



Effect of chemical dips and packaging materials on quality and shelf life of tomatoes (*Lycopersicon esculentum*) in Kura, Nigeria

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ABSTRACT

Purpose: Tomato postharvest losses are as high as 60% in Nigeria despite being 13th producer. This could be reduced when tomatoes were carefully treated and packaged. This research investigated the effects of chemical dips and packaging on storability of tomatoes.

Research method: The research was a factorial design laid out in RCBD with three replications. The field work was done in Kura while the laboratory was done at Kano University of Science and Technology. Tomatoes were harvested, sorted, weighed into 3 kg lots and treated (D_1 = dip in water, D_2 = dip in 200 ppm NaOCl and 1% $CaCl_2$ for 5 minutes and D_3 = dip in 200 ppm NaOCl and 3% $C_6H_7K_2O_2$ for 5 and 1 minutes respectively) and packaged as follows: (P_1 = kraft paper, P_2 = perforated polyethylene and P_3 = sealed polyethylene). Analyses of firmness, % weight loss, % rot, ascorbic acid and lycopene were carried out every 3 days. Data collected were analyzed using GLM procedure (SAS) and means separated using LSD. **Main findings:** Results showed fruits dipped in 200 ppm NaOCl and $CaCl_2$ for 5 minutes; packaged in perforated PE; and fruits dipped in 200 ppm NaOCl and $CaCl_2$ for 5 minutes and packaged in sealed polyethylene were the best combinations. The treatments maintained physico-chemical parameters of tomatoes within acceptable limit for 24 days. **Limitations:** Firmness measurement was a challenge of the study. **Originality/Value:** A combination of the two factors is novel in the study environment and this could help in reducing the postharvest losses thereby improving farmers' income.

INTRODUCTION

The origin of tomato can be traced back to the coastal highlands of Central and South America where they grew wild in Ecuador, Peru and Bolivia. Following its introduction to Spain in 16th century it became widely dispersed throughout African continent (De-Lennoy, 2001).

Tomato (*Lycopersicon esculentum* Mill.) is a herbaceous plant belonging to the family Solanaceae. It is one of the most popular vegetables worldwide and it plays a vital role in human diet (Sibomana et al., 2015). The fruits are consumed in salads, cooked into soups or processed into juice, ketchup, puree and paste (Adedeji et al., 2006).

Tomatoes are rich in vitamins (particularly A and C), minerals, sugars, essential amino acids, iron, dietary fiber and phosphorus (Ayandiji & Adeniyi, 2011). Tomatoes also contain high amounts of lycopene, a carotenoid with antioxidant properties and beneficial in reducing the incidence of some diseases like cancer (Basu & Imrhan, 2007) and cardiovascular diseases (Freeman & Reimers, 2010).

Nigeria is the second largest producer of tomato fruits in Africa and 13th in the world (FAOSTAT, 2014). The estimated total postharvest losses of tomato in Nigeria is about 60% according to Kutama et al. (2007) which translates to huge economic losses. An important factor contributing to the high postharvest losses in tomato fruits is the use of unsuitable packaging containers (Kutama et al., 2007).

These huge losses prompted the search for simple, effective and economical method to control pre and postharvest disorders and other losses in tomato value chain. Postharvest technologies like chemical dips, packaging and storage conditions positively influence the level of postharvest losses and the quality of produce (Srividya et al., 2014; Dandago et al., 2017). Many researchers have investigated the effectiveness of different chemical dips on different fruits and vegetables. Garcia et al. (1995) demonstrated that calcium has multiple effects on several physiological processes in fruits and vegetables playing important role in maintaining the quality. Calcium applied directly to the fruit before and after ripening help to prevent physiological disorders in some fruits. Njoroge and Kerbel (1993) showed that calcium can be used to delay tomato ripening without affecting quality relative to pH, soluble solids and colour. In addition, treatment with calcium resulted in improved tomato firmness and extended the storage periods before attaining the red colour. Vigneault et al. (2000) demonstrated that maintenance of free chlorine at up to 200 ppm in the cooling water and prevention of direct water pressure on fruit minimize decay risks and larger exposure time generally enhances efficacy of chlorine for controlling micro-organisms. Sood et al. (2011) also reported that application of chlorine solutions reduce enzymatic activity and postharvest decay by pathogens thereby extending the storage life of the produce. Modified atmosphere packaging (MAP) using polymeric films is also a simple inexpensive method to extend the postharvest life of fresh fruits like tomatoes. Modified atmosphere packaging has been shown to delay ripening and extend the shelf life of tomato fruits (Batu & Thompson, 1998). Mathooko (2003) reported that under tropical conditions, the quality and storage life of tomato fruits can be extended and ripening delayed by modified atmosphere packaging. Ait-Oubahou (1990) developed a model for MAP of tomato fruits in Morocco where it was demonstrated that modified atmosphere conditions retained fruit flesh firmness, low acidity, soluble solid concentration and delayed lycopene development in tomato fruits. The aim of this work was to investigate the combined effect of postharvest dip and packaging materials on the quality and shelf life of tomato fruits in Kura, Kano State, Nigeria.

