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Physiological and biochemical changes in tomato fruit (*Solanum lycopersicum* L.) during growth and ripening cultivated in Vietnam

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Tomato (*Solanum lycopersicum* L.) is one of the most widely grown and consumed vegetables in many countries, including Vietnam. Tomato is a nutritious food that enhances the body's resistance. This paper presents research results on some physiological indicator (pigments content), and biochemical indicators (reducing sugar content, starch, total organic acid, vitamin C, pectin, tannin, α-amylase enzyme, catalase enzyme, peroxidase enzyme) of tomatoes during growth and ripening cultivated in Vietnam, thereby determining the physiological ripening time of the fruit (the most appropriate time for fruit harvest). The results showed that significant changes occurred in pigments content, reducing sugar content, starch, total organic acid, vitamin C, pectin, tannin, α-amylase enzyme, catalase enzyme, peroxidase enzyme of tomatoes from formation to fruit ripening. Through the research process, we found that tomatoes achieve the best quality to harvest when fruits are 46 days old. The results of this study also provide additional and useful information for fresh consumption and processing as well as the use of tomatoes.

Keywords: Tomato, *Solanum lycopersicum*, biochemical indicators; physiological indicators, ripening.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops and is widely consumed in the world. Tomatoes are grown quite popular in tropical and subtropical climates (Morton, 1982; Bhatia et al., 2004). With the advantage of easy-to-plant, nutritious fruits and high yield, tomato plants have become an important crop in the world, contributing to economic development and improving the lives of farmers (Sulunke et al., 1974; Nicola et al., 2009; Erba et al., 2013). Studies have shown that tomatoes contain many nutrients that are beneficial to human health. Eating tomatoes has been shown to be associated with a decreased risk of chronic diseases, such as cancer and cardiovascular disease (Agarwal and Rao, 2000; Willcox et al., 2003). Currently, the production and planting area of tomato plants is on the rise due to higher economic efficiency than other crops, which stimulates gardeners to invest boldly in growing tomatoes.

There have been many studies on the physiological and biochemical changes of fruits at different stages of development (Hrazdina et al., 1984; Conde et al., 2008; Patel et al., 2011).

Research on physiological and biochemical changes of tomato fruit at different stages of development has been carried out many years ago (Dalal, 1965), and in many different ecological regions (Raffo et al., 2002; Guil-Guerrero and Rebolloso-Fuentes, 2009; Pinela et al., 2012; Opara et al., 2012). However, there are currently no full reports on the physiological and biochemical changes of tomatoes from formation to fruit ripening in Vietnam. The physiological and biochemical properties of fruits are affected by many pre- and post-harvest factors such as cultivation, the ripening stage at harvest and agricultural techniques (Dumas et al., 2003; Arah et al., 2015). Kamis et al., (2004) have shown that the physiological and biochemical properties of tomatoes are most affected at maturity and ripening stages.

In Vietnam, tomatoes are grown relatively popular with many new varieties for high and stable yield. However, the harvesting and preservation of tomatoes has not really had a scientific basis but based on the experience of gardeners, this makes the majority of tomatoes in the market not yet ensure quality, affecting the health of consumers. Therefore, we conducted fruit sampling, analyzing the physiological and biochemical indicators of tomatoes from formation to fruit ripening. Thereby finding out the physiological ripening time of tomatoes to help consumers use and preserve tomatoes better.

MATERIALS AND METHODS

Research materials

The tomato variety NHP11 (Product of Nong Hung Phu Company Limited, Vietnam) is grown in Quang Xuong district, Thanh Hoa province, Vietnam. Physiological and biochemical indicators were analyzed at the Plant Laboratory, Hong Duc University.

Sample collection method

Samples were collected according to the mixed sampling method. Across the experimental area, we collected samples at many points, on many plants, these plants were growing normally, pest-free, and care conditions are quite even.

When the fruit has just been formed, we conducted the fruit marking on the experimental trees, recording data by day and month. Each stage of the study we collected samples from all plants: 5-10 fruits per tree. The collected samples are mixed well, then put into plastic bags and labeled.

