Quality evaluation of fresh-cut 'Pérola' pineapple stored in controlled atmosphere

Avaliação da qualidade do abacaxi 'Pérola' minimamente processado, armazenado sob atmosfera controlada

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Abstract

The purpose of this research was to determine the best gas mixture in controlled atmosphere conditions to store fresh-cut 'Pérola' pineapple, particularly in relation to the maintenance of visual quality and reduction of microbial growth. After sanitation, fruit was manually peeled, sliced and dipped in 20 mg.L^{-1} NaOCl solution for 30 seconds. Then, the excess liquid was drained and the slices were placed in sealed glass jars connected to a flowboard installed in a cold room (5 ± 1 °C). Desired gas mixtures were supplied continuously for 12 days from cylinders connected to the flowboard. Controlled atmospheres of 2:5, 2:10, 2:15, 5:5, 5:10, 5:15, 8:5, 8:10 and 8:15 (O_2:CO_2, %) and air were used. The product was evaluated for pulp color, total and fecal coliforms, mesophilic and psychrotrophic aerobic, mold and yeast counts. Total and fecal coliforms were not detected. The fresh-cut 'Pérola' pineapple was not very sensitive to storage in controlled atmosphere, considering that the slices had little browning and were free of contamination, that would affect the food safety at the end of the storage period.
Keywords: *Ananas comosus*; minimal processing; gas mixture; quality; microbial growth.

Resumo

Procurou-se determinar a composição gasosa ótima para o armazenamento do abacaxi 'Pérola' minimamente processado, particularmente com relação à melhoria da qualidade visual e à redução do crescimento microbiano. Frutos previamente sanitizados foram descascados e fatiados manualmente. As fatias foram imersas em solução de NaOCl 20 mg.L^{-1} durante 30 segundos. Após período de repouso, para drenagem do excesso de líquido, foram acondicionadas em frascos de vidro herméticos conectados a um fluxcentro instalado em câmara refrigerada a 5 ± 1 °C. As composições gasosas desejadas foram fornecidas continuamente, durante 12 dias, a partir de cilindros conectados ao fluxcentro. As combinações de O_2:CO_2 (%), balanceadas com N_2, foram as seguintes: 2:5, 2:10, 2:15, 5:5, 5:10, 5:15, 8:5, 8:10 e 8:15. O tratamento controle foi o ar atmosférico. Os parâmetros analisados foram: cor, coliformes a 35 e a 45 °C, microrganismos aeróbios mesófilos, psicrotróFilos, bolores e leveduras. Não foram detectados coliformes totais e fecais. A combinação 5:15 (O_2:CO_2, %) reduziu ligeiramente o crescimento microbiano, entretanto o abacaxi 'Pérola' minimamente processado parece ser pouco sensível ao armazenamento sob atmosfera controlada, considerando-se que ao término do armazenamento as fatias apresentavam-se pouco escurecidas e livres de contaminação que comprometesse a segurança do alimento.
Palavras-chave: *Ananas comosus*; processamento mínimo; composição gasosa; qualidade; crescimento microbiano.

1 Introduction

Consumption of fresh-cut fruit and vegetables has been increasing because of their convenience and high quality. However, it is essential that these fresh-cut fruit and vegetables preserve the freshness and nutritional quality of the whole products, as well as being free of microbial contamination that would offer risks to the consumers[7,11]. Fresh-cut pineapple can be found in some shops, but its shelf-life is very limited (approximately 2-3 days) because of the quality loss represented, mainly, by pulp browning and the accumulation of liquid in the packaging.

Controlled atmosphere (CA) and low temperatures provide the maintenance of quality and shelf–life prolongation of fruit and vegetables. As every tropical fruit, the pineapple experiences chilling damage when stored at temperatures below 12 °C, O'CONNOR-SHAW et al.[14] did not observe symptoms of this disturbance in fresh-cut pineapple stored at 4 °C. Oxygen levels below 1% and/or CO_2 levels above 10% are needed to significantly suppress fungal growth[10, 20]. According to FARBER[6], the metabolic alterations caused by CO_2 cause the cell stress, resulting in the reduction of microbial growth rates.

