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Effects of Postharvest Dips and Storage Conditions on Quality and Storage life of Tomato Fruits (*Lycopersicon esculentum* MILL) in Kura, Kano State, Nigeria

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Abstract

Tomato is a popular vegetable worldwide and plays a vital role in human diet. Nigeria records high postharvest loss due to improper harvesting, handling, storage and diseases. This prompted the search for simple, effective and economical methods to control the high postharvest losses in tomatoes. The present study investigates the effects of dips and storage conditions on quality and life of tomatoes. The study was carried out at *Kofar yamma* in Kura town, Kano state. Green mature tomatoes were harvested and conveyed to site early in the morning. They were sorted, graded and divided into 3 kg lots each. Fruits were given postharvest dips (D_1= dip in tap water, D_2= dip in 200 ppm NaOCl and $NOaCl_2$ for 5 minutes each, D_3= dip in 200ppm NaOCl and $C_6H_7KO_2$ for 5 and 1 minutes respectively) and stored in the respective storage conditions (S_1= storage at ambient temperature, S_2= storage at refrigerated temperature and S_3= storage at zero energy cool chamber). Analyses on physico-chemical parameters were conducted on first day and there after every three days. Data generated were analyzed using GLM procedure of SAS and means separated using LSD. Results showed that dip in 200 ppm NaOCl and 1% $CaCl_2$ for 5 minutes and storage at refrigeration; and dip in 200 ppm NaOCl and $C_6H_7KO_2$ for 5 and 1 minute respectively were the best treatments. They maintained the physico-chemical parameter within acceptable limits for 24 days and as such they are recommended for storage of tomato fruits.

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Keywords:
Dips,, Kura, Postharvest, Storage and *Lycopersicon esculentum*

Introduction

The word tomato is a modification of the word „*tomati*" which literally means „the swelling fruit". Other names reported by historians are *tomatl*, *tumatle* and *tomatas* (Wikipedia, 2010). Tomato (*Lycopersicon esculentum* Mill.) is an herbaceous plant belonging to the family *Solanaceae*. It originated between Mexico and West coast of South America and following its introduction to Spain in 16th century it became widely dispersed throughout African continent (De-Lennoy, 2001). It is one of the popular vegetables worldwide and plays a vital role in human diet (Sibromana *et al*., 2015). Tomatoes are consumed whole peeled or in salads, cooked into soups or processed into juice, ketchup, paste and puree (Adedeji *et al*., 2005). They are rich in vitamins (particularly A and C), minerals sugars, essential amino acids, iron, dietary fibers and phosphorus (Ayendiji *et al*., 2011).

Vitamins A and C are vital in improving eye sight and warding off muscular degeneration. Tomato fruits also contain higher amounts of lycopene, a type of carotenoid with anti oxidant properties beneficial in reducing incidence of diseases like cancer (Basu and Imrhan, 2007) and cardiovascular disorders (Freeman and Reimers, 2010). Nigeria is the second largest producer of tomatoes in Africa and 13th in the world (FAOSTAT, 2014). Estimated total postharvest loss of tomatoes in Nigeria is about 60% (Kutama *et al*., 2007) which translates to huge economic loss. The huge loss has prompted the search for simple, effective and economical method to control pre and postharvest diseases and other losses in tomato fruits. Postharvest technologies like chemical treatments, packaging and storage positively influence the level of postharvest losses and the quality of produce (Srividya *et al*., 2014). An improvement in tomato postharvest handling, packaging and storage is really desirable. Therefore this study was aimed at investigating the combined effects of postharvest dips and storage on the quality and storability of tomatoes in Kura, a leading tomato producing town in Kano State.

Materials and Methods

The study was conducted in Kura local Government (Kano State, Nigeria) located between latitude 11° 46′ N and longitude 8° 25′ E between 2nd March to 27th March, 2014. The analyses were conducted in the Laboratories of the Department of Food Science and Technology, Kano University of Science and Technology Wudil and Kano area laboratory of Abuja Commodity Exchange Plc.

