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Influence of postharvest temperatures on physicochemical quality of tomatoes (*Lycopersicon esculentum* Mill.)

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Abstract

Tomato fruits (cv. Belle) were harvested at the middle-red ripe stage and exposed at 5°C and 10°C for up to 28 days. Weight loss percentage was faster for fruits held at 10°C compared to 5°C. While the weight lost during storage at 10°C was 18.7%, fruits at 5°C over the same period showed a 9.6% loss. There were only slight changes in soluble solids and titratable acids content during the storage period studied. Although soluble solids increased slightly over the storage period, there were no significant differences between the two temperatures. The titratable acidity, expressed as citric acid, tended to be lower at 5°C, with a significant difference observed only on Day 14 of storage. Total reduction of initial vitamin C content was 3.5 mg/100 g (at the 5°C) and 2.5 mg/100 g (at the 10°C). The results showed that lower temperature did not significantly reduce vitamin C content in comparison with higher temperature, with the exception on Day 7 of storage. At both temperatures and at every stage of storage time pericarp firmness decreased as storage time increased. The decrease in firmness was delayed by the lower temperature. The colour development (value *a*) of skin increased with increasing storage duration at both temperatures, but there were no differences among temperatures.

Key words: *Lycopersicon esculentum* Mill., temperature, storage, physicochemical quality.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable crops in the world of horticultural economy[1]. In Mediterranean countries it is also very popular, especially in summer time [2]. Keeping the fresh appearance of tomatoes long after harvest is the permanent challenge imposed by the consumers. One of the ways in which tomato quality can be kept is by controlling storage temperature. Temperature greatly influences the rate of respiration of fruits and vegetables, and is undoubtedly one of the most important factors in mainting post harvest quality of tomato fruits. The effect of temperature on quality and quantity changes in tomato fruits depends on several factors in previous investigators [6, 7] have reported that a storage temperature of 10-15°C and 85-95% relative humidity could extend the postharvest life of fruits. At these temperatures chilling injury and ripening rate are minimal. The injury is generally followed by an increased tendency to decay, particularly when the temperature is raised.

Tomato fruit quality is determined by a number of biochemical and developmental processes that result in changes of the quality attributes.

The purpose of this study was to investigate the hypothesis that storage temperature below the lowest recommended storage temperature (10°C) for tomatoes could be used without negatively affecting storage life. Tomato quality was followed as a function of storage time for 28 days from the harvesting time when the middle-red ripe fruits were picked. Quality attributes (weight loss, soluble solids, titratable acidity, vitamin C, firmness and skin colour) were evaluated every 7 days.

Material and Methods

Plant material and preparation of samples: The experimental plantation was carried out at the Experimental Field of Department of Agronomy, Biotechnical Faculty, Ljubljana, Slovenia, in 2008, using the determinate growing cultivar Belle (Enza Zaden). Tomato plants were grown outdoors under uniform conditions. Growing conditions such as average daily temperature and nutrient density were monitored.

Thirty of the tagged fruits per plot were harvested on the same day, when they reached the middle-red ripe stage. Maturity of the middle-red ripe stage was determined according to Kader and Morris [33]. Picked fruits were kept at 15°C for 24 hours to uniform their temperature. Afterwards fruits were carefully brought to the laboratory to avoid internal bruising. Samples were selected according to their colour and with no apparent mechanical injuries, insects or diseases and placed on cardboard trays. The weight of individual samples varied from 110 to 115 g.

Cardboard trays were randomly divided into two lots and stored for 28 days at 80-85% relative humidity. The first lot was stored at 5±1°C and the second one at 10±1°C. Each lot consisted of five replicate cardboard trays. The temperature conditions were measured with a single-point thermostat. Relative humidity inside the cold chambers was manually controlled daily using a wet bulb/dry bulb device and maintained by spraying water when necessary.

