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Research Article

Use of essential oil for extended shelf life and maintained physico-chemical qualities of tomato cv. Arka Rakshak

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Abstract
Tomatoes, one of the popular solanaceous vegetables, used to face high spoilage and low shelf life in ambient storage. Essential oils with proven antimicrobial properties were thus used in the present study to evaluate the impact on fruit decay, shelf life and physico-chemical qualities under ambient conditions (Temperature: 22±3^{0}C; Relative Humidity: 80±5%). The study was conducted during 2021-22 with greenhouse-grown mature green tomatoes cv. Arka Rakshak at Post Graduate Research Laboratory, Department of Horticulture, Aromatic and Medicinal Plants, Mizoram University, Aizawl, India, to evaluate the utility of different essential oils (0.5% v/v) as Basil (*Ocimum basilicum*), Cinnamon (*Cinnamomum zeylanicum*), Peppermint (*Mentha piperita*), Citronella (*Cymbopogon nardus*), Eucalyptus (*Eucalyptus globulus*), Thyme (*Thymus vulgaris*), Lavendar (*Lavandula angustifolia*) and Rosemary (*Rosmarinus officinalis*) emulsified with coconut oil. Results manifested that surface coating with Basil oil had reduced the weight loss percentage (4.83%) significantly and maintained better firmness of fruit (23.91 N/cm^2), Total Soluble Solids (TSS): acid ratio (17.86) and delayed accumulation of colour pigment-like carotenoids (14.26 µg g^{-1}) and lycopene (21.78 µg g^{-1}). Fruit under this treatment had high ascorbic acid content (21.38 mg 100g^{-1}) with better retention of total phenolics (0.31 mg g^{-1}) and higher antioxidant activity at 12 days after storage (DAS). Besides, fruits under this treatment had minimum fruit decay (10%) against control (45%). Application of Basil oil had a better-extended shelf life (18.85 days) than the control (13.75 days). Therefore, it may be concluded that postharvest use of basil oil was effective in extending shelf life while maintaining physico-chemical qualities in stored tomatoes under room conditions.

Keywords: Antioxidant, Basil, Carotenoids, Essential oil, Lycopene, Tomato

INTRODUCTION

Tomatoes are delicious and attractive solanaceous vegetable abundantly used in raw, cooked, and processed forms in different cuisines around the globe. This widely consumed vegetable is rich in dry matter, organic acids, sugars, ascorbic acid, vitamins and minerals (Kurina *et al.*, 2021; Judy *et al.*, 2019) and packed with glycosides, alkaloids, carotenoids, flavonoids and lycopene (Waheed *et al.*, 2020) which made it high in antioxidant and several health benefits. India produces 20573 thousand metric tonnes of tomatoes from an area of 812 thousand hectares and stands as 2nd largest producer; however, a reasonably low amount out of that undergoes processing (FAOSTAT, 2023), which signifies that the crops is mainly consumed as fresh. Through the supply chain of fresh tomatoes, starting from harvesting, handling, storage, packaging, transport and during marketing (Sibomana *et al.*, 2016; Ayomide *et al.*, 2019) it undergoes high postharvest losses amounting to 30-40% (Mohan *et al.*, 2023). Besides, lack of storage facilities is also responsible for high postharvest loss (Slathia *et al.*, 2021). Therefore, irrespective of the end use, whether raw or processed, such huge loss in postharvest conditions significantly impacted the tomato economics.

To reduce postharvest losses in tomatoes, several attempts have been made by researchers using chemicals (Anyasi *et al.*, 2016), fungicides (Hulbert and Bhowmick, 1987), plant growth regulators (Singh and Patel, 2014; Mandal *et al.*, 2018a; Chandrakar, 2019), ethylene antagonists/inhibitors (Taye *et al.*, 2019; Lacerda *et al.*, 2024), biopolymers and edible film coatings etc (Mandal *et al.*, 2017; Ahmed *et al.*, 2023). While selecting substances to extend the shelf life of food item(s), focusing on their impact on human consumption is crucial, particularly when mostly consumed raw with skin. Therefore, compounds generally considered safe are in limelight under such conditions. Essential oils, which are hydrophobic concentrated liquids obtained from aromatic plants, are rich in terpenes, terpenoids and other phenol-derived compounds (Bakkali *et al.*, 2008; Rashidinejad and Jafari, 2020), are safe and have potentially used for controlling postharvest pathogenic microbes (Khetabi *et al.*, 2022) and caused extension in shelf life of many fruits like papaya (Prasad *et al.*, 2022), banana (Goncalves *et al.*,2023), peach (Rahimi *et al.*, 2019), mango (Sefu *et al.*, 2015) and vegetables like carrot, radish, potatoes and kohlrabi (Cmikova *et al.*, 2023). However, there is scant information on the use of different essential oils to preserve the storability of tomatoes. Therefore, different essential oils were used in this study to evaluate the response to physico-chemical qualities and shelf life of stored tomatoes in ambient conditions.

