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STUDY ON CONTROLLING PHYSIOLOGICAL LOSSES DURING MARKETING OF TOMATO (*LYCOPERSICON ESCULENTUM* MILL.)

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ABSTRACT

Fresh and wholesome tomato is used in preparation of almost every cuisine in South-Asia. Due to its high perishability, an extended shelf life for a reasonable period remains the area of interest for the traders and consumers. This study has been designed to investigate the potential means of extending shelf life of tomato during marketing. For this purpose, an ethylene absorbent (i.e. $KMnO_4$) was applied on a wrapping material at different concentrations (1, 2 and 3 g/L). Tomatoes (green, half and full ripened) were placed in cardboard boxes and stored under normal conditions (temperature = 30-35°C). In general, it has been observed that the acidity was decreased while pH, decay, reducing, non-reducing and total sugars were increased under given storage conditions. A highly significant impact (P<0.005) was recorded on retarding the increase in reducing and non-reducing sugar content. As compared to control, about 50% reduction in the increase of reducing sugars was observed at 3 g/L $KMnO_4$ treatment. Decline in acid concentration (i.e. citric acid) of tomato with advancement in maturity is reflected by increase in pH from 4.18 to 4.69. Whereas, a negligible changes in pH (4.28 to 4.30) was observed in treated full ripened tomatoes. Similarly, a slight decrease in acidities of full ripened (0.394 to 0.392%), half ripened (0.448 to 0.444%) and green (0.456 to 0.448%) tomatoes were observed upon 3 g/L $KMnO_4$ treatment. There was insignificant impact of treatment with $KMnO_4$on the weight loss and decay of tomatoes. The results of present study suggested that a $KMnO_4$ treated wrapping material can be utilize for enhancing shelf life of tomatoes by retarding respiration and delaying ripening.

Key words: Tomato, $KMnO_4$, percent acidity, ripening, reducing and non-reducing sugars.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular vegetables around the world. Its ripening is a complex, process that causes changes in color, texture, flavor and chemical composition of the fruit. Also, fruit ripening starts after harvest, and final nutrient composition of the fruit might be harshly affected by ripening processes and storage environmental condition (Saeideh *et al.*, 2018; Javanmardi and Kubota, 2006).Tomato is a climacteric fruit, having respiratory peak during their ripening process. Being a climacteric and perishable, tomatoes have a very short life span. The practice from post-harvest to marketing is part of system of interlinked activities from the time of harvest to the delivery of the food to the consumer referred to as “farm to fork”. Post-harvest losses refer to the quantitative and qualitative changes in food postharvest system (FAO, 2013).

Postharvest losses in world are around 30 to 40% or greater loss in developing countries. Microbial decay of fruit, external injury during harvesting, handling and storage of tomato fruits, ethylene production, respiration rate and temperature during harvest and storage condition are main reasons of post-harvest losses cause severe effect on storage life and nutritional quality of tomatoes. During storage tomato, ethylene speeds up the ripening process of tomatoes and overripe it within few days, decreases the shelf life and making them unmarketable (Gustavsson *et al.*, 2011; Guillen *et al.*, 2007).

Quality of most fruits and vegetables is also affected by water loss during storage, which depends on the temperature and relative humidity conditions. After harvest, fruits suffer from physiological and biochemical changes because fruit is the living part and has high water content. In addition to changes, microbial attack releases the water content from fruits while temperature increases the respiration process which contributes to postharvest losses during ripening stage and storage space. By slowing down the microbial contamination and ripening process post-harvest shelf life of a fruit could be prolonged (Perez *et al.*, 2003).