The storage of pineapples in CA of 3-5% O_2 + 5-8% CO_2 provides the reduction of respiration rates and the prolongation of its shelf-life. The exposition of this fruit to O_2 levels below 2% and CO_2 levels above 10% seems to favor the development of off-flavors[12]. Relatively ampler limits of CO_2 and O_2 (1-20% CO_2 and 2-5% O_2) were established to preserve pineapples[15]. However, there is little available information concerningt the ideal conditions of CA to store fresh-cut fruit. It was reported that levels of 10% CO_2 cause the reduction in the deterioration of fresh-cut 'Champaka' pineapples, while O_2 levels below 5% lead to the development of off-flavors from the fermentative metabolism[9].

The low levels of O_2 used when being stored at 5 °C of fresh-cut 'Champaka' pineapples caused retention of the yellow color, whereas high CO_2 reduced brown discoloration[13]. According to these authors, storing fresh-cut pineapple in 2% O_2 + 10% CO_2 extended post-cutting life for more than two weeks.

Using CA (air + 15% CO_2) reduced color changes in fresh-cut 'Cantaloupe' and 'Honeydew' melons[16]. In a similar

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way, lower alteration in pulp color of fresh-cut 'Jonagored' apples when they were stored in CA of 2% O_2 + 12% CO_2[18] was observed.

The purpose of this research was to determine the best gas mixture, in CA conditions, to store fresh-cut 'Pérola' pineapple, particularly in relation to maintaining the visual quality and reduction of microbial growth.

2 Materials and methods

Pineapple fruits (*Ananas comosus* (L.) Merril, cv. Pérola) were harvested from a commercial grower in Miranorte - TO (Center-West region of Brazil), pre-selected and transported to the "Instituto de Tecnologia de Alimentos" (ITAL), Campinas - SP. Then, the fruit was selected in relation to the size and the shell color (fruit with the fruitlets center yellow), washed with water and neutral detergent and disinfected in 200 mg.L^{-1} sodium hypochlorite (NaOCl) solution for 2 minutes. Fruit was placed in washed and disinfected (200 mg.L^{-1} NaOCl solution) plastic boxes and kept at 20 °C conditions for approximately 20 hours. After that, the fruit was manually peeled and transversely sliced (approximately 10 mm thick) and the cores were removed[1].

The slices were dipped in a solution of NaOCl (20 mg.L^{-1}) for 30 seconds, which was kept at 10 °C. The excess liquid was drained for 2 minutes and the slices were placed in previously disinfected, air-tight glass jars (3.6 L) which were connected to a flowboard[3,4], installed in a cold room at 5 ± 1 °C. The flowboard system ensured the continuous flow of humid and cold air for 12 days. Gas mixtures were supplied from cylinders connected to the flowboard. Nine controlled atmospheres of 2:5, 2:10, 2:15, 5:5, 5:10, 5:15, 8:5, 8:10 and 8:15 (O_2:CO_2, %) and air were used.

Gas mixture flow was based on the respiration rate of fresh-cut pineapple. Studies carried out with fresh-cut 'Pérola' pineapple showed that respiration rates of slices and chunks were approximately 3.0 mg CO_2.kg^{-1}.h^{-1} between the 2nd and 12th days of storage at 5 ± 1 °C[1].

All the processing was carried out in refrigerated conditions, with temperatures between 12 and 15 °C. The equipment and utensils were disinfected with 200 mg.L^{-1} NaOCl solution to prevent crossed contamination. Disposable gloves, masks and headwear were used with the same intention.

Fresh-cut pineapple was evaluated on day 0, after sanitation, and at 2, 5, 8 and 12 days. Three replications were used for each treatment. Each replication consisted of a glass jar with eight slices (approximately 0.550 kg). The pulp color was measured with a Minolta Chromameter (Model CR-300, Minolta) in the CIE L*a*b* mode. The L* and a* parameters, recommended for apples[2], were used to evaluate fresh-cut pineapple browning.

The presence of total coliforms (35 °C) and fecal coliforms (45 °C) in the fresh-cut pineapple was evaluated on day 0. Mesophilic and psychrotrophic aerobic counts were made at 0, 5 and 12 days. Mold and yeast counts were made at 0, 2, 5, 8 and 12 days. The initial evaluation was made after washing with water and neutral detergent. Analyses were carried out according to the methodology described in the Compendium of Methods for the Microbiological Examination of Foods, "APHA"[5].