MATERIALS AND METHODS

Matured green tomatoes cv. Arka Rakshak, cultivated under greenhouse conditions, was used as the sample, freshly harvested from a local grower in Sihphir village in Aizawl district, Mizoram. Initially, fruits were sorted based on size, shape, colour, and texture and were free from injury and disease-pest incidence. After sorting, fruits were thoroughly washed in running water to remove dust and soil adhering. Later, fruits were washed in sterile water and air-dried under laboratory conditions. Randomly selected ten tomatoes were kept within a perforated zip-lock pouch in four replications under ten treatments. T_1: Cinnamon oil (*Cinnamomum zeylanicum*), T_2: Citronella oil (*Cymbopogon nardus*), T_3: Peppermint oil (*Mentha piperita*), T_4: Eucalyptus oil (*Eucalyptus globulus*), T_5: Lavender oil (*Lavandula angustifolia*), T_6: Thyme oil (*Thymus vulgaris*), T_7: Rosemary oil (*Rosmarinus officinalis*), T_8: Basil oil (*Ocimum basilicum*), T_9: Coconut oil (*Cocos nucifera*), T_{10}: Control (water dipped) and kept at ambient condition (Temperature: 22±3^{0}C; Relative Humidity: 80±5%) at Post Graduate Research Laboratory, Department of Horticulture, Aromatic and Medicinal Plants, School of Earth Science and Natural Resources Management, Mizoram University, Aizawl, India.

Complete randomized design (Mishra and Homa, 2020) was used for the experiment. Different essential oils (100% pure) like cinnamon, citronella, peppermint, eucalyptus, lavender, thyme, rosemary and basil oils were manufactured by Mesmara Essential Oil Ltd., Sangareddy, Telangana, India through hydro distillation of leaves, flowers, buds etc. Extra virgin coconut oil, which was natural and USDA-certified organically produced by Earthon Products Pvt. Ltd., Byculla, Mumbai, India, was purchased and used in the formulation of the treatments. Under different treatments, respective essential oils (0.5% v/v) were mixed with glycerol (1.2% v/v) in coconut oil (80% v/v) and sterile water for preparation of surface coatings. Then the formulation was homogenised for 5 minutes at 24,500 rpm to prepare the essential oil emulsions. Fruits were dipped in freshly prepared respective essential oil emulsions for 2 minutes (Mandal and Mualchin, 2021). Fruits for T_9 were dipped in coconut oil (100%) and T_{10} in sterile water for the same duration.

Different observations on physical parameters like physiological weight loss (by Digital balance, Sartorius, Germany), fruit firmness (by digital handheld fruit Penetrometer, PCE Instruments, UK) and fruit skin colour (by digital handheld colour meter, TES3150, Taiwan) were recorded, whereas biochemical parameters like total carbohydrate, starch, protein, total phenol, total chlorophyll, total carotenoids and lycopene were determined following the methods described by Sadasivam and Manickam (2018). The total sugar (AOAC, 2016), TSS (by digital handheld refractometer, Milwaukee Instrument, Romania), TSS: acid ratio (by dividing TSS/acidity), titratable acidity (AOAC, 2016), ascorbic acid (Ranganna, 2017), DPPH scavenging activity (antioxidant activity, Awad *et al*., 2017) and fruit decay (Mandal *et al.,* 2019) were recorded. All the physico-chemical parameters were recorded at 4, 8 and 12 days after storage (DAS) except fruit colour, antioxidant activity and fruit decay, which was recorded at 12 DAS. The shelf life of the stored fruit was determined based on its physico-chemical qualities, decay percentage and counting the days from harvest to the day with maximum visual, edible and marketable quality (Mandal *et al*., 2018b).

