EVALUATION OF THE EFFECT OF HOT WATER DIPPING ON QUALITY OF FRESH AGRICULTURAL PRODUCTS

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ABSTRACT

Hot water dipping (HWD) at a range of treated temperatures from 34.5 to 63^{0}C and exposure times from 10 sec to 210 min were applied to cherry tomato fruits (*Lycopersicon esculentum cv.* Coco) after harvest. During storage at 20^{0}C for ripening, the surface color development of treated tomato fruits was delayed in a particular range of HWD conditions and after that ripped to full red-ripe stage. HWD conditions, in which tomato surface color development was delayed without heat damage, accumulated the effective treatment area (ETA). At red ripe-stage (a*/b* =1), the qualities such as sugar content, titratable acidity and firmness of tomato fruits treated in an ETA were similar to the control fruits, except for the lower acidity of tomato fruits treated at low temperatures for long exposure times. Those findings suggest that HWD at high temperatures for short times in the ETA were preferred in both color-delay and quality maintenance of cherry tomato fruits. The discovery and utilization of HWD in ETA could have significant benefits for quality management of cherry tomato fruits.

Key words: hot water dipping (HWD), cherry tomato fruits, surface color, quality

I. INTRODUCTION

Recently, wide international interest in heat treatment for quality maintenance and disease control has reflected in a range of literatures. With exposure of fresh agricultural commodities to high temperature, heat shock proteins transcripts and protein levels in such commodities have been shown to increase (Lurie, 1998). Further more, a wide range of fruit ripening processes are affected by heat, such as color (Cheng et al, 1988; Tian et al., 1996), ethylene synthesis (Ketsa et al., 1998), respiration (Inaba and Chachin, 1988), fruit softening and cell wall metabolism (Lurie and Nussinovich, 1996), volatile production (McDonald et al, 1999). Postharvest heat treatment also can reduce chilling injury in many kinds of fruits during subsequent low temperature storage as well as reduce pathogen level and disease development (McDonald et al, 1999; Lurie, 1997).

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Agricultural commodities are large and respond differently by applied heat treatment. Inappropriate heat treatment can also lead to ripening acceleration or heat damage (McDonald et al., 1999). In spite of numerous achievements about heat treatment, all previous studies have been performed on limited treating conditions for temperature andexposure time, and thus from previous studies we cannot obtain the applicable information in terms of the effect of heat treatment on the various qualities of fresh agricultural products. With the purpose of further understanding the influence of treated temperature and exposure time to agricultural commodities, we desired to study on "Evaluation of the effect of hot water dipping on the quality of fresh agricultural products" in order to utilize such heat treatment technique for quality management and distribution of fresh agricultural products.

II. MATERIAL AND METHODS

Cherry tomato fruits harvested in a green house at Aichi prefecture, Japan, were chosen for the analysis. Non-defected cherry tomatoes of the uniform size of 28± 2mm at turning stage (U.S Department of Agriculture, 1991) were selected. The fruits were dipped in hot water of wide range of temperatures from 34.5 to 63^0C for various exposure times from 10 seconds to 210 minutes, and a total of 53 treated combinations were examined. After such hot water dipping, both treated and non-treated (control) fruits were stored at 20^0C for ripening and the following parameters were evaluated: surface color, titratable acidity, total sugar content, firmness and damage. Surface color was evaluated by a* and b* values from Commision Internationale de l'Eclairage L*, a*, and b* color space coordinates. The a* and b* values were measured on ten fruits at three positions (stem, equatorial and blossom end) of each fruit using Color Reader (Minolta, Model CR-13, Japan). Titratable acidity, total sugar content, firmness and damage were investigated when the fruits ripened to red-ripe stage. Total sugar content was measured by the phenol-sulphuric acid method (Dubois et al., 1951). Titratable acidity expressed as the amount of citric acid by titrating with 0.1N NaOH was measured by indicator method (Boland, 1995). Firmness was determined by Hardness Tester (Torsee, Model PS-50, Japan) and expressed as the force required to compressing the equatorial region of the tomato surface by 3mm. The fruits with pitting, decay or abnormal softening during storage were defined as heat damaged fruits. All data for quality evaluation were analyzed statistically by analysis of variance (ANOVA), and the means were compared by the least significant difference (LSD) test at a significance level of 0.05.

