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Full Length Research Paper

Influence of preharvest and postharvest treatments on stored tomato quality

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Preharvest ComCat® treated tomatoes and untreated controls were evaluated for changes in physiological and microbiological quality characteristics during storage at 13°C and room temperature (16.9 to 25.2°C) and a relative humidity of 34 to 76% after 8, 16, 24 and 30 days. The effectiveness of modified atmosphere packaging (MAP) in Xtend® film, disinfection treatments with chlorine or anolyte water and different storage temperatures were also evaluated. The O_2 and CO_2 concentrations remained above 15% and below 6% during storage, respectively. MAP retained ascorbic acid and slightly suppressed growth of microorganism. Storage temperature was the most dominant factor. Faster ripening of tomatoes at room temperature was accompanied by rapid changes in O_2 and CO_2 and faster growth of populations of microorganism. Disinfecting treatments significantly reduced microorganisms. Chlorine disinfection resulted in higher O_2 consumption and CO_2 production than anolyte water. ComCat® treated tomatoes had lower levels of ascorbic acid and microbial populations, than controls. ComCat® treatment had a significant effect on O_2 and N_2 concentrations, ascorbic acid, bacteria, moulds and yeasts, and coliform bacteria during storage. During storage at room temperature, the headspace of packages of ComCat® treated tomatoes had higher O_2, lower CO_2 and lower N_2 contents, which indicated a lower respiration rate, compared to controls. During storage, the ascorbic acid content was better retained in ComCat® treated tomatoes than in control tomatoes.

Key words: ComCat®, tomato, preharvest treatment, disinfection, modified atmosphere packaging, oxygen, carbon dioxide.

INTRODUCTION

Postharvest physiological, microbiological, chemical and biochemical qualities of tomatoes partly depend upon preharvest factors such as genetic, climatic, biotic, edaphic, chemical and hormonal factors, as well as combinations of these (Leonardi et al., 2000). Five major classes of plant hormones are generally recognised: auxin, gibberellin, cytokinin, abscisic acid and ethylene (Salisburg and Ross, 1992), which may change the rate of biological and biochemical changes in fruits. To achieve a given objective, postharvest research is necessary whenever new plant growth regulators or other chemicals are externally applied during growth and development, because the treatment could have positive or negative effects on the quality of fruits at harvest and or during storage. ComCat® is a substance extracted from plants, and consists of combinations of plant hormones (auxin, gibberellin, brassinosteroids, kinetins), aminoacids, natural metabolites and other ingredients that were shown to increase the yield of vegetables (Schnabl et al., 2001).

However, there are no data available on the postharvest physiology, microbiology, chemical and biochemical quality aspects of preharvest ComCat® treated tomatoes.The aims of postharvest treatment of fruit are to reduce enzymatic activities and postharvest decay problems. Chemical treatments were found to be effective in reducing the occurrence of postharvest decay by pathogens (Afek et al., 1998; Prusky et al., 2001) and hot water washing was also found to be very efficient to control postharvest decay in fruits and vegetables (Fallik

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et al., 1999, 2000). Most chemical treatments may leave residues and consequently encounter consumer acceptance problems (Johnson and Sangchote, 1994). This necessitates research in search of alternative disinfecting treatments. Anolyte is a good candidate, and has been shown to be effective in retarding growth and proliferation of microorganisms on carrots during storage (Seyoum et al., 2010).

Anolyte water is electrochemically activated water and is considered totally harmless to human tissue, yet highly microbiocidal. The raw products are water and saline. These are fed into a special unit which then "activates" the water. The activation process is a change of the molecular state of water from a stable to metastable state. Two kinds of electrochemically activated water are produced, anolyte and catholyte. The anolyte is described as having an oxidation-reduction potential (ORP) in the region of + 1000 mV and catholyte an ORP of -800 mV. Some of the biocidal agents in the solutions are ClO_2, HClO, Cl_2, ClO^-, H_2O_2, HO_2, NaHO, O_2, O_3, $H^•$ and $^•OH$.

The presence of the free radicals with their oxidizing effects in the solutions is considered of great importance. The objectives of this study were 1) to investigate the postharvest properties of ComCat® treated tomatoes; 2) to investigate anolyte water as an alternative disinfectant to a chemical treatment such as chlorine to reduce microbial load and suppress their growth thereafter during storage; and 3) to investigate the storage quality of preharvest ComCat® treated tomatoes, using modified atmosphere packaging (MAP) at 13°C and ambient temperature.

MATERIALS AND METHODS

Tomato production

Tomatoes (*Leucopersicon esculentum,* var. Marglobe) were grown during the autumn season in the area of Bloemfontain South Africa. ComCat® was applied at 10 g ha^{-1} in 350 L, and 0 g ha^{-1} as control, and was sprayed twice during the growth and development of tomatoes. Tomato Seeds were raised in a house for about 2 weeks and were pricked into nursery bed. Simultaneously, the experimental plot field land was ploughed, levelled and prepared for the field experiment. The plot size was 4.5 x 5 m with a total number of 60 plants per plot at a spacing of 75 cm between rows and 50 cm between plants. The spacing between plots in each replication and between adjacent replications was 1.5 and 2 m, respectively.

Seedlings were transplanted to the main field using Randomized Complete Block Design with three replications. The first spraying was performed prior to transplanting of the seedlings while the second spraying was at the start of flowering. The other preharvest practices were kept constant between the treatments during production of tomatoes in this experiment. Fruit were harvested manually at the green-mature stage and delivered to the laboratory immediately after harvest. In order to protect the tomatoes from mechanical injury during transportation, plastic crates were used. For each preharvest treatment, the tomato fruit were harvested from four random blocks in order to obtain representative samples. Fruit without observable mechanical injury, blemishes or defects were selected for the study. The working surfaces and all tools used for processing of tomatoes during disinfecting, packaging and storage were washed and disinfected with 1% Chlorobac (Syndachem, Pty, Ltd.) prior to use. Immediately after delivery to the laboratory, the fruit were hand washed with water, to remove field heat, surface dust and reduce microbial populations on the surface. Prepackaging disinfecting treatments and packaging of tomatoes were performed on the same day.

Postharvest treatment

After washing a total amount of 144 kg ComCat® treated tomatoes were subdivided into three groups of 48 kg each in preparation for dipping treatments in chlorinated water, anolyte water and tap water. Plastic containers were washed, disinfected and rinsed with distilled water prior to use for the dipping treatments. Plastic containers were used to avoid losses of charged ions from anolyte, which would be the case with metal containers. Tap water in plastic containers was adjusted to 100 $\propto$g. ml^{-1} total chlorine with standard grade sodium hypochlorite (5% NaOCl), in which tomatoes were dipped for 20 min.

Modified atmosphere packaging

The tomatoes were subdivided into 1 kg-samples, which were packed in commercial micro-perforated bags (Xtend® Film, Patent No. 6190710, StePac L.A., Ltd., Israel), which are specifically designed for tomato packaging and for storage at 13°C. The unpackaged 1 kg-sample tomatoes, for each treatment combination, were placed on perforated plastic bags and left open during storage at 13°C or room temperatures. Tomatoes were stored at 13°C and RH of 34 to 76% and at room temperature (16.9-25.2°C). On each sampling date, packages of tomato (1 kg each) were randomly taken in triplicate from each treatment for quality analyses. A new package was taken each time in order to maintain the microenvironment and avoid contamination through repeated opening and sealing.