There are different methods developed to extend fruit postharvest shelf life of fruits and vegetables. In tomato application of chemical as pre-and post harvest sprays or dips, packaging, edible coatings, heat treatment, controlled and modified atmosphere storage, exogenous application of calcium, $KMnO_4$, selenium, amino ethoxy vinyl glycine and 1-Methylcyclopropene used in extending the shelf-life of fresh produce and reducing the post harvest loss (Aguayo *et al.*, 2004; Martínez-Romero *et al.*, 2007; Zhu *et al.*, 2017)

Potassium permanganate ($KMnO_4$) is also used to extend the shelf life of fresh produces by reducing ethylene levels by oxidizing it to carbon dioxide and water. It was demonstrated that $KMnO_4$ retarded the ripening of many fruits. Potassium permanganate is a stable purple solid that is a strong oxidizing agent and readily oxidizes ethylene and delayed ripening in climacteric fruits such as banana, kiwi fruit, tomato, mango and avocado (Osman, and Abu-Gaukh, 2008; Ozdemir and Floros, 2004; Wills and Warton, 2004).Application of $KMnO_4$ as ethylene scrubber has been reported to play an important role in prolonging the shelf life of mature green and red ripe tomatoes (Senjaliya *et al.*, 2015).

Ethylene absorbent absorbs the ethylene gases that released from fruits and as a result slow down the ripening process and helps to enhance the shelf-life of fruit. However, suitable concentration is required. Nutritional quality of tomato is also dependent upon the harvesting stages. Generally, tomato when harvested at fully mature stages had reduced shelf life. other researchers had also reported about the extension of shelf life of tomato by using $KMnO_4$ to remove the ethylene gas which played an important role in tomato fruit ripening (Peppelenbos *et al.*, 2003) .Therefore, the present investigation was initiated to evaluate the effect of different concentration of $KMnO_4$ on different ripening stages and quality of tomato.

MATERIALS AND METHODS

Fruit collection

Tomato fruit (*Lycopersicon esculentum* Mill.) were collected from local market of Karachi; tomato variety Roma VF was selected by considering uniformity in shape, colour and size; diseased and damaged fruits were rejected.

Fruit washing

Fruit were washed with 0.01% sodium hypochlorite (NaOCl) solution to diminish microbial contamination. Surface drying was done by clean cloth before dividing into different lots.

Experimental setup

Fruits were segregated on the basis of three stages;M1;green mature, M2;half ripe and M3; full ripe before wrapping in packaging material treated with different concentrations of KMnO4. Temperature was recorded within range of 30-35°C during storage.

Treatments

Three concentrations of $KMnO_4$ (T0; control, T1; 1, T2; 2 and T3; 3g/L) were prepared and newspaper was soaked in desired concentration. Newspaper was dried under shade after 7 minutes of soaking. Tomato were packed in $KMnO_4$ treated newspaper and transfer to cardboard boxes. Each box was retaining 2kg fruit sample, replicated five times for each treatment.

Methods of analysis

Weight loss was calculated according to procedure adopted by Srivastava and Tandon (1968). Following formula used for calculation;

Weight loss (%) $=(X - Y) / X \times 100$

Where 'X' is initial weight and 'Y' is the final weight of fruit.

Decay/ rotting percentage is calculated by weighing fruit after removal of decayed or rotted fruit from box as proposed by Srivastava and Tandon (1968). Following formula was applied for estimation of decay losses.

Decay loss (%) = (A-B) / A x 100

Where, A= Total weight, B = Weight after removing decayed fruits

In chemical analysis pH, acidity, reducing sugar, non-reducing sugar and total sugar were determined by standard methods (AOAC, 2012).Statistically test results were taken in triplicate and data were interpreted by SPSS software (IBM SPSS Statistics 21).

RESULTS AND DISCUSSION

pH and Titrable Acidity (TA)

pH and %TA of fruits are important indicators of fruit ripening. Initial maturity stage and storage time were found to be the main precursor for the change of pH and TA %.It was found that at 12th day of storage, untreated (control) samples possessed varied increase in pH with variations in initial maturity stages viz. green fruits (M1), half ripened (M2) and full ripened (M3). The maximum pH attained at 12th day of storage in controlled samples was 4.29, 4.39 and 4.69 for M1, M2 and M3, respectively. Likewise the decrease in TA was observed in the controlled samples at 12th day storage life was found 0.39, 0.32 and 0.12 for M1, M2 and M3 respectively. Increased pH and decreased acidity is attributable to the decrease in citric acid content while other acids shows no significant decrease in acidity during ripening as evident by (Anthon *et al*., 2011).In post-harvest stage, respiration rate of fruits increases and organic acid decreases as it approaches maturity and ripening stages. The pH value increased with reduction in acidity as a result of decrease in organic acid concentration (Albertini *et al.*, 2006; Moneruzzaman *et al*., 2009).

