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Impact of Different Packaging Schemes and Transport Temperature on Post-Harvest Losses and Quality of Tomato (*Solanum lycopersicum* L.)

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ABSTRACT

In this study, two transport methods for tomato (room temperature and refrigerated transport) as well as post-harvest packaging treatments (thin polyethylene packaging bags, thick polyethylene packaging bags, use of 1%calcium chloride, use of absorbent paper in the box, and control) were examined at four stages of post-harvest consumer chain transport. These stages included: (1) Farm, after harvesting and putting in boxes, (2) Transport, after transferring products for wholesale and during discharging, (3) Wholesale, after discharging and when selling to local retailers usually 24-36 hours after harvesting time, and (4) Retail stores (2 days after harvesting time at most). The total acid level, vitamin C, and lycopene of the fruit differed across different farms, different transportation conditions, post-harvest treatments, and the four stages of product transport. The total percentage of unacceptable fruits was significant in post-harvest treatments and at different stages of transport. Among post-harvest treatments, packaging with high-density plastic and absorbent paper with 7.94 and 12.16% of weight loss, respectively, claimed the minimum and maximum physiological loss in fruit weight. The minimum post-harvest loss (4.21 percent) was related to high-density plastic packaging.

Keywords: Calcium chloride, Customer acceptability, Lycopene, Unmarketable fruits.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops containing vitamins A and C, micronutrients, and antioxidants. It is known as a product with a high nutritional value and is widely used in the food industry (Kaveh *et al.*, 2013). Research shows that a major post-harvest loss of this valuable product occurs at four stages including production (farm), transport to wholesale, the wholesale, and retail (Yeole and Curran, 2016). The major loss occurring in the farm is due to mechanical damages during harvesting and packaging. Untimely harvesting with regards to physiological maturity can increase the severity of the damage. Also, injured and poor quality products that are not removed due to failure in sorting can damage healthy products through fungal and bacterial contamination as well as the increased production of ethylene (Arah *et al.*, 2015). After harvesting, products are usually placed in large boxes and, due to extreme heat and through increased metabolic activity, tissue softness and sensitivity to transport would result. Use of treatments such as pre-cooling or transport systems involving cooling equipment can mitigate the damage. The optimum temperature for the product harvest is 20°C (Akbudak *et al.*, 2012). In the harvest season, temperature reaches about 32 to 35°C. Various treatments have been used to enhance the storage life of tomato. Such treatments include: (a) Use of packaging

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systems that reduce ethylene production; (b) Use of absorbent systems that absorb ethylene and humidity; and (c) Use of substances, which increase the tissue firmness, reduce ethylene production, and enhance the fruit resistance such as calcium chloride (Coolong *et al.*, 2014; Fagundes *et al.*, 2015; Domínguez *et al.*, 2016).

Therefore, the present study aimed to investigate the causes and the amount of losses in tomato during post-harvest, packaging, and transport to markets nearby. In addition, it sought to find ways to decrease the losses. Once the losses decreased, it is possible to achieve a more marketable product. Also, through maintaining the current production level, without increasing the area under cultivation, or utilizing pesticides and fertilizers, the added value of the total production of tomato can be elevated.

The treatments in the experiments were designed to maintain fruit firmness and quality, and to reduce metabolism rate, ethylene generation, and accumulation inside the fruit during transport. Refrigerated transport, packaging with polyethylene films, calcium chloride solution, and absorbent papers are ordinary methods of different fresh produce delivery systems.

MATERIALS AND METHODS

In this experiment, we used "*Urbana*" tomato cultivar produced with almost the same production conditions in four farms near Mashhad, Khorasan Razavi, Iran. For this purpose, tomato was harvested at a similar stage of maturity (light red stage) in each farm and received the designed treatments.

Experimental Treatments

The experiment involved four tomato farms around Mashhad (block), two methods of transport (factor A), and five post-harvest treatments (factor B), including:

Transport Conditions (A)

Transport at ambient temperature (25-35°C) and transport under refrigerated conditions (6 to 10°C).

Post-Harvest Treatments (B)

These treatments included Low-density (thin) polyethylene packaging (B1) or LDPE which is a flexible, translucent, weatherproof polyethylene with low water absorption and density of 0.91 $g.cm^{-3}$; high-density (thick) polyethylene packaging (B2) or HDPE which is a flexible, translucent/waxy, and weatherproof with low water absorption and density of 0.941 $g.cm^{-3}$ or higher; absorbent paper in the box (B_3); calcium chloride 1% (B_4), and control;, used as a factorial experiment based on a randomized complete block design. To apply treatments B_1 and B_2, the tomatoes of two fruit boxes (randomly selected from among harvested fruit boxes of each farm) were packaged by thin polyethylene and two fruit boxes by thick polyethylene. In addition, three holes were made in the packages. A pair of fruits was put in each polyethylene package. The mouth of the film bags was not closed air-tightly. In treatment B_3, an absorbent paper (which was made exactly from materials similar to newsprint paper) was placed between each row of fruits in two fruit boxes, which had been randomly selected. In treatment (B_4), two fruit boxes were placed in a tank containing 1% calcium chloride solution for 5 minutes. In the control, fruits were transported to the market without any post-harvest treatments under both ambient and refrigerated conditions.

Sampling and Measurements

Sampling of harvested products was conducted at four stages of consumer supply chain. These stages were: (1) Once harvested, placing the product in the box

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before loading, (2) Transportation (after transferring the product to the wholesale and during discharging), (3) The wholesale (after discharging, and at the time of selling to local retailers, 24 to 36 hours after harvest), and (4) At a retail store (at most 2 days after harvesting). At each stage, 40 boxes were examined and measured from each farm.

