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Effect of Ozone Solution Immersion Treatment on The Quality of Fresh Red Chilies During Modified Cold-Storage

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ABSTRACT

Chili is a vegetable with a characteristic of high moisture content, so easily damaged, and short shelf life. Most Indonesian households prefer to consume red chilies in fresh form. So, specific treatment is required to ensure the quality and shelf life of fresh red chilies. The objective of this study was to analyze the quality of red chilies stored in modified cold storage with and without dissolved ozone solution treatment. Red chilies were stored in perforated polyethylene (PE) plastic at 8±2°C and 89±2% relative humidity. Fresh red chilies were investigated for hardness, color, moisture content, vitamin C, and capsaicin after 0, 1, 2, 3, and 4 weeks of storage. The modified cold storage preserved fresh red chilies for three weeks without ozone treatment and four weeks with ozone treatment. The moisture and vitamin C content remained stable, but the color, hardness, and capsaicin content significantly decreased.

1. INTRODUCTION

Red chili is a strategic commodity that has the potential to be marketed both domestically and internationally. Fresh red chilies still dominate domestic consumption. Red chilies are offered in fresh form and are in high demand on the market (Asgar *et al*., 2017). According to Taufik (2011), from a scientific and economic standpoint, numerous types of red chili were efficient to be developed as agribusiness commodities, with earnings ranging from Rp.11.20 million to Rp.21.77 million per hectare, with B/C ranging from 2.10 to 3.14. The primary impediment to red chili entrepreneurship is its perishability. Red chilies are readily damaged and have a relatively limited shelf life due to their high moisture content in their fresh state (Asgar *et al*., 2015; Asgar *et al*., 2017). The high moisture content of fresh chilies increases the potential for physiological injury and the activity of microorganisms that might destroy fresh chilies (Budiarti & Kurnianingrum, 2017). As a result, suitable post-harvest handling procedures are required to maintain quality and increase the shelf life of fresh chilies.

Several research showed that storing red chilies at 10°C could minimize weight losses by up to 8.38% after 14 days of storage (Asgar *et al*., 2015) and could maintain red chili's freshness for up to 13 days in cardboard packaging (Nurdjannah *et al*., 2014). Lamona *et al*. (2015) observed that weight losses might be slowed by up to 0.12% on curly red chilies using polypropylene (PP) plastic and stored at 10°C for 29 days. While, Edowai *et al*. (2016) reported that the ripening level of green and reddish-green fruit could sustain cayenne pepper quality during storage.

Several different handling techniques have been recorded, including styrofoam packing covered by transparent polyethylene with a maturity level of 50 to 60% that could preserve chilies at room temperature for up to 9 days (Rochayat & Munika, 2015). Plastic is used to decrease fresh product moisture loss, dehydration, and to preserve food from harm and pollution (Ansar *et al*., 2021). Polyethylene (PE) plastic is used to package horticultural items which is soft, translucent, flexible, and impact-resistant and tear resistant. PE plastic increases CO_2 and decreases O_2, inhibiting material degradation (Anggraini & Sugiarti, 2018), and its thickness reduces O2 and CO2 permeability (Ansar *et al*., 2019).

According to Rostia (2019), 7 kJ/m^2 UV-C irradiation and 8 seconds of ozone exposure in air media could preserve the quality and enhance the shelf life of red chilies. Red chilies could be preserved for up to 14 days by immersing in 10 ppm GA_3 and five ppm benomyl at a low temperature of 10°C (Setyabudi *et al*., 2016). Setyabudi *et al*. (2019) also claimed that the controlled atmosphere storage (CAS) approach could preserve red chili's freshness for up to 5 weeks.

Ozone is also reported to be capable of extending the shelf life of red chilies. According to Asgar *et al*. (2015), immersion in 1 ppm ozone solution followed by storing at 10°C was capable of preserving the color, freshness, appearance, and preference of the panelists of red chilies Kencana variety for up to 14 days. Ozone immersion treatment at 0.4 ppm improved the freshness and appearance of red chili (Asgar *et al*., 2017). According to Pratama *et al*. (2016), red chilies with ozone immersion and refrigerated storage could survive up to one month. Hot water treatment (HWT) and ozone exposure revealed that the chili was of high grade. Combining HWT, ozone exposure, and storing at 15°C can boost vitamin C levels, prevent weight losses, total microbial, and maintain the firm and color of red chilies. This mixture slightly increases the shelf life of red chilies by up to 28 days (Fhadilla, 2019).