The experiment was arranged in completely randomized design, with three replications, where interaction between gas mixture and the storage period were studied. Data were analyzed by analysis of variance (ANOVA) and the separation of means was by Tukey's multiple range test at $p \leq 0.05$. Mesophilic and psychrotrophic aerobic, mold and yeast population were transformed into log (x) and expressed in log CFU.g^{-1}.

3 Results and discussion

The pulp color analysis based on the L* value showed that no statistical difference was found between the fruit stored in CA and the control (Figure 1a). There was a slight reduction in this parameter with the storage period for all treatments, attributed to the gradual loss of the samples lightness. The values varied between 75.78 and 71.80 during the period of cold storage, resulting in a reduction of 5.25% (Figure 1c). Similar results were found by GIL et al.[8], who did not observe statistical differences in the L* value of the pulp color of 'Fuji' apple slices when stored for 3 days in 0.25% O_2 or in air. However, slices stored in 0% O_2 were significantly lighter in color than those stored in either air or 0.25% O_2. In another way, the different conditions of CA (air, 2% O_2, air + 12% CO_2 and 2% O_2 + 12% CO_2) did not interfere in the rapid browning of peaches after slicing[19].

The low O_2 concentrations (2%) with 10% CO_2 or 15% CO_2 resulted in a* values of the pulp color statistically lower than the control. However, no significant difference was found between both gas mixtures (Figure 1b). There was a gradual increase in the a* value from the 2nd day of storage in CA (Figure 1d). An increase of 22% in this parameter of color was observed, with values between –3.04, on day 0 and –2.37 on the 12th day of storage. However, this alteration was not visually noticeable. The contribution of red to the color is characterized when the a* values become positive, and this fact was not observed until the end of the storage period.

Total and fecal coliforms were not detected in fresh-cut samples collected on day 0 (after disinfection), which suggest an absence of the microorganisms in the fruit and indicate that processing was carried out under appropriate sanitary conditions.

A relatively low population of mesophilic aerobic, psychrotrophic and mold and yeast (3.65, 1.78 and 3.95 log CFU.g^{-1}, respectively) was observed in the initial evaluation of the fruit, made after washing with neutral detergent and water.

Statistical interaction between the factors (gas mixture and storage period) for mesophilic aerobic and mold and yeast population was observed, but not for psychrotrophic aerobic microorganisms. Regardless of the storage period, the psychrotrophic aerobic population found in the slices stored in CA conditions varied between 2.79 and 4.18 log CFU.g^{-1}, without differing from the population observed in the samples stored in air (3.74 log CFU.g^{-1}). Although not differing from the control, the highest population (4.18 log CFU.g^{-1}) was ob-

