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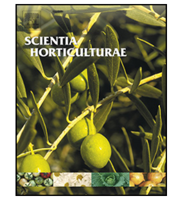

Effects of intermittent heat treatment on sensory quality and antioxidant enzymes of cucumber

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ABSTRACT

Effects of intermittent heat treatment on sensory quality and antioxidant enzymes were investigated by immersing cucumber in hot water (40 °C) for 30 (H1), 50 min (H2) continuously, or for 30 (I1), 50 (I2) min intermittently, respectively, and the intermittent treatment was realized through the temperature return process by room temperature water after every 10 min continuous treatment. Compared with the control group, the relative lower weight loss, decay index, and higher CAT activity et al., indicated that H1, I1 and I2 helped to delay cucumber ripening, and I1, I2 performed better. At the end of storage, the weight losses of I1, I2 were 79.93, 69.63% of H1, and the POD activity of I1, I2 was 1.31 and 1.23 times of H1. Nevertheless, the severe softening and etiolation implied a slight heat injury occurred in H2 due to heat stress. In addition, results from the analysis of heat transfer characteristics suggested: the superior preservation effect were probably result of the faster temperature change and the higher average temperature gradient of cucumber; the highest temperature that the cucumber achieved and the duration were the important reasons for heat stress.

1. Introduction

With the increasing concern over the presence of chemical residues on plant, heat treatment, as a safe and effective physical method, has achieved growing interest. A century ago, heat treatments have been used to free plant materials from pathogens, and now they are widely used in plant for the excellent performance in keeping storage quality, inhibiting chilling injury, etc (Paull and Chen, 2000). Heat treatments can reduce the methane dicarboxylic aldehyde (MDA) content, increase the activity of superoxide dismutase (SOD), and protect the ultra-structure of cells against chilling injury (Aghdam et al., 2013; Zhang et al., 2005), they also restrain the EGase and ß-Xyl activities in strawberries (Vicente et al., 2005). Ummarat et al., 2011 point out that postharvest heat treatments suppress softening in bananas, and express an induction of antioxidants. Some protein spots have been confidently identified from heat treated peach, and all protein spots have been involved in the regulation of fruit development and ripening (Zhang et al., 2011). Researches of Soto-Zamora et al., 2005 and Siomos et al., 2010 indicate that heat treatments can effectively inhibit transformation of tomato carotenoids and discolor of peeled white asparagus. In the meantime, heat treatment also performs better in reducing mechanical damage (Serrano et al., 2004). Conclusively, heat treatment occupies a predominant position in field of postharvest treatment for its positive effects.

Currently, continuous heat treatment plant for certain duration is primary method. The temperature of plant increases with the continuous heat treatment time, which will reduce the temperature difference between plant and treatment medium gradually. The physiological stress response of plant to high temperature and the duration of heat treatment are the main factors for preservation (Lurie, 1998), and the reduced temperature difference between plant and medium may decrease the effect of preservation. Intermittent heat treatment, which is realized through temperature return process by immersing plant in room temperature medium after every short time of continuous heat treatment, will improve the temperature difference between plant and treatment medium in the later process of heat treatment. And the improved temperature difference between plant and medium may increase the effect of preservation. Now few studies have demonstrated the effects of intermittent heat treatment on plant sensory quality and antioxidant enzymes during storage. Meanwhile, there have been few outcomes about the impact factors on heat treatment effect from the perspective of heat transfer characteristics during heat treatment.

Cucumber is one of the most economically important vegetable crops belonging to the family Cucurbitaceae (Jeffery, 1980). Total

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world production of cucumber in 2012 was 65.1 million tons, of which over 73.7% was produced in China [FAOSTAT, 2014, date available at http://faostat.fao.org/]. However, the quality of cucumber rapidly decline when ripened, and the short shelf-life, mainly caused by disease infection and severe water transpiration, have become limited factors for storage. Improving the storage quality and prolonging the shelf-life of postharvest cucumbers are two critical points.

Therefore, the objective of this work is to research the effects of intermittent heat treatment on sensory quality and antioxidant enzymes during storage, and cucumbers are selected as materials to continuous and intermittent heat treatment. At the same time, the distributions of continuous and intermittent heat treatment cucumbers internal temperature will be measured to evaluate the relationships between heat treatment effect and heat transfer characteristics.

2. Materials and methods

2.1. Plant materials

Freshly harvested "Fire phoenix" cucumbers of eight mature, were obtained from a local farm in Tianjin (China), and transported to the laboratory within 3 h. Being of similar size and color, about two hundred cucumbers without mechanical damage and insect pest were selected for experiments.