MATERIALS AND METHODS

The study was conducted between 2nd March to 27th March, 2014 at Kofar Yamma in Kura local Government Area of Kano State (Nigeria) located between latitude 11° 46' N and longitude 8° 25' E. The analyses were conducted at the Food Analysis Laboratory of the Department of Food Science and Technology, Kano University of Science and Technology Wudil and Kano area laboratory of Abuja Commodity Exchange Plc. Tomato fruits (UC 82B grown in Kura) of fairly uniform size were carefully harvested at green mature stage and free from visible defect. The factorial experiment laid out as a randomized complete block design (RCBD) with two factors at 3 levels and replicated three times was used. The treatments consisted of:

- i. freshly harvested tomato fruits dipped in tap water for 5 minutes (D₁)
- ii. freshly harvested tomato fruits dipped in 200 ppm Sodium hypochlorite (NaOCl) for 5 minutes and later dipped in 1% w/v Calcium chloride (CaCl₂) for 5 minutes (D₂)
- iii. freshly harvested tomato fruits dipped in 200 ppm Sodium hypochlorite (NaOCl) for 5 minutes and later dipped in 3% Potassium sorbate (C₆H₇KO₂) solution for 1 minute (D₃)

The packaging consisted of three levels also which were:

- i. Packaging of fresh tomato fruits in kraft paper bags (P₁)
- ii. Packaging of fresh tomato fruits in sparsely perforated low density polyethylene bags with 6 holes (P₂)
- iii. Packaging of fresh tomato fruits in sealed low density polyethylene bags (P₃)

Each treatment consisted of 3 kg of wholesome fruits dipped in the various dips and subjected to various forms of packaging and stored accordingly. Determinations were conducted on the following physicochemical parameters every three days.

Fruit firmness

The firmness of tomato fruits was measured with the aid of HP-FFF analog fruit firmness tester (Number 56695 Qualitest International Inc. Canada) using 0.25 cm² test anvil specifically for tomato fruits (Dandago et al., 2017). The tester was placed on two different points of the fruit (opposite each other) with a constant press. The firmness of the fruit was calculated as a quotient of the number directly displayed on the instrument (kgf). Triplicate determinations were conducted on each sample and average calculated.

Weight loss percentage

The weight loss percentage of the stored tomato fruits was determined as a percentage of the initial weight stored as reported by Dandago et al. (2017). This was done every three days for the period of storage of the tomato fruits (1).

$$\% \text{ Weight loss in Tomato} = \frac{\text{Total weight stored} - \text{Final weight}}{\text{Initial weight stored}} \times 100 \quad (1)$$

Decay percentage

Rotted fruits when spotted during storage were isolated and the percentage of rot calculated as a percentage of initial weight of tomato stored (Dandago et al., 2017) (2).

$$\% \text{ Decay in Tomato} = \frac{\text{Total weight stored} - \text{Weight of rotted fruits}}{\text{Initial weight stored}} \times 100 \quad (2)$$

Ascorbic acid content

The ascorbic acid content of the tomato fruits was determined by the indophenol method as reported by Onwuka (2005). The fruit was pulped using domestic juice extractor (Master Chef Model MC-J2101). Two grams of the blended pulp was weighed and 100 ml of distilled water added to it in a volumetric flask. The solution was filtered using a filter paper to get a clear solution. 50 ml of unconcentrated juice was then pipetted into 100 ml volumetric flask in triplicate. 25 ml of 20% Metaphosphoric acid was added as a stabilizing agent and diluted to 100 ml volume. About 10 ml of the solution was then pipetted into small flask and 2.5 ml of acetone added. The solution was titrated with 2,6 - Dichlorophenol indophenol to a faint pink color which persisted for roughly 15 seconds. The amount of ascorbic acid in the tomato fruit was calculated as follows (3):

$$\text{Vitamin C (mg / 100 g)} = 20 \times V \times c \quad (3)$$

Where V= ml indophenol solution in titration and c= mg vitamin C per ml indophenol