Ozone technology is reported to be able to shed pesticide contaminants, pathogens, and heavy metals clinging to fruits and vegetables (Asgar *et al*., 2017). The mechanism of ozone in removing bacteria is that ozone penetrates the cell wall, resulting in changes in permeability and inducing lysis of microbial cells (Asgar *et al*., 2017). Ozone immersion treatment can suppress the growth rate of microbe in chilies (Osiriphun *et al*., 2019; Sasmita *et al*., 2018). Therefore, the objective of this study was to investigate the effect of ozone immersion treatment, combined with modified cold storage and packaging, on the physicochemical parameters of red chilies (*Capsicum annum* L.) during storage.

2. MATERIALS AND METHODS

The research was conducted at Indonesian Center for Agricultural Postharvest Research and Development – Bogor. Fresh red chilies were used as the primary component in this research, obtained from farmers in Lembang, West Java. The chemicals were used in the research including ethanol 96%, 0.01 N iodine, and 1% amylum.

The equipment was used in the research, including cold storage room whose temperature has been set at around 8±2℃, with a relative humidity of 89±2%, polyethylene (PE) plastic packaging at 50×85 cm^2 with 80 µm of thickness, chromameter (Minolta CR-300), texture analyzer (Brookfield, UK), hot air oven, and a high-performance liquid chromatography (HPLC, Ultimate 3000 UHPLC).

2.1. Sample Preparation

Fresh red chilies were sorted as soon as the materials arrived to distinguish those which were still fresh with excellent quality form those which have been damaged, rotting, or wilted. Red chilies with good qualities were then weighed up to 7.5 kg. The red chilies were then divided into two groups, those without soaked in ozone solution, and those with soaked in ozone solution. Each group were replicated three times.

For the first group, fresh red chilies weighing 7.5 kg were packaged in perforated polyethylene (PE) plastic on measuring 50 × 85 cm^2 with 80 µm of thickness, and ready to be stored in a modified cold storage room.

Fresh red chilies were immersed in 1 ppm ozone solution for 30 minutes before being removed, drained, and packed in 50×85 cm^2 polyethylene (PE) plastic in 80 µm of thickness with perforated holes for the second group. Fresh red chilies were packaged and ready to be kept in the cold storage room.

2.1.1. Plastic packaging preparation

The packaging plastic was polyethylene (PE) plastic measuring 50 × 85 cm^2, 80 µm of thickness, with 96 holes on it, with each hole having a diameter of 0.5 cm.

2.1.2. Storage room preparation

The storage room was a cold storage room which was set at a temperature of 8±2℃, with relative humidity set at 89±2%.

2.2. Hardness Analysis

The hardness level of fresh red chili was observed using texture analyzer (Pro CT3, Brookfield) following the Setyabudi *et al*. (2019) methods. Red chilies samples were sampling randomized, and the hardness of the fruit was tested at the base, middle, and tip for three replications. Using a 25 mm cylindrical probe to assess a two-cycle compression test, the hardness level of fresh red chilies was analyzed. The samples were compressed twice to 50% of their origin thickness at a rate of 1 mm/s under a weight of 5 kg that was activated. The degree of hardness was recorded.

2.3. Color Analysis

The color of red chilies was measured using chromameter (Minolta CR-300) following Lin *et al*. (2019) methods. L^* parameter was used to indicate the brightness of the red chili, a^* parameter was used to indicate the reddish to greenish color, while the value of b^* described the level of bluish to yellowish color.

2.4. Moisture Content Analysis

Moisture content was measured using gravimetric methods (Asgar *et al*., 2017). The measurement was started with disk preparation that has been dried at the hot air oven at 105℃, for 30 minutes, cooled in a desiccator, then weighed (a). The sample was weighed ± 2 g and put in the disk (b), then dried in the hot air oven at 105℃ for 6 hours, until the sample has a constant weight. The sample was cooled in a desiccator for 30 minutes, and weighed (c). The moisture content was calculated as:

$$Moisture\ content\ (\%) = \frac{b-c}{b-a} \times 100\% \quad (1)$$

2.5. Vitamin C Analysis

The iodometric technique was used to determine the vitamin C concentration (Asgar *et al*., 2017). Red chili samples were cleaned, dried, chopped into small pieces and mashed. The sample was then weighed, 2 – 10 g, and placed in a 250 mL volumetric flask, followed by 250 mL of distilled water. The red chili samples were mixed to ensure homogeneity, and filtered using filter paper. A total of 25 mL of the sample was placed in a 100 mL volumetric flask, followed by 1 to 2 mL of 1% amylum solution, and titration using 0.01 N iodine solution. Vitamin C level were calculated as follows:

$$Vitamin\ C\ \left({}^{mL}/_{100\ g}\right) = V_{titration} \times \frac{N_{iod}}{0.01\ N} \times \frac{FP \times 0.88 \times 100}{sample\ weight} \quad (2)$$

where FP defined as the dilution factor, and N_{iod} defined as the iodine concentration.

