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Impact of extracts from plant leaves as edible coatings on quality retention of tomato (*Solanum lycopersicum* L.) fruits during storage after artificial inoculation with fungal isolates

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ABSTRACT

The presence of decay is a very serious defect which renders tomato unmarketable. Fungi are the most important and prevalent pathogens infecting a wide range of fruits and causing destructive and economic important losses of fruits during storage, transportation and marketing. Impact of extracts from plant leaves as edible coatings on quality retention of tomato (*Solanum lycopersicum* L.) fruits after inoculation with fungal isolates was investigated. The experiment was conducted in the Botany Laboratory of the Benue State University, Makurdi. Healthy tomato fruits of the Roma variety were collected at semi ripe stage from the experimental farm. A total of five fungi namely; *Aspergillus flavus*, *Penicillium waksmanii*, *Lasiodiplodia theobromae*, *Fusarium oxysporum* and *Colletotrichum asianum* were artificially inoculated into the healthy tomato fruits. The inoculated tomato fruits were coated with leaf extracts of *Moringa*, Neem and Bitterleaf at 80%w/v and 100% w/v and stored at room temperature. Quality parameters of tomato fruits evaluated include; Beta-carotene content, Lycopene content, pH and Total soluble solids. Analysis of Variance (ANOVA) was used to analyze data. Leaf extract of *Moringa*, Neem and Bitter leaf at 100% w/v gave the best quality retention of tomato fruits. There was a significant increase ($P \leq 0.05$) in Beta-carotene and lycopene content of tomato fruits treated with *Moringa*, Neem and Bitter leaf extracts at 100% w/v over the storage period. pH and total soluble solids content of tomato fruits treated with *Moringa*, Neem and Bitter leaf extracts decreased with increased rate of concentration over the duration of storage. Plant extracts have the potential to maintain the quality parameters of tomato fruits during storage. Therefore, it is recommended that improvement on methods of coating and the amount of additives should be made to impact effectively on overall quality of the food product during storage.

Keywords: Edible coating, tomato fruits, storage, plant leaves, fungi, quality.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) which belongs to the family solanaceae is one of the world's major vegetables with a total area and production of 4.4 million hectares and 115 million metric tonnes respectively (FAO, 2004). It is considered a cash and industrial crop in many parts of the world, not only because of its economic importance, but also its nutritional value to human diet (Ayandiji and Adeniyi, 2011). It is rich in sugars, acids, significant amount of water, minerals, lycopene, sodium, phosphorus, iron, beta carotene and magnesium (Passam *et al*., 2007). The activity of its antioxidants such as vitamin C and E, flavonoids, β-carotene, lycopene and other phenolic compounds is based on their ability to inhibit the oxidation of biomolecules in the human body by preventing the initiation of oxidizing chain reactions (Radzevicius *et al*., 2009).

Global postharvest losses of tomato are as high as 30-40% (Agrios, 2005) but this is much higher in developing countries like Nigeria due to lack of methods to prevent decay caused by fungal pathogens. The presence of decay is a very serious defect which renders tomato unmarketable. Fungi are the most important and prevalent pathogens infecting a wide range of fruits and causing destructive and economic important losses of fruits during storage, transportation and marketing (Sommer, 2008). Over the last century, growth in fresh fruit consumption, particularly whole tomato fruits have led to improvements in preservation treatments to control postharvest disease proliferation and maintain fruit quality and consequently to extend its shelf life (Seymour *et al*., 2003). Several synthetic fungicides have been used to control postharvest decay of fruits (Adaskaveg *et al*., 2005). However, there were three major concerns; increasing consumer concern over pesticide residues on foods, many of which are toxic, development of resistant strains due to excessive use of fungicides and environmental pollution concerns.

In recent years, there is increasing interest to use edible coatings to maintain fruit quality (Tzoumaki *et al*., 2009). The use of edible coating has also received more attention in recent years due to the growing interest for reducing environmental pollution, the need to prolong the shelf life of foods and the increasing demand for healthier ecological foods. Extracts of botanicals such as *Moringa*, Neem and Bitter leaf have been studied as edible coatings for their ability to retard postharvest decay thereby increasing the shelf life and appearance of foods. They have been successfully used in postharvest preservation of fruits and vegetables. Therefore, the objective of this work was to determine the effect of *Moringa*, Neem and Bitter leaf as edible coatings for extended storage life and quality retention of tomato fruits.