A complete randomized design (CRD) was used for the experiment with four replications. Data were used to analyse variance (ANOVA) and the least significant difference (LSD) was calculated at 5% probability level. Separation of means was done using the DMRT test. SPSS version 22.0 statistical software for Windows was used for data analysis.

RESULTS AND DISCUSSION

Physiological loss in weight (PLW)

Tomato fruits stored under ambient conditions had significantly lost their physiological weight. Physiological weight of the stored tomatoes decreased because of increased respiration and depletion of moisture due to transpiration, dehydration and metabolic activity (Umeohia and Olapade, 2024). At 4 DAS, PLW ranged between 1.79% to 6.16 %, which increased and ranged between 2.45% to 13.26% at 8 DAS (Table 1). Tagele *et al*. (2022) had a similar observation of increment in PLW of stored tomato cv. ARP D2 under ambient environment storage. In the present study, at 12DAS, a minimum PLW (4.83%) was found in tomatoes treated with basil oil (T_8) compared with the control (18.93%). Mohammadi *et al*. (2021) found that postharvest use of basil essential oil delayed weight loss in stored strawberry fruit. Basil essential oil enriched with coconut oil, when coated on tomatoes, may have created a protective barrier and reduced surface moisture loss.

Fruit firmness and colour

The tomatoes' firmness at ambient conditions was drastically reduced from four to twelve days after storage. At 4 DAS, the firmness of the stored tomatoes ranged between 32.68 to 39.21 Ncm^{-2} whereas it decreased and ranged between 19.53 and 33.22 Ncm^{-2} at 8 DAS (Table 1). At 12 DAS, fruit firmness was minimum in control (11.17 Ncm^{-2}) compared with the fruit coated with basil oil (T_8: 23.91 Ncm^{-2}). Loss of firmness during storage of tomatoes is due to loss in turgor pressure of the cell and degradation of cell wall and polysaccharides (Al-Dairi *et al*., 2021). Coconut oil with basil oil coating may have decreased the moisture loss and maintained the turgor pressure, thus causing high firmness at 12 DAS. Mohammadi *et al.* (2020) found the application of basil oil with aloe vera to maintain fruit firmness in peaches during storage.

After 12 days of ambient storage, fruits at control were turned to completely dark red (L: 38.15, a: 40.10, b: 41.72) whereas, fruits at T_8 (basil oil) were yellowish red (L: 86.69, a: 4.32, b: 80.48). Ripening caused the skin colour of stored tomatoes to turn green to red. However, coconut oil-enriched basil oil may have retarded the ripening process, which may have caused delayed accumulation of colour (Table 1). Karunanayake *et al.* (2020) observed that basil oil mixed with bee wax delayed the ripening of the climacteric fruit mango.

Total soluble solids (TSS), Titratable acidity and TSS: Acid ratio

During the period of storage, TSS content of tomatoes gradually increased. TSS content ranged between 4.00 to 6.00 ^{0}Brix at 4 DAS, which increased and ranged between 6.25 and 8.00 ^{0}Brix at 12 DAS (Table 2). Fruits coated with coconut oil enriched basil oil had minimum TSS (6.25^{0}Brix) compared with control (8.00 ^{0}Brix). Kabir *et al.* (2020) reported an increment in TSS content of tomatoes during storage. Titratable acidity of the stored tomatoes also marked a slight increase during storage. At 4 DAS, titratable acidity ranged between 0.19% to 0.45%. It increased and ranged between 0.35% and 0.58% at 12DAS. Dominguez *et al.* (2016) found an increment in the titratable acidity of the stored tomatoes. A proportionately higher acid increment than TSS decreased the TSS:acid ratio of the stored tomatoes. Fruits treated with coconut and enriched basil oil had comparatively lower TSS accumulation and higher maintained acidity, possibly due to delayed ripening. Basil oil is reported to cause ripening delay in mangoes (Karunanayake *et al.*, 2020).

