Effect of Plants extract on the shelf life and quality of tomato fruits postharves And marketing

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Abstract

In Iraq, tomato is one of the most significant vegetable fruit grown for consumption in every home, consumed both fresh and in paste form and a cheap source of vitamin A, C, E and minerals which protect the body against diseases. Tomato is a perishable fruit that has a somewhat limited shelf life. Fresh products, like tomatoes, have different firmness and nutritional values depending on how they are stored. The objective of this study was to determine how biopreservatives (garlic and neem or their combined) affected tomato shelf life and quality at doses of 100 and 200 mg/ml. According to the findings, tomatoes treated with biopreservatives had a longer shelf life (22 days), were firmer, more marketable, and had better quality than untreated fruits. They also showed lower percentages of weight loss and postharvest degradation. Although not to a statistically significant degree, treated fruits had higher titratable acidity, beta carotene, and lycopene values than control. Consequently, the application of biopreservatives seems to be the most effective method for increasing tomato quality and shelf life.

Keyword: Tomato; Garlic; Neem; biopreservatives ; Postharvest; ; Shelf Life; Quality

Introduction

Tomatoes are one of the most profitable and popular vegetables grown worldwide, are ranked second after potatoes among vegetable plants, and the first among processed crops in terms of the areas planted and the production with vegetables, globally(15). Tomato fleshy berries are rich in minerals (mainly K, P, Mg), vitamins (ascorbic acid and niacin), carotenoids (lycopene, β-carotene, lutein) and polyphenols (chlorogenic acid, quercetin, naringenin), which makes it an adequate source for these nutrients (8). Tomatoes are an essential food for humans, but they have a limited shelf life, are highly perishable, and are easily contaminated by post-harvest, which can lead to large losses in harvested fruit during storage and transportation. These losses might be classified as off-farm or on-farm (16). The results of (24) revealed that biopreservatives treated tomatoes showed better shelf life and quality relative to untreated fruits. Post-harvest losses can be decreased in part by effective post-harvest stage coordination and management in addition to post-harvest technologies (11). Tomatoes spend so much time on shelves and refrigerators that an estimated 20% are lost due to spoilage. From the jiffy produce is harvested the clock starts ticking and decaying starts (13). There is still no totally reliable protocol to identify and control postharvest diseases. Strategies usually include biological control, heat treatment, natural compounds (5). Because most fruits have a short shelf life, it is critical to look for environmentally responsible ways to preserve the quality of these items (32). The plant kingdom is rich in its by-products with a bitter taste, Phytochemicals compound depending on how they contribute to plant metabolism are categorized as primary and secondary metabolites(17).

which have been used as a treatment against most incurable diseases that affect humans and

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animals, and have been used to kill and inhibit the growth of many pathological microorganisms (19). Many synthetics have been used to preserve tomato fruits but consumers are becoming very concerned on the use of synthetics on horticultural crops like tomatoes. The use of plant materials as preservatives apart from extending shelf life of foods, are less toxic to humans and animals than synthetic preservatives (2). After analysis of different physico-chemical analysis garlic extract coating found to be very effective in minimising the various losses occur during the postharvest life of fruit.

Plant extract postharvest treatments maintain enhanced antioxidant capacity, heightened non-enzymatic antioxidant activity, hormone biosynthesis modulation, and postponed cell wall degradation (7). Neem extract and garlic extract are two of these extracts. Neem extract contains antifungal and antibacterial qualities, which belong to the family Meliaceae. This plant possesses antibacterial, antioxidant, and medicinal qualities. Several bioactive substances found in its extract, it was used as an edible coating on tomatoes in an experiment, and it significantly enhanced the texture, color, and flavor of the tomatoes (25). (12) conducted a research on Postharvest shelf life and quality of tomato fruits and found that neem leaf powder can extend the shelf life of tomatoes. (19) concluded that combined garlic and ginger (2 and 4%) suitably preserved tomato paste for 8 weeks without deterioration at refrigeration temperature (4±1 ℃). Edible coating is an innovative method of food preservation, producing a physical barrier on the surface of fruits and vegetables that causes moisture and solute migration, gas exchanges and respiration and oxidative reaction rates reduction, extending the shelf-life and reducing the risk of pathogen growth on food surfaces (10). In Iraq, tomato is one of the most important vegetable fruit grown for consumption in every home, consumed both fresh and in paste form and a cheap source of vitamin A, C, E and minerals which protect the body against diseases. Therefore, the aim of this study was to evaluate the effect of biopreservatives (neem and garlic)on the shelf life and quality of tomato.

