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RESEARCH ARTICLE

Effects of harvest ripeness on storage quality of tomato fruits

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ABSTRACT

For studying the different recovery maturity influence on tomato postharvest storage quality, in different harvest maturity tomato (green ripe period, color-changing period, red period) as experiment material, put it in 3℃ and 28℃ temperature storage, and the determination of three different harvest maturity tomato in weightlessness rate, decay rate in the process of storage, reducing sugar content, titratable acid content, lycopene content and the content of ascorbic acid and so on six indicators, according to the fuzzy weight methods to establish comprehensive evaluation index weights, determine the harvest maturity of science. The results showed that under two different temperature environments, the highest comprehensive evaluation index of tomato was 0.6644 and the storage quality was the best. The comprehensive evaluation index of tomatoes harvested in the color-changing period was 0.4709, which was more suitable for storage at 3℃. The comprehensive evaluation index of tomatoes harvested in green ripening period was 0.3919, and the storage quality was relatively poor.

Keywords: Tomato; Ripeness; Effect of storage; Quality; Fuzzy weight methods

INTRODUCTION

Tomato is a perennial herb of tomato subgenus tomato, also known as tomato, persimmon, originated in tropical and subtropical areas(González-Pérez et al., 2021).Fruit taste rich sweet and sour delicious, rich in human body needs a variety of vitamins and minerals, high nutritional value; And can be used as both vegetables and fruits, by the majority of consumers love(Tagele et al., 2022). However, tomato production has significant seasonality, and low temperature in winter and high temperature in summer make storage management of tomatoes after picking a difficult problem. Secondly, as tomatoes are typical fruits of respiratory jump type(Zhang et al., 2017), during postharvest storage and transportation, the fruits will soon mature and become soft or even deteriorate and rot due to respiration, and the postharvest loss accounts for about 24.5% of the total production, which not only causes great difficulties for the transportation, processing and sales of tomatoes in the later stage, but also increases the operating costs of farmers.

At present, the research methods to improve the storage resistance of tomato are mainly divided into physical, chemical and biological methods(You et al., 2022).For example, Zhao et al., (2023) studied the effect of high-voltage electrostatic field intensity of 150 kV/m on the postharvest storage characteristics of tomatoes and found that tomatoes had the best quality when treated for 60 minutes. Taye et al., (2019) treated cherry tomato fruits with 1-MCP at 0.1μL to maintain tomato freshness for up to 15 days. Kaewklin et al., (2018)found that active packaging of chitosan-titanium dioxide nanocomposite membrane could prolong the storage period of tomato fruit. Aragüez et al., (2020) developed a new packaging system - activated boxes of black wheat film containing KMnO - to protect cherry tomatoes from the adverse effects of ethylene and extend their storage life. Luz et al., (2020) used the lactic acid bacteria isolated from tomato and carried out fermentation and used the fermentation products to carry out biological preservation of tomato. These methods have good effect on fruit and vegetable storage, but there are still some limitations, such as high cost, immature technology, difficult adjustment of process parameters, high performance requirements of equipment, etc. (Zhao et al., 2023), and also bring potential health hazards and ecological environmental pollution

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(Zhang et al., 2020; Panahirad et al., 2021). Therefore, a safe, pollution-free and low investment cost storage method is sought. However, the optimum storage temperature and time of tomato with different maturity were different, and the flavor quality was different.

According to the ripening process, tomato can be divided into green ripening stage, color turning stage and red ripening stage (Getinet et al., 2008). In the green ripening stage, the fruit skin is pale green and white, the fruit surface is shiny, the accumulation of nutrients is basically complete, the content of aldehyde is high, and the flavor of grass is green. This stage is in the early stage of respiratory jump, and the storage is good; The skin gradually turns red, the content of volatile substances increases, the fruit taste is more obvious, and it is not suitable for long-term storage. Red ripe period all turned red, soft flesh, fruity flavor, suitable for ready-to-eat but not suitable for storage (Hatami et al., 2012). There are few and incomplete studies on the influence of different harvest maturity and different temperature on tomato storage-tolerance and the trend of nutrient index changes, and there is no unified comprehensive analysis of each nutrient quality. Therefore, with tomato as the research material, this paper studied the storage-resistance and quality changes of tomato through two variables of temperature and different harvesting maturity, and integrated the data by fuzzy weight method, so as to determine a more scientific harvesting maturity, improve the storage-resistance and quality of tomato, thereby reducing the loss of tomato and reducing the cost.

MATERIAL AND METHODS

Experimental materials

The tomato variety is the local big tomato, picked from the farm in Fuxi Township, Emeishan City, Sichuan Province. Immediately after harvest, they were transported back to the laboratory and stored in the conditions of the experiment to ensure their freshness and reduce experimental errors.

