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## Physico-chemical and physiological properties of 'Shivam' variety tomato at different Maturity stages

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**Abstract**

Tomato (*Solanum lycopersicum* L.) is the important fresh produce of higher economic and nutritional significance among consumers globally. Moreover, tomatoes are a majorly rich in bioactive compounds. This present study was investigated to analyze various physicochemical and physiological changes of un-ripen and ripen tomatoes of the 'Shivam' variety. Different properties like colour value, total soluble solids, pH, titratable acidity, firmness, ascorbic acid, lycopene content and respiration rate of tomatoes were evaluated. The result findings of both stages of maturity (Mature green, Ripe red) tomatoes were compared and discussed in detail for understanding the changes that take place upon ripening. Upon ripening pH, TSS, redness, respiration rate, lycopene and ascorbic acid content increases and TA, firmness, lightness and yellowness of tomatoes decreases. The results suggest that ripening process has a significant effect on 'Shivam' variety tomatoes' physicochemical and physiological properties.

**Keywords:** Physicochemical properties, physiology, Shivam variety, semi-ripen, ripen, respiration rate

**1. Introduction**

The regular consumption of fruits and vegetables is increasing hugely during the last decade, mostly due to increased consumers' nutritional knowledge about their beneficial effects on avoiding several chronic diseases (González-Chavira, Herrera-Hernández, Guzmán-Maldonado, & Pons-Hernández, 2018) [16]. Tomato (*Solanum lycopersicum* L.) is one of the important horticultural crops with global production of 163.43 million tonnes, valued at 59.88 billion dollars (FAOSTAT., 2013) [13]. Tomatoes are commonly consumed either in the form of raw or processed products and significantly provide antioxidants. Tomatoes are rich in antioxidants like lycopene, ascorbic acid,  $\beta$ -carotene, ascorbic acid, flavonoids and phenolics which can substantially contribute to free radical scavenging properties. Adequate intake of raw or processed tomato products prevents several cardiovascular diseases and different types of cancer. Carotenoids will offer colour, pro vitamin A and antioxidant activities (Shwetha, Sinija, Durgadevi, Yadav, & Shanmugasundaram, 2018) [32]. These protective actions in tomatoes are due to various bioactive compounds comprising antioxidant activities within them (Borguini & da Silva Torres, 2009) [9]. Recycling of tomato waste increase profit and decrease pollution (Karunanithi, 2019) [20].

In tomato composition, several interdependent factors such as varieties, maturity stages, environmental changes, cultivation and storage conditions may affect it (Anza, Riga, & Garbisu, 2006) [3]. Moreover, tomatoes fall under the category of high perishable commodity, having a shorter life span. The mechanism of the tomato ripening process covers the significance of its economy because the tomatoes undergo remarkable changes from an unripe stage to an edible ripen stage (Baldassarre *et al.*, 2015) [1]. The ripening process is related with pigment synthesis, cell wall transformations, softening, conversion of polysaccharides (starch) to soluble simple sugars and volatile compounds synthesis that renders the development of distinctive aroma and taste (Leng, Yuan, & Guo, 2013) [23]. This concept is in accordance with the several notable changes on the exterior portion of the fresh produce including the color, firmness, textural characteristics and development of rottenness (Moneruzzaman, Hossain, Sani, & Saifuddin, 2008) [25].

The colour and firmness of tomatoes are considered as a key parameter to determine their quality and are strongly impacted by the variety and ripening stage. Therefore, the ripening of tomatoes has been studied widely and the process is highly dependent on ethylene production. Inhibition of ethylene development would delay the process of ripening and biochemical changes associated with it, also it helps extend the shelf life of the commodity (Poyesh, Terada, Sanada, Gemma, & Koshio, 2018) [20]. The time gap between tomato after harvesting and consumption may delay upto several weeks and during the time various biochemical changes take place upon ripening which ultimately affects the nutritional value. Hence, the present study was performed with a focus on evaluating the physicochemical and physiological changes associated with tomatoes of different maturity stages.