Gas sampling and analysis

Micro atmosphere gas analysis was performed at days 0, 3, 5, 9, 17, 25 and 32 of the storage period. Gas samples were withdrawn from the package by piercing the test film with a pressure lock syringe (Precision Sampling Crop, Baton Rouge, Lousiana) with a fine needle and withdrawing a 5 ml gas sample (Jeon and Lee, 1999). At each sampling date, three packages from each storage condition were tested separately.

CO_2, O_2 and N_2 concentrations were analysed by gas chromatography (GC) on a Varian 3300 equipped with a Porapak Q 1.2 m X 2.3 mm stainless steel column, with thermal conductivity detection at 200 mA and H_2 as carrier at 19.5 ml. min^{-1} flow rates for CO_2 determination. For analysis of N_2 and O_2, a 0.8 m Molsieve column (PHASE SEP.) was used, with thermal conductivity detection operated at 200 mA and H_2 as carrier at 12.5 ml. min^{-1}. The GC oven temperature was set at 45°C for both analyses. The opening made by the needle during gas sampling was immediately sealed with drawing tape, to avoid leaking of gas from the packages.

Ascorbic acid analysis

The tomato samples were frozen at –20°C on each sampling interval until analysis was possible within 6 weeks (Seyoum et al., 2010). The ascorbic acid content (AA) of tomato was determined by

the 2, 6–dichloro-phenolindophenol method (AOAC, 1970). An aliquot of 10 ml tomato juice extract was diluted to 50 ml with 3% metaphosphoric acid in a 50 ml volumetric flask. An aliquot was centrifuged at 10 000 x g for 15 min and titrated with the standard dye to a pink end-point (persisting for 15 s). The ascorbic acid content (%) was calculated from the titration value, dye factor, dilution and volume of the sample.

Microbiological analysis

Microbial populations were estimated by the procedure followed by Brackett (1990). Three carrots were cut aseptically into pieces with sterile knives. Samples of 25 g were blended with 225 ml 0.1% peptone water (pH 7.0) in a stomacher for 3 min. The slurries were serially diluted in 9 ml 0.1% peptone water. To determine populations of total aerobic microorganisms, duplicate samples were placed on plate count agar (Oxoid CM463, and pH 7.0±0.2) and incubated at 30°C for 2 days. For the estimation of *Escherichia coli* and coliform population, duplicate samples were placed on violet red bile agar (VBRA with MUG, Oxoid CM978) and incubated at 37°C for 1 day. To determine moulds and yeasts, duplicate samples were placed on Rose-Bengal Chloramphenicol Agar Base (Oxoid CM549) and incubated at room temperature for 3 to 5 days. In all the cases pour plate methods were used. The mean $\log_{10}$ of viable counts from two duplicate plates were noted. Microbial populations were not analysed immediately after disinfection, as they were assumed to be around 0 $\log_{10}$ CUF.g^{-1} as was shown by Seyoum et al. (2003).

Experimental design and data analysis

A factorial experiment with 2 preharvest treatments, 3 prepackaging disinfecting treatments, 2 storage temperatures and 3 replications were used in the study. The experimental design was a randomized complete block design in a factorial arrangement with three samples from each treatment combination. A pack of carrots were taken randomly from each treatment group on each sampling day and used for the different quality analyses. Statistically significant differences between the treatments were determined by analysis of variance (ANOVA) with an MSTAT-C software package (MSTAT, Michigan State Univ., East Lansing) and multiple comparisons of the treatment means by Duncan's multiple range test.

RESULTS

Ascorbic acid

Table 1 displays the changes in ascorbic acid content in ripening tomatoes, subjected to different pre- and postharvest treatments, as between 11.10 and 23.23 $g.100^{-1}$. The general tendency observed was an increase in AA during days 8 to 16, followed by a decrease towards the end of storage. MAP seemed to maintain higher AA contents in tomatoes during storage than unpackaged fruit. Disinfecting treatments also affected the AA content of tomatoes. Anolyte disinfecting resulted in higher AA content throughout ripening at both storage temperatures when compared to chlorine disinfecting and water washing. Storage temperature significantly ($P \leq 0.001$) affected the AA content of tomatoes. In general, higher levels of AA were observed in tomatoes stored at 13°C than at room temperature. The AA content of tomatoes rapidly increased during the first 8 days, the fast ripening period, at room temperature, but drops thereafter. At 13°C, the AA content of ripening packaged tomatoes continued to increase up to 24 or 30 days.

The AA content of tomatoes was significantly ($P \leq 0.05$) affected by the preharvest ComCat® treatment during storage at 13°C and room temperature. The AA content in ComCat® treated tomatoes was higher at harvest, although not significantly ($P > 0.05$), but remained significantly ($P \leq 0.05$) higher after most of the postharvest treatments during storage. The AA content was significantly ($P \leq 0.05$) influenced by the interaction between ComCat® treated and disinfecting + MAP treatments. The AA content of the fruits was highly ($P \leq 0.001$) affected by the interaction between the pre- and postharvest treatments. It was shown that AA content was better maintained in tomatoes during ripening in low temperature storage, use of packaging and disinfecting treatment as well as preharvest ComCat® treatments.

Microbiological changes

Table 2 displays the change in total aerobic bacteria in preharvest ComCat® treated and control tomatoes subjected to different postharvest treatments. Populations of aerobic bacteria did not exceed 8.5 $\log_{10}$CFU g^{-1} during the storage time of 30 days at either temperature. MAP had a significant effect on the growth of microorganisms on tomatoes during storage. After 30 days at 13°C, the populations of total aerobic bacteria were higher in unpackaged treated tomatoes than in packaged ones. Disinfecting treatments reduced the number of aerobic bacteria significantly ($P \leq 0.001$). During storage, there was a significant difference between the water washed tomatoes, which had higher aerobic bacteria populations than the disinfected ones. The populations of aerobic bacteria did not exceed 3.3 $\log_{10}$CFU g^{-1} in both ComCat® treated and control tomatoes disinfected with chlorinated and anolyte water for 16 days at 13°C.

However, there was no significant difference between the chlorine and anolyte water dipping treatment. The total aerobic bacteria population was affected by the preharvest ComCat® treatment ($P \leq 0.05$). At harvest the population of aerobic bacteria was significantly lower in ComCat® treated tomatoes, when compared with the controls. Highly significant interactions ($P \leq 0.001$) were obtained between the ComCat® treated and storage temperature, as well as between the disinfection treatments + MAP and the storage temperature ($P \leq 0.001$). Population of moulds and yeasts on tomatoes, as influenced by treatment and time of storage at 13°C or room temperature, are shown in Table 3. Populations of viable fungi did not exceed 5 $\log_{10}$CFU g^{-1} during the storage time of 30 days at either temperature. MAP suppressed the growth of moulds and yeasts during the

Table 1. Changes in ascorbic acid of tomatoes packaged in Xtend® film or unpackaged and stored at 13°C and room temperature (RT) for 30 days (n = 3 over four storage times).