Samples were collected in the morning, then refrigerated and transferred to the laboratory. Part of the sample is used to immediately analyze indicators of pigments content, enzymes, vitamin C. The rest of the sample is stored at -80 ^{o}C to analyze other indicators.

Analysis of physiological indicators

Determination of pigment content in the peel by spectral method (MacKinney, 1941; MacLachlan and Zalik, 1963)

* Chlorophyll content is calculated by the formula:

C_a (mg/L) = 9.784 x E_{662} – 0.990 x E_{644}

C_b (mg/L) = 21.426 x E_{644} – 4.650 x E_{662}

$C_{(a+b)}$(mg/L) = 5.134 x E_{662} + 20.436 x E_{644}

* Carotenoids content is calculated by the formula:

$C_{carotenoids}$(mg/L) = 4.695 x $E_{440.5}$ – 0.268 x $C_{(a+b)}$.

Then the pigment content per 1g of fresh fruit peel is calculated by the formula:

$$A = \frac{C \times V}{P \times 1000}$$

Where: E_{662}, E_{644} *and* $E_{440.5}$ are the results of measuring chlorophyll color at wavelengths of 662 nm, 644 nm and 440.5 nm; C_a, C_b, C_{a+b} are respectively chlorophyll content a, b and total; *A* is the content of chlorophyll in 1g of fresh fruit peel; *C* is the chlorophyll content of the pigment extract (mg/L); *V* is the volume of pigment extract (10 mL); *P* is the sample mass (g).

Analysis of biochemical indicators

Determination of reducing sugar content, starch by Bertrand method (Mui, 2001)

Reducing sugar content is calculated to the formula:

$$X = \frac{a \times V_1 \times 100}{V \times b \times 1000}$$

Where: *X* is the reducing sugar content (%); *a* is the weight (mg) of glucose obtained when examining the table for volume $KMnO_4$ 1/30N (mL) used for titration of the laboratory sample minus the volume $KMnO_4$ 1/30N (mL) titration in the control sample; *V* is the volume of the diluted sample solution (mL); V_1 is the volume of the analyzed sample solution (mL); *b* is the weight of the test sample (g); *100* is the conversion factor to %; the coefficient converts g to mg.

The starch content is calculated by the formula:

$$Y = \frac{a \times V_1 \times 100 \times 0.9}{V_2 \times b}$$

Where: *Y* is the content of starch (%); *a* is the amount of reducing sugar; V_1 is the volume of

analyzed sample solution (mL); V_2 is the volume of diluted sample solution (mL); *b* is the weight of analyzed sample (g); *100* is the conversion factor to %; *0.9* is the coefficient of converting glucose into starch.

Determination of total organic acid content (Chau et al., 1998)

Total organic acid content is calculated by the formula:

$$X = \frac{a \times V_1 \times 100}{V_2 \times P}$$

Where: *X* is the amount of total organic acid present in the extract; *P* is the amount of analytical sample (g); V_1 is the total volume of extract (mL); V_2 is the volume to be titrated (mL); *a* is the amount of 0.1N NaOH titration (mL).

Determination of vitamin C content by titration method (Arya et al., 2000)

Vitamin C content is calculated by the formula:

$$X = \frac{V \times V_1 \times 0.00088 \times 100}{V_2 \times b}$$

Where: *X* is the content of vitamin C in the materials (%); *V* is the volume of diluted sample solution (mL); V_1 is the volume of 0.01N I_2 solution (mL); V_2 is the volume of analyzed solution (mL); *b* is the weight of sample (g); *0.00088* is the weight (g) of vitamin C which was equivalent to 1 mL of 0.01N I_2.

Determination of α-amylase enzyme activity on spectrophotometer at 656nm wavelength (Mui, 2001)

α-amylase enzyme activity is calculated by the formula:

$$HdA = \frac{6.889 \times C - 0.029388}{W}$$

$$C = \frac{OD_1 - OD_2}{OD_1} \times 0.1$$

Where: , with *C* is the amount of starch hydrolyzed; OD_1 is the optical density at the control vessel; OD_2 is the optical density at the experimental flask; *0.1* is the amount of starch analyzed; *W* is the amount of analytical enzyme composition (g).