2. MATERIALS AND METHODS

2.1 Experimental location

The experiment was carried out in the Botany Laboratory of the Benue State University, Makurdi. Makurdi is located in North Central Nigeria along the Benue River between latitude 07°44′28″N and longitude 08°32′44″E. Temperature within the region fluctuate between 25-42ºC. It is situated within the Benue trough at an elevation of 104 metres above sea level and found in the Guinea savannah region.

2.2 Collection of tomato fruits

Healthy tomato fruits of the Roma variety were carefully harvested at semi ripe stage by hand picking from the experimental farm. Fruits were selected on the basis of similar sizes and maturity level with absence of visual symptoms of disease and defects. The fruits were carefully placed in plastic crates and taken to the laboratory for further studies.

2.3 Collection and disinfection of plant leaves

Fresh leaves of *Moringa oleifera* (Drumstick tree), *Azadirachta indica* (Neem) and *Vernonia amygdalina* (Bitter leaf) were collected from different locations in Makurdi metropolis. A cutlass was used to cut the branches while the leaves were harvested by hand picking. The leaves were put in clean polythene bags and taken to the laboratory. In the laboratory, the leaves of each plant were first prewashed carefully under a gentle stream of tap water for or two minutes to remove surface dirt. This was followed by washing for thirty seconds in sterile distilled water containing 1% sodium hypochloride. The leaves were then removed and rinsed in three successions of sterile distilled water.

2.4 Preparations of plant extracts and extract concentrations

Concentration of each plant species were prepared to give 80% w/v and 100% w/v. Extract concentration of 80% w/v was obtained by weighing 80g of each plant leaf species respectively on a weighing balance. The leaves of each species were grounded separately using a mortar and pestle. Thereafter, the macerates of each plant species were transferred into 100mls of sterile distilled water and allowed to soak for 1 to 2 hours after which sieving was done using a muslin cloth into separate beakers for each plant species. The same principle was applied to 100% w/v.

2.5 Potential of plant leaf extracts to maintain the quality attributes of tomato fruits after artificial inoculation with fungal isolates

Semi ripe, firm and healthy tomato fruits of the Roma variety were surfaced sterilized by dipping them in 1% sodium hypochloride solution for thirty seconds and rinse in three changes of sterile distilled water. The fruits were then inoculated by dipping them in spare suspensions of 4×10^4 conidia/ml each of *Aspergillus flavus*, *Penicillium waksmanii*, *Lasiodiplodia theobromae*, *Fusarium oxysporum* and *Colletotrichum asianum* respectively for 1-2 minutes and incubated for 24 hours at room temperature. After incubation, the fruits were dipped into the aqueous extracts of the plant leaves at different concentrations of 80% w/v and 100% w/v of each plant species. Control fruits were dipped in sterile water only. The fruits were removed and placed in plastic crates and stored at room temperature.

Experimental design/layout

Factors in the experiment were;

1. 3 plant species
2. 5 fungi species
3. 3 extract concentrations including control

Therefore experimental design is 3 × 5 × 3 factorial in completely randomized design

Treatment combinations = 45

Replications =3

Total units = 135

Each unit contained 25 fruits; 25 × 135 = 3,375 fruits

Data collected during the storage duration include;

Beta-carotene (mg/100g)

Tomato fruits were chopped into small pieces and ground into a fine paste by an electric blender for one minute. 10 mls of juice were transferred into a beaker after which 10 mls of acetone were added and the solution vigorously shaken for 1 minute. The solution was filtered through Whatman filter paper and the filtrate was taken for spectrophotometric determination. Sample absorbance was measured at 45nm and beta-carotene was calculated using the formula as given by Ibitoye (2005).

$$\beta\text{- carotene} = A_{451} \times 19.96\ (mg/100g)$$
where A_{451}- absorbance at 451nm
19.96 – extinction coefficient

Lycopene (mg/100g)

