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RESEARCH ARTICLE

Postharvest treatments and maturity stages impact sensory attributes and shelf life of tomato fruits var. Pearson kept in Zero Energy Cool Chamber

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ABSTRACT

The investigation has been carried out under ZECC conditions located at the research farm of agriculture faculty of Kabul University, Afghanistan. The objective was to understand the effect of postharvest treatments and harvesting stages on the shelf life and sensory quality of tomato fruits. It was found that both main factors had a significant effect and the highest shelf life noted for the fruits of H_1 (turning color stage) and D_1 (dipped in 6 % $CaCl_2$ solution) was 26.19 and 25.17 days, respectively. At the end of the storage period, the final evaluation average scores for overall sensory attributes of turning color fruits were higher whereas it was noted lower for light red color fruits compared with initial scores. The highest scores for all attributes such as color, flesh texture, flavor, and overall acceptance were noted for the fruits of H_1 and D_1 respectively. Thus, the turning color stage has seen as a suitable harvesting stage and then followed by pink color stage of the tomatoes of the Pearson variety that could be considered for various purposes after storage respectively. The 6 % $CaCl_2$ solution could increase tomatoes shelf life and maintain the quality that it had retained the fruits sensory attributes to an acceptable level.

Keywords: Pearson tomatoes; Harvesting stages; Postharvest treatments; ZECC, Sensory attributes and Shelf life.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the world's largest vegetable crop known as protective food due to its distinct nutritive value and widespread production.

Tomato is an important source of lycopene, which is a powerful antioxidant that acts as an anticarcinogen (Dandago et al., 2017). Tomatine reduces cholesterol and triglyceride levels in blood plasma, boosting body immunity against bacterial contaminations. Tomato is also a good source of various Vitamins (Pricedeep Singh, 2013; Dumas et al., 2003).

Among various vegetables, tomato is one of the important commercial crops of Afghanistan. It is the 4th most cultivated vegetable and the export of tomato fruits in the year 2020 reported 135,690 metric tons (NSIA n.d.).

Historically, the "Pearson" variety is most popular because of its good commercial value, its uniform globe shape, and medium to large size; its taste, flavor, and higher juice and pulp content. However, this variety is very sensitive to handling and thus has very short storage life. Pearson tomatoes at the full red stage has a maximum shelf life of about three to six days in Afghanistan (Agriculture Statistic Department, 2017).

Therefore, farmers face losses of tomato production mostly due to over ripe fruits and in the market consumers may not find acceptable fruits based on its eating and overall senosry quality. To extend the shelf life of tomatoes, reduce waste and maintain its quality, one should determine the proper harvesting stage and consider the postharvest management practices (Saraswathy et al., 2008).

Zero Energy Cool Chamber (ZECC) declines the temperature and raises the relative humidity for increasing the shelf life of fresh horticultural crops. Latent heat absorbs by the increased humidity and reduce it in the air inside storage Rayaguru et al. (2010) thus extend the

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shelf life and retain fruit quality having acceptable sensory characteristics. The shelf life of tomato under ZECC extended up to 29 days whereas it was up to a maximum of 7 days under ambient conditions (Islam and Morimoto, 2012; Hakimi et al., 2021). The quality maintained sensory characteristics and overall quality of fruits could be due to the suitable temperature and relative humidity of cooling technolgy (Wabali et al., 2017). Storage condition and $CaCl_2$ application as a postharvest treatments positively affect the shelf life and quality of fruits corroborating with (Haleema et al., 2020). Calcium chloride infiltration lead to enhance the shelf life of tomato and keep it with an acceptable quality (Senevirathna and Daundasekera, 2010).

Tomato fruits of the pink stage treated with 6 % $CaCl_2$ for 20 minutes retained their quality to the optimum level (Arthur et al., 2015). Hence tomato maturity is very crucial at the time of harvesting to avoide them from short storage life, quality and sensory attributes losses. Early maturity stage can help tomatoes for longest shelf life, uniform repining and thus to have good sensory quality (John et al., 2020; Sammi and Masud, 2007).