Materials and methods

Collection of Tomato Fruit Samples

Healthy tomato fruits used for this study were obtained from local market,. The fruits were ripe, firm, smooth and free of any defects

Collection of Garlic bulbs and Neem Leaves

Neem (Azadirachta indica) plants were purchased from nurseries at Babil Governorate, while garlic (Allium sativum) cloves were purchased from local markets.

Design and treatments of the experiment

A experiment replicated three times laid out in a completely randomized design (CRD) is used in this study. Postharvest biopreservatives with their concentrations are distribute randomly in each replication, (i. Control (Sterile distilled water), ii. Garlic extract at 100 and 200mgml^{-1}, iii. Neem extract at 100 and 200mgml^{-1}, iv. Mixing between the concentrations of neem and garlic extracts (100neem+100garlic mgml^{-1}) and (200neem +200garlic mgml^{-1}),v. Fungicide Carbendazim 2gl^{-1}).

Extraction of Water extract Water is used as the solvent in this extraction process. 100 and 200 g of garlic and neem powder are individually dissolved in 1 liter of hot, sterile, distilled water (100°C) in 2 liter sterile conical flasks. The flasks are then violently shaken and left on the bench for 24 hours at room temperature (25±2°C). Following that, filtered with two-layered Muslin's cheese cloth filter.

After that, the filtrate was centrifuged for 15 minutes at 6000 rpm. To get concentrations of 100 and 200 gl^{-1}, the collected supernatant is filtered once more using Whatman's No.1 filter paper to remove undesirable particles (31).Then, the filtrate was transferred into sterile universal bottles and kept cold (4°C) in the refrigerator until used.

Applying Bio-Preservatives

Tomato fruits used in this study are selected based on their uniformity in size, appearance, The stage of maturity at harvested; and washed in clean water to remove dirt, rinsed again in water and kept to air-dry before treatment, but were not surface sterilized so as not to interfere with surface pathogens. Tomatoes are dipped into the solutions of various prepared plant extract treatments and sterile distilled water, in addition to the fungicide Carbendazim for 5 min at room temperature (25°C) and air dried. Treated tomatoesLittle(few) per treatment in each replicate) are weighted by sensitive balance. The weighted tomato fruits are kept in plastic bag and stored at 25°C for 22 days. Each treatment replicated three times. During the postharvest storage period the experimental fruits were profoundly observed every day to observe any change. Physical observations such as postharvest decay percentage (PDP), weight loss percentage (WLP), firmness and marketability are recorded every 3, 5, 7, 9, 11, 13, 15, 17, 19 and 22 days of storage, in addition to shelf life. For estimation of chemical analysis like pH, titratable acidity (TA), β-carotene and lycopene of each sample are analysis at the end of study22 days of storage, as follow:

1. Weight Loss percentage (WLP)

Using a weighing balance, tomato fruits were weighed both at the start and throughout the storage period. Total weight loss during the storage interval was defined as the difference between the fruits' initial and final weights, and it is calculated using the following formula and expressed as percentage (24):

Weight Loss (%) = (IW- FW/IW) x100

Where IW= Initial Weight, FW= Final Weight

2. **Postharvest Decay Percentage (PDP)**

Postharvest decay or rotting is estimated by visually inspecting the product for signs of deterioration during storage, postharvest decay or rotting was identified. Samples exhibiting signs of deterioration were counted, recorded, and expressed in percentage as displayed below (Tunwari *et al*., 2019):

PDP = (Number of fruits Decaying / Total number of fruits) x100

3. Shelf Life The number of days that tomato fruits were still suitable for marketing after being subjected to various postharvest storage treatments is used to calculate the shelf life of tomato fruits. This is done by calculating the days that the fruits must decay by 25% as to retaining their edible properties. Fruit peel degradation or black spots are graded according to their degree (24).