The impact of KMnO4 treated packaging at three concentrations of 1,2 and 3g/L denoted as T1,T2 and T3 were evaluated. Trend of pH and TA were reflected along the 12 days storage time among different maturity stages and respective treatments (Fig. **1a**), (Fig. **1b**). It was revealed that the overall impact of treatments were positive to retard the respiration rate in comparison to control samples in all three stages(i.e. M1,M2 and M3). Although the T2 andT3 was found to have a profound effect on the ripening of tomato as evident in terms of pH and TA content increase and decreased levels, respectively in comparing to the control(untreated) samples.

Along the storage period change in pH units from initial to the 12th day was 0.41, 0.08, 0.03 and 0.02 for M3 at T0, T1,T2,T3, respectively. Similar patterns were observed for other M2and M1 stages. This reflects clearly that these treatments aid to retard the ripening process and T3 was found to have the largest impacts. The pH value was increased with extending the postharvest life of papaya using modified atmosphere packaging with $KMnO_4$ for 6 days at ambient temperature (Jayathunge *et al.*, 2011). It was also reported that increase in pH of postharvest treated fruits was less as compare to non treated (Islam, 2012; Nirupama *et al.*, 2010). It was reported that fruits treated with $KMnO_4$, retarded the reduction of acidity as compare to untreated (Kader, 2002; Elamine and Abu-Goukh, 2009). Decrease in TA due to $KMnO_4$, is due to the increases in CO_2 concentration as it degrades the ethylene into CO_2 and water. Ethylene absorbents delayed fruit ripening. A study showed that decrease of TA during the storage could be related to ripening rate and higher respiration, where organic acids are used as important component in respiration and ripening process converted into sugars (Tigist*et al.*, 2013; Silva *et al.*, 2009).

Physiological Weight Loss (PWL) and Decay Percentage

Both PWL and decay percent increases with the proceeding of storage time. Overall increase was found in PWL during twelve days, among all treatmentsKMnO4treated fruits have recorded lowest reduction inPWL in comparing to the control(Fig.**2a**).Decrease in respiration rate due to antioxidant activity of KMnO4 lowers the permeability of skin and resulting in lesser shriveling that cause reduction in the market value and consumer satisfaction. However, ethylene absorbers retain the weight of fruits as compared to control. Most promising results were obtained from 3g/L$KMnO_4$keep hold the weight.

Decay or rot percent increased with the increase of storage duration, rotting percent was higher in case of non treated fruits. Result was observed that full ripened (M3) stage has highest decay or rotting percent (Fig.**2b**). High rate of transpiration, respiration and water/moisture loss and cell wall susceptibility compel microorganism to grow and cause spoilage and decay by infecting and ultimately contribute to short life span.

Different studies demonstrated the reduction of PWL by different treatments for different fruits i.e. $KMnO_4$treatment for banana, mango and papaya treated with polythene and $KMnO_4$, papaya treated with modified atmospheric packaging and $KMnO_4$. $KMnO_4$found to delays the fruits ripening by decreasing tissue permeability (Osman and Abu-Goukh, 2008;Shattir and Abu-Goukh, 2012; Muhammad *et al.*, 2018; Islam, 2012;Jayathunge *et al.*, 2011; Xing *et al.*, 2015; Nath *et al.*, 2012; Mahajan *et al.*, 2013)

In present study decay percent increased with storage intervals, absorbent did not very much retard the decay percent in half ripe and full ripe but in green tomatoes decay started from 9 day as compared to other maturity stages where decay starts from 3rd day. Previously conducted study showed that decay was connected with ripening and post harvest storage duration, higher water content and physiological process provided favorable environment for microbial attack. It was reported that the decay loss and spoilage of fruit might be reduce by using ethylene absorbent and cause reduction in ethylene production (Guillen *et al.*, 2006; Pangaribuan *et al.*, 2003). Similar results were recorded in apple and tomatoes (Khosravi *et al.*, 2015; Nath *et al.*, 2015).