Also, the mint leaves' extract might have been a good substitute for chemicals due to its antimicrobial and antifungal activities (Al-Sum and Al-Arfaj, 2014; Moghaddam et al., 2013).

Inspite of the bove mentioned researches, the study of tomatoes sensory attributes of various maturity stages and their shelf life under ZECC may be a new investigation in Afghanistan and other developming countries and might have positive impacts on fruit quality treated with postharvest treatments. Hence, the tangible outcome and suitable treatment could be recommended to farmers. Considering the above statements, the objective of this study was to understand the impact of postharvest treatments and maturity stages on sensory attributes and shelf life of Pearson tomatoes kept in ZECC.

MATERIAL AND METHODS

The study has conducted for two years at the research farm of Agriculture Faculty, Kabul University, Kabul, Afghanistan, located at 34^0 52 N and 69^0 12 E with the elevation of 1810 meters above sea level and its climate is dry temperate with a common growing season from April to November (Hakimi et al., 2021).

Tomatoes production and postharvest management

The quality seeds of the Pearson variety were sowed for nursery production on the 9th and 11th of March 2018 and 2019 respectively. The seedlings were transplanted to the main field after 38 and 40 days from germination during two respective years. The tomato field was managed properly and best agricultural practices were considered for quality production.

The fruit color chart and the visual appearance of the tomato fruits helped researcher to find the right stage of tomato maturity. Tomatoes of three different maturity stages (Turning, Pink and Light red color) were harvested on the same day and followed by sorting, grading and precooling accordingly.

Zero energy cool chamber

Before tomatoes harvesting, the standard Pusa ZECC was established next to the tomato production field having a size of 165 x 115 x 67.5 cm^3 as reported by (lal Basediya et al., 2013).

During 29 days' storage, the two years average temperature decreased from 20.56 ^{0}C to 11.85 ^{0}C. Also, the two-year average relative humidity has increased from 25.68 % to the 95.64 % inside the ZECC recorded by a digital hygrometer. Furthermore, the average wind speed in the area of research was 4.86 (m/s) (POWER Data Access Viewer n.d.).

Experimental details

The experiment has conducted considering two factorial Completely Randomized Design (CRD). The study contains two factors as (harvesting stage x postharvest treatment) at three and eight levels respectively shown in Table 1.

The calcium chloride and mints have provided by the authorized company and the central market in Kabul respectively. Mints leaves' extraction used without adding reagents. The fruits were treated and dipped for 20 minutes of all 24 treatments.

Observation

The sensory attributes and shelf life data have been recorded.

Table 1: Factors' level and details

Factors	
Factor I - Harvesting stage (H)	H_1 - (Turning color stage)
	H_2 - (Pink color stage)
	H_3 - (Light red color stage)
Factor II - Postharvest treatment (D)	D_0 (Dip in distilled water)
	D_1 (Dip in 6% $CaCl_2$ solution)
	D_2 (Dip in 2% mint leaves' extract solution)
	D_3 (Dip in 4% mint leaves' extract solution)
	D_4 (Dip in 6% mint leaves' extract solution)
	D_5 (Dip in 6% $CaCl_2$+2% mint leaves' extract solution)
	D_6 (Dip in 6% $CaCl_2$+4% mint leaves' extract solution)
	D_7 (Dip in 6% $CaCl_2$+6% mint leaves' extract solution)

1. Shelf Life of tomato fruits (Days)

The shelf life of tomato fruits is observed daily till the fruits were healthy and acceptable for marketing Moneruzzaman et al. (2009).

2. Sensory evaluation

Nine-point Hedonic scale method as given by Amerine et al. (2013) was considered for conducting the sensory evaluation of fresh fruits before and after the storage period as initial and final observation. The sensory characteristics were evaluated by giving them score from 1 to 9 that defined tomato sensory quality from dislike extremely up to like extremely (Table 2).

