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HARVEST STAGES AND PRE-COOLING INFLUENCE THE QUALITY AND STORAGE LIFE OF TOMATO FRUIT

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ABSTRACT

The study was carried out to investigate the influence of harvesting stages and pre-cooling on the physico-chemical quality characteristics of stored tomato fruit during the years 2008-2009. Tomato fruits of three maturity stages e.g. breaker, yellow and pink were harvested on 30th June at mid-day and either left untreated (control) or subjected to pre-cooling treatment. Data was recorded on various physico-chemical quality characteristics after 28 days storage at 12±2°C. Harvesting stages significantly affected the fruit quality parameters. The least weight loss (9.167 %) and reducing sugars (2.93%) were recorded in fruits harvested at yellow mature stage, which also had the highest juice (34.16%) and ascorbic acid content (8.06 mg/100ml). The fruit harvested at breaker stage had the highest firmness (7.833 kg/cm^2), but least juice content (26.66%), TSS (7.91%), fruit pH (3.58) and disease incidence (14.5%), while the highest weight loss (11.167%), fruit pH (4.0) and disease incidence (17.5%) was observed in fruits harvested at pink mature stage. Pre-cooling resulted in significantly lower weight loss, TSS, fruit pH, reducing sugars and disease incidence as well as higher juice content, fruit firmness, nonreducing sugars and ascorbic acid as compared control. The interaction of harvesting stages and pre-cooling revealed that the treatment resulted in significantly higher fruit firmness, ascorbic acid content and lower disease incidence, however it was more effective at the yellow stage of maturity.

Key words: Fruit Quality, Harvesting Stages, Pre cooling, Tomato.

INTRODUCTION

Tomato fruit is a good source of minerals (Colla, *et al*., 2002). The tomato is generally harvested at edible maturity, characterized by attaining pink-reddish color and maximum size (Frary *et al*., 2000). The tomato fruit when harvested at edible maturity is prone to post-harvest losses (Sankar *et al*., 2002). The quality is also lost due to biochemical changes which are influenced by growth, maturation, and storage environment. The storage performance of tomato fruit depends on cultivars; harvesting and storage conditions stage (Getinet *et al*., 2008). Thus, attempts are being made to decrease postharvest losses and extend storage life by harvesting at physiological maturity and pre cooling (Karki, 2005). The physiological maturity stages in the tomato fruit are described as mature green, breaker, yellow, pink, and red (Alpert *et al*., 2005). Mature green tomato has a yellowish 'star' on the blossom end, but the only definitive test of maturity is to cut the tomato in half and observing the seeds. The cut seed is a sign immature fruit (Chaudhry *et al*., 2003). The breaker stage occurs after the mature green stage and is distinguished by the development of pale yellow coloration on the blossom end (Karki, 2005). There is an increasing tendency to harvest the fruit at physiological maturity and ripened in a ripening room, when desired, which helps in decreasing the post-harvest losses and extending the storage life of tomato fruit (Puttaraju and Reddy, 1997).

The tomato fruit accumulates heat during the harvesting and postharvest operations, which decrease their storage quality (Venema *et al*., 2005). The removal of field heat, by pre-cooling the fruit, reduces post harvest decay, control development of physiological disorders; improve fruit quality and delay aging or ripening (Shehla and Tariq, 2007). Pre-cooling decreases the metabolic activities of harvested produce such as respiration rate and ethylene production (Etan *et al*., 2002), thus, delays the ripening and senescence. Pre-cooling is, therefore, used to retain fruit quality during storage and extend the shelf life (Becker and Fricke, 2002). The fruit after pre-cooling are stored at low temperature to prolong the storage life and retain fruit quality (Etan *et al*., 2002; Venema *et al*., 2005). In Pakistan, the fruit and vegetables are generally stored and marketed without pre-cooling (Chohan and Ahmad, 2008). The present experiment was, therefore, conducted to examine the effect of pre-cooling and harvesting stages on storage life of tomato.

