Effect of Maturity Stage on Ripening and Quality Characters of Four Tomato (*Solanum lycopersicum* L.) Varieties of Sri Lanka

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ABSTRACT. *The effect of maturity stage on ripening and quality characters of four tomato (Solanum lycopersicon) varieties was evaluated. The varieties selected were Thilina, Bathiya, Maheshi and Lanka cherry, due to their widespread cultivation and popularity among consumers. Tomato fruits of three maturity stages e.g. colour breaker, 25% maturity and 50% maturity were considered.*

Maturity stages significantly affected the fruit ripening and quality parameters. The fruits harvested at colour breaker stage had the highest weight loss (22.45%) except in the variety Lanka cherry. Total soluble solid (TSS) content was not significantly different at different maturity stages except in the variety Thilina ($P \leq 0.05$). But in the variety Thilina, the highest TSS was recorded in the fruits harvested at 50% maturity (4.07). In varietal comparison, both varieties Lanka cherry and Thilina had the highest TSS values in each maturity stages compared to other two varieties. Titrable acidity in varieties Bathiya (9.95%) and Maheshi(8.4%) was significantly higher at colour breaker stage than the rest of two maturity stages, while in the case of Lanka cherry and Thilina, though titrable acidity was not significant among colour breaker stage and 25% maturity stages, it was significantly lower at 50% maturity stage. As expected, pH had increased with the progression of the maturity except in two varieties, Thilina and Maheshi.

The study indicates that identification of effective maturity stage is an important to retain superior fruit quality by maintaining a low rate of weight loss and softening in tomato fruits after harvest for prolong storage and distant markets.

Keywords: *fruit quality, Maturity stage, Solanum lycopersicon, titrable acidity total soluble solid*

INTRODUCTION

Tomato (*Solanum lycopersicum* L.), a member of the family Solanaceae, is a most widely cultivated vegetable crop in Sri Lanka. It is native to Central, South and Southern North America from Mexico to Argentina (Rick and Butler, 1956). In worldwide tomato is grown for its edible fruits and it is a good source of minerals (Colla *et al*., 2002).

Tomato grows well on most mineral soils that have proper water holding capacity and aeration. It prefers deep well drained sandy loam soils. Soil depth of 15 to 20 cm is needed to grow a healthy crop. The optimum temperature for the growth would be in between 21 - 27 ^{0}C (Saimbhi *et al*., 1987). Soil pH should be in between 5.8-6.8 and prefers an elevation of 1,000-2,000 m (Saimbhi *et al*., 1987). The plants typically grow to 1-3 m in height and have a weak stem that often sprawls over the ground and vines over other plants.

Proper harvesting determines the nutrient contents as well as post harvest life of any fruit. Tomato is normally harvested at different maturity stages, such as green mature stage, half ripen stage and red ripen stage (Alpert *et al.,* 2005). Frary *et al*., (2000) have reported that tomato is generally harvested at edible maturity, characterized by attaining pink-reddish colour and maximum size. However, edible maturity of tomato fruit is prone to post-harvest losses (Sankar *et al*., 2002) and quality is also lost due to biochemical changes.

The post harvest life of tomato is largely influenced by the harvest maturity. Fruits and vegetables are living entities and continue to respire for some time after harvest. Kader, (1992) reported that the magnititute of

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post harvest losses in fresh fruits and vegetables is estimated to be 5-25% in developing countries. Water losses can be one of main causes of determination since it results in not only quantitative losses but also affects the appearance, textural and nutritional quality (Kader, 1992). It was reported that the post harvest losses of tomato in Sri Lanka is around 35-40%. The most important quality criteria for tomatoes are red colour, firm but juicy texture, and good flavor. Tomatoes with high sugar and relatively high acid contents are the best flavored; low sugar and low acid contents result in poor flavored tomatoes (Stern *et al*., 1994). Therefore, harvesting them at optimum stage of maturity can have tomatoes with better quality and longer marketability.

It has become vital to grow improved varieties and harvest crops at the appropriate physiological maturity stage if postharvest loss in agricultural produce is to be minimized. Department of agriculture in Sri Lanka has recommended several tomato varieties, KWR, T146, T245, Thilina, Ravi, Tharidu, Rashmi, Rajitha, Lanka Sour (GorakaTakkali), Maheshi, Bathiya and Lanka cherry etc., having different varietal characters. The aim of this study therefore was to determine the correct maturity stage of tomato fruit at harvest in selected recommended tomato varieties (Thilina, Bhathiya, Maheshi and Lanka cherry) that will prolong fruit shelf life and quality.

