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Effects of maturity indices and modified atmosphere packaging (MAP) on shelf life and post-harvest quality of cherry tomato

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Abstract

The present experiment was carried out at the Laboratories of the Department of Horticulture and Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh during the period from February to April 2019 to study the effect of maturity indices and modified atmosphere packaging (MAP) on the extension of shelf life and quality retention of cherry tomato. The two-factor experiment consisted of three maturity indices viz. (i) Maturity index 1 (M_1: Mature green color), (ii) Maturity index 2 (M_2: Yellow color), and (iii) Maturity index 3 (M_3: Red color) and five postharvest treatments viz. (i) Control (T_0), (ii) Low density perforated poly ethylene, LDPPE (T_1), (iii) Low density poly ethylene, LDPE (T_2), (iv) Low density perforated plastic box, LDPPB (T_3), and (v) Low density plastic box, LDPB (T_4). The experiment was conducted in completely randomized design with 3 replications. The maximum weight loss (7.77%) was recorded in mature green color fruits (M_2) treated with control (T_0), while the minimum (3.22) was found in yellow color fruits (M_2) treated with LDPPB (T_3). The maximum color change was observed from yellow color fruits (M_2) with LDPPB (T_3) and the minimum was observed from mature green color fruits (M_1) treated with control (T_0). The maximum TSS content (7.20%) was recorded from yellow color fruits (M_2) treated with LDPB (T_4), while the minimum (5.67%) was found in mature green color fruits (M_1) treated with LDPPB (T_3). The highest disease incidence and severity (16.67% and 21.67%, respectively) were recorded in red color fruits (M_3) treated with control whereas the lowest disease incidence (1.67%) and severity (2.33%) were found in yellow color fruits (M_2) treated with LDPPB. The longest shelf life (25.00 days) was obtained in yellow color fruits (M_2) treated with LDPPB (T_3) and the shortest shelf life (7.00 days) was observed in red color fruits (M_3) treated with control (T_0). Thus, yellow color fruits (M_2) treated with LDPPB (T_3) could be used for the extension of shelf life and quality retention of cherry tomato.

Key words: Cherry tomato, maturity indices, MAP, diseases, shelf life, quality

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Introduction

Cherry tomato (*Solanum lycopersicum* var. *cerasiforme*) belonging to the family Solanaceae, is a popular type of table tomato believed to be an intermediate genetic admixture between wild current-type tomatoes and domesticated garden tomatoes (Nesbitt and Tanksley, 2002). The demand for cherry tomato has increased in the market, chiefly due to the recognition of its high quality and good taste (Kobryn and Hallmann, 2005). Cherry tomatoes are smaller in size (1.5-3.5 cm diameter), spherical to slightly oblong in shape, and usually red in color. Cherry tomato is beneficial to human health because of its high content of antioxidant and anti-carcinogenic property, vitamin A and C, ascorbic acid, and phytochemical compounds, including lycopene, beta-carotene, flavonoids and many essential nutrients (Rosales *et al.,* 2011). The fruits can be used directly as raw vegetable, salad and after cooking.

Cherry tomato is a new crop for Bangladesh, and many consumers unfamiliar with the small-fruited tomatoes and hence, growing cherry tomato could be a profitable activity for the Bangladeshi farmers. However, decreasing production area due to the change of farming land use into settlements has become one of major obstacles for sustainable production in agriculture (Sitawati *et al.*, 2016). The major vegetable growing areas of Bangladesh are Jashore, Bogura, Cumilla and Chattogram, and a major part of the Bangladesh is an agro-based country, which produces a lot of fruit and vegetables apart from staple food rice. Fresh vegetables are very much important for diet mainly for vitamins, minerals and antioxidants. To meet the requirement of vast number of people’s demand of vegetables it is needed to reduce postharvest loss. For a human body minimum requirement of vegetables 400 g/day/capita (FAO, 2003) but the present consumption of vegetables in Bangladesh is only 211 g/day. Presently, Bangladesh has produced 10931 thousand metric tons of vegetables per year (BBS, 2011). Postharvest losses are very high in fruit, vegetables and root crops as they are much less hardy and are quickly perishable, and if care is not taken in their harvesting, handling and transport, they soon decay and become unfit for human consumption (BAU, 2013). In Bangladesh, vegetables were wasted about 23.6-43.5% (Hassan, 2010). The present vegetable production in Bangladesh is around one million tons for every year, 70% of which is delivered during the cool season. Accordingly, there is an intense lack of vegetables during the late spring, which leads to chronic malnutrition vegetables produced in these areas are transported to the capital or other cities as soon as possible through different marketing channels (Hossain, 2000).

Maturity is a very important index for harvesting of fruits and vegetables at the right time to maintain its quality and shelf life (Rashid *et al.,* 2015). Respiration and transpiration are the most important postharvest physiological processes affecting storage life and quality of vegetables. Harvesting at proper maturity stage is a very important determinant for storage-life and final fruit quality, while at improper maturity can lead to uneven ripening and over ripe fruits (Rashid and Habib, 2019). Being a climacteric and perishable cherry tomatoes have a short life span, usually 2-3 weeks. The small size snacking tomatoes (cherry, grape types) contain high concentrations of sugars and acids, major contributors to tomato flavor, and now comprise about 24% of retail sales of cherry tomatoes in the U.S. Cherry tomatoes are consumed widely throughout the world and their consumption has recently been demonstrated to possess health benefits because of its rich content of phytonutrients.

Postharvest recommendations indicate that tomatoes, including cherry tomatoes, should be stored at 10°C or higher to avoid chilling injury and even 10°C may be detrimental to tomato flavor quality. Cherry tomatoes are sometimes held at lower than recommended temperatures. Also cherry tomatoes are routinely used as components on fresh cut vegetable trays under modified atmospheres, with expected shelf-life of 14-20 days at normal temperature. A few studies have characterized changes in small cherry tomatoes stored at below recommended temperatures alone or in combination with modified atmosphere packaging. Different studies explained that harvesting of fruits at proper maturity, different packaging materials and organic treatments reduced postharvest decay, controlled development of physiological disorders, improved quality and delayed aging or ripening (Rashid *et al*., 2018). It improves the skin strength making the cell wall and tissues more resistant and less accessible to the enzymes that are produced 3 by fungi and bacteria, limiting infection while controlling ripening, softening, storage breakdown, rotting and decay at the same time. To maintain the quality at different levels of postharvest operations like harvesting, sorting, grading, packaging, loading, unloading, cooling and storage are hardly used in Bangladesh (Hassan, 2010). However, very limited postharvest research has been conducted on cherry tomato to extend its shelf life and quality during storage. The present experiment was, therefore, undertaken to study the effects of maturity indices and modified atmosphere packaging (MAP) on the extension of shelf life and quality retention of cherry tomato.