MATERIALS AND METHODS

The experiment to determine the influence of harvesting stage and pre-cooling on storage life and quality of tomato was conducted during 2008- 2009. The results being comparable for both years, only one year data is presented. The experiment was laid out in two factorial, Randomized complete block design (RCBD) with three replications, containing 10 fruits each. Five fruits were separately stored for weight loss data. The tomato fruits were harvested at three stages of physiological maturity i.e. breaker, yellow and pink, in the month June at mid-day. The air temperature at the time of harvest was (38°C), fruits temperature was (36°C -38.5°C) and soil temperature was (34.5-36°C).

The fruits were grouped on the basis of maturity stages as breaker having yellowish star appearing at the blossom end, yellow having pale green to yellow color and pink when fruit were more pink than yellow. The tomato fruits were sorted for size, and physical damage or symptoms of physiological disorders and diseases. Fruit of about the same size were selected for each maturity stages and were then divided into two groups. One group of fruits was treated by dipping in water cooled to 10 ±2°C for 15 minutes to remove the field heat. After the treatment, the surface water was removed with a gentle air blower, while the other group of fruits was left without pre-cooling (control). The fruits were then transferred to a refrigerated storage (12±2 °C) for 28 days. The relative humidity of during the storage was maintained at 60-70%. Data on different quality parameters were recorded.

The percent weight loss was calculated by taking five fruits in each treatment and replication and recording the initial weight and weight after storage for 28 days using electronic balance. The readings of five fruit in each treatment were averaged to represent that treatment. The percent weight loss was calculated as under:

$$Percent\ \ weight\ loss = \frac{Weight\ of\ \ fresh\ \ fruit\ -Weight\ \ after\ storage}{Weight\ of\ \ fresh\ \ fruit}\ x100$$

The juice content (%) of the fruit was calculated by weighing the fruit and the juice extracted from same tomato fruit and converted to percent juice content.

The fruit firmness of 5 fruit in each treatment and each replication was recorded with the help of Effegi hand-held penetrometer equipped with FT 011 probe (Facchini, Alfonsine, Italy). The probe was inserted gently into the equatorial region of the fruit and the firmness reading were recorded and averaged to represent the fruit firmness for each treatment. To determine the total soluble solids (TSS), the juice from tomato fruit was extracted by gently cutting and squeezing the fruit and so that a few drops could be added onto the refractometer prism plate and the TSS measured with hand held refractometer (KROSS HRN-16) after prior calibration using distilled water. After each test, the prism plate was cleaned with distilled water and wiped with a soft tissue. The data were averaged and recorded in percent TSS.

Juice pH was determined by Electronic pH meter by crushing the tomato fruits of about the same weight gently using the laboratory mortar and pestle. The pH data was taken using the Jenway 3505 pH meter after 28 days storage at 12±2 °C.

Reducing and non reducing sugars (%) tomato fruit juice was determined by the method as described in AOAC (1990). For this purpose 10 fruits from each treatment in each replication were taken at random. The juice was extracted from the fruit with the help of locally made juice extractor and 25 grams of filtered (whattman-4) juice was transferred to 250 ml volumetric flask to which 100 ml of water was added and pipetted 100 ml solution into conical flask. It was added with 10 ml dilute HCl and boiled for 5 minutes. On cooling, it was neutralized with 1N NaOH and transferred to 250 ml volumetric flask and volume made up to the mark. This solution was titrated against Fehling solution. Sugars were calculated as:

$$Percent\ \ \ Reducing\ \ \ \ Sugars\ \ = \frac{Factor\ \ \ x\ diltion\ \ \ \ x\ 100}{Titre\ x\ Vo\ \ \ \ lume\ of\ sa\ \ \ \ mples}$$

$$Percent\ nonreducin\ g\ Sugars = (Total\ \ Sugars\ \%) - (\%\ \mathrm{Re}\ ducing\ \ Sugars\ )\ x\ 0.95$$