The physiological loss in weight calculated by using Equation (1):

Physiological loss in weight= $[(W_i - W_t)\times W_i^{-1}]\times 100$ (1)

Where, W_i is the initial Weight of fruit and W_t represents the Weight of fruit at the time of sampling.

The pH of the fruit juice was measured using a benchtop pH meter (HI221-HANNA Instruments). The soluble solid content was measured by master-A refractometer (ATAGO- Japan). Total acidity was measured by titration method using phenolphthalein and NaOH 0.2N solution (Boggala *et al.*, 2015).

Lycopene was measured by the spectrophotometric method according to Pataro *et al.* (2015) with some modifications. Two grams of the homogenized sample, 5 mL 0.05% solution (w/v) of butylated hydroxytoluene, 5 mL of 95% ethanol, and 10 mL of hexane were poured into a vial and put in an ice bath. Then, it was stirred for 15 minutes whereby a smooth mixture was made. Then, 3 mL of deionized water was added to the solution and stirred again for 5 minutes. The samples were kept at room temperature for 5 minutes and after separating different phases, the light absorption of hexane phase (upper part of the solution) and hexane solution with no sample was measured by T80 UV/VIS Spectrophotometer (PG Instruments Ltd.) at 503 nm.

Lycopene Content (mg kg^{-1} fresh weight): $(A_{503}\times 537\times 20\times 0.55)/(W\times 172)$ (2)

Where, 537 g mol^{-1} is the molecular weight of lycopene, 20 is the volume of mixed solvent, 0.55 shows the volume ratio of the upper layer to the mixed solvents, 172 mM^{-1} denotes the molecular extinction coefficient of lycopene in hexane solution, and W is the exact tissue weight (kg).

Organoleptic characteristics were examined according to flavor, color, tissue, and general acceptance (consumer acceptance) of the product. The products were ranked using 9-point hedonic test for each sample by 10 referees. Point 9 is the most popular while point 1 represents the least popularity (Kong *et al.*, 2016).

Post-Harvest Loss

For each sample, 10 boxes were randomly selected. Then, after weighing each box, non-marketable fruits (including the damaged and infected fruits during harvesting and post-harvest) were separated, weighed, and returned to their box. Since post-harvest loss is cumulative, to obtain the loss rate at each stage, the percentage of unmarketable fruits' weight at each stage was subtracted from the average number of the previous step. For example, when the loss percentage during transportation was 17.6% and loss percentage at farm was 9%, the percentage of actual loss during transport would be 17.6–9 = 8.6%.

The Amount of Unmarketable Fruit

Fruit rot because of different pathogenic activities as well as physical and physiological imperfections such as spot, abrasion, bruise, wound, deformation, scar, and damages caused by pressure and mechanical injuries were visually evaluated. Unmarketable fruits at every stage were divided into four categories as unhealthy, deformed, imperfect, and damaged ones. Also, their percentages were separately calculated relative to the total amount of unmarketable fruits. Next, immature and green fruits and those with original defects not due to post-harvest transition and transportation were also measured, with the result being subtracted from total unmarketable fruits. The amount of

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unmarketable fruit was calculated in terms of percentage based on the number of unacceptable fruits compared to the total number of those inside the box.

Statistical Analysis

Data were statistically analyzed through SAS-JMP software. The means were also compared by conducting Tukey-HSD test at a 5% probability level.

RESULTS AND DISCUSSION

Analysis of the data revealed that physiological loss in weight, soluble solid content, customer acceptability, and total percentage of post-harvest loss were significantly affected by the applied packaging treatments, different stages of consumer product supply chain, and transporting conditions. The total value of acid, vitamin C, and lycopene also differed significantly across products of different farms, different transporting conditions, post-harvest treatments, and 4 stages of product transfer to the market. The total percentage of unmarketable fruits was significant in post-harvest treatments and at different stages of products transfer to the market. The percentage of infected and unhealthy fruits was also influenced by transporting conditions, post-harvest treatment, and product marketing stages. In deformed, damaged, and immature fruits, the farm and stages of transfer to the market had significant effects, indicating that the product quality differed among different farms. Also, since it is the first stage of product delivery to the market, the difference between stages of consumer supply chain was significant (Table 1).

Among post-harvest treatments, packaging with HDPE and absorbent paper with 7.94 and 12.16% of weight loss accounted for the minimum and maximum physiological loss, respectively. HDPE had the minimum post-harvest loss (4.21%) (Table 2).

In general, the greatest weight loss in response to physiologic loss was observed in the control treatment and normal conditions of transportation (57.02%), most of which occurred in retail stores. Packaging with thin and thick polyethylene, regardless of transporting conditions, was more effective than other treatments. With 42.65 and 35.73% reductions, respectively, these two treatments had a better efficiency than treatments including absorbent material, calcium chloride, and control with 44.26, 44.21, and 51.26% reductions, respectively, in low temperature transportation, and even under transporting conditions at room temperature. Having compared postharvest treatment, those in refrigerator-temperature condition were more efficient (4.36-6.10%) than the treatments in room-temperature condition, in preventing the physiological weight loss (Figure 1).