Materials and Methods

***Experimental location and material*:** The present study was conducted to study the effect of maturity indices and modified atmosphere packaging (MAP) on the extension of shelf life and quality retention of cherry tomato at the Laboratories of the Department of Horticulture, and Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh during the period from February to April 2019. Well developed, uniform sized, and healthy cherry tomato fruits were harvested from the Landscaping section of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh and taken to the postgraduate laboratory. Only good cherry tomato fruits of uniform maturity were selected for the experiment and were kept under ambient temperature (25 ± 1°C) prior to further treatments.

***Treatments of the investigation and experimental design*:** The two-factor experiment consisted of three maturity indices viz. (i) Maturity index 1 (M_1: Mature green color), (ii) Maturity index 2 (M_2: Yellow color), and (iii) Maturity index 3 (M_3: Red color) and five postharvest treatments viz. (i) Control (T_0), (ii) Low density perforated poly ethylene, LDPPE (T_1), (iii) Low density poly ethylene, LDPE (T_2), (iv) Low density perforated plastic box, LDPPB (T_3), and (v) Low density plastic box, LDPB (T_4). The experiment was conducted in a completely randomized design with 3 replications.

***Modified atmosphere packaging (MAP) materials*:** For MAP, LDPPE, LDPE, LDPPB and LDPB treated cherry tomato fruits were kept in the respective bags and box. For MAP treatment, the bags were sealed and made airtight so as to prevent the exchange of gases. For LDPPE and LDPPB treatments, the bags and boxes were perforated and the fruits were stored in these perforated bags and plastic box. Most widely used material is obtained by polymerization of ethylene gas under high pressures of 1000-3000 atmospheres. Low density polyethylene (LDPE) is fairly soft, slightly translucent flexible material with waxy feel. It possesses excellent resistant to most chemicals, good barrier to water vapor, but less barrier to oxygen. It has high permeability to volatiles and swells in contact with fats and oils. It gives a very good heat seals and easily coated on to other material and serves as a good laminated layer. Low density polyethylene bags and plastic box (15 x 20cm) were selected and each circular hole of polyethylene bag and plastic box were punched on polyethylene bags and plastic boxs at equidistance from each other. Half the number of bags are kept with and without making holes and used as bags with and without perforated. Out of 300 cm_2 area of the bag 60 cm^2 top portions were sealed with the help of sealing machine by using formula π r2. So it almost 10 holes were made at equal-distance from one another.

***Application of the postharvest treatments*:** Postharvest treatments used in the storage were sequentially assigned to the collected fruits. After applying the treatments cherry tomato fruits were kept on a brown paper which was previously laid out in completely randomized design and placed on the laboratory table at ambient temperature. To ensure the application of different storage treatments to cherry tomato fruits the following procedures were adopted. For control (T_0), fruits were selected randomly from a lot of cherry tomato and the fruits were kept on brown and white paper of the laboratory table at room condition arranging at random by replication. For LDPPE (T_1), low density perforated polyethylene were used for this treatment. An individual fruit was taken into LDPPE, 13 fruits were kept into it and the top of the bag was tied and then placed on brown paper for observation. For LDPE (T_2), low-density polyethylene was used for this treatment. An individual fruit was taken into LDPPE, 13 fruits were kept into it and the top of the bag was tied and then placed on brown paper for observation. For LDPPB (T_3), low density perforated plastic box were used. An individual fruit was taken into LDPPB, 13 fruits were kept into it and the top of the bag was tied and then placed on brown paper for observation. For LDPB (T_4), low-density plastic box were used. An individual fruit was taken into LDPB, 13 fruits were kept into it and the top of the box was tied and then placed on brown/white paper for observation. After application of all the treatments the fruits were kept under ambient temperature (25 ± 1°C) prior to further treatments.

Parameters studied

***External appearance and color**:* During the entire storage period, the cherry tomato fruits, used for the experiment, were keenly observed everyday but data was recorded on total weight loss as well as physic-chemical changes during 3, 6, 9, 12 and 15 DAS and shelf life 25 days up to damage stage as influenced by different treatments. Changes in external color of cherry tomato fruits were recorded through scoring using a color chart.

***Firmness**:* Firmness was determined by using fruit Penetrometer (Model Cat.No.166), the cherry tomato fruits were punctured at two places opposite to each other in radial axis with the plunger and the pressure required was recorded and expressed in kg/cm^2.

Weight loss: Weight loss of cherry tomato fruit was measured by weighing the fruits at every 3 days' intervals using a top pan electric balance. Ten fruits per treatment were taken for this purpose and same fruits were used until the end of the experiment (Rashid and Rahman, 2020). The percentage of weight loss was calculated by using the following formula:

$$\% \text{ Weight loss} = \frac{W1 - W2}{W1} \times 100$$

Where, *W1* = Initial weight of fruit (0 days); *W2* = Fruits weight at various storage periods (0, 3, 6, 9, 12 and 15 days).

***Pulp pH**:* The pH of cherry tomato fruit pulp was measured by using a Portable pH Meter (Model pHS-1701, Shanghai, China), which was standardized with the help of a buffer solution as described by Ranganna (1994).

***Total soluble solids (TSS)**:* Total soluble solids concentration of cherry tomato fruit was determined by using a hand held refractometer (Model N-1 α, Atago, Japan). The remaining fruit pulp from pH determination was used to measure the TSS of the fruit. Before measurement, the refractometer was calibrated with distilled water to give a zero reading. One or two drops of the filtrate were placed on the prism of the refractometer to obtain %TSS reading. The reading was multiplied by dilution factor to obtain an original %TSS of the fruit tissues. Since differences in sample temperature could affect the TSS measurement, temperature corrections were made by using the methods described by Ranganna (1994).

