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Quality changes in fresh cut tomato as affected by modified atmosphere packaging

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Abstract

Fresh cut 'Durinta' tomato slices were stored for 7 and 10 days at 0 and 5 °C under active (12–14 kPa O_2 + 0 kPa CO_2) modified atmosphere packaging (MAP). Changes in firmness, colour, soluble solids content, pH, titratable acidity, maturity index and microbiological and sensory attributes were monitored. Sealed bags, made of three polymeric films, containing two sliced tomatoes per tray were used. After 10 days, gas composition within low permeability packages reached 4–5 kPa O_2 + 9–12 kPa CO_2 at 0 °C and 2 kPa O_2 + 20 kPa CO_2 at 5 °C. No significant changes in gas composition were induced by a C_2H_4 absorbent. Juice accumulation, moisture condensation, water loss, and seed germination were overcome. In perforated and high permeability films an increase in the microbial counts higher than 3 log units at 5 °C occurred while a slight increase at 0 °C was observed. After storage at 0 °C no effect of gas composition on tomato keeping quality was shown. However, the best overall tomato slice quality was found at 5 °C under higher CO_2.

Keywords: *Lycopersicon esculentum*; Minimally processed; Sensorial quality; Microbial counts; Quality attributes

1. Introduction

Fresh cut produce sales have increased spectacularly during the last decade in Europe and USA, mainly due to changes in consumer, demand but also to improvements in the cool chain and processing technology, including modified atmosphere packaging (MAP). Quality and marketability of tomato slices deteriorates rapidly after cutting compared with other vegetables, and a long-life cultivar has been used for fresh cut to slow ripening and extend storage life (Artés et al., 1999). Some studies have been conducted on the physiological and biochemical responses of excised tomato tissue (Gross and Saltveit, 1982; Edwards et al., 1983). The effect of slicing on the postharvest behavior of fresh cut tomato slices includes a rapid rise in CO_2 and C_2H_4 production which reduced shelf-life (Mencarelli and Saltveit, 1988; Mencarelli et al., 1989; Artés et al., 1999).

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Controlled atmosphere is a good supplement to cold storage in extending shelf-life of fresh cut tomato (Mencarelli and Saltveit, 1988). Thus, atmospheres of 3 kPa $O_2 + 0$ kPa CO_2 or 3 kPa $O_2 + 3$ kPa CO_2 reduce C_2H_4 production in tomato slices and delay ripening (Mencarelli and Saltveit, 1988). Moreover, surface sterilization of whole tomato with sodium hypochlorite as well as the use of potassium bicarbonate, calcium chloride and calcium lactate extend the shelf-life of fresh cut tomato (Hong and Gross, 1998; Gil et al., 1999).

Most of the defects of fresh cut tomatoes observed during processing and storage, such as juice accumulation, seed germination and moisture condensation, have been overcome. A water-absorbent paper in the trays avoided juice accumulation (Mencarelli et al., 1989; Gil et al., 1999). Ripening slices at either 20 or 25 °C in humidified atmospheres containing either 9 or 20 μl C_2H_4 per l reduced seed germination and radicle growth (Mencarelli and Saltveit, 1988).

The purpose of this study was to develop an inexpensive and easy method for extending the shelf-life of tomato slices. The present study evaluates the effect of two storage temperatures and several modified atmospheres on fresh cut tomato quality. The influence of a C_2H_4 absorbent within packages was also evaluated.

2. Material and methods

2.1. Plant material

'Durinta' tomatoes (*Lycopersicon esculentum*, Mill.) a slow ripening cultivar were grown in a greenhouse on the Mediterranean southeast coast of Spain (Mazarrón, Murcia) by a commercial grower. Fruit were hand-harvested during March–May at stage 7–8 (partially ripe) according to the Kleur–Stadia (Holland) tomato colour chart and USDA color stage 5–6 with a mean weight of 70 ± 8 g. After harvest, tomatoes were transported by car to the laboratory (45 km) where they were stored at 10 ± 0.5 °C until the next day. Fruit firmness and surface colour were used to select uniform fruit (Artés et al., 1999). Tomatoes requiring about 20 N force to deform the surface 5 mm at a speed of 10 mm min^{-1} and with a surface colour measured as hue ($h° =$ arctangent b^*/a^*) between 65 and 75 ° were selected.