Care was taken to prepare fresh Fehling A and B solutions each time the sugars determinations were made

Ascorbic acid was determined by the standard method as described in AOAC (1990). The standard dye solution for Ascorbic acid determination was prepared by weighing 50 mg of 2, 6 dichlorophenol indophenol dye and 42 mg of sodium bicarbonate, dissolving in hot distilled water and volume made up to 250 ml. Ascorbic acid standard solution was prepared by taking 50 mg of ascorbic acid in 50 ml volumetric flask and the volume was made up with 0.4% oxalic acid.

The fruit samples were prepared by taking 100 g of peeled tomato and the juice was extracted with a small amount of Oxalic acid. The juice was transferred to a conical flask and allowed to stand for 30 minutes in dark. The nonsedemented layer of juice was transfer to 100 ml flask, diluteed with 2% Oxalic acid making up the volume. From both the standard and sample solutions, 10 ml was taken for titration against the dye solution. A balnk sample was also titrated to determine the Dye factor.

The 10 ml of prepared sample taken in the flask and titrated against dye until light pink color appeared,

which persisted for 15 seconds. Three consecutive readings were taken for each sample. The ascorbic acid (mg/100 g) was calculated by using the following formula;

$$Ascorbic \quad Acid\ (mg/\ 100\ g) = \frac{Factor\ x\ T\ x\ 10\ x\ 100}{S\ x\ D}$$

F = Factor for standardization = ml of ascorbic acid/ ml of dye

T = ml of dye used for sample – ml of dye used for blank

D = Weight of sample

S = ml of dilute sample taken for titration

The data calculated on different parameters were subjected to Analysis of Variance (ANOVA) technique to observe the differences between the different treatment as well as their interactions and significantly different means were further assessed for differences through Least Significant Difference (LSD) test. Statistical computer software, MSTATC (Michigan State University, USA), was applied for computing both the ANOVA and LSD (Steel and Torrie, 1984).

RESULTS AND DISCUSSION

Weight Loss (%): The weight loss in tomato fruit was significantly affected by harvest stages and pre-cooling but their interaction was not significant. The mean weight loss was the least (9.133%) in fruits harvested at yellow stage of maturity, which was statistically at par with breaker mature stage (9.833%) but significantly lower than fruit harvested at pink mature stage (11.167%). The mean weight loss decreased significantly form 10.5% in control to 9.5% with pre cooling treatment (Table 1). Post-harvest weight loss of tomato is a common but serious problem during storage (Getinet *et al.,* 2008). The weight loss is attributed to the loss of moisture and carbohydrates (Karki, 2005). The intensity of weight loss during storage depends on maturity stage (Moneruzzaman *et al*., 2009). The least weight loss in fruit harvested at yellow mature stage was 17.91% lower than fruits harvested at pink stage of maturity. The loss of moisture from the fruit is controlled by wax surface coating, that lose its structural integrity when the fruit advance in maturity (Bargel and Neinhuis, 2005). Thus, the resistance of the fruit to moisture loss decreases as it advances in maturity to the pink and red stages. Pre-cooling also decreased the weight loss by 9.47% (Dragon and Tomaz, 2006). The pre-cooling decrease the rate of metabolism (Reina *et al*., 1995) and may also slow down the degradation of surface materials hence resulting in lower weight loss as compared to non-treated control (Reina *et al*., 1995; Karki, 2005).