***Titratable acidity (TA)**:* Titratable acidity of cherry tomato fruits was determined by the method of Elif Das *et al*. (2006). A known volume of filtered juice was diluted with a known volume of distilled water. An aliquot was taken from this sample and titrated with 0.1N NaOH using phenolphthalein indicator. The appearance of light pink color was marked as the end point. Acidity was computed and expressed as per cent citric acid.

$$\% \text{ Ascorbic acid} = \frac{\text{Titre value x Normality x m.eq.wt. of acid}}{\text{Volume of sample}} \text{ x } 100$$

Milli-equivalent weight of citric acid = 0.06404

Ascorbic acid (Vitamin C) content: Ascorbic acid (vitamin C) was measured by 2,6-dichlorophenol-indophenol titration as described by Ranganna (1994). The amount of ascorbic acid was calculated by the following formula and expressed as mg/100 g fresh weight.

$$\text{Ascorbic acid content (mg/100 g)} = \frac{\text{Titre value x dye factor x volume made up}}{\text{Aliquot taken x weight of sample}} \times 100$$

Disease incidence (percentage of infected fruits): Ten fruits for each treatment were critically examined every day for the appearance of the disease symptoms and the incidence was recorded. The first count was made at the 1st day of storage. The disease development was identified by the visual quality, which was observed on the scale of 1 to 5 (1 = very bad, 2 = bad, 3 = good, marketable, 4 = very good, and 5 = excellent) (Islam *et al*., 2017). Number of fungus-contaminated cherry tomato was counted and they were converted to fungal incidence percentage by the following formula:

$$\text{\% Disease incidence} = \frac{\text{Number of infected fruits}}{\text{Total number of fruits assessed}} \times 100$$

Disease severity (percentage of skin infected fruits by fungal diseases): The percentage cherry tomato fruits skin disease was recorded five times starting at the 6th day of storage. All the infected fruits were selected to determine percent fruit area infected. The percentage fruit area diseased was measured based on eye estimation. The mean values regarding infected fruit area were calculated, presented and discussed later.

Shelf life: Shelf life of fruits means the days required for fully ripe as to retaining optimum marketing and eating qualities. In order to determine the shelf life, ten fruits were taken for each treatment and then the treated fruits were kept under ambient temperature (25 ± 1°C). Shelf life was measured according to visual quality (≥3; good, marketable) and determinants such as mold growth, decay, shriveling, smoothness, shininess, and homogeneity (Rashid and Rahman, 2020; Rashid *et al*., 2015).

***Statistical analysis*:** The collected data on various parameters were analysed statistically using MSTAT computer programme. The means for all the treatments were calculated and analysis of variance (ANOVA) was performed by F-test. The mean difference between a pair of treatments was tested by least significant difference (LSD) at 5 and 1% levels of probability (Gomez and Gomez, 1984).

Results and Discussions

***External appearance and color*:** The change in external appearance was noticeable due to maturity indices and MAP treatments (Photo 1-7). The combined effect of maturity indices and postharvest treatments on external color was significant at 12 and 15 days after storage (DAS) but non-significant at 6 and 9 DAS (Table 1). The highest external color (5) in M_3T_0, M_3T_0, M_3T_1, M_3T_2, M_3T_2, M_3T_4 and the lowest (1) was recorded in M_1T_0, M_1T_1 M_1T_2, M_1T_3 and M_1T_4 at 3 DAS. At 6, 9, 12, and 15 DAS, the maximum external color (5.67, 6.33, 7.33, and 8.00 %) was observed in M_3T_0 and the minimum external color was recorded M_1T_2 (Table 1).

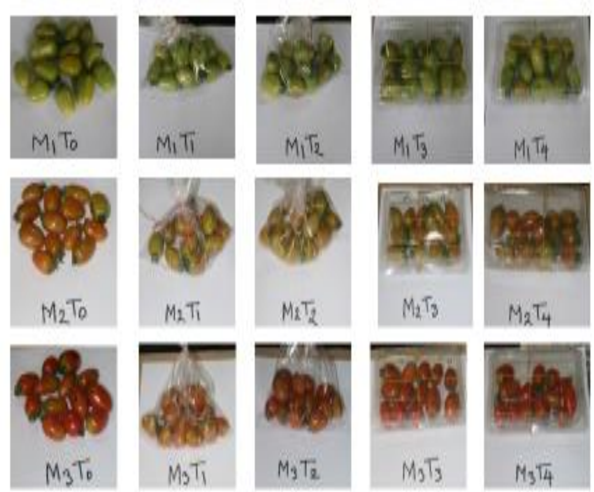

Plate 1. Photograph showing the differences in external appearance of cherry tomato under different postharvest treatments at 3 DAS.

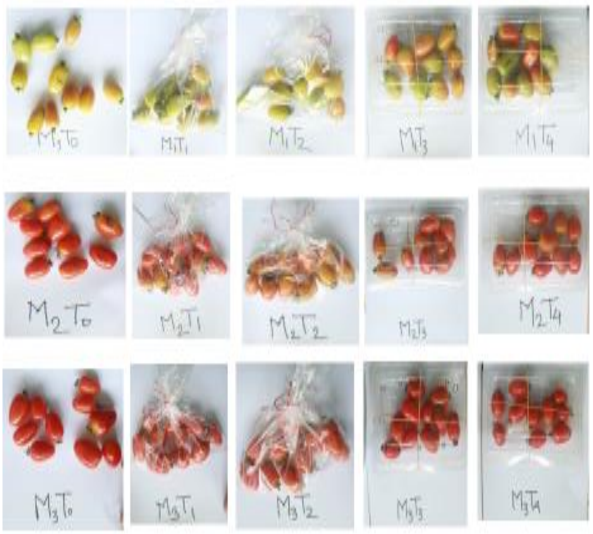

Plate 2. Photograph showing the differences in external appearance of cherry tomato under different postharvest treatments at 6 DAS.

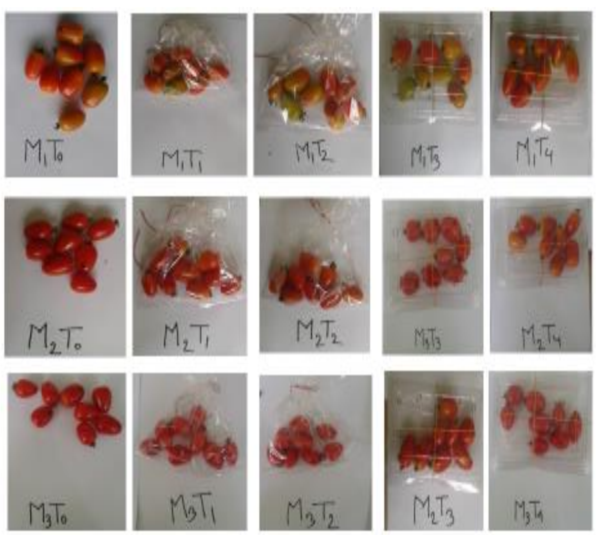

Plate 3. Photograph showing the differences in external appearance of cherry tomato under different postharvest treatments at 9 DAS.