The fruits (UC 82B grown in Kura) of fairly uniform sizes were carefully hand harvested at green mature stage. The design was a factorial design laid out in randomized complete block design (RCBD). There were three factors; postharvest treatments, packaging and storage each having 3 levels which were replicated three times. Postharvest treatments consisted of three levels which were:

i. freshly harvested fruits dipped in tap water for 5 minutes (D_1)
ii. freshly harvested fruits dipped in 200 ppm Sodium hypochlorite for 5 minutes and 1% w/v Calcium chloride for 5 minutes (D_2).
iii. freshly harvested fruits dipped in 200 ppm Sodium hypochlorite for 5 minutes and 3% Potassium sorbate for 1 minute (D_3).

The storage conditions consisted also of three levels which were:

i. Storage of fruits at ambient room temperature 32ºC and 29% RH (S_1)
ii. Storage of fruits at refrigerated chamber 11ºC and 90-95% RH (S_2)
iii. Storage of fruits in "zero energy" cool chamber 24ºC and 71% RH (S_3)

Each treatment consisted of 3 kg sound, unblemished mature green tomato fruits of fairly uniform size dipped in the various dips and subjected to various forms of packaging and stored in the various storage structures. Determinations were conducted on the various physicochemical parameters on day one and thereafter every three days.

Fruit firmness

The firmness of tomato fruits was measured with the aid of HP-FFF analog fruit firmness tester (Qualitest International Inc. Canada) using 0.25cm^2 test anvil (specifically for tomato fruits). To test the firmness the tester was placed on two different points of the fruit (opposite each other and free of blemishes) with a constant press. The degree of firmness of the fruit was calculated as a quotient of the number directly displayed on the instrument.

Percentage weight loss

The percentage weight loss of the stored tomato fruits was determined as a percentage of the total weight stored.

$$\%\,Weight\ loss\ in\ Tomato = (Initial\ weight\ stored\ -\ Final\ weight)/(Total\ weight\ stored) \times 100$$

Percentage decay: For the determination of % decay, rotted fruits were isolated and the percentage decay calculated as a percentage of the total amount of tomato fruits stored.

$$\%\,Decay\ in\ Tomato = \frac{Initial\ weight\ stored - Weight\ of\ decayed\ fruits}{Total\ weight\ stored} \times 100$$

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. Fifty milliliters of unconcentrated juice was then pipetted into 100 ml volumetric flask in triplicate. Twenty five milliliters of 20% Metaphosphoric acid was added as a stablising 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 colour which persisted for roughly 15 seconds The amount of ascorbic acid in the tomato fruit was calculated as follows:

Vitamin C $(mg\ /\ 100\ g) = 20 \times V \times c$

Lycopene content

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 100µl micro pipette and the outside glass bore was wiped clean using tissue paper. The pipette was allowed to stand to dispel air bubbles from 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. Eight milliliters 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 miutes to allow phases to separate and all air bubbles disappear. The cuvette of the spectrophotometer was rinsed clean with upper layer from one of the blanks. The liquid was the 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 the determined using spectrophotometer at 503 nm. Lycopene content was then calculated using the following relationship:

$$Lycopene\ (mg/kg\ fresh\ weight) = (\mathrm{A}_{503} \times 137.4)$$

Statistical Analysis: Data generated over the study period were analysed using generalised linear model (GLM) procedure of Statistics Analysis System (SAS) and means separated using LSD.

Results and Discussion

Effect of dip and storage conditions on firmness

Fruits firmness on day 6 decreased generally in all the dips as storage methods were changed (Table 1). As the postharvest dips were changed, a decrease in fruit firmness was observed in storage in room at ambient temperature and storage in zero energy cool chamber. Firmness was maintained in storage in zero energy cool chamber after the decrease as the dips were changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$. In storage at refrigeration fruits firmness were maintained after initial increase as the dips were changed. Fruits dipped in tap water and stored in room at ambient temperature recorded highest firmness of 0.0230 kgf and was therefore the best combination.

On day 9 of the experiment a decrease in firmness before an increase was observed in fruits dipped NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. On the other hand, storage in room at ambient temperature recorded an initial increase before a decrease to 0.0214 kgf; while storage in refrigerator recorded a gradual increase in fruit firmness as the dips were changed to dip in NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. Storage in zero energy cool chamber recorded gradual decrease in fruit firmness. Fruits dipped in NaOCl with $CaCl_2$ and stored at ambient room temperature had the highest firmness of 0.0220 kgf and was therefore the best combination.