Treatment		Ascorbic acid (g 100g^{-1} FW)				
Preharvest	**Postharvest**	**Day 0**	**Day 8**	**Day 16**	**Day 24**	**Day 30**
ComCat®	Cl_2, MAP, 13°C	11.6^{ab}	12.5^{hij}	14.4^{def}	16.7^{bc}	16.5^{bcd}
	Anolyte, MAP, 13°C	11.6^{ab}	16.1^{defg}	17.5^{ab}	19.4^{a}	23.2^{a}
	Cl_2, MAP, RT	11.6^{ab}	17.2^{cde}	12.7^{efg}	8.7^{i}	
	Anolyte, MAP, RT	11.6^{ab}	15.6^{efg}	17.0^{abc}	16.6^{bc}	
	H_2O, MAP, 13°C	11.6^{ab}	16.8^{cde}	15.9^{bcd}	12.7^{fgh}	15.7^{de}
	H_2O, MAP, RT	11.6^{ab}	22.6^{a}	18.6^{a}	15.0^{cde}	
	H_2O, 13°C	11.6^{ab}	19.8^{b}	11.8^{fg}	12.3^{gh}	13.2^{efgh}
	H_2O, RT	11.6^{ab}	15.4^{efg}	13.8^{def}	12.7^{fgh}	
Control (0®	Cl_2, MAP, 13°C	13.9^{a}	13.9^{ghi}	14.9^{cde}	15.6^{cde}	15.0^{def}
	Anolyte, MAP, 13°C	13.9^{a}	14.6^{fgh}	15.6^{cd}	18.7^{ab}	18.8^{b}
	Cl_2, MAP, RT	13.9^{a}	13.3^{hij}	10.9^{g}	11.0^{h}	
	Anolyte, MAP, RT	13.9^{a}	11.1^{j}	13.5^{defg}	16.5^{bc}	
	H_2O, MAP, 13°C	13.9^{a}	13.6^{ghi}	12.7^{efg}	16.1^{bcd}	18.4^{bc}
	H_2O, MAP, RT	13.9^{a}	11.7^{ij}	12.9^{efg}	16.0^{cd}	
	H_2O, 13°C	13.9^{a}	17.0^{cde}	12.8^{efg}	13.3^{efgh}	11.7^{h}
	H_2O, RT	13.9^{a}	18.4^{bcd}	14.9^{cde}	11.8^{h}	
Significance						
Preharvest treatment (A)				*		
Disinfecting + MAP (B)				***		
Storage temperature (C)				***		
A X B				*		
A X C				NS		
B X C				***		
AXBXC				***		

Nonsignificant, *** Significant at P ≤ 0.05 or 0.001 respectively. Means within a column followed by the same letter(s) are not significantly different according to Duncan's multiple range test (P < 0.05). The LSD Value = 2.069, S.E. = 0.085, MSE = 1.644 and C.V. = 0.089.

Table 2. Changes in total aerobic bacteria populations in tomatoes packaged in Xtend® film or unpackaged and stored at 13°C and room temperature (RT) for 30 days (n = 3 over four storage times).

Treatment		Total aerobic bacteria (log_{10}cfu g^{-1} FW)				
Preharvest	**Postharvest**	**Day 0**	**Day 8**	**Day 16**	**Day 24**	**Day 30**
ComCat®	Cl_2, MAP, 13°C	3.1^{b}	<1^{kl}	1.5^{ij}	2.2^{lmn}	<1^{fg}
	Anolyte, MAP, 13°C	3.1^{b}	1.4^{hij}	1.0^{j}	2.3^{klmn}	2.7^{gh}
	Cl_2, MAP, RT	3.1^{b}	3.3^{fg}	3.4^{fgh}	3.7^{hijk}	
	Anolyte, MAP, RT	3.1^{b}	2.3^{ghi}	2.7^{ghi}	3.7^{hijk}	
	H_2O, MAP, 13°C	3.1^{b}	2.5^{ghi}	4.7^{cde}	3.9^{hijk}	4.6^{cdef}
	H_2O, MAP, RT	3.1^{b}	4.1^{def}	4.0^{fgh}	6.3^{cde}	
	H_2O, 13°C	3.1^{b}	3.1^{fgh}	5.7^{abc}	5.9^{def}	7.0^{ab}
	H_2O, RT	3.1^{b}	5.3^{cde}	6.4^{a}	5.5^{defg}	
Control (0®	Cl_2, MAP, 13°C	5.2^{a}	<1^{k}	1.3^{ij}	3.3^{ijk}	1.3^{hi}
	Anolyte, MAP, 13°C	5.2^{a}	<1^{ghi}	2.3^{hij}	2.9^{jklm}	3.2^{cd}
	Cl_2, MAP, RT	5.2^{a}	3.5^{efg}	5.9^{abc}	5.2^{efgh}	
	Anolyte, MAP, RT	5.2^{a}	3.7^{efg}	5.6^{abcd}	4.3^{hijk}	

Table 2. Contd.

	H_2O, MAP, 13°C	5.2 ^{a}	3.8 ^{efg}	4.8 ^{bcd}	5.2 ^{efgh}	5.8 ^{bc}
	H_2O, MAP, RT	5.2 ^{a}	3.6 ^{erg}	5.7 ^{abcd}	8.7 ^{a}	
	H_2O, 13°C	5.2 ^{a}	6.4 ^{a}	5.5 ^{abcd}	4.4 ^{fghij}	7.6 ^{a}
	H_2O, RT	5.2 ^{a}	6.0 ^{ab}	6.2 ^{ab}	8.4 ^{b}	
Significance						
Preharvest treatment (A)				*		
Disinfecting + MAP (B)				***		
Storage temperature (C)				***		
A X B				NS		
A X C				***		
B X C				***		
AXBXC				NS		

Nonsignificant, *, *** Significant at P ≤ 0.05 or 0.001 respectively. Means within a column followed by the same letter(s) are not significantly different according to Duncan's multiple range test (P < 0.05). The LSD Value = 1.362, S.E. = 0.161, MSE = 0.712 and C.V. = 0.199.

Table 3. Changes in yeast and moulds populations in tomatoes packaged in Xtend® film or unpackaged and stored at 13°C and room temperature (RT) for 30 days (n = 3 over four storage times).