2.2. Slice preparation

An isolated and cleaned minimal-processing room at 8 °C was used for tomato processing and conditioning. Whole fruit were dipped into sodium hypochlorite solution (1.3 mM) for 1 min at 4 °C and then blotted dry. The tomatoes were cut into slices 7 mm thick from the stem-end portion perpendicularly to the long axis of the fruit with a commercial slicing machine (Jata, model Slim, Vizcaya, Spain). According to our previous studies, dehydration of tomato slices was a crucial symptom of quality loss (Artés et al., 1999). To minimize dehydration by reducing surface exchange of water vapor the slices were regrouped to reconstruct the initial whole tomato shape with the ends included.

Each replicate was composed of two fresh cut tomatoes and all data are the mean of three replicates. Samples were stored at 0 and 5 °C with 95% RH and analyzed at the beginning of the experiments and after 7 and 10 days of storage under different conditions, although only data on day 0 and 10 days are shown.

2.3. Packages and polymeric films

Two fresh cut tomatoes were placed in polypropylene trays (13 cm length × 8.5 cm width × 4.5 cm depth) containing two layers of absorbent paper on the bottom to avoid juice accumulation. The trays were packed into heat-sealed plastic bags with similar dimensions made of three polymeric films. As control, perforated polypropylene film (PP) (33 holes of 2 mm dm^{-2}) 35 μm thickness (Borden, Alicante, Spain) providing an air atmosphere within the packages was used. Two other polymeric films were studied and compared: composite film (Vascolan, Vaessen Schoemaker Industrial, Barcelona, Spain) 80 μm thickness and a permeance at 23 °C and 75% RH of $< 2.4 \times 10^{-14}$ mol s^{-1} m^{-2} Pa^{-1} for O_2 and $< 6.1 \times 10^{-14}$ mol s^{-1} m^{-2} Pa^{-1} for CO_2 was

measured. This film was selected to provide the recommended gas composition for storage of fresh cut tomatoes (Mencarelli and Saltveit, 1988). The other polymeric film was a bioriented polypropylene film (OPP) (DF300, Derfilm, Cepsa S.A., Madrid, Spain) with permeance at 23 °C and 90% RH of 3.3×10^{-12} mol s^{-1} m^{-2} Pa^{-1} for O_2 and 3.1×10^{-9} mol s^{-1} m^{-2} Pa^{-1} for CO_2 (unpublished data). This medium permeability film is commonly used in the industry. An ethylene absorbent pad (EAP) containing $KMnO_4$ on celite (GK, Nuevas Tecnologías Alimentarias, S.L., Murcia, Spain) was also incorporated in the trays to study the effect of ethylene removal on tomato slice quality and deterioration. Tomato slice trays were placed into the different polymer bags without ethylene absorbent pad as control.

2.4. MAP and analysis

A gas exchange device with a vacuum packaging machine (Zermat, Carburos Metálicos S.A., Madrid, Spain) and a mixing station (Witt–Gasetechnik, model KM 100-3 M, Carburos Metálicos S.A., Madrid, Spain) was used. Active MAP was carried out by flushing a gas mixture of about 12–14 kPa $O_2 + 0$ kPa CO_2 balanced with N_2 into the composite and OPP bags. Changes in O_2 and CO_2 concentrations were monitored using a gas chromatograph (Perkin–Elmer autosystem, CT, USA) equipped with a thermal conductivity detector. C_2H_4 was analyzed using a gas chromatograph (Hewlett Packard 5370 A, Avondale, PA, USA) equipped with a flame ionization detector. Samples were analyzed in triplicate and monitored daily for 10 days.