The fruits were selected randomly from the bulk of each harvesting stage and subjected to initial sensory evaluation before to apply postharvest treatments. Similarly, for final sensory assessment, tomatoes selected from each experimental treatment at the end of storage life before to discard the fruits. For both initial and final evaluation, the same panel of 8 judges comprising of faculty members has been selected and considered to evaluate fruits' sensory attributes. The fruit color, flesh texture, flavor and overall acceptability have assessed. Each of the evaluator was used the above form for scoring the fruit quality based on their sensory judgment. The view of fruits for initial evaluation, session of initial evaluation, fruits of final evaluation, and session of final sensory evaluation are shown in Figs. 1-4 respectively.

Data analysis

The data is processed with the Microsoft Excel program. The Statistical Tool for Agricultural Research (STAR) program has used for two-way ANOVA analysis to see the effects of H (Harvesting Stage) and D (Post harvest treatment) on response variables. P-values are considered in the ANOVA Table. The Least Significant Difference (LSD) Test was used for comparing the least square means of two-way analysis of harvesting stages, postharvest treatments and also their interactions at $\alpha = 0.05$.

RESULT

Postharvest treatments and harvesting stages had a significant effect on shelf life and sensory attributes of tomatoes stored under low cost evaporative cooling technology.

Fig 1. Fruits of initial sensory evaluation.

Fig 2. Session of initial sensory evaluation.

Table 2: A sample of table of sensory evaluation of tomatoes **Evaluator name: ..... Date: / /**

Score	Liking	Tomato Sensory attributes				Code No
		Color	Flesh texture	Flavor	Overall acceptance	
9	Like extremely					101
8	Like very much					102
7	Like moderately					103
6	Like slightly					104
5	Neither like nor dislike					105
4	Dislike slightly					106
3	Dislike moderately					107
2	Dislike very much					108
1	Dislike extremely					109
						110
						111

Table 3: The harvesting stages, postharvest treatments and their interaction's impact on the shelf life of tomatoes

Factor	Year											
	2018				2019				Mean			
	H_1	H_2	H_3	Mean D	H_1	H_2	H_3	Mean D	H_1	H_2	H_3	Mean D
D_0	25.00	22.00	20.00	22.33^{c}	25.00	22.00	20.00	22.33^{c}	25.00	22.00	20.00	22.33^{c}
D_1	29.00	24.00	23.00	25.33^{a}	28.00	24.00	23.00	25.00^{a}	28.50	24.00	23.00	25.17^{a}
D_2	25.00	20.00	21.00	22.00^{c}	25.00	21.00	20.00	22.00^{c}	25.00	20.50	20.50	22.00^{c}
D_3	25.00	21.00	20.00	22.00^{c}	25.00	21.00	21.00	22.33^{c}	25.00	21.00	20.50	22.17^{c}
D_4	26.00	22.00	20.00	22.67^{c}	25.00	22.00	20.00	22.33^{c}	25.50	22.00	20.00	22.50^{c}
D_5	26.00	24.00	22.00	24.00^{b}	27.00	24.00	22.00	24.33^{ab}	26.50	24.00	22.00	24.17^{b}
D_6	27.00	23.00	23.00	24.33^{ab}	26.00	23.00	22.00	23.67^{b}	26.50	23.00	22.50	24.00^{b}
D_7	28.00	24.00	22.00	24.67^{ab}	27.00	23.00	23.00	24.33^{ab}	27.50	23.50	22.50	24.50^{ab}
Mean H	26.38^{a}	22.50^{b}	21.38^{c}		26.00^{a}	22.50^{b}	21.38^{c}		26.19^{a}	22.50^{b}	21.38^{c}	
Source of Variation	**P- Value**		**F-Test**	**SEM ±**	**P- Value**		**F-Test**	**SEM ±**	**P- Value**		**F-Test**	**SEM ±**
H	0.000		**	0.27	0.000		**	0.26	0.000		**	0.18
D	0.000		**	0.44	0.000		**	0.43	0.000		**	0.30
H x D	0.581		NS		0.967		NS		0.572		NS	
CV (%)	4.61				4.47				3.09			