On day 12 of the experiment, fruit firmness decreased in all the dips even though for NaOCl with $C_6H_7KO_2$ firmness was maintained when storage method was changed from refrigeration to zero energy cool chamber. Fruits firmness generally increased in fruits stored at ambient room temperature as the dips were changed. Fruits stored under refrigeration and zero energy cool chamber, followed the same trend of initial increase before decrease as the dips were changed. Fruits dipped in NaOCl with $C_6H_7KO_2$ had the highest firmness of 0.0252 kgf and was therefore the best combination.

Table 1: Interaction between Postharvest Dip and Storage Environment on Firmness (kgf)

Dips	6 Days			9 Days			12Days		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
D_1	0.023	0.0202	0.0208	0.0211	0.0209	0.0211	0.0229	0.0224	0.0213
D_2	0.022	0.0204	0.0201	0.022	0.021	0.0208	0.0233	0.0226	0.0221
D_3	0.0212	0.0204	0.0201	0.0214	0.0211	0.0207	0.0252	0.0211	0.0211
Mean	0.0209			0.0211			0.0223		
P≤F	0.0145			0.0456			0.0001		
LSD	0.001			0.0005			0.0007		
	15Days			18Days					
	S_1	S_2	S_3	S_1	S_2	S_3			
Dips									
D_1	0.0232	0.0203	0.0216	0.0215	0.0214	0.022			
D_2	0.0217	0.0211	0.0214	0.0228	0.0214	0.023			
D_3	0.021	0.0208	0.0213	0.0233	0.0208	-			
Mean	0.0214			0.0217					
P≤F	0.0001			0.0007					
LSD	0.0047	0.0047	0.0047	0.0053	0.0053				

Key:
D_1 :fruits dipped in tap water for 5 minutes
D_2: fruits dipped in NaOCl for 5 minutes and $CaCl_2$ for 5 minutes
D_3: fruits dipped in NaOCl for 5 minutes and $C_6H_7KO_2$ for 1 minute
S_1: Storage of fruits at ambient room temperature (32ºC and 29% RH)
S_2: Storage of fruits at refrigerated chamber (11ºC and 90-95% RH)
S_3: Storage of fruits in “zero energy” cool chamber (24ºC and 71% RH)
(-): Sample rotted away

On day 15 of the experiment, a similar trend of initial decrease before an increase was observed in all the postharvest dips as the storage methods were changed. On the other hand, fruits stored under ambient temperature and zero energy cool chamber followed the same trend of decrease, while fruits stored under refrigeration had an increase in firmness before a decrease. The highest firmness value of 0.0232 kgf was recorded in treatment that involved dip in tap water and storage at ambient temperature and this was therefore the best combination.

On day 18 of the experiment, a general trend of decrease in fruit firmness before an increase was observed in fruits dipped in tap water and fruits dipped in NaOCl with $CaCl_2$; while an increase was observed in NaOCl with $C_6H_7KO_2$ dipped fruits. An increase in firmness was observed in fruits stored under ambient temperature as the postharvest dips were changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. For fruits stored under refrigeration, fruits firmness was maintained when the dips was changed to NaOCl with $CaCl_2$ and it later decrease when changed to NaOCl with $C_6H_7KO_2$. In fruits stored under zero energy cool chamber, firmness slightly increased as the dip was changed to NaOCl with $CaCl_2$. Fruits dipped in NaOCl with $C_6H_7KO_2$ and stored under ambient temperature gave the highest firmness and was therefore the best combination, while fruits dipped in $C_6H_7KO_2$ and stored under zero energy cool chamber rotted away and was therefore the worst treatment.

The firmness values ranged from 0.0201 to 0.0252 kgf. The firmness values were lower than 0.0490 kg reported by Ranatunga *et al.* (2014). Fruits dipped in Potassium sorbate and stored in room at ambient temperature recorded the highest firmness of 0.0252 kgf. The increased firmness retention here might be due to the effect of the sorbate which according to El-Eryan and El-Metwally (2014)

Effect of dip and storage conditions on percentage weight loss

Table 2 presents the results of interaction between postharvest dip and storage on percentage weight loss of tomato fruits on different days in storage. The percentage weight loss on day 9 of the experiment for all dips followed the same trend of initial decrease before an increase as the storage methods were changed to refrigeration and zero energy cool chamber respectively. As the postharvest dips were changed, the percentage weight loss in fruits stored in room under ambient temperature and those stored in zero energy cool chamber all recorded an increase as the dips was changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. For fruits stored under refrigeration, the percentage weight loss had an initial decrease before an increase. The least percentage weight loss of 0.583% was recorded in treatment combination involving dip in NaOCl with $CaCl_2$ and storage under refrigeration; and this was therefore the best combination for the day.