2.5. Quality evaluations

A test panel consisting of three trained judges evaluated quality attributes (i.e. visual quality, aroma, texture and defects) as previously reported (Gil et al., 1999). Visual quality was scored on a nine point scale (9, excellent; 7, very good; 5, good, limit of marketability; 3, fair, limit of usability; and 1, poor, inedible). Aroma evaluation used a scale of 5 to 1 (5, full characteristic, 3, moderate and 1, complete lack of characteristic aroma). Texture was evaluated by manual appreciation based on a 5–1 scale (5, fresh, 3, moderately fresh and 1, soft). Defects and disorders (e.g. dehydration symptoms, discoloration, seed germination, translucency and cutting damage) were scored as 1, none, 3, moderate, and 5, severe. Tomato slice firmness, soluble solids content (SSC) expressed in °Brix (refractometric readings at 20 °C), titratable acidity (TA) (in g of citric acid per 100 ml juice), pH and maturity index (SSC/TA) ratio were determined according to (Artés et al., 1999). Juice colour was measured using a chromameter (Minolta CR-300, Ramsey, NY) coupled to a liquid sample holder (CR-A70, Ramsey, NY) containing 35 ml of juice and values expressed as hue angle.

2.6. Microbial evaluation

To determine microbial load, a 10 g sample was mixed with 90 ml peptone saline solution in a sterile stomacher bag and homogenized for 1 min using a Colworth Stomacher 400 (Steward Laboratory, London, UK). Dilutions were made in peptone water (Merck) as needed for plating. Plate count agar (Merck) was used as the media for total psychrotrophic counts per plate, incubated at 22 °C for 5 days. Microbial analyses were performed on days 0 (immediately after cutting) and after 10 days of storage. All samples were carried out in duplicate and each microbial count is the mean of three packages. Microbial counts were expressed as $\log_{10}$ cfu/g.

2.7. Statistical analysis

The effect of storage temperature and film permeability on the quality of tomato slices was assessed using an analysis of variance (ANOVA) and mean values compared using the least significant difference (LSD) test. Temperature, film and their interaction were considered the main factors.

3. Results

Changes in gas composition within composite film packages stored at 0 and 5 °C were analyzed

to determine the effect of atmosphere composition on quality of fresh cut tomato slices during storage (Fig. 1). Throughout storage at 0 °C, O_2 level decreased from the initial value (12 kPa) to 4–5 kPa, while CO_2 reached 9 or 12 kPa in the packages with or without ethylene absorbent pads, respectively. Only a slight decrease in the accumulation of CO_2 at 0 °C was noted after 9 and 10 days in packages with EAP compared with control packages (Fig. 1). The steady state gas composition within composite film packages at 0 °C was not reached during the storage period (Fig. 1). At 5 °C, CO_2 accumulated continuously in both control and packages with EAP and O_2 declined during storage of tomato slices in composite bags, without reaching a steady state. There were no differences in the gas composition between control and packages with EAP throughout the storage.

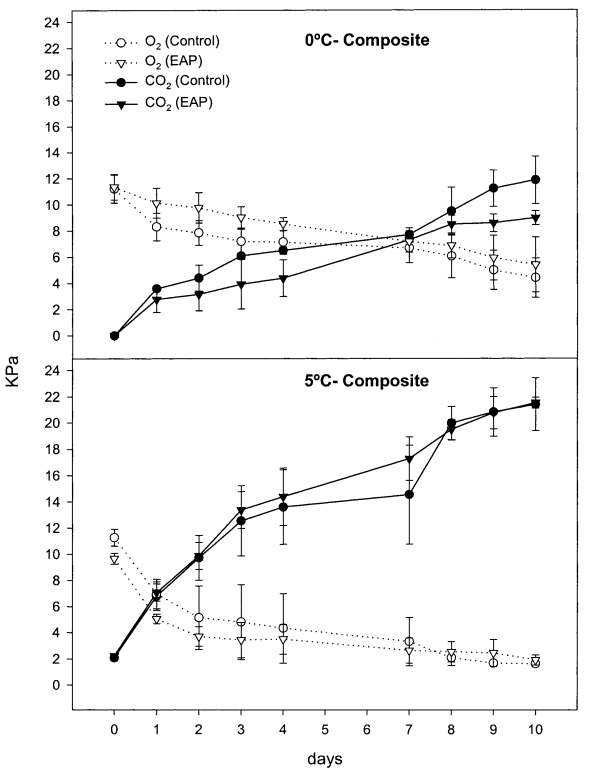

Fig. 1. Changes in O_2 and CO_2 levels of fresh- cut 'Durinta' tomato within composite packages at 0 and 5 °C with an ethylene absorbent pad (EAP) and without (Control) throughout 10 days. Vertical lines represent S.D.