4. Firmness

Tomato fruit firmness was measured by hand by estimating the percentage of shrinkage condition of tomato during storage using a numerical rating scale of 1 to 5. Where 1= >40% shrinkage (very poor), 2=>30-40% shrinkage(poor), 3= >20-30% shrinkage (acceptable), 4=1-10% shrinkage(good), and 5= no shrinkage(excellent) (29., 24).

5. Marketability

The formula determined the percentage of marketable fruits during the trial based on descriptive quality parameters such the degree of visible lesion, shriveling, smoothness, and shininess of the fruit is calculated by the following formula (29).

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Marketability of Tomato Fruit = (Number of marketable fruits / Total number of Fruits) x100.

For chemical properties, pH meters are used to estimate pH.Titratable acidity determine following (23).Tomato beta-carotene content is estimated following the method of Nagata and Yamashita (1992), and using a spectrophotometer, the lycopene content absorption is determined according to method of. (3).

Data Analysis

The data collected for various parameters were subjected to ANOVA using the Statistical Analysis System- SAS program according to Completely Randomized Design-CRD with three replicates, least significant difference – LSD-Test was used to significant compare between means at *P≤0.05*.

Results and Discussion

Results

Physical Properties

Postharvest Decay Percentage (PDP)

Effects of plant extracts on post-harvest decay percentage (PDP) of tomato fruits are presented in Table 1, twenty-two days is the storage duration. PDP of tomato fruits during storage showed that there was significant difference P≤ 0.05between treated and control fruits except on day3. On days13, 16, 20 and 22, the post-harvest decay was observed on all treated and untreated fruits which increased gradually, except for 100G mgml^{-1} that showed no post-harvest decay at the period of storage except at the day22 exhibited some post-harvest decay (11.10%), followed by200G+200N mgml^{-1} which maintained a low level of decay (22.2%), while the highest decay was recorded on day22 on the control fruits (88.87%). Garlic extract-treated tomato fruits displayed minimal deterioration followed by neem extract (Table1).

Table 1. Effect of plant extracts on post-harvest decay percentage (%) of tomato during different days of storage.

Treatment	Storage duration (day) and post-harvest decay percentage (%)							
	3	5	7	9	13	16	20	22
Control	0	33.30	33.30	33.30	55.50	66.60	88.87	88.87
100 N	0	0	0	0	22.20	22.20	44.40	44.40
200 N	0	0	11.10	11.10	22.20	33.30	44.40	44.40
100 G	0	0	0	0	0	0	0	11.10
200 G	0	0	11.10	11.10	22.20	33.30	44.40	55.50
100N+G	0	0	11.10	11.10	11.10	22.20	44.40	55.50
200N+G	0	0	11.10	11.10	11.10	22.20	22.20	22.20
Carbendzim	0	0	11.10	11.10	11.10	11.10	44.4	44.4
LSD value	N.S	1.03	25.85	25.85	31.49	38.44	39.49	35.15
*** (P≤0.05), N.S.: Non-Significant**								

Weight Loss Percentage (WLP)

It was discovered that the weight loss of tomato fruits is consistently (P≤ 0.05) decreased by garlic extract and neem extract. There was notable variation in the weight loss percentage calculated for each bio-preservative. However, There was gradual decrease of weight loss over twenty-two day storage period (Table 2).On 7th, 9th, 13th, 16th and22th day, no significant differences were observed between control and other treatments, However, the control fruits showed higher weight loss (13.42 ,25.83,31.41 and

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48.38 %) at9th,13th,16th and22th day, respectively. On day 20, the treated fruits with 100G mgml-1 showed the significant lowest in weight loss (18.20%) compared to the rest treatments, the control fruits had a higher weight loss (43.46%). However, there was progressive loss in fruits weight at all treatments in the course of this research.