III. RESULTS

3.1 Color delay effect

Fig.1 shows the typical color developments for treated cherry tomato and non-treated (control) ones, and Fig.1 (A) and (B) show the results of the combination of constant exposure time but different treating temperatures and of constant treating temperature but different exposure times, respectively. During storage at 20^0C after HWD, the surface color of control fruits developed normally and reached a full red-ripe stage characterized with a color value a*/b*=1.07 after 6 days.

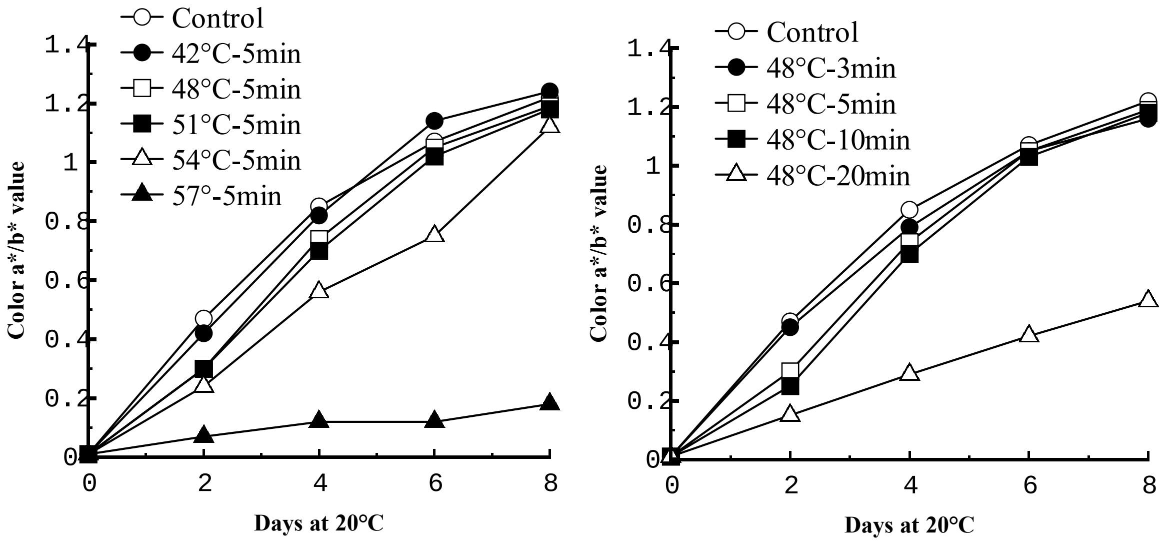

Fig. 1: Color developments of HWD cherry tomato fruits during storage at 20^0C. (A): Effect of different treated temperatures on color development of cherry tomato treated for 5min. (B): Effect of different exposure times on color development of cherry tomato treated at 48^0C.

The color development patterns of treated tomato fruits depended on the combinations of treating temperatures and exposure times. The color development of the tomato fruits treated at 42^0C (Fig. 1A) or for 3 min (Fig. 1B) was similar to that of the control fruits. With increase in treated temperature or exposure time during storage, color development delayed but finally reached a similar level as the control. The extent of delay became more remarkable at higher temperatures (Fig. 1A) or longer exposure times (Fig. 1B). However, further increase in temperature such as 57^0C (Fig. 1A) or exposure time such as 20min (Fig. 1B) induced not only suppression of the color development but also the occurrence of heat damage.