METHODOLOGY

The study was conducted during *Maha* 2014 at the Horticultural Crop Research and Development Institute (HORDI), Gannoruwa. The experiment was laid out in complete Randomized Design (CRD) having 10 replicates containing five fruits for each four tomato varieties (Thilina, Bhathiya, Maheshi and Lanka cherry) which have high demand in the market. The tomato fruits were harvested at three stages of physiological maturity i.e. colour breaker stage, 25% maturity (yellow) and 50% maturity (greenish red).

Plate1. Harvested three stages of physiological maturity

Colour breaker stage | 25% maturity (yellow) | 50% maturity (greenish red)

(a) Weight Loss%

The percent weight loss was calculated by taking five fruits in each replicate and recording the initial weight and weight after storage (one week) under ambient temperature by using electronic balance. The readings of five fruits in each treatment were averaged to represent that treatment. The percent weight loss was calculated as,

$$\text{Percentage weight loss} = \frac{\text{Weight of fresh fruit} - \text{weight after storage}}{\text{Weight of fresh fruit}} * 100$$

(b) Total Soluble Solids (TSS)

To determine the total soluble solids (TSS), the juice from tomato fruit was extracted by and few drops could be added onto the prism plate of refractometer. After each test, the prism plate was cleaned with distilled water and wiped with soft cotton. The data were averaged and recorded in percent TSS.

(c) Titrable acidity and pH

The pH of extracted tomato juice was determined using Electronic pH meter by crushing the tomato fruits of about the same weight gently using the laboratory mortar and pestle. To determine total acidity, 10 ml of tomato juice extracted from 100g of peeled fruit sample was transferred to conical flask and volume up to 30 ml and then titrated with 0.1 N NaOH (Sodium hydroxide).

The data were analyzed using Analysis of Variance (ANOVA) procedure and mean separation was done using Duncan's multiple range test (DMRT).

(d) Disease Index and Visual Quality Rating Index

Disease index and visual quality rating index was determined by observing fruits according to a scale given in the following table. Both visual quality rating index and disease index values were analyzed by using Krushkal-Wallis test.

Table 1. Rating scale of Disease index and visual quality rating index

Scale	Description
Disease index	
0	No disease at all
1	Slight (1-10%)
2	Moderate (11-20%)
3	High (20-30%)
4	Disease (>30%)
Visual quality rating index	
1	Non edible
3	Limited marketability
5	Fair (moderate defects)
7	Good (slight defects)
9	Excellent

RESULTS AND DISCUSSION

Weight Loss (%)

Tomato weight was quite variable in variety 'Thilina'; the largest variation was observed in 50 % maturity stage (50.90±18.91 g). Tomato weight has increased with maturity, and the most pronounced increase was between the 25% and 50% maturity stages. The largest difference from 25% to 50% stage was observed in variety 'Lanka cherry', exhibiting a 25% increase.

The mean weight loss was significantly different at different maturity stages in all four varieties. Weight loss from harvesing stage to full ripen stage has been given in the results (Table 1). The weight loss was significantly greater in fruits harvested at 25% maturity except in the variety Lanka cherry. Sihag and Mentha (1999) made a statement that water loss increases with increasing periods of storage and it coincides with the result of this study, indicating that fruits harvested at 25% maturity stage have undergone the long storage than fruits harvested at 50% maturity stage.

Table 2. Impact of maturity stage on weight loss in different tomato varieties.

Variety	Maturity stage	Weight (g)	Weight loss %
Lanka cherry	Colour breaker	6.00±1.06	
	25%	6.70±1.15	2.04b
	50%	7.50±0.53	2.78a
Bathiya	Colour breaker	51.40±7.11	
	25%	51.70±5.03	22.45a
	50%	59.40±8.02	4.47b
Thilina	Colour breaker	41.50±7.11	
	25%	50.90±13.00	10.20a
	50%	50.90±18.91	4.29b
Maheshi	Colour breaker	35.40±5.64	
	25%	37.11±6.13	22.45a
	50%	44.14±4.60	5.40b

Note: Means followed by similar letters in columns are statistically not significant at $\alpha = 0.05$.