Determination of catalase enzyme activity by A.N.Bac and A.I.Oparin method (Mui, 2001)

Catalase enzyme activity is calculated by the formula:

$$X = \frac{(V_1 - V_2) \times 1.7 \times V_x}{V_c \times 30 \times 0.034 \times a}$$

Where: *X* is the catalase activity calculated by the number of micromol H_2O_2 resolved in 1 minute under the action of catalase enzyme in 1g sample at 30°C; V_1 is the volume of $KMnO_4$ 0.1N used to titrate H_2O_2 in the control vessel (mL); V_2 is the volume of $KMnO_4$ 0.1N used to titrate H_2O_2 in the experimental flask (mL); V_x is the total volume of enzyme extract (mL); V_c is the volume of analytical extract (mL); *a* is the weight of the crushed sample (g); *1.7* is the conversion coefficient from the titrant $KMnO_4$ 0.1N to mg H_2O_2 resolved; *30* is the duration of enzyme action (min); *0.034* is the conversion factor of mg to micromol.

Determination of peroxidase enzyme activity by A.N.Boiarkin method on spectrophotometer (Mui, 2001)

Peroxidase enzyme activity is calculated by the formula:

$$A = \frac{E \times (a \times b)}{p \times d \times t}$$

Where: *A* is the peroxidase activity in 1g of sample; *E* is the selected optical density; *a* is the total volume of extract (mL); *b* is the degree of extract dilution; *p* is the weight of the plant sample (g); *d* is the cup thickness (cm); *t* is the time (s).

Determination of pectin content by calcium pectate precipitation method (Mui, 2001)

The amount of pectin taken for saponification (B) is calculated by the formula:

$$B = \frac{W \times V_2}{V_1}$$

Where: *W* is the weight of pectin introduced into the solution (g); V_1 is the volume of the initial pectin solution (mL); V_2 is the volume of pectin solution taken for saponification (mL).

The content of calcium pectate is calculated by the mass of filter paper with precipitate minus the amount of filter paper without precipitation. The content of pectin (P) is calculated by the formula:

$$P = \frac{W \times 0.92 \times 100}{B}$$

Where: *W* is the amount of the calcium pectate precipitate (g); *B* is the amount of pectin taken for saponification (g); *0.92* is the transfer coefficient except for the calcium content of the precipitate (meaning pectin accounts for 92% of the mass of calcium pectate); *100* is the conversion factor to indicate the result in %.

Determination of tannin content by Leventhal method (Chau et al., 1998)

The tannin content is calculated by the formula:

$$X(\%) = \frac{(a-b)\times V \times k \times 100\%}{V_f \times g}$$

Where: *X* is the tannin content (%); *a* is the volume of $KMnO_4$ used for titration in the flask (mL); *b* is the volume of $KMnO_4$ used for titration in the control vessel (mL); *V* is the total volume of extract (mL); V_f is the volume of the analyzed extract (mL); *g* is the weight of the analyzed sample (g); *k* is the tannin coefficient = 0.00582 (every 1 mL $KMnO_4$ 0.1N is equivalent to 0.00582g tannin).

Statistical analysis

All experiments were conducted three times independently. The results are expressed as mean values and standard deviation (SD). The results were subjected to an analysis of variance. Data were compared according to Tukey's test using IRRISTAT software (version 5.0) for Windows computers (IRRI, 2005).