Table2.Effect ofplant extracts on weight loss percentage(%) of tomato during different days of storage.

Treatment	Storage duration (day) and loss weight percentage (%)							
	3	5	7	9	13	16	20	22
Control	1.20	2.40	5.84	13.42	25.83	31.41	43.46	48.38
100 N	1.57	2.91	6.53	10.73	15.82	19.79	26.94	44.50
200 N	0.88	1.57	5.71	12.27	14.45	17.14	21.46	37.17
100 G	0.87	1.75	5.38	9.43	14.99	15.82	18.20	33.64
200 G	0.84	2.28	4.54	8.39	13.24	19.57	24.77	32.24
100N+G	0.31	1.94	4.90	9.98	23.65	29.35	40.47	30.43
200N+G	0.99	2.16	5.56	9.74	19.96	25.41	29.31	28.44
Carbendzim	0.76	1.87	5.36	8.88	13.34	24.77	20.63	20.00
LSD value	0.723	1.027	N.S	N.S	N.S	N.S	25.03	N.S
* (P≤0.05), N.S.: Non-Significant								

Shelf Life

Based on the results of Figure1, it can be inferred that neem and garlic extract have the potential to greatly extend tomato fruits shelf lives, when compared to the control group (untreated with plant extract). The study took into consideration the shelf life of treated tomato fruits, which was found to be highly significant.It could be mentioned that maximum (22days) shelf life of tomato fruits was belong to 100N,200N and 100G followed by 200G mgml-1 (20 days) treated fruits and minimum (5 days) shelf life was recorded in controlled fruits (Figure 1). The amount of days it took for the fruits to completely deteriorate showed how much the application of plant extracts extended the shelf life of tomato fruits.

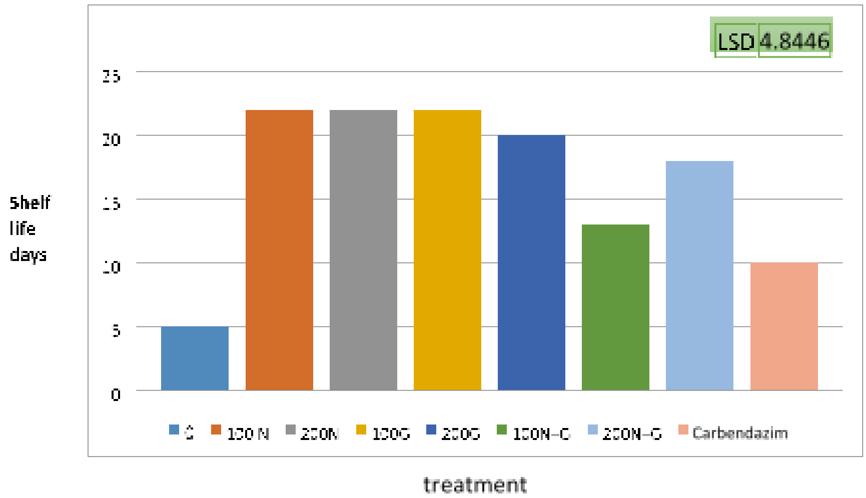

Figure 1. Effect of plant extracts on shelf life(days) of tomato fruitsFirmness

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The effects of plant extracts on the firmness of tomato fruits taken at intervals of 3, 5, 7, 9, 13, 16, 20, and 22 days are displayed in Table 3.Tomato fruits treated with neem, garlic and their combination extracts exhibited better degree of firmness, they were found to be significant compare with control treatment, except on day3, where not found to be significant differ compare with control treatment. It is noted that using 100 garlic concentrate was superior in maintaining the firmness of tomato fruits throughout the experiment (Table3).