## 2. Materials and Methods

### 2.1 Purchase of tomatoes

Unripen (Mature Green, MG) and ripen tomatoes (Red Ripe, RR) of the 'Shivam' variety were procured from the farmer field of Dharmapuri district, Tamil Nadu. Tomatoes were carefully examined and those with a clear, smooth and firm texture, no moulds visible on the exterior surface selected for this study. All the analyses throughout the research were performed with a similar variety of tomatoes that are purchased from the same farmer field.



Fig 1: Shivam Variety Tomatoes

### 2.2 Pre-processing of tomatoes

The selected tomatoes were initially graded with concerning size, shape, weight, colour and maturity stage to maintain uniformity throughout the research work. Consequently, tomatoes that were graded are washed with potable water thoroughly and gentle air dried in order to remove dirt and other foreign particles that were present on the external surface of tomatoes.

### 2.3 Physico-chemical properties

The following physicochemical and physiological properties were analyzed in triplicates for both stages of un-ripen and ripen tomatoes.

#### 2.3.1 pH

The pH values of the tomatoes were estimated by a pH meter LI 120 (ELICO Pvt Ltd), which comprises a glass electrode connected to a digital meter that helps in measuring the acidity degree of tomato juice of semi-ripen and ripen samples (100 ml).

#### 2.3.2 Total soluble solids (TSS)

TSS of tomatoes were measured in triplicates using a refractometer (ATAGO-RX-7000). Few drops of tomato juice were spread over the prism of the refractometer to measure the readings directly, the mean values with standard deviation were expressed in terms of °Brix (Ranjitha Gracy, Gupta, & Mahendran, 2019) [30].

#### 2.3.3 Titratable acidity (TA)

Tomato juice of both semi-ripen and ripen tomatoes was extracted. The extracted juice is dissolved in distilled water (10 ml) and titrated against 0.1 N of sodium hydroxide (NaOH) solution with few drops of phenolphthalein as an indicator. The appearance of pink color was considered as an endpoint of the titration. The acidity of samples was expressed in the percent of anhydrous citric acid and calculated by the following equation (Gaikwad, Yadav, & Sugumar, 2020) [14].

$$\text{Titrateable acidity (\%)} = \frac{M \times 0.1 N \times N \times C}{W} \times 100 \quad \dots(2.1)$$

#### Where

M = Titre value

N = Volume made up, ml

C = Equivalent weight of citric acid

W = Weight of sample, gm

#### 2.3.4 Ascorbic acid

The ascorbic acid content of the samples was determined by adopting the 2, 6 – dichlorophenol indophenol titration method. A known amount of sample was added with 50 ml of oxalic acid. The solution was thoroughly mixed and filtered. 10 ml of the extract was titrated against the standardized dye. The pale pink colour persistence for 5-10 s is considered as an endpoint (Tilahun, Park, Taye, & Jeong, 2017) [35].

$$\text{Ascorbic acid content (mg/100 g)} = \frac{M \times D \times N}{W} 100 \quad \dots(2.2)$$

#### Where

M = Titre value

N = Volume made up (ml)

D = Dye factor (0.1/titre value)

W = Weight of sample(gms)

#### 2.3.5 Lycopene content

A known weight of samples was crushed thoroughly using pestle and mortar and the lycopene pigment was extracted by dissolving in 10ml of acetone. The mixture was shaken at 140 rpm for 30 minutes and then centrifuged at 12000 rpm for 15 min. The final volume of the supernatant solution was made up by adding acetone (100 ml). Finally, lycopene content was determined by measuring absorbance at 503 nm (Tilahun *et al.*, 2017) [35].

$$\text{Lycopene content (mg/100 g)} = \frac{31.206 \times A}{W} \quad \dots(2.3)$$

Where,

A = Absorbance at 503 nm

W= Weight of sample extracted(g)

### 2.3.6 Colour value

The color analysis of the tomato samples was carried out with the help of a Hunter Lab spectrophotometer (Color Flex EZ, Austria, USA). Before the analysis, the equipment was primarily calibrated using a black glass plate followed by a white tile. The results were represented with chromaticity coordinates  $L^*$  (black [0] -white [100]),  $a^*$  (red [+ve] -green[-ve]) and  $b^*$  (blue[-ve] -yellow[+ve]) (Patras, 2019) [28].