Also, research has documented that packaging with polyethylene bags could effectively prevent fruit weight loss (Akbudak and Akbudak, 2007; Fagundes *et al.*, 2015). A part of the reduction is related to preventing moisture loss, while other losses are associated with increased concentration of carbon dioxide inside the package and reduced respiratory rate. Post-harvest storage of tomato at 5°C enhanced its marketability, increased its storage life, and decreased physiological loss in weight (Fagundes *et al.*, 2015). In another study, tomato storage was examined at 25, 12, and 5°C. The results showed that an increase in storage temperature caused a sharp reduction in weight compared to lower temperature storage (Javanmardi and Kubota, 2006). Therefore, storage at higher temperature is not recommended since it can lead to a high weight loss. Although tomato storage at low temperature increases the risk of chilling damage, it has beneficial effects. Cold tolerance depends on the ripeness of the harvested product and storage duration (Tadesse and Abtew, 2015).

The results of the study indicated that total acidity differed among different treatments and was higher at low temperature. No significant difference was observed between different stages of consumer supply chain

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Table 1. Mean square of the studied traits during postharvest storage of tomato.[a]

Source of Variance	df	Physiological loss in weight	pH	Soluble solid content	Total acidity	Ascorbic acid	Lycopene	Marketability	Postharvest loss	Unmarketable fruits (%)	Defected Fruits (%)	Deformed Fruits (%)	Injured fruits (%)	Unripe fruits (%)
Field (Block)	3	0.084**	0.005**	0.212**	0.0027063**	0.0027304**	0.264940**	0.351**	0.544**	0.008	0.025	0.111**	0.518**	0.408**
Transport condition (A)	1	136.115**	0.104**	0.150**	0.0127146**	0.0128343**	8.201566**	19.527**	66.049**	0.293	0.808**	0.008	0.375*	0.027
Postharvest treatments (B)	4	160.046**	0.058**	0.314**	0.0294526**	0.0297391**	2.051912**	12.328**	40.123**	1.701*	1.653**	0.003	0.167*	0.012
Consumer Chain Transport (C)	3	3776.015**	0.073**	11.407**	0.0001750**	0.0001760**	0.017052**	25.589**	1047.569**	1246.019**	64.709**	71.369**	7.516**	259.081**
AB	4	2.648**	0.012**	0.004**	0.0001536**	0.0001560**	0.618564**	0.081**	0.747**	0.0004	0.003	0.003	0.02	0.012
BC	12	23.314**	0.003*	0.029**	0.0000002	0.0000002	0.000007	1.886**	5.947**	2.209**	0.315**	0.003	1.203**	0.012
AC	3	21.168**	0.0001	0.018**	0.0000003	0.0000003	0.000006	2.165**	10.347**	0.224	0.04	0.008	0.115	0.027
ABC	12	2.451**	0.001	0.009**	0.0000001	0.0000001	0.000019	0.074**	0.685**	0.204	0.024	0.003	0.046	0.012
Error	117	0.016	0.001	0.00005	0.0000002	0.0000002	0.000026	0.001	0.068	0.394	0.038	0.009	0.044	0.031

[a] * and **: Significant at P≤ 5% and P≤ 1%, respectively in F test.

Table 2. Effects of postharvest treatments on studied traits.[a]

Postharvest treatment [b]	Unripe fruits (%)	Injured fruits (%)	Deformed fruits (%)	Defected fruits (%)	Unmarketable fruits (%)	Postharvest loss	Marketability	Lycopene (mg 100 g^{-1} fresh fruit)	C vit (mg 100 g^{-1} fresh fruit)	TA (mg acid per 100 gr fresh juice)	SSC	pH	Physiological loss in weight
Absorbent paper	1.28[a]	1.19[b]	0.67[a]	1.23[b]	4.38[ab]	5.73[b]	7.23[c]	5.37[d]	0.54[d]	0.53[d]	4.88[b]	3.96[c]	12.16[b]
$CaCl_2$	1.28[a]	1.31[ab]	0.67[a]	1.11[bc]	4.38[ab]	5.69[b]	6.68[d]	5.16[e]	0.59[a]	0.59[a]	4.82[d]	4.07[a]	11.60[c]
Control	1.28[a]	1.23[ab]	0.67[a]	1.49[a]	4.68[a]	7.33[a]	6.23 [b]	5.42[c]	0.52[e]	0.51[e]	5.03[a]	4.05[a]	13.54[a]
HDPE[1]	1.24[a]	1.22[ab]	0.65[a]	0.92[d]	4.03[b]	4.22[d]	7.79[a]	5.63[b]	0.58[b]	0.57[b]	4.77[e]	4.00[b]	7.94[e]
LDPE[2]	1.28[a]	1.37[a]	0.67[a]	0.98[cd]	4.30[ab]	5.31[c]	7.45[e]	5.83[a]	0.56[c]	0.56[c]	4.85[c]	4.02[b]	9.40[d]

[a] Means with different letters are significantly different P≤ 5% (Tukey HSD) at each column.