RESULTS AND DISCUSSION

Changes in the pigment content of tomato during maturation

The data from Table 1 shows that, in the first weeks, the content of chlorophyll in tomato peel is high. The content of chlorophyll a is 0.2657 mg/g fresh peel, chlorophyll b is 0.4548 mg/g fresh peel and total chlorophyll is 0.7205 mg/g fresh peel at 7 days old. The content of chlorophyll in tomato peel reaches the highest value at 26 days old (Chlorophyll a is 0.3526 mg/g fresh peel, chlorophyll b is 0.6419 mg/g fresh peel, chlorophyll a+b is 0.9945 mg/g fresh peel), at this time the tomato fruit is dark green. After 26 days old, the content of chlorophyll gradually decreases and decreases rapidly at 46 and 50 days old, this is because fruits begin to move to the stage of ripening, decomposed chlorophyll pigment and carotenoid pigment are synthesized (Gierson and Kader, 1986).

Table 1. **Content of pigment systems in tomato peel at different maturation stages**

Age of fruit development	**Chlorophyll a** *(mg/g fresh peel)*	**Chlorophyll b** *(mg/g fresh peel)*	**Chlorophyll a+b** *(mg/g fresh peel)*	**Carotenoids content** *(mg/g fresh peel)*
7 days	0.2657	0.4548	0.7205	0.0128
14 days	0.2845	0.5662	0.8507	0.0634
20 days	0.3239	0.6125	0.9364	0.0965
26 days	0.3526	0.6419	0.9945	0.1287
32 days	0.2809	0.3606	0.6415	0.1863
37 days	0.1962	0.3223	0.5185	0.2456
42 days	0.1237	0.2158	0.3395	0.3418
46 days	0.0941	0.1649	0.2590	0.4235
50 days	0.0852	0.1083	0.1935	0.4827

Carotenoids content in tomato peel increases with age of fruit development. In the first weeks of tomatoes, low carotenoids content reached 0.0128 mg/g fresh peel at 7 days old. From 7 to 26 days old, the content of carotenoids increased slowly, then increase rapidly according to the ripening of the fruit. At 50 days old, the content of carotenoids reached 0.4827 mg/g fresh peel.

Thus, it can be seen that the reduction of chlorophyll content along with the increase of the carotenoids content of fruit development is suitable for the process of tomato development and reflects the true color of fruit when ripe (Raffo et al., 2002).

Changes in biochemical indicators of tomato during maturation

Changes in reducing sugar content and starch content

The results in Table 2 shows that the content of reducing sugar in the early period of tomato fruit (7 days) is relatively low, reaching 0.852% weight of fresh fruit flesh. From 7 to 26 days old, the content of reducing sugar increased slowly and reached 1.525% when fruit was 26 days old. After this period, the flesh increases rapidly, the cells continue to grow and expand, thus increasing the synthesis of energy and the

components that make up the cell. In the fruit period from 26 to 46 days old, the content of reducing sugar increased rapidly and reached 3.474% when fruit was 46 days old. At this time, some organic acids and starches are converted into sugars. This is the time when tomatoes with a characteristic taste, aroma and tomato harvest at this stage are most appropriate, if harvested earlier will reduce the quality of the fruit. At 50 days old, the content of reducing sugar decreased to 3.293% weight of fresh fruit flesh so the quality of the fruit decreased.

Table 2. Content of reducing sugar and starch in tomatoes at different maturation stages[1]

Age of fruit development	Reducing sugar content *(% weight of fresh fruit flesh)*	Starch content *(% weight of fresh fruit flesh)*
7 days	$0.852^{f} \pm 0.015$	$1.056^{b} \pm 0.008$
14 days	$0.893^{f} \pm 0.018$	$1.234^{ab} \pm 0.031$
20 days	$1.137^{e} \pm 0.009$	$1.327^{a} \pm 0.029$
26 days	$1.525^{d} \pm 0.016$	$1.512^{a} \pm 0.005$
32 days	$2.246^{c} \pm 0.023$	$0.963^{b} \pm 0.014$
37 days	$2.476^{c} \pm 0.011$	$0.752^{c} \pm 0.021$
42 days	$2.805^{b} \pm 0.026$	$0.684^{c} \pm 0.065$
46 days	$3.474^{a} \pm 0.034$	$0.538^{d} \pm 0.103$
50 days	$3.293^{a} \pm 0.041$	$0.504^{d} \pm 0.049$

Note: [1] Numbers represent mean values of three independent replicates ± SD.