Harvest maturity can be divided into the following three categories:

Green maturity period (maturity I): The volume of the fruit becomes more extensive, and the top of the fruit turns from green to white, but red has not yet appeared; Color conversion period (maturity II): the coloration degree of the top of the fruit reaches about 1/4; Red ripening period (Maturity III): The fruit is fully mature, and the pulp begins to soften.

Experimental method

Tomato treatment

This study sets two variables of three different maturities (green ripening period, color conversion period, red ripening period) and two different storage temperatures (3℃ and 28℃). During the storage period, the tomato samples were measured every 1d, and each index was calculated repeatedly three times, and the average value was taken. In the experiment, the fruits of each group of each maturity degree must be similar in size and uniform in shape, free of diseases, insect pests, and mechanical damage (Zhang et al., 2021), and the mass of each group is 4 kg.

Decay rate and Weightlessness rate

The tomato decay rate is slightly modified according to the method of Njie et al., (2022) and calculated according to the following formula:

Decay rate = diseased fruit number/total fruit number *100%

The tomato sample is weighed according to the following formula:

Weightlessness rate = (Weight before storage - Weight after storage)/Weight before storage*100%

Ascorbic acid

According to the official method, the ascorbic acid content was titrated with 2, 6-dichlorophenol (AOAC, 2005). Dissolve about 0.1g of 2, 6-dichloroindophenol sodium with water and fill it with water in a 1000mL volumetric bottle. Refrigerate it in a brown reagent bottle. Add 10mL of freshly prepared sample solution into a conical bottle, titrate with blue 2, 6-dichlorophenol indophenol standard solution, and shake while titrating until complete reaction. When the color of the solution in the beaker becomes light red and does not fade or change within 15s, the state is the end point of titration and titration is stopped. The consumption of 2, 6-dichlorophenol indophenol solution was recorded to calculate the ascorbate content.

Lycopene content

According to Suwanaruang (2016), hexane: ethanol: acetone (2:1:1)(v/v) mixture was extracted, and finally the absorbance of the sample was determined by spectrophotometry at 503 nm, and the content was calculated according to the formula.

$$\text{Lycopene (mg/kg)} = \text{Abs } 503\text{nm} \times 137.4$$

Reducing sugar

According to Gonçalves et al., (2010), the 1.0 mL sample was evenly mixed with 0.5 mL DNS solution, placed in a boiling water bath for 5 min, transferred to ice water for cooling, then added 4 mL of water, and the absorbance was measured at 540 nm with water as blank. Linear regression method was used to fit the regression curve.

Titratable acid

According to Anthon et al., (2012), Add 10 mL of fruit juice into a 100mL volumetric bottle, add distilled water for constant volume and shake well, take diluent and put it into a cone-shaped bottle, add 1 drop of 1% phenolphthalide indicator, and titrate with a labeled sodium hydroxide solution until the solution turns red for 30s and does not fade. The volume of sodium hydroxide solution consumed by titration was recorded, and the titratable acid content in the sample juice was calculated according to the volume consumed.

Statistical analysis

The significance test of the difference of the experimental data was analyzed by SPSS17.0 statistical software, and the data integration analysis was carried out by fuzzy weight method.

RESULTS AND DISCUSSION

Effect of different harvest maturity on decay rate and weight loss rate

The comparison between Table 1 and 2 indicated that the weight loss rate of tomatoes with different harvest maturity at 28℃ is all higher than 3℃when the tomato was stored to the full maturity stage. As the increase of storage temperature, the weight loss rate of tomatoes will increase accordingly. This is because, in the low-temperature environment, there will be steam water droplets on the surface of the tomato, which resulted in higher water content in the storage environment. Ambient temperature is a key factor affecting fruit transpiration and respiratory metabolism (Petriccione et al., 2015). Gao et al., (2019) also found that the higher the temperature, the faster the transpiration rate, the greater the respiratory intensity, and the weight and water content of tangerine fruits stored at 25℃ were significantly lower than those stored at 5℃. So the internal water evaporation of tomatoes is slower, and the weight loss rate at 3°C is lower than at 28°C.

The decay rate at 3℃ was also lower than that at 28℃. The rotting rate at green ripe stage and red ripe stage was 58.3% at 28℃, twice as much as that at 3℃ respectively. The rotting rate at 28℃ was four times as much as that at 3℃, and there was a significant difference between the two temperatures ($P < 0.05$). It may be that the respiration and transpiration of tomato fruit are inhibited under low temperatures, and the metabolic rate is low, which leads to a higher decay rate at 28℃ than that at 3 ℃. It may also be related to the microbial factor. As one of the important factors affecting fruit decay, the surrounding environment is mainly caused by microbial infection (Aljasser, 2010). For example, Botrytis cinerea can infect tomato fruit at 28℃ and make it rot (Romanazzi et al., 2014). There was a significant difference between the decay rate of tomatoes at two different temperatures and the other two maturities at the color-changing stage ($P < 0.05$), which may be due to the highest respiration rate of tomatoes at the color-changing stage (Basediya et al., 2013), resulting in the highest decay rate at this time. Lower respiratory intensity and transpiration of fruits result in less water loss and therefore lower fruit decay (Olosunde et al., 2016).

