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RESEARCH ARTICLE

Influence of chlorine and rosemary essential oil postharvest pre-treatments on quality parameters of fresh tomatoes during storage

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ABSTRACT

Tomato is perishable and its high moisture content makes it susceptible for various postharvest losses. Tomato quality changes continuously after harvesting, when fruits start lose quality because of environmental stress and pathogen infection. The study determined the effects of chlorine and rosemary essential oil (REO) on the quality parameters and shelf life of fresh tomatoes during storage at ambient temperature. Tomatoes of uniform shape and colour and free from pathogens were selected. Treatments were applied in a central composite design where chlorine (100, 200, 300 and 400 ppm of NaClO as hypochlorite of sodium), immersion time (1.5, 3, 4.5 and 6 minutes) and REO (200, 500, 700 and 1000 ppm) were factors considered. Data were analysed through XLSTAT and STATISTICA. Results indicate that significant decrease in weight loss was observed where there was increase in REO concentrations. All tomatoes converted towards full red independently of the factors from D10 of storage. Presence of defects was observed with different intensity in treatments. Most fruits softened with the increase in fruit colour and storage time. Chlorine and REO concentrations had an influence on the tomato flavour. There was extended shelf life of fruits since they were harvest at later stage for storage (light red).

Keywords: Chlorine, Fruit quality, Rosemary essential oil, Shelf fife, Tomato

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INTRODUCTION

Tomato (*Solanum lycopersicum* Mill.) is one of the most consumed foods throughout the world (Méndez et al., 2011). It is a horticultural crop of great interest, having good nutritional value, medicinal properties and economic importance of being widely consumed either fresh or processed in products (juice, soup, paste, puree, ketchup, sauce and salsa); unfortunately, it is highly perishable and has limited shelf life at ambient conditions (Davoodi et al., 2007); which is about 48 hours under tropical conditions (Arah et al., 2016). Spoilage of tomatoes is a continuing problem, although significant improvements have been made in packaging and refrigeration. Softening and ripening during storage and distribution of tomatoes can be a major problem because it may increase their susceptibility to damage (Batu, 2004; Ndirangu et al., 2017). The use of 1-MCP at low concentrations has been shown to slow down many of the metabolic activities associated with the ripening process such as colour change, cell wall breakdown, and respiration rates making it a useful technique in extending storage life of fruits (Arah

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et al., 2016), but when used at high concentrations, it increased their decay (Cai et al., 2006). Fruits lose quality after harvest because of environmental stress and pathogen infection (Lai et al., 2011). Lipid oxidation and bacterial contamination are the main factors that determine food quality loss and shelf life reduction (Rozman and Jersek, 2009). The presence of spoilage organisms in fruits and vegetables is a result of contamination of their surfaces; therefore, there is need to reduce contamination by ensuring sanitization of fruits and vegetable surfaces (Potter and Hotchkiss, 1993 as cited by Magashi and Bukar, 2007). Different chemical washing agents have been studied to determine their efficacy in the inactivation of pathogenic bacteria on vegetables (Petri et al., 2011; Arah et al., 2016). It has been reported that fruits and vegetables are washed in chlorine or potassium permanganate before packaging in order to reduce micro flora, especially bacteria from the produce (Giraldo et al.,1977 as cited by Nasrin et al. 2008; Bartz et al., 2013). Chlorine is the most commonly used sanitizer due to its efficacy, cost-effectiveness ratio and simple use (Petri et al., 2011). Washing raw produce with water containing sodium hypochlorite (NaOCl) is the most commonly used method for removing pathogens from the surfaces of vegetables (Povratanak et al., 2015; El-Ramady et al., 2015; Arah et al., 2016). Chlorine water is achieved by adding 200 ppm sodium hypochlorite in clean water (Povratanak et al., 2015).