(a) **and NS stand for highly significant and non-significant respectively.
(b) Not only in this table, the Mean of H and D factors are mentioned as Mean H and Mean D at the end of H values and right of H3 respectively

Table 4: The harvesting stages, postharvest treatments and their interaction's impact on the color of tomatoes

Factor	Year											
	2018				2019				Mean			
	H_1	H_2	H_3	Mea	H_1	H_2	H_3	Mean	H_1	H_2	H_3	Mean
D_0	7.38	7.13	6.25	6.92^{c}	7.63	7.00	7.00	7.21^{d}	7.50	7.06	6.63	7.06^{e}
D_1	8.50	8.13	8.13	8.25^{a}	8.75	8.25	8.00	8.33^{a}	8.63	8.19	8.06	8.29^{a}
D_2	7.13	7.13	6.75	7.00^{c}	7.75	7.50	6.88	7.38^{cd}	7.44	7.31	6.81	7.19^{e}
D_3	7.88	8.00	7.25	7.71^{b}	7.88	7.63	6.88	7.46^{cd}	7.88	7.81	7.06	7.58^{d}
D_4	8.13	7.88	7.63	7.88^{ab}	8.00	8.00	7.00	7.67^{bcd}	8.06	7.94	7.31	7.77^{cd}
D_5	8.25	7.88	7.75	7.96^{ab}	7.88	8.25	7.50	7.88^{abc}	8.06	8.06	7.63	7.92^{bc}
D_6	8.38	8.13	7.75	8.08^{ab}	8.13	7.88	8.00	8.00^{ab}	8.25	8.00	7.88	8.04^{abc}
D_7	8.38	8.25	8.00	8.21^{a}	8.25	8.25	8.13	8.21^{a}	8.31	8.25	8.06	8.21^{ab}
Mean	8.00^{a}	7.81^{a}	7.44^{b}		8.03^{a}	7.84^{a}	7.42^{b}		8.02^{a}	7.83^{a}	7.43^{b}	
Source of Variation	**P- Value**		**F-Test**	**SEM ±**	**P- Value**		**F-Test**	**SEM ±**	**P- Value**		**F-Test**	**SEM ±**
H	0.000		**	0.09	0.001		**	0.11	0.000		**	0.07
D	0.000		**	0.14	0.000		**	0.18	0.000		**	0.12
H x D	0.933		NS		0.808		NS		0.897		NS	
CV (%)	9.06				11.54				7.28			

(a) ** and NS stand for highly significant and non-significant respectively.
(b) The initial color (score) is 2018 (H1: 6.25, H2: 7.50, H3: 8.40), 2019 (H1: 6.60, H2: 7.50, H3: 8.50), Average (H1: 6.43, H2: 7.50, H3: 8.45).

1. Shelf life (Days)

The storage life of tomatoes is prolonged according to their harvesting stages and the effect of postharvest treatments. The data in the Table 3 reveal that the main effect of both factors was highly significant whereas the two-way interaction was non-significant during both years and with mean of two seasons. Hence considering each factor, the highest mean shelf life were 26.19 and 25.17 days recorded for fruits of the H_1 (turning color stage) and D_1 (dipped in 6 % $CaCl_2$ solution) respectively. However, the highest mean shelf life had known 28.5 days for fruits of the H_1 treated with D_1 but the difference is non-significant. The lowest mean shelf life were 21.38 and 22.00 days recorded for tomatoes of the H_3 (Light red color stage) and D_2 (dipped in 2 % mint leaves' extract solution) respectively.

2. Sensory attributes

Similarly the above said factors positively affected the sensory characteristics of tomatoes under the cool & humid environment discussed below individually.

Color

The Table 4 pinpointed that, the main effect of harvesting stages and postharvest treatments has illustrated highly significant for maintaining acceptable tomatoes' color

Fig 3. Fruits of final sensory evaluation.