On day 12 of the experiment, the percentage weight loss followed the same trend as in day 9 of the experiment. The percentage weight loss for fruits stored under ambient temperature had an increased trend while it increased and later decreased in fruits stored under refrigeration.

For fruits stored in zero energy cool chamber there was a decrease initially before an increase. The best treatment combination was dip in NaOCl with $C_6H_7KO_2$ and storage in refrigerator having the least percentage weight loss of 0.2810%.

The percentage weight loss on day 15 also had the same trend as in day 9 and 12. The percentage weight loss in fruits stored in room at ambient condition, decreased to 6.808% before subsequent increase to 9.710%. Fruits stored under refrigeration as well as zero energy cool chamber all recorded an increase in the percentage weight loss as the dip was changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. Dip in tap water and storage under refrigerator had the least

reduces fruit weight loss in tomato fruits; and loss of water through transpiration has also been reported (Kader, 2011) to be responsible for changes in textural quality to fruits. The values for fruit firmness can generally be said to decrease as storage progressed and this could be attributed to increased conversion of hemicelluloses and pectin to simple sugars as reported by Sood *et al.* (2015).

percentage weight loss of 0.730% and was therefore the best combination.

On day 18 of the experiment, the percentage weight loss in fruits dipped in tap water and those dipped in NaOCl with $CaCl_2$ followed the same trend as in days 9, 12 and 15; while for fruits dipped in NaOCl with $C_6H_7KO_2$ decreased to 0.783% as the storage method was changed to refrigeration. The percentage weight loss decreased in fruits stored in room at ambient temperature as well as those stored in zero energy cool chamber as the dips were changed. For fruits stored under refrigeration, there was an increase initially before a decrease as the dips were changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. The least percentage weight loss of 0.783% was recorded in fruits dipped in NaOCl with $C_6H_7KO_2$ and stored under refrigeration and this was therefore the best combination while fruits dipped in NaOCl with $C_6H_7KO_2$ and stored under zero energy cool chamber rotted away and was therefore the worst combination.

On day 24 of the experiment, the percentage weight loss in all the dips recorded a decrease as the storage methods were changed. The percentage weight loss in fruits stored under ambient temperature continually increased as the dips were changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. For fruits stored under refrigeration, the reverse of what happened under ambient conditions was recorded. The best treatment was dip in NaOCl with $C_6H_7KO_2$ and storage under refrigeration because it recorded the least percentage weight loss of 1.086% while treatment combination involving dip in NaOCl with $CaCl_2$ and storage in zero energy cool chamber was the worst combination because rotted away.

The percentage loss in weight ranged from 0.281 – 23.770 %. The values were higher than 2.25 – 19.03% reported by Bhatturai and Gautam (2006) but similar to 0.31 – 23.93 % reported by Okolie and Sanni (2012). The highest value of 23.770 % was recorded by treatment dip in Potassium Sorbate and stored in zero energy cool chamber. The high percentage weight loss could be due to the effect of

Sodium hypochlorite and Potassium Sorbate. The results were contrary to the report of Islam and Hatou (2012) and Singh and Yadev (2015) who all reported reduced weight loss in zero energy cool chamber compared to other treatments employed. Weight loss in stored fruits is usually due to the loss of water through transpiration which leads to wilting and shriveling as well as due to loss of moisture due to respiration (Znidarcic *et al.*, 2010).