### 2.3.7 Firmness

The firmness (N)textural property of all the tomato samples was determined using a Texture Analyzer (Stable microsystem Ltd., UK) with a 2 mm diameter stainless steel cylindrical probe. The experiments were carried out with a compression test mode, pre-test speed of 1.5 mm/s, test speed of 1.0 mm/s, post-test speed of 10.0 mm/s, 6.0 mm distance target mode and force 5 (g). Four distinct regions of each tomato were considered to measure the tomato firmness and data for peak identification was determined using a texture expert exceed software (Kahramanoğlu, 2019) [19].

## 2.4 Physiological properties

### 2.4.1 Respiration rate

The respiration rates of tomatoes were determined at ambient conditions using a glass jar and sealed airtight. The composition of  $O_2$  and  $CO_2$  gases concentration inside the chamber were measured using a  $O_2$  and  $CO_2$  the analyser (PBI Dan sensor checkmate II). The composition of gases was analyzed immediately after the sealing of container for every 1 hr interval until the concentration of  $O_2$  fall below 1%. All the samples were analyzed in triplicates and the depletion curve of gases was obtained by determining the linear regression. The  $O_2$  or  $CO_2$  concentration was predicted with an increment at 5 hr for all the treatment conditions. The respiration rates of tomatoes were calculated using the following equation suggested by (Guo *et al.*, 2014) [17];

$$RR = \frac{(C_1 - C_2) \times (V_1 - V_2) + (S \times W \times \frac{M}{100} \times 10^{-1})}{W \times (T_1 - T_2)} \quad ..(2.4)$$

#### Where

RR = Respiration rate of  $O_2$  uptake or  $CO_2$  release in  $ml\ kg^{-1}\ hr^{-1}$

$C_1$  = Initial concentration of  $O_2$  or  $CO_2$  in percentage

$C_2$  = Final concentration of  $O_2$  or  $CO_2$  in percentage

$(V_1 - V_2)$  = Difference in the volume of container and volume of tomato in ml

W = Weight of tomato in kg

M = Moisture content of the tomato in ml

$(T_1 - T_2)$  = Difference in the initial and final period in hr

S = Solubility of gases

### 2.5 Statistical analysis

Simple t test – Two samples assuming unequal variance was performed using Microsoft Excel 2016 and the significant differences between the samples during the study with a probability level of significance ( $p < 0.05$ ). The results of experimental data are expressed in terms of mean  $\pm$  standard deviation for the triplicate values.

## 3. Results and Discussion

### 3.1 pH, TSS and TA

The pH, TSS and TA values are the essential quality

characteristics that strongly determine the taste of commodity and consumer acceptability (Amoriello, Ciccoritti, Paliotta, & Carbone, 2018) [2].

In this study, pH values of tomatoes showed a significant difference ( $p < 0.05$ ) between the samples as shown in Table 1. pH values obtained for un-ripen tomatoes (3.6) were below neutral pH showing the acidic nature of the fruit. The increasing trend of pH value was noted for ripen tomato (4.2), this could be due to the decrease in the levels of hydrogen ions attributed by organic acids during the ripening stage (Barragán-Iglesias *et al.*, 2018) [6].

An inverse relationship was observed between pH and TA as the ripening proceeds which was in agreement with the previous study (Moneruzzaman *et al.*, 2008) [25].

Table 1 summarises the results of TSS and TA for both un-ripen and ripen tomatoes and showed a significant difference ( $p < 0.05$ ). The TA of tomatoes decreased upon ripening, this is in line with previous work where TA decrease and TSS increase with maturation.

The TA value was decreased from 0.56 (unripen) to 0.47 (ripen) of tomatoes. The uptake of organic acids as a respiration substrate or their conversion into sugars and derivatives during the maturation results in decreasing of titratable acidity of ripened tomatoes (Usenik, Stampar, & Kastelec, 2013) [36]. Besides, decreasing trend of acidity during ripening in tomatoes may be due to metabolic translocation and transformation.

A gradual increase in TSS value was noted for the ripened tomatoes due to the maturation. The TSS content was found to be higher for the ripened tomato (5.1) when compared to the un-ripen (3.7) and showed a significant difference ( $p < 0.05$ ). This could be due to the accumulation of simple sugars by starch breakdown upon ripening which gives a desirable flavour to the product (Kaur, Sharma, Abas Wani, Singh Gill, & Sogi, 2006) [21].