Fig 4. Session of final sensory evaluation.

Table 5: The harvesting stages, postharvest treatments and their interaction's impact on the flesh texture of tomatoes

Factor	Year											
	2018				2019				Mean			
	H_1	H_2	H_3	Mean	H_1	H_2	H_3	Mean	H_1	H_2	H_3	Mean
D_0	7.13	6.75	6.25	6.71^{c}	7.25	7.00	7.63	7.29^{cd}	7.19	6.88	6.94	7.00^{de}
D_1	8.00	7.63	7.50	7.71^{a}	8.50	8.13	7.88	8.17^{a}	8.25	7.88	7.69	7.94^{a}
D_2	7.00	6.88	6.88	6.92^{c}	7.13	6.88	6.50	6.83^{d}	7.06	6.88	6.69	6.88^{e}
D_3	7.13	6.75	6.63	6.83^{c}	7.13	7.00	7.25	7.13^{cd}	7.13	6.88	6.94	6.98^{de}
D_4	7.25	7.00	6.88	7.04^{bc}	7.38	7.38	8.00	7.58^{bc}	7.31	7.19	7.44	7.31^{cd}
D_5	7.50	7.25	7.50	7.42^{ab}	8.00	7.25	7.13	7.46^{bc}	7.75	7.25	7.31	7.44^{bc}
D_6	8.13	7.75	7.25	7.71^{a}	8.25	8.00	7.75	8.00^{ab}	8.19	7.88	7.50	7.85^{a}
D_7	7.50	7.50	7.63	7.54^{a}	8.13	7.88	8.00	8.00^{ab}	7.81	7.69	7.81	7.77^{ab}
Mean H	7.45^{a}	7.19^{ab}	7.06^{b}		7.72	7.44	7.52		7.59^{a}	7.31^{b}	7.29^{b}	
Source of Variation	**P- Value**		**F-Test**	**SEM ±**	**P- Value**		**F-Test**	**SEM ±**	**P- Value**		**F-Test**	**SEM ±**
H	0.035		*	0.11	0.228		NS		0.026		*	0.09
D	0.000		**	0.18	0.000		**	0.19	0.000		**	0.14
H x D	0.969		NS		0.745		NS		0.978		NS	
CV (%)	11.94				12.59				9.23			

(a)*,**and NS stand for significant, highly significant and non-significant respectively.
(b) The initial flesh texture (score) is 2018 (H1: 6.63, H2: 6.63, H3: 7.88), 2019 (H1: 6.75, H2: 7.25, H3: 7.38), Average (H1: 6.69, H2: 7.44, H3: 7.63).

Table 6: The harvesting stages, postharvest treatments and their interaction's impact on the flavor of tomatoes

Factor	Year											
	2018				2019				Mean			
	H_1	H_2	H_3	Mean	H_1	H_2	H_3	Mean	H_1	H_2	H_3	Mean
D_0	6.88	6.50	6.38	6.58^{b}	6.88	6.75	6.63	6.75^{d}	6.88	6.63	6.50	6.67^{d}
D_1	8.13	7.88	7.63	7.88^{a}	8.25	8.13	7.75	8.04^{a}	8.19	8.00	7.69	7.96^{a}
D_2	7.00	6.50	6.25	6.58^{b}	7.00	6.88	6.63	6.83^{d}	7.00	6.69	6.44	6.71^{d}
D_3	6.88	6.75	6.25	6.63^{b}	6.88	7.00	6.50	6.79^{d}	6.88	6.88	6.38	6.71^{d}
D_4	7.13	7.13	6.63	6.96^{b}	7.25	7.00	7.13	7.13^{cd}	7.19	7.06	6.88	7.04^{c}
D_5	7.50	7.63	7.38	7.50^{a}	7.50	7.63	7.25	7.46^{bc}	7.50	7.63	7.31	7.48^{b}
D_6	8.00	7.63	7.50	7.71^{a}	8.38	7.75	7.50	7.88^{ab}	8.19	7.69	7.50	7.79a^{b}
D_7	7.63	7.88	7.50	7.67^{a}	8.13	8.00	7.75	7.96^{ab}	7.88	7.94	7.63	7.81^{a}
Mean	7.39^{a}	7.23^{a}	6.94^{b}		7.53^{a}	7.39^{ab}	7.14^{a}		7.46^{a}	7.31^{a}	7.04^{b}	
Source of Variation	**P- Value**		**F-Test**	**SEM ±**	**P- Value**		**F-Test**	**SEM ±**	**P- Value**		**F-Test**	**SEM ±**
H	0.004		**	0.10	0.047		*	0.11	0.000		**	0.07
D	0.000		**	0.16	0.000		**	0.18	0.000		**	0.12
H x D	0.990		NS		0.998		NS		0.986		NS	
CV (%)	10.61				12.20				7.86			

