 + 1.5 kPa O_2; CA3 = 10 kPa CO_2 + 1.5 kPa O_2. Small letters compare significant differences between values at harvest and after cold storage under different treatments according to Tukey test ($p \leq 0.05$), for each storage period. Capital letters compare significant differences between values at ripening after harvest and ripening after cold storage under different treatments according to Tukey test ($p \leq 0.05$), for each storage period.

in the inhibition of colored pigments and volatile compounds synthesis. Cold temperature and modified atmosphere during the storage of fruits have been found to affect the physiology and biochemistry of the fruits (CHITARRA; CHITARRA, 2005; NILSSON, 2000).

The PCA showed that the CA2 and CA3 treatments were more characterized by the fresh peach flavor, fresh peach appearance, juiciness and flesh firmness. Control and CA1 treatments were characterized by the mealiness. The fruits evaluated after harvest showed higher intensity for yellow color, fresh peach smell and flavor (Figure 4). In this study, the two main components were used together and explained 96.9% of the total variability observed between the treatments.

Table 4 summarizes the results of the correlations between the attributes. There was high positive correlation (0.93) between fresh peach appearance and flesh firmness, as well as fresh peach appearance and juiciness (0.99); probably the firmer and juicier fruits presented an overall impression of freshness. The opposite was found between fresh peach appearance and mealiness, which showed high negative correlation (-0.98). Juiciness and mealiness presented high negative correlation (-0.98), the same way firmness and mealiness (-0.91), certainly the fruits with woollier and drier texture released little amount of juice in chewing and required lower force in the bite.

Rombaldi et al. (2002) evaluated the storage life of 'Chiripá' peaches under CA (5.0 kPa CO_2 and 1.5 kPa O_2)

Table 3. Mean values for the texture (flesh firmness, juiciness and mealiness) of 'Douradão' peaches after harvest and under CA after cold storage (CS) at 1 ± 1 °C during 14, 21 and 28 days, plus 4 days ripening in air at 25 ± 1 °C.

			Flesh firmness			
After		+ 4 d ripening		+ 4 d ripening		+ 4 d ripening
harvest	7.1[x a]	5.3[a]	7.1 [a]	5.3[a]	7.1 [a]	5.3[a]
Treatments	After 14 d CS	+ 4 d ripening	After 21 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	7.6[a]	5.2[a]	6.5[a]	4.1[B]	5.5[c]	3.8[C]
CA1	7.2[a]	5.4[a]	6.9[a]	4.4[B]	5.7[bc]	4.3[BC]
CA2	7.7[a]	5.6[a]	7.1[a]	5.4[a]	6.7[ab]	5.4[a]
CA3	7.6[a]	5.5[a]	7.3[a]	5.3[a]	6.7[ab]	5.1[aB]
	Juiciness					
After harvest		+ 4 d ripening		+ 4 d ripening		+ 4 d ripening
	6.4 [a]	7.6[a]	6.4 [a]	7.6[a]	6.4 [a]	7.6[a]
Treatments	After 14 d CS	+ 4 d ripening	After 21 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	4.9 [b]	5.2 [B]	4.0 [b]	4.3 [B]	3.1 [c]	3.4 [D]
CA1	5.4[ab]	5.9 [B]	4.3 [b]	4.7 [B]	3.9 [bc]	4.2 [D]
CA2	5.4[ab]	7.4[a]	4.9 [b]	7.1[a]	4.9 [b]	6.6 [B]
CA3	5.4[ab]	7.3[a]	4.8 [b]	7.0[a]	4.4 [bc]	5.4 [C]
	Mealiness					
After harvest		+ 4 d ripening		+ 4 d ripening		+ 4 d ripening
	0.8 [b]	0.3 [C]	0.8 [c]	0.3 [C]	0.8 [d]	0.3 [D]
Treatments	After 14 d CS	+ 4 d ripening	After 21 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	2.5[a]	4.2[a]	4.4[a]	5.9[a]	5.7[a]	7.1[a]
CA1	1.5[ab]	1.1 [B]	3.6[a]	4.3 [B]	4.7 [b]	5.8 [B]
CA2	0.6 [b]	0.3 [C]	1.8 [bc]	0.6 [C]	1.8 [c]	1.0 [D]
CA3	0.7 [b]	0.3 [C]	2.4 [b]	0.6 [C]	2.4 [c]	3.4 [C]