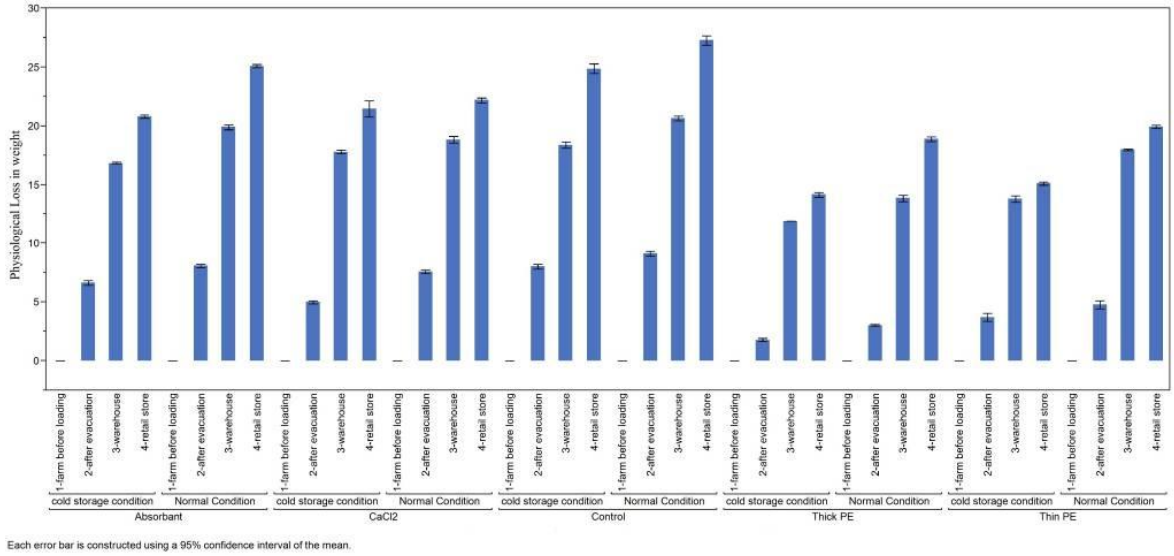

Figure 1. Effect of postharvest treatments, transportation temperature and four stages of Consumer Chain Transport on physiological loss in weight.

and total acidity (Figure 2). The significantly minimum amount of fruit total acidity was observed in calcium chloride treatment, followed by absorbent paper, thin and thick polyethylene packages without any significant difference (Figure 2).

It has been reported that the total acidity of tomato is significantly affected by the storage temperature. At higher storage temperature, the respiration rate is higher than that at low temperature and due to lower respiration and ripening rate, the highest titratable acidity occurs at temperature close to chilling injury (Tadesse and Abtew, 2015). In the present study, it was also found that both the temperature and type of packaging could partially change the total acidity. These changes are probably due to variations in respiration rate and enzyme activities. In the process of respiration, organic acid is used as a substrate whose values decrease (Saliba-Colombani *et al.*, 2001). Therefore, all factors that reduce cellular respiration and catabolism prevent decomposition and reduction of organic acid in the product.

Soluble Solid Content (SSC) was higher at the two last stages of sampling. No significant difference was found between the two transporting methods. At each stage of consumer chain transport, the control had the highest soluble solid content, followed by absorbent material, packaging with thin, thick polyethylene bags, and calcium chloride, respectively (Figure 3). Sugar content of tomato differs in different cultivars, which are genetically different, and relates to the fruit metabolic activities and their genetic controlling processes (Mounet *et al.*, 2009; Beckles, 2012). Increased respiration rate and ethylene production 40 days after flowering, will accelerate the decomposition of starch and, hence, change sugar content in the form of glucose and fructose (Luengwilai and Beckles, 2009). The increase in ethylene production and respiration, which happens during post-harvest in climacteric products, changes sugar decomposition. Application of appropriate methods that reduce respiration and/or ethylene production effectively (storage temperature, packaging and etc.) can help maintain sugar content and its marketability. However, in varieties with high starch storage, as respiration grows, SSC content would increase, while tissue firmness, taste, and marketability of the product may diminish.

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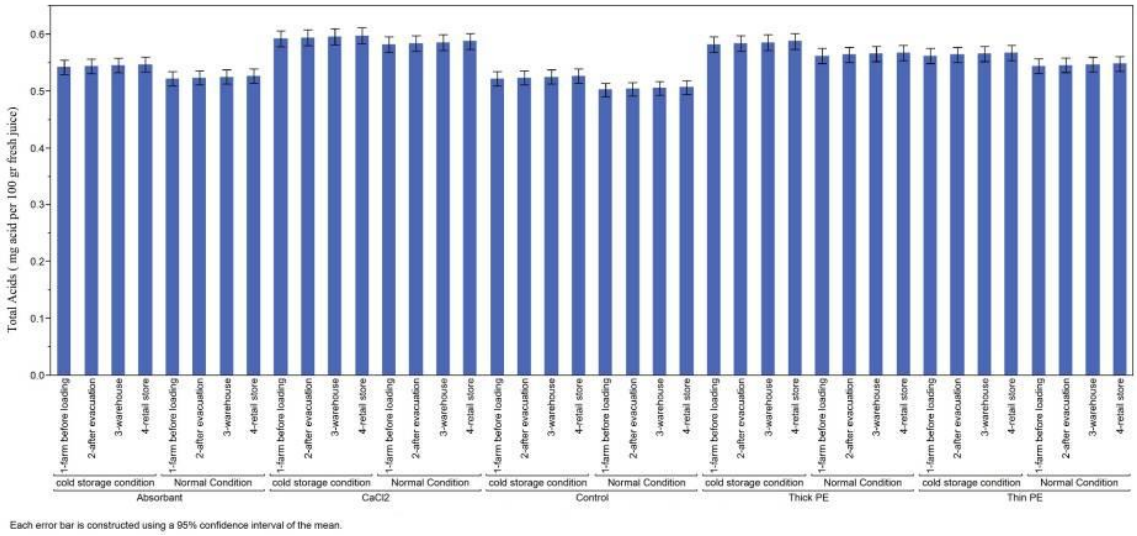

Figure 2. Effect of postharvest treatments, transportation temperature and four stages of Consumer Chain Transport on fruit total acidity.