There has been increasing interest to replace synthetic preservatives with natural, effective and nontoxic compounds (Marija and Nevena, 2009; Oliveira et al., 2013). In the search for natural preservatives, much attention has been directed to herbs and spices (Govaris et al., 2010). Essential oils from are known to possess biological activity, notably antibacterial, antifungal, and antioxidant properties (Celikel and Kavas, 2008). A number of essential oils components that are considered to present no risk to the health of the consumer have been registered for use as flavourings in foodstuffs by the European Commission (Hamedo and Abdelmigid, 2009). Rosemary (*Rosmarinus officinalis* L.) is widely used as a culinary herb for its desirable flavour throughout the world. It is reported that rosemary has been widely accepted as one of the spices with the highest antioxidant activity and rosemary essential oil is also used as an antibacterial, antifungal and anticancer agent (Peng et al., 2005; Genena et al., 2007; Rozman and Jersek, 2009).

An increase in the storage life and improvement of tomato fruit quality is really desirable and the extending the shelf life of tomatoes is very important for domestic and export markets. Thus, the objective of this study was to determine the effects of a rosemary essential oil (REO) combined to chlorine, on the fresh-like aspect, shelf life and quality of tomato fruits.

MATERIALS AND METHODS

Raw materials Selection

Tomatoes (*Rio Grande* cv. at red light stage) were procured from a local producer and immediately transported to the Microbiology Laboratory (University of Yaoundé I, Cameroon). Rosemary essential oil was bought on the market. It was produced from flowers and stems of the plant and delivered by Reynauld et Fils (France). The lot essential oil was declared pure, without any mixture or dilution by the producer.

Treatments

Tomato fruits of uniform shape and colour and free from visible microbial infection were selected, and dipped in a hypochlorite solution (100, 200, 300 and 400 ppm of NaOCl as sodium hypochlorite) at different times (1.5, 3, 4.5 and 6 minutes). Fruits were then left to drip for on an absorbent paper and exposed to different concentrations of Rosemary essential oil (REO) released by spray (200, 500, 700 and 1000 ppm) according to a central composite design (CCD) (Table 1). The spray was done in order to cover all the surface of the tomatoes. In all, 20 treatments were performed according to the experimental design and kept in boxes at ambient temperature, varying between 28-30°C.

TABLE 1. Central Composite Design (CCD)

Central Composite Design (CCD)				Corresponding values			
Treatments	***F_1 (ppm)**	**F_2 (min)**	**F_3 (ppm)**	**Treatments**	**NaOCl (ppm)**	**Time (min)**	**REO (ppm)**
1	-1	-1	-1	1	100	1.5	200
2	-1	1	1	2	100	4.5	700
3	1	-1	1	3	300	1.5	700
4	1	1	-1	4	300	4.5	200
5	0	0	0	5	200	3	500
6	-1	-1	1	6	100	1.5	700
7	-1	1	-1	7	100	4.5	200
8	1	-1	-1	8	300	1.5	200
9	1	1	1	9	300	4.5	700
10	0	0	0	10	200	3	500
11	-2	0	0	11	0	3	500
12	2	0	0	12	400	3	500
13	0	-2	0	13	200	0	500
14	0	2	0	14	200	6	500
15	0	0	-2	15	200	3	0
16	0	0	2	16	200	3	1000
17	0	0	0	17	200	3	500
18	2	-2	2	18	400	0	1000
19	2	2	2	19	400	6	1000
20	-2	-2	-2	20	0	0	0

Observations

During storage, observations were taken after 2 days interval for 22 days, except for the weight loss. Tomato fruit quality was determined by visual assessment, and the quality characters (appearance, colour, texture, and flavour) were assessed by 10 trained panellists, aged between 20 and 40 years on a 5 point hedonic scale. Storage indices for each parameter were analyzed using the following formula:

$$Is = \frac{[\sum(SCOREi \ X \ DAYi)]}{(\textbf{Maximum score X} \sum DAYi)} ,$$

Where by:

Is is the storage index
SCOREi is the evaluation of a certain criteria on a certain dayi
Maximum score is the highest evaluation possible for that criteria, and
∑DAYi is the sum of the numbers of days at each analysis

The colour development was assessed using a tomato colour chart as proposed by Abdullah et al. (2004). The effect of the treatments on the shelf life was determined with respect to the control, after 22 days of storage. Selected fruits were weighed before applying the treatments using electronic digital balance at the beginning and the end of storage experiment. The loss in weight was determined by the following formula and expressed as percentage (Gharezi et al., 2012):

$$\text{Weight loss (\%)} = \frac{\text{Initial fruit weight} - \text{Final fruit weight}}{\text{Initial fruit weight}} \times 100$$

Statistical Analyses

A central composite design was used with 20 treatments. Statistical analyses were performed using XLSTAT and STATISTICA packages. Results and Regression analysis were statistically evaluated by variance analysis (ANOVA) and statistical differences between the mean of the groups was determined by Tukey test ($\alpha \leq 0.05$).

RESULTS AND DISCUSSION

Evaluation of fruit quality parameters

Table 2 shows the storage indices with regards to fruit colour development, presence of defects, fruit firmness and fruit flavour.

Colour development

All tomatoes converted towards full red independently of the factors (Table 2). Initially, all fruits were light red in colour; the full red colour was quite effective from day 10 of storage. Colour in tomato is the most important external characteristic to assess ripeness and postharvest life. Red colour is the result of chlorophyll degradation as well as synthesis of lycopene and other carotenoids (Radzevicius et al., 2008; Tigist et al., 2015; Dari et al., 2018). The increment in colour index might be an indication of the development of deep red colour in tomato. After harvest, ripening continues and tomatoes can become overripe very rapidly (Batu, 2004). It has been reported that colour development depends on a number of factors including temperature (which influences colour uniformity of tomatoes), maturity stage and the storage duration (Grierson and Kader, 1986 and Tijskens and Evelo, 1994 as cited by Tigist et al. 2015). Ripening processes are associated with increasing lycopene content that varies considerably between cultivars, stages of maturity and growing condition (Shalluf, 2010).

Defects presence

Fruit lose quality after harvest because of environmental stress and pathogen infection (Lai et al., 2011). From the results (Table 2), statistical analyses show significant differences in terms of pathogen infection in all treatments at different days of storage. Results (Table 2) show that after 10 days of storage, some fruits started showing signs of pathogen infection, thus affecting the fruit quality. At the end of the storage period, most fruits from the treatments had defects, though at different levels: < 25% for treatments T2, T9, T10, T16 and T17; 25 - 50% for T4, T5, T7, T11, T12, T13, T15, T19 and T20 and > 50% for treatments T1, T3, T6, T8 and T18. Results show that the very high percentage of defects presence (> 50%) could probably be related to the reduced time of immersion (0-1.5 minutes) in chlorinated water for fruits surface disinfection. It is known from literature that not only higher concentration of chlorine can increase its effectiveness of killing microorganisms but also that its bactericidal activity increases with longer exposure time. Also, Hong and Gross (1998) state that sodium hypochlorite treatment has a pronounced effect on texture of tomato tissue after treatment; this in explanation to the lower percentage of defects presence (42%) observed in the control treatment (T20). The lowest percentage (< 25%) observed might have resulted from the combination of both treatments: immersion time (3- 4.5 minutes) and rosemary essential oil concentrations (500-1000 ppm). The presence of defects on tomato fruits could probably be the consequences of microbial growth during storage period associated to others uncontrolled factors (internal or external). According to Bartz et al. (2013), certain pathogens, including bacteria and viruses, may survive on or in fresh tomato fruit. The movement of living bacteria or fungal structures into fruit tissues is known as internalization and leads to a situation that cannot be corrected. It has also been mentioned that active growth of a pathogen may also occur in food from improper storage as a result of passive transfer of pathogens to food (Celiktas et al., 2007).