### 3.2 Colour value

The surface colour of the fresh produce is the most important quality index that facilitates the consumer purchase behaviour and acceptability of the products (Pathare, Opara, & Al-Said, 2013) [27]. Most commonly, the colour of the commodity arises from the natural pigment present in it which alters with the ripening of the fresh produce. Thus, colour is the most significant parameter in determining the ripening stage (Amoriello *et al.*, 2018) [2].

The colour values ( $L^*$ ,  $a^*$ ,  $b^*$  and  $a^*/b^*$ ) of un-ripen and ripen tomatoes were recorded and showed significant difference ( $p < 0.05$ ) between the maturity stages (Table 1). As the ripening process proceeds the lightness value ( $L^*$ ) decreases from 50.53 (unripen) to 33.72 (ripen) upon ripening process. This is because the darkening of tomato takes place with amassing of carotenoids upon ripening and decreasing green colour. Declining of yellowness from 19.72 (unripen) to 16.40 (ripen) could be due to effects of  $\beta$ - carotene and major effects from the red colour contributed by lycopene (Bui, Makhlof, & Ratti, 2010) [10]. Meanwhile the redness value ( $a^*$ ) increases which was confirmed with the colour value results of ripen tomatoes.

The positive value  $a^*$  of ripen tomato (21.82) shows the redness of tomatoes and negative value of  $a^*$  (-4.74) represents the greenness of unripen tomatoes. This could be due to the lycopene synthesis associated with the degradation of chlorophyll upon ripening. Similar results were in agreement with the previous study (Ayour, Sagar, Alfeddy, Taourirte, & Benichou, 2016) [4]. The ratio of  $a^*/b^*$  indicates the red colour



index of tomatoes, increases from -0.24 (unripen) to 1.33 (ripen) with ripening and maturation which was confirmed with the findings of ripened tomatoes.

**Table 1:** Colour parameters of 'Shivam' variety tomato at different maturity stages

Maturity stages	Colour Value			
	L*	a*	b*	a*/b*
Unripen tomato (MG)	50.53±0.05 <sup>b</sup>	-4.74±0.04 <sup>a</sup>	19.72±0.03 <sup>b</sup>	-0.24±0.02 <sup>a</sup>
Ripen Tomato (RR)	33.72±0.03 <sup>a</sup>	21.82±0.06 <sup>b</sup>	16.40±0.02 <sup>a</sup>	1.33±0.04 <sup>b</sup>

Different letters a & b in the superscript within the same column represent the significant differences among the samples ( $p < 0.05$ ; t test: Two samples assuming unequal variance)

### 3.3 Firmness

During ripening process fruit's firmness and texture plays a vital role in the organoleptic properties of fruits (Ghai, Gupta, & Gupta, 2016) [15]. Moreover, firmness property influences the commercialization, marketability and shelf life of tomatoes. Change in these textural properties are an indicator for measuring the ripening stage taken place. The firmness of tomatoes is generally reduced as the process of ripening occurs during post-harvest conditions. (Tilahun *et al.*, 2017) [35]. The results obtained for firmness were significantly different ( $p < 0.05$ ) between the maturity stages (Table 1). In this study, the firmness of ripened tomatoes rapidly decreased (1.36 N/mm), while un-ripened tomatoes showed comparatively higher value (3.28 N/mm). This could be because the fresh produce undergoes compositional and structural modifications due to an increase in water-soluble polyuronides and depolymerization of pectin during the ripening process (Lee & Hwang, 2017) [22]. These changes lead to soften the tissue and accelerate microbial damages, which can result in a decreased fruit quality. Moreover, solubilization and degradation of cell wall polymers accompanied with high enzymatic activity would result in degradation of outer tissue strength and inter-cellular adhesion (Fan, Zhao, Wang, Cao, & Jiang, 2017) [12]. Besides, transportation of unripened tomatoes would result in lower bruises and shock, also these types of tomato could be stacked in greater heights than ripen tomatoes.

