INFLUENCE OF SHORT ANOXIA TREATMENT AND MATURITY ON QUALITY AND STORAGE LIFE OF TOMATOES

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Abstract: The influence of short anoxia treatment on physical, chemical and sensory attributes of mature green and pink red tomatoes during storage was investigated. Matured green and pink red fruits were kept for 24 hrs under humidified pure N2, while the control was not treated. Subsequently, the fruits were stored at 12°C and 20°C for 14 days. Quality parameters including weight loss, firmness, total soluble solids, colour, sensory and decay were analysed. Generally, weight loss increased after 14 days of storage and depending on anoxia treatment, maturity and storage temperature. Tomato fruit treated with anoxia and kept at 12°C showed a minimal deterioration of the quality attributes and could be stored for longer periods compared to those stored at 20°C. Results for TSS were higher in tomato fruit treated with anoxia. However, pink red fruit stored at 20°C showed lower TSS than untreated fruit. Untreated and anoxia-pretreated mature green tomatoes showed higher sourness and off-flavour scores than those stored at 20°C. However, mature green and pink red tomatoes kept at 20°C showed higher acceptance (%) than those stored at 12°C. Therefore, combined effect of anoxia and low temperature could have delayed the ripening of the tomatoes.

Key words: anoxia, quality attributes, store, tomato.

Introduction

Tomato is a worldwide important agricultural commodity, with remarkably high concentrations of L-ascorbic acid, lycopene and is considered to be an important contributor to carotenoids to the human diet (Beecher, 1998).

Today’s markets demand high quality and fresh tomatoes with premium colour, texture and flavour and overall acceptability. Tomatoes are commonly harvested at the ‘mature green’ stage of ripening in order to minimise the damage incurred during transport. Tomato is a climacteric fruit, reaching respiratory peak during its ripening process. Being a climacteric and perishable vegetable, tomatoes have a very short life span, usually 2 to 3 weeks (Sammi and Masud, 2009).

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Increased storage life and improvement of tomato fruit quality is really desirable, and the initial step required for ensuring successful marketing is to harvest the crop at the optimum stage of maturity.

Oxygen is closely tied to the rate of respiration of harvested products and their quality. As its internal concentration decreases, respiration also decreases until the oxygen concentration reaches a value called ‘the extinction point’ (Wills et al., 1998). The storage of fruit under a low-oxygen environment for a period longer than tolerable provokes detrimental effects such as abnormal ripening, flesh browning and a large increase in ethanol and acetaldehyde. Reduced levels of oxygen have been used as an alternative to chemical in the shelf life extension and control of postharvest pathogens and disinfestations. Oxygen (O₂) and carbon dioxide (CO₂) are biologically active molecules of importance in primary and secondary metabolic processes in plants. The pretreatment of various fruits with anoxia can delay ripening (Lurie and Pesis, 1992; Pesis and Marinansky, 1993). This non-chemical and inexpensive treatment deserves further development and application, especially under commercial distribution conditions or in developing countries where refrigeration is inadequate (Fallik et al., 2003). Fruits have different levels of tolerance to anoxic conditions and the conditions are influenced by commodity, level of CO₂ concentration and stage of ripeness. Short-term anoxic treatments have been used as an inexpensive non-chemical technology to prevent physiological disorders and delay ripening in fruits.

The purpose of this work was to compare the physical, chemical, sensory attributes of mature green and pink red tomatoes treated for 24 hrs with anoxia (99% N₂) with control.

**Materials and Methods**

**Preparation of fresh tomatoes**

Fresh tomatoes fruits were harvested in the greenhouse early in the morning taking care to avoid damage by impact, and transferred to the laboratory. The selection of samples was made based on size uniformity, colour (matured green and pink red), and absence of physical defects. The calyx was removed from each fruit, after which fruits were cleaned with cotton pads that had been soaked in sterile distilled water and drained. The fruits were then divided into fifteen (15) fruits per treatments. In total, 120 fruits were used for the experiment.