Table 2. Storage indices of tomato fruit quality parameters

Treatments	NaOCl	Time	REO	Colour index (Ci)			Defects index (Di)			Firmness index (Fi)			Flavour index (Fl)		
	(ppm)	(min)	(ppm)	Ci 1*	Ci 10*	Ci 22*	Di 1	Di 10	Di 22	Fi 1	Fi 10	Fi 22	Fl 1	Fl 10	Fl 22
1	100	1.5	200	0.80	0.98	1.00	0.20	0.45	0.63	0.20	0.38	0.55	1.00	0.19	0.54
2	100	4.5	700	0.80	0.99	1.00	0.20	0.20	0.23	0.20	0.42	0.56	0.80	0.20	0.60
3	300	1.5	700	0.80	0.99	1.00	0.20	0.45	0.56	0.20	0.38	0.55	0.80	0.20	0.46
4	300	4.5	200	0.80	0.99	1.00	0.20	0.38	0.40	0.20	0.50	0.58	0.80	0.20	0.46
5	200	3	500	1.00	1.00	1.00	0.20	0.38	0.40	0.20	0.42	0.56	0.80	0.20	0.60
6	100	1.5	700	0.80	0.99	1.00	0.20	0.45	0,56	0.20	0.45	0.56	0.80	0.26	0.40
7	100	4.5	200	0.80	0.99	1.00	0.20	0.35	0.39	0.20	0.32	0.53	0.80	0.20	0.60
8	300	1.5	200	0.80	0.99	1.00	0.20	0.45	0.56	0.20	0.45	0.56	0.80	0.26	0.32
9	300	4.5	700	0.80	0.99	1.00	0.20	0.20	0.20	0.20	0.35	0.54	0.80	0.20	0.60
10	200	3	500	1.00	1.00	1.00	0.20	0.20	0.20	0.20	0.35	0.54	0.80	0.20	0.60
11	0	3	500	0.80	0.95	0.99	0.20	0.35	0.39	0.20	0.35	0.54	0.80	0.20	0.60
12	400	3	500	0.80	0.99	1.00	0.20	0.20	0.34	0.20	0.35	0.54	1.00	0.19	0.46
13	200	0	500	0.80	0.99	1.00	0.20	0.38	0.40	0.20	0.47	0.57	1.00	0.19	0.45
14	200	6	500	0.80	0.98	1.00	0.20	0.20	0.34	0.20	0.20	0.51	0.80	0.20	0.60
15	200	3	0	0.80	0.99	1.00	0.20	0.35	0.39	0.20	0.38	0,55	0.80	0.20	0.46
16	200	3	1000	0.80	0.99	1.00	0.20	0.20	0.20	0.20	0.45	0.56	0.80	0.20	0.60
17	200	3	500	0.80	0.99	1.00	0.20	0.20	0.20	0.20	0.47	0.57	0.80	0.20	0.60
18	400	0	1000	0.80	0.99	1.00	0.20	0.32	0.53	0.20	0.47	0.57	0.80	0.26	0.32
19	400	6	1000	0.80	0.99	1.00	0.20	0.20	0.35	0.20	0.35	0.54	1.00	0.19	0.60
20	0	0	0	0r.80	0.95	0.99	0.20	0.35	0.42	0.20	0.38	0.55	1.00	0.19	0.57

** the number followed by the indices refers to the day of storage*

Fruit Firmness

Generally, the fruit firmness decreases with increase in the storage period (Znidarcic and Pozrl, 2006; Tabaestani et al., 2013). Results (Table 2) indicate significant differences in treatments at 10 days of storage, where fruits from T14 were slightly firmer compared to other treatments with regards to day 1 of storage. Reaching 22 days of storage, all treatments were softened. It has been reported that maturation causes a slight softening in tomato (Batu, 2004), and that flesh softening of tomato fruit is usually the result of fruit ripening which is accompanied by a burst in ethylene production (Lai et al., 2011). According to Luna-Guevara et al. (2014), during the ripening and storage period, the loss of firmness in tomatoes is the actions of different enzymes like cellulose, pectinesterase and polygalacturonase (which is the principal responsible of softening in tomato) on cell wall, media lamella and plasmatic membrane. The breakdown of these large polymers into smaller water-soluble components during ripening leads to fruit softening as observed during the breakdown of pectin in tomato (El-Ramady et al., 2015).