Effect of different harvest maturity on ascorbic acid

Fig. 1A has shown that the ascorbic acid content of tomatoes with three different harvest maturity decreased gradually with the increase of storage time at 28 ℃, and the difference of ascorbic acid content of three tomatoes with different harvest maturity during storage was highly significant ($P < 0.01$). Among them, ascorbic acid content was the highest in tomatoes picked at the red ripe stage; After a period of storage, the ascorbic acid content was still the most elevated. Some studies have found that an increase in fruit fructose may increase fruit ascorbic acid,

Table 1: Changes of decay rate and weight loss rate in 28℃ of tomatoes

Recovery Maturity	Late red ripening			Maturity stage		
	Storage Days	Decay rate	Weight Loss rate	Storage Days	Decay rate	Weight Loss rate
Green maturity period	14^{d}	0%^{b}	9.16%^{a}	18^{d}	58.3%^{c}	18%^{a}
Color conversion period	9^{d}	0%^{b}	2.94%^{c}	12^{d}	66.7%^{b}	5.29%^{c}
Red ripe stage	4^{d}	16.7%^{a}	6.32%^{b}	6^{d}	83.3%^{a}	10.45%^{b}

Table 2: Changes of decay rate and weight loss rate in 3℃ of tomatoes

Recovery Maturity	Late red ripening			Maturity stage		
	Storage Days	Decay rate	Weight Loss rate	Storage Days	Decay rate	Weight Loss rate
Green maturity period	20^{d}	0%^{b}	2.46%^{a}	27^{d}	26.7%^{b}	5.34%^{b}
Color conversion period	17^{d}	0%^{b}	2.21%^{a}	23^{d}	16.7%^{c}	4.82%^{c}
Red ripe stage	15^{d}	16.7%^{a}	3.68%^{a}	18^{d}	58.3%^{a}	8.49%^{a}

because the synthesis of ascorbic acid begins with glucose (Stevens et al., 2008).

It can be seen from Fig. 1B that at 3℃, the changing trend in three varieties of tomatoes with different harvest maturity is gradually decreasing. Only the ascorbic acid content in the green ripening stage was significantly lower than that in the color-changing stage and red ripening stage ($P < 0.01$), which is different from that in 28℃. But there was no significant difference in ascorbic acid content between the color-changing and red ripening stages ($P > 0.05$). It indicated that the ascorbic acid content might be related to the color of tomato peel. The deeper the color of tomato peel is, the higher the maturity is, and the higher the ascorbic acid content is. The ascorbic acid content of tomatoes harvested in the green ripening stage decreased significantly in the early storage period. The change tended to be gentle on the 8th day of storage. The ascorbic acid content on the 16th day was close to that of 28℃ in the final ripening stage. This data indicated a metabolism of ascorbic acid oxidation during the storage period of tomatoes and explained the decrease of ascorbic acid in tomatoes in three maturities at two temperatures (Martí et al., 2018). In this process, ascorbic acid peroxidase and ascorbic acid oxidase worked together to ensure the regular metabolic activity of tomato fruit. In the early stage of green ripening fruit storage, the actions of these two enzymes may be higher, leading to a more significant decline in ascorbic acid content in the early stage. The decrease in ascorbate was consistent with the onset of ripening, and the color change was consistent with an increase in the activity of ascorbate oxidase (Stevens et al., 2008).

Effect of different harvest maturity on Lycopene Content

It can be concluded from Fig. 2A that under the storage condition of 28 ℃, the higher the harvest maturity of tomato, the higher the lycopene content. The lycopene content in the green ripening stage was significantly lower than that in the red ripening stage ($P < 0.05$). The lycopene content of tomatoes harvested at three maturities increased with storage time. However, the lycopene increase suddenly increased on the fourth day of the color-changing period (the red ripening period). The lycopene concentration was similar to the lycopene content of tomatoes picked in the red ripening period. However, the lycopene content of tomatoes harvested in the green stage increased suddenly on the 8th day of the red stage. The lycopene increase was minimal throughout the three mature tomatoes in the early and middle storage period; However, the lycopene content increased significantly from 15.3 mg/kg to 36.9 mg/kg from the fourth day. The tomato picked in the color-changing