Total sugar, carbohydrate and starch content

Enumeration of the data presented in Table 3 showed that the total sugar content of the stored tomatoes increased with decreased total carbohydrate content and starch. At 4 DAS, total sugar content ranged between 2.22% and 2.86%, total carbohydrate ranged between 5.24% and 6.49% and starch ranged between 0.36% and 0.58%, whereas at 12 DAS, total sugar content increased and ranged between 4.44% and 5.84%, however, total carbohydrate content (4.62%-4.87%) and starch content (0.06%-0.14%) reduced markedly (Table 3). Alenazi *et al.* (2020) reported a gradual increment in the total sugar content of stored tomatoes. John *et al*. (2020) observed that carbohydrate content reduced as fruit moisture content increased during tomatoes' storage. Further, Shahnawaz *et al.* (2012) claimed that hydrolysis of starch due to enzymes caused a reduction in the amount of starch stored in tomatoes. As climacteric fruit, storage of mature green tomatoes in ambient conditions caused faster changes in biochemical composition due to the advent of ripening and consequently accumulated more moisture with a reduction in total carbohydrate due to the action of hydrolytic enzymes, starch was converted to sugar, which in turn increased the total sugar content with decreased starch content. However, coconut oil emulsified with basil essential oil delayed the ripening process, causing slow starch degradation and sugar accumulation. Karunanayake *et al.* (2020) reported that us-

Table 1. Effect of post-harvest treatments on physiological weight loss, fruit firmness and colour of tomato

Treatments	Physiological Weight Loss (%)			Fruit Firmness (Ncm^{-2})			Fruit Colour at 12DAS		
	4DAS	8DAS	12DAS	4DAS	8DAS	12DAS	L	a	b
T_1: Cinnamon Oil	3.92c	7.11de	11.35cd	34.23ab	22.93b	16.07b	41.41	48.85	32.35
T_2: Citronella Oil	2.45a	3.96b	7.54b	35.42abc	25.45bc	20.74cd	70.17	26.50	41.92
T_3: Peppermint Oil	2.08a	3.47ab	6.12ab	36.54bcd	28.02cd	21.36cde	64.76	28.36	50.25
T_4: Eucalyptus Oil	3.18b	5.43c	5.84ab	34.48ab	28.75d	22.91de	72.72	23.58	45.03
T_5: Lavender Oil	2.31a	2.96ab	7.24ab	37.51bcd	27.26cd	22.42de	70.77	25.76	48.18
T_6: Thyme Oil	4.76d	7.93e	14.82e	38.89cd	22.93b	19.33c	50.58	44.62	37.00
T_7: Rosemary Oil	5.13d	8.42e	13.58de	36.75bcd	23.19b	20.68cd	60.01	38.17	49.66
T_8: Basil Oil	1.79a	2.45a	4.83a	39.21d	33.22e	23.91e	86.69	4.32	80.48
T_9: Coconut Oil	3.45bc	5.92cd	10.42c	35.21ab	23.19b	18.78bc	62.57	38.14	39.00
T_{10}: Control	6.16e	13.26f	18.93f	32.68a	19.53a	11.17a	38.15	40.10	41.72
LSD (P=0.05)	0.724	1.351	2.476	3.542	2.653	3.018	-	-	-

Means followed by the same letters do not differ significantly at 5% level of probability, LSD: Least Significant Difference, DAS: Days after storage, L: represents lightness, a: represents red-green colour, b: represents blue-yellow colour

Table 2. Effect of post-harvest treatments on TSS, Acidity and TSS: Acid ratio of tomato

Treatments	TSS (^{0} Brix)			Titratable Acidity (%)			TSS: Acid Ratio		
	4DAS	8DAS	12DAS	4DAS	8DAS	12DAS	4DAS	8DAS	12DAS
T_1: Cinnamon Oil	5.89e	6.13ef	7.45cd	0.20bc	0.41de	0.51cd	29.45bc	14.95ab	14.61ab
T_2: Citronella Oil	4.79bc	5.22bc	7.22c	0.18abc	0.36cde	0.42abc	26.61ab	14.50ab	17.19cd
T_3: Peppermint Oil	4.26ab	5.14bc	7.08bc	0.16ab	0.31bcd	0.40abc	26.63ab	16.58ab	17.70d
T_4: Eucalyptus Oil	4.23ab	4.68a	6.34ab	0.13a	0.21ab	0.38ab	32.54d	22.29c	16.68bcd
T_5: Lavender Oil	4.08a	4.85ab	6.39ab	0.13a	0.28abc	0.38ab	31.38cd	17.32b	16.82cd
T_6: Thyme Oil	5.15cd	5.48cd	6.89abc	0.19abc	0.38cde	0.45abc	27.11ab	14.42ab	15.31abc
T_7: Rosemary Oil	5.21cd	5.87de	7.25cd	0.21bc	0.43e	0.48bcd	24.81a	13.65a	15.10abc
T_8: Basil Oil	4.00a	4.50a	6.25a	0.13a	0.19a	0.35a	30.77cd	23.68c	17.86d
T_9: Coconut Oil	5.75de	6.02e	7.28cd	0.18abc	0.35cde	0.45abc	31.94cd	17.20b	16.18bcd
T_{10}: Control	6.00e	6.50f	8.00d	0.24c	0.45c	0.58d	25.00a	14.44ab	13.79a
LSD (P=0.05)	0.611	0.437	0.761	0.067	0.116	0.115	2.911	3.108	2.123