Treatment		**Total fungi count (log_{10}CFU g^{-1} FW)**				
Preharvest	**Postharvest**	**day 0**	**day 8**	**day 16**	**day 24**	**day 30**
ComCat®	Anolyte, MAP, 13°C	1.8 ^{ab}	<1 ^{i}	<1 ^{h}	<1 ^{gh}	1.0 ^{fg}
	Cl_2, MAP, RT	1.8 ^{ab}	<1 ^{i}	2.0 ^{cdef}	2.1 ^{def}	
	Anolyte, MAP, RT	1.8 ^{ab}	1.4 ^{efghi}	1.8 ^{cdef}	1.6 ^{efgh}	
	H_2O, MAP, 13°C	1.8 ^{ab}	<1 ^{ghi}	3.3 ^{abc}	2.5 ^{cde}	3.1 ^{abc}
	H_2O, MAP, RT	1.8 ^{ab}	<1 ^{i}	<1 ^{fgh}	4.1 ^{ab}	
	H_2O, 13°C	1.8 ^{ab}	<1 ^{ghi}	3.2 ^{abc}	2.8 ^{bcde}	4.2 ^{a}
	H_2O, RT	1.8 ^{ab}	3.1 ^{abcd}	3.7 ^{ab}	3.6 ^{abc}	
Control (0 ComCat®)	Cl_2, MAP, 13°C	2.3 ^{a}	<1 ^{hi}	<1 ^{gh}	1.4 ^{efgh}	1.3 ^{efg}
	Anolyte, MAP, 13°C	2.3 ^{a}	<1 ^{hi}	<1 ^{gh}	<1 ^{gh}	<1 ^{g}
	Cl_2, MAP, RT	2.3 ^{a}	<1 ^{i}	4.2 ^{a}	3.4 ^{abc}	
	Anolyte, MAP, RT	2.3 ^{a}	<1 ^{i}	2.9 ^{bcd}	1.8 ^{defg}	
	H_2O, MAP, 13°C	2.3 ^{a}	1.0 ^{fghi}	3.4 ^{ab}	3.1 ^{abcd}	2.9 ^{abcd}
	H_2O, MAP, RT	2.3 ^{a}	1.8 ^{defgh}	3.3 ^{abc}	4.8 ^{a}	
	H_2O, 13°C	2.3 ^{a}	2.2 ^{cdefg}	3.5 ^{ab}	3.8 ^{abc}	4.3 ^{a}
	H_2O, RT	2.3 ^{a}	4.3 ^{a}	4.1 ^{a}	4.5 ^{ab}	
Significance						
Preharvest treatment (A)				*		
Disinfecting + MAP (B)				***		
Storage temperature (C)				***		
A X B				NS		
A X C				*		
B X C				*		
AXBXC				NS		

NS, *, *** Nonsignificant or significant at P ≤ 0.05 or 0.001 respectively. Means within a column followed by the same letter(s) are not significantly different according to Duncan's multiple range test (P < 0.05). The LSD value = 1.270, S.E. = 0.080, MSE = 0.619 and C.V. = 0.3594.

Table 4. Changes in total coliform populations in tomatoes packaged in Xtend® film or unpackaged and stored at 13°C and room temperature (RT) for 30 days (n = 3 over four storage times).

Treatment		Total coliform bacteria (log_{10}CFU g^{-1} FW)				
Preharvest	**Postharvest**	**Day 0**	**Day 8**	**Day 16**	**Day 24**	**Day 30**
ComCat®	Cl_2, MAP, 13°C	2.3^{b}	$<1^{g}$	1.5^{ijk}	1.7^{ghij}	1.1^{g}
	Anolyte, MAP, 13°C	2.3^{b}	1.2^{erg}	1.2^{ijk}	2.0^{gn}	2.1^{er}
	Cl_2, MAP, RT	2.3^{b}	$<1^{fg}$	1.3^{ijk}	2.9^{fgn}	
	Anolyte, MAP, RT	2.3^{b}	2.0^{defg}	3.3^{efgh}	3.4^{efgh}	
	H_2O, MAP, 13°C	2.3^{b}	1.4^{efg}	3.9^{cdef}	4.0^{er}	5.8^{abcd}
	H_2O, MAP, RT	2.3^{b}	3.9^{abcd}	3.5^{defg}	5.7^{cd}	
	H_2O, 13°C	2.3^{b}	2.7^{cde}	3.9^{cde}	3.9^{er}	6.7^{ab}
	H_2O, RT	2.3^{b}	4.3^{abc}	6.6^{a}	7.9^{ab}	
Control (0 ComCat®)	Cl_2, MAP, 13°C	5.3^{a}	$<1^{g}$	$<1^{k}$	1.7^{ghi}	1.3^{g}
	Anolyte, MAP, 13°C	5.3^{a}	$<1^{g}$	2.7^{fghi}	2.2^{fghi}	2.7^{f}
	Cl_2, MAP, RT	5.3^{a}	3.6^{abcd}	5.2^{abcd}	4.9^{cde}	
	Anolyte, MAP, RT	5.3^{a}	1.5^{efg}	5.3^{abcd}	4.0^{def}	
	H_2O, MAP, 13°C	5.3^{a}	2.9^{bcde}	3.9^{cdef}	5.6^{cd}	6.2^{abc}
	H_2O, MAP, RT	5.3^{a}	3.7^{abcd}	5.4^{abc}	8.0^{a}	
	H_2O, 13°C	5.3^{a}	2.5^{cdef}	4.7^{bcde}	4.9^{cde}	6.7^{a}
	H_2O, RT	5.3^{a}	5.3^{a}	5.9^{ab}	8.2^{a}	
Significance						
Preharvest treatment (A)				*		
Disinfecting + MAP (B)				***		
Storage temperature (C)				***		
A X B				NS		
A X C				***		
B X C				**		
AXBXC				**		

NS, **, *** Nonsignificant or significant at P ≤ 0.001 respectively. Means within a column followed by the same letter(s) are not significantly different according to Duncan's multiple range test (P < 0.05). The LSD Value = 1.475, S.E. = 0.1114, MSE = 0.838 and C.V. = 0.238.

first few weeks of storage. The population of these microorganisms was generally lower in packaged tomatoes, compared to unpackaged ones during storage at both temperatures. At room temperature storage, the number of viable moulds and yeasts was significantly lower in packaged tomatoes than in unpackaged ones during 16 days of storage.

However, the populations in packaged tomatoes started to exceed that of unpackaged fruits after 16 days at room temperature. The number of viable moulds and yeasts was significantly lower in tomatoes disinfected in chlorinated and anolyte water, compared to water washed ones, and did not exceed 1 log_{10}cfu g^{-1} in both disinfected ComCat® and controls for 16 days at 13°C. The results showed that disinfecting with anolyte water seemed to be more effective than chlorinated water, as lower counts of moulds and yeasts were observed, although significant differences were only observed in the packaged control tomatoes stored at room temperature.

As a general trend, ComCat® treatment resulted in lower yeast and mould populations at harvest, a few significant differences were observed during storage, where this trend was continued. The populations were also significant (P ≤ 0.05).

The effect of ComCat® treatment and different postharvest treatments on the growth of total coliform bacteria is shown in Table 4. Populations of coliform bacteria did not exceed 8.3 log_{10}CFU g^{-1} during the storage time of 30 days at either temperature, and *E. coli* was not detected. The other very important factor affecting microorganism growth and multiplication is storage temperature. Populations of coliform bacteria in tomatoes were significantly (P ≤ 0.001) affected by the storage temperature. The number of viable coliforms rapidly increased in tomatoes stored at room temperature. Reducing storage temperature to the minimum temperature specific for tomatoes, that is 13°C, had a positive effect on controlling them. Disinfecting