### 3.4 Lycopene content

The red colour is a typical quality trait in commercially grown tomato fruit (*Solanum lycopersicum* L.) and it is mainly due to the presence of the lycopene pigment. Lycopene

categorized under a large group of carotenoids and it can be noticeable in both skin and pulp of tomatoes (Borghesi, Ferrante, Gordillo, & Rodríguez-Pulido, F. J., Cocetta, G., Trivellini, A.,... & Heredia, 2016) [8]. It is predominant carotenoid in tomatoes, also plays a significant role pigmentation of fruits with red, yellow and orange colour. Moreover, lycopene exhibits higher antioxidant activity and has the strongest radical scavenging activity among 600 natural origin carotenoids (Alda *et al.*, 2009) [1]. Lycopene is good indicator of the maturation level of tomatoes. Lycopene content in ripening tomatoes was higher (12.96 mg/100g) when compared to the un-ripened tomatoes (0.49 mg/100 g) and were significantly different ( $p < 0.05$ ) as shown in Table 1. With the advancement of maturity, a massive accumulation of lycopene may have resulted in rapid degradation of chlorophyll upon storage (Tadesse, Ibrahim, & Abteaw, 2015). Liu *et al.* (Liu, Shao, Zhang, & Wang, 2015) [33] reported that a rapid increase in lycopene content is as related with a drastic increase in ethylene production during the onset of the ripening process. Besides, lycopene content is highly dependent on several factors such as cultural practices, environmental conditions and genotype (Serio, Leo, Parente, & Santamaria, 2007) [37].

### 3.5 Ascorbic acid content

Ascorbic acid is also well-known as vitamin C or L-ascorbic, it is not only recognized as a co-factor in various biochemical reactions also an essential nutrient for human beings. Besides, it is potential in scavenging reactive oxygen species with its soluble antioxidant properties (Ivanov, Ivanov, Tsukanov, Gafarov, & Obyedkov, 2016) [18]. A major difference was seen in the ascorbic acid content at various maturity levels. ( $p < 0.05$ ) as shown in Table 2. In this study, results of ascorbic acid content revealed that unripened tomatoes had lowest level (20.3 mg/100 g), which gradually increased upon ripening in the ripened tomatoes (35.5 mg/100 g). These results were in accordance with the previous study (Bhandari & Lee, 2016) [7]. The author demonstrated that ascorbic acid tends to increase continuously from the breaker stage to red stage of tomato. These changes in ascorbic acid content could be due to the oxidative privation of ascorbic acid as the cellular respiration rate increases with the commencement of the ripening process which is a physiological characteristic of climacteric fruits including tomatoes (N'Dri *et al.*, 2010) [26].

**Table 2:** Physicochemical properties of 'Shivam' variety tomato at two different maturity stages

Maturity stages	Physico-chemical properties					
	Firmness (N/mm)	pH	TSS ( <sup>o</sup> Brix)	TA (%)	Lycopene (mg/100g)	Ascorbic acid (mg/100g)
Unripen tomato (MG)	3.28±0.02 <sup>b</sup>	3.6±0.01 <sup>a</sup>	3.7±0.02 <sup>a</sup>	0.56±0.03 <sup>b</sup>	0.49±0.07 <sup>a</sup>	20.3±0.08 <sup>a</sup>
Ripen tomato (RR)	1.36±0.04 <sup>a</sup>	4.2±0.02 <sup>b</sup>	5.1±0.03 <sup>b</sup>	0.47±0.02 <sup>a</sup>	12.96±0.09 <sup>b</sup>	35.5 ±0.12 <sup>b</sup>

Different letters a & b in the superscript within the same column represent the significant differences among the samples ( $p < 0.05$ ; t test: Two samples assuming unequal variance).

### 3.6 Respiration rate

Respiration is the most important metabolic activity that accompanies the natural ripening process, senescence and consequently leads to deterioration of the fresh produce during the storage period. Also, the respiration rate of fruit is the most important factor in determining postharvest quality in terms of weight loss, firmness, pigment synthesis and ethylene production.