Table 2: Interaction between Postharvest Dip and Storage condition on percentage Weight loss

Dips	9Days			12Days			15Days		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
D_1	2.107	0.633	0.841	2.749	0.493	1.689	9.032	0.73	2.022
D_2	11.499	0.583	2.201	7.943	0.579	1.461	6.808	0.983	3.545
D_3	14.976	0.691	11.1	9.16	0.281	10.959	9.71	7.576	23.77
Mean	4.959			3.722			6.118		
P≤F	0.0057			0.0001			0.0003		
LSD	5.108			2.753			3.878		
	18Days			24Days					
	S_1	S_2	S_3	S_1	S_2	S_3			
D_1	11.367	0.906	4.585	5.105	1.698	1.38			
D_2	6.305	1.054	3.645	13.443	1.406	-			
D_3	6.02	0.783	-	14.593	1.086	-			
Mean	3.859			3.705					
P≤F	0.0001			0.0001					
LSD	1.268			0.889					

Key:
D_1 :fruits dipped in tap water for 5 minutes
D_2: fruits dipped in NaOCl for 5 minutes and $CaCl_2$ for 5 minutes
D_3: fruits dipped in NaOCl for 5 minutes and $C_6H_7KO_2$ for 1 minute
S_1: Storage of fruits at ambient room temperature (32ºC and 29% RH)
S_2: Storage of fruits at refrigerated chamber (11ºC and 90-95% RH)
S_3: Storage of fruits in "zero energy" cool chamber (24ºC and 71% RH)
(-): Sample rotted away

Effect of dip and storage conditions on percentage rot

Table 3 presented the results of interaction between postharvest dip and storage on percentage rot of tomato fruits for different days in storage. It can be observed that on day 3 of the experiment the percentage fruits rot in all the three dips drastically decreased before it increased as the storage methods were changed to refrigeration and zero energy cool chamber respectively. As the postharvest dips were changed, the percentage fruit rot in fruits stored under ambient condition and those under zero energy cool chamber increased initially before decreasing as the postharvest dips were changed to NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$ respectively. For fruits stored under refrigerated condition, the percentage rots initially decrease to 0.008% before increasing to 0.044% as the dips were changed to NaOCl with $CaCl_2$. The least percentage rot of 0.008% was recorded in fruits dipped in NaOCl with $CaCl_2$ and stored under refrigeration and this was therefore the best treatment combination.

On day 6 of the experiment, the percentage rot in fruits followed the same trend as in day 3 and dip in NaOCl with $C_6H_7KO_2$ and storage under refrigeration was the best treatment combination.

On day 18 of the experiment the percentage rot for fruits dipped in tap water decreased initially before increasing as the storage methods were changed to refrigeration and zero energy cool chamber. In fruits dipped in NaOCl with $CaCl_2$ and NaOCl with $C_6H_7KO_2$, the percentage fruit rot had a drastic decrease. The best treatment combination was dip in NaOCl with $C_6H_7KO_2$ and storage under refrigeration for having least percentage rot of 0.056% while the worst treatment was dip in NaOCl with $CaCl_2$ and storage in zero energy cool chamber as well as dip in NaOCl with $C_6H_7KO_2$ and storage under zero energy cool chamber having rotted away.

Day 21 and 24 followed the same trend as in day 18 of the experiment. The best treatment for day 21 was dip in tap water and storage in refrigerator. The best treatment on day 24 was dip in NaOCl with $C_6H_7KO_2$ and storage under refrigeration. The worst treatment for days 21 and 24 were the same as in day 18 of the experiment.

The interactions for the dip and storage condition were also significant on 3, 6, 12, 15, 18, 21 and 24 days. The percentage rot values ranged from 0 – 58.489 %. The highest percentage rot of 58.48 % and 57.58 % were obtained in fruits dipped in Calcium chloride and stored in zero energy cool chamber; and also fruits dipped Potassium sorbate for 1 minute and stored in zero energy cool chamber respectively. The results of this study were contrary to the report of Nila *et al*. (2010) who reported that Calcium chloride treated fruits stored at ambient temperature recorded a significant reduction in the percentage decay. Arthur *et al*. (2015) also reported a reduction in the percentage decay in Ca^{2+} treated fruits compare to non-treated ones.

Effect of dip and storage conditions on ascorbic acid content

The result of interaction effect of dip and storage in fruits ascorbic acids content for different days in storage are presented on Table 4. On day 3 of the experiment the ascorbic acid content in fruits dipped in tap water initially decrease to 21.478 mg/100g before it increased to 33.796 mg/100g. Fruits dipped in NaOCl with $CaCl_2$ recorded an increase in ascorbic acid content while those dipped in NaOCl with $C_6H_7KO_2$ recorded a decrease as the storage methods were changed. The ascorbic acid content in fruits stored in ambient condition decreased and later increased as the postharvest dips were changed. The opposite was observed in fruits stored under refrigeration as the dips were changed. Fruits stored in zero energy cool chamber recorded a decreased in the amount of ascorbic acid as the postharvest dips were changed. The best combination was dip in tap water and storage under zero energy cool chamber.