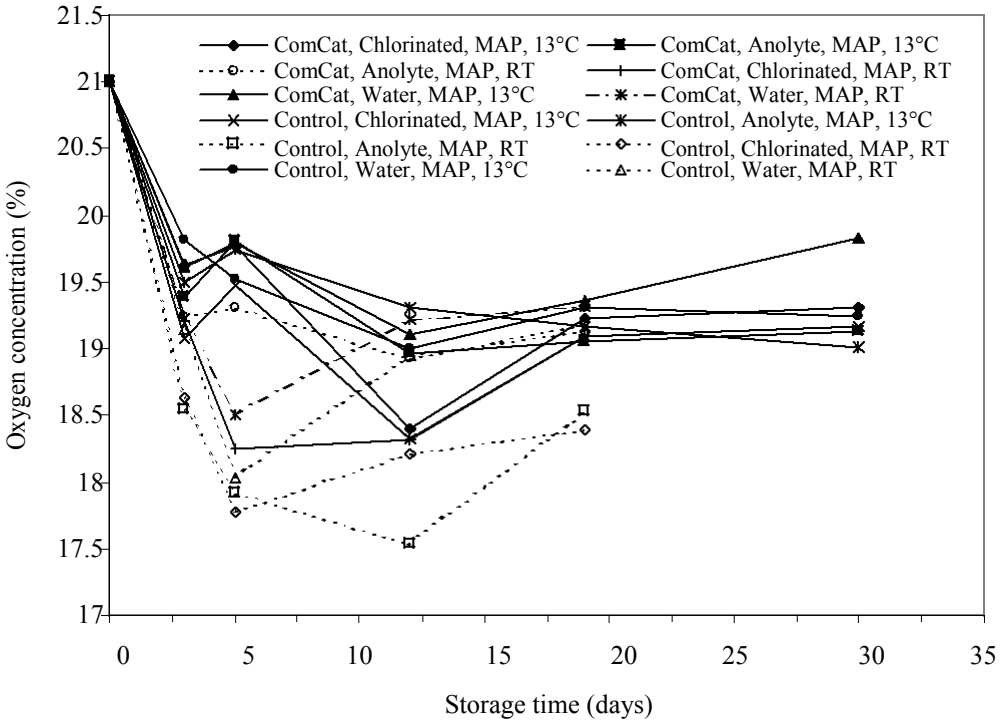

Figure 1. Changes in O_2 content (%) in packages of tomatoes in Xtend® film stored at 13°C and room temperature (RT) for 30 days (n = 3 over five storage times). $LSD_{0.05}$ Value = 0.563, S.E. = 0.034 and C.V. = 0.018.

treatments reduced the number of coliform bacteria. During storage, there was a significant difference between the disinfected tomatoes, which had lower coliform populations than the water washed ones. There was also a difference between the disinfecting treatments, as chlorine treatment resulted in less coliform development compared to anolyte treated tomatoes.

The number of total coliforms was influenced ($P \leq 0.05$) by ComCat® treatment. At harvest, the number of viable coliforms were significantly lower in ComCat® treated tomatoes compared to the controls. As a general trend, the population of total coliform bacteria was found to be lower in ComCat® treated tomatoes, stored at 13°C or room temperature, than in control tomatoes. However, this difference was only significant for the storage of disinfected tomatoes at room temperature. The population of coliform bacteria was influenced significantly ($P \leq 0.001$) by the interaction between preharvest treatment and storage temperature. Similarly, there was a significant ($P \leq 0.01$) influence of the interaction between disinfecting + MAP and storage temperature on coliforms. The three-way interaction between pre-and postharvest treatments was also significant ($P \leq 0.01$).

Headspace gas concentration

The changes in O_2 concentration in tomato packages sealed with the Xtend® film are shown in Figure 1. The storage temperature highly ($P \leq 0.001$) affected O_2 levels in the headspace of packages of tomatoes during storage. The results presented in Figure 1 show that ambient temperature storage increased O_2 utilisation as a result of higher respiration rates of fruit. A rapid decrease in O_2 concentration in packages of tomatoes stored at room temperature to below 18.6% was evident, after the first five days of storage, followed by an equilibration of the O_2 concentration. During the first five days of storage, the O_2 concentration in packages of tomatoes stored at 13°C remained above 19%, after which it dropped up to 12 days, slightly increased up to 20 days and then stabilised at approximately 19% thereafter.

The disinfecting treatment also had a significant ($P \leq 0.05$) effect on the changes in O_2 concentrations in packages. After 12 days at 13°C, the O_2 concentration decreased to 18.5% in packages of ComCat® treated as well as control tomatoes dipped in chlorinated water, while that of the anolyte treated tomatoes remained above 19%. After 19 days at 13°C the O_2 concentrations of the chlorine disinfected tomatoes equilibrated at approximately 19%. There was a difference in the O_2 concentrations in packages of ComCat® treated tomatoes dipped in anolyte after five days at room temperature, being above 19%, while all other tomato packages stored at room temperature had O_2 concentrations below 18.5%. In general, the O_2 concentration in packages of ComCat® treated tomatoes dipped in anolyte water was found to

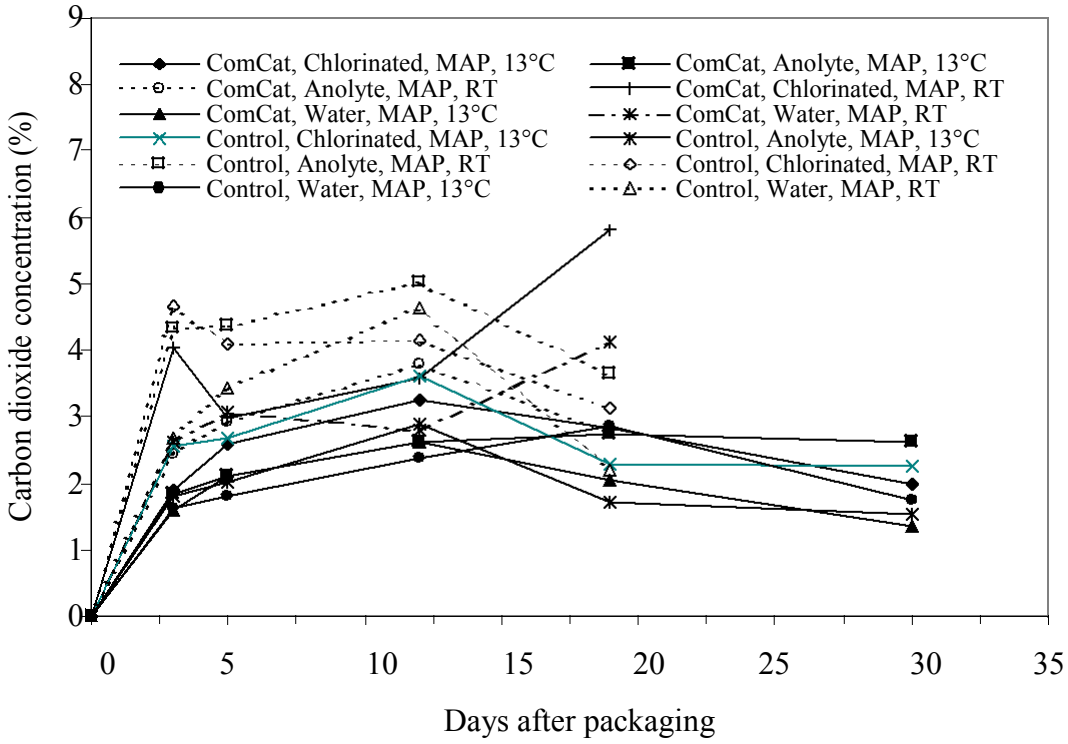

Figure 2. Changes in CO_2 content (%) in packages of tomatoes in Xtend® film stored at 13°C and room temperature (RT) for 30 days (n = 3 over five storage time). $LSD_{0.05}$ Value = 1.303, S.E. = 0.064 and C.V. = 0.278.

follow O_2 content pattern of tomatoes stored at 13°C.