Table 3. Effect ofplant extracts ontexture of tomato during different days of storage.

Treatment	**Storage duration (day) and firmness**							
	3	5	7	9	13	16	20	22
Control	5	3.66	2.66	2.33	1.66	1	1	1
100 N	5	5	4.66	4	4	3	2.66	1.66
200 N	5	4.66	4.33	4.33	3.66	3.33	3	2.66
100 G	5	5	5	4.33	4.33	4	3.66	3
200 G	5	5	5	4.66	4	2	2	2
100N+G	5	4.66	4.33	4.0	2.33	2	1.33	1
200N+G	5	4.66	4.66	4.33	4	3	3	3
Carbendzim	5	4.33	3.66	3	2.33	2	1.66	1.66
LSD value	N.S	0.752	1.330	1.792	1.604	2.009	1.660	1.671
*** (P≤0.05), N.S.: Non-Significant**								

Marketability

The Marketability of tomato fruits during the storage duration revealed that treated and control tomato fruits differed significantly ($p < 0.05$), with the exception of day 3 were all tomato fruits were still marketable (100%)(Table4). Until 5th day all fruit treated with plant extracts were still marketable (100%) When compared to the control (untreated) and treated with fungicide (66.63%). On 9th day to 22thday tomato fruits treated with neem and garlic extracts or their combination at the concentration of 200 mgml-1 exhibited the highest marketable compared to other treatments. It is noted that the untreated tomato fruits rotted completely on the 20th and 22th day, as well as the fruits treated with the fungicide on the 22th day. It is interesting that more than half of the fruits (55.5%) treated with the concentration of 100 mgml-1 garlic maintained their marketable on the 22th day, while the untreated fruits and the fruits treated with the fungicide (Carbendzim) completely rotted(0%)(Table4).

ISSN 2072-3857

Table 4. Effect of plant extracts on marketabilityof tomato during different days of storage.

Treatment	Storage duration (day) and marketability (%)							
	3	5	7	9	13	16	20	22
Control	100	66.63	66.6	44.40	22.2	11.10	0	0
100 N	100	100	100	77.73	66.63	66.63	44.40	44.40
200 N	100	100	100	88.87	66.63	66.63	55.50	44.40
100 G	100	100	100	88.87	66.63	66.63	66.63	55.50
200 G	100	100	88.87	88.87	55.50	55.50	22.20	22.20
100N+G	100	100	55.53	33.3	33.30	22.20	22.20	11.10
200N+G	100	100	100	88.87	66.63	55.50	55.50	22.20
Carbendzim	100	66.63	77.77	55.53	33.30	11.10	11.10	0
LSD value	N.S	23.84	37.44	42.49	43.90	49.12	41.01	40.71
*** (P≤0.05), N.S.: Non-Significant**								

Chemical Properties

In terms of the chemical properties under investigation, such as pH, titrable acidity, beta-carotine, and lycopene content, tomato fruits treated with plant extracts showed difference from control but not reach the significant level.For instance, the results showed that notable pH fluctuations were seen in several post-harvest tomatoes. 200 N $mgml^{-1}$ had the highest pH value (4.63). Of the two, 200N+G $mgml^{-1}$ and carbendazim (fungicide) had the lowest value (3.6).The concentration100N+G $mgml^{-1}$ had the highest titrable acidity value (0.707%), β-carotene (0.415 mg $100g^{-1}$) lycopene content (1.755 mg $100g^{-1}$)(Table5).

Table5.Effect of plant extracts on chemical properties of tomato fruits.