Lycopene was determined by the spectrophotometric method which consisted in its extraction using a solution of water and alcohol in a 1:1 ratio. The amount of lycopene extracted was the difference between the absorbance at wavelength λ_2 = 570nm and absorbance at wavelength λ_1 = 780nm (AOAC, 1990). Amount of lycopene in the sample was calculated using the formula;

$$\text{Lycopene} = \frac{A\lambda 1 - A\lambda 2}{M} \times 100\ (mg/100g)$$

Where $A\lambda_1$ = 780nm, $A\lambda_2$ = 570nm, M = Mass of tomato paste

Total soluble solids (TSS) (°brix)

The TSS content of the tomato fruits was determined using a hand held refractometer. A homogenous sample was prepared by blending the tomato fruits in a blender for one minute. Two drops of the sample were carefully applied on the refractometer using a plastic dropper and the reading was obtained directly as percentage soluble solids concentration in °brix (AOAC, 2007).

pH

Tomato fruits were chopped into small pieces and ground into a fine paste by an electric blender for one minute. 10 mls of the tomato juice were transferred into a beaker and pH of the paste was determined by inserting the pH meter into the paste and taking the readings (Ibitoye, 2005).

3. DATA ANALYSIS

Data obtained from the study were analyzed using Analysis of Variance (ANOVA) and the Fisher's Least Significant Difference was used to separate the means at 5% level of significance.

4. RESULTS

The main effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Aspergillus flavus* is shown in Table 1. *Moringa* leaf extract (MLE) gave the highest β-carotene content of 27.92 followed by Neem leaf extract (NLE) with 27.91 and Bitter leaf extract (BLE) with 27.76. However, there were no significant differences in β-carotene content among the treatments.

BLE had the highest lycopene content (2.33) followed by NLE (2.30) while MLE gave the least (2.12) but no significant differences were observed among the treatments.

The pH of fruits treated with BLE and NLE were significantly higher ($P \leq 0.05$) with 4.02 each compared with MLE with 3.98.

Total soluble solids (TSS) were higher in MLE and NLE with 4.94 respectively compared with BLE (4.91). However, there was no significant difference in TSS among the treatments.

The main effect of concentration showed that 100% w/v gave higher β-carotene content with 28.45 compared with the control (25.57). Lycopene content was significantly lower ($P \leq 0.05$) in the control (2.08) and increased as concentration increased with 100% w/v having the highest lycopene content (2.41).

At 100% w/v, pH value was lower with 3.99 compared with control with 4.01 while there were no significant differences among the concentrations. It was observed that TSS at 100%w/v was higher with 4.94 compared with control with 4.93 although no significant differences were observed among concentrations.

The interaction effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *A. flavus* is shown in Table 2. NLE at 100% w/v gave the highest β-carotene value with 29.37 and the lowest β-carotene content (27.04) and this was not significantly different from all the other interactions.

NLE at 100% w/v was significantly higher (2.53) in Lycopene content compared with the control (2.12). There was an increase in β-carotene and lycopene content as concentration increased. The pH and TSS content were found to be highest in NLE at 0%w/v and 80% w/v respectively while MLE at 100%w/v and BLE at 80%w/v gave the least pH and TSS of 3.95 and 4.87 respectively but there was no significant difference in pH and TSS among the interactions.

Table 1. Main effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Aspergillus flavus*.

Leaf extract	BC	LYC	pH	TSS
BLE	27.76	2.33	4.02	4.91
MLE	27.92	2.12	3.98	4.94
NLE	27.91	2.30	4.02	4.94
LSD P≤ 0.05	**NS**	**NS**	**0.03**	**NS**
Concentration	**BC**	**LYC**	**pH**	**TSS**
0	25.57	2.08	4.01	4.93
80	27.55	2.24	4.01	4.93
100	28.45	2.41	3.99	4.94
LSD P≤ 0.05	**NS**	**0.18**	**NS**	**NS**

Key: BC- Beta carotene, LYC- Lycopene, TSS- Total soluble solids, MLE- *Moringa* leaf extract, NLE- Neem leaf extract, BLE- Bitter leaf extract, NS- No significant difference

Table 2. Interaction effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Aspergillus flavus.*