In the same data column, values with similar letters represent non-significant differences, values with different letters represent differences in significance (α=0.05) by Tukey's test.

When the fruit has just formed, low starch content only reaches 1.056% weight of fresh fruit flesh (7 days old). After that, saccharose from leaves and peels is transferred into the fruit to provide materials for the synthesis of starch, so the starch content in the fruit increases gradually. The highest starch content was 1.512% at 26 days old. After 26 days old, the content of starch in the fruit decreases due to the strong metabolism in the fruit. Under the action of α-amylase enzyme, starch converts into sugar as a material for energy-generating respiration. When fruit enters the ripening period, starch decomposes into sugar to increase the amount of reducing sugar to create sweetness for the fruit (Patel et al., 2011). During this period, the activity of α-amylase enzyme also increased.

Changes in total organic acid content and Vitamin C content

The data in Table 3 shows that, at the stage when fruit starts to formation, the accumulation of large organic matter amounted to 40.124 lđl/100g fresh fruit flesh. The fruit period from 7 to 26 days old, the total organic acid content increased gradually and reached the highest value of 48.128 lđl/100g fresh fruit flesh at 26 days old. This is because in the fruit, protein exchange processes, hydrocarbon exchange, lipids take place strongly, creating intermediate products such as amino acids, xetoaxit, etc., increasing the content of organic acids (Gierson and Kader, 1986).

The fruit period from 26 to 50 days old, organic acid content decreased due to organic acid used in respiration to provide energy for starch synthesis processes. On the other hand, energy continues to be needed for the biosynthesis of fruit-specific ripening substances such as enzymes for hydrolysis, esters to create aroma for fruit in the ripening period and synthesis of sugar to create sweetness for fruits, resulting in a decrease in total acid content (Prasanna et al., 2007).

The content of vitamin C from 7 to 32 days old increases rapidly, this is a period of strong flesh fruit development and the accumulation of vitamin C along with other nutrients in the fruit. After 32 days, vitamin C content continued to increase, but at a slower rate, the highest value reached 33.680 mg/100g fresh fruit flesh on the 46th day, then vitamin C content decreases. Changes in the vitamin C content of tomato fruits at different stages of maturity are consistent with the research of Opara et al., (2012).

Changes in pectin content and tannin content

The results of the data in Table 4 shows that the content of pectin in tomatoes increased slightly from young fruit to 26 days old. At this

time, pectin content did not increase much (from 1.358% to 1.620% of fresh fruit weight). This is because at this stage, the number of cell changes is small but the size and mass of the cells increase rapidly, so that the content of pectin that makes up the intercellular binder (mainly canxipectate) also increases to ensure the bonding of cells together (Duan et al., 2008). Pectin content decreased sharply in the period from 26 to 50 days old (from 1.620% to only 0.618%). This is a period of ripe fruit, a strong decrease in pectin content during this period due to the increase in the activity of protopectinase enzyme that has dissolved pectin (Brummell, 2006)

Table 3. Content of total organic acid and Vitamin C in tomatoes at different maturation stages[1]

Age of fruit development	Total organic acid content *(lđl/100g fresh fruit flesh)*	Vitamin C content *(g/100g fresh fruit flesh)*
7 days	$40.124^{h} \pm 0.007$	$22.728^{e} \pm 0.031$
14 days	$41.564^{g} \pm 0.025$	$23.115^{e} \pm 0.015$
20 days	$45.015^{d} \pm 0.043$	$25.356^{d} \pm 0.064$
26 days	$48.128^{a} \pm 0.056$	$26.113^{d} \pm 0.057$
32 days	$47.604^{ab} \pm 0.120$	$29.545^{c} \pm 0.032$
37 days	$47.115^{b} \pm 0.068$	$31.167^{b} \pm 0.105$
42 days	$46.428^{c} \pm 0.109$	$32.539^{a} \pm 0.136$
46 days	$44.136^{e} \pm 0.042$	$33.680^{a} \pm 0.005$
50 days	$43.725^{f} \pm 0.016$	$31.129^{b} \pm 0.004$

Note: [1] Numbers represent mean values of three independent replicates ± SD.

