The Effect of Hot Air Treatments in Air or in Low $O_2$ Atmosphere on the Quality and Antioxidants of Tomato Fruit

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Keywords: Postharvest, Lycopersicon esculentum, controlled atmosphere, chlorophyll, carotenoids, β-carotene, lycopene, tocopherol, enzymes

Abstract
Tomato fruit is an excellent source of antioxidants. However, the fruit is sensitive to chilling injury (CI). We have determined the effect of forced hot air treatments on the quality, CI, and the contents of some antioxidants. ‘Rapsody’ tomato fruit was exposed to 34°C for 24 h in air, to 38°C for 24 h in air, or to 38°C for 24 h in 5% $O_2$, all at low RH, and then stored in air at 4°C or 10°C for up to 30 d. Fruit exposed to 38°C at 5% $O_2$ were injured the most, while fruit that were not heated, and those heated in air at 34°C for 24 h were the least injured. Fruit that were maintained at 10°C and were previously either not heated, or heated at 34°C developed the best color when ripened, having the least chlorophyll and the highest lycopene contents. Color developed slowly at 4°C than at 10°C. β-carotene increased in fruit that were not heated and to a lesser extent in those that were heated in air at 34°C or 38°C. Fruit that were exposed to 38°C in 5% $O_2$ had lower α-tocopherol content and higher peroxidase, ascorbate peroxidase, superoxide dismutase, glutathione reductase, and glutathione S-transferase activity than fruit of other treatments. We conclude that heating of tomato fruit at 34°C for 24 h caused the least injury and fruit color developed adequately.

INTRODUCTION
Tomato fruit is sensitive to CI at temperatures below 7-10°C (Cheng and Shewfelt, 1988). Heat treatments have been proposed to ameliorate CI (Lurie, 1998). However, the effect of heat treatments in tomato is variety-dependent. For example treatment of mature-green ‘Trust’ tomatoes with forced air at 38°C and 50% RH for 24 h injured the fruit, increased weight loss, prevented the development of red color and reduced the production of ascorbic acid (Yahia et al., 2000). Heat treatments in controlled atmospheres have been tested for insect control (Yahia and Ortega, 2000), but have not been tested for CI amelioration.

The objective of this work was to study the effect of postharvest hot air treatments in air at 34°C or 38°C or in low $O_2$ atmosphere at 38°C for 24 h at 50% RH on quality, important pigments, and on some of the important antioxidants in tomato fruit.

MATERIALS AND METHODS
Tomato fruit (Lycopersicon esculentum, ‘Rapsody’) were grown in a greenhouse and fruit were harvested in the mature-green stage. One lot of fruit was heated in air at 38°C, another lot was heated in air at 34°C, a third was heated in 5% $O_2$ at 38°C, all for 24 h and at 50% RH, and the fourth lot was not heated (control). Fruit of each treatment were then divided into 2 groups and stored either at 4°C or 10°C and 85% RH.

Heat treatments and controlled atmospheres (Fig. 1) were conducted inside a purpose built gas-tight, temperature-controlled, and forced-air chamber (Ortega and Yahia, 2000a; Ortega and Yahia, 2000b; Yahia and Ortega, 2000; Yahia et al., 1997).

Fruit were evaluated for up to 30 days for injury, weight loss, color, chlorophyll content, carotenoids, α-tocopherol, ascorbate peroxidase activity, and activity of super-
oxide dismutase, glutathione reductase, and glutathione S-transferase (Yahia et al., 2001, Yahia et al., 2000).

RESULTS AND DISCUSSION

Fruit injury increased during storage (Fig. 2). Fruit heated in 5% O₂ at 38°C and stored at 4°C or 10°C had the most intense injury, while fruit heated in air at 38°C and stored at 4°C were also severely injured. Fruit heated in air at 34°C and stored at 4°C had intermediate injury scores closely similar to those not heated. Fruit heated in air at 34°C and stored at 10°C, and non-heated fruit stored at 4°C or 10°C showed the least injury. Shewfelt (1993) reported that the maturation of tomato showed a physiological dysfunction when exposed to temperatures from 30 to 40°C. Inaba and Crandall (1988) showed that a high temperature stress can diminish the quality of the fruit causing tissue destruction and physiological dysfunction.

Weight loss increased during storage (Fig. 2). Non-heated fruit stored at 4°C and 10°C presented the least mass loss. Fruit heated in air at 34°C and then stored at 4°C had a final mass loss of 8.8%, while those stored at 10°C had a mass loss of 9.8%. Fruit heated in air at 38°C and stored at 4°C had a final mass loss of 10.5%, while those stored at 10°C had a final mass loss of 11.2%. Fruit heated in 5% O₂ at 38°C and stored at 4°C and 10°C had a final mass loss of 8.0 and 9.8%, respectively.