The change in external color of cherry tomato fruits was significantly affected by maturity indices and modified atmosphere packaging (MAP) (Table 1). The change in the external color of the cherry tomato peel from green to yellow and yellow to red are the most obvious change which occurs during storage in fruits and softer after ripening. In the control, protoplast was changed into chromoplast normally, while in treated samples, this process was suppressed by the treatment effect (Rashid *et al*., 2019).

Plate 4. Photograph showing the differences in external appearance of cherry tomato under different postharvest treatments at 12 DAS.

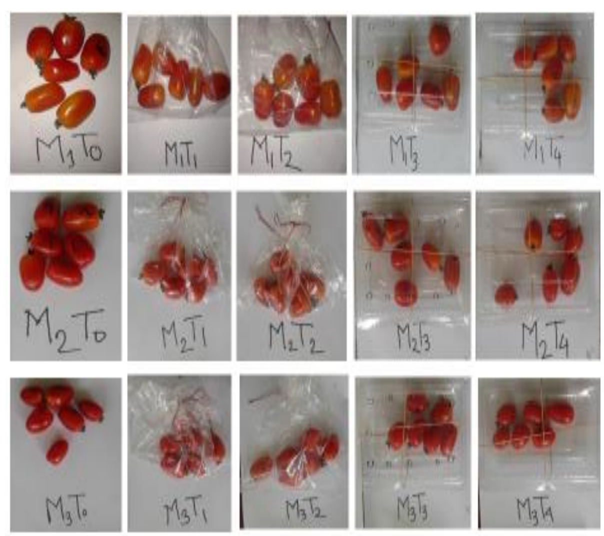

Plate 5. Photograph showing the differences in external appearance of cherry tomato under different postharvest treatments at 15 DAS.

Similar results with respect of during color change, the pulp becomes softer and sweeter as the ratio of sugars to starch increase and the characteristics aroma in produced (Robinson, 1996). The change of peel color involves chlorophyll degradation or qualitative and quantitative alternations of the green pigments into others pigments as reported by Salvador *et al.* (2007).

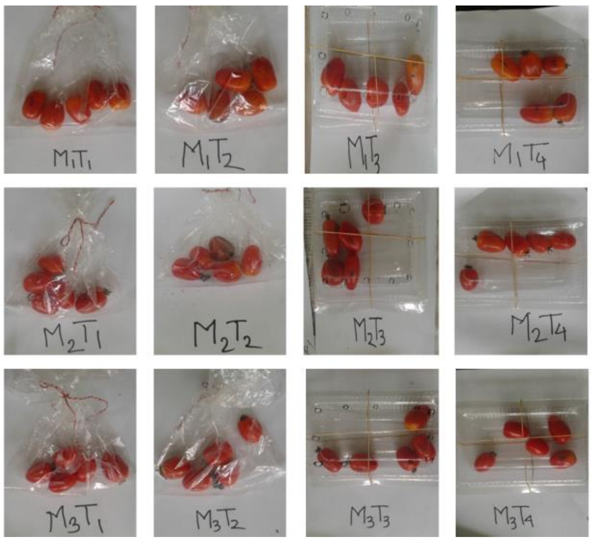

Plate 6. Photograph showing the differences in external appearance of cherry tomato under different postharvest treatments at 20 DAS.

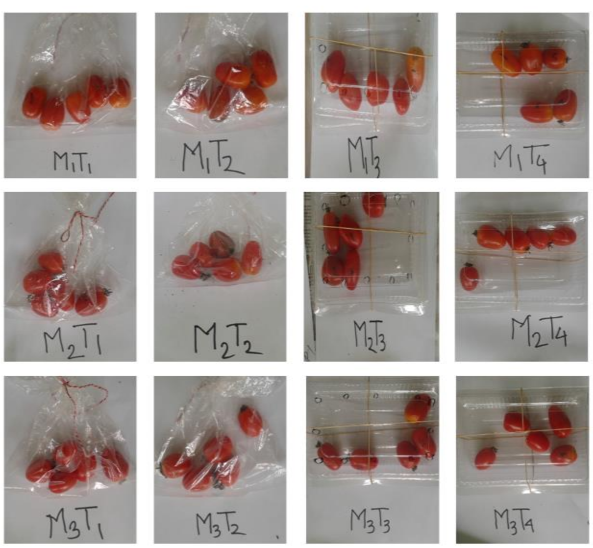

Plate 7. Photograph showing the differences in external appearance of cherry tomato under different postharvest treatments at 25 DAS.

***Firmness*:** The combined effect of maturity indices and postharvest treatments on firmness was significant at 9, 12 and 15 DAS (Table 2). The highest firmness (1.67 kg/cm^2) was recorded in M_3T_0 (Red color fruit treated with LDPPE) and the lowest (0.00 kg/cm^2) was recorded in M_2T_3 (yellow color fruit treated with LDPPB) at 9 DAS. At 12 and 15 DAS, the maximum firmness (3.00 and 4.33 kg/cm^2, respectively) was observed in M_3T_3 while the minimum firmness (0.00 kg/cm^2) was observed in M_2T_3 (yellow color fruit treated with LDPPB). This could be due to increase in the rate of physiological process like transpiration and respiration. Similar results was confirmed by Badshah *et al.* (1997) in cherry tomato, Mustafa and Mughrabi (1994) in tomato, Ali Batu and Keith Thomson (1998) in tomato, Sammi and Masud (2007) in tomato, Naik *et al.* (1993) in tomato, Benyehoshua *et al*. (1991) in lemon and Jadhav *et al*. (1992) in custard apple.

***Weight loss*:** The combined effect of maturity indices and postharvest treatments on weight loss was significant at all DAS (Table 2). The highest weight loss (3.72%) was recorded in M_1T_0 (mature green fruits treated with LDPPE) and the lowest (1.25%) was recorded in M_2T_3 (yellow color fruit treated with LDPPB) at 3 DAS. At 6, 9, 12, and 15 DAS, the maximum weight loss (4.50, 6.30, 7.40 and 7.77%, respectively) was observed in M_1T_0 (mature green fruits treated with LDPPE) and the minimum weight loss (1.29, 1.67, 2.97 and 3.22%, respectively) was observed in M_2T_3 (yellow color fruit treated with LDPPB). Weight loss of cherry tomato fruits was significantly affected by maturity indices and modified atmosphere packaging (MAP). The significant difference was noticed with respect to the different modified atmosphere packaging of polythene bags and plastic boxes. This could be attributed to the fact that polyethylene packages and plastic boxes created modified atmosphere with perforation. It was observed that fruit develop chilling injury as a result failed ripen normally and act as a physical barrier for transpiration losses. Similarly, Gheyas and Haque (1989) reported that weight loss in banana fruits during the period from

Table 1. Combined effects of maturity indices and postharvest treatments on external color at different days after storage (DAS) of cherry tomato.