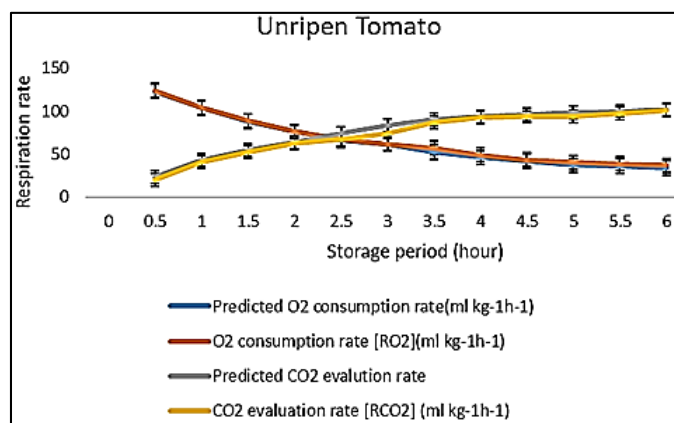
During postharvest storage, the respiration rate of tomatoes increases as it proceeds towards ripening and maturity stage (Fagundes *et al.*, 2015) [11]. So, respiration study was

conducted with the 'Shivam' variety tomatoes at two different maturity stages unripen and ripen.

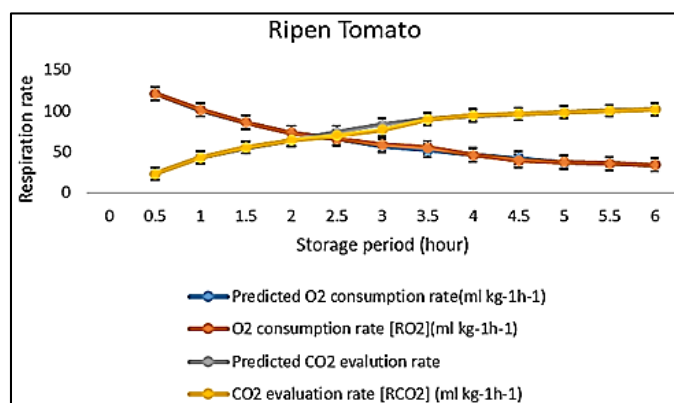
The changes in the respiration rate of un-ripen and ripen tomatoes are shown in Fig 2 and Fig 3 respectively. Total volume of the container was 1950 ml<sup>3</sup> for 0.2 kg of tomato with 167.504 ml<sup>3</sup> volume. Later, void volume of the container was calculated and noted as 1782.496 ml<sup>3</sup>. The results suggested that O<sub>2</sub> percent decreased with time and fell below <1% and CO<sub>2</sub> percent increased from 0.03 – 20% in 40 – 50 long hours at 20°C.

The change in concentrations of  $O_2$  and  $CO_2$  was higher for ripen tomatoes when compared to unripened ones. The respiration rate was calculated with predicted gas concentrations at 20 °C for both maturity stages. It was noticeable that respiration rate ( $CO_2$  released  $ml\ kg^{-1}hr^{-1}$ ) of unripened tomatoes decreased with decreased  $O_2$  concentration. Similar trend was also noticed for the ripen tomatoes.

This confirms that concentrations of  $O_2$  and  $CO_2$  in the airtight glass chamber influences RR. This also suggests that ambient condition i.e. 21% of  $O_2$  reported higher respiration rate. As the tomatoes ripen, the metabolic activities remain to be greater and the respiration rate increases.



**Fig 2:** Respiration Rate of 'Shivam' Variety Tomato at Unripen stage



**Fig 3:** Respiration rate of 'Shivam' Variety Tomato at Ripen Stage

#### 4. Conclusion

The tomatoes procured at different ripening stages were studied for their physicochemical and physiological changes. The present study confirmed that these properties are statistically varying ( $p < 0.05$ ) with the maturity stages and substantially improved the functional properties of tomatoes. The results obtained with un-ripen (MG) and ripen (RR) tomatoes reported textural softening, loss of firmness, increase in pH, TSS,  $a^*$ ,  $a^*/b^*$  values, respiration rate and decrease in  $L^*$ ,  $b^*$  and TA values. Higher values of ascorbic acid and lycopene were found in ripened tomatoes, indicating their possible antioxidant properties. Overall, the results suggested that the organoleptic characteristics and functional value of tomatoes improve with the ripening process. These findings will support the pack house and processors to select proper packaging methods to extend the shelf life of 'Shivam' variety tomatoes during supply chain management.

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