Lycopene content

Lycopene content of the fruits was determined according to the method described by Dandago et al. (2017). Fresh tomato fruits were squeezed using potable juice extractor (Master Chef Model MC-J2101) to obtain pure tomato juice. The freshly squeezed sample was drawn into a 100 µl micro pipette and the outside glass bore was wiped clean using tissue paper. The pipette was allowed to stand so as to dispel air bubbles out of the pipette. The sample was then dispensed into 50 ml separating funnel and closed tightly. Blank samples using 100 µl of water instead of tomato juice was prepared. 8 ml of hexane: ethanol: acetone in ratio 2:1:1 was carefully added immediately and kept out of bright light. After about 10 minutes 1 ml of water was also carefully added and vortex again. The sample was allowed to stand for another 10 minutes to allow the phases to separate and air bubbles disappear. The cuvette of the spectrophotometer was rinsed clean with upper layer from one of the blanks.

The liquid was discarded and another fresh blank was used to zero the spectrophotometer (Jenway Model 752) at 503 nm. The absorption of the upper layers of the sample was then determined using spectrophotometer at 503 nm. Lycopene content was then calculated using the following relationship (4):

$$\text{Lycopene (mg/kg fresh weight)} = \frac{(A_{503} \times 537 \times 8 \times 0.55)}{(0.10 \times 172)} = (A_{503} \times 137.4) \quad (4)$$

Statistical analysis

Data generated were analysed using Generalised linear model (GLM) procedure of Statistical Analysis System and means separated using LSD (SAS/STAT® software release 9.2.).

RESULTS AND DISCUSSION

Table 1 presents the interaction between postharvest dip and packaging on tomato fruit firmness. On the day 9 of the experiment as the dips were changed from tap water to NaOCl with CaCl_2 , and then to NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ fruit firmness increased to 0.0219 and 0.0218 respectively. The two were however not statistically different. When perforated low density polyethylene bags were used for storage, tomato fruit firmness was significantly lower than the values obtained from NaOCl with CaCl_2 , and then to NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ in kraft paper packaging. When seal low density polyethylene bags were used for packaging the fruits, the firmness of fruits dipped in NaOCl for 5 minutes and CaCl_2 for 5 minutes was not different from that of the control and also statistically similar to those in perforate low density polyethylene bags. Fruits that were dipped in NaOCl for 5 minutes and $\text{C}_6\text{H}_7\text{KO}_2$ for 1 minute had the lowest firmness. The results show that the use of NaOCl with CaCl_2 , and then to NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ as postharvest dips along with storage of tomato fruits in kraft paper could keep tomato fruits longer and maintain higher fruit firmness. This might be an indication that tomato fruit deterioration under kraft paper is slower than perforate or seal polyethylene bags. Kraft paper has the tendency of preventing microorganisms from coming in contact with the tomato fruits and at the same time reducing the amount of CO_2 that may accumulate as a result of respiration which can hasten senescence and deterioration. Fruit firmness values ranged from 0.0204 to 0.0224 kgf. Dip in Calcium chloride and packaged in kraft paper bag had the highest firmness of 0.0219 kgf and 0.0224 kgf on day 9 and 15 respectively.

This could be attributed to the combined effect of kraft paper and Calcium chloride which according to Shunmye et al. (2014) combined effect of integrated postharvest treatment resulted in higher levels of fruit firmness. Pila et al. (2010) reported that calcium application may affect fruit firmness through its cellular role in strengthening of plant cell wall. The values were lower than reported values of Runatunga et al. (2009).