Juice Content (%): The mean juice content was significantly affected by harvest stages with the highest juice content (34.16%) observed in fruit harvested at yellow mature stage, followed by pink and breaker stages with 29.16 and 26.6%. Pre cooling treatment also resulted in significantly higher juice content (35%) as compared 25% in control. The juice content is a function of water present in the fruit and the waxy layer that act as barrier to moisture loss (Burghardt and Riederer, 2006). Since the weight loss in tomato fruit depends on maturity stage (Moneruzzaman *et al*., 2009) and was significantly higher at both breaker and pink mature stage (Table 1), it may the reason for 21.94 and 14.64% lower juice content at these stages accordingly (Safdar *et al*., 2006). Similarly, the juice content was 28.57% higher in pre-cooled fruits. Since pre-cooling decreases the temperature of the fruit, it may retain the juice content by decreasing moisture loss due to evaporation and respiration (Karki, 2005). The significantly higher juice content at yellow than the breaker and pink mature stages may due to poorly developed waxy layer on tomato fruit in breaker fruits and the loss of surface wax in more mature stage during storage (Bargel and Neinhuis, 2005).

Total Soluble Solids (%): The mean total soluble solids content (TSS) in control (8.66%) was higher than pre cooled fruit (8.33%). The means for harvesting stages revealed that total soluble solids were the highest in fruits harvested at pink mature stage (8.86%) as compared to yellow and breaker stages (8.75 and 7.91%, respectively). The difference in pink and yellow mature stages was, however, non-significant. The TSS/TA determines the overall taste of the fruit (Baldwin *et al*., 1998). The total soluble solid was low at the breaker but increased by 10.42% when tomato fruits were harvested at pink mature stage (Getinet *et al.,* 2008). The total soluble solids generally increase with advancement in maturity and during storage (Karki, 2005; Getinet *et al.,* 2008). The increase in TSS could be attributed to the breakdown of starch into sugars or the hydrolysis of cell wall polysaccharides (Crouch, 2003). The significantly lower TSS with pre-cooling could be due to slowing down of metabolic activities leading to increased TSS during storage (Reina *et al*., 1995).

Fruit pH: The fruit pH was significantly affected by pre cooling treatment and harvest stages, while the interaction of field heat removal and harvest stages was not significant. Pre cooling treatment resulted in significantly lower fruit pH (3.76) as compared to 3.86 in control. The mean pH 3.58, recorded at breaker stage increased to 3.86 and 4.00, when tomato fruit were harvested at yellow and pink mature stages respectively. Since, the acidity of the fruit is due to various organic acids, that are consumed during respiration (Albertini *et al*., 2006), the acidity, thus, decreased with advancing maturity or increasing storage duration with a corresponding increase in fruit pH. (Moneruzzaman *et al*., 2009). Since pre-cooling decreases the rate of ethylene production and ripening (Reina *et al*., 1995), thus the mean pH was lower in pre-cooled fruits.

Reducing sugar (%): The reducing sugars content was significantly affected by harvest stages, while the effect of the pre cooling treatment and interaction between harvest stages and pre cooling treatment was not significant. The maximum mean reducing sugar (4.2%) was recorded in fruit harvested at pink stage; followed 3.39 and 2.93% recorded in tomato fruits harvested at yellow and breaker stages of maturity (Table 1). The reducing sugars increased by 13.57 and 30.24% from breaker to yellow and pink stages of maturity. Similar pattern of increasing reducing sugars with maturation has also been observed in citrus fruit (Ladaniya, 2008; (Moneruzzaman *et al*., 2009). Thus, it is likely to observe higher reducing in more mature tomato fruit. The pre-cooling of tomato fruit lowered the rate of increase in reducing sugars by 7.95%, probably be decreasing the metabolic loss of reducing sugars (Valero and Serrana, 2010).

Non Reducing Sugar (%): The non reducing content of tomato fruit was significantly affected by pre cooling treatment and harvest stages but the interaction of pre cooling treatment and harvest stages was not significant. The non reducing sugars content was 4.98 in control, but increased to 5.54 with pre cooling treatment (Table 1). The means for harvesting stages indicated that non reducing sugars content was the highest 5.89% in fruits harvested at breaker stage, which decreased significantly to 5.26 and 4.63%, when tomato fruits were harvested at yellow and pink mature stages respectively (Table 1). This observation is in accordance with (Moneruzzaman *et al*., 2009), who reported the decline of non-reducing sugars with maturation due to hydrolysis of complex carbohydrates (Ladaniya, 2008). However, pre-cooling of tomato fruits resulted in higher non-reducing sugars (Reina *et al*., 1995).