The two-way interaction between preharvest treatment and storage temperature was highly significant ($P \leq 0.001$) on the changes of O_2 levels in tomato packages. The three-way interaction between preharvest, disinfecting and storage temperature factors were also found to be highly significant ($P \leq 0.001$) on the changes in O_2 level in tomato packages during 30 days of storage at 13°C and 19 days of storage at room temperature. The storage temperature was the dominant factor affecting CO_2 concentrations in the headspace of tomato packages during storage, and was highly significant ($P \leq 0.001$). The CO_2 concentrations in packages of tomatoes subjected to pre- and postharvest treatments showed differences at room temperature, compared to those stored at 13°C. The CO_2 level increased slowly up to 12 days of storage to between 2.0 and 3.5% and seemed to equilibrate thereafter in packages stored at 13°C (Figure 2). In tomato packages stored at room temperature, CO_2 levels of 3.5 to 4.5% were reached after 12 days, after which these levels dropped to between 2.0 and 3.5%.

A CO_2 level of 4% was reached quickly, after 3 days, in packages of control fruits, compared to the ComCat® treated tomatoes, and stayed higher up to 12 days of storage. After 12 days of storage the CO_2 level continued to increase in packages of ComCat® treated fruits, except in the case of anolyte water treated tomatoes stored at room temperature. These differences, however, were not significant ($P > 0.05$). The CO_2 concentration was significantly ($P \leq 0.05$) affected by the prepackaging disinfecting treatments. The CO_2 concentrations increased in all packages of ComCat® treated tomatoes stored at 13°C, and which were subjected to different disinfectant and water treatments, up to day 12, declined and stabilised thereafter. At room temperature storage, the chlorine washed ComCat® treated tomatoes showed a CO_2 level of 4% after 3 days, which was in the same order of magnitude as for the controls. The CO_2 level dropped between day 5 and 12, but then increased sharply at 19 days to above 5.5%. At 19 days storage, the CO_2 levels of packages of water washed ComCat® treated tomatoes also increased sharply, but to 4%. The CO_2 levels of anolyte washed ComCat® treated tomatoes stored at room temperature, on the contrary, were much lower and followed the CO_2 pattern of tomatoes stored at 13°C.

There was a highly significant ($P \leq 0.001$) interaction between preharvest ComCat® treatment, disinfecting treatments and storage temperature on the response of the N_2 contents in packages of tomatoes during the 30 days of storage (Figure 3). The N_2 concentrations increased up to 5 and 12 days storage in packages of tomatoes stored at room temperature and 13°C respectively. This increase in N_2 was followed by an equilibration between 80.5 and 81% during the rest of the storage period at 13°C. The storage temperature had a

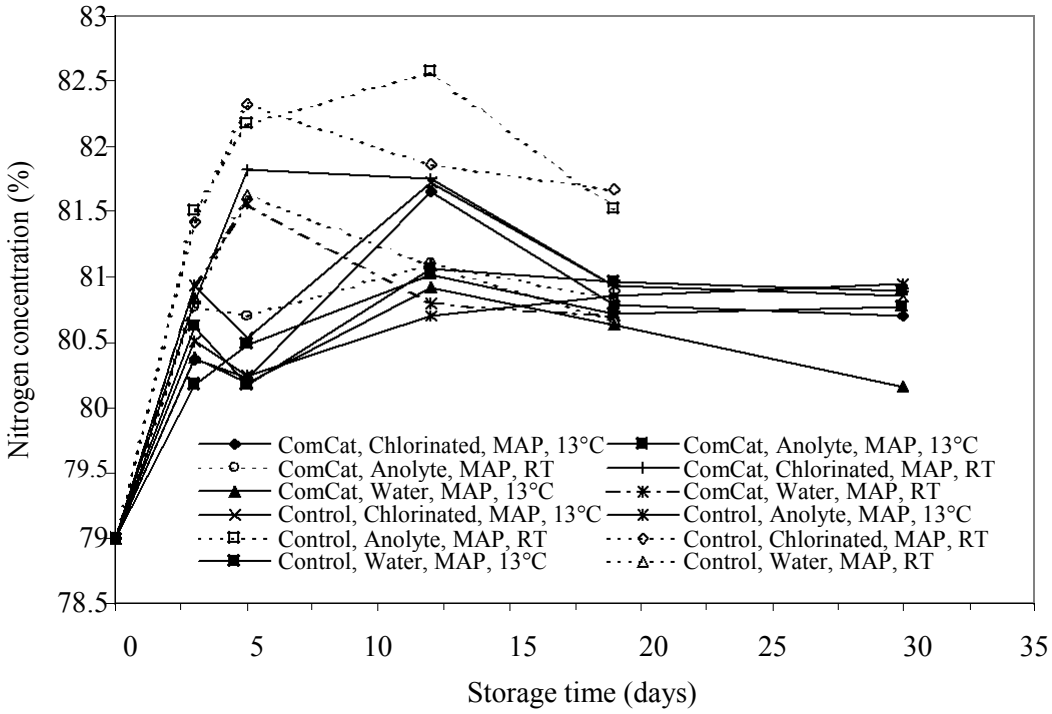

Figure 3. Changes in N_2 content (%) in packages of tomatoes in Xtend® film stored at 13°C and ambient temperature (RT) for 30 days (n = 3 over five storage time). $LSD_{0.05}$ Value = 0.618, S.E. = 0.0175 and C.V. = 0.005.

highly significant ($P \leq 0.001$) effect on the N_2 concentration in packages of tomatoes during storage. The N_2 concentrations remained higher in the packages of tomatoes stored at room temperature that is above 81.3%, especially during the first five days of storage. At day 5 of storage at room temperature, the N_2 levels of control tomatoes, which were disinfected with chlorine or anolyte, increased to above 82%, and stayed higher than the water washed ones throughout storage. The N_2 levels of the ComCat® treated and chlorine washed packaged tomatoes increased to above 81.5% from day 5 to day 12, but dropped to 81% at day 19. The water washed ComCat® treated tomato packages also had approximately 81.5% of N_2 content at day 5, but dropped to 81% at day 12, while the anolyte treated ones stayed below 81%, following approximately the same pattern as the tomatoes stored at 13°C. The two-way interaction between the preharvest ComCat® treatment and storage temperature had a significant ($P \leq 0.001$) effect on the changes in the N_2 concentration in packages of tomatoes during storage. The N_2 concentrations were also significantly ($P \leq 0.001$) influenced by the three-way interaction between preharvest ComCat® treatment, disinfecting treatments and storage temperature.

DISCUSSION

The quality that fresh produce has at harvest can be extended by a variety of postharvest processes, such as MAP (Jeon and Lee, 1999; Seyoum et al., 2001). The results of this chapter show that MAP with microperforated Xtend® film not only resulted in normal respiration of tomatoes, but also reduced moisture loss from the produce. This is in agreement with previous findings that the medium or least permeable film, maintains the moisture in packages at a proper level during storage (Jeon and Lee, 1999). Condensation is also prevented by this material, thus preventing microbial growth due to high relative humidity (Zagory and Kader, 1988).

The O_2 utilisation by the tomatoes was faster during the first 3 days of storage at 13°C as well as room temperature. This pattern was similar to that previously described for many packaged fruits and vegetables (Smith et al., 1987; Carlin et al., 1990). During MAP, O_2 and CO_2 concentrations remained above 15% and below 6% in microperforated Xtend® film during storage, respectively (Figures 1 and 2), suggesting that there was normal respiration of tomatoes during the storage period (Exama et al., 1993; Jeon and Lee, 1999).