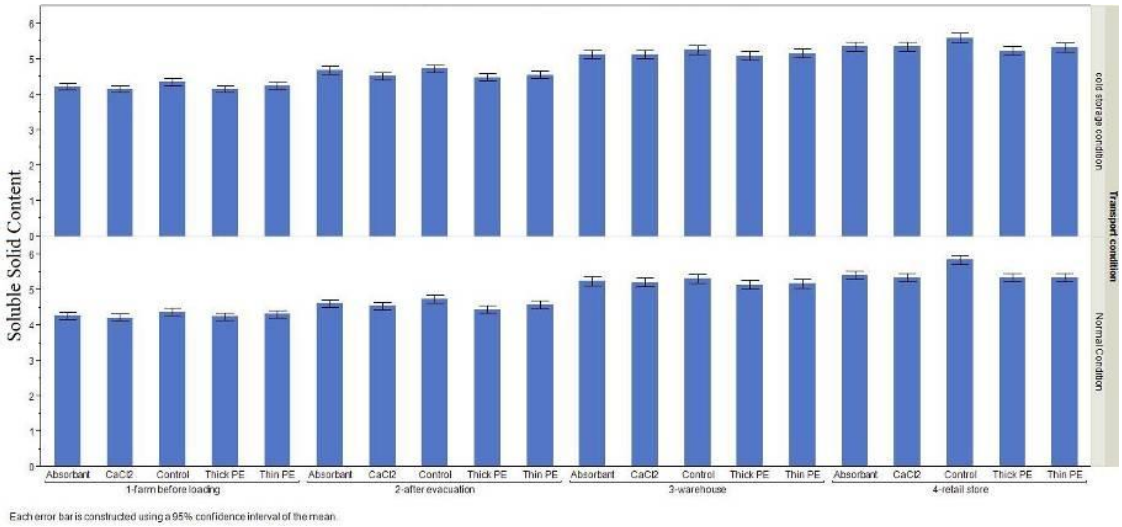

Figure 3. Effect of postharvest treatments, transportation temperature and four stages of Consumer Chain Transport on Soluble Solid Content.

One study in Nigeria showed that as mechanical damage increased, SSC declined compared to healthy fruits (Beckles, 2012). In another study, Prudent *et al*. (2009) stated that injuries with increased starch decomposition because of ameliorated enzyme activity increases TSS (Prudent *et al.*, 2009). The results of the present study showed that calcium chloride treatment, which increases tissue firmness and reduces ethylene production, had less SSC compared to other treatments. As discovered previously, calcium in the cell wall reduces ethylene activity by its inhibiting mechanism, thereby reducing respiration and decomposition of complex sugars into simple ones (Chepngeno *et al.*, 2016).

In addition to increasing produce marketability, lycopene has also a significant effect on improving nutritional properties and nutritional value of the product. As the most important pigment in tomato, it provides a good measure of color quality and nutritional value. The results revealed that fruits transported at ambient temperature (25-35ºC) were better in color. Differences in various stages of consumer supply chain for lycopene were not significant in any of the studied treatments. Thin and thick polyethylene packaging bags and the control transported at ambient

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temperature (25-35ºC) had a higher lycopene content compared to other treatments (Figure 4).

Research has shown that tomato storage at a lower temperature can lead to delayed ripeness and less lycopene accumulation. Tomato storage at 7 and 12ºC had a lower lycopene content compared to storage at room temperature (Javanmardi and Kubota, 2006). Since the maximum production and lycopene accumulation happen at 16 to 21ºC, reduction of storage temperature decreases the synthesis of lycopene (Türk *et al.*, 1993). Clearly, such changes in lycopene content occur in products that are harvested at green or pink stages. They need higher temperature treatments for increasing the synthesis of lycopene. Red ripe stage harvest reduces the effect of storage temperature and post-harvest treatments on the synthesis of pigments. Accordingly, post-harvest treatments that help to preserve lycopene and prevent decomposition of pigments will enjoy a higher priority.

A study on using calcium chloride with concentrations of 0, 2, and 3% during the period of tomato post-harvest revealed that the control had the best lycopene content (Mujtaba and Masud, 2014), which is in line with the finding of the present study. The effect of calcium chloride is likely related to prevention of ethylene activity and reduction of chlorophyll decomposition, resulting in less lycopene accumulation (Gharezi *et al.*, 2012).

For fresh tomato, quality is a combination of external factors (size, color, and shape of the fruit) and internal factors. Internal factors can be divided into organoleptic properties and nutritive quality of the fruit. Organoleptic quality depends on taste (sweetness, acidity, etc.), smell, fragrances and tactile aspects (firmness, tissue, etc.). Generally, taste depends on the amount of organic acid and reducing sugar. Reducing sugars constitute 50% of the dry weight while organic acids account for more than 10% of the dry weight of the fruit. Four hundred volatile components are known in tomato. Thirty components are responsible for the fresh fruit aroma. Some researchers have recommended measuring the brix, pH, and titratable acidity in order to determine chemical properties of each of non-volatile compounds associated with taste (Matsukura, 2016).