[x]Average (n = 14). Control = air; CA1 = 3 kPa CO_2 +1.5 kPa O_2; CA2 = 5 kPa CO_2 +1.5 kPa O_2; CA3 = 10 kPa CO_2 +1.5 kPa O_2. Small letters compare significant differences between values at harvest and after cold storage under different treatments according to Tukey test ($p \leq 0.05$), for each storage period. Capital letters compare significant differences between values at ripening after harvest and ripening after cold storage under different treatments according to Tukey test ($p \leq 0.05$), for each storage period.

Table 4. Correlations for the odour, colour, appearance, flavour, firmness, juiciness and mealiness of 'Douradão' peaches after 28 days cold storage at 1 ± 1 °C under CA plus 4 days ripening in air at 25 °C.

	Fresh peach smell	Yellow colour	Fresh peach appearance	Fresh peach flavour	Firmness	Juiciness	Mealiness
Fresh peach smell	1.00						
Yellow colour	0.92	1.00					
Fresh peach appearance	0.92	0.85	1.00				
Fresh peach flavour	0.96	0.85	0.98	1.00			
Firmness	0.79	0.78	0.93	0.89	1.00		
Juiciness	0.93	0.89	0.99	0.97	0.92	1.00	
Mealiness	-0.87	-0.82	-0.98	-0.95	-0.91	-0.98	1.00

and regular atmosphere (fresh air), for 45 days at 0 °C and 90% RH. In the sensory analysis, the control treatment (fruits maintained in fresh air) showed lower scores for overall quality (0 = unacceptable and 9 = excellent), the flesh browning and woolliness attributes influenced on unacceptable organoleptic quality. For the fruits maintained under CA, also there was quality loss; however, they presented higher scores and were considered acceptable.

Olsen and Schomer (1975) also mentioned that the use of CA maintained the appropriate quality characteristics of 'Stark's Red Gold' nectarines during cold storage (0.5 °C). After 6 weeks, the fruits in CA with 5% CO_2 and 2.5% O_2 had good-to-fair flavor, flesh color, firmness and overall quality, being superior to those stored in air. The authors related that, with the use of CA, the storage life of nectarines was extended for about two weeks compared to commercial practice.

3.2 Physical and chemical analysis

Flesh color: hue angle and lightness

CA had no influence on flesh color during a 28-day cold storage. The Hue angle value was similar in all treatments; it did not differ significantly between each other. After 4 days ripening, decreases in Hue angle values were detected for all treatments. The fruits maintained at cold temperature differed significantly from the fruits evaluated after harvest, which showed more intense color (Table 5). Cold temperature probably inhibited chlorophyll degradation and carothenoids synthesis.

After all cold storage periods, no significant changes in lightness (L*) in Control and CA treatments were found, and no significant difference from fruit at harvest (Table 5). However,

Table 5. Mean values for the Hue angle, L*, pH and ratio (soluble solids content/titratable acidity) of 'Douradão' peaches after harvest and under CA after cold storage (CS) at 1 ± 1 °C during 14, 21 and 28 days, plus 4 days ripening in air at 25 ± 1 °C.