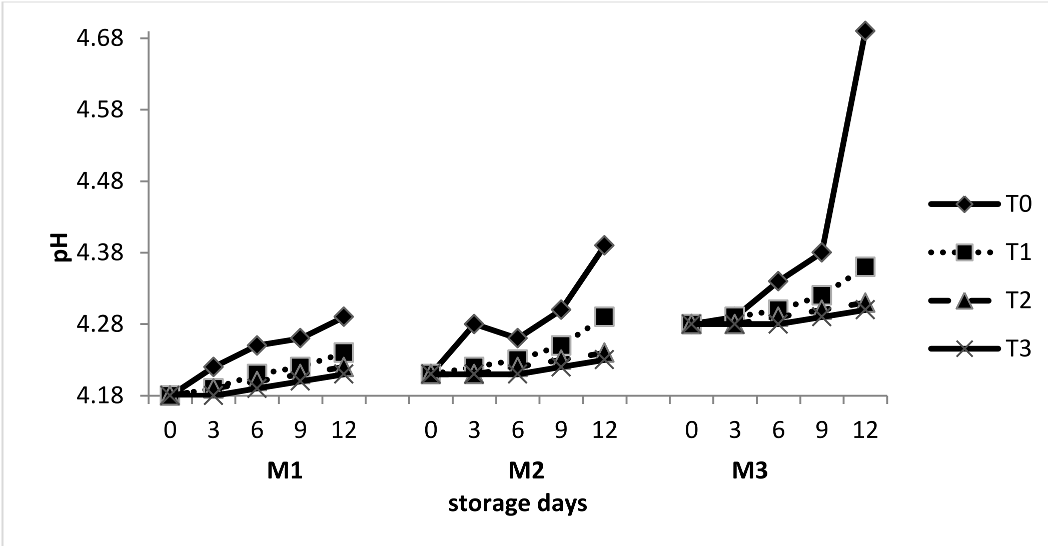

Fig. **1a**. Effect of different concentration of $KMnO_4$ and storage period on pH of tomatoes.
M1= Green, M2= Half ripe and M3= Full ripe tomato, T0= without $KMnO_4$, T1= 1 g/L $KMnO_4$, T2= 2 g/L $KMnO_4$, T3= 3g/L $KMnO_4$.

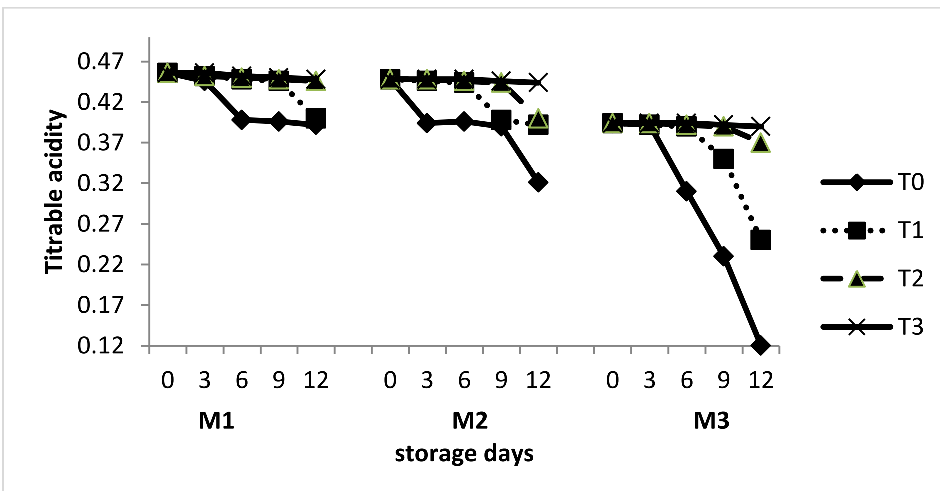

Fig. **1b.** Effect of different concentration of $KMnO_4$ and storage period on titrable acidity of tomatoes.
M1= Green, M2= Half ripe and M3= Full ripe tomato, T0= without $KMnO_4$, T1= 1 g/L $KMnO_4$, T2= 2 g/L $KMnO_4$, T3= 3g/L $KMnO_4$.