Marketability in this study was measured by 9-point hedonic test. From the perspective of referees, the highest score in terms of the quality and marketability was

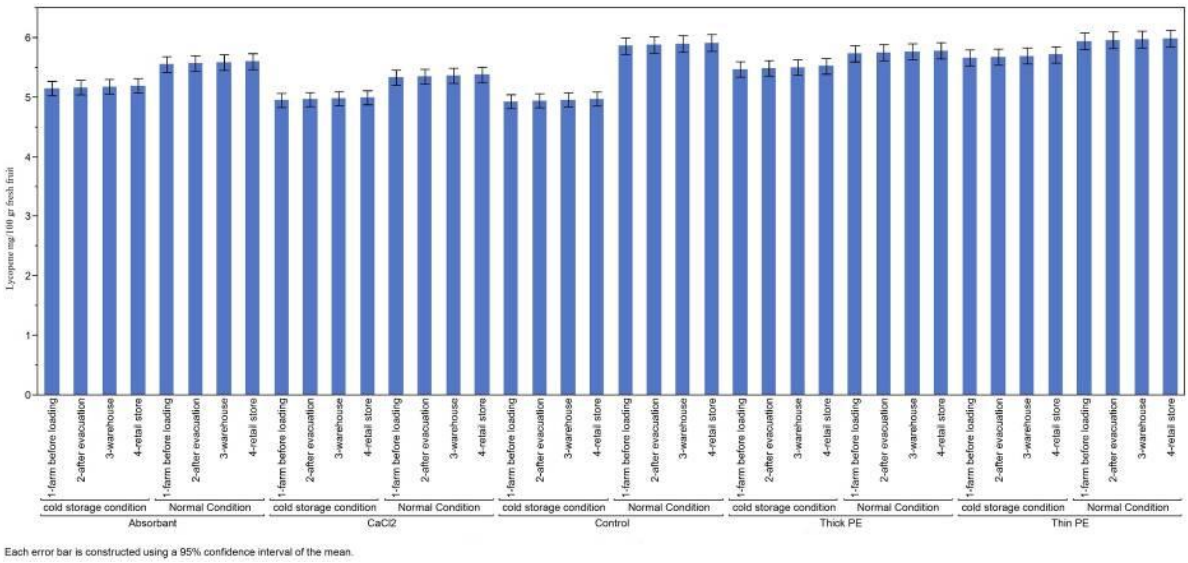

Figure 4. Effect of postharvest treatments, transportation temperature and four stages of Consumer Chain Transport on lycopene content.

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given to products packaged in thick polyethylene bags. The transporting method had an effect on marketability (Figure 5). Low temperature treatment in transportation had greater marketability, which was seemingly due to better tissue firmness. Marketability differed at four stages of consumer supply chain. The minimum amount of marketability was associated with retailer store.

Fruit maturity stage at harvest affects the quality of the product's flavor. Over-ripening can reduce the fruit marketability properties and its commercial value. It is possible to control its changes via different post-harvest treatments such as ethylene production controller, temperature, and packaging (Daş *et al.*, 2006). Also, some appropriate treatments can be used to reduce mechanical damage as well as microbial and fungal infection in order to maintain marketability properties of the product at a proper level and to enhance its storage life. Based on previously conducted studies, initial cooling treatment, separating damaged and infected products at the beginning of the product provision cycle (sorting), and using packaging or special storage will improve tomato product quality during post-harvest time through reducing ethylene production (Suslow and Cantwell, 2009).

The highest percentage of the product loss at a certain stage of consumer supply chain was related to retail store. In the second, third, and fourth stages of products delivery to the market, all post-harvest treatments were able to reduce loss rate at 5% level. Among post-harvest treatments, the most significant efficiency was related to thick polyethylene packaging bags with a total of 14.45% (transportation at low temperature) and 19.27% (transportation at room temperature) of loss during the four stages of consumer supply chain. In transportation at low temperature, these polyethylene packaging bags and absorbent paper (19.57% and 19.77%, respectively) were the third and fourth treatments in this regard. Transportation at low temperature had less loss. Even in the control, which had the maximum loss, a difference was found between transportation at low and at room temperatures (26.17 and 32.50%, respectively, Figure 6). Mechanical damage and bruise occur before, during, and after harvest, which reduce the product quality. In industrial production, tomato is harvested mechanically at green stage, packaged after washing and sorting, and transferred to remote markets. At each stage of