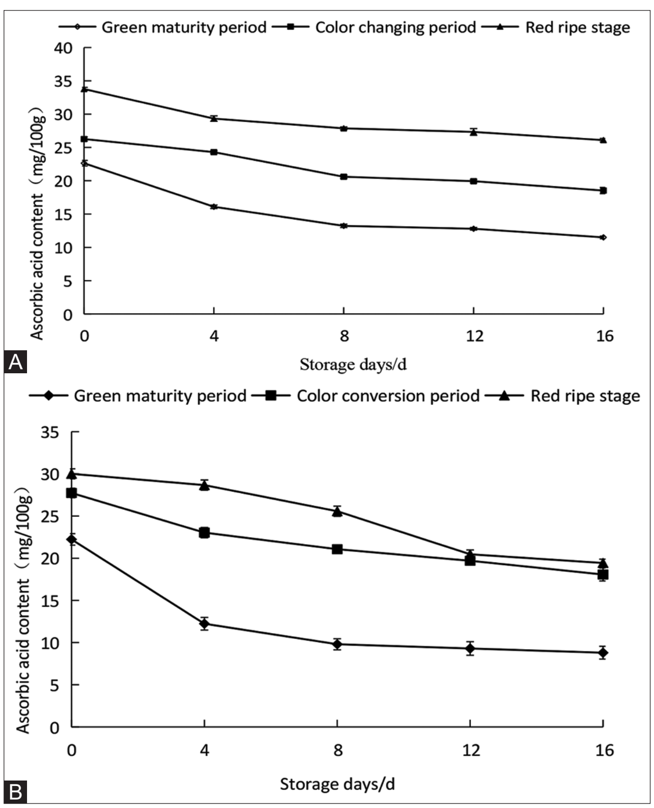

Fig 1. (a) Effects of ascorbic acid content with different harvest in 28℃. (b) Effects of ascorbic acid content with different harvest in 3℃.

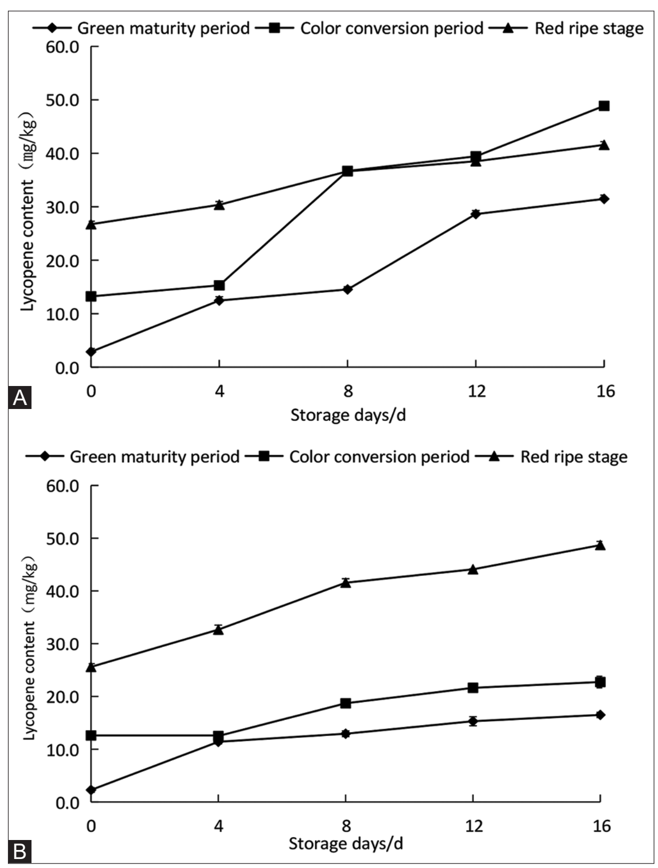

Fig 2. (a) Effects of lycopene content with different harvest in 28℃. (b) Effects of lycopene content with different harvest in 3℃.

period was in the early stage of red maturity. The results showed that when the tomato was fully mature, the fruit changed from green to red, and lycopene content increased.

According to Fig. 2B, the lycopene content of tomato picked in the green ripening stage increased gradually during the whole storage period at 3 ℃, but the increase was not significant; lycopene content was much less than that of lycopene at 28 ℃. In addition, there was no significant difference in lycopene content between the green ripening stage and the color-changing stage ($P > 0.05$). However, the lycopene content of tomatoes harvested in the red ripening stage was significantly higher than that in the green ripening stage and color-changing stage ($P < 0.01$). It was 48.7 mg/kg more elevated than that in 3 ℃ storage. The results showed that the formation of lycopene was inhibited when the temperature was lower than 10 ℃ or higher than 30℃.

Effect of different harvest maturity on the titratable acid content

It can be concluded from Fig. 3A that the highest titratable acid content of tomato harvested at the red ripe stage is 0.45mg/kg at 28 ℃. However, with the extension of storage time, the titratable acid content was only 0.2mg/kg. The content of titratable acid in tomatoes harvested in the color-changing period decreased in the same way. The titratable acid content in tomatoes harvested in the color-changing period was almost the same as that in the red ripening period. There was a significant difference among the three different harvest maturity ($P < 0.05$).