Treatment combination	External color at different DAS				
	3	**6**	**9**	**12**	**15**
M_1T_0	1.00	1.00	2.00	3.00	4.33
M_1T_1	1.00	1.00	2.00	2.33	3.00
M_1T_2	1.00	1.00	2.00	2.67	3.67
M_1T_3	1.00	1.00	2.00	2.33	3.33
M_1T_4	1.00	1.00	2.00	3.00	4.33
M_2T_0	3.00	4.00	5.00	5.67	6.67
M_2T_1	3.00	4.00	4.67	5.67	6.67
M_2T_2	3.00	4.00	4.33	5.33	6.33
M_2T_3	3.00	4.00	6.00	7.00	8.00
M_2T_4	3.00	4.00	5.00	5.67	6.67
M_3T_0	5.00	5.67	6.33	7.33	8.00
M_3T_1	5.00	5.00	6.00	6.67	8.00
M_3T_2	5.00	5.33	5.67	6.67	7.67
M_3T_3	5.00	5.33	6.00	6.67	7.33
M_3T_4	5.00	5.33	6.00	7.00	8.00
$LSD_{0.05}$	-	0.50	0.90	0.82	0.99
$LSD_{0.01}$	-	0.67	1.21	1.11	1.34
Level of significance	-	NS	NS	**	**

** = Significant at 1% level of probability, NS = Not significant, M_1 = Mature green color, M_2 = Yellow color, M_3 = Red color, T_0 = Control (Without packaging), T_1 = Low density perforated polyethylene (LDPPE), T_2 = Low density polyethylene (LDPE), T_3 = Low density perforated plastic box (LDPPB), T_4 = Low density plastic box (LDPB).

harvest to ripening may be attributed by respiration and loss of water though transpiration. This could be due to increase the rate of physiological process like transpiration and respiration Mustafa and Mughrabi (1994) and Badshah *et al.* (1997) in tomato. This is mainly attributed to continuous moisture and other nutrient loss as the cherry tomato fruits are alive (Nirupama, *et al.*, 2010).

Pulp pH**:** The combined effect of maturity indices and postharvest treatments on pulp pH was significant at all DAS (Table 3). The highest pulp pH (6.23) in M_3T_0 (Red color fruit treated with control) and the lowest (5.60) was recorded in M_1T_1 (Mature green fruits treated with LDPPE) at 3 DAS. At 6 DAS the maximum pulp pH (6.43) in M_2T_4 (Yellow color fruits treated with LDPB) and the minimum (5.73) was observed in M_1T_4 (Mature green fruits treated with LDPB). At 9 DAS, the highest pulp pH (6.40) in M_2T_4 (Yellow color fruits treated with LDPB) and the minimum (5.80) was found in M_1T_3 (Mature green fruits treated with LDPPE). At 12 DAS, the highest pulp pH (6.37) in M_3T_2 (Red color fruits treated with

Table 2. Combined effects of maturity indices and postharvest treatments on firmness and weight loss of cherry tomato at different days after storage (DAS).

Treatment combination	Firmness (kg/cm^2) at different DAS					Weight loss (%) at DAS				
	3	**6**	**9**	**12**	**15**	**3**	**6**	**9**	**12**	**15**
M_1T_0	0.00	0.00	1.00	2.33	3.00	3.72	4.50	6.30	7.40	7.77
M_1T_1	0.00	0.00	1.00	1.67	2.00	3.40	3.83	4.40	5.83	6.73
M_1T_2	0.00	0.00	1.00	1.00	1.67	3.27	3.83	4.40	4.83	5.53
M_1T_3	0.00	0.00	1.00	1.67	2.00	1.47	3.07	4.27	5.37	6.47
M_1T_4	0.00	0.00	0.67	1.33	2.00	2.47	3.77	4.77	6.33	7.07
M_2T_0	0.00	0.00	1.00	1.33	2.33	1.70	3.29	3.53	5.05	6.10
M_2T_1	0.00	0.00	0.33	1.00	1.33	1.52	3.21	3.51	4.75	5.79
M_2T_2	0.00	0.00	0.67	1.33	2.33	1.66	3.36	5.05	5.05	6.53
M_2T_3	0.00	0.00	0.00	0.00	0.00	1.25	1.29	1.67	2.97	3.22
M_2T_4	0.00	0.00	0.00	0.33	1.33	1.39	2.08	2.75	3.49	4.17
M_3T_0	0.00	0.00	1.67	2.33	3.33	2.60	3.56	4.43	5.88	7.20
M_3T_1	0.00	0.00	1.67	3.00	4.33	2.67	3.80	4.30	5.03	5.90
M_3T_2	0.00	0.00	1.67	2.33	3.00	2.33	3.80	4.23	5.33	6.00
M_3T_3	0.00	0.00	2.00	3.00	3.67	1.36	2.47	3.20	4.22	5.17
M_3T_4	0.00	0.00	1.33	2.33	3.33	2.08	3.17	3.73	4.51	5.53
$LSD_{0.05}$	-	-	0.450	0.483	0.377	0.129	0.307	0.659	0.395	0.425
$LSD_{0.01}$	-	-	0.607	0.651	0.507	0.174	0.414	0.887	0.531	0.572
Level of significance	-	-	*	**	**	**	**	**	**	**

**, * = Significant at 1 and 5% levels of probability, respectively. M_1 = Mature green color, M_2 = Yellow color, M_3 = Red color, T_0 = Control (Without packaging), T_1 = Low density perforated polyethylene (LDPPE), T_2 = Low density polyethylene (LDPE), T_3 = Low density perforated plastic box (LDPPB), T_4 = Low density plastic box (LDPB).

LDPE) and the lowest (5.93) was recorded in M_1T_3 (Mature green fruits treated with LDPPE). At 15 DAS the maximum pulp pH was observed (6.40) in M_2T_3 (Yellow color fruits treated with LDPPB) and M_2T_4 (Yellow color fruits treated with LDPB), and the minimum (5.93) was observed in M_1T_4 (Mature green fruits treated with LDPB), respectively (Table 3). The chemical properties of cherry tomato pulp pH presented. It showed increasing trend up gradually then decline. Perforated plastic box show significant difference. This could be attributed, the increase in pH of fruit during ripening, corresponding decrease in acidity caused by degradation of acids during ripening and senescence. The results are in conformity with finding by Sammi and Masud (2007) in tomato and Nirupama *et al.* (2010) in tomato.