Means followed by the same letters do not differ significantly at 5% level of probability, LSD: Least Significant Difference, DAS: Days after storage

ing basil oil coating had delayed ripening in mango.

Protein, total phenol and ascorbic acid content

The data presented in Table 4 showed that protein content in the stored tomatoes was reduced with the duration of storage. At 4 DAS it ranged between 1.23 to 1.65 g $100g^{-1}$, which reduced and ranged between 0.76 to 1.18 g $100g^{-1}$ at 12 DAS. John *et al.* (2020) reported that the fruit's protein content had decreased gradually with increasing ripening and storage duration. In the present study, the total phenol content of the stored tomatoes decreased with storage duration. At 4 DAS, total phenol content of the tomato fruit ranged between 0.24 to 0.36 mg g^{-1}, which at 12 DAS ranged between 0.11 to 0.31 mg g^{-1}. Ali *et al.* (2013) opined that mature green tomato increased respiration rate and degradation of phenolic compounds due to senescence when ripened in storage. Enumeration of the data for ascorbic acid content in the tomato fruits at ambient storage showed a significant drop in it. After 4 days of storage, ascorbic acid content of the tomato fruits ranged between 21.72 to 29.83 mg $100g^{-1}$, whereas it ranged between 17.87 and 25.37 mg $100g^{-1}$ at 8 DAS and between 14.48 and 21.38 mg $100g^{-1}$ at 12DAS. Tilahun *et al.* (2017) reported a fall in the stored tomatoes' ascorbic acid content due to oxidation. The present study revealed that coconut oil emulsified with essential oils like eucalyptus and basil oil had slowed the ripening and delayed the loss of protein, phenolics and ascorbic acid content in the stored tomatoes. El-Bana and Ennab (2023) found eucalyptus oil had delayed ripening and prolonged storage periods in guava. Khaliq *et al*. (2020) reported delayed ripening with better maintenance of ascorbic acid and phenolics in jamun coated with basil oil in guggul gum.

Total chlorophyll, total carotenoids, lycopene content and antioxidant activity

Total chlorophyll content on the stored tomatoes was drastically reduced from four to twelve days of storage. Total chlorophyll content of mature green tomatoes at 4 DAS ranged from 5.86 to 8.13 µg g^{-1}, which on ripening reduced and ranged between 4.16 and 6.38 µg g^{-1} at 8 DAS and between 3.27 and 5.14 µg g^{-1} at 12 DAS (Table 5). Jia *et al.* (2022) recorded the degradation of chlorophyll in stored tomatoes. It was observed in the present study that total carotenoids and lycopene content immensely increased with the ripening of stored tomatoes. Total carotenoids and lycopene content, which ranged between 1.87 to 3.48 µg g^{-1} and 6.74 to 13.36 µg g^{-1}, respectively, at 4 DAS, had increased and ranged from 14.26 to 20.71 µg g^{-1} and 21.78 to 39.44 µg g^{-1}, respectively at 12 DAS. Al-Dairi *et al.* (2021) observed an increment in total carotenoids and lycopene content in the stored tomatoes during the storage. Being a climacteric fruit, mature green tomatoes gradu-

Table 3. Effect of post-harvest treatments on total sugar, carbohydrate and starch content of tomato