Sugar Content

The sugar contents in terms of total (TS), reducing (RS) and non-reducing sugars (NRS) were examined. Increase in sugar contents is a function of fruit ripening process. Evaluating the impact of treatments on ripening process in terms of sugar contents, it was observed that along the storage period TS, RS, NRS contents were increased with lower pace in comparison of all three stages as shown in Table 1. Full ripe tomato contained maximum sugar content whereas the mature green tomato found to contain the lowest quantity along three days intervals of observations. Total sugar content of tomato pulp changed extensively among three maturity stages (M1, M2 and M3). In a study it was explained that the concentration of TSS progressively increased with storage, break down of organic acid resulted to increase the sugar content in cherry tomatoes (Pila *et al.*, 2010; Rai *et al.*, 2012; Ahmed *et al.*, 2014; Dong *et al.*, 2001; Morrelli and Kader, 2002; Golding *et al.*, 2005). Sugar increase with the advancement of maturity due to conversion of starch into sugar (Moneruzzaman *et al.*, 2009). Ripening conditions was found to significantly affect total sugar content of tomato at different storage durations, sugar content in treated fruits increased but not as much as without treatment. Ripening involves various metabolic changes which results decrease in acids cause increased in sugar content contributing texture softening, compositional and structural changes (Anthon *et al.*, 2011).

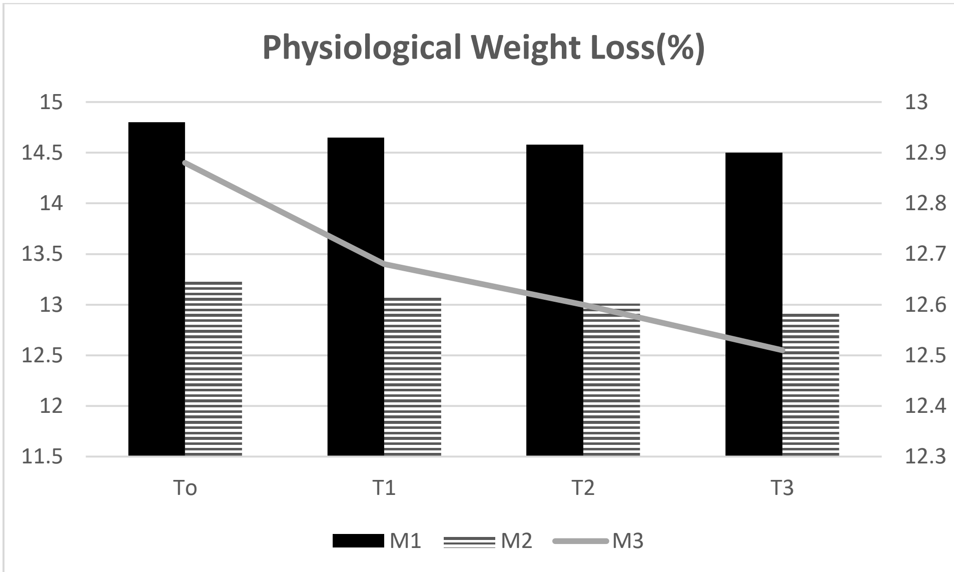

Fig. **2a.** Effect of different concentration of $KMnO_4$ and storage period on physiological weight loss (%) of tomatoes.
M1= Green, M2= Half ripe and M3= Full ripe tomato, T0= without $KMnO_4$, T1= 1 g/L $KMnO_4$, T2= 2 g/L $KMnO_4$, T3= 3g/L $KMnO_4$.