The weight loss is attributed to the loss of moisture and carbohydrates (Karki, 2005) and causing fruit softening and shriveling (Wilsony., 1999). It is a common but serious problem during storage (Getinet *et al.,* 2008). The intensity of weight loss during storage depends on maturity stage (Moneruzzaman *et al*., 2009) and same trend was evident with the results of this study as well. Thus, the resistance of the fruit to moisture loss decreases as it advances in maturity to the pink and red stages (Ali *et al*., 2013). Though, resistance of the fruit to moisture loss is greater at the 25% maturity stage, increasing period of storage may cause rapid water loss. However, the rate at which weight is lost depends on the variety. Comparing among four varieties, the rate of weight loss was greater in variety 'Bathiya' and 'Thilina' at 25% maturity stage, while in the variety 'Maheshi' at 50% maturity stage. The significant factor in water loss is the ratio of the surface area of the type of plant part to its volume. That is, the greater the surface area in relation to the volume the more rapid water is lost.

Total Soluble Solids (%) (TSS)

Total soluble solids content of variety Maheshi, Lanka cherry and Bathiya were not significantly different at the different maturity stages (at P≤0.05). But it was significantly different in variety 'Thilina' (Table 3). Though, there was significant difference in each stage with the 50% maturity stages, The TSS in between colour breaker and 25% maturity stages were not significant at P≤0.05.

In varietal comparison, varieties 'Lanka cherry' and 'Thilina' had given significantly greater values for TSS in each maturity stage with compared to varieties 'Bathiya' and 'Maheshi'. However there was no significant difference in TSS values in between 'Lanka cherry' and 'Thilina' in each maturity stages (Table 3).

The TSS determines the overall taste of the fruit (Baldwin *et al*., 1998). Getinet *et al.,* 2008 have reported that the total soluble solid was low at the colour breaker stage but increased when tomato fruits were harvested at pink mature stage. Though results of this study have not clearly showed significant difference in TSS at different maturity stages except variety 'Thilina', generally TSS increases with the 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).

In sauce production, colour and soluble solids content of tomatoes are considered as major attributes of product quality. The flavor of the product is influenced by the balance between sugar content and acidity (Berrett and Garcia, 2006). However based on the results of the study, among the tested four tomato varieties, there is possibility to use 'Lanka cherry' and 'Thilina' for sauce production.

Table 3. Maturity comparison of TSS at different varieties.

	Lanka cherry	Bathiya	Thilina	Maheshi
Colour breaker	4.65±0.22a	4.55±0.18a	3.87±0.21b	3.73±0.24a
25 % maturity	4.75±0.18a	4.53±0.30a	3.82±0.13b	3.53±0.15a
50 % maturity	4.75±0.37a	4.77±0.15a	4.07±0.08a	3.53±0.31a
P<	ns	ns	0.01	ns
CV	5.82	4.75	3.32	6.73

Note: Means followed by similar letters are statistically not significant at α = 0.05.

Titrable Acidity (%) and pH

Titrable acidity was significantly different (at P≤0.05) at different maturity stages in all varieties. In varieties Bathiya and Maheshi, titrable acidity was significantly higher at colour breaker stage than the rest of two maturity stages (25% and 50% maturities). But acidity was not significant in between those two maturities. In the case of variety Lanka cherry, though titrable acidity was not significant among colour breaker and 25% maturity stages, it was significantly lower at 50% maturity stages. The highest acidity values were exhibited at colour breaker stage and harvesting at colour breaker stage could be used for the purpose of high acidity (tomato juice, tomato paste in all the cultivars. However in the varietal comparison, largest acidity values were exhibited by variety 'Bathiya' followed by variety 'Lanka cherry' at colour breaker stage (Table 6).

Table 4 The effect of maturity stage on total acid content in different Tomato varieties.

	Lanka cherry	Bathiya	Thilina	Maheshi
Colour breaker	8.10±0.14 a	9.95±0.07 a	6.45±0.01 a	8.40±0.10 a
25 % maturity	8.10±0.29 a	4.80±0.09 b	5.55±0.04 ab	5.30±0.04 b
50 % maturity	5.08±0.10 b	5.42±0.09 b	5.42±0.09 b	6.60±0.14 b
P<	0.0001	0.0001	0.0017	0.0821
CV	2.72	9.98	12.26	10.53

Note: Means followed by similar letters are statistically not significant at $\alpha = 0.05$.