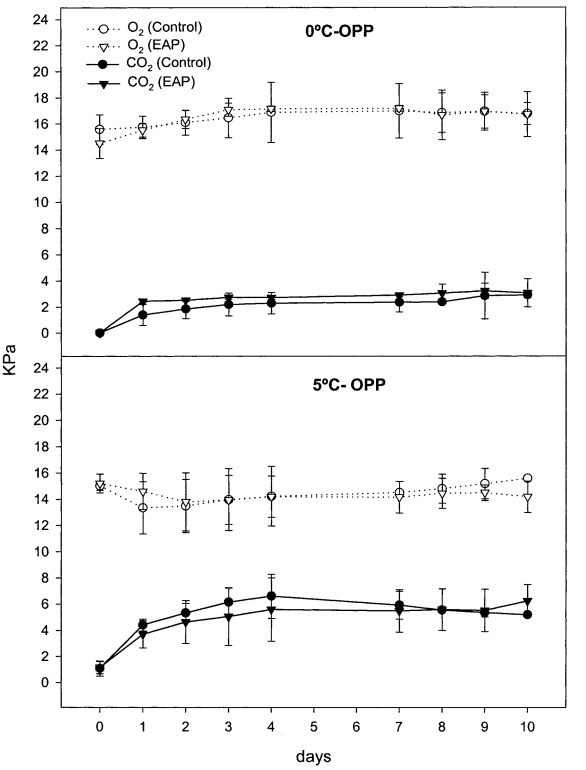

Fig. 2. Changes in O_2 and CO_2 levels of fresh cut 'Durinta' tomato within OPP packages at 0 and 5 °C with an ethylene absorbent pad (EAP) and without (Control) throughout 10 days. Vertical lines represent S.D.

In OPP packages at both temperatures, CO_2 and O_2 were slightly modified from the initial atmosphere (14 kPa $O_2 + 0$ kPa CO_2) and the steady state was rapidly reached (Fig. 2). The 15 kPa O_2 was maintained during storage in OPP packages, while CO_2 reached 3 and 6 kPa at 0 and 5 °C, respectively, and then remained stable throughout the storage period. No differences in gas composition were observed between control and OPP packages with EAP during storage at either temperature (Fig. 2).

Gas composition in perforated packages maintained CO_2 and O_2 levels at atmospheric values during the storage period and no C_2H_4 accumulation was detected (data not shown).

No accumulation of C_2H_4 was observed in packages with EAP throughout storage (Fig. 3). On the contrary, there was a relatively high C_2H_4

accumulation within the control packages (no-pad) from the beginning of the experiment due to the wound response. C_2H_4 accumulation in composite and OPP controls was higher at 5 than at 0 °C. At 0 °C, there was a little detectable C_2H_4 production in fresh cut tomato packed in OPP film (Fig. 3). In a continuous flow system, C_2H_4 production from fresh cut tomato increased immediately after cutting and then decrease gradually until day 7, only to increase near the end of the storage period (Artés et al., 1999; Hong and Gross, 2000). In our 0 °C experiment, C_2H_4 within composite control packages accumulated during 4 days to fairly stable levels (Fig. 3). However, C_2H_4 production at 5 °C gradually decreased after 7 days probably due to the increase in film permeability at higher temperature, the concomitant effect of high CO_2 accumulated in this period, and the over ripeness stage of tissue. This fact has been observed in fresh cut green peppers where C_2H_4 increased to a maximum on day 7 of storage to decrease afterwards (Senesi et al., 2000).

Firmness of tomato slices in perforated, composite and OPP packages remained constant and neither storage temperature nor film promoted softening (data not shown). Previous experiments demonstrated that loss of firmness of fresh cut tomato slices was probably linked to the ripening stage of the whole fruit (Gil et al., 1999). On the contrary, storage at higher temperatures significantly increased juice red color showing lower hue values at 5 °C than values after cutting (Table 1). However, when samples were stored at 0 °C a decrease in the red color (> hue) compared with the initial value after cutting was observed. Storage at 0 °C inhibited the decline of hue values, one symptom of chilling injury as failure of color