Although, the modified atmosphere created by microperforated Xtend® film did not excessively reduce O_2 and increase CO_2 levels, the data clearly show that the metabolic activity was retarded due to MAP when compared to unpackaged fruit. MAP also resulted in the preservation of quality attributes such as AA content. After 24 days at room temperature the AA was 15.0 and

26.4% more in packaged ComCat® treated and control tomatoes respectively (Table 1). Similarly, the AA retention was 16.1 and 36.7% more in packaged ComCat® treated and control tomatoes stored at 13°C for 30 days, respectively. The modified atmospheres created by Xtend® film delayed the ripening of tomatoes, and the AA increased with ripening during storage. This is in agreement with similar findings reported by Batu and Thompson (1998) and Saito et al. (2000). Although the least permeable packaging might be preferred to reduce microbial growth (Batu and Thompson, 1998), MAP with high permeability was reported to be significantly protective (Seyoum et al., 2001). The current results showed that the population of total aerobic bacteria, molds, yeasts and total coliforms were generally found to be less in packaged tomatoes than in unpackaged tomatoes stored at 13°C, as well as room temperature (Tables 2 to 4), although some discrepancies were observed during some storage intervals.

Storage temperature was the most important factor affecting the postharvest quality and shelf life of tomatoes. With increasing temperature, the headspace concentrations of oxygen decreased, while carbon dioxide increased rapidly (Figures 1 and 2). Before equilibration, the concentrations of O_2 decreased up to 5 and 12 days in packages of tomatoes stored at room temperature and 13°C, respectively. Similarly, the CO_2 concentrations increased up to 5 and 12 days in the headspace of packages of tomatoes stored at room temperature and 13°C, respectively, after which equilibrium was attained. This would indicate that at higher temperature the metabolism in tomatoes was enhanced and the utilisation of O_2 increased with subsequent production of CO_2. Varoquaux and Wiley (1994) reported similar findings. Lowering the storage temperature therefore reduces the respiration, and delays senescence, while high temperature storage hastened the senescence of tomatoes. The changes in AA, microbiological and enzyme activity occurred at substantially faster rates in tomatoes stored at room temperature than in tomatoes stored at 13°C.

After 24 days of storage, the AA content was better retained in tomatoes stored at 13°C compared to those stored at room temperature (Table 1). The AA content of tomatoes was increasing in tomatoes during ripening and storage. Mohammed et al. (1999) reported a similar relationship in the changes in AA content of tomatoes during ripening in storage at 20°C. In general, the depletion of AA in tomatoes stored at room temperature could be attributed to the enhanced metabolism, ripening and senescence of these tomatoes compared to those stored at 13°C. Higher nutritional values in terms of higher AA content of tomatoes stored at 13°C for 30 days were evident from these data (Table 1). The AA content generally increased with ripening in tomatoes during 30 days of storage at 13°C. However, at room temperature the AA rapidly increased within 8 to 16 days of ripening and showed a decline after full ripeness of tomatoes. This trend was in agreement with previous data that AA content increased with ripeness (Mohammed et al., 1999), however, Watada et al. (1976) observed no change in AA content with ripeness. Chlorine solution and anolyte water are disinfecting agents and were used to control microorganisms. The use of chlorine is well studied and described. It was reported that chlorine treatment at 200 ppm reduced the population of pathogens by 0.35 to 3 log CFU cm^{-2} in tomatoes (Beuchat et al., 1998; Ukuku and Sapers, 2001).

In the current study, chlorinated water dipping treatment for 20 minutes significantly reduced the populations of total aerobic bacteria, moulds and yeasts, and total coliforms, compared to the populations in water washed tomatoes (Tables 2 to 4). However, the effectiveness of chlorine treatment decreased when tomatoes were stored at room temperature. These findings were similar to those reported by Ukuku and Sapers (2001) that the effectiveness of chlorine treatment diminished with increase in temperature and storage time. The anolyte water reduced ($P \leq 0.001$) and suppressed the growth of total aerobic bacteria, molds, yeasts and total coliform bacteria in tomatoes during storage as effectively as chlorinated water (Tables 2 to 3). It was also shown that 5 min dipping in anolyte water was sufficient for desirable control of microorganisms. The main reason for this is that the anolyte water contains freely available radicals (Seyoum et al., 2003), which are immediately available for action on the microorganisms, whereas in the case of chlorinated water these radicals are not freely available, and are formed slowly. As a result, anolyte water was found to be an effective method in controlling postharvest decay through killing and suppressing growth of total aerobic bacteria, moulds and yeasts, and total coliform bacteria during tomato storage for 30 days at 13°C as well as 24 days at room temperature.

The advantages of anolyte water above chlorine treatment were not only restricted to control of microorganisms. During the early active ripening period of tomatoes, the lowest O_2 and highest CO_2 concentrations were found in packages of tomatoes dipped in chlorinated water, compared to those dipped in anolyte, and those washed with water (Figures 1 and 2). These results thus suggested that the tomatoes dipped in chlorinated water had higher rates of respiration and metabolism than tomatoes dipped in anolyte water, or those washed with water. The loss of moisture was generally higher in tomatoes dipped in chlorinated water than in anolyte water (Table 1). This could be attributed to the effect of chlorine solution on the skin of tomatoes and surface tissue. It was observed that chlorinated water dipping treatment generally left a taint on the surface of tomatoes, while the surface of tomatoes dipped in anolyte water remained very shiny during the 30 days of storage at 13°C. These results thus implied that chlorinated water

might not be the optimum treatment for tomatoes, because it affects tomatoes by causing some stress condition. The effectiveness of microperforated packaging film increased when combined with a prepackaging disinfecting treatment. The main advantage of microperforations is that, it allows gas dynamics to create optimum gas composition specific to each fruit and vegetables.

However, at relatively higher O_2 and lower CO_2 level, the growth of microorganisms could not be suppressed, due to low CO_2 concentration. In this study, the prepackaging disinfecting treatment seemed to solve the problem of microorganisms and maximise the effectiveness of the modified atmosphere, created by the microperforated film during storage of tomatoes. These results thus showed that the coupled effect of disinfecting treatment and MAP was highly significant ($P \leq 0.001$) on the population of total aerobic bacteria, moulds and yeasts, and total coliforms in tomatoes (Tables 2 to 4). Similarly, the interaction between disinfecting treatment + MAP and storage temperature had a significant effect on gas concentrations and AA content (Figures 1 to 3, Table 1). The effect of ComCat® on postharvest quality and shelf life of tomatoes was investigated under different postharvest treatment practices. Directly after harvest the ComCat® treated tomatoes differed from the control tomatoes in having lower contents of AA and natural microbial populations. This treatment also had an effect on some of the quality parameters during storage.

Although the differences in gas concentrations (O_2, CO_2 and N_2) in the headspace of packages were not clear for storage at optimum temperature (13°C), the differences were highly significant in packages of ComCat® treated and control tomatoes stored at room temperature (Figures 1 to 3). The small difference in O_2, CO_2, and N_2 concentrations in packages of ComCat® treated and control tomatoes stored at 13°C suggest that at this storage temperature, both products had similar respiration and metabolism rates. However, during storage at room temperature, the air in the headspace of ComCat® treated tomatoes had higher O_2, lower CO_2 and lower N_2 concentrations than the microatmosphere in the packages of control tomatoes. This indicates that control tomatoes had a higher rate of respiration, utilising more O_2 and releasing more CO_2 at room temperature than the ComCat® treated ones.