Fruit properties were examined every 7 days during storage from 10th October to 9th November 2008. A random sample of 10 fruits per cardboard were used to analyse quality parameters.

Methods: The weight loss was calculated and expressed as a percentage of the initial weight of the fruits from the 1st day of the experiment. The weight of fruits was recorded to an accuracy of ± 0.01 g using a Mettler balance model Toledo PB 602.

Soluble solids amount was determined by placing 0.5 ml of juice on the prism of a hand-held Atago PR1 refractometer, and results were reported in %Brix.

Titratable acidity was determined by titrating 10 ml of fruit juice to pH 7.6 using 0.1 M sodium hydroxide and expressed as g l^{-1} citric acid.

The content of vitamin C was determined as the sum of ascorbic acid and dehydroascorbic acid by Šircelj and Batič [8] method adopted by Veillet *et al.* [9]. The analysis was performed by a high performance liquid chromatography (HPLC) using a Merck-Hitachi system with UV detector (Table 1).

Table 1. HPLC conditions for analysing vitamin C.

Cartridge	Phenomenex, Synergi Hydro – RP 80 A 250 x 4.6 mm
Sample	20 µl
Eluent	3.54 g l^{-1} KH_2PO_4; pH 2
Flow rate	0.6 ml min^{-1}
Temperature	25°C
Detector	UV-VIS, 245 nm, Knauer

Pericarp firmness was determined at the equatorial region on two opposite paired sides of each tomato fruit at a location of 180° apart. The firmness was measured with the digital penetrometer Chattilon DFG-50. The fruit was pressed orthogonally with a blade steel moving at a constant speed of 0.95 mm s^{-1}. The pericarp firmness was defined as a puncture force (kg cm^{-2}) [10].

Fruit colour was measured by a Minolta chromameter model CR-200b (Minolta, Japan) having an 8 mm aperture and a standardized white reference plate (L= 93.8, a = 0.3164, b = 0.3208). The colour of fruit skin was expressed as the a value of the Hunter L, a, b coordinates to indicate the index colour [11] of the tomato. The a value was performed on each tomato fruit on the same signed point on the equatorial part of the fruit.

Results were analysed using Duncan's multiple range test at P= 0.05. Four experiments were carried out with five replicate cartons in each treatment. Fisher's least significant difference (LSD) was used to discriminate among the means. All data are presented as the mean ± standard error (vertical bars represent SE).

Results and Discussion

Weight: A weight change was positively related to temperature. Fruits held at 10°C had greater weight loss than fruits held at 5°C (Fig. 1). The intensity of weight loss during storage of the first two weeks did not differ between temperatures. Fruits lost weight from 2.2% (5°C) to 2.7% (10°C) after two weeks of storage. The greatest change between temperatures in weight loss was observed on the 21st day, e.g. when the weight loss at 10°C was 16% but at 5°C only 6.2%. At the end of the storage period the fruits stored at 5°C showed 9.6% loss in fresh weight compared to 18.7% weight loss at 10°C. This is likely due to faster ripening leading to a higher respiration activity.

In general, weight loss progressively increased with the increasing storage time at both temperatures examined. According to Ball [12], postharvest weight loss in vegetables is usually due to the loss of water through transpiration. Weight loss can lead to

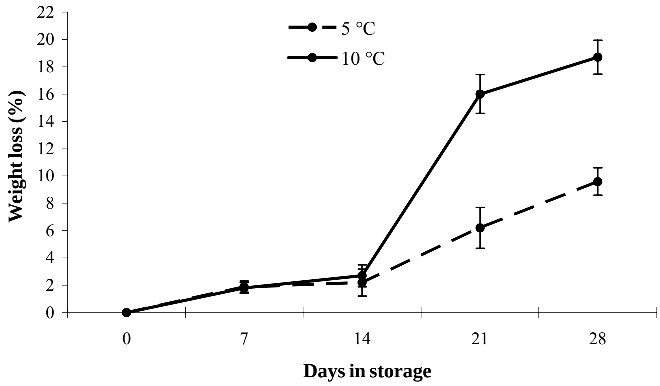

Figure 1. Changes in weight loss (%) in tomato cv. Belle stored at different temperature conditions.

wilting and shrivelling which both reduce market value and consumer acceptability. Our results are in agreement with De Castro *et al.* [13] who tested different storage temperatures and demonstrated that weight loss was proportional to the storage period and storage temperature.