Firmness (kg/cm^2): The fruit firmness was significantly affected by pre cooling treatment and harvest stages as well as their interaction. The pre cooling treatment retained higher fruit firmness 7.67 kg/cm^2 as compared to 6.43 kg/cm^2 kg recorded in control. The mean fruit firmness was the highest (7.90 kg/cm^2) at breaker stage, which declined 6.95 and 6.3 kg/cm^2 in fruit harvested at yellow stage and pink mature stages. The interaction effect revealed that the fruit firmness decreased in both control and pre-cooled fruit with advancing maturity stages. The fruit firmness declined from 7.3 to 6.3 and 5.7 kg/cm^2 in control fruit. By contrast, it decreased from 8.5 to 7.6 and 6.9 kg/cm^2 in pre-cooled fruit (Table 2). The fruit firmness is an important quality attribute that influences consumer's acceptance (Chang- Hai *et al*., 2006). Since maturation to red ripe stage involve cell wall breakdown (Wakabayashi, 2000), the fruit firmness generally decrease with advancing maturity. The mean fruit firmness with pre-cooling was 21.05% higher than control but it was least effective at breaker stage (16.44%) as compared to 20.63 and 21.05 at yellow and pink stages of maturity. Pre-cooling delays fruit ripening (Getinet *et al.,* 2008), by lowering metabolism (Valero and Serrana, 2010) especially rates of respiration and ethylene production (Reina *et al*., 1995). Thus, it is likely to observe higher firmness as compared to control.

Ascorbic Acid (mg/100g): The ascorbic acid content of tomato was significantly affected by pre cooling treatment, harvesting stages and their interaction. The ascorbic acid content was significantly higher (6.83 mg/100 g) with pre cooling treatment as compared to control (6.15 mg/100 g). The mean ascorbic acid was the lowest (5.07 mg/100 g) in fruits harvested at breaker stage as compared to Pink and yellow stages 6.35 and 8.06 mg/100 g, respectively. The interaction of pre cooling treatment and different stages revealed that ascorbic acid was the highest at yellow stage of harvesting and least at pink harvesting stage, though at both these stages the difference in control and pre cooling was non significant. At the breaker stage the ascorbic acid in control (5.29 mg/100 g) was significantly retained higher (7.4 mg/100 g) with pre cooling treatment (Table 3). Ascorbic acid is a very labile vitamin of fruit. Ascorbic acid is usually high at the optimum maturity stage. However, in tomato fruit the highest ascorbic acid content was observed at breaker stage that declined at yellow and pink stages of maturity (Kirki (2005, Moneruzzaman *et al*., 2009). Similarly, the ascorbic acid content tend to decline during storage (Rajwana *et al*., 2010). Since pre-cooling slows down metabolic activities several metabolic activities, it likely to observe higher ascorbic acid with pre-cooling treatments (Reina *et al*., 1995), yet its influence was more pronounced at the yellow stage of maturity (Table 3).

Disease Incidence (%): The analysis of the data indicated that percent incidence of diseases was significantly affected by pre cooling treatment and harvest stages as well as by the interaction of pre cooling treatment and harvest stages. The mean disease incidence in control (18.27%) decreased significantly to 15.22% with pre cooling treatment. The mean disease incidence of increased from 13.66 to 17.08 and 19.50%, when harvesting was delayed from breaker to yellow and pink mature stages respectively (Table 4). The interaction of pre-cooling treatment and harvesting stages was also significant. The disease incidence was 15.66, 17.50 and 20.66% in control fruit as compared to 11.66, 16.66 and 17.33 in control fruit at breaker, yellow and pink mature stages respectively (Table 4). The disease incidence in tomato fruit generally increases with advance in maturity sage (Moneruzzaman *et al*., 2009). However the rate of advance in maturity can be decreased by 14 to 28% (Shehla and Tariq, 2007). Pre-cooling is one of the most effective methods that decline the rate of maturation

Table 1. Effect of harvesting stages and pre-cooling on weight loss, Juice content, TSS, fruit pH and Reducing and Non-reducing sugars content of tomato fruit. Means followed by similar letters in columns are statistically not significant at α = 0.05.