Leaf extract	Concentration	BC	LYC	pH	TSS
BLE	0	27.64	2.19	4.02	4.92
	80	27.46	2.50	4.02	4.87
	100	28.17	2.37	4.02	4.95
MLE	0	27.75	1.92	3.99	4.93
	80	28.21	2.12	4.00	4.95
	100	27.81	2.32	3.95	4.92
NLE	0	27.31	2.12	4.04	4.92
	80	27.04	2.15	4.01	4.96
	100	29.37	2.53	4.00	4.93
LSD P≤ 0.05		**NS**	**0.18**	**NS**	**NS**

Key: BC- Beta carotene, LYC- Lycopene, TSS- Total soluble solids, MLE- *Moringa* leaf extract, NLE- Neem leaf extract, BLE- Bitter leaf extract, NS- No significant difference

Main effect of leaf extract and concentrations on quality parameters of tomato fruits inoculated with *Penicillium waksmanii* is shown in Table 3. Tomato fruits treated with MLE had the highest β-carotene value with 27.78 but this was not significantly different from fruits treated with NLE and BLE with 26.99 and 26.97 respectively. Lycopene content in fruits treated with MLE was significantly lower with 2.03 compared with NLE and BLE with 2.15 and 2.19 respectively. There was no significant difference in pH value among treatments with BLE having the highest value with 4.03 followed by MLE and NLE with 4.02 respectively. TSS content in fruits treated with MLE was significantly higher with 4.96 compared with BLE (4.90).

Main effect of concentration revealed that β-carotene was higher in control with 27.42 but was not significantly different from 80 and 100% w/v with 27.10 and 27.22 respectively. Lycopene content was significantly lower in control and increased as concentration increased with 100% w/v giving the highest value with 2.19. At 100% w/v, pH value was significantly lower compared with the control. 80% w/v gave the highest TSS value (4.94) but this was not significantly different from the other concentrations.

The interaction effect of extract and concentration on quality parameters of tomato fruit inoculated with *P. waksmanii* is presented in Table 4. MLE at 80% w/v gave the highest β-carotene content with 28.66 but was not significantly different from the other interactions. Lycopene content in fruits treated with NLE at 100% w/v was significantly higher with 2.37 compared with BLE and MLE with 2.15 and 2.06 respectively. It was observed that as concentration increased lycopene content increased. MLE and NLE at 80%w/v gave the highest TSS content (4.97) respectively but this was not significantly different from all the other interactions. For pH, NLE at 100% w/v had the highest value with 4.05 but was not significantly different from MLE and BLE with 3.99 and 4.03 respectively.

Table 3. Main effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Penicillium waksmanii*.

Leaf extract	BC	LYC	pH	TSS
BLE	26.97	2.19	4.03	4.90
MLE	27.78	2.03	4.02	4.96
NLE	26.99	2.15	4.02	4.95
LSD P≤ 0.05	NS	0.10	NS	0.04
Concentration	**BC**	**LYC**	**pH**	**TSS**
0	27.42	2.03	4.03	4.92
80	27.10	2.11	4.04	4.94
100	27.22	2.19	4.01	4.92
LSD P≤ 0.05	**NS**	**0.10**	**0.02**	**NS**

Key: BC- Beta carotene, LYC- Lycopene, TSS- Total soluble solids, MLE- *Moringa* leaf extract, NLE- Neem leaf extract, BLE- Bitter leaf extract, NS- No significant difference

Table 4. Interaction effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Penicillium waksmanii*.

Leaf extract	Concentration	BC	LYC	pH	TSS
BLE	0	26.96	2.12	4.03	4.86
	80	27.31	2.30	4.03	4.89
	100	26.65	2.15	4.03	4.87
MLE	0	27.60	2.03	4.02	4.95
	80	28.66	1.99	4.03	4.97
	100	27.08	2.06	3.99	4.96
NLE	0	27.71	2.11	4.03	4.94
	80	25.33	2.05	4.05	4.97
	100	27.93	2.37	3.99	4.93
LSD P≤ 0.05		**NS**	**0.14**	**NS**	**NS**

Key: BC- Beta carotene, LYC- Lycopene, TSS- Total soluble solids, MLE- *Moringa* leaf extract, NLE- Neem leaf extract, BLE- Bitter leaf extract, NS- No significant difference