(a)*,**and NS stand for significant, highly significant and non-significant respectively.
(b) The initial flavor (score) is 2018 (H1: 6.00, H2: 7.38, H3: 8.00), 2019 (H1: 5.88, H2: 8.00, H3: 8.13), Average (H1: 5.94, H2: 7.69, H3: 8.07).

Table 7: The harvesting stages, postharvest treatments and their interaction's impact on the overall acceptance of tomatoes

Factor	Year											
	2018				2019				Mean			
	H_1	H_2	H_3	Mean D	H_1	H_2	H_3	Mean D	H_1	H_2	H_3	Mean D
D_0	7.13	6.88	6.50	6.83^{c}	7.25	7.00	6.50	6.92^{bc}	7.19	6.94	6.50	6.88^{d}
D_1	8.38	7.88	7.63	7.96^{a}	8.63	8.25	7.88	8.25^{a}	8.50	8.06	7.75	8.10^{a}
D_2	7.00	7.00	6.50	6.83^{c}	7.00	6.75	6.25	6.67^{c}	7.00	6.88	6.38	6.75^{d}
D_3	7.00	6.88	6.75	6.88^{c}	6.88	6.88	6.75	6.83^{bc}	6.94	6.88	6.75	6.85^{d}
D_4	7.13	7.00	7.13	7.08^{bc}	7.38	7.25	7.25	7.29^{b}	7.25	7.13	7.19	7.19^{cd}
D_5	7.38	7.25	7.25	7.29^{b}	8.25	7.75	7.38	7.79^{a}	7.81	7.50	7.31	7.54^{bc}
D_6	8.00	7.63	7.63	7.75^{a}	8.13	8.00	7.75	7.96^{a}	8.06	7.81	7.69	7.85^{ab}
D_7	8.13	7.88	7.50	7.83^{a}	8.38	8.25	7.88	8.17^{a}	8.25	8.06	7.69	8.00^{ab}
Mean H	7.52^{a}	7.30^{ab}	7.11^{b}		7.73^{a}	7.52^{a}	7.20^{b}		7.63^{a}	7.41^{b}	7.16^{c}	
Source of Variation	**P- Value**		**F-Test**	**SEM ±**	**P- Value**		**F-Test**	**SEM ±**	**P- Value**		**F-Test**	**SEM ±**
H	0.005		**	0.09	0.002		**	0.10	0.000		**	0.07
D	0.000		**	0.14	0.000		**	0.17	0.000		**	0.11
H x D	0.973		NS		0.995		NS		0.943		NS	
CV (%)	9.50				11.02				7.48			

(a)**and NS stand for highly significant and non-significant respectively.
(b) The initial overall acceptance (score) is 2018 (H1: 6.00, H2: 7.50, H3: 8.13), 2019 (H1: 6.25, H2: 7.88, H3: 8.13), Average (H1: 6.13, H2: 7.69, H3: 8.13).

but the effects of two ways interaction were noted non-significant in both seasons and mean values of two years. Accordingly, the highest mean values stated under H_1 and D_1 as 8.02 and 8.29 (scores) respectively. Moreover, the H_3 (Light red color stage) and D_0 (dipped in distilled water) showed the lowest color scores 7.43 and 7.06 respectively.