In order to evaluate the extent of delay of color development quantitatively shown in Fig.1, we defined color-delay index as a new parameter. Cherry tomatoes are commonly harvested at red-ripe stage with a*/b* value range of 1.0~1.1 and the tomato fruits reached a red-ripe stage in 6 days during storage at 20^0C in this experiment. In the present study, the color-delay index was calculated as follows:

$$\text{Color - delay index} = \frac{\left(\int_0^6 (a^*/b^*)_{control}\,dt - \int_0^6 (a^*/b^*)_{treated}\,dt\right)}{\int_0^6 (a^*/b^*)_{control}\,dt} \times 100$$

3.2 HWD and effective treatment area

Data from color-delay indices shows that the color delay effect was observed in a wide range of treated temperatures and treated times. With increasing treated temperature and treated time, the color changes were more retarded but the heat damage also increased.

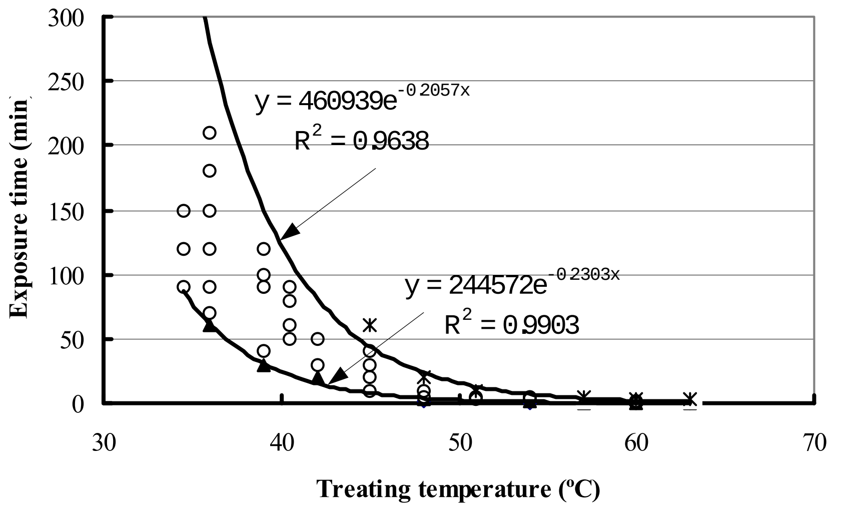

Fig.2: Effect of HWD on color development and heat damage of cherry tomato fruits treated at different HWD conditions.
Triangle marks (▲) indicate non color-delay conditions, circle marks (○) indicate effective HWD conditions (delay in color development and non-damage) and star marks (*) indicate heat damage conditions.

We found that hot water dipping induce not only color-delay but also damage of tomato. In the present study we determined whether the tomatoes fruits suffered pitting, decay or abnormal softening as heat damaged tomatoes. Fig. 2 shows the influence of HWD on the delay in color development and heat damage occurred at different treatment conditions. We found that applied HWD conditions could be divided into three parts, namely non color-delay area (▲ conditions), effective treatment area (○ conditions) and heat damage area (* conditions). Effective treatment area is in a range of restricted exposure times at treated temperature from 34.5 to 63^{0}C.

3.3 Quality evaluation

Table1 shows the qualities at red-ripe stage of tomato fruits treated at three typical HWD conditions in ETA. At high temperature for short exposure time conditions such as 60^{0}C for 40 sec and at 48^{0}C for 7 min, tomato fruits reached a red-ripe stage after 8 days with 2 days later than control fruits. The acidity, sugar and firmness were the same levels as the control. At low temperatures for long exposure time conditions such as 39^{0}C for 90min, treated fruits reached a red-ripe stage after 7 days with 1 day later than control and had the same level of sugar and firmness as control except for acidity.