The ascorbic acid content on day 9 of the experiment in fruits dipped in tap water recorded a gradual increase as the storage methods were changed. Fruits dipped in NaOCl with $CaCl_2$ recorded initial decrease before subsequent increase. The trend was reversed in fruits dipped in NaOCl with $C_6H_7KO_2$ as the storage methods were changed. Fruits dipped in NaOCl with $C_6H_7KO_2$ and stored under refrigeration were the best combination. The amount of ascorbic acid in fruits stored under ambient conditions and those stored under zero energy cool chamber increased initially before it later decreased as the dips were changed. The opposite was recorded in fruits stored under refrigeration. The best combination was dip in NaOCl with $C_6H_7KO_2$ and storage under refrigeration.

On day 18 of the experiment, the ascorbic acid content in fruits dipped in tap water behaved the same way as in day 9. Fruits dipped in NaOCl with $CaCl_2$ initially increase to 25.506 mg/100g before it decreased to 18.05 mg/100g. Fruits dipped in NaOCl with $C_6H_7KO_2$ recorded a decrease in ascorbic acid as the storage was changed. The amount of ascorbic acid in fruits stored under ambient conditions initially decreased before it later increased as the dips were changed. The opposite of this was observed in fruits stored under refrigeration. Fruits stored under zero energy cool chamber recorded an increase as the dips were changed. Dip in tap water and storage under zero energy cool chamber was the best combination; while dipped in NaOCl with $C_6H_7KO_2$ and stored in zero energy cool chamber was the worst treatment having rotted away.

The ascorbic acid content on day 24 of the experiment for fruits dipped in tap water and those dipped in NaOCl with $C_6H_7KO_2$ decreased as the storage methods were changed. Fruits dipped in NaOCl with $CaCl_2$ recorded an increase as storage method was changed. The ascorbic acid of fruits stored under ambient conditions had the same behavior as in day 21 of the experiment; fruits stored under refrigeration also had the same trend as in day 18 of the experiment. The highest ascorbic acid content was observed in fruits dipped in tap water and stored under temperature ambient conditions. Two treatments dip in NaOCl with

$CaCl_2$ and storage in zero energy cool chamber as well as dip in NaOCl with $C_6H_7KO_2$ and storage in zero energy cool chamber rooted away and were therefore the worst treatment combinations.

Ascorbic acid values ranged from the values 14.733 – 33.796 mg/100g.Ascorbic acid values in the present study were higher than the range of 8.33 – 20.07 mg/100g and 17.88 – 21.84 mg/100g reported by Moneruzzaman *et al*. (2009) and Gharezi *et al*. (2012) respectively.

Table 3: Interaction between Postharvest Dip and Storage Environment on Percentage Tomato Fruit Rot

Dips	3Days			6Days			12Days			15Days		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
D_1	2.433	0.056	5.866	6.09	0.089	7.399	10.999	0.574	53.23	26.51	0	22.908
D_2	9.117	0.008	11.293	13.457	0.06	20.899	23.031	0.056	47.297	20.269	0	58.489
D_3	5.75	0.044	6.451	9.938	0.058	16.981	14.612	0	57.587	12.372	0	35.993
Mean	4.558			8.33			23.367			17.436		
P≤F	0.0004			0.014			0.0275			0.0016		
LSD	1.997			2.969			9.350			22.290		
	18Days			21Days			24Days					
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3			
D_1	22.371	2.128	18.77	6.793	0	7.275	2.475	1.55	9.06			
D_2	25.258	1.587	-	19.1	1.111	-	15.623	6.436	-			
D_3	29.028	0.056	-	15.987	2.009	-	3.893	0.617	-			
Mean	10.391			4.428			4.166					
P≤F	0.0004			0.0004			0.025					
LSD				2.134			3.281					