Flesh texture

The scores for the tomatoes' flesh texture in Table 5 revealed that the main effect of harvesting stages and postharvest treatments has been recorded significant and highly significant in 2018 and the mean values of both seasons but in the year 2019, the effect of harvesting stages and postharvest treatments stated non-significant and highly significant respectively. Though, the two ways interaction effects were non-significant in both seasons and mean values of two years. Hence, the highest mean scores listed for H_1 and D_1 as 7.59 and 7.94 respectively. While, the H_3 (light red color stage) and D_2 (dipped in 2 % mint leaves' extract solution) have gotten the lowermost scores as 7.29 and 6.88 respectively.

Flavor

In the year 2018 and also for mean data of two years, the flavor of tomatoes was affected highly significantly by both factors shown in Table 6. Whereas in 2019, it was obtained significant and highly significantly different for harvesting stages and postharvest treatments respectively. Still, the effect of two ways interaction was verified non-significant during two years and the mean values of both seasons. Thus, the H_1 and D_1 upheld the top scores for the tomatoes' flavor as 7.46 and 7.96 respectively. While, the 7.04 and 6.67 are the low scores saved for H_3 (light red color fruits) and D_0 (dipped in distilled water) respectively.

Overall acceptance

The main effect of harvesting stages and postharvest treatments showed highly significant for the overall acceptance of tomatoes during both seasons and the mean data of two years present in Table 7. While, the two ways interaction effects showed non-significant in both years and mean values of two seasons. With regard to the main effects, the 7.63 and 8.10 were noted as the highest scores under H_1 and D_1 respectively. Followed, the D_7 (dipped in 6 % $CaCl_2$ + 6 % mint leaves' extract solution) listed on par with D_1 (7.16). Although, the H_3 (Light red color) and D_2 (2 % mint leaves' extract solution) showed the 7.16 and 6.75 scores as the lowest respectively.

DISCUSSION

The harvesting stages and postharvest treatments have positively affected the storage life and overall postharvest quality of tomatoes that also reported by (Al and Naser, 2011; Dandago et al., 2017). The overall better quality of fruits might be because of low temperature and high relative humidity of ZECC corroborating (Haleema et al., 2020; Rayaguru et al., 2010).

1. Shelf life (Days)

The quality of retained fruits with enhanced shelf life might be due to harvesting tomatoes at earlier maturity stage as also said by (Parker and Maalekuu, 2013; John, et al., 2020). Fruits harvested at an earlier stage (turning color) could have longer shelf life due to low physiological activity compared to later stages under ZECC condition (Hakimi et al., 2020; Islam et al., 2013). Furthermore, the $CaCl_2$ application maintains fruits firmness and quality attributes,

and further enhancing shelf life, similar reported by (Arthur et al., 2015; Chepngeno et al., 2016; Senevirathna and Daundasekera, 2010). In general, decreasing temperature cause an increase in shelf life Tadesse et al. (2015) that provide with ZECC.

2. Sensory attributes

The quality retained fruits with a prolonged shelf life and acceptable sensory attributes might be due to early harvest fruits stored in an evaporative cooling technology Islam et al. (2013) and the chemical treatments might also support the tomatoes quality (Wabali et al., 2017).

Color

Compare to the initial data, the highest scores for fruits color might be due to the gradual and uniform ripening of early harvested fruits that continued their color enhancing up to the end of storage life as also reported (Sammi and Masud, 2007; Casierra-Posada and Aguilar-Avendaño, 2008). Besides, the application of $CaCl_2$ might have not allowed the fruits to get very dark color but maintained fruits with delay ripening, shiny red color and acceptable quality that the same supported by (Chacon et al., 2017; Sammi and Masud, 2007; Wabali et al., 2017). Moreover, the ZECC could have saved the attractive shiny color fruits through facilitating low and suitable temperature and high relative humidity that might have greatly affected fruits color and quality as the related idea said with (Hatami et al., 2013; Islam et al., 2013).