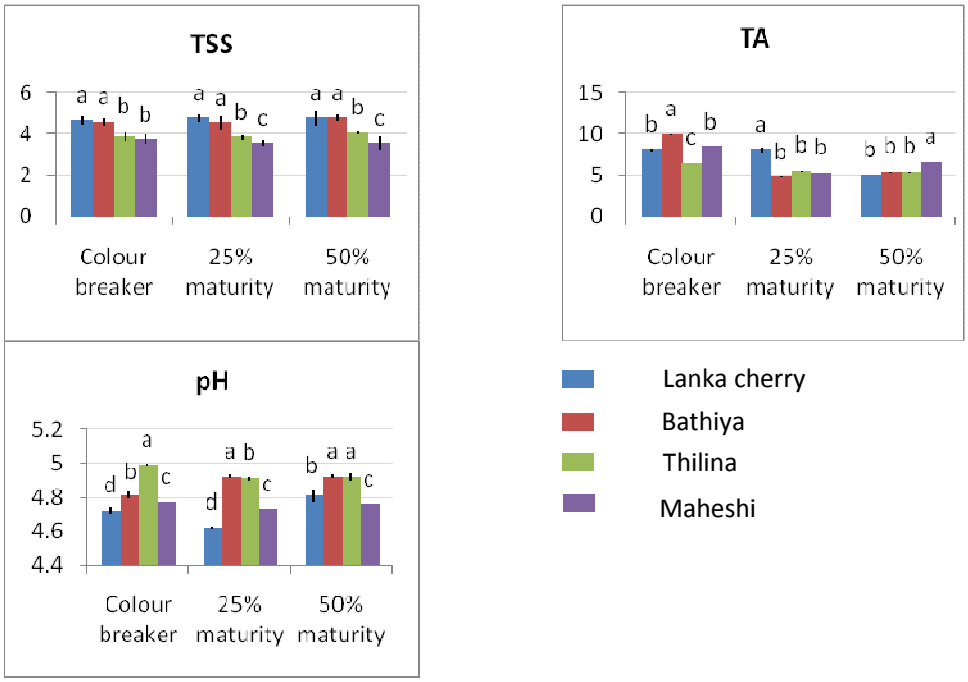
Titrable acidity has reached its peak at colour breaker stage and then started to decrease with the advancement of the fruit ripening. The vitamin C and titrable acidity content of tomato juice was increased with maturity stages and reached the peak and thereafter started to decreased (Sinaga, 1986). It was found that pH value increased with the advancement of fruit ripening and same trend was evident with the results of varieties Lanka cherry and Bathiya (Table 5). 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 with a corresponding increase in fruit pH (Moneruzzaman *et al*., 2009). Hence there is an inverse relationship between pH and titrable acidity, though sometimes the relationship is an inaccurate (Stevens, 1972). All the varieties exhibited pH values exceeding 4.6. The pH is an important factor for safe food production during thermal processing to control microbial spoilage and enzyme inactivation in tomato products. As expected, pH has increased with the progression of the maturity except two varieties, 'Thilina' and 'Maheshi'. However tomato pH is dependent on factors including variety, maturity stage, cultural practices, growing location and seasonal variations as well (Gould, 1992).

Table 5. The effect of maturity stage on fruit pH in different Tomato varieties.

	Lanka cherry	Bathiya	Thilina	Maheshi
Colour breaker	4.72±0.02 b	4.81±0.01 b	4.99±0.04 a	4.77 ±0.01 a
25 % maturity	4.62±0.02 c	4.92±0.01 a	4.91±0.01 c	4.73±0.01 c
50 % maturity	4.81±0.01 a	4.92±0.01 a	4.92±0.02 b	4.76±0.01 b
P<	0.0001	0.0001	0.0001	0.0001

Note: Means followed by similar letters are statistically not significant at $\alpha = 0.05$.

Fig. 1. The varietal comparison on TSS, TA and fruit pH at different maturity stages



Disease Index and Visual Quality Rating Index

The analysis of the data indicated that both diseases index and visual quality rating index were not significantly affected by the maturity stage. However, Moneruzzaman *et al*., (2009) has stated that disease incidence in tomato fruit generally increases with advance in maturity stage.

Conclusion

The study indicates that identification of effective maturity stage is an important to retain superior fruit quality by maintaining a low rate of weight loss and softening in tomato fruits after harvest for prolong storage and distant markets. However the effective maturity stage depends on the varietal characters.
In summary, the results of this study indicates that tomato fruits harvested at colour breaker stage had lowest reducing sugars, while having highest weight loss and tritable acidity in each variety (Thilina, Bhathiya, Maheshi and Lanka cherry). Total soluble solids levels increased with progression of maturity. The variety 'Lanka cherry' and 'Thilina' exhibited largest TSS values in each maturity stage showing that there is possibility to use them in sauce production.

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