Although the AA content was slightly less in ComCat® treated tomatoes at harvest (Table 1), it increased more in ComCat® treated tomatoes during storage at 13°C up to 30 days. The AA content was 8.7 and 19.1% more in ComCat® treated tomatoes disinfected in chlorinated and anolyte water after 30 days at 13°C respectively, when compared with controls. The results that ComCat® treated tomatoes were superior to the controls, in many cases at room temperature storage, was indicated by the two-way interaction between preharvest ComCat® treatment and storage temperature, which was highly significant ($P \leq 0.001$) on gas concentrations, AA content and microbiological flora of tomatoes during storage. Lower metabolism at room temperature in ComCat® treated tomatoes contributed to the conservation of better quality at room temperature storage. Otherwise, storage at 13°C was the optimum storage temperature for both ComCat® treated and control tomatoes, and made the differences in quality attributes more complex.

Conclusion

The results showed that chlorine treatment may not be the optimum disinfectant, as is generally accepted. Other alternatives should be investigated. The anolyte water used here was showed to be a promising candidate in saving time, having less effect on the fruits and being environmentally friendly. Preharvest ComCat® treatment not only improved crop yield, as was found in previous work by other researchers, but resulted in better keeping quality of tomatoes. Benefits at 13°C storage offered a new strategy for preharvest plant protection and strong produce at harvest.

Moreover, combining preharvest ComCat® treatment with optimum storage temperature maintained better microbiological and nutritional quality in terms of higher AA content at full ripeness. Preharvest ComCat® treatment ensured better shelf life of tomatoes at 13°C due to a delayed senescence. Further benefits on the shelf life at room temperature storage, being lower respiration (high O_2, low CO_2, and low N_2) and delayed senescence, better microbiological quality in terms of lower total aerobic bacteria, moulds, and yeast populations. The findings that ComCat® treated tomatoes showed better storage performance than untreated controls, not just at 13°C, but also at room temperature, opens the possibility to investigate the storage performance of these tomatoes at temperatures higher than the optimum storage temperature of 13°C, but under controlled conditions such as evaporative cooling.

REFERENCES

Afek U, Orenstein J, Nuriel E (1998). Increased quality and prolonged storage of sweet potatoes in Israel. Phytoparasitica, 26: 307-312.

AOAC (1970). Official Methods of analysis. Assoc. Offic. Agr. Chemist. Washington, D.C.

Batu A, Thomposon AK (1998). Effects of modified atmosphere packaging on post harvest qualities of pink tomatoes. Turkish J. Agric. Forst., 22(4): 365-372).

Beuchat LR, Nail BV, Adler BB, Clavero RS (1998). Efficiency of spray application of chlorinated water in killing pathogenic bacteria on row apples, tomatoes and lettuce. J. Food Prot., 61(10): 1305-1311.

Brackett RE (1990). Changes in the microflora of packaged fresh bell peppers. J Food Prot., 53: 255-257.

Carlin F, Nguyen-The C, Hilbert G, Chambroy Y (1990). Modified atmosphere packaging of fresh, “ready-to-use” grated carrots in polymeric films. J. Food Sci., 55(4): 1033-1038.

Exama A, Arul J, Lenckiand R, Li Z (1993). Suitability of various plastic films for modified atmosphere packaging of fruits and vegetables:

Gas transfer properties and effect of temperature fluctuation. Acta Hort., 343: 175-180.

Fallik E, Aharoni Y, Copel A, Rodov V, Tuvia-Alkalai S, Horev B, Yekutieli O, Wiseblum A, Regev R (2000). A short hot water rinse reduces postharvest losses of 'Galia' melon. Plant Pathol., 49: 333-338.

Fallik E, Grinberg S, Alkalai S, Yekutieli O, Wiseblum A, Regev R, Beres H, Bar-Lev E (1999). A unique and fast postharvest method to improve storage quality of sweet pepper. Posth. Biol. Technol., 15: 25-32.

Jeon BS, Lee CY (1999). Shelf-life extension of American fresh ginseng by controlled atmosphere storage and modified atmosphere packaging. J. Food Sci., 64(2): 328-331.

Johnson GI, Sangchote S (1994). Control of postharvest diseases of tropical fruits: challenges for the 21th century. In: Postharvest Handling of Tropical Fruits, ACIAR Proceedings, 50: 140-161.

Leonardi C, Guichard S, Bertin N (2000). High vapour pressure deficit influences growth, transpiration and quality of tomato fruits. Sci.. Hort., 84: 285-296.

Mohammed M, Wilson LA, Gomes PI (1999). Postharvest sensery and physiochemical attributes of processing and nonprocessing tomato cultivars. J. Food Qual., 22: 167-182.

Prusky D, Eshel D, Kobiler H, Yakoby N, Moualem DB, Ackerman M, Zuthji Y, Arie RB (2001). Postharvest chlorine treatments for the control of the persimmon black spot disease caused by Alternaria alternata. Posth. Biol. Technol., 22(3): 271-277.

Saito M, Rai DR, Masuda R (2000). Effect of modified atmosphere packaging on glutaathione and ascorbic acid content of asparagus spears. J. Food Proc. Preserv., 24: 243-251.

Salisbury FB, Ross CW (1992). Plant Physiology. Belmont, CA: Wadsworth, pp. 357-407, 531-548.

Schnabl H, Roth U, Friebe A (2001). Brassinosteroids-induced stress tolerances of plants. Recent Res. Dev. Phytochem., 5: 169-183.

Seyoum TW (2010). Feasibility and economic evaluation of low-cost evaporative cooling system in fruit and vegetables storage. Afr. J. Food Agric. Nutr. Dev., 10(8): 2984-2997.

Seyoum TW, Osthoff G, Pretorius JC, Hugo CJ (2003). Comparison of anolyte and chlorinated water as disinfecting dipping treatment for stored carrots. J. Food Qual., 28: 23-56.

Seyoum TW, Woldetsadik K (2001). Natural ventilation evaporative cooling of mango. J. Agric. Biotechnol. Environ., 2(1): 1-5.

Smith SM, Geeson JD, Stow J (1987). Production of modified atmospheres in deciduous fruits by the use of films and coatings. HortSci., 22: 772.

Ukuku DO, Sapers GM (2001). Effect of sanitizer treatments on Salmonella Stanley attached to the surface of cantaloupe and cell transfer to fresh-cut tissues during cutting practices. J. Food Prot., 64(9): 1286-1291.

Varoquaux P, Wiley RC (1994). Biological and biochemical changes in minimally processed refrigerated fruits and vegetables. In: R. C. Wiley (ed.). Minimally Processed Refrigerated Fruits and Vegetables. Chapman and Hall, London, pp. 226-258.

Watada AE, Aulenbach BB, Worthington JK (1976). Vitamin A and C in ripe tomatoes as affected by stage of ripeness at harvest and supplementary ethylene. J. Food Sci., 41: 856-858.

Zagory D, Kader AA (1988). Modified atmosphere packaging of fresh produce. Food Technol., 42(9): 70-77.