The main effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Lasiodiplodia theobromae* is presented in Table 5. NLE gave significantly higher β-carotene content with 27.61 compared with BLE and MLE which gave 27.45 and 25.08 respectively. Tomato fruits treated with NLE gave significantly higher lycopene value with 2.20 compared with MLE (2.03). The pH value of tomato fruits treated with BLE was significantly higher with 4.05 compared with fruits treated with MLE and NLE with 4.02 respectively. There was a significant difference in TSS value among extracts with TSS value of fruits treated with MLE significantly higher with 4.96 compared with NLE and BLE with 4.94 and 4.90 respectively. The effect of concentration revealed that β-carotene value at 80% w/v with 27.55 was significantly higher compared with 100%w/v (25.87) but not significantly different from 0%w/v (26.73). It was found that lycopene content increased as concentration increased with 100% w/v giving the highest value with 2.16 but was not significantly different from the control (2.08). pH value was significantly higher at 80% w/v (4.05) compared to the other concentrations. TSS increased as concentration increased with 100% w/v producing the highest TSS of 4.94 but this was not significantly different from 80% w/v and control with 4.93 and 4.92 respectively.

The interaction effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *L. theobromae* is shown in Table 6. The interaction effect of concentration and extract on β-carotene content revealed that NLE at 100% w/v produced significantly higher β-carotene content (28.89) compared with the control across all interactions. NLE at 100% w/v produced the highest Lycopene content (2.34) while MLE at 0%w/v produced the least (1.99). BLE at 80%w/v produced the highest pH content (4.08) but this was not significantly different from the other interactions. MLE at 80%w/v produced the highest TSS content while NLE at 0%w/v produced the least but they were not significantly different from each other.

Table 5. Main effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Lasiodiplodia theobromae*.

Leaf extract	BC	LYC	pH	TSS
BLE	27.45	2.13	4.05	4.90
MLE	25.08	2.03	4.02	4.96
NLE	27.61	2.20	4.02	4.94
LSD P≤ 0.05	**0.90**	**0.10**	**0.02**	**0.04**
Concentration	**BC**	**LYC**	**pH**	**TSS**
0	26.73	2.08	4.03	4.92
80	27.55	2.12	4.05	4.93
100	25.87	2.16	4.01	4.94
LSD P≤ 0.05	**0.90**	**NS**	**0.02**	**NS**

Key: BC- Beta carotene, LYC- Lycopene, TSS- Total soluble solids, MLE- *Moringa* leaf extract, NLE- Neem leaf extract, BLE- Bitter leaf extract, NS- No significant difference

Table 6. Interaction effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Lasiodiplodia theobromae*

Leaf extract	Concentration	BC	LYC	pH	TSS
BLE	0	26.81	2.11	4.05	4.89
	80	27.97	2.18	4.08	4.90
	100	27.56	2.09	4.03	4.94
MLE	0	26.25	1.99	4.03	4.95
	80	27.84	2.03	4.02	4.96
	100	21.16	2.05	4.01	4.90
NLE	0	27.12	2.13	4.01	4.91
	80	26.82	2.13	4.06	4.94
	100	28.89	2.34	4.00	4.97
LSD P≤ 0.05		**1.55**	**NS**	**NS**	**NS**

Key: BC- Beta carotene, LYC- Lycopene, TSS- Total soluble solids, MLE- *Moringa* leaf extract, NLE- Neem leaf extract, BLE- Bitter leaf extract, NS- No significant difference

The main effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Fusarium oxysporum* is shown in Table 7. Tomato fruits treated with BLE gave the highest β-carotene content (27.71) but this was not significantly different from fruits treated with NLE (27.45) and MLE (27.34) respectively. Lycopene content in fruits treated with MLE was significantly lower (2.02) compared with NLE and BLE with 2.24 and 2.26 respectively. There was a significant difference in pH value with BLE and NLE giving the highest value of 4.02 each compared with MLE with 3.99. MLE gave the highest TSS value with 4.97 but was not significantly different from TSS of tomato treated with BLE and NLE with 4.92 and 4.88 respectively. The main effect of concentration showed that β-carotene was significantly lower in control with 27.00 compared with 100%w/v (28.31) and increased as concentration increased. For the lycopene content, the value was higher at 80% w/v with 2.21 but was not significantly different from control and 100% w/v at 2.16 and 2.20 respectively. TSS decreased as concentration increased with 100% w/v having the lowest value of 4.88 compared with control and 80% w/v with 4.94 and 4.93 respectively. There was no significant difference in the pH content among concentrations.