Hue angle						
After harvest		+ 4 d ripening		+ 4 d ripening		+ 4 d ripening
	$84.64^{x} \pm 2.47^{y}$ b	80.88 ± 1.19 B	84.64 ± 2.47 b	80.88 ± 1.19 B	84.64 ± 2.47 b	80.88 ± 1.19 B
Treatments	After 14 d CS	+ 4 d ripening	After 21 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	87.83 ± 1.39 ^{a}	85.29 ± 2.12 ^{A}	86.66 ± 2.19 ^{ab}	84.33 ± 2.01 ^{A}	87.61 ± 1.93 ^{a}	83.93 ± 2.25 ^{A}
CA1	87.51 ± 2.02 ^{a}	86.51 ± 2.34 ^{A}	87.48 ± 1.36 ^{a}	85.16 ± 1.51 ^{A}	88.22 ± 1.70 ^{a}	84.97 ± 1.32 ^{A}
CA2	87.48 ± 1.67 ^{a}	85.89 ± 1.81 ^{A}	87.58 ± 1.88 ^{a}	86.00 ± 1.87 ^{A}	87.13 ± 0.76 ^{a}	84.60 ± 2.26 ^{A}
CA3	87.98 ± 1.45 ^{a}	86.72 ± 1.03 ^{A}	88.82 ± 0.93 ^{a}	85.86 ± 1.72 ^{A}	86.79 ± 2.32 ^{ab}	85.31 ± 2.33 ^{A}
L*						
After harvest		+ 4 d ripening		+ 4 d ripening		+ 4 d ripening
	71.03 ± 1.64 ^{a}	69.47 ± 2.17 ^{A}	71.03 ± 1.64 ^{a}	69.47 ± 2.17 ^{A}	71.03 ± 1.64 ^{a}	69.47 ± 2.17 ^{A}
Treatments	After 14 d CS	+ 4 d ripening	After 21 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	72.61 ± 2.78 ^{a}	69.08 ± 0.81 ^{A}	70.62 ± 0.71 ^{a}	68.92 ± 1.67 ^{A}	70.54 ± 0.71 ^{a}	68.85 ± 1.47 ^{A}
CA1	71.26 ± 2.05 ^{a}	69.43 ± 1.32 ^{A}	71.08 ± 1.91 ^{a}	69.48 ± 1.30 ^{A}	71.06 ± 1.95 ^{a}	69.42 ± 2.07 ^{A}
CA2	72.04 ± 2.70 ^{a}	69.99 ± 0.33 ^{A}	71.04 ± 2.16 ^{a}	69.68 ± 0.86 ^{A}	71.00 ± 0.67 ^{a}	69.45 ± 0.86 ^{A}
CA3	71.19 ± 1.83 ^{a}	69.53 ± 0.59 ^{A}	70.95 ± 1.11 ^{a}	69.41 ± 1.05 ^{A}	70.81 ± 1.99 ^{a}	69.29 ± 1.28 ^{A}
pH						
After harvest		+ 4 d ripening		+ 4 d ripening		+ 4 d ripening
	4.43 ± 0.21 ^{a}	4.49 ± 0.09 ^{A}	4.43 ± 0.21 ^{ab}	4.49 ± 0.09 ^{A}	4.43 ± 0.21 ^{ab}	4.49 ± 0.09 ^{A}
Treatments	After 14 d CS	+ 4 d ripening	After 21 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	4.41 ± 0.18 ^{a}	4.61 ± 0.11 ^{A}	4.61 ± 0.15 ^{a}	4.65 ± 0.16 ^{A}	4.38 ± 0.13 ^{ab}	4.80 ± 0.11 ^{A}
CA1	4.41 ± 0.20 ^{a}	4.48 ± 0.17 ^{A}	4.48 ± 0.12 ^{ab}	4.60 ± 0.18 ^{A}	4.42 ± 0.11 ^{ab}	4.70 ± 0.13 ^{A}
CA2	4.37 ± 0.14 ^{a}	4.59 ± 0.17 ^{A}	4.33 ± 0.13 ^{b}	4.52 ± 0.25 ^{A}	4.46 ± 0.16 ^{a}	4.71 ± 0.14 ^{A}
CA3	4.33 ± 0.19 ^{a}	4.61 ± 0.23 ^{A}	4.39 ± 0.15 ^{b}	4.41 ± 0.25 ^{A}	4.25 ± 0.09 ^{b}	4.69 ± 0.25 ^{A}
Ratio (SSC/TA)						
After harvest		+ 4 d ripening		+ 4 d ripening		+ 4 d ripening
	32.77 ± 3.78 ^{a}	50.05± 2.98 ^{A}	32.77 ± 3.78 ^{ab}	50.05± 2.98 ^{A}	32.77 ± 3.78 ^{a}	50.05± 2.98 ^{A}
Treatments	After 14 d CS	+ 4 d ripening	After 21 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	30.90 ± 3.81 ^{a}	40.10 ± 3.18 ^{AB}	43.62 ± 3.17 ^{a}	47.66 ± 3.06 ^{A}	30.48 ± 3.35 ^{a}	47.23 ± 2.58 ^{A}
CA1	28.01 ± 2.75 ^{a}	33.71 ± 2.61 ^{B}	34.42 ± 3.08 ^{ab}	42.48 ± 3.99 ^{AB}	33.19 ± 2.67 ^{a}	44.95 ± 3.57 ^{A}
CA2	29.93 ± 3.68 ^{a}	40.32 ± 3.04 ^{AB}	30.66 ± 3.74 ^{ab}	42.49 ± 2.06 ^{AB}	34.68 ± 3.19 ^{a}	57.16 ± 3.80 ^{A}
CA3	27.48 ± 2.91 ^{a}	38.26 ± 3.90 ^{AB}	29.03 ± 3.92 ^{b}	34.69 ± 3.20 ^{B}	32.10 ± 3.94 ^{a}	47.18 ± 2.81 ^{A}