Treatment	pH	TA (%)	B-carotene (mg $100g^{-1}$)	Lycopene (mg $100g^{-1}$)
0	4.6	0.36	0.215	1.411
100N	4.23	0.293	0.191	1.645
200N	4.63	0.053	0.415	1.140
100G	4.47	0.667	0.183	1.755
200G	3.9	0.537	0.159	1.511
100N+G	4.14	0.717	0.415	1.340
200N+G	3.6	*0.187*	0.209	1.440
Carbendazim	3.6	*0.493*	0.140	1.298
LSD 0.05	N.S	N.S	N.S	N.S

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Discussion

The finding that extracts from garlic cloves and neem leaves can reduce the amount of tomato decay suggests that these extracts may be a viable substitute for preventing pathogen-induced tomato deterioration. This observation is consistent with other reports that found that the most effective methods for protecting plant fruits from pathogenic and environmental factors were extracts from medicinal plants such as neem and garlic (16; 6). Because their extracts inhibited the activity of several fungi that cause tomato fruit spoiling, neem and garlic were able to reduce the amount of decay that occurred to the tomato fruits in this investigation. The amount of damaged fruits in the tomato fruits that were treated and those that were not was different from one another. On day 22 of storage, the control fruits were 88.87 percent rotting, whereas the treated fruits, at 100 grammes per millilitre, were just 11% rotten and preserved their colour(Table1). Garlic and neem extracts have the ability to reduce tomato decay, suggesting that they may be used as a possible alternative in the prevention against pathogen-induced tomato deterioration. (1) discovered that when garlic extract coating is applied, spoiling only occurs after 21 days of storage, while it began significantly sooner in the case of control fruits, which were occurs after 15 days. The results of Table 2 indicate that the largest percentage of weight loss (48.38%) occurred in the control fruits, possibly as a result of increased transpiration, evaporation, or respiration rate (26). Fruit shelf life can be increasedplant extracts it with neem or garlic, which slows down the rate of respiration and moisture loss. Regardless of the biopreservatives utilised in this investigation, the weight loss percentage increased with storage time, peaking at the end of the storage day, in line with findings of (24).

Over the course of 22 days at room temperature, the tomato's weight loss gradually increased. The study found that during storage, weight loss varied between 20.63 and 48.38%. At the end of the trial period, the control fruits showed the most percentage loss in weight (Table 2). The weight loss of fruits increased with the length of storage time, according to similar findings reported by othor authors (27; 12.,; 1; 29; 24). Consequently, bio-coatings effective in reducing post-harvest losses include neem and garlic. Additionally, it lessens transportation losses by preventing injuries and cuts that may occur when food is transported from the coating location to the final customer. Because coatings aid to prevent moisture loss and gaseous exchange, they also modify the levels of internal carbon dioxide, oxygen, and ethylene, slow down the ripening process, and preserve the fruit's natural form. According to (28), the film produced on fruit skin serves as an extra barrier.

Bio-coating materials are typically used to extend the shelf life and improve fruit quality while it is being stored. These coatings work by minimising moisture loss and improving the natural appearance and quality of the product while it is being stored. Tomato fruits' shelf life was increased by applying neem extract and garlic, as evidenced by the number of days it took for the fruits to totally fall apart. The findings of this investigation are in line with those of. (29) and (24), who discovered that neem significantly, increased the shelf life of tomato fruits. Neem and garlic extracts, as well as their combination, showed a significant ability to inhibit tomato fruit deterioration and extend their shelf life at varying concentrations (Figur1). This

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demonstrates that tomatoes sold in stores may be kept fresh for up to 22 days without losing their firmness or texture. These findings aligned with the findings of *l*. (12) and. (2), who found that tomatoes can be preserved for up to 22 days and stay fresh when soaked in neem or garlic extracts; and (24), that tomatoes' shelf life can be increased to 14 days by using neem or garlic extracts. In current study a high deterioration and the shortest shelf life were discovered in the control, within five days, the control treatment deteriorated (Figure1). (29) and (24) found the same result, with tomato fruits deteriorating at 7 days, but different from. (12) who reported 19 days. Washing the tomato's surface not only prolongs its shelf life and improves its marketability, but it also wards off fungus growth. Additionally, according to (9), plant extracts have the ability to operate as a biopesticidal agent against phytopathogens, making them a viable substitute for conventional fungicides in the preservation of plant goods. Produce that has been coated has a brighter exterior appearance, making it appear more shiners than untreated produce (22).