Harvesting Stages	Weight Loss (%)	Juice Content (%)	TSS (%)	Fruit pH	Reducing Sugars (%)	Non- Reducing Sugars (%)
Breaker	9.833 b	26.66 b	7.91 b	3.58 c	2.93 b	5.89 a
Yellow	9.167 b	34.16 a	8.75 a	3.86 b	3.39 b	5.26 b
Pink	11.167 a	29.16 b	8.83 a	4.00 a	4.2 a	4.63 c
LSD	1.190	4.697	0.3523	0.0986	0.566	0.304
Treatments						
Control	10.556 a	25.00 b	8.66 a	3.86 a	3.65	4.98 b
Pre-cooled	9.556 b	35.00 a	8.33 b	3.76 b	3.36	5.54 a
LSD	0.9718	3.835	0.2877	0.1220	NS	0.2486
HS X T	NS	NS	NS	NS	NS	NS

Table 2. Effect of harvesting stages and pre-cooling treatment on firmness of tomato fruit. Means followed by similar letters are not significant at α = 0.05.

	Maturity Stages			
Treatments	**Breaker**	**Yellow**	**Pink**	**Means**
Control	7.3 bc	6.3 cd	5.7d	5.7 b
Pre-Cooled	8.5 a	7.6 b	6.9 c	6.9 a
Means	7.9 a	6.95 b	6.3 c	

LSD Harvesting stages = 0.5753
LSD Treatments =0.7046 LSD HS x T = 0.704

Table 3. Effect of harvesting stage and pre-cooling on ascorbic acid of tomato fruit stored for 28 days at 12±2 °C. Means followed by similar letters are not significant at α = 0.05.

	Maturity Stages			
Treatments	**Breaker**	**Yellow**	**Pink**	**Means**
Control	8.01	5.29	4.99	6.10
Pre-Cooled	8.11	7.4	5.15	6.89
Means	8.06	6.35	5.07	

LSD Harvesting stages = 0.4709
LSD Treatments = 0.3845 LSD value HS X T = 0.667

(Shahi *et al*., 2012) by slowing down the metabolic activities responsible for ripening and hence decreases the incidence of decay in tomato (Reina *et al*., 1995) and other fruits (Thompson *et al*., 2002). Pre-cooling, however, was more effective in decreasing disease incidence at yellow stage of maturity (Table 4).

The study indicates that the pre-cooling was effective in retaining superior fruit quality during storage by decreasing weight loss, retention of firmness and decreasing disease incidence. The tomato fruit harvested at the yellow mature stage had the lowest weight loss and reducing sugars, while ascorbic acid content was the highest in fruit harvested at breaker stage and stored for 28 days at 12±2°C. Pre-cooling resulted in significantly higher fruit quality attributes, yet the most effective stage of harvest for pre-cooling application was the yellow mature stage.

Table 4. The influence of harvesting stage and pre-cooling on disease incidence of tomato fruit after 28 days storage at 12±2 °C. Means followed by similar letters are statistically not significant at α = 0.05.

	Maturity Stages			
Treatments	**Breaker**	**Yellow**	**Pink**	**Means**
Control	15.52 b	18.56 a	19.89 a	17.99 a
Pre-Cooled	13.48 b	15.76 b	18.11 a	15.78 b
Means	14.5 c	17.16 b	19.00 a	

LSD Harvesting stages = 1.279
LSD value treatments = 1.045 LSD HS x T= 2.378

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