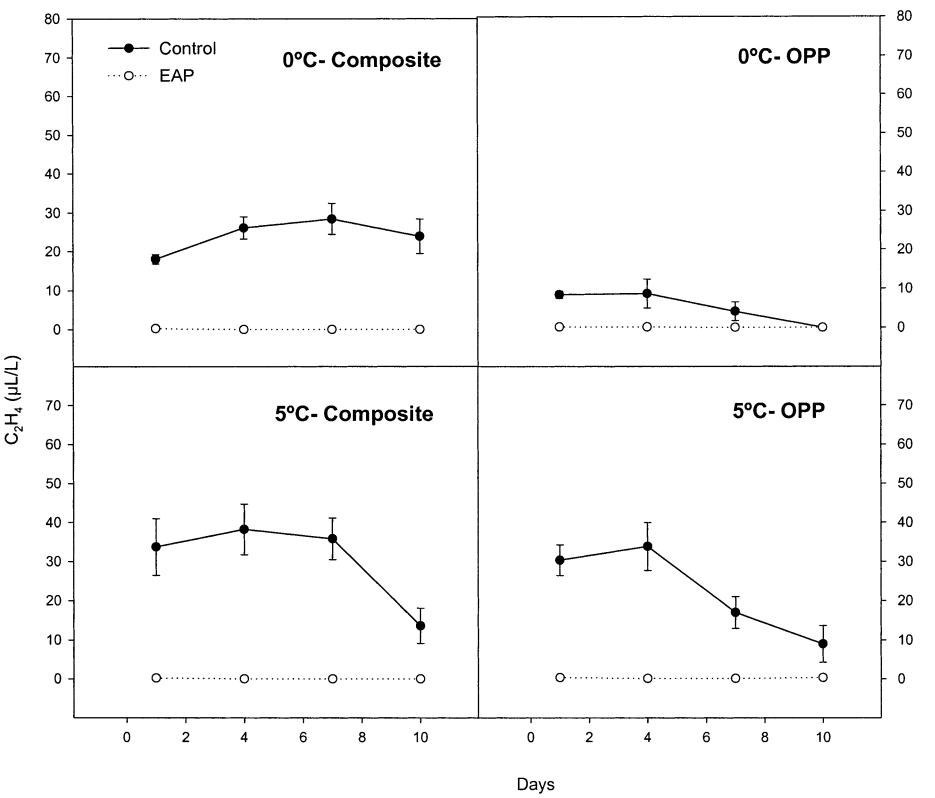

Fig. 3. Changes in C_2H_4 levels of fresh cut 'Durinta' tomato within composite or OPP packages at 0 and 5 °C with an ethylene absorbent pad (EAP) and without (Control) throughout 10 days. Vertical lines represent S.D.

Table 1
Effect of temperature and package on color (hue), titratable acidity (TA) (g citric acid/100 ml), and maturity index (SSC/TA ratio) of fresh cut 'Durinta' tomato after 10 days of storage at 0 and 5 °C

Storage	Conditions package	Hue angle	TA	SSC/TA
Immediately after cutting		78.3	0.35	14.7
After 10 days at 0 °C	Perforated	81.0	0.31	16.1
	Composite	79.3	0.31	16.9
	Composite + EAP	80.1	0.34	14.9
	OPP	79.0	0.28	18.0
	OPP + EAP	81.3	0.31	16.7
After 10 days at 5 °C	Perforated	76.9	0.30	16.6
	Composite	78.8	0.33	14.5
	Composite + EAP	78.9	0.32	16.9
	OPP	77.6	0.27	18.6
	OPP + EAP	76.1	0.27	18.4
Temperature		(1.7)[a]	(0.0)[a]	NS
Package		NS	(0.0)[c]	(1.3)[c]
Temperature × Package		NS	NS	(1.9)[b]

Values are the mean ($n = 18$ slices). NS, not significant. LSD values are in brackets.
[a] $P = 0.05$.
[b] $P = 0.01$.
[c] $P = 0.001$.

development as reported for whole tomato (Artés and Escriche, 1994). Perforated, composite and OPP films had no effect on tomato color. The pH of the juice ranged between 4.1 and 4.6 and SSC between 4.7 and 5.4 (°Brix) and neither temperature nor gas composition had any significant effect on them (data not shown). TA decreased during storage at both temperatures compared with that after cutting, except for tomato slices kept in composite packages with EAP at both temperatures and for control samples packed in composite film at 5 °C which remained at the initial values (Table 1). The maturity index (SSC/TA) was not affected by the storage temperature but was significantly ($P < 0.001$) influenced by the type of film. The maturity index for OPP increased at both temperatures, remained unchanged for composite-EAP at 0 °C and for composite at 5 °C (Table 1). The increase in the maturity index may be related more to the decrease in TA than to the increase in SSC.