2.6. Capsaicin Content Analysis

The capsaicin concentration of red chili was determined using HPLC (Ultimate 3000 UHPLC) following Renate *et al*. (2014) method with modification. The crushed red chili sample was weighed up to 2 g, placed in a test tube, and 96% ethanol was added. The test tube was covered in aluminum foil until it was light-tight, placed in an 80℃ water-bath for 4 hours, and manually stirred every hour. The sample was cooled at room temperature before being filtered using 0.45 µm of filter paper, and placed in the sample vial. The column employed was C-18, with a flow rate of 1 mL/min and a retention time of 15 mins at 60℃.

2.7. Statistical Analysis

The study used completely randomized design (CRD) with 2 factors. The first factor was without/with ozone solution immersion treatment; and the second factor was storage time, 0, 1, 2, 3, and 4 weeks. Data analysis used two-way ANOVA and continued with Tukey's test with a significance level of 0.05.

3. RESULTS AND DISCUSSION

3.1. Effect of Ozone Immersion on Physical Characteristic of Fresh Chilies

During modified cold storage, the average hardness of red chilies ranged from 677.73 to 721.92 N without and with ozone solution immersion treatment, respectively, as is showed at Table 1. It showed that ozone immersion treatment has no significant influence on the hardness of fresh red chilies. These results are in line with those presented by Zainuri *et al*. (2018) which stated that there was no effect of ozonation on the texture of tomatoes stored for 12 days with PE packaging. After harvest and during the ripening phase, the texture of horticultural products is strongly related to the metabolic response and biochemical breakdown of particular chemical components (such as pectin) (Zainuri *et al*., 2018). It indicated that packaging reduced the amount of gas in the surrounding fruit, hence decreasing the respiration rate and biochemical deterioration, which is connected to the fruit texture (Zainuri *et al*., 2018). Therefore, the hardness of ozone-treated and untreated packaged chilies became not significantly different.

Ozone immersion treatment has no significant impact on the brightness level of red chilies as well. Immersion in ozone solution considerably altered the levels of redness (a) and yellowness (b) in fresh red chilies. The ozone immersion treatment resulted in a redness level that was, 41.79, greater than the redness level without ozone treatment, 34.52. Similarly for the yellowness level of chilies. The immersion treatment with ozone resulted in a greater degree of yellowness, 35.13, compared to no immersion treatment, 28.35, showed at Table 1. This result is in line to Asgar *et al*. (2015) which stated that 1.0 ppm ozone solution immersion provided better color and freshness level than no ozone treatment. This indicated that ozone treatment could suppress fungal development and microbial growth without affecting polyphenol and carotenoid components (Sukarminah *et al*., 2017), producing the better redness (a*) and yellowness (b*) level than that of without ozone treatment.

Table 1. Physical properties of fresh red chilies during storage

Ozone solution treatment	Hardness N	L*	a*	b*
Without immersion	721.92 ± 200.20^{a}	37.21 ± 2.95^{a}	34.52 ± 8.06^{b}	28.35 ± 12.44^{b}
With immersion	677.73 ± 130.67^{a}	36.32 ± 3.12^{a}	41.79 ± 3.52^{a}	35.13 ± 7.28^{a}

Notes: values (mean ± SD) within a column followed by different superscripted lowercase letters are significantly ($p<0.05$) different

Redness (a*) and yellowness (b*) represent the strength of the color in the sample product; the higher the intensity, the greater the concentration. This research did not analyze the relationship between color and customer acceptance. However, previous research on chilies have shown that the initial color (degree of redness) and physiological activity of chili might influence chili color, which is essential quality criterion for evaluating customer approval (Munarso *et al*., 2020). According to a prior research, customers prefer the color of chili that has been kept cold at 10°C for 8 and 14 days over chili that has been stored at room temperature (Asgar *et al*., 2015). Nonetheless, customer acceptability of chili without ozone treatment and with ozone treatment did not alter substantially between 8 and 14 days after storage (Asgar *et al*., 2015).

3.2. Effect of Ozone Immersion on Chemical Characteristic of Fresh Chilies

Immersion in an ozone solution did not significantly alter the moisture content of fresh red chili, which varied between 81.34 and 82.09%, showed at Table 2. Similarly, the vitamin C concentration of fresh red chilies ranged between 14.12 and 15.16 mg/100 g, while ozone treatment had no significantly effect. These finding are consistent with that of Setiasih *et al*. (2020), which stated ozone treatment on red chili had no effect on moisture content or vitamin C levels. This phenomenon were most likely due to the influence of temperature and humidity in the room storage chamber on respiration rate, the lower the temperature, the slower the respiration, thus only a small amount of water was lost and a little of vitamin C was decomposed (Asgar *et al*., 2015; Asgar *et al*., 2017).