According to Fig. 3B, under the condition of 3℃, the titratable acid content of three kinds of tomatoes with different harvest maturity continued to decline over time, and the downward trend was the same. There were highly significant differences ($P < 0.01$). Compared with tomatoes stored at 28℃, the decrease of titratable acid content at this temperature was smaller. Finally, the titratable acid content of tomatoes harvested at the red maturity stage was the highest at each maturity stage. The results showed that the physiological metabolism of tomato fruit would consume acid during storage (Quinet et al., 2019), resulting in the decrease of titratable acid content.

Effect of different harvest maturity on reducing sugar content

It can be seen from Fig. 4A that under the condition of 28℃, there is no significant difference in reducing sugar content among the three tomatoes with different harvest maturity. The reducing sugar content of tomato harvested at red ripe was the highest; with the increase of storage time, the content of reducing sugar gradually decreased, but the decrease was not significant. The content of

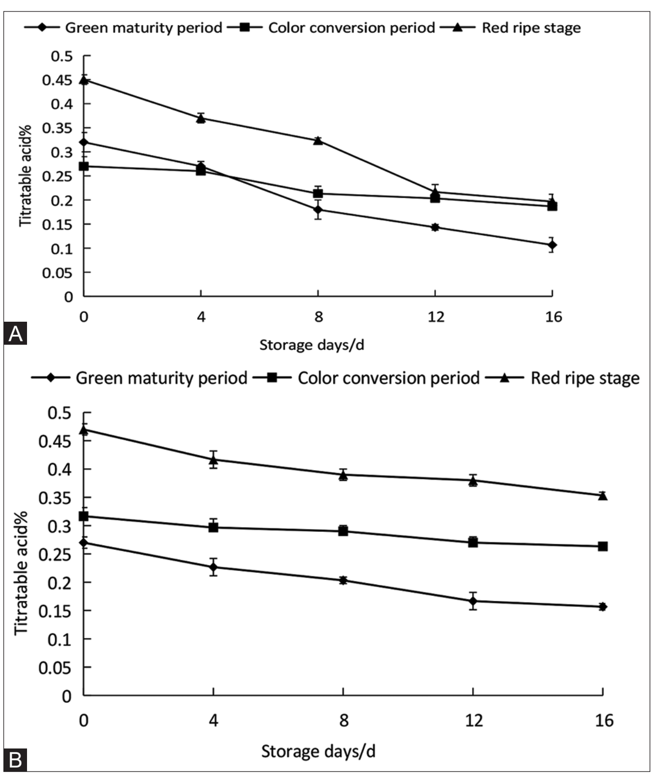

Fig 3. (a) Effects of titratable acid content with different harvest in 28℃. (b) Effects of titratable acid content with different harvest in 3℃.

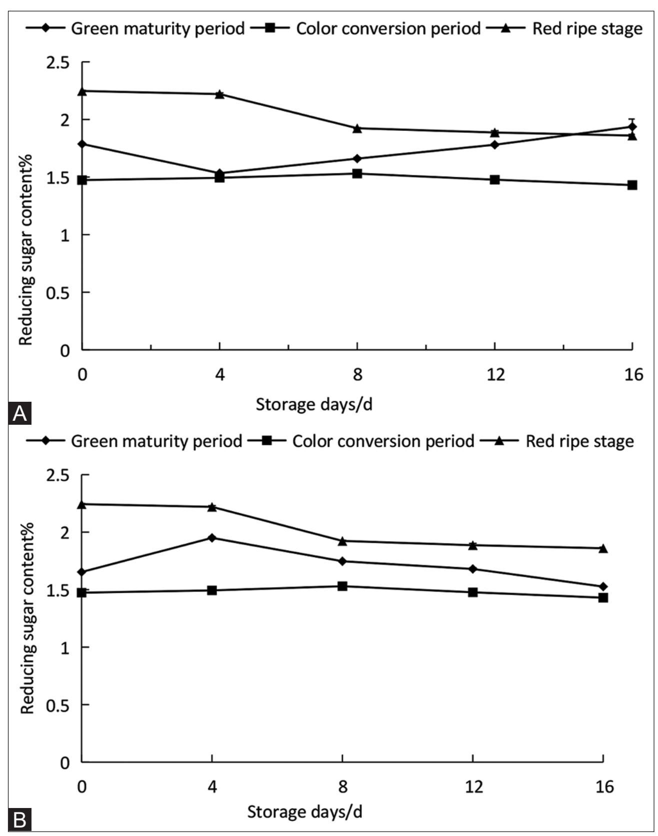

Fig 4. (a) Effects of reducing sugar content with different harvest in 28℃. (b) Effects of reducing sugar content with different harvest in 3 ℃.

reducing sugar in ripe red tomatoes was significantly higher than that in ripe green tomato and color-changing tomatoes ($P < 0.01$). During storage, the sugar content of tomatoes harvested in the color-changing period was almost unchanged and maintained at a relatively stable level. However, the sugar content of tomatoes harvested in the green maturity stage decreased slightly on the fourth day of storage but then gradually increased. After 12 days of storage, reducing sugar content was somewhat higher than that in the red maturity stage. Simultaneously, the reducing sugar content of tomatoes harvested in the green maturity stage was significantly lower than that in the color conversion stage ($P < 0.05$). The results showed that there was starch in the tomato. At 28℃, the activity of amylase in tomato was lower, and the content of reducing sugar was lower than that consumed by respiration (Saqib et al., 2020), so reducing sugar content decreased gradually.