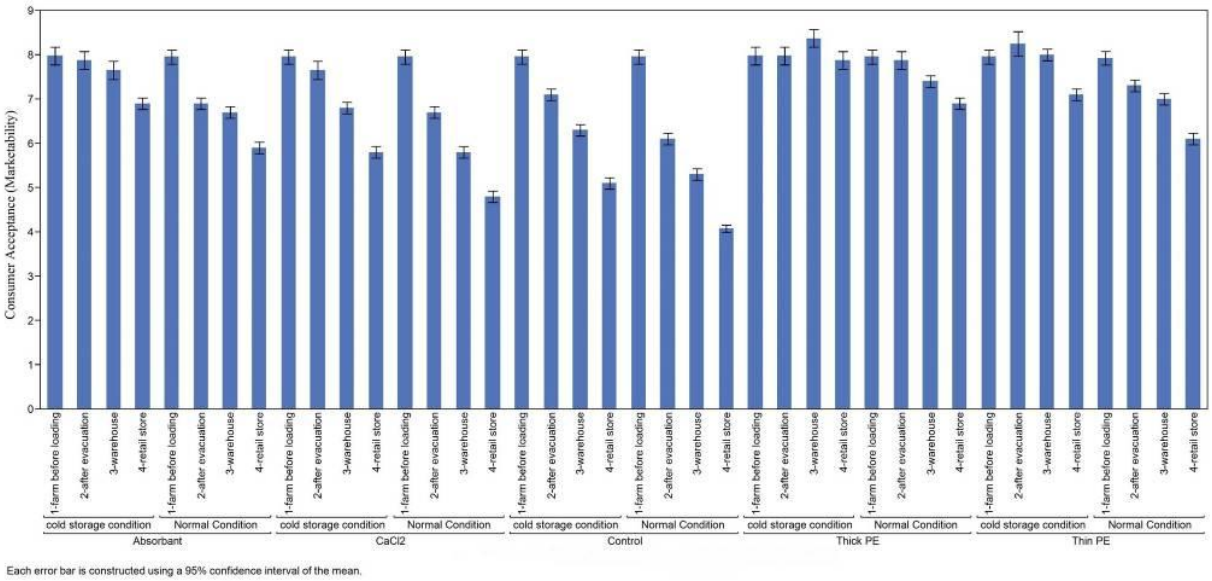

Figure 5. Effect of postharvest treatments, transportation temperature and four stages of Consumer Chain Transport on consumer acceptance.

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transportation and preparation, there is a probability of cut, damage, abrasion, and scar on the fruit. These injuries are cumulative and their number would increase at different stages (Miller *et al.*, 2003; Beckles, 2012). The injuries result in cells mucus and unwanted chemical reactions, increased evaporation and respiration, and more production of ethylene and pathogen infection.

As seen in Figure 7, the maximum amount of unmarketable and undesirable fruit was related to the first stage of product delivery to the market. However, due to lack of fruit sorting, undesirable fruits are transported to the market and, as a result, the cost of product delivery to the target market increases. In addition, infection can spread from damaged fruits to other ones, thereby intensifying the loss rate.

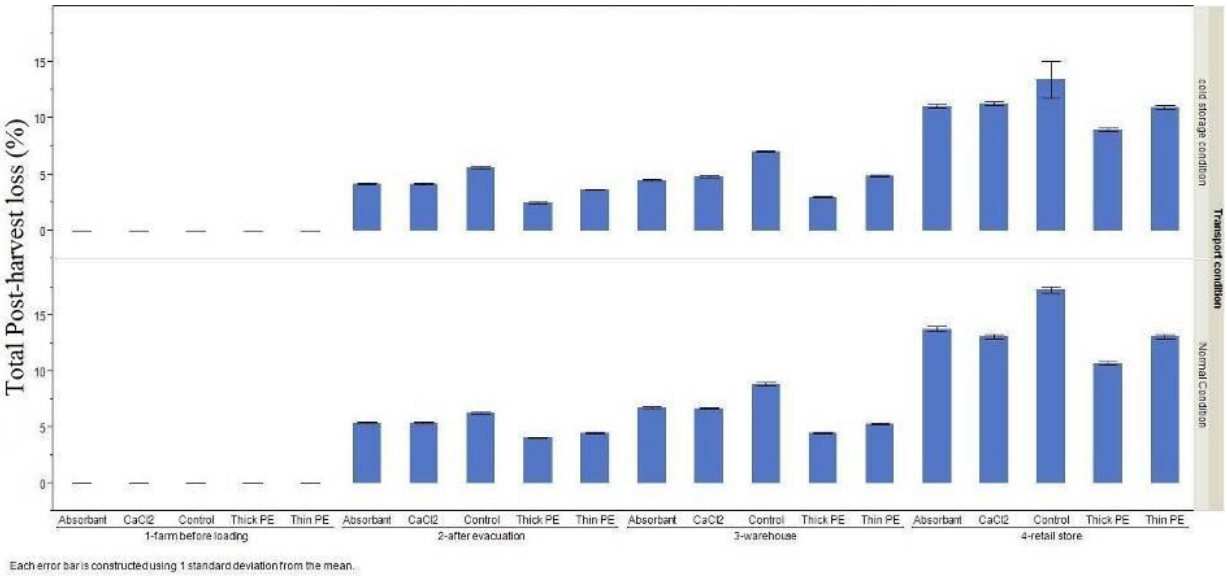

Figure 6. Effect of postharvest treatments, transportation temperature and four stages of Consumer Chain Transport on postharvest loss.