Table 3. Percentage of spoiled fruits during storage

Treatments	NaOCl (ppm)	Time (min)	REO (ppm)	Day 10	Day 22
1	100	1.5	200	25	50
2	100	4.5	700	0	25
3	300	1.5	700	20	40
4	300	4.5	200	0	22
5	200	3	500	10	10
6	100	1.5	700	14.29	42.86
7	100	4.5	200	10	20
8	300	1.5	200	25	37.5
9	300	4.5	700	0	25
10	200	3	500	0	0
11	0	3	500	11.11	22.22
12	400	3	500	10	30
13	200	0	500	10	10
14	200	6	500	0	10
15	200	3	0	0	10
16	200	3	1000	0	0
17	200	3	500	0	0
18	400	0	1000	20	30
19	400	6	1000	0	10
20	0	0	0	10	30

Fruit Shelf life

The shelf life (expressed in days) is a period of time which starts from harvesting and extends up to the start of rotting of fruits (Mondal, 2000 as cited by Nasrin et al., 2008). Although some fruits had shown the presence of defects all along the period of the experiment, the shelf life was determined when the fruits started decaying. Our results (Table 3) indicate that at 10 days of storage, treatments T2, T4, T9, T10, T14,T15, T16, T17 and T19 had fruits that did not show any sign of decay; and all other treatments had 10-25% of decayed fruits. This observation could be the right effect of immersion time of fruits in chlorinated water together with high concentration of REO; most treatments that had spoiled fruits were either not disinfected in chlorinated water or dripped in chlorinated water in less than 3 minutes. At the last day of storage period, only treatments T10, T16 and T7 maintained the fresh aspects of fruit (0% of spoiled fruits), while treatments T5 and T13 had maintained fruits in the same aspect as from 10 day of storage (10% of spoiled fruits). At 22 days of storage, all treatments that had less than 3 minutes immersion in chlorinated water had realised more than 30 % spoiled fruits.

From the results above, the fruit shelf life was increased in most of the treatments regarding the harvesting stage (red light) since after harvest, ripening continues and tomatoes can become overripe very rapidly, resulting in restricted shelf life; this probably because according to Nasrin et al. (2008), shelf life of tomato can be extended at ambient temperature up to 17 days without excessive deterioration in quality by treating the fruits with chlorine, and packaging in perforated polyethylene bags. It is also well known that, being a climacteric and a perishable vegetable, tomatoes have a very short life span, usually 2-3 weeks (Dilmacunal et al., 2011) when harvested at mature green stage.

Fruit flavour

Significant differences result among the treatments. A regression analysis for flavour prediction was obtained in order to explain the effect of different variables on the tomato flavour. According to this equation,

Flavour score = 0.436+0.007*[HE] +0.0024*[CL]*[t]-0.0031* [t]*[HE]-
Where, HE refers to REO; CL refers to NaOCl, and t to immersion time

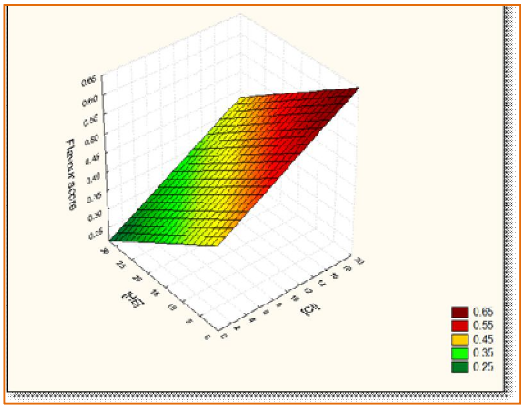

Figure 1: Influence of chlorine and EO at 4.5 min treatment on the flavour of fresh tomatoes