Table 2 presents the results of interaction between postharvest dips and packaging on tomato fruit weight loss for different days in storage. It was observed that on day 3 of the experiment for fruits dipped in tap water, the percentage of weight loss decreased continually as the packaged when perforate and seal polyethylene bags respectively. The percentage of weight loss in fruits dipped in NaOCl with CaCl_2 and NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ initially decreased before it increased as the packaging was changed to perforate to seal polyethylene bag respectively. As the postharvest dips were changed, the percentage of weight loss of fruits packaged in kraft paper bag rises initially before it decreased. The same trend was observed in fruits packaged in seal polyethylene bag. On the other hand, fruits packaged in perforate polyethylene bag had a gradual decrease in percentage of weight loss all through as the dip was changed to NaOCl with CaCl_2 and NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ respectively. Fruits dipped in tap water and packaged in seal polyethylene bag were the best combination having recorded the least percentage of weight loss of 0.18%.

On day 6 of the experiment, the percentage of weight loss in fruits for dipped in tap water and in NaOCl with CaCl_2 solution decreased initially before it increased while in fruits dipped in NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ the reverse was recorded. The percentage weight loss in fruits packaged in kraft paper bag and those packaged in perforate polyethylene bag increased as the dips were changed to NaOCl with CaCl_2 and NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ respectively. For fruits packaged in seal polyethylene bag, the percentage weight loss increased to 6.911% before it decreased to 0.22% as the dips were changed to NaOCl with CaCl_2 and NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ respectively.

Table 1. Interaction of postharvest dip and packaging material on tomato fruit firmness (kgf) in storage

Dips †	09 Days			15 Days		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
D ₁	0.0210	0.0210	0.0211	0.0233	0.0210	0.0203
D ₂	0.0219	0.0208	0.0211	0.0224	0.0216	0.0204
D ₃	0.0218	0.0210	0.0204	0.0210	0.0210	0.0208
Mean	0.2110			0.0214		
P≤F	0.005			0.0001		
LSD	0.0004			0.0050		

†D₁: fruits dipped in tap water for 5 minutes; D₂: fruits dipped in NaOCl for 5 minutes and CaCl₂ for 5 minutes; D₃: fruits dipped in NaOCl for 5 minutes and C₆H₇KO₂ for 1 minute; P₁: Packaging fruits in Kraft paper bags; P₂: Packaging fruits in mildly perforated low density PE bags with 6 holes; P₃: Packaging fruits in sealed low density low density PE bag.

Table 2. Interaction of postharvest dip and packaging material on weight loss in stored tomato fruits

Dips †	3 Days			6 Days			9 Days		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
D ₁	2.15	1.59	0.18	1.34	0.27	0.32	2.28	0.59	0.71
D ₂	2.86	0.47	1.72	2.68	0.35	6.91	2.50	7.51	4.28
D ₃	2.77	0.33	0.64	3.54	6.09	0.22	5.75	18.47	2.54
Mean	1.413			2.41			4.96		
P≤F	0.0007			0.017			0.0006		
LSD	0.819			2.844			5.855		
	12 Days			15 Days			18 Days		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
D ₁	1.78	1.70	1.46	8.58	2.02	0.76	2.26	7.63	6.88
D ₂	2.50	2.87	4.61	3.94	3.08	4.35	4.80	1.71	1.17
D ₃	1.89	12.94	6.83	7.41	15.34	13.58	4.74	0.34	0.42
Mean	3.72			6.12			3.86		
P≤F	0.0001			0.002			0.0001		
LSD	2.839			4.807			1.515		
	21 Days			24 Days					
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃			
D ₁	2.45	4.87	0.31	3.63	0.76	0.93			
D ₂	6.26	1.49	0.37	7.88	0.85	1.04			
D ₃	6.85	0.38	0.39	8.33	0.68	0.51			
Mean	3.33			3.71					
P≤F	0.017			0.049					
LSD	1.604			0.954					

†D₁: fruits dipped in tap water for 5 minutes; D₂: fruits dipped in NaOCl for 5 minutes and CaCl₂ for 5 minutes; D₃: fruits dipped in NaOCl for 5 minutes and C₆H₇KO₂ for 1 minute; P₁: Packaging fruits in Kraft paper bags; P₂: Packaging fruits in mildly perforated low density PE bags with 6 holes; P₃: Packaging fruits in sealed low density low density PE bag.

A combination of dip in NaOCl with $C_6H_7KO_2$ and packaging in seal polyethylene had the least percentage of weight loss of 0.22% and was therefore the best combination.