Key:
D_1 :fruits dipped in tap water for 5 minutes
D_2: fruits dipped in NaOCl for 5 minutes and $CaCl_2$ for 5 minutes
D_3: fruits dipped in NaOCl for 5 minutes and $C_6H_7KO_2$ for 1 minute
S_1: Storage of fruits at ambient room temperature (32ºC and 29% RH)
S_2: Storage of fruits at refrigerated chamber (11ºC and 90-95% RH)
S_3: Storage of fruits in “zero energy” cool chamber (24ºC and 71% RH)
(-): Sample rotted away

Table 4: Interaction between Postharvest Dip and Storage Environment on Tomato Ascorbic Acid Content (mg/100g)

Dips	3Days			9Days		
	S_1	S_2	S_3	S_1	S_2	S_3
D_1	22.87	21.478	33.796	14.733	17.586	18.899
D_2	21.7	27.054	32.466	19.677	16.91	22.839
D_3	27.792	23.04	19.613	18.128	27.814	18.332
Mean	25.566			19.425		
P≤F	0.0008			0.0095		
LSD	6.761			5.307		
	18Days			24Days		
	S_1	S_2	S_3	S_1	S_2	S_3
D_1	20.356	21.636	28.5	24.8	18.505	17.5
D_2	17.867	25.506	18.05	15.483	23.37	-
D_3	20.45	18.758	-	24.067	22.417	-
Mean	21.31			21.311		
P≤F	0.0015			0.0002		
LSD	8.195			4.126		

Key:
D_1 :fruits dipped in tap water for 5 minutes
D_2: fruits dipped in NaOCl for 5 minutes and $CaCl_2$ for 5 minutes
D_3: fruits dipped in NaOCl for 5 minutes and $C_6H_7KO_2$ for 1 minute
S_1: Storage of fruits at ambient room temperature (32ºC and 29% RH)
S_2: Storage of fruits at refrigerated chamber (11ºC and 90-95% RH)
S_3: Storage of fruits in "zero energy" cool chamber (24ºC and 71% RH)
(-):Rotted

The variation in the amount of Ascorbic acid could be attributed to varietal, soil, and cultural as well as postharvest operation of the fruits. Here also fruits treated with tap water and stored in zero energy cool chamber and fruits treated with Calcium chloride and stored in zero energy cool chamber recorded the highest ascorbic acid content of 33.796 mg/100g and 32.466 mg/100g respectively. Because the two treatments involved ZECC as the storage method, the high ascorbic acid could be attributed to it. Singh and Yadev (2015) reported higher Ascorbic acid retention in tomato fruits stored at zero energy cool chamber compared to other treatments.

Effect of dip and storage conditions on lycopene content

Table 5 presented the results of interaction between postharvest dip and storage environment on lycopene content of tomato fruits during storage. On day 3 of the experiment, the lycopene content of the fruits dipped in tap water and also in fruits dipped in NaOCl with $CaCl_2$ decreased at initial stage before it increased later as the storage methods were changed. On the other hand fruits dipped in NaOCl with $C_6K_7KO_2$ recorded an increase in the amount of lycopene. There was gradual increase in lycopene content as the postharvest dips were changed in fruits stored under ambient temperature condition. Fruits stored under refrigeration recorded a decrease initially before an increase. Dip in NaOCl with $CaCl_2$ and storage in refrigerator had the least lycopene of 89.781 mg/kg and was therefore the best combination.

The lycopene content in fruits dipped in tap water and those dipped in NaOCl with $C_6K_7KO_2$ on day 6 of the experiment decreased initially before it later increased as the storage methods were changed. Fruits dipped in NaOCl with $CaCl_2$ on the other hand recorded a decrease in the amount of lycopene as the storage methods were changed. The lycopene content in fruits stored under ambient temperature decreased first before it slightly increased later.

Fruits stored in zero energy cool chamber had the same trend. On the other hand fruits stored in refrigerator recorded a modest increase in the lycopene content. Dip in tap water and storage under refrigeration had the least lycopene content of 106.295 mg/kg and was therefore the best combination.

The amount of lycopene on day 12 of the experiment for fruits dipped in tap water and also in fruits dipped in NaOCl with $C_6K_7KO_2$ initially decreased before it later increased as the storage methods were changed to refrigeration and zero energy cool chamber respectively. Fruits dipped in NaOCl with $CaCl_2$, on the other hand recorded a fair increase in the lycopene content. The amount of lycopene in fruits stored under ambient temperature and in fruits stored under zero energy cool chamber

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initially decreased before it later increase. On the other hand the opposite was recorded in fruits stored under refrigeration. The best combination remained dip in NaOCl with $C_6K_7KO_2$ and storage in refrigeration as it had the least lycopene content of 31.571 mg/kg.