A very good visual quality of tomato slices was observed after 7 days of storage. Nevertheless, after 10 days visual quality decreased, although it was always over the threshold of marketability (Table 2). Visual quality was not directly affected by temperature, but depended on the film used. In general, visual quality scored higher for packages with EAP than for packages without EAP, particularly for composite packages at 5 °C. Aroma was good for most packages and only slight losses were found after 10 days for slices in composite bags at 5 °C (Table 2). Texture was excellent at 0 °C while it decreased slightly at 5 °C, particularly for air-stored samples. The main defects observed were discoloration of the parenchymatous tissue and epidermis, and this was especially evident in slices kept at 0 °C. Slight dehydration was also noted for samples in perforated and OPP films at 5 °C. These minor defects increased, when the storage period was increased, except for slices kept in composite packages with EAP at both temperatures where no defects were found (Table 2).

Fungal development was not detected at any time probably due to initial sample selection, chlorine treatment, short storage time and low temperature. The total microbial count slightly increased throughout storage although an acceptable level at the end of the storage period for all conditions was found (Fig. 4). The maximum values for safe consumption is suggested by

Table 2
Effect of temperature and package on visual quality, aroma, texture and defects of fresh cut 'Durinta' tomato after 10 days of storage at 0 and 5 °C

Storage	Conditions Package	Visual quality	Aroma	Texture	Defects
Immediately after cutting		9.0	5.0	5.0	1.0
After 10 days at 0 °C	Perforated	6.5	5.0	4.8	1.2
	Composite	6.5	4.5	4.5	1.5
	Composite + EAP	7.0	5.0	5.0	1.0
	OPP	6.0	4.5	4.5	1.0
	OPP + EAP	6.5	5.0	4.8	1.2
After 10 days at 5 °C	Perforated	5.5	5.0	4.0	1.6
	Composite	8.0	4.0	4.7	1.0
	Composite + EAP	7.0	4.5	4.2	1.0
	OPP	6.0	5.0	4.5	1.5
	OPP + EAP	6.5	4.8	4.5	1.6
Temperature		NS	NS	(0.3)[a]	NS
Package		(0.4)[c]	(0.3)[c]	NS	NS
Temperature × Package		(0.5)[c]	(0.4)[a]	NS	(0.4)[a]

Values are the mean ($n = 18$ slices); NS, not significant. LSD values are in brackets, [a]$P = 0.05$, [b]$P = 0.01$, [c]$P = 0.001$.

French legislation to be 5×10^7 cfu/g (log cfu/g = 7.7) (CTIFL, 1994). Microbial count was particularly low for samples kept at 0 °C and at this temperature no differences among different films were observed. In contrast, at 5 °C moderate or high increases in cfu counts were found depending on the film and gas composition. Compared with those at 0 °C in air, in samples at 5 °C yeasts and moulds counts increased more than 3 log units. However, compared with air, under OPP with 6 kPa CO_2 a reduction in in vitro microbial growth was found. In slices under 20 kPa CO_2 at 5 °C, only slight microbial development occurred.

4. Discussion

Exposure to C_2H_4 had no effect in promoting ripening of fresh cut tomato slices in agreement with reports of Mencarelli and Saltveit (1988). Recently, Hong and Gross (2000) studied the involvement of C_2H_4 in the chilling injury development of fresh cut tomato slices. They used the watersoaked areas as an indicator to express the degree of chilling injury. Tomato slices in packages with high C_2H_4 level had less watersoaked areas than slices in packages with low C_2H_4. Translucency of watersoaked areas was the most frequent disorder observed in our study. This disorder, very often detected at low temperatures, has been considered a chilling injury symptom (Hobson, 1987; Hong and Gross, 1998). These last authors proposed that watersoaked areas in fresh cut tomato slices, mainly developed closer to the blossom end than to the stem end of the fruit, and could be related to differences in ripening stage. From our results, translucency development was well related to concomitant low temperature and advanced ripening stage.