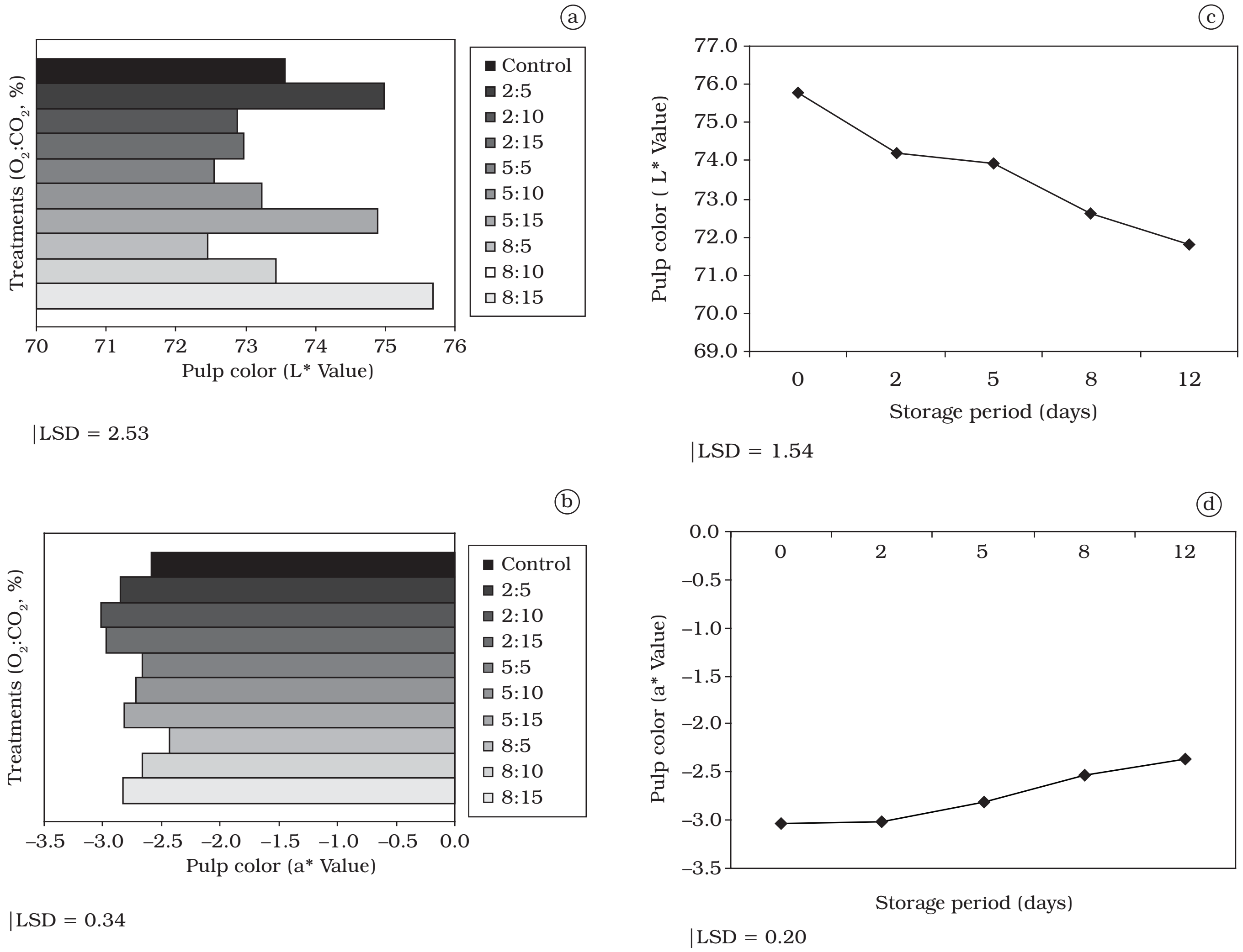

Figure 1. Pulp color of fresh-cut 'Pérola' pineapple stored in different conditions of controlled atmosphere for 12 days at 5 ± 1 °C (a and c: L* value; b and d: a* value). Vertical bars show the least significant differences at 0.05 level.

served in the samples stored in CA of 8% O_2 + 5% CO_2. Five treatments differed from this one and three of them presented 15% CO_2 in their gas mixture (Figure 2a). Considering the population observed in the initial evaluation (1.78 log $CFU.g^{-1}$), an increase of 2.0 log cycles was observed on day 0, when the population reached 3.47 log $CFU.g^{-1}$. Although maintaining itself in 10^3 $CFU.g^{-1}$, a reduction in this count was observed on the 5th day, followed by an increase that raised the population to levels observed on day 0 (3.44 log $CFU.g^{-1}$).

The minimal processing of pineapple did not provide an increase in the mesophilic aerobic population, considering the counts in the initial evaluation and on day 0 (3.65 and 3.63 log $CFU.g^{-1}$, respectively). There were no significant differences between the control and the population of slices stored in CA until the 5th day of refrigerated storage. In this evaluation, the highest population (4.71 log $CFU.g^{-1}$) was observed in the samples stored in CA of 8% O_2 + 5% CO_2. On the 12th day, the mesophilic aerobic population in the slices stored in the CA conditions of 5% O_2 + 15% CO_2 and 8% O_2 + 15% CO_2 were statistically lower than in the control, without differing between them. The CA of 5% O_2 + 15% CO_2 promoted the lowest mesophilic aerobic count (2.83 log $CFU.g^{-1}$) and reduction in the population by 2.0 log cycles when compared to the control (4.33 log $CFU.g^{-1}$). The population of 3.09 log $CFU.g^{-1}$ was observed in slices stored in CA of 8% O_2 + 15% CO_2. Although these gas mixtures provided low counts on the 12th day, the mesophilic aerobic population presented little variation, with values oscillating between 10^2 and 10^4 $CFU.g^{-1}$ (Figure 3).