The analysis in Fig. 4B showed that under 3℃, the content of reducing sugar of tomatoes picked in the green ripening stage and color-changing stage increased first and then decreased during the whole storage process. The results implied that 3℃ was the optimum temperature for amylase. When the amylase activity was higher, the content of reducing sugar produced by enzymatic hydrolysis was higher than that of respiration (Jamaleddine et al., 2022). Hence, the content of reducing sugar gradually increased to a small peak. The tomato harvested in the green ripening stage reached the peak value of 1.95 mg/kg on the fourth day of storage. On the eighth day, the highest value of 1.57 mg/kg was obtained for the tomato picked in the color-changing period. The changing trend of red maturity gradually decreased under two different temperature environments; The highest peak value of its content was 2.04 mg/kg at harvest time of red maturity. It was also the highest peak value among different maturity. There were highly significant differences among the three maturities at 3℃ ($P < 0.01$).

Correlation analysis

This experiment used the Pearson correlation coefficient method in SPSS software was to analyze the correlation and significance between the three storage stages and six groups of four groups of experimental data. Table 3 demonstrated that the content of titratable acid in tomatoes stored at the half-ripe stage, red ripe stage, and full ripe stage at two different storage temperatures were significantly negatively correlated with that at the level of 0.01, implying that the content of titratable acid in tomatoes harvested at three maturity stages decreased significantly during storage. Correlation coefficient comparison: 28℃: red ripe stage > green ripe stage > color-changing stage; 3℃: green ripe stage > red ripe stage > color-changing stage. The higher the absolute value of the correlation coefficient is, the more the titratable acid content decreases. In this experiment, at 28℃, the correlation degree of the color-changing period was the lowest; that is, the decreased value of titratable acid content in the color-changing period was the least compared with that in fresh picking. However, the content of reducing sugar in the green ripening stage at 28℃ was significantly positively correlated with that in the fresh harvesting stage at 0.05 level, but not in the color-changing stage, and negatively correlated with that in red ripening stage at 0.05 level. Correlation: green ripe stage > red ripe stage > color-changing stage, which showed that the content of reducing sugar in green ripe stage was the highest. At 3 ℃, there was a significant negative correlation between the green mature stage and new harvest stage and a significant negative correlation between color changing and the red mature stage at the 0.01 level. Therefore, in this experiment, reducing the sugar of tomato harvested in green ripening stage was the least when stored at 3 ℃.

There was a significant negative correlation at the level of 0.05 between the three different maturity tomatoes and the freshly harvested tomatoes, and the correlation coefficient of the tomatoes harvested in the color conversion period was the lowest compared with the newly harvested tomatoes, so the decreased value of ascorbic acid content in the tomatoes harvested in the color conversion period was the minimal during storage. However, the content of lycopene in tomatoes at 28℃ between three different maturities was significantly positively correlated with that at the level of 0.01; Correlation contrast: red ripe stage > green ripe stage > color-cha0nging stage, so the increased value of lycopene content in the red ripe stage was the

Table 3: Correlation and significance analysis of nutritional quality

Storage temperature	Determination index	Green maturity period	Color changing period	Red ripe stage
28℃	Titratable acid content	0.976**	0.961**	0.978**
	Reductive sugar content	0.962**	0.821	0.960**
	Ascorbic acid content	0.969**	0.967**	0.968**
	lycopene content	0.984**	0.972**	0.987**
3℃	Titratable acid content	0.967**	0.964**	0.966**
	Reductive sugar content	0.957*	0.965**	0.959**
	Ascorbic acid content	0.948*	0.944*	0.951*
	lycopene content	0.963**	0.968**	0.976**

largest during storage. At 3 °C, there was a significant positive correlation at the level of 0.01, lower than that at 28°C. Different storage environments and different harvest maturity affect the changes of tomato quality indexes during storage. The titratable acid and ascorbic acid content remained the maximum in tomatoes harvested in the color-changing period (Martínez-Hernández et al., 2016). On the other hand, the reducing sugar content is the highest in tomatoes harvested at the green maturity stage (Al-Dairi et al., 2021). The lycopene content of tomato harvested in the red ripe stage was in its climax. Hence tomatoes can be picked according to a particular nutritional quality utilization way to obtain the best effect. The comparison of tomato changes at different storage times is shown in Fig 5.