The percentage of weight loss on day 9 of the experiment in fruits dipped in tap water decreased initially to 0.59% before it increased to 0.71%. On the other hand, fruits dipped in NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ followed a reverse trend as the packaging material was changed to perforate and seal polyethylene bags respectively. Weight loss percentage in fruits packaged in kraft paper and perforate polyethylene followed the same trend of increase while fruits packaged in seal polyethylene had an initial increase before a decrease.

Fruits dipped in tap water and packaged in perforate polyethylene had the least percentage of weight loss of 0.59% and was therefore the best combination.

On day 12 of the experiment, the percentage of weight loss in tap water dipped fruits had a gradual decrease for all the packaging materials as they were changed. The reverse was the case of fruits dipped in NaOCl with $CaCl_2$ as the packaging was changed to perforate and seal polyethylene bags. On the other hand fruits dipped in NaOCl with $C_6H_7KO_2$ solution initially increased to 12.94% before it decreased to 6.83%. The percentage of weight loss in fruits packaged in kraft paper increased to 2.50% initially before it decreased to 1.89% as the dip was changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. Fruits packaged in perforate and seal polyethylene had the same pattern of increase as the dips were changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. A combination of dip in tap water and packaging in seal polyethylene bag was the best combination having recorded the least percentage of weight loss of 1.46%.

Table 3. Interaction of postharvest dip and packaging materials on percentage rot in stored tomato fruits

Dips †	03 Days			06 Days		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
D ₁	2.89	2.48	2.99	6.80	4.51	2.27
D ₂	6.08	3.57	10.76	11.71	7.61	15.10
D ₃	5.12	1.82	5.31	7.88	9.99	9.11
Mean	4.56			8.30		
P≤F	0.0007			0.049		
LSD	2.028			2.226		
	12 Days			15 Days		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
D ₁	9.03	29.24	26.54	16.36	20.36	7.16
D ₂	14.73	20.29	35.36	16.87	35.03	17.70
D ₃	19.84	17.16	36.05	13.81	7.88	12.37
Mean	23.37			17.44		
P≤F	0.006			0.052		
LSD				21.160		

†D₁: fruits dipped in tap water for 5 minutes; D₂: fruits dipped in NaOCl for 5 minutes and $CaCl_2$ for 5 minutes; D₃: fruits dipped in NaOCl for 5 minutes and $C_6H_7KO_2$ for 1 minute; P₁: Packaging fruits in Kraft paper bags; P₂: Packaging fruits in mildly perforated low density PE bags with 6 holes; P₃: Packaging fruits in sealed low density low density PE bag.

Table 4. Interaction of postharvest dip and packaging material on ascorbic acid contents (mg/100g) in stored tomato fruits

Dips †	18 Days			21 Days		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
D ₁	18.53	19.15	27.17	25.35	20.76	28.35
D ₂	21.98	23.36	22.35	21.01	22.85	16.20
D ₃	17.92	22.67	18.78	15.46	17.89	19.71
Mean	21.31			20.78		
P≤F	0.036			0.014		
LSD	7.986			5.139		
	24 Days					
D ₁	21.23	15.18	21.10			
D ₂	19.05	18.07	29.44			
D ₃	23.51	24.70	19.59			
Mean	21.31					
P≤F	0.0001					
LSD	2.906					

†D₁: fruits dipped in tap water for 5 minutes; D₂: fruits dipped in NaOCl for 5 minutes and CaCl₂ for 5 minutes; D₃: fruits dipped in NaOCl for 5 minutes and C₆H₇KO₂ for 1 minute; P₁: Packaging fruits in Kraft paper bags; P₂: Packaging fruits in mildly perforated low density PE bags with 6 holes; P₃: Packaging fruits in sealed low density low density PE bag.

The percentage of fruit weight loss on day 15 of the experiment in tap water dipped fruits decreased as the packaging materials were changed to perforate and seal polyethylene bags respectively. For fruits dipped in NaOCl with CaCl₂ solution, the percentage of weight loss decreased to 3.08% before it increased to 4.35%; and in fruits dipped in NaOCl with C₆H₇KO₂, it increased before decreasing as the packaging was changed to perforate and seal polyethylene bags respectively. The percentage of weight loss in fruits packaged in kraft paper bag decreased to 3.94% initially before it increased to 7.41% as the dips was changed to NaOCl with CaCl₂ and NaOCl with C₆H₇KO₂ respectively. Fruits packaged in perforate polyethylene and seal polyethylene bags had the same trend of increase as the dip was changed to NaOCl with CaCl₂ and NaOCl with C₆H₇KO₂ respectively.