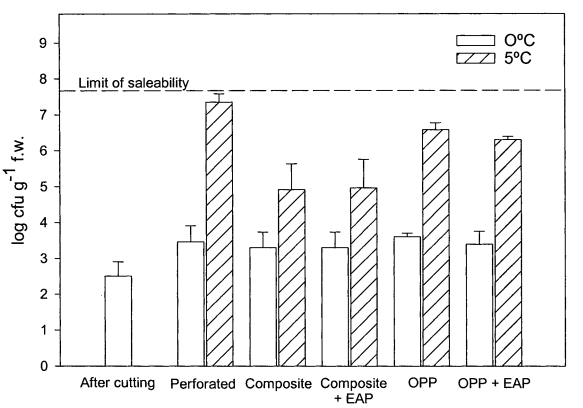

Fig. 4. Microbial counts (log cfu/g) of fresh cut 'Durinta' tomato stored at 0 or 5 °C for 10 days in perforated, composite, composite with EAP, OPP and OPP with EAP films. Error bars represent S.D.

Concomitant with low O_2 and high CO_2 levels, a change to orange in the epidermis and pericarp tissue at 0 °C was noticed. As a consequence of the delay in ripening a green color of the parenquimatic tissue was also found. In both air and MAP color change was tremendously influenced by temperature. Therefore, at 0 °C, the final red color was less intense than at 5 °C. This agrees with results found for whole tomato as an initial chilling injury symptom (Artés and Escriche, 1994).

Water loss was slightly higher in air at 5 °C than at 0 °C and decreased in MAP-stored slices due to saturated water vapor atmosphere within packages compared with samples kept in perforated packages. When processing was carried out with tomatoes at a turning ripening stage, advanced seed germination occurred. Therefore, tomato for fresh cut processing should be of an appropriate ripening stage with uniform color development. Tomato slice dehydration was recently described as a white appearance of the cut surface in contact with the atmosphere (Artés et al., 1999). A regrouped presentation of slices generating the previous tomato shape reduced surface contact with air, minimizing water loss. In all samples, a slight loss of flavour after storage was detected, in agreement with Mencarelli and Saltveit (1988) who associated the insipid flavour to low SSC/TA ratio and pH. In the present experiment, the high-quality tomatoes that showed about 5 °Brix and a SSC/TA ratio higher than 14.5 conferred a good slice taste and flavour.

At low storage temperature microbial proliferation could be retarded and the shelf-life could possibly be prolonged for more than 10 days. However, as tomato is chilling sensitive, storage at 0 °C caused some chilling injuries leading to less intense red color and water-soaked areas, which were considered as product defects. The storage temperature of 5 °C is considered optimum to prevent chilling injury and promote maximum shelf-life. If the fresh cut tomato slices are stored at 5 °C, they should be packed with low permeability films and they can have a shelf-life of 10 days without any quality deterioration. From our results, not enough beneficial effects could justify the use of EAP. The microbial proliferation could be over the limit suggested as being safe for human consumption with low and medium permeability films. It can be concluded that low temperature was the main effect to control microbial growth. Our results agree with those of King and Bolin (1989) and of Carlin et al. (1990) who reported that when temperature abuses occur, atmospheres rich in CO_2 and poor in O_2 have the effect of controlling microbial growth.

5. Conclusions

For keeping quality of 'Durinta' tomato slices up to 10 days the best storage conditions were obtained at 0 °C independently of the kind of film used. After 7 days no differences in tomato quality between storage at 0 and 5 °C were observed. However, when storage was prolonged up to 10 days, quality attributes were better preserved in tomato slices at 0 °C. In order to assure a good quality of fresh cut tomato during 10 days at 5 °C an active MAP of 12 kPa O_2 and 0 kPa CO_2 combined with a low permeability film was needed. Due to the short storage period, use of a C_2H_4 absorbent within packages did not improve shelf-life of tomato slices. When storage temperature increased from 0 to 5 °C in air, yeast and moulds counts increased by more than 3 log U and thus lowering temperature was a more critical factor than MAP in reducing microbial counts. However, high CO_2 and low O_2 levels inhibit yeast and mold growth without off-flavor development.

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