**Pretreatment of tomatoes with anoxia**

The 30 matured green fruits were placed inside a 15 kg plastic container and flushed with N₂ gas. Gas composition was monitored by an O₂ and CO₂ detector
Influence of short anoxia treatment and maturity on quality and storage life of tomatoes

(Model CYES-II, Shanghai Scientific Instruments) until the O₂ concentration in the plastic container was 0.05%. Then, the fruits were kept for 24 hrs under humidified pure N₂ flow. After the above treatments for 24 hrs, the fruits were removed from the plastic containers, divided into two groups by 15 fruits then transferred to humidify for a total of 14 days at 20°C and 12°C. A total of 30 fruits kept in humidified air for 24 hrs at the same flow rate as N₂ gas was used as control. Control fruits (non-treated fruits) were not flushed with nitrogen but kept at the two storage temperatures (12°C and 20°C) for 14 days. A similar experiment was conducted for the pink red colour tomatoes. The fruits were observed for firmness, juice content, or fruit firmness, total soluble solids (TSS), and colour during storage. Quality parameters were evaluated immediately after the harvest and at the end of 14 days storage at 12°C and 20°C. Quality parameters were measured at the beginning and at the end of storage as follows:

Physical, chemical and sensory analyses

Weight loss was determined by measuring weight on a precision scale at the beginning and at the end of the study. The colour of tomato fruits on two different marked ends of tomatoes was assessed by Minolta colorimeter (type CR-300) (Ilič and Fallik, 2002) with Hue angle: ∼110 = light green; ∼70 = light pink; ∼60 = pink; ∼50 = light red; ∼40 = red; ∼30 = dark red.

The firmness of tomatoes, measured as depth of penetration and force in Newton, was determined with a manual shore durometer (Jamaica type-02, MFG.CO, New York), a cylindrical embolus of 2.5 mm diameter. Two determinations, each penetrating 2.5 mm, were made on opposite sites of the fruit’s equatorial region, prior to removal of the epicarpium. The mean of the two values was considered an independent repetition. Units of firmness (arbitrary) were: UFBr< 20 = very soft; 21~30 = soft; 31~40 = firm; > 41 = very firm.

Total soluble solids (TSS) of the fruit were determined by manually extracting juice of five fruits. Few drops of the juice were placed on the sensor of a hand refractometer (Japanese ATANGO PR-1) which had been calibrated. Total soluble solids (TSS) were measured in degree Brix (Ilič and Fallik, 2002).

The incidence of decay was determined as the percentage of decayed fruits in a whole lot of treated fruits. Decay was identified as softening/watery spots, discolouration, offensive odour and aggregation of fungal spores and mycelium on fruit surface. Sensory analysis was performed by five untrained sensory panelists. Fruits were cut into pieces (about 2 cm/2 cm) and placed on dark glass dishes. Off-flavour was scored on a scale of 0-3, with: 0 = /no off-flavour, 3 = high flavour. Sweetness was evaluated on a scale of 1 = no sweet to 5 = very sweet. Similarly, sourness was assessed on a scale of 1 = no sour to 5 = very sour. Acceptance of the samples was indicated as a ‘yes’ or ‘no’ answer.
Results and Discussion

Table 1 shows the effect of a short (24 hrs) anoxia pretreatment on quality parameters of matured green and pink red tomatoes after 14 days of storage at 12°C or 20°C. Quality parameters including weight loss (%), firmness (UFM), total soluble solids and colour (hue, lightness and chroma) were investigated. Exposing fruit and vegetables to anoxia (N2) after harvest has many beneficial effects, such as reducing respiration rate, inhibiting ethylene production and action, delaying ripening and reducing the incidence of some physiological disorders (Fallik at al., 2003). Changes in these quality attributes were affected by storage temperature. Generally, weight loss increased after 14 days of storage. Average weight loss from tomato varied between 7.51-23.38% depending on maturity and storage temperature (Table 1).

Table 1. Effect of anoxia treatment on quality of matured green and pink red tomatoes after 14 days of storage at 12°C or 20°C.