^{x}Average (n = 10) and ^{y}Standard deviation. Control = air; CA1 = 3 kPa CO_2 +1.5 kPa O_2; CA2 = 5 kPa CO_2 +1.5 kPa O_2; CA3 = 10 kPa CO_2 +1.5 kPa O_2. Small letters compare significant differences between values at harvest and after cold storage under different treatments according to Tukey test ($p \leq 0.05$), for each storage period. Capital letters compare significant differences between values at ripening after harvest and ripening after cold storage under different treatments according to Tukey test ($p \leq 0.05$), for each storage period.

after the exposure to room temperature, decrease in L* values were detected in all treatments.

Hue angle values were negatively correlated with sensory scores for intensity of yellow color (r = -0.91), significant at the 5% level. However, lightness showed low correlation to sensory scores for fresh peach appearance (r = 0.29).

Ratio (SSC/TA) and pH

Fruits evaluated after harvest presented higher ratio values than fruits cold stored, probably cold temperature delayed fruit ripening; however, no significant differences were found between treatments and fruits after harvest. With the exposure to room temperature, a significant increase in SSC/TA was detected in all treatments and no significant differences were found between treatments, except for CA3 treatment that differed from Control after 21 days of cold storage (Table 5).

In general, fruit pH presented no significant difference during cold storage, except for CA3 treatment that differed from Control after 21 days of cold storage. With the exposure to room temperature, an increase in pH value was verified in all treatments; however, no significant differences between them were found (Table 5).

Ratio values were better correlated to sensory scores for intensity of fresh peach smell (r = 0.91), while pH showed lower correlation to this attribute (r = 0.71), significant at the 5% level.

Watada, Anderson and Aulenbach (1979) correlated sensory and chemical characteristics of 'Redskin' and 'Rio Oso' nectarines stored at 0 °C under CA (5% CO_2 and 1% O_2) for 9 weeks. A sensory panel evaluated the fruits quality using a ten-centimeter non-structured scale with the intensity terms anchored at its ends (0 = low intensity and 10 = high intensity). The authors reported that volatile and nonvolatile components accounted for some of the variation in sensory attributes. Thus, intensities of fresh fruit flavor and acidity of both cultivars decreased during storage period. However, the scores showed that sweetness of 'Redskin' decreased during CA storage, in contrast to the increased soluble solids content; these contrasts were probably due to one or more factors that masked the sweetness of soluble solids in the sensory analysis. Response of assessors to acidity was closely associated to the decrease of malic acid content that occurred with maturation and during storage. The pH accounted for a large part of the variation of fruitiness, mustiness and desirability.