To evaluate the preservation potential of garlic and neem extracts, the firmness of the tomato fruits utilised in the study was also taken into account as a quality measure. This is because, while purchasing tomatoes, the majority of consumers like to feel and touch the fruits, particularly after observing their hue. The decline in firmness can be ascribed to increased rates of metabolic activity and activity of enzymes that break down cell walls, which weaken fruit skin and increase cell permeability, leading to a faster rate of moisture loss. After the trial period, neem and garlic extracts appear to show some degrees of firmness in terms of marketability and firmness (Tables 3; 4). During storage, the other treatments—particularly the control—lost their firmness (Table 3). The decrease in firmness can be ascribed to increased metabolic activity and the activity of enzymes that break down cell walls, which loosen the fruit peel and increase cell permeability, leading to a higher rate of moisture loss. When compared to control fruits, previous studies (12) likewise found that tomato fruits treated with neem and garlic had the highest marketability.

Chemical properties

pH level of tomato juice treated with neem and garlic extracts showed no significant decrease, while Lycopene, TA and beta-carotene content showed no significant increase as compared to control tomato juice(Table5). Daily variations in pH values and decreasing acidity are caused by the widespread catabolization of organic acids and their transformation into sugar (24). The tomato juice pH results in this investigation varied from 3.6 to 4.6 (Figure4.10). These results are consistent with those of (24), who recorded pH values ranged 5.03-4.5 Moreover, because there was no covering on the untreated fruits, they ripened more quickly. They consequently showed a higher pH value (4.6). The results align with the research findings published by. (30). There was a slight declining trend in titratable acidity (TA) content of tomato fruits at neem extracts treatments and a slight increase at garlic extracts compared to control (Table5). Fruit coating is helpful for reduction of respiration rate and minimizes the utilization of respiratory products such as organic acid. As a result control fruits have less TA value than coated fruits with 100 and200G $mgml^{-1}$ and100N+G $mgml^{-1}$. It is also supported by the findings of (24) who observed that coated fruits recorded the high values. In this study, β-carotene content of tomato showed no significant variations in case of biopreservatives and their combined effects. Although, the accumulation rate of the beta-carotene content in the control fruits was lower by half compared to the coating treated a fruit with 200N and 200N+Gmgml^{-1}(Table5)which is supported by the findings of.(14). According to (21), carotenoid production increases while chlorophyll gradually degrades throughout ripening.By lowering the respiration rate and maintaining the coated fruits' quality in storage, biopreservatives created a protective coating on fruit. Tomato lycopene content did not significantly change when biopreservatives and their combined effects were considered (Table5). Herbal extracts may be able to preserve or improve the amount of lycopene, ascorbic acid, and total phenolic components in tomatoes as well as increase their shelf life (6). According to. (21), ripening tomato fruits may also contribute to elevated lycopene levels in tomatoes during storage. The ripening of tomato fruits and the conversion of chloroplasts into chromoplasts may be the cause of tomatoes' elevated lycopene levels during storage. TA, B- carotene and Lycopene were observed in control during the storage weight loss is may be mainly due to the water loss and that lead to higher concentration of solids in fruits. This came in line with the results of (1).

Conclusion

Garlic and neem effectively reduced weight loss, extend the shelf life and examined the tomato's pH, TA, B-carotene, and lycopene levels in an effort to preserve the freshness and integrity of the fruit's bio-preservative. Therefore, when packaged, garlic and neem are ideal for long-term preservation, home use, and potential application in the processing sector.

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