The least percentage of weight loss was recorded in treatment involving dip in tap water and packaging in seal polyethylene and therefore this was the best treatment combination.

On day 18 of the experiment, the percentage of weight loss in fruits dipped in tap water increase to 7.634% initially before decreasing to 6.88% as the packaging was changed to perforate and seal polyethylene bags respectively. For fruits dipped in NaOCl with CaCl₂ solution, the percentage of weight loss decreased to 1.71% and was maintained as the packaging was changed while in fruits dipped in NaOCl with C₆H₇KO₂ it decrease before it increased slightly. Tomato fruit weight loss in fruits packaged in kraft paper initially increased to 4.80% before decreasing slightly to 4.74% as the dip was changed to NaOCl with CaCl₂ and NaOCl with C₆H₇KO₂ respectively. Fruits packaged in perforate and seal polyethylene bags had the same trend of decrease as the dips were changed to NaOCl with CaCl₂ and NaOCl with C₆H₇KO₂ respectively. Dip in NaOCl with C₆H₇KO₂ solution and packaging in perforate polyethylene gave the least percentage of weight loss and was therefore the best treatment combination.

On day 21 of the experiment the percentage of weight loss for fruits dipped in tap water had the same trend as that of day 18. For fruits dipped in NaOCl with CaCl₂, the percentage of weight loss decreased all through as the packaging material was changed to perforate and seal

polyethylene bags respectively. On the other hand, fruits dipped in NaOCl with $C_6H_7KO_2$ solution decreased initially and slightly increased as the packaging was changed to perforate and seal polyethylene bags respectively. The percentage of weight loss in fruits packaged in kraft paper bag and seal polyethylene bag followed same trend of increase as the dip was changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$; while for fruits packaged in perforate polyethylene it followed a reverse trend. The best combination involved dip in tap water and packaging in seal polyethylene bag because it recorded the least percentage of weight loss.

On day 24 of the experiment, fruits packaged in kraft paper bag had the same trend as that on day 21. For fruits packaged in perforate and seal polyethylene, the percentage of weight loss in the fruits had a slight increase before a slight decrease as the dip was changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. The least percentage of weight loss of 0.51% was recorded in fruits dipped in NaOCl with $C_6H_7KO_2$ solution packaged in seal polyethylene and therefore this was the best combination on this day.

The weight loss values ranged from 0.18% to 18.47%. The values were higher than 1.82-5.81% reported by Hour et al. (2015) and 2.58 – 15.45% reported by Abiso et al. (2015) but similar to the 2.25 – 19.03% reported by Bhattarai and Gautam (2006). The highest weight loss was recorded by treatment dip in Potassium sorbate and packaged in perforate polyethylene bag. The effect could be due to the effect of the packaging material (perforate polyethylene bag) and sorbate because El-Eryan and El-Metwally (2014) reported that Potassium sorbate can reduce fruit weight loss. The trend of weight loss was not regular as it increases and decreases as storage advanced. Znidarcic et al. (2010) reported that postharvest weight loss in fruits and vegetables is usually due to the loss of water through transpiration which leads to wilting and shriveling.

Table 3 presents the results of interaction of postharvest dips and packaging on percentage of fruit rot on different days in storage. On day 3 of the experiment, the percentage of rot for fruits dipped in tap water was less evident before it gradually becomes more evident as storage progressed.

For fruits dipped in NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$, percentage of fruit rot decreased before it increased as the packaging materials were changed to perforate and seal polyethylene bags respectively. As the postharvest dips were changed, the percentage of fruit rot in all the packaging materials increased before it decreased, fruits dipped in NaOCl with $C_6H_7KO_2$ and packaged in perforate polyethylene had the least percentage rot of 1.82% and was therefore the best treatment combination.

The percentage fruit rot on day 6 of the experiment for fruits dipped in tap water decreased as the packaging was changed to perforate and seal polyethylene bag respectively. Fruits dipped in NaOCl with $CaCl_2$ solution initially decreased before it increased and the reverse trend was observed in those fruits dipped in NaOCl with $C_6H_7KO_2$. The percentage of rot for fruits packaged in kraft paper bag and those in seal polyethylene bag increased before it decreased as the dips were changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. Fruits packaged in perforate polyethylene bag recorded continuous increase as dips were changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. The least percentage of rot of 2.27% was recorded in fruits dipped in tap water and packaged in seal polyethylene bag and this was therefore the best treatment combination.