Treatments	Total sugar (%)			Total Carbohydrate (%)			Starch (%)		
	4DAS	8DAS	12DAS	4DAS	8DAS	12DAS	4DAS	8DAS	12DAS
T_1: Cinnamon Oil	2.78c	3.58de	5.71de	5.35a	5.02ab	4.68ab	0.38ab	0.14ab	0.06a
T_2: Citronella Oil	2.53b	2.86ab	5.07bc	6.25cd	5.15cd	4.79cd	0.51ef	0.19cde	0.12cd
T_3: Peppermint Oil	2.50b	3.08bc	4.87abc	6.45d	5.28e	4.81de	0.54fg	0.19cde	0.10bc
T_4: Eucalyptus Oil	2.35ab	2.82ab	4.76ab	6.42d	5.29e	4.85de	0.51ef	0.21ef	0.12cd
T_5: Lavender Oil	2.48b	2.85ab	4.82ab	6.40d	5.24de	4.86e	0.48de	0.20def	0.13cd
T_6: Thyme Oil	2.74c	3.52de	5.18bcd	5.48ab	5.08abc	4.71b	0.43bcd	0.17bcd	0.07ab
T_7: Rosemary Oil	2.74c	3.54de	5.41cde	5.82bc	5.11bc	4.74bc	0.41abc	0.16bc	0.07ab
T_8: Basil Oil	2.22a	2.72a	4.44a	6.49d	5.31e	4.87e	0.58g	0.23f	0.14d
T_9: Coconut Oil	2.52b	3.33cd	4.96abc	6.12cd	5.16cd	4.82de	0.45cd	0.12a	0.08ab
T_{10}: Control	2.86c	3.64e	5.84e	5.24a	4.98a	4.62a	0.36a	0.11a	0.06a
LSD (P=0.05)	0.196	0.298	0.580	0.431	0.114	0.061	0.054	0.036	0.039

Means followed by the same letters do not differ significantly at 5% level of probability, LSD: Least Significant Difference, DAS: Days after storage

Table 4. Effect of post harvest treatments on protein, total phenol and ascorbic acid content of tomato

Treatments	Protein (g $100g^{-1}$)			Total phenol (mg g^{-1})			Ascorbic Acid (mg $100g^{-1}$)		
	4DAS	8DAS	12DAS	4DAS	8DAS	12DAS	4DAS	8DAS	12DAS
T_1: Cinnamon Oil	1.34ab	1.12a	0.78ab	0.26ab	0.24bc	0.12a	22.45a	18.23a	14.78a
T_2: Citronella Oil	1.31ab	1.23ab	0.98cde	0.31cd	0.29de	0.21bc	26.81cd	24.87d	17.67b
T_3: Peppermint Oil	1.42abcd	1.34bc	1.01def	0.34de	0.30de	0.26de	25.23bc	21.34bc	16.29ab
T_4: Eucalyptus Oil	1.60cd	1.45c	1.18f	0.36e	0.32ef	0.29ef	28.78de	24.61d	20.78c
T_5: Lavender Oil	1.52bcd	1.29bc	1.06def	0.34de	0.32ef	0.25cde	27.56d	22.75cd	19.69c
T_6: Thyme Oil	1.41abc	1.36bc	0.81abc	0.31cd	0.27cd	0.14a	22.89a	19.62ab	14.85a
T_7: Rosemary Oil	1.45abcd	1.34bc	0.88abcd	0.30bcd	0.25bc	0.19b	22.78a	19.72ab	14.89a
T_8: Basil Oil	1.65d	1.39bc	1.08ef	0.38e	0.35f	0.31f	29.83e	25.37d	21.38c
T_9: Coconut Oil	1.48bcd	1.32bc	0.96bcde	0.28abc	0.22ab	0.23bcd	23.39ab	19.82ab	15.07a
T_{10}: Control	1.23a	1.08a	0.76a	0.24a	0.19a	0.11a	21.72a	17.87a	14.48a
LSD (P=0.05)	0.236	0.169	0.189	0.041	0.037	0.046	2.004	2.644	1.903

Means followed by the same letters do not differ significantly at 5% level of probability, LSD: Least Significant Difference, DAS: Days after storage

Table 5. Effect of post-harvest treatments on total chlorophyll, total carotenoids and lycopene content of tomato