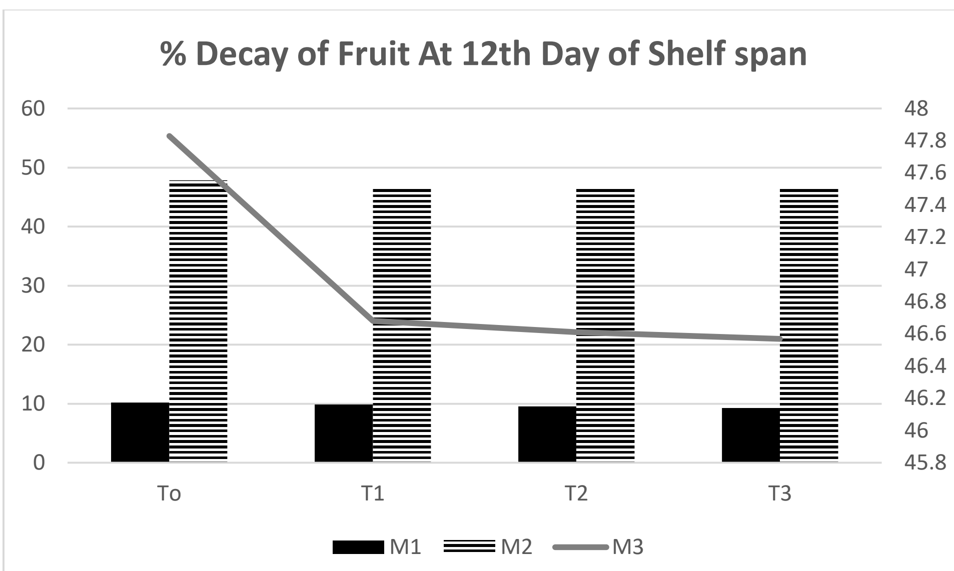

Fig. **2b.**Effect of different concentration of $KMnO_4$ and storage period on decay (%) of tomatoes.
M1= Green, M2= Half ripe and M3= Full ripe tomato, T0= without $KMnO_4$, T1= 1 g/L $KMnO_4$, T2= 2 g/L $KMnO_4$, T3= 3g/L $KMnO_4$.

Table 1. Effect of different concentration of $KMnO_4$ and storage period on reducing, non -reducing and total sugar content of tomatoes.

Storage Time (days)	M1				M2				M3			
	To	T1	T2	T3	To	T1	T2	T3	To	T1	T2	T3
												Reducing Sugars (%)
0	2.54	2.54	2.54	2.54	2.76	2.76	2.76	2.76	3.07	3.07	3.07	3.07
3	3.11	2.67	2.57	2.58	3.32	2.83	2.8	2.78	3.35	3.18	3.14	3.11
6	3.57	2.74	2.63	2.64	3.63	2.9	2.86	2.81	3.7	3.25	3.2	3.17
9	3.76	2.86	2.7	2.69	3.75	2.98	2.91	2.85	3.78	3.38	3.27	3.22
12	3.98	2.94	2.81	2.75	4.11	3.12	3.01	2.9	4.4	3.38	3.35	3.32
	1.44j	0.4g	0.27d	0.21b	1.35i	0.36f	0.25c	0.14a	1.33h	0.31e	0.28d	0.25c
												Non- Reducing Sugars (%)
0	0.82	0.82	0.82	0.82	0.86	0.86	0.86	0.86	0.89	0.89	0.89	0.89
3	0.84	0.84	0.83	0.82	0.89	0.87	0.87	0.87	0.97	0.95	0.92	0.9
6	0.89	0.88	0.85	0.83	0.92	0.9	0.89	0.88	0.98	0.96	0.94	0.92
9	0.9	0.9	0.87	0.84	0.95	0.92	0.91	0.89	1.02	0.98	0.96	0.94
12	0.94	0.92	0.89	0.85	0.97	0.94	0.92	0.9	1.05	1.01	0.98	0.95
	0.12g	0.10f	0.07c	0.03a	0.11g	0.08d	0.06c	0.04b	0.16h	0.12g	0.09e	0.06c
												Total Sugars (%)
0	3.36	3.36	3.36	3.36	3.62	3.62	3.62	3.62	3.96	3.96	3.96	3.96
3	3.95	3.51	3.4	3.4	4.21	3.7	3.67	3.65	4.32	4.13	4.06	4.01
6	4.46	3.62	3.48	3.47	4.55	3.8	3.75	3.69	4.32	4.13	4.06	4.01
9	4.66	3.76	3.57	3.53	4.7	3.9	3.82	3.74	4.8	4.36	4.23	4.16
12	4.92	3.86	3.7	3.6	5.08	4.06	3.93	3.80	5.45	4.39	4.33	4.27
	1.56j	0.5g	0.34d	0.24b	1.46h	0.44f	0.31c	0.18a	1.49i	0.43f	0.37e	0.31c