A slight reduction in the mold and yeast population was observed on day 0 (3.53 log $CFU.g^{-1}$) when compared to the initial population (3.95 log $CFU.g^{-1}$). Up to the 5th day of storage, there were no significant differences between the control and the population of fresh-cut fruit stored in CA. This behavior was also observed in the mesophilic aerobic population. Although not differing from the control, the highest populations were observed in the slices stored in CA of 8% O_2 + 5% CO_2 on the 2nd and 5th days. Statistically lower populations than the control were observed in the slices stored in the CA conditions of 2:10,

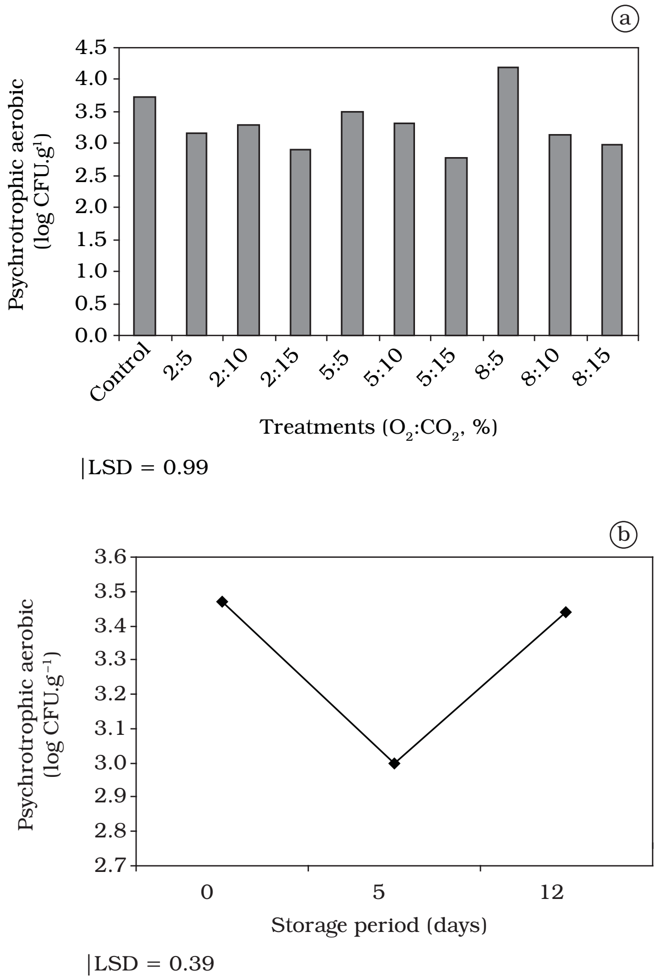

Figure 2. Psychrotrophic aerobic (log CFU.g^{-1}) in fresh-cut 'Pérola' pineapple stored in different conditions of controlled atmosphere a); and for 12 days at 5 ± 1 °C b). Vertical bars show the least significant differences at 0.05 level.

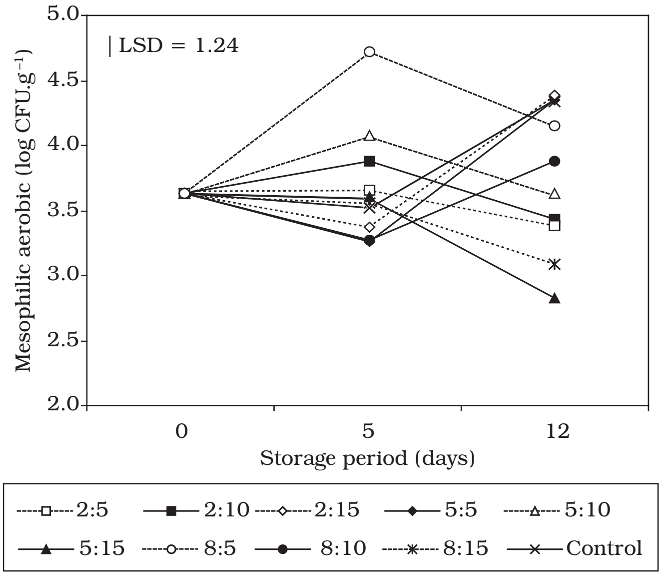

Figure 3. Mesophilic aerobic (log CFU.g^{-1}) in fresh-cut 'Pérola' pineapple stored in different conditions of controlled atmosphere for 12 days at 5 ± 1 °C. Vertical bar shows the least significant differences at 0.05 level.