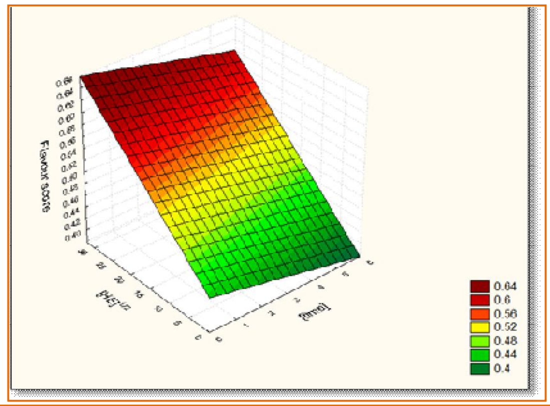

Figure 2: influence of time of treatment and EO when chlorine is used at 200ppm on the flavour of fresh tomatoes

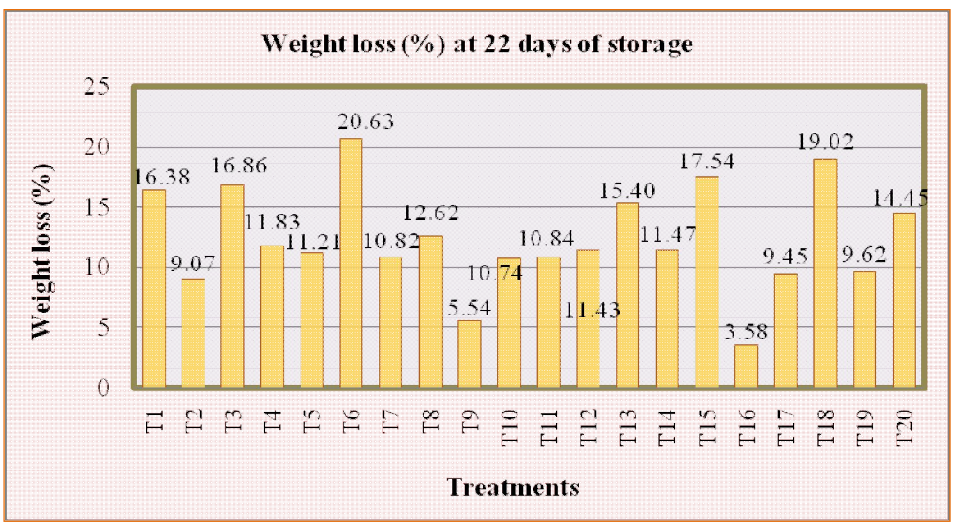

Figure 3. Percentage of fruit Weight loss after 22 days of storage

Results from the above figures indicate that the higher the concentrations of chlorine and REO, the higher the tomato flavour. It should be remembered here that high tomato flavour means flavour associated to freshly harvested product. It is noted that flavour of tomato results mainly from a combination of volatile compounds for aroma and of sugars and acids for taste (Barret et al., 2010; Aoun et al., 2013). Several studies report aroma composition by cultivars, stages of ripeness, different culture conditions, and treatments suggesting that these parameters influence the aroma composition of tomato (Messina et al., 2012). Alteration and ripeness during storage contributes to flavour decay.

Weight loss

Weight change is most related to storage duration; the weight loss of fresh tomatoes is primarily due to transpiration and respiration which can lead to wilting and shrivelling (Znidarcic and Pozrl, 2006; Gharezi et al., 2012). The lowest percentage in weight loss was observed in T16 (3.57%) whereas the highest was in T6 (20.63%) (Fig.3).