On day 12 of the experiment, the percentage of rot in fruits dipped in tap water initially increased before it decreased and the opposite was observed in fruits dipped in NaOCl with $C_6H_7KO_2$. For fruits dipped in NaOCl with $CaCl_2$ an increase in percentage of rot was generally observed. The percentage of rot in fruits packaged in kraft paper bag and in seal

polyethylene recorded an increase as the dips were changed to NaOCl with CaCl_2 and NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ while the opposite was recorded in fruits packaged in perforate polyethylene bag. Fruits dipped in tap water and packaged in kraft paper bag were the best combination having recorded the least percentage of rot of 9.02%.

On day 15 of the experiment, the percentage of rot in fruits dipped in tap water and those dipped in NaOCl with CaCl_2 solution increased before it decreased. An opposite trend was observed in fruits dipped in NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$. The percentage of fruits rot in fruits packaged in all the three packaging materials recorded an increase initially before a decrease as the dips were changed to NaOCl with CaCl_2 and NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ respectively. Fruits dipped in tap water and packaged in seal polyethylene bag had the least percentage of rot of 7.16% and was therefore the best combination.

The results of interaction were significant on 3, 6, 12 and 15 days. The highest percentage of rot was recorded in fruits dipped in Potassium sorbate and packaged in seal polyethylene bag; and fruits dipped in Calcium chloride and packaged in seal polyethylene bag with 36.05% and 35.36% respectively. The two treatments with highest percentage of rot all involved polyethylene as the packaging material. This agreed with the report of Moneruzzaman et al. (2009) who reported highest rot in Calcium chloride treated tomatoes packed in polyethylene bag. The least percentage of rot of 1.8 17% in fruits dipped in Potassium sorbate and packaged in perforate polyethylene bag could be attributed to the action of Potassium sorbate which Liu et al. (2014) has demonstrated its effectiveness in inhibiting the growth and sporulation of yeast, fungi as well as bacteria. The percentage of rot increased as storage progressed.

Table 4 presented the results of interaction between postharvest dip and packaging in ascorbic acid content of the fruits during storage. The ascorbic acid content of the fruits in day 18 of the experiment in fruits dipped in tap water recorded an increase as the packaging materials were changed. Fruits dipped in NaOCl with CaCl_2 and NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ on the other hand recorded an initial increase before a decrease as the packaging materials were changed. As the postharvest dips were changed, the ascorbic acid content in fruits packaged in kraft paper as well as in perforate polyethylene increased initially and later decreased. Fruits packaged in sealed polyethylene bag recorded a decrease as the dips were changed. The best treatment combination was dip in tap water and packaging in seal polyethylene having recorded the highest ascorbic acid value of 27.17 mg/100g.

On day 21 of the experiment, the ascorbic acid content in fruits dipped in tap water had an initial decrease before it increased. The opposite was observed in fruits dipped in NaOCl with CaCl_2 as the packaging was changed. Fruits dipped in NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ recorded a fair increase in ascorbic acid as the packaging was changed. The ascorbic acid content in fruits packaged in kraft paper bag recorded a decrease as the dips were changed.

Fruits packaged in perforate polyethylene recorded on initial increase and a decrease later as the dips were changed. Opposite trend was recorded in fruits packaged in seal polyethylene bag. The best combination was same as in day 18 of the experiment.

The ascorbic acid content on day 24 of the experiment for fruits dipped in tap water and also in fruits dipped in NaOCl with CaCl_2 behaved in same manner as dip in tap water in day 21 of the experiment. Fruits dipped in NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ recorded in increase and a later decrease as the packaging materials were changed.

The ascorbic acid content in fruits packaged in kraft paper bag decreased at initial stage before it increased. The opposite of this was observed in fruits packaged in seal polyethylene bag while fruits packaged perforate polyethylene bag recorded a steady increase as the postharvest dips were changed to NaOCl with CaCl_2 and NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ respectively.

Highest ascorbic acid content of 29.44 mg/100g was recorded in fruits dipped in NaOCl with CaCl_2 and packaged in seal polyethylene bag and this therefore was the best combination.