Date integration

Due to the contradictory changing trend of some indicators and the incompatibility of each indicator contained in this experiment, it is difficult to analyze the data and draw the final comprehensive conclusion. To solve the difference of each measurement index's unit and change trend, the

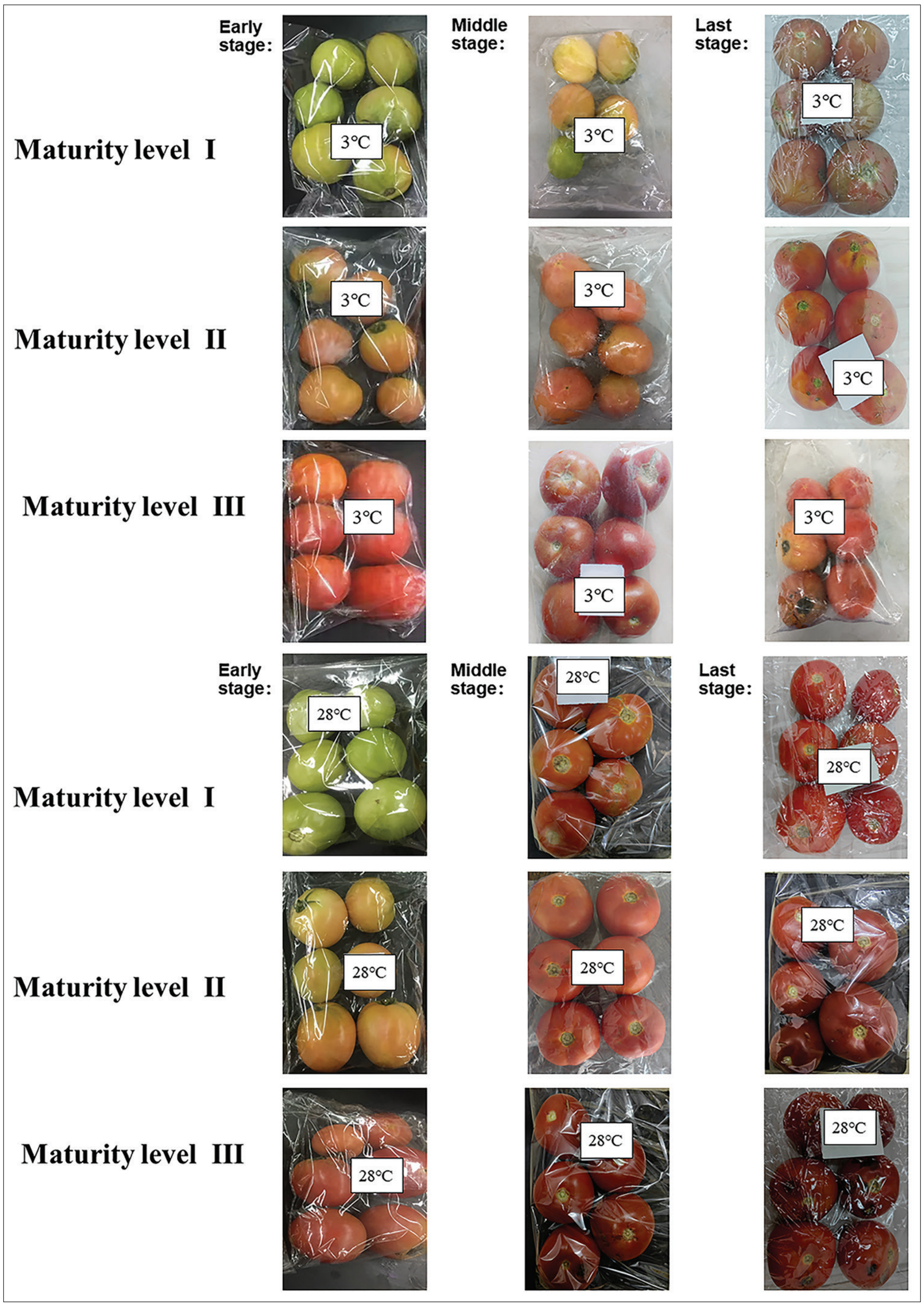

Fig 5. The comparison of tomato changes at different storage times.

variable and increase and decrease trends of each index are unified for analysis. This experiment refers to the method of Ouyang et al., (2022), according to the relevant concepts of fuzzy mathematics, the comprehensive evaluation index is established. Firstly, the data of each group were standardized according to the following formula. Then the reasonable weighting coefficient was given by fuzzy weight method according to the degree of influence of each index quality on the whole tomato storage.