2:5, 8:15 and 5:15 (O_2:CO_2, %) on the 8th day. At this time of evaluation, the lowest mold and yeast count (3.16 log CFU.g^{-1}) was observed in the fresh-cut pineapple stored in CA of 5% O_2 + 15% CO_2. However, this population did not differ from that found in the slices stored in CA of 2:10, 2:5 and 8:15 (O_2:CO_2, %). On the 12th day, the CA of 5% O_2 + 15% CO_2 provided lower mold and yeast count (3.46 log CFU.g^{-1}) and a reduction in the population by 2.0 log cycles when compared to the control (5.22 log CFU.g^{-1}). However, the population found in this gas mixture did not differ from that observed in the CA conditions of 8:15, 2:15, 2:5, 8:10 and 5:10 (O_2:CO_2, %). Regardless of the fresh-cut pineapple stored in air and CA of 8% O_2 + 5% CO_2 which presented the highest mold and yeast populations at the end of the storage period (5.22 and 6.02 log CFU.g^{-1}, respectively), it was observed that these populations oscillated between 10^3 and 10^4 CFU.g^{-1} throughout the first 8 days of refrigerated storage (Figure 4).

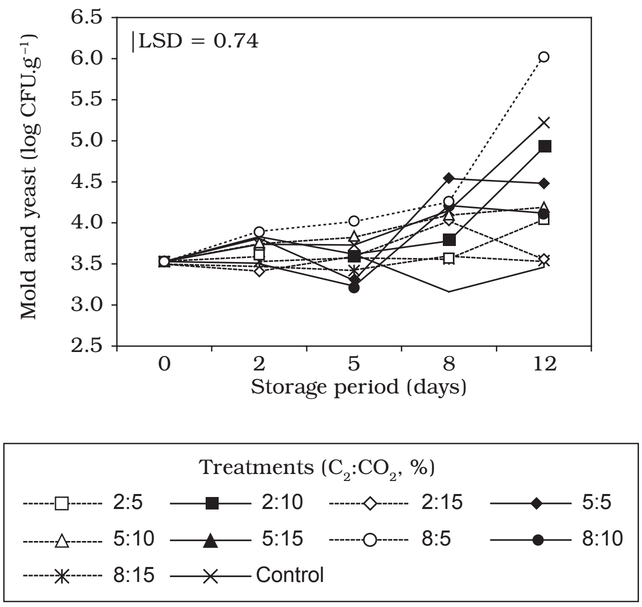

Figure 4. Mold and yeast (log CFU.g^{-1}) in fresh-cut 'Pérola' pineapple stored in different conditions of controlled atmosphere during 12 days at 5 ± 1 °C. Vertical bar shows the least significant differences at 0.05 level.

QI et al.[17] observed lower mesophilic aerobic and mold and yeast population in fresh-cut 'Honeydew' melon, when the cubes were stored in CA of 2% O_2 + 10% CO_2 and 5 °C. However, the mold and yeast population observed in this gas mixture differed from the control only on the 10th day, and similar behavior was not observed in the mesophilic aerobic population. According to O'CONNOR-SHAW et al.[14], the microbial growth did not appear to contribute to spoilage in diced pineapple for 11 days of storage at 4 °C.

In spite of the gas mixture of 5% O_2 + 15% CO_2 having slightly reduced the microbial growth, fresh-cut 'Pérola' pineapple seems to be not very sensitive to storage in CA considering that the slices had little browning and were free of contamination that would affect the food safety at the end of the storage period. Perhaps, maintaining the microbial population in relatively low levels was a result of refrigerated storage, low initial contamination of the intact product and sanitary conditions, and not an effect of the CA storage.

4 Conclusions

Fresh cut 'Pérola' pineapple is not very sensitive to storage in controlled atmosphere. The controlled atmosphere of 5% O_2 + 15% CO_2 slightly reduces the microbial growth in fresh-cut 'Pérola' pineapple.

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