Table 3. Combined effects of maturity indices and postharvest treatments on pulp pH and TSS content of cherry tomato at different days after storage (DAS).

Treatment combination	Pulp pH at different DAS					TSS content (%brix) at different DAS				
	3	6	9	12	15	3	6	9	12	15
M_1T_0	5.77	5.80	6.17	6.00	6.13	6.00	6.27	6.33	6.20	6.00
M_1T_1	5.60	5.83	5.87	6.07	6.00	6.00	6.13	6.33	6.00	6.00
M_1T_2	5.87	5.97	6.07	6.17	6.10	5.93	6.27	6.40	6.13	5.73
M_1T_3	6.13	5.87	5.80	5.93	5.97	6.07	6.20	6.40	6.07	6.07
M_1T_4	5.63	5.73	5.87	6.10	5.93	6.00	6.13	6.13	5.87	5.67
M_2T_0	5.93	5.93	5.97	6.27	6.00	6.67	6.93	6.87	6.67	6.53
M_2T_1	6.00	6.13	6.13	6.23	6.23	6.60	6.40	6.50	6.27	6.00
M_2T_2	6.07	5.93	5.87	6.10	6.13	6.73	6.87	7.00	6.53	6.53
M_2T_3	6.17	6.13	6.20	6.27	6.40	6.63	6.67	7.13	6.73	6.53
M_2T_4	6.17	6.43	6.40	6.33	6.40	6.47	6.60	6.80	6.73	6.53
M_3T_0	6.23	6.27	6.27	6.23	6.23	7.13	7.33	7.60	6.93	6.87
M_3T_1	5.83	5.79	6.13	6.10	6.20	7.39	6.84	7.07	6.67	6.60
M_3T_2	6.03	6.13	6.30	6.37	6.27	7.59	7.27	7.47	7.40	7.13
M_3T_3	5.83	6.07	6.13	6.23	6.37	7.47	7.53	7.60	7.13	6.87
M_3T_4	6.06	6.13	6.20	6.30	6.20	7.12	6.73	7.27	7.27	7.20
$LSD_{0.05}$	0.105	0.149	0.167	0.091	0.149	0.183	0.149	0.204	0.284	0.358
$LSD_{0.01}$	0.142	0.201	0.225	0.123	0.201	0.246	0.201	0.275	0.382	0.482
Level of significance	**	**	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability. M_1 = Mature green color, M_2 = Yellow color, M_3 = Red color, T_0 = Control (Without packaging), T_1 = Low density perforated polyethylene (LDPPE), T_2 = Low density polyethylene (LDPE), T_3 = Low density perforated plastic box (LDPPB), T_4 = Low density plastic box (LDPB).

***Total soluble solids (TSS)*:** The combined effect of maturity indices and postharvest treatments on total soluble solids was significant at all DAS (Table 3). The highest TSS content (7.59%) was found from M_3T_2 (Red color fruits treated with LDPE) while the lowest (6.00%) was recorded in M_1T_0 (Mature green fruits treated with control), M_1T_1 (Mature green fruits treated with LDPPE) and M_2T_1 (Yellow color fruits treated with LDPPE) at 3 DAS. At 6 and 9 DAS, the maximum TSS (7.53 and 7.60%, respectively) was observed in M_3T_3 (Red color fruits treated with LDPPB) and the minimum TSS (6.13%) was observed in M_1T_4 (Mature green fruits treated with LDPB) (Table 3). At 15 DAS, the highest TSS (7.20%) was recorded in M_3T_4 (Red color fruits treated with LDPB) and the lowest TSS (5.73%) was recorded in M_1T_2 (Mature green fruits treated with LDPE) (Table 3). This could be attributed due to the increase in TSS of cherry tomato fruits ripening, softer and sweeter, corresponding decrease in acidity caused by degradation of acids during ripening and senescence. Similarly, the increase TSS could be attributed to conversion of starch and other in soluble compounds (Wasker *et al.*, 1997) in sapota, Sudhir Yadav *et al.* (2005) and Mahajan and Sharma (2000) in peach.

Titratable acidity (TA): The combined effect of maturity indices and postharvest treatments on titratable acidity was significant at 9, 12 and 15 DAS but non-significant at 3 and 6 DAS (Table 4). The highest TA (0.29%) was recorded in M_2T_3 (Yellow color fruits treated with LDPPB) and M_1T_0 (Mature green fruits treated with control), and the lowest (0.24%) was observed in M_1T_2 (Mature green fruits treated with LDPE) at 9 DAS. At 12 DAS, the maximum TA (0.28%) was observed in M_2T_3 (Yellow color fruits treated with LDPPB) while the minimum TA (0.21%) was recorded in M_3T_0 (Red color fruits treated with control). At 15 DAS, the highest TA (0.24%) was recorded in M_3T_3 (Red color fruits treated with LDPPB) and M_2T_3 (Yellow color fruits treated with LDPPB), and the lowest TA (0.18%) was found from M_1T_0 (Mature green fruits treated with control), respectively (Table 4). Similar findings were also noticed by Tamil Selvan and Bal (2005) in Guava, and Upadhayaya and Sanghavi (2001) in strawberry with respect to the polyethylene packages used. The results were in conformity with Naik *et al.* (1993) in tomato, and Ingawale (2005) in custard apple.

Ascorbic acid (Vitamin C) content**:** The combined effect of maturity indices and postharvest treatments on ascorbic acid was significant on almost all the days after storage except 6 DAS (Table 4). The highest ascorbic acid (18.40 mg/100g) was obtained from M_2T_1 (Yellow color fruits treated with LDPPE) while the lowest (14.78 mg/100g) was recorded from M_1T_2 (Mature green fruits treated with LDPE) at 3 DAS. At 9 DAS, the maximum ascorbic acid (19.57 mg/100g) was observed in M_1T_0 (Mature green fruits treated with control) and the minimum ascorbic acid (17.17 mg/100g) was observed in M_3T_0 (Red color fruits treated with control). At 12 DAS, the highest ascorbic acid (18.13 mg/100g) was observed in M_3T_4 (Red color fruits treated with LDPB) and the lowest ascorbic acid (16.55 mg/100g) was recorded in M_2T_0 (Yellow color fruits treated with control). At 15 DAS, the highest ascorbic acid (17.60 mg/100g) was observed in M_3T_4 (Red color fruits treated with LDPB) while the lowest ascorbic acid (15.20 mg/100g) was obtained from M_3T_0 (Red color fruits treated with control) (Table 4). This could be due to lower rate of conversion of ascorbic acid to dehydro-ascorbic acid. Similar results were also reported by Sammi and Masud (2007) in tomato, Moneruzzaman *et al.* (2009) in tomato, and Upadhayaya *et al.* (2001) in strawberry. Biochemical changes during storage under different polyethylene sealed packages increases ascorbic acid content in conformity with Sudhir yadhav *et al.* (2005).