2.2. Treatment and storage

After flushing with clear water for 1 min, cucumbers were divided evenly into five groups (H1, H2, I1, I2, and CK) of 40 cucumbers in each group. Six cucumbers were tagged in each group randomly. Cucumbers were immersed in hot water at 40 °C for continuous 30(H1), 50(H2) min, or for intermittent 30(I1), 50(I2) min, and the intermittent treatment was realized through immersing cucumbers in room temperature water for temperature return after every 10 min continuous heat treatment. No treatment as control group (CK). After drying the surface moisture by an industrial fan, all cucumbers were transferred to a cold storage at 10 °C with a relative humidity of 90% and an air velocity of 1.2 m/s for 15 days. A preliminary test had been implemented before the formal experiment.

2.3. Temperature field

The distributions of cucumber internal temperature at center, $R/3$ and $2R/3$ radial direction were measured by T-type thermocouples(Tianjin Zhonghuan Temperature Meters Co., Ltd., Tianjin, China), with measurement accuracy: ±0.1 °C, and R is the radius of cucumber.

2.4. Weight loss

The six tagged cucumbers of each group were weighted during the storage for every 3 days. Results were expressed as percentage of weight loss relative to the initial weight.

2.5. Decay index

The percentage of decayed cucumber was recorded according to the area of water-soaked spots with four levels (n): 0, no decaying; 1, 1–25% of fruit surface; 2, 26–50% of fruit surface; 3, 51–100% of fruit surface. Decay levels of the six tagged cucumbers from each group were recorded during the storage for every 3 days. And the date was calculated as $n/3$.

2.6. Firmness

Firmness of six untagged peeled cucumber was measured with a penetrometer (Model GY-3, Hangzhou Huier Equipment Co., Ltd., Hangzhou, China) for every 3 days. The test of each cucumber was repeated 4 times.

2.7. Skin color

The chromaticity L(lightness), a(green to red color index), b(blue to yellow color index) values at the same positions of the tagged cucumbers were measured by a Chromameter (Model WSC-S, Shanghai Precision & Scientific Instrument Co., Ltd., Shanghai, China) for every 3 days. The total color difference (ΔE) was equal to $[(L-L_o)^2+(a-a_o)^2+(b-b_o)^2]^{1/2}$, in which the subscript "o" represents initial value before treatment.

2.8. CAT activity

CAT activity was measured according to Cakmak and Marschner, 1992 with modifications. Cucumber (1.0 g) was ground with extraction solution (5 mL), which containing 5 mmol/L DTT and 5% PVP (w/v). The homogenate was centrifuged at 12,000 g for 30 min at 4 °C, then filtered the sample and mixed the supernatant (0.1 mL) with 20 mmol/L H_2O_2 solution (2.9 mL) together. The decrease in absorbance of the mixture at 240 nm was recorded every 30 s with a spectrophotometer (Model UV-720, Shanghai Precision & Scientific Instrument Co., Ltd., Shanghai, China). One unit of enzyme activity was defined as an increase 10 U of absorbance at 240 nm. Six independent replicates were analyzed for each group.

2.9. POD activity

POD activity was assayed according to Lurie et al., 1997 with modifications. Cucumber (1.0 g) was ground with extraction solution (5 mL), which containing 1 mmol PEG, 4% (w/v) PVPP and 1% (v/v) Triton X-100. The homogenate was centrifuged at 12,000 g for 30 min at 4 °C, then filtered the sample and mixed the supernatant (0.5 mL) with 25 mmol/L guaiacol solution (3 mL) and 0.5 mol/L H_2O_2 solution (0.2 mL) together. The increase in absorbance of the mixture at 470 nm was recorded every 30 s with a spectrophotometer (Model UV-720, Shanghai Precision & Scientific Instrument Co., Ltd., Shanghai, China). One unit of enzyme activity was defined as an increase 100 U of absorbance at 470 nm. Six independent replicates were analyzed for each group.

2.10. Statistical analysis

Date were compared by one way analysis of variance (ANOVA) and Duncan's multiple comparisons, and means were compared by the least significant difference ($P = 0.05$). Statistical analyses were done using SPSS software, and date were shown as means ± standard error.

3. Results and discussion

3.1. Heat transfer characteristics during heat treatment

Heat transfer characteristics of continuous and intermittent heat treatment were analyzed from perspective of cucumber temperature distribution and temperature gradient. Took H2 and I2 for instance, and radius of the tested cucumber was 3.6 ± 0.1 cm, the process of temperature return for intermittent heat treatment was ignored.

The distributions of cucumber internal temperature (center, $R/3$ and $2R/3$) were described in Fig. 1, where H2 and I2 showed the