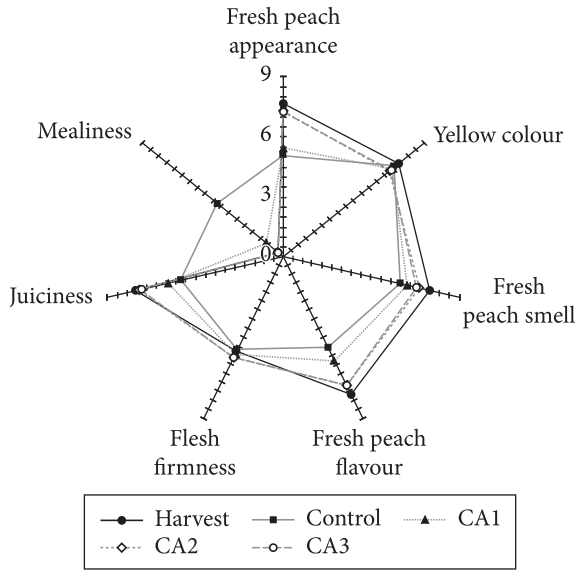

Figure 1. Profiles of the mean values for the appearance, smell, flavour and texture of 'Douradão' peaches stored under CA at 1 °C for 14 days followed by 4 days at 25 °C.

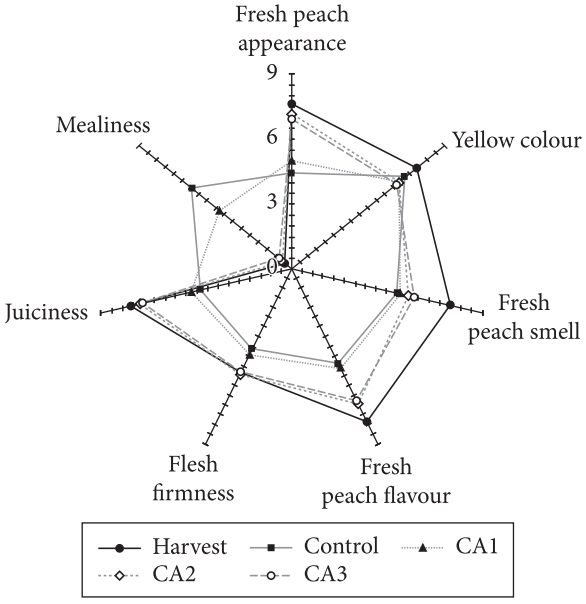

Figure 2. Profiles of the mean values for the appearance, smell, flavour and texture of 'Douradão' peaches stored under CA at 1 °C for 21 days followed by 4 days at 25 °C.

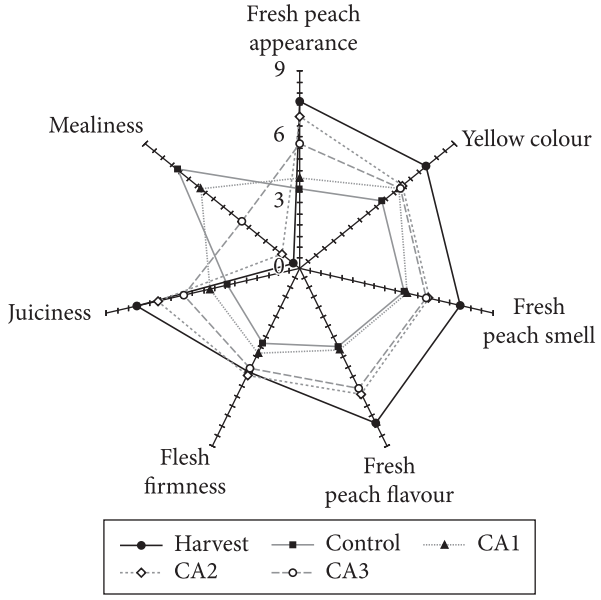

Figure 3. Profiles of the mean values for the appearance, smell, flavour and texture of 'Douradão' peaches stored under CA at 1 °C for 28 days followed by 4 days at 25 °C.