<table>
<thead>
<tr>
<th>Quality parameters</th>
<th>0 day before treatment</th>
<th>14 days after treatment stored at 12°C</th>
<th>Matured green</th>
<th>Pink red</th>
<th>Matured green</th>
<th>Pink red</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight loss (%)a</td>
<td>0 ± 0</td>
<td>8.84 ± 5.47</td>
<td>11.19 ± 5.92*</td>
<td>7.51 ± 5.54</td>
<td>9.36 ± 6.91*</td>
<td></td>
</tr>
<tr>
<td>Firmness (UFM)b</td>
<td>60.75 ± 1.52</td>
<td>50.8 ± 4.22</td>
<td>52 ± 4.11</td>
<td>55.3 ± 4.96**</td>
<td>30.2 ± 5.55</td>
<td>27.7 ± 4.62**</td>
</tr>
<tr>
<td>Hand feelc</td>
<td>3 ± 3</td>
<td>4.66 ± 0.15</td>
<td>4.0 ± 0.14</td>
<td>4.46 ± 0.11*</td>
<td>3.66 ± 0.39</td>
<td>3.84 ± 0.23</td>
</tr>
<tr>
<td>TSS (%)d</td>
<td>4.66 ± 0.15</td>
<td>117.33 ± 0.43</td>
<td>54.34 ± 0.03</td>
<td>51.00 ± 2.32</td>
<td>52.59 ± 3.03</td>
<td>55.47 ± 2.73</td>
</tr>
<tr>
<td>Colour (hue)e</td>
<td>15.14 ± 0.31</td>
<td>15.36 ± 5.61</td>
<td>17.4 ± 1.50</td>
<td>17.32 ± 2.11</td>
<td>20.05 ± 1.05</td>
<td>16.41 ± 2.10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quality parameters</th>
<th>14 days after treatment stored at 20°C</th>
<th>Matured green</th>
<th>Pink red</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight loss (%)a</td>
<td>0 ± 0</td>
<td>23.88 ± 12.29</td>
<td>18.85 ± 8.15*</td>
</tr>
<tr>
<td>Firmness (UFM)b</td>
<td>60.75 ± 1.52</td>
<td>50.8 ± 4.22</td>
<td>24.8 ± 3.70</td>
</tr>
<tr>
<td>Hand feelc</td>
<td>3 ± 3</td>
<td>4.66 ± 0.15</td>
<td>4.0 ± 0.10</td>
</tr>
<tr>
<td>TSS (%)d</td>
<td>117.33 ± 0.43</td>
<td>57.63 ± 5.61</td>
<td>32.6 ± 15.3</td>
</tr>
<tr>
<td>Colour (hue)e</td>
<td>15.14 ± 0.31</td>
<td>51.00 ± 2.32</td>
<td>47.25 ± 3.59</td>
</tr>
</tbody>
</table>

Data are mean ± sd; a Percent of weight loss from the initial; b Units of firmness (arbitrary): UFB < 20 = very soft; 21-30 = soft; 31-40 = firm; >41 = very firm; c Hand feel: 1-hard, 2-medium, 3-soft; d Total soluble solids; e Hue angle: ~110 = light green; ~70 = light pink; ~60 = pink; ~50 = light red; ~40 = red; ~30 = dark red. The significance of differences between the control and the treatment and between the treatment at different temperatures, mean values were determined by students t-test at the significance level of (*P<0.05, **P<0.01, ***P<0.001).
However, untreated matured green and pink red tomatoes kept at 20°C showed higher weight loss than anoxia-pretreated samples. Moreover, untreated and treated tomatoes stored at 20°C showed higher weight loss than those stored at 12°C. The results showed statistically significant differences between (P<0.5) anoxia-pretreated mature green tomatoes MGA kept at 12°C and 20°C. There was a significantly higher weight loss in MGA 20 in comparison with MGA 12. Similarly, there was a significant difference (P<0.5) between untreated mature green tomatoes MGC and anoxia-pretreated mature green tomatoes MGA kept at 12°C. Untreated matured green and pink red tomatoes stored at 12°C showed lower average weight loss than samples subjected to anoxia pretreatment.