Disease incidence and severity**:** The combined effect of maturity indices and postharvest treatments on disease incidence was significant on almost all the days after storage except 3 DAS (Table 5). At 6 DAS, the highest disease incidence (3.0%) was recorded in M_3T_0 (Red color fruits treated with control) followed by (1.67%) in M_1T_0 (Mature green fruits treated with control) and the lowest (0.00%) was recorded in rest of the treatment combinations (Table 5). At 9 and 12 DAS, the maximum disease incidence **(**5.67, and 8.67%, respectively) was observed in M_1T_0 (Mature green fruits treated with control) while the minimum disease incidence (0.00, and 1.00%, respectively) was observed in M_2T_3 (Yellow color fruits treated with LDPPB). At 15 DAS, the highest disease incidence (16.67%) was recorded from M_3T_0 (Red color fruits treated with control) while the lowest disease incidence (1.67 %) was observed in M_2T_3 (Yellow color fruits treated with LDPPB) (Table 5).

The combined effect of maturity indices and postharvest treatments on disease severity was also significant on almost all the DAS except 3 DAS (Table 5). The highest disease severity (7.33%) was recorded

Table 4. Combined effects of maturity indices and postharvest treatments on titratable acidity (TA) and ascorbic acid (vitamin C) contents of cherry tomato at different DAS.

Treatment combination	Titratable acidity (%) at different DAS					Ascorbic acid (mg/100 g) at different DAS				
	3	6	9	12	15	3	6	9	12	15
M_1T_0	0.28	0.28	0.29	0.26	0.18	18.26	18.62	19.57	17.74	15.58
M_1T_1	0.28	0.29	0.26	0.25	0.20	18.20	18.50	18.57	17.40	15.57
M_1T_2	0.28	0.26	0.24	0.23	0.19	14.78	18.40	18.30	16.95	15.40
M_1T_3	0.27	0.26	0.25	0.22	0.19	18.13	18.10	18.30	16.83	15.65
M_1T_4	0.27	0.26	0.25	0.23	0.19	17.97	18.37	18.07	16.58	15.73
M_2T_0	0.27	0.27	0.26	0.23	0.20	16.93	18.55	18.80	16.55	15.63
M_2T_1	0.28	0.26	0.25	0.23	0.23	18.40	18.33	18.35	17.23	16.50
M_2T_2	0.27	0.26	0.26	0.25	0.22	18.20	18.43	18.60	17.07	16.37
M_2T_3	0.28	0.28	0.29	0.28	0.24	18.25	18.45	19.20	18.87	17.50
M_2T_4	0.28	0.26	0.26	0.24	0.19	18.20	18.23	18.17	17.50	16.20
M_3T_0	0.28	0.26	0.25	0.21	0.19	18.15	18.00	17.17	17.23	15.20
M_3T_1	0.27	0.27	0.25	0.23	0.19	17.85	17.83	17.27	16.93	16.57
M_3T_2	0.27	0.27	0.25	0.22	0.19	17.88	17.90	17.43	16.33	16.33
M_3T_3	0.28	0.27	0.28	0.26	0.24	17.57	17.80	18.17	18.13	17.60
M_3T_4	0.27	0.27	0.26	0.24	0.21	17.77	17.80	17.27	16.90	16.50
$LSD_{0.05}$	0.022	0.029	0.015	0.037	0.032	0.258	0.224	0.284	0.307	0.190
$LSD_{0.01}$	0.029	0.039	0.020	0.049	0.043	0.348	0.301	0.382	0.414	0.256
Level of significance	NS	NS	**	*	*	**	NS	**	**	**

**, * = Significant at 1 and 5% levels of probability, respectively, NS = Not significant. M_1 = Mature green color, M_2 = Yellow color, M_3 = Red color, T_0 = Control (Without packaging), T_1 = Low density perforated polyethylene (LDPPE), T_2 = Low density polyethylene (LDPE), T_3 = Low density perforated plastic box (LDPPB), T_4 = Low density plastic box (LDPB).

from M_1T_0 (Mature green fruits treated with control) while the lowest (0.00%) was observed in M_2T_3 (Yellow color fruits treated with LDPPB) at 6 DAS. At 9 DAS, the maximum disease severity (11.33%) was observed in M_1T_0 (Mature green fruits treated with control) and the minimum disease severity (0.00%) was observed in M_2T_3 (Yellow color fruits treated with LDPPB). At 12 DAS, the highest disease severity (16.00%) was obtained in M_3T_0 (Red color fruits treated with control) and the lowest disease severity (1.67%) was obtained from M_2T_3 (Yellow color fruits treated with LDPPB). At 15 DAS, the highest disease severity (21.67%) was observed in M_1T_0 (Mature green fruits treated with control) and M_3T_0 (Red color fruits treated with control), while the lowest disease severity (2.33 %) was observed in M_2T_3 (Yellow color fruits treated with LDPPB) (Table 5).

Table 5. Combined effects of maturity indices and postharvest treatment on percent disease incidence and severity of cherry tomato at different days after storage (DAS).