There was significant fruit weight loss among the treatments after 22 days of storage at ambient temperature among different treatments (Table 4). Significant differences observed in weight loss of fruits could be due to the interaction effects of treatments. Tables (5, 6 and 7) show differences among treatments in regards to interactions among factors. Results indicate that there was a significant decrease in percentage weight loss where there was an increase in the concentration of rosemary essential oil (REO). This reduction in weight loss is probably due to the effects of the coating as a semi-permeable barrier against O2, CO2, moisture and solute movement, thereby reducing respiration, water loss and oxidation reaction rates (Abd-Alla et al., 2009; Dilmacunal et al., 2011; Gharezi et al., 2012; Tabaestani et al., 2013).

Table 4. ANOVA for percentage in fruit weight loss

Source	Df	SS	MS	F	Pr > F
Treatments	16	346.497	21.656	15.428	0.022
Error	3	4.211	1.404		
Total	19	350.708			

(α=*0.05*)

Table 5. Mean separation of NaOCl and immersion time for the % in weight loss

Factors	Mean	Standard error	Groups				
NaOCl400*min0	26.977	1.616	A				
NaOCl400*min6	17.582	1.616		B			
NaOCl100*min1,5	16.997	1.039		B			
NaOCl200*min0	16.471	1.294		B			
NaOCl300*min1,5	13.230	1.039		B	C		
NaOCl200*min6	12.538	1.294		B	C	D	
NaOCl400*min3	12.502	1.294		B	C	D	
NaOCl0*min3	11.905	1.294		B	C	D	
NaOCl200*min3	11.536	0.604			C	D	
NaOCl0*min0	8.441	1.616			C	D	E
NaOCl100*min4,5	8.436	1.039				D	E
NaOCl300*min4,5	7.174	1.039					E

Table 6. Mean separation of NaOCl and REO for the % in weight loss

Factors	Mean	Standard error	Groups			
NaOCl200*REO0	20.986	1.452	A			
NaOCl400*REO500	19.414	1.378	A			
NaOCl00*REO0	16.925	1.428	A	B		
NaOCl200*REO500	13.908	0.820		B	C	
NaOCl100*REO700	12.658	1.142		B	C	
NaOCl400*REO1000	12.524	0.881		B	C	
NaOCl100*REO200	11.407	1.142		B	C	D
NaOCl300*REO200	10.032	1.142		B	C	D
NaOCl0*REO500	9.847	1.523			C	D
NaOCl300*REO700	9.005	1.142			C	D
NaOCl200*REO1000	7.018	1.317				D

Table 7: Mean separation of immersion time and REO for the % in weight loss

Factors	Mean	Standard error	Groups			
min1,5*REO700	23.143	1.283	A			
min0*REO0	20.374	1.246	A	B		
min1,5*REO200	18.898	1.283	A	B	C	
min4,5*REO200	15.721	1.283	A	B	C	D
min3*REO0	15.059	1.584	A	B	C	D
min0*REO500	13.296	0.996	A	B	C	D
min4,5*REO700	11.701	0.897		B	C	D
min6*REO500	11.701	0.897		B	C	D
min3*REO500	7.981	0.837			C	D
min0*REO1000	6.406	1.517			C	D
min6*REO1000	4.811	1.086				D
min3*REO1000	1.091	1.805				D

CONCLUSION

Physiological changes occurred during storage of fresh tomatoes. At 10 days of storage, all fruits converted to full red independently of the factors, though they were stored at the red light stage. Results have established that the presence of defects is related to the shorter time of immersion in chlorinated water for fruits surface disinfection, that immediately impact on the fruit shelf life. The longer the time of fruits immersion in chlorinated water coupled with high concentration of REO, the better the results. Reduction in fruit weight loss was effective in treatments with REO application. At the end of storage, most fruits softened in relation to the ripening stage and storage time. The study also established that chlorine and REO concentrations had a positive influence on the preservation tomato fresh flavour.

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