Flesh softening is a crucial event for characterisation of fruit ripening and, thus, is used as an indicator of shelf life of kiwifruit (Bonghi et al., 1996). Generally, firmness of the fruit as measured by dorometer decreased with storage days, treatment and storage temperature. Anoxia-pretreated mature green tomatoes showed higher firmness values than the control. However, pink red tomatoes treated with anoxia showed lower firmness value. The fruits kept at 20°C showed lower firmness values than those stored at 12°C (Table 1). This result was further confirmed by hand feeling of the fruit firmness. The results showed a statistically significant difference (P<0.01) between untreated mature green tomatoes MGC and anoxia-treated mature green tomatoes MGA kept at 20°C, anoxia-treated pink red tomatoes PKA kept at 12°C and anoxia-treated pink red tomatoes kept at PKA 20°C; anoxia-treated mature green tomatoes MGA kept at 12°C and anoxia-treated mature green tomatoes MGA kept at 20°C; anoxia-treated mature green tomatoes MGA 20°C and anoxia-treated pink red tomatoes PKA kept at 20°C. There was a significantly higher firmness value in treated mature green tomatoes than in control, both kept at 20°C. Similarly, there was a significantly high firmness result at treated pink red tomatoes kept at 12°C, than treated pink red tomatoes kept at 20°C. The similar result was obtained when we compared the treated mature green tomatoes and treated pink red tomatoes kept at 20°C. The significantly large differences are between treated mature green tomatoes kept at 12°C and treated mature green tomatoes kept at 20°C.

In experiment, both matured green and pink red fruits showed higher hardness score. Hardness, measured by hand feel, decreased with storage days and anoxia treatment. Matured green and pink red fruits showed higher hand feel score at 12°C than at 20°C. A combined effect of anoxia and low temperature could have delayed the ripening of the tomatoes. Pretreatments with N₂ at 97% (low O₂) atmospheres or with air enriched with 30% to 90% CO₂ delay ripening in various fruits and vegetables (Pesis and Marinansky, 1993). Treatments with high N₂ or CO₂ for 24hrs to 48 hrs, which resulted in increased endogenous AA and ethanol, inhibited ripening in tomato (Lycopersicon esculentum Mill.) (Pesis and Marinansky, 1993). Shackel et al. (1991) hypothesised that fruit softening in
tomato resulted from turgor loss of cells companying with damage of cellular membranes. Loss of membrane integrity during ripening and senescence of harvested fruit and vegetable could be partly due to lipid peroxidation (Jiang at al., 2002).

Total soluble solids (TSS) of matured green and pink red tomatoes decreased with storage time and treatment. Total soluble solids of matured green and pink red tomatoes decreased from 4.66 and 4.22 to between 4.0-4.60 and 3.66-4.60. Generally, tomatoes pretreated with anoxia showed higher TSS than the control. However, pink red fruit stored at 20°C showed lower TSS than the untreated fruit (Table 1). Fallik et al. (2003) reported that tomato exposure to anoxia for 24 hrs did not affect TSS or acidity, nor did the sensory panel find any effect on fruit flavour. The carbon flux from the acid to sugars in tomato pericarp tissue and the stimulation of the process by AA were accompanied by extinction of the fructose 2,6-biphosphate levels (Halinska and Frenkel, 1991). The results showed statistically significant differences between (P<0.05) anoxia-pretreated mature green tomatoes kept at 12°C in relation to the control. Similarly, there was a significant increase of TSS in anoxia-pretreated mature green tomatoes kept at 20°C as compared with control.

Effects of anoxia and storage temperature

Visually, there was colour difference between untreated and anoxia-treated pink red tomatoes stored at 12°C after 14 days of storage, however, there was no colour difference in those stored at 20°C. Generally, hue value of both mature green and pink red tomatoes decreased with storage time and anoxia treatment. Anoxia-pretreated tomatoes consistently showed higher hue and lightness values after 14 days of storage. However, tomatoes kept at 12°C showed higher hue and lightness than at 20°C. The results showed a statistically significant difference between (P<0.05) anoxia-pretreated mature green tomatoes and treated pink red tomatoes kept at 12°C. The pink red tomatoes showed increase of hue value in comparison to mature green tomatoes. The results observed for the chroma value did not show trend that could be generalised.