Interaction effects of postharvest dip and packaging on ascorbic acid content of the fruits were observed to be significant on 18, 21 and 24 days of storage. The ascorbic acid values ranged from 15.18 mg/100g – 29.44 mg/100g. The values in the present study were higher than the range of ascorbic acid (17.88 – 21.84 mg/100g) reported by Gharezi et al. (2012) but lower than 21.03-76.56 mg/100g reported by Vinha et al. (2013). The highest ascorbic acid content was observed in fruits dipped in Calcium chloride and packaged in seal polyethylene bag. This can be attributed to the effect of Calcium chloride as reported by Sammi and Masud (2007) and polyethylene bag as reported by Shahnawaz et al. (2012).

Table 5 presented the result of interaction between postharvest dip and packaging in lycopene content during storage. The lycopene content in fruits dipped in tap water on day 6 of the experiment initially decreased before it slightly increased as the packaging materials were changed. The same trend was also observed in fruits dipped in NaOCl with CaCl_2 . Fruits dipped in NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ recorded a decrease in lycopene as the packaging was changed. As the postharvest dips were changed, the lycopene content in fruits packaged in kraft paper bag and those in perforate polyethylene bag initially decreased before it increase. The opposite was observed in fruits packaged in seal polyethylene bag. Dip in NaOCl with CaCl_2 and packaging in perforated polyethylene bag was the best combination.

On day 24 of the experiment, fruits dipped in tap water and those dipped in NaOCl with $\text{C}_6\text{H}_7\text{KO}_2$ recorded a decrease in lycopene content while fruits dipped in NaOCl with CaCl_2 recorded an initial decrease and a later increase as the packaging materials were changed. The lycopene content in fruits packaged in kraft paper bag and those in perforate polyethylene bag initially decreased before it later increased as the postharvest dips were changed. Fruits packaged in seal polyethylene recorded the opposite. The best combination remained the same. The best combination remained the same as in day 6 of the experiment.

Effects of postharvest dip and packaging on lycopene were significant on 6 and 24 days only. The lycopene values ranged slightly above the 63 – 155 mg/kg and 60 – 160 mg/kg reported by Markovic et al. (2010) and Brandt et al. (2003) respectively. The slight variation may be due to varietal, soil, cultural, temperature as well as postharvest handling differences. The highest amount of lycopene (181.17 mg/kg) was observed in treatment fruits dipped in tap water and packaged in mildly perforated polyethylene bug. This is contrary to report of Alsadon et al. (2004) that low density polyethylene resulted in slowing down colour development in stored tomato fruits.

Table 5. Interaction of postharvest dip and packaging materials on lycopene content (mg/kg) of stored tomato fruits

Dips †	06 Days			24 Days		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
D ₁	181.17	133.32	135.78	147.97	86.53	61.78
D ₂	99.64	97.83	155.32	107.20	58.58	72.81
D ₃	129.82	122.00	112.15	148.10	96.09	67.05
Mean	129.41			104.12		
P≤F	0.011			0.02		
LSD	37.35			15.58		

†D₁: fruits dipped in tap water for 5 minutes; D₂: fruits dipped in NaOCl for 5 minutes and CaCl_2 for 5 minutes; D₃: fruits dipped in NaOCl for 5 minutes and $\text{C}_6\text{H}_7\text{KO}_2$ for 1 minute; P₁: Packaging fruits in Kraft paper bags; P₂: Packaging fruits in mildly perforated low density PE bags with 6 holes; P₃: Packaging fruits in sealed low density low density PE bag.

CONCLUSION

Results indicate that dip in 200 ppm Sodium hypochlorite for 5 minutes and 1% Calcium chloride for 5 minutes and packaged in perforated polyethylene bag as the best treatment combination to store green mature tomato fruits for up to 24 days of storage. This was followed by dip in 200 ppm Sodium hypochlorite for 5 minutes and Calcium chloride for 5 minutes; packaged in sealed polyethylene bag.

The two combinations were best for maintaining tomato physico-chemical parameters such as fruit firmness, lower weight loss and higher lycopene within acceptable limits for 24 days thereby extending the storage life of the fruits. The best combination for storing tomato therefore was dipping in 200 ppm Sodium hypochlorite for 5 minutes and packaged in mildly perforate polyethylene bag.

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CONFLICT OF INTEREST

The authors have no conflict of interest to report.

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