The interaction effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *F. oxysporum* is shown Table 8. β-carotene increased as concentration increased with NLE at 100% w/v giving the highest value with 28.81 but was not significantly different from BLE and MLE with 28.34 and 27.77 at the same concentration. Lycopene content in tomato fruits treated with NLE was higher (2.38) and was not significantly different from lycopene content of tomato fruits treated with BLE and MLE (2.12) and (1.95) respectively but increased as concentration increased. BLE, MLE and NLE gave higher pH value at 100% w/v with 4.01 respectively but were not significantly different from other concentrations. MLE gave the highest TSS value at 80% w/v with 4.98 but was not significantly different from BLE and NLE with 4.94 and 4.72 respectively.

Table 7. Main effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Fusarium oxysporum*.

Leaf extract	BC	LYC	pH	TSS
BLE	27.71	2.26	4.02	4.92
MLE	27.34	2.02	3.99	4.97
NLE	27.45	2.24	4.02	4.88
LSD P≤ 0.05	**NS**	**0.18**	**0.02**	**NS**
Concentration	**BC**	**LYC**	**pH**	**TSS**
0	27.00	2.16	4.01	4.94
80	27.19	2.21	4.00	4.93
100	28.31	2.20	4.01	4.88
LSD P≤ 0.05	**1.02**	**NS**	**NS**	**NS**

Key: BC- Beta carotene, LYC- Lycopene, TSS- Total soluble solids, MLE- *Moringa* leaf extract, NLE- Neem leaf extract, BLE- Bitter leaf extract, NS- No significant difference

Table 8. Interaction effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Fusarium oxysporum*.

Leaf extract	Concentration	BC	LYC	pH	TSS
BLE	0	27.33	2.39	4.03	4.91
	80	27.48	2.26	4.00	4.89
	100	28.34	2.12	4.01	4.94
MLE	0	26.99	1.95	3.97	4.95
	80	27.27	2.15	3.99	4.98
	100	27.77	1.95	4.01	4.85
NLE	0	26.68	2.13	4.02	4.97
	80	26.85	2.22	4.02	4.94
	100	28.81	2.38	4.01	4.72
LSD P≤ 0.05		**1.55**	**NS**	**NS**	**NS**

Key: BC- Beta carotene, LYC- Lycopene, TSS- Total soluble solids, MLE- *Moringa* leaf extract, NLE- Neem leaf extract, BLE- Bitter leaf extract, NS- No significant difference

The main effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Colletotrichum asianum* is shown in Table 9. There was no significant difference in β-carotene content among the treatments. NLE extract gave significantly higher lycopene content (2.21) compared with MLE (2.06). pH value was significantly lower in MLE (3.98) compared with BLE and NLE with 4.02 and 4.00 respectively. There was significant difference in TSS content of tomato fruits among the extracts with MLE and NLE having the higheest value of 4.95 respectively. At 100% w/v, β-carotene was significantly higher (28.05) compared with the control (26.90) and increased as concentration increased. There was no significant difference in lycopene content among concentrations. At 0% w/v and 80%w/v, pH had the highest content of 4.01 respectively in the fruits and this was not significant across the extracts. 80%w/v produced the highest TSS content (4.95) but this was not significant compared to 0%w/v (4.92) and 100%w/v (4.94).

The interaction effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *C. asianum* is shown in Table 10. β-carotene content increased as concentration increased with MLE at 100% w/v having the highest value with 28.67 but this was not significantly different from BLE and NLE with 27.75 and 27.72 at the same concentration. There was no significant difference in lycopene, pH and TSS content among treatment interactions. TSS was observed to decrease as concentration increased during the storage duration.

Table 9. Main effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Colletotrichum asianum*.