The lightness, L*, was correlated to the lycopene content, decreasing in the early maturity stages, reflecting the darkening of the tomatoes because of carotenoid synthesis and the loss of green colour. According to Thompson et al. (2000) the hue value of the tomato puree was a better indicator of lycopene content than surface hue of the tomato, indicating that a large proportion of lycopene is located inside the fruit. The two main carotenoids in tomatoes and tomato products are lycopene and b-carotene, which comprise about 78%, respectively, of the total carotenoid content. The red colour of tomatoes is mainly caused by its large lycopene content.
Sensory evaluation

Figure 1 shows the effect of anoxia pretreatment on quality attributes of matured green MG and pink red PK tomatoes. Pink red samples stored at different temperature (12°C and 20°C) showed higher sweetness scores. Good aroma and taste are important factors influencing tomato commercialisation. In addition, untreated matured green tomatoes kept at 20°C showed high sweetness score. Untreated and anoxia-pretreated mature green tomatoes showed higher sourness scores than other samples. However, tomatoes stored at 12°C generally showed higher sourness scores than those stored at 20°C. Olive’s fruit (Olea europaea cv. Picual) storage at 5°C maintained the initial sensorial and chemical qualities for 45 days, but at 8°C, these qualities were maintained for only 15 days. At room temperature, these qualities deteriorated just after 7 days of storage. Anoxia-treated fruits that were held at 20°C for 12 days had organoleptic qualities similar to those of untreated fruits that were held at 12°C for 10 d plus 2 d at 20°C, and the trained panel preferred these two treatments. The taste and smell (sensory quality) of pink harvested tomatoes could be sustained for about two weeks at ambient temperature under a short anoxia treatment (Fallik et al., 2003).

Figure 1. Effect of anoxia pretreatment on quality attributes of mature green MG and pink red PK tomatoes after 14 days of storage at 12°C or 20°C.

Generally, samples stored at 12°C showed higher off-flavour scores than those stored at 20°C. However, mature green and pink red tomatoes kept at 20°C showed higher acceptance (%) than those stored at 12°C (Figure 2). In general, samples treated with anoxia and kept at 12°C showed a minimal deterioration of the quality attributes and could be stored for longer periods compared to those stored at 20°C.
When the O$_2$ concentration is lowered below the Pasteur point, the anaerobic metabolism induces the accumulation of AA and ethanol, which can lead to the development of off-flavours (Pesis, 2005). For many fruit, reduction of O$_2$ inside the fruit is accompanied by fermentation and accumulation of anaerobic off-flavours related to the production of ethanol and AA. This has been demonstrated in fruit such as strawberry (Pesis and Avissar, 1990) and sweet cherry (Petracek et al., 2002). Low temperature and anoxia treatment may have combined to affect the sensory attributes of the tomatoes. The harvest of immature fruit, mechanical damage, inadequate postharvest treatments and storage conditions can adversely affect the flavour of ripe tomatoes (Baldwin et al., 2000; Moretti et al., 2002). Inappropriate ethylene ripening programs as well as storage at excessively low temperatures have detrimental effects on aroma and taste of tomatoes (Maul et al., 2000). The characteristic flavour of a fresh tomato is the result of complex interactions between organic acids, soluble sugars and over 400 volatile compounds that are synthesised during the ripening process in the intact fruit (primary aroma compounds) and upon tissue disruption (secondary aroma compounds) (Baldwin et al., 2000). From the large number of volatiles present in tomato, only about 30 are considered as impact aroma compounds since they have positive values of odour logarithms (Baldwin et al., 2000). These volatiles are derived from different biochemical pathways such as the catabolism of lipids, amino acids, lignins and carotenoids (Sanz et al., 1997).