Flesh texture

The highest scores of tomato flesh texture might be due turning color stage and then followed by the pink color that is harvested early before full ripening. Such fruits could have been ripened slowly with low physiological activities and might not be lost the flesh texture and overall quality that similar reported (Sammi and Masud, 2007; Casierra-Posada and Aguilar-Avendaño, 2008). The $CaCl_2$ application might have maintained fruits firmly with good pericarp and free from a fungal infection that could have affected their texture and overall physiology as same ideas said with (Wabali et al., 2017; Pinheiro and Almeida, 2008). Also, the ZECC condition might have maintained fruits further good that saved their flesh texture and other organoleptic attributes (Brashlyanova et al., 2014; Wabali et al., 2017).

Flavor

The Aroma, Taste and Flavor of tomatoes are correlated with each other and overall quality. The highest scores for the fruits of turning color stage and then followed by pink color stage might be due to their harvesting at early maturity stages that could have kept them in low physiological activities, gradual repining, firm & and juicy with suitable nutritious quality as the similar reported with (Al and Naser, 2011; John et al., 2020; Sammi and Masud, 2007; Casierra-Posada and Aguilar-Avendaño, 2008). Such fruits may not ripen faster. The $CaCl_2$ related treatments could have been maintained the pericarp thickness, fruits firmness and suitable shelf life that might have resulted of acceptable aroma, taste and flavor (Gharezi et al., 2012; Haleema et al., 2020; Pinheiro and Almeida, 2008). Likewise, the fruits could have been retained much fresh inside the suitable cool and humid environment of ZECC. Under such conditions, fruits might have been kept with gradually physiological activities, no water loss, good juiciness, sourness, enough nutritional quality that all might have resulted tasty and flavored fruits till the end of storage as also been stated by (Maul et al., 2006; Godana et al., 2015; Islam and Morimoto, 2012; Tolasa et al., 2021; Tadesse et al., 2015).

Overall acceptance

The quality maintained tomatoes could have been positively evaluated and accepted through the panel. The maximum scores for the overall acceptance of the tomatoes could have been due to the quality retained and fresh fruits of early harvested stages with external freshness, internal quality, less water losses supported (Parker and Maalekuu, 2013; John et al., 2020; Moneruzzaman et al., 2009). Also, it might be due to the highly firm fruits through $CaCl_2$ penetration inside the pericarp that might also prevent them from any fungal infections as said by (Dandago et al., 2019; Senevirathna and Daundasekera, 2010; Sammi and Masud, 2007). The low temperature and high relative humidity of ZECC may surely affect the overall quality of tomato fruits. Since it retains fruit quality attributes and sensory characteristics as much better as possible through its action alongside both factors efficiency as reported by (Maul et al., 2006; Hatami et al., 2013; Islam et al., 2013).

CONCLUSION

To be concluded, the highest mean shelf life was recorded for the fruits in the turning color stage and those dipped in 6 % $CaCl_2$ solution respectively. Sensory attributes of tomatoes were noted better for fruits of turning color, then followed by pink color, and light red color stage respectively. The mint leaves extract solutions might not have been effective due to their low concentration. The ZECC was found as extremely effective evaporative cooling technology.

As recommendations, the turning color stage could be recommended as a suitable maturity stage for the tomatoes and then followed by the pink color stage that may have long shelf life and highest sensory and quality attributes. Moreover, the light red color fruits may be considered for immediate use. The 6 % $CaCl_2$ application could be

recommended for enhancing shelf life and quality retaining of tomatoes.

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Authors' contribution

Sayed Samiullah Hakimi conceptualized and designed the study, conducted the research, analyzed the data and written the complete article. Dr. Ravinder Raina and Dr. Yashpal Singh Saharawat contributed in the research design, setting and writing of methodology, data analysis and review of the whole article.

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