This experiment has taken the hardness, weight loss rate, reducing sugar content, titratable acid content, lycopene content, and ascorbic acid content as the indexes and integrate the indexes mentioned above into a formula: $X_{ab} = (X - X_{min})/(X_{max} - X_{min})$. Thereinto, Xab: the evaluation result of the second detection index in tomatoes of group a, X: the measured result of the second index in tomatoes of group a, Xmax: the maximum value of the measured value of the second index in 6 groups tomatoes, and X: the minimum value of the measured value of the j index in 6 groups tomatoes. For example, suppose the evaluation index of the second factor in tomatoes of group a is X_{ab}, and the weighting coefficient of the second factor is I. In that case, the comprehensive evaluation index (R_a) of the internal quality index of group A tomatoes is $Ra = \sum X_{ab} \times IAB$. By using fuzzy weight method, the indexes of tomatoes in different storage periods with different maturity at different temperatures are evaluated integrally. The standardized values are multiplied by the corresponding weighting coefficients and then summed to obtain the comprehensive evaluation index. The higher the comprehensive evaluation index, the better the storage quality.

The comprehensive evaluation index of tomato was 0.2 × Reducing sugar evaluation index + 0.2 × Titratable acid evaluation index + 0.1 × (1 - decay rate) + 0.2 × Ascorbic acid content evaluation index + 0.2 × Lycopene evaluation index + 0.1 × (1 - weight loss rate)

According to the comprehensive evaluation index and significance analysis in Table 4, some conclusions can be drawn as follow:

There was no significant difference in maturity I (green maturity), maturity II (color change), and maturity I (green maturity) at 28 ℃ and 3 ℃ ($P > 0.05$), but there were significant differences in other maturity and temperature, so the results were meaningful.

Under the storage condition of 28 ℃, the comprehensive evaluation index of maturity III (red maturity stage) was the highest, which was 0.6407, about twice the other two comprehensive evaluation indexes. The highest comprehensive evaluation index of tomato was 0.6644 when harvested at maturity III under 3 ℃. Therefore, if we want to improve the quality of tomatoes during storage, we can choose to harvest at red maturity; However, due to the high decay rate of red ripe tomatoes, it is more suitable for short-term transportation and storage.

It can be seen from the above table that the comprehensive evaluation index of maturity II, that is, the tomato harvested in the changing color period, is 0.4709, and the evaluation index of decay rate is 0.2864. Therefore, if you want to ensure the overall quality of tomato in long-term storage, you can choose the tomato harvested in the color changing period and store it at 3 ℃.

There was no significant difference in the comprehensive evaluation index of maturity III; that is, the tomato harvested in the red mature stage, under the two temperature conditions, and the tomato stored at 3 ℃ was slightly higher. The comprehensive evaluation index of maturity II, the tomato harvested in the color-changing period, was higher at 3 ℃ than at 28 ℃ under two temperatures. The comprehensive evaluation index of maturity I, that is, tomato harvested at Green maturity stage at 28 ℃ was higher than that at 3 ℃. Therefore, although the decay rate and weight loss rate of tomatoes harvested at the green maturity stage at 3 ℃ were lower than those at 28 ℃, the tomato harvested at a higher maturity stage contained higher lycopene and other nutritional indexes soften and change color better.

Table 4: The comprehensive assessment of tomatoes′ quality index

Different harvest maturity	Temperature/℃	Evaluation index						Comprehensive evaluation index
		Weight Loss rate	Decay rate	reducing sugar	Titratable acid	Ascorbic acid	Lycopene	
I	28	0.7065	0.6999	0.3735	0.9904	0.2042	0.3913	0.3919
II	28	0.0448	0.8007	0.0576	0.1538	0.6105	0.5072	0.3813
III	28	0.2620	0.9546	0.7653	0.5192	0.8645	0.6630	0.6407
I	3	0.2691	0.2864	0.5938	0.1719	0.1106	0.1827	0.3563
II	3	0.2078	0.2864	0.1917	0.4480	0.6237	0.3384	0.4709
III	3	0.6170	0.4379	0.7438	0.6125	0.7419	0.7511	0.6644

CONCLUSION

In general, the comprehensive index of tomatoes harvested in the red ripe stage is higher. Therefore, tomatoes can be picked in the red ripe stage with the highest nutritional index to meet the demand of high-quality sales if short-term storage is acceptable. There was no significant difference in long-term storage quality between the green ripening and color-changing stages ($P > 0.05$). Therefore, the storage quality of tomatoes can be kept as good as possible at 4 ℃ in the red ripe stage for short-term storage and transportation. If the tomatoes need to be stored and transported for a long time, they can be harvested in the color-changing and green maturity periods stored at 3 ℃ and 28 ℃, respectively.

Conflicts of interest

There is no conflict of interest to be declared by the authors.

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Author contributions

Hualing Zhang: Writing-original draft. Xuan Chen, Qinru Song and Qiaoqin Wang: Data curation. Haiying Wang and Youwen Zhang: Validation. Xu Liu: Funding acquisition.

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