![Figure 2. Effect of anoxia pretreatment on acceptance of matured green and pink red tomatoes after 14 days of storage at 12°C or 20°C.](image)

The incidence of decay was determined as the percentage of decayed fruits in a whole lot of treated fruits. However, tomato fruit pretreated with 24 hrs of anoxia
did not suffer from any injury. The 24 hrs of anoxia pretreatment slowed down the ripening process, and helped to maintain the physical, chemical and sensory attributes of tomatoes during storage. According to Fallik et al. (2003), anoxia treatment for 24 hrs maintained several tomato fruit quality traits. Exposure to N₂ for 12 hrs or 24 hrs, however, accelerated the rate of disease development of the fruit during storage of litchi, as opposed to the exposure for 3hrs or 6 hrs (Jiang et al., 2004). One of the hypotheses for the mode of action of the anoxia treatment for decay is that the resistance of harvested litchi fruit to pathogens increased or decreased mainly by regulating physiological processes. There were no signs of decay or spoilage in both the untreated and anoxia-treated tomatoes probably because of the short period of exposure. Bonghi et al. (1999) and Pesis et al. (2001) reported that keeping fruit and vegetables in very low oxygen atmospheres reduced some physiological disorders and disease development.

**Conclusion**

A short anoxia pretreatment affected physical, chemical and sensory attributes of mature green and pink red tomatoes. Weight loss increased after 14 days of storage. Average weight loss from tomato varied between 7.51-23.38% depending on anoxia pretreatment, maturity and storage temperature. Anoxia-pretreated mature green tomatoes showed higher firmness values than the control. However, pink red tomatoes treated with anoxia showed lower firmness value. Fruits kept at 20°C showed lower firmness values than those stored at 12°C. Hardness, measured by hand feel, decreased with storage days and anoxia treatment. Matured green and pink red fruit showed higher hand feel score at 12°C than at 20°C. Anoxia-pretreated tomatoes consistently showed higher hue and lightness values. Tomatoes kept at 12°C showed higher hue and lightness values than at 20°C. Pink red samples stored at 12° and 20°C showed higher sweetness scores. Untreated and anoxia-pretreated mature green tomatoes showed higher sourness scores than other samples. Mature green and pink red tomatoes kept at 20°C showed higher acceptance (%) than those stored at 12°C. There were no signs of decay or spoilage in both the untreated and anoxia-treated tomatoes. Tomato fruit treated with anoxia and kept at 12°C showed a minimal deterioration of the quality attributes and could be stored for longer periods compared to those stored at 20°C. Therefore, combined effect of anoxia and low temperature could have delayed the ripening of the tomatoes.

**References**


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UTICAJ KRATKOG TRETMANA ANOKSIJOM I ZRELOSTI NA KVALITET I ROK UPOTREBE PARADAJZA

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Rezime

Ispitivan je uticaj kratkog tretmana anoksijom na fizička, hemijska i senzorna svojstva zrelog zelenog i ružičasto crvenog paradajza u periodu skladištenja. Uzorci zelenih i ružičasto crvenih plodova su čuvani 24 sata u čistom azotu dok kontrola nije tretirana. Nakon toga, plodovi su skladišteni 14 dana na 12 i 20°C. U toku ogleda praćeni su parametri kvalitete: težina, vrsto, sadržaj ukupno rastvorljivih materija, titracijska kiselost, boja, senzorni i pokazatelji propadanja plodova. Generalno, došlo je do gubitka težine nakon 14 dana skladištenja što je zavisilo od tretmana anoksijom zrelosti plodova i temperature skladištenja. Plodovi tretirani anoksijom i držani na 12°C pokazali su minimalno pogoršanje kvaliteta i mogu se čuvati duže vreme u odnosu na one skladištene na 20°C. Rezultati za ukupne rastvorljive materije su bili bolji kod plodova paradajza izloženih anoksiji u odnosu na kontrolu. Kontrola i tretirani plodovi zrelog zelenog paradajza pokazali su veću kiselost od onih uskladištenih na 20°C. Međutim, zrelo zeleni i ružičasto crveni plodovi čuvani na 20°C pokazali su veći % prihvatljivosti od plodova uskladištenih na 12°C. Kombinovani efekat anoksije i niske temperature mogu da odlože sazrevanje plodova paradajza u skladištu.

Ključne reči: anoksija, kvalitativne osobine, skladištenje, paradajz.

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