In the same data column, values with similar letters represent non-significant differences, values with different letters represent differences in significance (α=0.05) by Tukey's test.

Table 4. Content of pectin and tannin in tomatoes at different maturation stages[1]

Age of fruit development	Pectin content *(% fresh fruit weight)*	Tannin content *(% fresh fruit weight)*
7 days	$1.358^{b} \pm 0.017$	$5.474^{a} \pm 0.035$
14 days	$1.403^{b} \pm 0.015$	$5.265^{a} \pm 0.146$
20 days	$1.552^{a} \pm 0.036$	$4.681^{b} \pm 0.238$
26 days	$1.620^{a} \pm 0.047$	$3.506^{c} \pm 0.065$
32 days	$1.372^{b} \pm 0.027$	$3.102^{c} \pm 0.136$
37 days	$1.168^{c} \pm 0.109$	$2.793^{d} \pm 0.069$
42 days	$1.075^{cd} \pm 0.064$	$1.325^{e} \pm 0.072$
46 days	$0.892^{d} \pm 0.072$	$1.218^{e} \pm 0.049$
50 days	$0.618^{d} \pm 0.048$	$0.673^{f} \pm 0.058$

Note: [1] Numbers represent mean values of three independent replicates ± SD.

In the same data column, values with similar letters represent non-significant differences, values with different letters represent differences in significance (α=0.05) by Tukey's test.

Tannin in tomato fruit has a relatively high content from 7 days old (reached 5.474%). The content of tannin is high in the early period of making tomato fruit acrid and pungent. The tannin content in tomatoes gradually decreases with age and rapidly decreases in the period of 26 to 42 days old. This decline is due to hydrolytic tannin being decomposed into pirogalol and CO_2, making the tomato turn to ripening (Del Bubba et al., 2009). In the period of fruit maturity from 46 to 50 days old, tannin content decreased to only 0.673% at 50 days old, makes tomatoes ripen soft, not acrid.

Changes in the activity of enzymes α-amylase, catalase, peroxidase

Table 5 shows that, when tomatoes have just formed at 7 days old, α-amylase enzyme activity is low (reached 0.019 UI/g/h) and increases slowly between 7 and 14 days old. In this period, the fruit will enhance the accumulation of starch reserves.

Table 5. Activity of enzymes α-amylase, catalase, peroxidase in tomatoes at different maturation stages[1]

Age of fruit development	α-amylase activity *(UI/g/h)*	Catalase activity *(μM H_2O_2/g/min)*	Peroxidase activity *(UI/g/sec)*
7 days	$0.019^{e} \pm 0.002$	$3.019^{f} \pm 0.040$	$0.052^{f} \pm 0.003$
14 days	$0.022^{e} \pm 0.002$	$5.637^{e} \pm 0.015$	$0.069^{e} \pm 0.007$
20 days	$0.036^{d} \pm 0.004$	$6.125^{d} \pm 0.026$	$0.094^{d} \pm 0.001$
26 days	$0.042^{d} \pm 0.001$	$7.054^{d} \pm 0.016$	$0.105^{d} \pm 0.005$
32 days	$0.049^{d} \pm 0.013$	$9.245^{c} \pm 0.028$	$0.135^{c} \pm 0.006$
37 days	$0.064^{c} \pm 0.009$	$10.806^{a} \pm 0.064$	$0.120^{c} \pm 0.012$
42 days	$0.073^{b} \pm 0.005$	$10.241^{b} \pm 0.032$	$0.185^{b} \pm 0.009$
46 days	$0.081^{a} \pm 0.021$	$10.138^{b} \pm 0.058$	$0.206^{b} \pm 0.002$
50 days	$0.066^{c} \pm 0.006$	$9.264^{c} \pm 0.027$	$0.245^{a} \pm 0.003$

Note: [1] Numbers represent mean values of three independent replicates ± SD.