Soluble solids: The fruit content of soluble solids remained relatively constant during the postharvest period (Fig. 2). It can be seen that there were no differences among the studied temperatures. Soluble solids increased slightly from 5.23 to 6.36% at 5°C and from 5.23 to 6.8% at 10°C. At every stage of the storage time, except at the initial storage period, soluble solids content in fruits at 10°C was always slightly greater than that found in fruits stored at 5°C. From the qualitative point of view, however, soluble solids concentration reached an absolute maximum at the end of the storage period.

Soluble solids are a large fraction of the total solids in tomato. Soluble solids content is an indicator of sweetness, although sugars are not the sole soluble component it measures [14]. In addition, Salunkhe *et al.* [15] reported that soluble solids content increases with fruit maturity through biosynthesis process or degradation of polysaccharides.

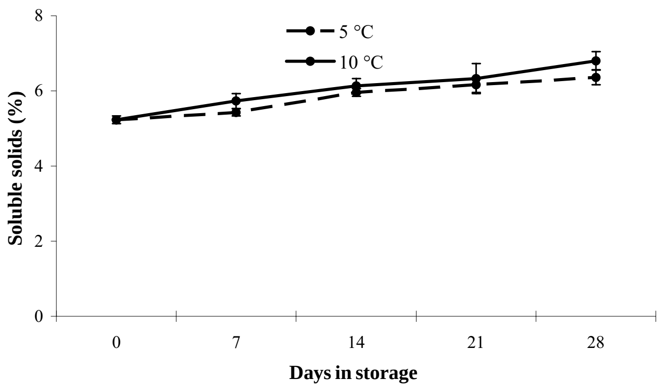

Figure 2. Changes in soluble solids (%) in tomato cv. Belle stored at different temperature conditions.

Titratable acidity: Changes in titratable acidity during storage were relatively small. The quantity of titratable acidity of fruits at the time of storage varied similarly for both temperatures. As shown in Fig. 3 acidity at both temperatures grew and peaked after 1st week of storage. During the first 7 days the titratable acidity increased with statistically significant variances by 0.62 g

l^{-1} (at 5°C) and by 0.83 g l^{-1} (at 10 °C) on average per day. After the 1st week acidity tended to decline. The final rating of titratable acidity was 3.5 g l^{-1} at the lower temperature and 3.6 g l^{-1} at the higher temperature. The decrease of titratable acidity after 7 days was almost linear in all cases although the decrease of acidity was delayed at 5°C.

Though many authors have reported some information of the titratable acidity in tomatoes, results of these reports have been inconclusive. De Souza *et al.* [16] reported that the increment of titratable acidity is caused by the gaseous conditions (elevation of CO_2 concentration and reduction of O_2) during storage period. These can affect the glycolytic enzyme system, resulting in a build-up of acids. On the other hand Wills *et al.* [17] mentioned that the amount of organic acids usually decreases during maturity, because organic acids are substrates of respiration. Our results corresponded (after the first week of storage) with those from De Castro *et al.* [7] presenting an acidity decrease with the progress of maturity. On the other hand, our results are opposite to the findings of Auerswald *et al.* [18] who observed that titratable acidity decreased in the first 7 days storage period.