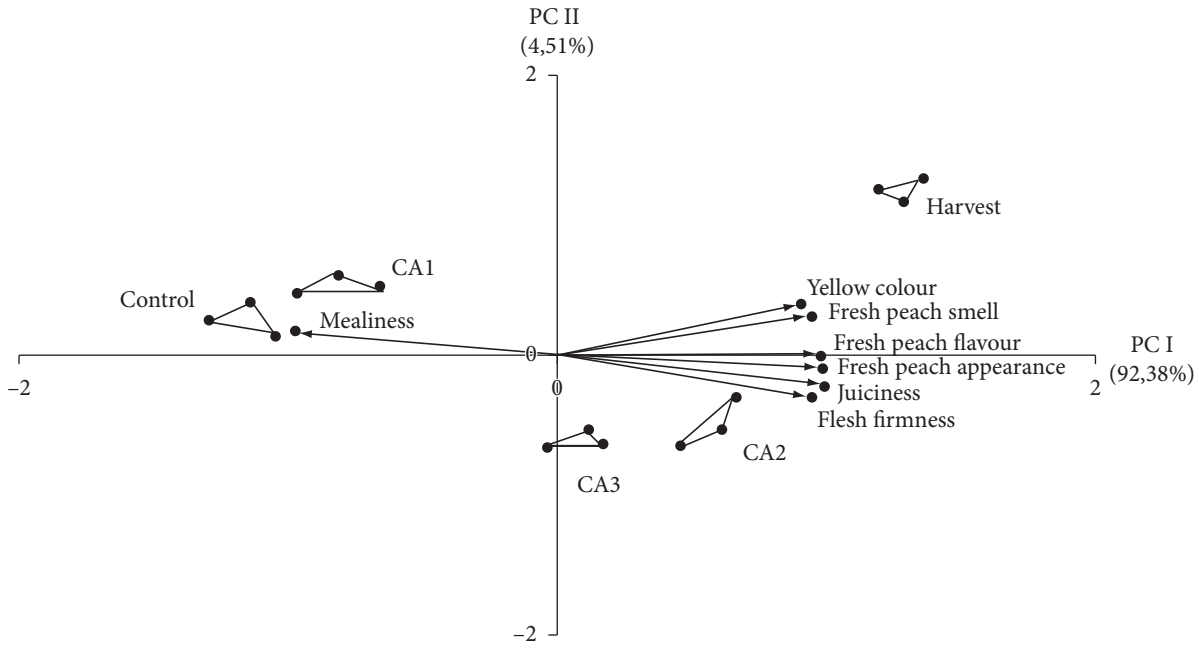

Figure 4. PCA of sensory data of 'Douradão' peaches after 28 days cold storage at 1 ± 1 °C under CA plus 4 days ripening in air at 25 °C. PCA loadings and scores for principal component 1 and 2, including all evaluated sensory attributes.

4 Conclusions

The studied treatments presented significant differences with reference to the descriptors terms according to Quantitative Descriptive Analysis. The first two main components explained 96.9% of the total variability observed between the treatments.

CA2 and CA3 treatments were effective in keeping the good quality of 'Douradão' peaches during the 28-day storage. The ripe fruits were more characterized by the fresh peach appearance, fresh peach flavor, juiciness and flesh firmness.

Control and CA1 treatments were ineffective for quality maintenance of the fruits during cold storage. The ripe fruits were characterized by mealiness.

The fruits evaluated after harvest showed higher intensity for yellow color and fresh peach smell.

Higher correlation coefficients between instrumental and sensory characteristics, significant at the 5% level, were found to the Hue angle and intensity of yellow color, as well as to ratio and intensity of fresh peach smell.

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