Treatment combination	Disease incidence (%) at different DAS					Disease severity (%) at different DAS				
	3	6	9	12	15	3	6	9	12	15
M_1T_0	0.00	1.67	5.67	8.67	10.67	0	7.33	11.33	14.67	21.67
M_1T_1	0.00	0.00	4.00	9.00	11.33	0	5.00	9.67	11.33	14.00
M_1T_2	0.00	0.00	4.67	7.33	9.67	0	1.67	5.00	6.33	6.67
M_1T_3	0.00	0.00	3.33	6.33	11.67	0	3.33	5.67	8.33	13.33
M_1T_4	0.00	0.00	3.67	6.00	9.67	0	3.67	5.33	9.00	13.00
M_2T_0	0.00	0.00	4.00	6.33	9.00	0	5.67	9.67	14.33	20.00
M_2T_1	0.00	0.00	2.67	6.33	9.67	0	4.33	7.67	10.00	12.00
M_2T_2	0.00	0.00	2.00	5.67	8.33	0	3.33	7.67	10.00	15.00
M_2T_3	0.00	0.00	0.00	1.00	1.67	0	0.00	0.00	1.67	2.33
M_2T_4	0.00	0.00	1.00	1.50	2.67	0	0.00	0.00	2.00	3.67
M_3T_0	0.00	3.00	6.00	10.00	16.67	0	6.67	10.67	16.00	21.67
M_3T_1	0.00	0.00	2.67	7.00	9.33	0	5.67	10.67	15.33	21.33
M_3T_2	0.00	0.00	3.67	7.67	11.33	0	4.33	7.33	10.67	13.33
M_3T_3	0.00	0.00	3.33	6.67	12.67	0	3.33	7.33	11.00	14.00
M_3T_4	0.00	0.00	4.67	7.33	11.00	0	2.67	6.33	9.33	12.00
$LSD_{0.05}$	-	0.329	1.054	1.159	1.533	-	0.862	2.823	3.541	3.992
$LSD_{0.01}$	-	0.443	1.420	1.560	2.064	-	1.160	3.802	4.769	5.376
Level of significance	-	**	**	**	**	-	**	**	**	**

** = Significant at 1% level of probability. M_1 = Mature green color, M_2 = Yellow color, M_3 = Red color, T_0 = Control (Without packaging), T_1 = Low density perforated polyethylene (LDPPE), T_2 = Low density polyethylene (LDPE), T_3 = Low density perforated plastic box (LDPPB), T_4 = Low density plastic box (LDPB).

The data pertaining to the disease indices and severity were recorded of cherry tomato fruits revealed that there was an increased in the number of spoilage fruits at the storage period irrespective of the maturity indices, modified atmosphere packaging and their interactions. This could be attributed to postharvest treatment which is contributed to the strengthening the cell walls and skin of fruit so that micro-organism cannot get enter to spoilage the cherry tomato fruits. Low density perforated plastic box and polythene packaging anti-microbial property, which might help the inhibition of spoilage to some extent. Our observation was confirmed by Nirupama *et al.* 2010) in tomato, Vishalnath and Bhargava (1998) in ber fruits and Moneruzzaman *et al.* (2009) in tomato. The results were also confirmed by Sammi and Masud (2007), Ali Batu and Keith Thomson (1998), Naryana *et al.* (2002) in banana and Jadav *et al.* (1992) custard apple.

***Shelf life*:** Shelf life is the period from harvesting up to the last edible stage. This is the basic quality of fruits, which helps marketing duration, and it is the most important aspect in loss reduction technology of fruits (Mondal *et al*., 2011; Rashid *et al*., 2015). The extension of shelf life of fruit has been one of the prime concerns of marketing throughout the record of history (Rashid and Rahman, 2020). The combined effects of the maturity indices and postharvest treatments were significant in respect of shelf life of cherry tomato (Figure 1). The longest shelf life of cherry tomato fruits (25 days) was obtained from M_2T_3 (Yellow color fruits treated with LDPPB) while the shortest shelf life of cherry tomato fruits (7 days) was recorded in fruits without any postharvest treatment. Similar results were also reported by Dinesh Singh *et al.* (2005) in peach fruit, Ingawale and Patgaunkar Jadhav (2005) in custard apple, Shivani Jindal *et al.* (2005) in sapota, and Akath Singh et al. (2007) in strawberry.

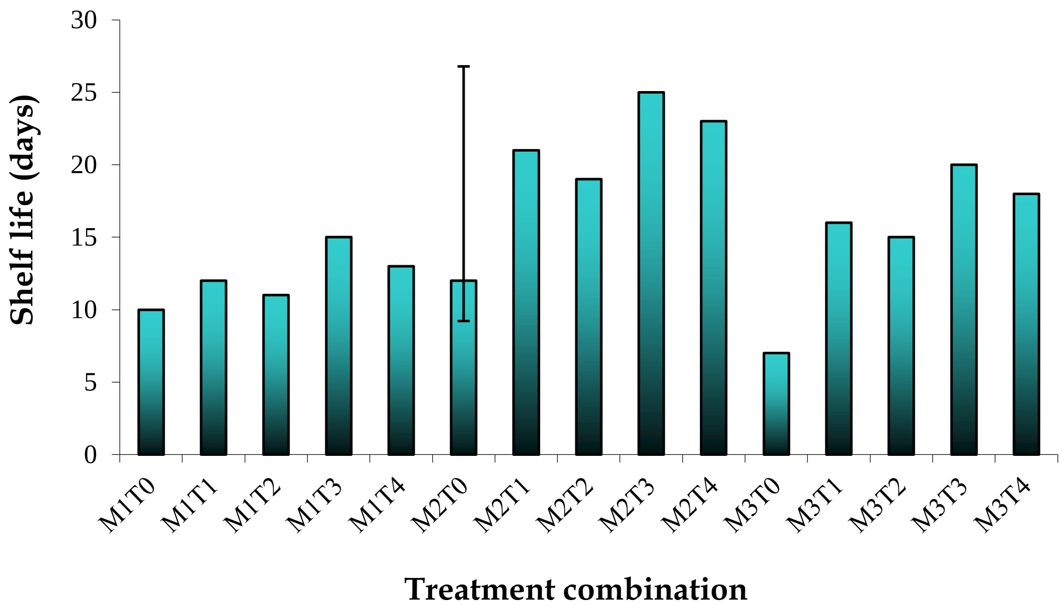

Figure 1. Combined effects of maturity indices and postharvest treatments on shelf life of cherry tomato at different days after storage (DAS). The vertical bar indicates LSD at 1% level of significance. M_1 = Mature green color, M_2 = Yellow color, M_3 = Red color, T_0 = Control (Without packaging), T_1 = Low density perforated polyethylene (LDPPE), T_2 = Low density polyethylene (LDPE), T_3 = Low density perforated plastic box (LDPPB), T_4 = Low density plastic box (LDPB).

Conclusion

Results indicated that significant variation existed due to the effect if maturity indices and postharvest treatments. From the present study it was found that highest shelf life and better quality of cherry tomato was obtained from M_2T_3 (Yellow color cherry tomato fruits treated with low density perforated plastic box, LDPPB). Therefore, it may be concluded that cherry tomato fruits under maturity index 2 (M_2) along with the application of LDPPB (low density perforated plastic box) could be used to reduce postharvest fungal infection, shelf life extension and quality retention of cherry tomato.

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