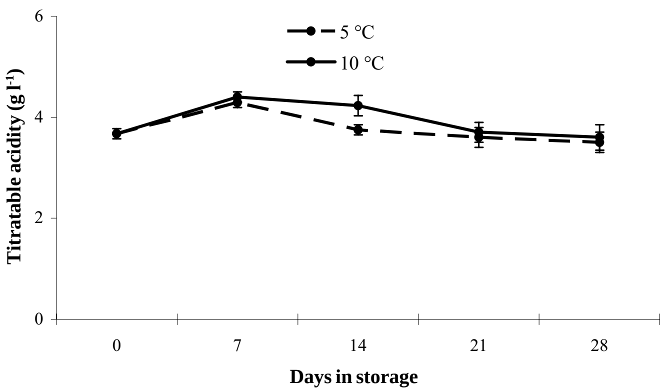

Figure 3. Changes in titratable acidity (g l^{-1}) in tomato cv. Belle stored at different temperature conditions.

Vitamin C: The evolution of vitamin C content is presented in Fig. 4. The initial level of vitamin C content was about 7.7 mg/100 g fresh weight. Vitamin C amount in the mature red fruits was 13% and 26% higher than that in the middle-red ripe fruits, respectively. The vitamin C change was negatively related to the period of storage. The decrease of vitamin C was approximately linear during the storage period. During the first 14 days the content of the vitamin decreased on a fresh weight basis by 0.15 mg/100 g (at the 5°C) and 0.13 mg/100 g (at the 10°C) on average per day, whereas during the rest of the postharvest period it decreased by only 0.07 (at the 5°C) and 0.09 mg/100 g (at the 10°C).

The range of vitamin C content in our study is less than in an earlier study, where the ascorbic acid content in tomato fruits varied about 28 mg/100 g [19]. It is also noticeable that vitamin C change was negatively related to the storage period. Storage contributed to a significant reduction of vitamin C amount found in our study. However, lower temperature storage reduced the rate of vitamin C loss compared to the higher temperature only during the first seven days of storage. These results correspond with the findings of Adis [20] and Christakou *et al.* [21] who observed that increasing storage period causes a decrease of vitamin C in fruits and vegetables. The decomposition of vitamin C during storage of vegetables is attributed to ascorbic acid degradation due to oxidation that can occur because of the presence of catalysts and oxidizing enzymes [22]. The values for vitamin C presented negative trend with the soluble solids. Our results conform with some of the earlier reports [23], which mentioned that increasing the soluble solids content decreased the concentration of vitamin C.

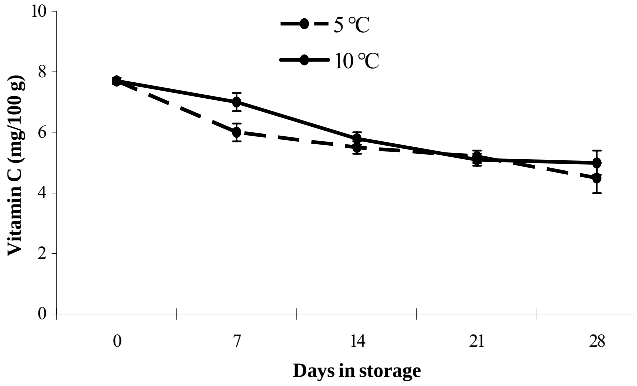

Figure 4. Changes in vitamin C (mg/100 g) in tomato cv. Belle stored at different temperature conditions.

Firmness of pericarp: The development of pericarp firmness, i.e. the softening of the fruits, was significantly affected by storage time and temperature (Fig. 5). Firmness decreased notably at both temperatures during the storage period. This decrease was more pronounced at 10°C. Firmness decreased gradually in the first 7 days of storage at both temperatures. After the 1st week, firmness remained unchanged until the end of storage at 5°C. In contrast, firmness decreased sharply at 10°C after the first 7 days of storage.