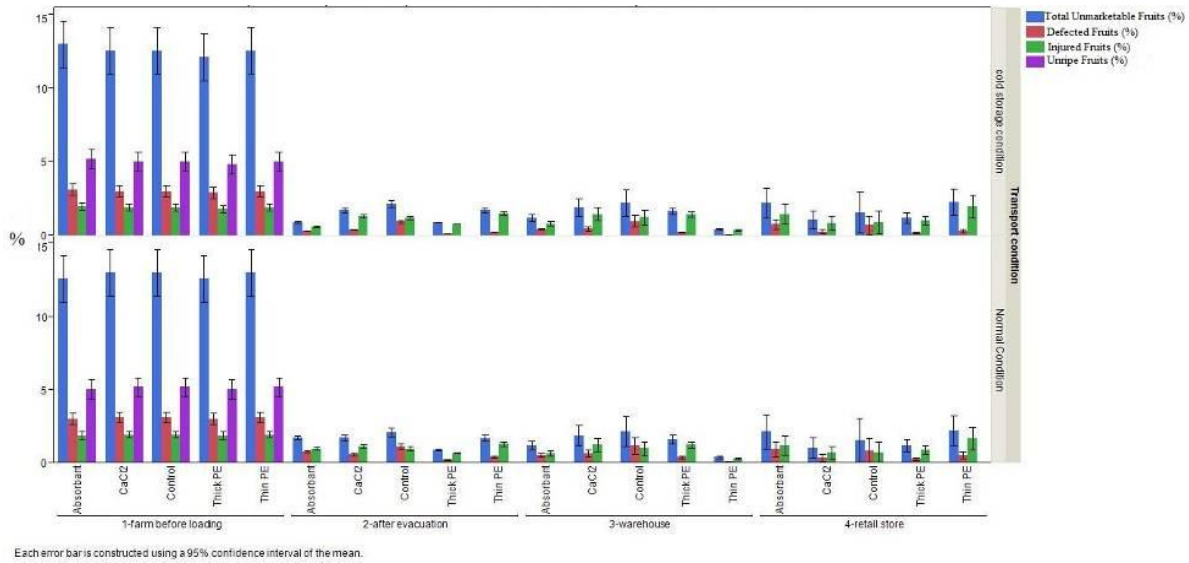

Figure 7. Effect of postharvest treatments, transportation temperature and four stages of Consumer Chain Transport on unmarketable fruits.

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Post-harvest infection spread was appropriately controlled in packaging with both thin and thick polyethylene films. Also, transporting products in the low temperature treatment prevent damages caused by bacteria and fungi through reducing oxidant and enzymatic activities in the fruit flesh (Figure 7). Investigations of Mondal *et al*. (2003) shows that storage of tomato fruits at higher temperatures causes sever oxidative damages to membrane (Mondal *et al.*, 2003). This kind of membrane deterioration makes fruit more susceptible to bacterial or fungal infections. Therefore, handling and storage at lower temperatures, except those that increase chilling injury, would be beneficial in extending shelf life of tomato fruits.

Transportation methods and post-harvest treatments had no effect on fruit deformity. It was at its maximum level in the first stage of consumer supply chain (Figure 7).

Increase in the percentage of damaged fruits in boxes was affected by transportation temperature. At lower transportation temperatures, significantly fewer damages occurred due to reduced activity of the enzyme, poly-galacturonase, and increased firmness and resistance of the tissue. Calcium chloride was the best treatment that reduced post-harvest damage, followed by thick polyethylene packaging bags. Mechanical damage at the second, third, and fourth stages of consumer supply chain played the most important role in increasing the number of undesirable fruits, whose control plays a significant role in reducing the product loss (Figure 7).

Unripe fruit percentage is related to the first stage of consumer supply chain (Figure 7). In cumulative determination of unripe fruits during post-harvest at room temperature, the number of immature fruits was reduced, though the change was not significant and the products could not obtain a desirable marketability level. Separating unripe fruits and performing special temperature-based treatments plus ethylene treatment in the consumer supply chain increased the product quality and price, while the percentage of unmarketable fruit decreased.

CONCLUSIONS

The results of this study suggested that, regardless of transportation temperature, packaging with polyethylene film had a positive and significant effect on the quantitative and qualitative properties of the product. Therefore, packaging fruits with thick polyethylene bags was the most effective post-harvest treatment associated with better marketability and lower post-harvest loss. Although transportation at low temperatures is costly, mechanical damage can be lessened and the product durability during post-harvest can be improved through reducing weight loss of the product by about 10% and enhancing the product resistance by improving the tissue firmness.

Application of refrigerated handling, or through a proper packaging practice like absorbent-paper and LDPE, could prevent additional costs for retailers, and decrease the capital loss by providing uniform products in terms of appearance and taste and greater consumer acceptance.

In future studies, the effect of sorting, classification, and separation of unripe, damaged, and infected products should be studied as a practical and low-cost measure at the harvesting time.

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بررسی اثر تیمارهای مختلف بسته بندی و دمای حمل و نقل بر تلفات پس از برداشت و کیفیت گوجه فرنگی (*Solanum lycopersicum* L.)

ح. فیضی، ح. کاوه، و ح. صحابی

چکیده

در این پژوهش دو روش حمل‌ونقل (حمل‌ونقل در دمای معمولی و حمل‌ونقل در یخچال)، تیمارهای پس از برداشت محصول (بسته‌بندی با پلی‌اتیلن شفاف نازک، بسته‌بندی با پلی‌اتیلن شفاف ضخیم، کلرید کلسیم ۱ درصد، استفاده از کاغذ جاذب در جعبه و شاهد) در چهار مرحله بازاررسانی محصول پس از برداشت (۱- مزرعه ،پس از برداشت محصول و قرار گرفتن در جعبه قبل از بارزدن. ۲- حمل‌ونقل، پس از حمل محصول به میدان تره‌بار و در هنگام تخلیه محصول. ۳- میدان تره‌بار، پس از تخلیه بار و در زمان فروش به فروشندگان محلی، ۲۴ تا ۳۶ ساعت بعد از برداشت و ۴- در محل فروشگاه جزء فروشی ،حداکثر ۲ روز پس از برداشت محصول) مورد ارزیابی قرار گرفتند. مقدار اسیدکل، ویتامین سی و لیکوپن میوه نیز در محصولات مزارع مختلف، شرایط مختلف حمل‌ونقل، تیمارهای پس از برداشت و مراحل چهارگانه بازار رسانی بطور معنی‌داری اختلاف داشتند. بین تیمارهای پس از برداشت بسته‌بندی با پلاستیک ضخیم و کاغذ جاذب بترتیب با ۷/۹۴ و ۱۲/۱۶درصد کاهش وزن کمترین و بیشترین میزان افت فیزیولوژیک وزن میوه را به طور معنی‌داری به خود

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اختصاص‌دادند. کمترین تلفات پس از برداشت (۴/۲۱ درصد) هم بطور معنی‌داری به پوشش پلاستیک ضخیم مربوط شد.

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