Leaf extract	BC	LYC	pH	TSS
BLE	27.12	2.10	4.02	4.90
MLE	27.65	2.06	3.98	4.95
NLE	27.13	2.21	4.00	4.95
LSD P≤ 0.05	**NS**	**0.12**	**0.02**	**0.03**
Concentration	**BC**	**LYC**	**pH**	**TSS**
0	26.90	2.13	4.01	4.92
80	26.95	2.13	4.01	4.95
100	28.05	2.11	4.00	4.94
LSD P≤ 0.05	**0.62**	**NS**	**NS**	**NS**

Key: BC- Beta carotene, LYC- Lycopene, TSS- Total soluble solids, MLE- *Moringa* leaf extract, NLE- Neem leaf extract, BLE- Bitter leaf extract, NS- No significant difference

Table 10. Interaction effect of leaf extract and concentration on quality parameters of tomato fruits inoculated with *Colletotrichum asianum*.

Leaf extract	Concentration	BC	LYC	pH	TSS
BLE	0	26.75	2.11	4.02	4.86
	80	26.87	2.15	4.02	4.92
	100	27.75	2.05	4.03	4.93
MLE	0	26.88	2.09	3.98	4.93
	80	27.40	2.07	3.98	4.96
	100	28.67	2.01	3.98	4.95
NLE	0	27.07	2.19	4.02	4.96
	80	26.59	2.17	4.02	4.95
	100	27.72	2.25	3.99	4.94
LSD P≤ 0.05		**NS**	**NS**	**NS**	**NS**

Key: BC- Beta carotene, LYC- Lycopene, TSS- Total soluble solids, MLE- *Moringa* leaf extract, NLE- Neem leaf extract, BLE- Bitter leaf extract, NS- No significant difference

5. DISCUSSION

During the study, the total soluble solid content of the tomato fruit treated with leaf extract of *Moringa*, Neem and Bitter leaf decreased over storage period compared to the untreated. This decrease in total soluble solid might be caused by a decline in the amount of carbohydrates and pectins, partial hydrolysis of protein and decomposition of glycosides into sub units during respiration (Athmaselvin *et al*., 2012). This was similar to the work by Moalemiyan *et al*. (2012); Yaman and Bayoindirli (2002) on mango and cherries respectively in which they reported a decrease in total soluble solids over the storage period.

The pH value also showed a decrease in trend which gives the tomato fruits higher acidity. The higher acidity in treated fruits in this study might be because of reduced respiration rate as a result of concentration of leaf extract which limits the availability of oxygen to the fruits (Jiang and Li, 2001).

Lycopene is the major carotenoid compound in tomatoes, it gives the fruit its characteristic red colour. It was observed that lycopene content from all treatments increased as concentration increased over storage time with the untreated having the least lycopene content. The increase in lycopene content of fruits treated with leaf extract might be due to faster ripening rate of fruit which leads to the conversion of chloroplasts to chromoplasts and lycopene accumulation in internal membrane system (Grierson and Kader, 1986). This was similar to the works of Abebe *et al*. (2017); Ali *et al*. (2013) on tomato in which they reported that lycopene content increased over storage period.

In this study, the accumulation rate of β-carotene increased with increased rate of concentration with the control having the lowest β-carotene compared with tomato fruits treated with plant extracts. This is contrary to the report from a similar work by Tigist and Wosene (2015) who stated that β-carotene was higher in control while treated fruits had lower carotene content. The difference in opinions might be because carotenoid composition of fruits and vegetables varied significantly among other factors, by types as well as variety of a given crop. Their levels are affected by factors such as climatic conditions, part of the plant utilized (peels, seeds, fleshy portion) storage and the presence of other carotenoids (Cadoni *et al*., 2000).

6. CONCLUSION

The findings of this study have established that leaf extract of plant origin can be used as edible coating to maintain the physiological quality of tomato fruits during storage. These botanicals are eco friendly and safe for consumers and they provide a simple method by which deterioration of the produce can be restricted as much as possible at ambient temperatures between harvest and end use.

Recommendations

1. The use of leaf extract of *Moringa*, Neem and Bitter leaf at 100% w/v concentration should be utilized in coating tomato fruits to maintain its quality parameters during storage.
2. Improvement on methods of coating and the amount of additives should be enhanced to effectively impact on the overall quality of food product during storage.

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