Treatments	Total chlorophyll (µg g^{-1})			Total Carotenoids (µg g^{-1})			Lycopene (µg g^{-1})		
	4DAS	8DAS	12DAS	4DAS	8DAS	12DAS	4DAS	8DAS	12DAS
T_1: Cinnamon Oil	6.83abc	4.87bc	3.78b	2.62cd	8.83cd	18.79cd	11.34de	24.37g	34.59fg
T_2: Citronella Oil	7.31bc	5.62d	4.89cde	2.65d	7.82abc	16.68abc	8.97bc	18.33de	28.69cd
T_3: Peppermint Oil	7.82c	6.21e	4.92cde	2.28bc	7.24ab	16.13abc	8.39abc	16.79cd	27.83cd
T_4: Eucalyptus Oil	8.10c	6.38e	5.06de	2.21ab	7.59abc	15.21ab	7.24ab	13.37ab	23.49ab
T_5: Lavender Oil	8.13c	6.18e	4.98cde	2.13ab	7.47abc	15.82abc	7.83ab	14.89bc	25.62bc
T_6: Thyme Oil	7.78c	4.89bc	3.45a	2.58cd	9.68de	17.93bcd	10.01cd	22.34fg	30.27de
T_7: Rosemary Oil	7.56bc	5.25cd	4.86cd	2.89d	8.78cd	18.29cd	9.83cd	20.67ef	32.33ef
T_8: Basil Oil	8.08c	6.32e	5.14e	1.87a	6.89a	14.26a	6.74a	11.80a	21.78a
T_9: Coconut Oil	6.35ab	4.72b	4.72c	2.71d	8.45bcd	17.38bc	12.82ef	25.12g	36.72gh
T_{10}: Control	5.86a	4.16a	3.27a	3.48e	10.52e	20.71d	13.36f	27.96h	39.44h
CD at 5%	1.427	0.446	0.279	0.341	1.531	2.971	1.995	2.829	3.137

Means followed by the same letters do not differ significantly at 5% level of probability, LSD: Least Significant Difference, DAS: Days after storage

ally ripened in ambient storage, which may have reduced total chlorophyll and increased in carotenoids and lycopene content marked by changing colour from green to yellow and red. Tadesse *et al.* (2015) reported similar observations of accumulation in β- carotene and lycopene with chlorophyll degradation in stored tomatoes with change of colour index. Tomatoes coated with coconut oil emulsified with basil essential oil had recorded slow degradation of chlorophyll and accumulation of carotenoids and lycopene, which signified delayed ripening of the fruits in storage. Mandal and Vanlalawmpuia (2020) reported basil oil delayed ripening and accumulation of flesh colour in stored pineapple based on the record of Digital Handled Colour Meter. Besides, the present study revealed that tomato fruits treated with eucalyptus oil and basil oil had higher antioxidant activity with increasing concentration of its ethanolic extract compared with control (Fig. 1). Fruits treated with these oils had delayed senescence and caused better retention of phenolics, ascorbic acid and pigments like carotene and lycopene may have contributed to higher antioxidant activity. Sivakumar and Baustista-Banos (2014) suggested that essential oils had increasing antioxidant capacity and free radical scavenging activity. Xylia *et al.* (2022) claimed eucalyptus oil's positive effect on stored cucumber's antioxidant activity. Fakhar *et al.* (2014) found better maintenance of antioxidant properties of stored plum fruit when applied with basil oil.

Fruit decay and shelf life

The present study showed that tomato fruits coated with essential oil had lesser fruit decay than the control. Essential oils are potential antimicrobial agents, controlled postharvest pathogens responsible for decay in multiple fruits, as also reported by Sivakumar and Bau-