Even though there were remarkable differences in chemical attributes of fruits between the different temperatures, the most significant differences in our study were found in firmness. It was suggested by Ball [12] that a postharvest change in firmness can occur due to the loss of moisture through transpiration, as well as enzymatic changes. In addition, hemicelluloses and pectin become more soluble, which resulted in to disruption and loosening of the cell walls [24]. Storage temperatures and time had significant effect on fruit firmness. Fruits softened at both temperatures during the storage period. At the higher temperature, the decrease in firmness was more noticeable. A close relationship between the softening of the fruits, higher temperature and extension of storage time was described by many authors [25-28].

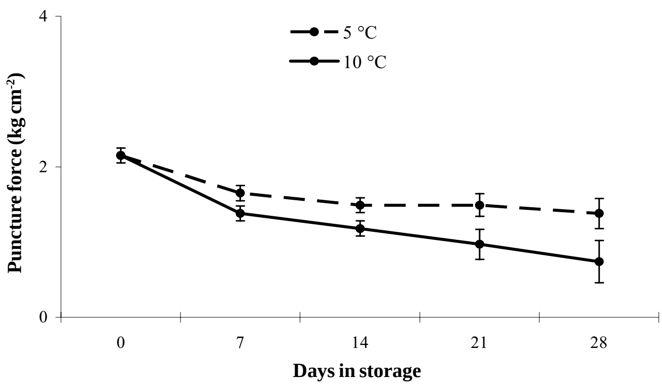

Figure 5. Changes in puncture force (kg cm^{-2}) in tomato cv. Belle stored at different temperature conditions.

Colour of pericarp: Fig. 6 shows the changes of colour in tomato skin as illustrated by the *a* value of the Minolta chromameter. A change in *a* value indicates fruit ripening. The fruits stored under the higher temperature showed overall higher visual quality. The initial fruit colour at the middle-red ripe stage was 15.6 (*a* value). The *a* value in skin followed a similar course at both temperatures; as fruits ripened, *a* was increased. Ripe tomato colour continued to increase clearly by 7.5 (at 5°C) and by 8.4 (at 10°C). Carotenes and xanthophylls, especially lycopene, oxidized during the storage and gradually changed the colour from bright red to dark brown. However, after 21 days fruits reached their minimum of *b* value at both temperatures (data not shown), and although the fruits at lower temperature tended to be less red than the fruits at the higher temperature, these differences were not significant.

The skin *a* value increased quite uniformly at both temperatures. The tomatoes reached the full red stage at day 21 of storage at both temperatures. The findings of Iwahashi *et al.* [29] supported our results. The colour evaluation in fruits corresponds to a fall in chlorophyll and an increase in carotenoid accumulation [30], reflecting the transformation of chloroplasts to chromoplasts [31]. The colour development rate of fruits increased with increasing maturation [32].

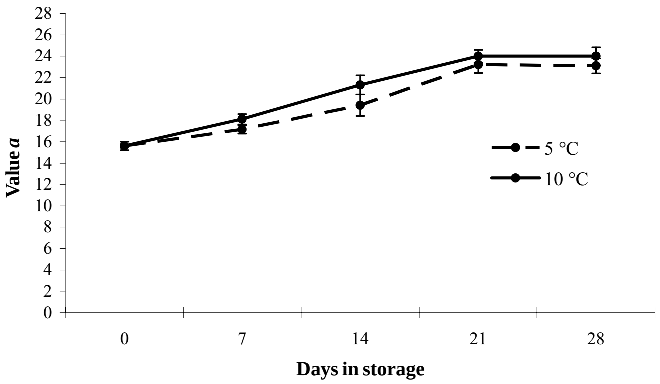

Figure 6. Changes in value a in tomato skin cv. Belle stored at different temperature conditions.

Conclusions

Our findings suggest that physical and chemical changes during storage of tomato fruits are influenced by temperature and storage time. Although ideal storage temperature for tomatoes is more problematic, it may be concluded that cv. Belle could be stored using temperatures below the recommended storage temperature of 10°C. We can conclude that the reduction of temperature for cv. Belle delays the climacteric peak, and consequently the ripening.

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