In the same data column, values with similar letters represent non-significant differences, values with different letters represent differences in significance (α=0.05) by Tukey's test.

From 14 days old onwards, α-amylase enzyme activity in fruits increased rapidly and reached a peak at 46 days old (0.081 UI/g/h). At this time the fruit enters the ripening stage, so there is a strong resolution of starch under the action of amylase enzyme to create sugar as a material to provide respiratory breakdown and to create sweetness for the fruit. Therefore, at this stage, the content of reducing sugar will increase and the amount of starch in the fruit will gradually decrease (Jain et al., 2001). After 46 days, the enzyme amylase activity decreased.

Since the fruit has just formed, the catalase activity has been very high reaching 3.019 μM H_2O_2/g/min at 7 days old. Catalase activity increased gradually from 7 to 37 days old, reached the highest value at 37 days old with 10.806 μM H_2O_2/g/min. During this period, the metabolism took place strongly, resulting in a rapid increase in mass, strong oxidation reactions, H_2O_2 created a lot. High catalase activity, enhance H_2O_2 resolution, detoxify cells. In the period from 37 to 50 days old, catalase activity decreased, the result was the accumulation of sugar, starch, water, oxidation reactions slowed down, H_2O_2 produced less.

From 7 to 32 days old, the activity of peroxidase enzyme was low and increased slowly (from 0.052 UI/g/sec to 0.135 UI/g/sec). Because at this time, the oxidation process of substances is strong, has created a large amount of H_2O_2, the resolution of H_2O_2 belongs to catalase. From 32 to 50 days old, peroxidase enzyme activity increased rapidly (from 0.135 UI/g/sec to 0.245 UI/g/sec). This is due to the oxidation of reduced substances, lower H_2O_2 concentration in the fruit, H_2O_2 resolution process is undertaken by peroxidase. At this time the peroxidase enzyme catalyzes the decomposition reaction of tannin so that the fruit enters the ripening stage, creating many ring compounds. In addition, this enzyme catalyzes the metabolic reactions of ring compounds, indole, and amines (Patel et al., 2011). On the other hand, it is also involved in the production of ethylene - the hormone that stimulates ripening (Ku et al., 1970).

The results of the study on changes in the activity of amylase enzyme, catalase and peroxidase in tomato fruits are consistent with the research of Patel et al., (2011), when studying the changes in physiological and biochemical indicators of sunberry fruit during growth and ripening.

CONCLUSION

The pigment system of tomato peel has low chlorophyll a content, chlorophyll b content is high, gradually increasing from the fruit has just formed to 26 days old, then reduce rapidly until the fruit is fully ripening. In contrast, low carotenoids content from fruit formation to 26 days old, then increase rapidly until the fruit is fully ripening.

The starch content increases gradually from the beginning and reaches the maximum when the fruit is 26 days old, then gradually decreases. Reducing sugar content is low until fruit reaches 26 days old, then increases rapidly to 46 days old and then gradually decreases. Total organic acid

content and vitamin C increased continuously and reached maximum at 46 days old, then decreased slightly.

The content of pectin in tomatoes increased slightly from young fruit to 26 days old. From 26 to 50 days old, pectin content decreased sharply. The tannin content in tomatoes gradually decreases with age and rapidly decreases in the period of 26 to 42 days old. α-amylase activity fluctuates in accordance with the fluctuation of starch and reducing sugar according to the development age of the fruit. The catalase activity gradually increases and reaches its maximum at 46 days old, then gradually decreases. Peroxidase activity increases continuously until the fruit ripens.

Over the course of the study, we found that tomatoes achieved the best quality when they were 46 days old. Therefore, this is the time to harvest the most appropriate. If harvested earlier or later, the quality of the tomato fruit will be significantly reduced.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

LVT and BBT conceived the idea and designed the experiments. LVT, VTT and LQT implemented the experiments. LVT, BBT and NTK analyzed the research data. LVT and BBT wrote the manuscript. All authors agreed with the final version of the manuscript.

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