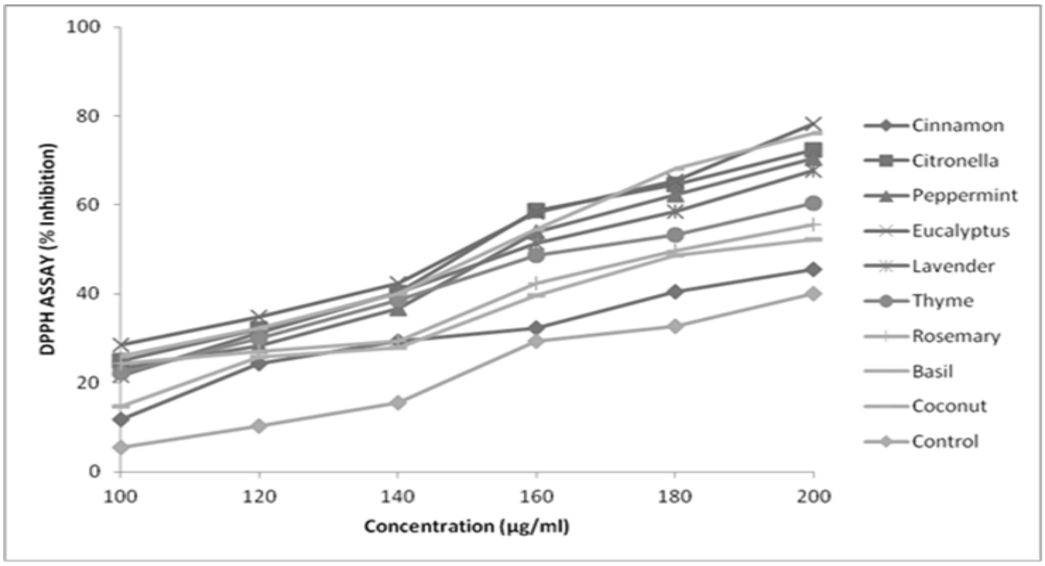

Fig. 1. *Effect of postharvest treatments on antioxidant activity of tomatoes at 12 DAS*

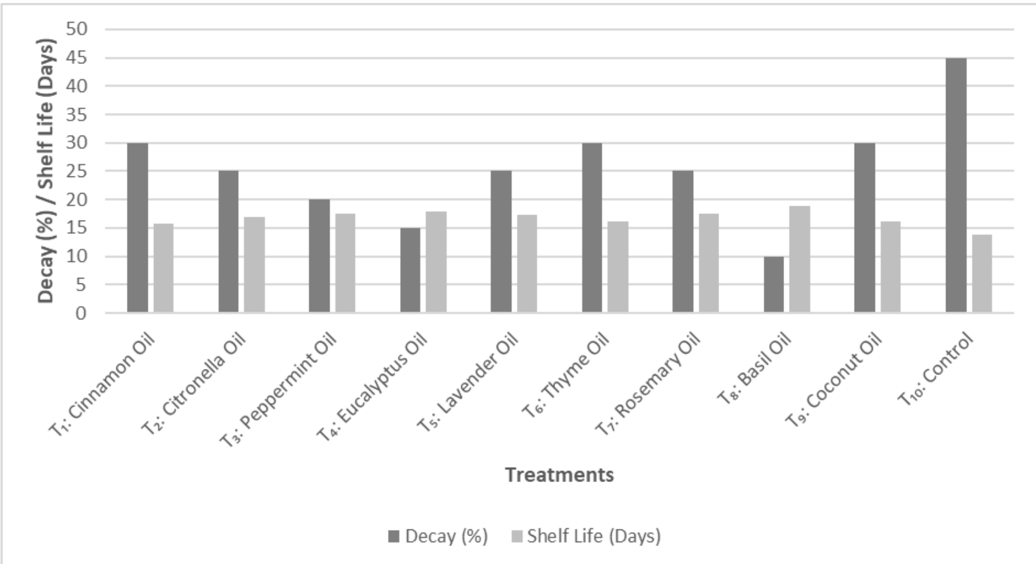

Fig. 2. *Effect of postharvest treatments on fruit decay percentage and shelf life of tomatoes*

tista-Banos, 2014). At 12DAS, fruits coated with basil oil had minimum fruit decay (10%) followed by eucalyptus oil (15%) compared with control (45%) (Fig. 2). Mohammadi *et al.* (2021) reported that basil oil contains a high concentration of linalool and eugenol, which effectively controlled postharvest fruit decay in stored strawberry. Bhandari *et al.* (2022) found that eucalyptus oil had significantly inhibited microbial decay of Kinnow mandarin in storage. Consequently, the shelf life of the stored fruits was found to be maximum in the case of basil oil (18.85 days), whereas it was found to be minimum in control (13.75 days). Khaliq *et al.* (2020) found that jamun fruit coated with basil oil in guggul gum extended shelf life in ambient conditions.

Conclusion

The present study showed that tomato fruits coated with basil oil (T_8) had minimum physiological weight loss and fruit decay with delayed ripening and accumulation of colour pigments like carotene and lycopene. Besides, stored tomatoes had significantly higher firmness, TSS: acid ratio, total phenol, ascorbic acid content and antioxidant activity under this treatment. Furthermore, tomatoes treated with basil oil had a higher shelf life in ambient storage. Therefore, it can be concluded that mature green tomatoes can be coated with basil essential oil to extend shelf life up to 18 days, control spoilage, and delay ripening while maintaining physico-chemical qualities under ambient conditions.

Conflict of interests

The authors declare that they have no conflicts of interest.

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