On day 15 of the experiment, the amount of lycopene in all the three dips initially decreased before it increased later. On day 15 of the experiment, the lycopene content in fruits stored under ambient temperature and those under refrigeration initially decreased before they later increased. The opposite was observed in fruits stored in zero energy cool chamber. Dip in NaOCl with $CaCl_2$ and storage under refrigeration recorded the least lycopene content of 25.580 mg/kg and was therefore the best combination

Table 5: Interaction between Postharvest Dip and Storage Environment on Tomato Lycopene Content (mg/kg)

Dips	3Days			6Days			12Days		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
D_1	141.741	122.684	167.328	172.851	106.295	176.908	52.344	32.258	87.29
D_2	143.666	89.781	167.591	116.398	111.553	108.568	38.228	43.693	48.874
D_3	147.777	154.764	154.03	117.083	114.282	133.699	104.232	31.571	77.797
Mean	142.981			129.406			54.294		
P≤F	0.0001			0.027			0.0002		
LSD	46.700			32.300			20.120		
	15Days			21Days					
	S_1	S_2	S_3	S_1	S_2	S_3			
D_1	70.969	36.268	78.408	52.147	42.788	125.3			
D_2	38.252	25.58	113.638	94.93	32.771	-			
D_3	118.016	51.68	57.638	108.08	36.709	-			
Mean	58.844			53.328					
P≤F	0.0001			0.0005					
LSD	35.360			27.800					

Key:

D_1 :fruits dipped in tap water for 5 minutes
D_2: fruits dipped in NaOCl for 5 minutes and $CaCl_2$ for 5 minutes
D_3: fruits dipped in NaOCl for 5 minutes and $C_6H_7KO_2$ for 1 minute
S_1: Storage of fruits at ambient room temperature (32ºC and 29% RH)
S_2: Storage of fruits at refrigerated chamber (11ºC and 90-95% RH)
S_3: Storage of fruits in “zero energy” cool chamber (24ºC and 71% RH)
(-): Sample rotted away

The amount of lycopene on day 21 of the experiment for fruits dipped in tap water decreased initially before it increased later as the storage methods were changed. The other two postharvest dips all recorded a decrease in the lycopene content as the storage was changed. On day 21 of the experiment, the lycopene content in fruits stored under ambient condition recorded an increase as the postharvest dips were changed to NaOCl with $CaCl_2$ and NaOCl with $C_6K_7KO_2$ respectively. Fruits stored under refrigeration initially decreased before a slight increase as dips were changed. Dip in NaOCl with $CaCl_2$ and storage under ambient temperature had the least lycopene of 32.771 mg/kg as such was the best treatment. The worst treatment were dip NaOCl with $CaCl_2$ and storage in zero energy cool chamber; as well as dip in NaOCl with $C_6K_7KO_2$ and storage in zero energy cool chamber because they all rotted away.

Effect of dip and storage on lycopene content was significant on 3, 6, 12, 15 and 21 days of storage. Lycopene content of tomato fruits ranged from 25.580 mg/kg to 176.908 mg/kg. The ranges were slightly above the 60 – 160 mg/kg and 63 – 155 mg/kg reported by Gharezi *et al.* (2012) and Markovic *et al*. (2010). The highest amount of lycopene of 176.908 mg/kg was recorded in tomatoes stored in zero energy cool chamber. Lycopene increased with advancement in maturity and during storage due to loss of chlorophyll and synthesis of colour pigments (Hobson and Davis, 1971).

Conclusion

The dip in 200 ppm Sodium hypochlorite and 1% Calcium chloride for 5 minutes and storage in refrigerated chamber; and dip in 200 ppm Sodium hypochlorite for 5 minutes and 3% Potassium sorbate for 1 minute and storage in refrigerated chamber were best treatment combinations to extend the shelf life of fresh tomatoes. The two treatments were followed by dip in tap water for 5 minutes and stored in zero energy cool chamber. That is to say where electricity is a problem, dipping the fruits in clean tap water and storing it in zero energy cool chamber can extend the storage life of the fruits**.**

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