M1= Green, M2= Half ripe and M3= Full ripe tomato, T0= without KMnO4, T1= 1 g/L KMnO4, T2= 2 g/L KMnO4, T3= 3g/L KMnO4. Figures with different letters are statistically different ($p<0.05$).

Higher values of RS were found in tomatoes than NRS in the control samples. Higher values of RS were found for control of M1 than M3. Full ripe tomatoes contained high amount of reducing sugar comparison to green tomatoes (Moneruzzaman *et al.,* 2009; Tilahun, 2013). In previous studies, increase in reducing sugar was reported during storage due to conversion of polysaccharide into water soluble sugar (Monika *et al*., 2011). Reducing sugar was increased due to conversion of starch to sugar as ripening process increased in banana (Zewter *et al.,* 2012). However the rate of reducing sugar formation was linger on by applying treatments, delayed the ripening process and enhancing the shelf life. Result showed an increasing trend of reducing sugar with the increase of storage time and maturity during 12 days of storage. Treatments of $KMnO_4$ showed better results to retard the reduction of sugar. Reducing sugar enhanced due to degradation of starch into sugar by the activity of starch hydrolyzing enzyme. Among three different treatments, 3g/L $KMnO_4$ have given best results of about 50% reduction in reducing sugar.

The NRS was also increased within progression of storage period. Significant increase was observed in non-reducing sugar content among the maturity stages of tomato mature to full ripe as given in Table 1. Non reducing sugar was increased at lower rate in treated tomatoes as compare to untreated tomatoes during storage period. NRS contents increases with the maturity might be due to starch breakdown and its conversion into sucrose. It was reported that degradation of starch content results in synthesis of sucrose, other sugar represents postharvest transformation in climacteric fruit (Pinto *et al.,* 2004).

Conclusion

Tomato is an important cash crop with high nutritional value. Perishability of the tomato fruit gives rise to the need of evolving the techniques to enhance the shelf life. In markets tomatoes are sold at different maturity stages. Present study aimed to reveal the impact of $KMnO_4$ treated packaging on ripening at different concentrations and at different maturity stages of tomatoes. It was found that maturity stage and storage durations both are the important factors related with the post-harvest quality of tomato during marketing for consumer requirements. The obtained results indicated that indirect $KMnO_4$ treatment plays a very effective role in controlling some compositional changes in total sugars, reducing sugars, non-reducing sugars, acidity and pH of tomato stored at ambient condition for 12 days. With the progress of maturity and storage time decline in titrable acidity and an increase in pH content and sugars taken place, while the change in these contents were found to be retarded in treated samples significantly. $KMnO_4$ treated packaging material at concentration of 3g/L found to retard the ripening process most effectively. It was showed that physiological weight loss and decay was not as much affected with treatments. Total, reducing and non-reducing sugar showed an enhancement trend with the advancement of maturity without or with treatment. As evident that $KMnO_4$ treatment in packing material can be exploited in the extension of shelf life of tomatoes at different maturity stages that will aid to enhance the consumer acceptability and marketing.

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