Table 1: Influence of hot water dipping temperatures and exposure time in effective treatment area on days to red-ripe stage, titratable acidity, total sugar and firmness of cherry tomato measured at red-ripe stage with color a/b*=1.*

Treatment condition	Days to red-ripe stage (day)	Titratable acidity (g/100 ml)	Total sugar (mg/g f.w.)	Firmness (N)
60^0C- 40 sec	8	0.69^{ns}	34.3^{ns}	3.29^{ns}
48^0C- 7 min	8	0.68^{ns}	33.3^{ns}	3.18^{ns}
39^0C- 90 min	7	0.61^{*}	35.5^{ns}	3.20^{ns}
Control	6	0.70	31.8	3.42

Marks (ns) and (*) indicate non significant and significant difference at $P < 0.05$, respectively.

IV. DISCUSSION

During ripening, mature green cherry tomato changed color from green to red characterized with increasing a*/b* value. With HWD, the delay in color development was occurred and was observed by retarding a*/b* value. Our data are in accordance with previous researches (Lurie et al., 1996; Iwahashi et al., 1999). The delay in color development by high temperature was attributed to an inhibition of lycopene biosynthesis (Sayre et al., 1953) or its precursors phytoene and phytofluene (Yakir et al., 1984). Lurie et al., (1996b) specified that the inhibition of lycopene was due to the inhibition of transcription of mRNA for lycopene synthase and then recovered after removal from heat.

In our experiments, the color development of fruits was influenced by HWD temperatures and exposure times. At any treated temperature ranging from 34.5 to 60^0C, when exposure time was short, the treated fruits ripped normally compared with control fruits. With an increase in exposure time, the color development of treated tomato fruits was delayed. However, longer exposure times caused heat injuries and treated tomato fruits did not ripe normally after transferring them to 20^0C environment. Figure 3 shows three distinguished areas of HWD conditions. In the non color-delay area, treated cherry tomato ripped normally compared with control ones during storage. We suggested that the heat quantity in this area was low enough to affect to lycopene biosynthesis. In ETA, the heat quantity was considerable high to inhibit lycopene synthesis so that the color delay phenomenon was observed. The last, in heat damage area, too high heat quantity stimulated the convention of lycopene to beta-carotene so that tomato fruits had an orange color instead of red. High heat quantity also caused heat damage. The upper mentioned phenomenon was observed at any treated temperature ranging from 34.5 to 60^0C for different exposure times.

Concerning the quality, treated tomato fruits in ETA had the same titratable acidity, sugar content and firmness values compared to control fruits when measured at the same a*/b* value except that of fruits treated at low temperatures for long exposure times such as 39^0C for 90 min condition had a lower acidity values. Similarities in the quality of treated and control fruits showed that a wide range of temperature/time combinations in ETA could be the effective HWD conditions. In our study the acidity level of high temperature/short time treated fruits was similar to control fruits, but the acidity was lower at low temperature/long exposure time such as the case of 39^0C for 90 min treatment. The explanation about differences in acidity could be due to the effect of heat treatment on respiration metabolism of tomato fruits. Lurie and Klein, (1990) reported that the heat treatment provoked an increase in respiration rate and a significant amount of organic acid was used a substrate in respiration metabolism process. We suggest that in HWD conditions of high temperature for short time, the exposure times were short enough that the increased respiration exhausted inconsiderable quantity of organic acids. In HWD conditions of low temperature for long exposure time, the long exposure times led to considerable increase in respiration rate and a significant amount of organic acid was used.

V. CONCLUSION

Hot water dipping retarded color development and slowdown ripening process in cherry tomato fruits without affect the quality. The existence of ETA showed influence of treated temperature and exposure time on color development. Hot water dipping at high temperatures for short exposure times in ETA are preferred in both color-delay and quality maintenance of cherry tomato fruits. Beside that, these treatments are fast, simple to apply and do not require any special handling. Even though the above-mentioned ETA is for cherry tomato fruits, a similar area could be determined for other agricultural commodities. The application of these advantages could make HWD to be an effective, inexpensive and environmentally safe method to manage quality of cherry tomato fruits as well as other agricultural commodities.

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