Fruit heated in 5% O₂ and then stored at 4°C or 10°C showed only a very slight increase in a* value, and they did not develop adequate red color (Fig. 3). Fruit heated in air at 34°C and stored at 10°C and those that were not heated and stored at 10°C showed the highest a* value, followed by fruit heated in air at 38°C and stored at 10°C, fruit heated in air at 38°C and stored at 4°C, and those not heated and stored at 4°C, and fruit heated in air at 34°C and stored at 4°C. Fruit heated in 5% O₂ and then stored at 4°C or 10°C showed almost no change in their Hue value, while fruit not heated or heated in air at 34°C or 38°C and then stored at 4°C or 10°C showed an increase in their Hue value indicating a change from green to red color. L* value ranged between 42 and 60 (Fig. 2). Fruit heated in air at 4°C or at 10°C showed an increased L* value. However, other treatments did not show a clear behavior. There was a decrease in the color intensity of the fruit (Fig. 3). Fruit heated in 5% O₂ and then stored at 4°C or 10°C presented the lowest color intensity (Fig. 3).

Chlorophyll decreased during storage (Fig. 4). The highest reduction was in fruit that were not heated and in those heated in air at 34°C. Chlorophyll slightly decreased in fruit heated in air at 38°C, and in those that were heated in 5% O₂ and stored at 10°C. Total carotenoids were highest in fruit that were not heated and those that were heated in air at 34°C and stored at 10°C (data not shown). They were lower in fruit that were heated in air at 38°C, and were very low in fruit heated in 5% O₂ at 38°C. Storage at 4°C inhibited the production of carotenoids in all treatments. Lycopene was highest in fruit that were not treated, followed by those that were heated in air at 34°C, and then by those that were heated in air at 38°C. Fruit that were heated in 5% O₂ and stored at 10°C had about 10% of the lycopene present in the other treatments. Storage at 4°C inhibited the production of lycopene in all treatments. β-Carotene increased during storage, and was highest in fruit that were not heated, followed by those that were heated in air either at 34 or 38°C.

α-Tocopherol in ‘Rapsody’ tomatoes ranged between 0.26 mg/g to 0.35 mg/g (data not shown). There were no major differences between heated and non-heated fruit in air. However, α-tocopherol decreased in fruit that were heated in 5% O₂.

Ascorbate peroxidase activity (data not shown) increased in storage, and the highest activity was in fruit heated in 5% O₂. There were no major differences among fruit heated in air and those that were not heated. Storage at 4°C slightly decreased the activity of this enzyme. There were no major differences in peroxidase activity between fruit that were heated in air and those that were not heated. Fruit that were heated in 5% O₂ had a much higher peroxidase activity than the fruit heated in air and those that were not heated. Catalase activity decreased in storage in heated and not heated fruit.
Superoxide dismutase activity was low in heated and non-heated fruit (data not shown). Heating in 5% O₂ stimulated an increase in the activity of glutathione reductase (data not shown) in the first 10 days of storage, but decreased afterwards. There was an increase in the activity of glutathione S-transferase activity (data not shown) during storage in heated and in non-heated fruit. Heating of the fruit increased the activity of this enzyme.

We conclude that heating of ‘Rapsody’ tomato fruit at 34°C for 24 h caused the least injury and fruit color developed adequately.

**Literature Cited**


Fig. 1. Changes in temperature and oxygen concentration during heat treatment.
Fig. 2. Injury scores, weight loss, and L* value.

- • Control at 4°C, ■ Control at 10°C, ▲ air at 38°C and 4°C, ▲ air at 38°C and 4°C, ◇ 5% O₂ at 4°C, ◇ 5% O₂ at 10°C, ◇ air at 34°C and 4°C, ■ air at 34°C and 10°C.
Fig. 3. Values of a*, hue and chroma.

- Control at 4°C, — Control at 10°C, ▲ air at 38°C and 4°C, ▲ air at 38°C and 4°C, ◇ 5% O₂ at 4°C, ▼ 5% O₂ at 10°C, ◆ air at 34°C and 4°C, — air at 34°C and 10°C.
Fig. 4. Chlorophyll (total, a and b) content.

- Control at 4°C, —■— Control at 10°C, —▲— air at 38°C and

4°C, —▲— air at 38°C and 4°C, —●— 3% O₂ at 4°C, —❖— 3% O₂ at

10°C, —❖— air at 34°C and 4°C, —❖— air at 34°C and 10°C.