Table 2. Chemical properties of fresh red chilies during storage

Ozone solution treatment	Moisture content %	Vitamin C mg/100 g	Capsaicin ppm
Without immersion	81.34 ± 2.20[a]	15.16 ± 2.04[a]	22.18 ± 19.24[b]
With immersion	82.09 ± 1.44[a]	14.12 ± 1.73[a]	28.31 ± 22.94[a]

Notes: values (mean ± SD) within a column followed by different superscripted lowercase letters are significantly ($p<0.05$) different

For the capsaicin concentration of fresh chilies, there was a significant difference between 22.18 ppm without ozone immersion and 28.31 ppm with ozone immersions, showed at Table 2. It showed that ozone immersion treatment could maintain the capsaicin content on modified-cold stored of fresh red chilies.

3.3. Effect of Storage Time on Physical Characteristic of Fresh Chilies

The hardness and color of fresh red chilies during modified-cold storage were shown in Table 3. Fresh red chilies hardness was rose during the first week of storage, then gradually declined in the following week. The rise of hardness during first week was caused by rehydration process in red chilies during the initial storage period. Red chilies that had previously wilted during the postharvest and shipping procedures were able to rehydrate, adapted to the modified cold storage which has temperature of 8±2°C, and relative humidity of 89±2%. The moisture was absorbed during rehydration processes, and increased the hardness of red chilies. However, this process was short-lived, as storage time increases, the red chilies hardness progressively reduced. This hardness reduction after storage was in line with previous research (Asgar *et al*., 2017). The hardness of red chilies decreased after storage owing to chemical changes in the cell walls throughout the metabolic process from protopectin, which was not soluble in water, causing the texture to soften. Furthermore, the content of pectin molecules in cell walls reduced during storage (Zainuri *et al*., 2018).

Table 3. Physical properties of fresh red chilies during storage

Period of storage	Hardness (N)	*L**	*a**	*b**
0 weeks	563.83 ± 55.01[b]	41.63 ± 0.83[a]	36.24 ± 7.93[c]	32.39 ± 11.61[b]
1 week	887.75 ± 172.35[a]	34.22 ± 1.37[c]	40.90 ± 5.12[b]	35.40 ± 6.22[ab]
2 weeks	773.17 ± 64.38[a]	36.41 ± 1.98[b]	31.72 ± 6.19[d]	19.75 ± 6.91[c]
3 weeks	594.92 ± 102.71[b]	35.68 ± 0.57[bc]	42.83 ± 3.74[ab]	39.00 ± 8.16[a]
4 weeks	637.00 ± 107.13[b]	34.54 ± 0.28[c]	43.66 ± 0.48[a]	35.96 ± 0.57[ab]

Notes: values (mean ± SD) within a column followed by different superscripted lowercase letters are significantly ($p<0.05$) different

As indicated in Table 3, the brightness level of red chilies reduced from 41.63 to 34.54 as storage duration increased. Nonetheless, the redness (*a**) and yellowness (*b**) level of chilies increased as storage time increased. This is in line with Edowai *et al*. (2016). Some pigments exhibit transformations after storage. Carotenoid pigments provided the yellow, orange, and red coloration. Lannes *et al*. (2007) stated that as chilies ripen, the carotenoid pigments, capsanthin, capsorubin, and cryptocapsin were synthesized. The most noticeable color changes occurred during ripening, including synthesis of carotenoids, degradation of chlorophyl, and creation of anthocyanins (Edowai *et al*., 2016).

3.4. Effect of Storage Time on Chemical Characteristic of Fresh Chilies

As reported in Table 4, neither the moisture content nor the vitamin C content of fresh red chilies significantly altered during storage. It associated with the temperature and humidity in the storage room which influence the respiration rate. When respiration rate slower, then water lost and vitamin C decay could be suppressed (Sukarminah *et al.*, 2017). Furthermore, appropriate post-harvest handling technology is critical for reducing or delaying water loss from the product. Packaging, for example, has a major impact on the environment surrounding the items, which can lower the rate of respiration and transpiration in the fruit (Zainuri *et al.*, 2018).

Table 4. Chemical properties of fresh red chilies during storage

Period of storage	Moisture content %	Vitamin C mg/100 g	Capsaicin ppm
0 weeks	82.04 ± 2.61^{a}	16.40 ± 2.25^{a}	49.61 ± 9.13^{a}
1 week	81.21 ± 1.40^{a}	14.47 ± 0.88^{a}	42.22 ± 17.39^{b}
2 weeks	80.91 ± 1.61^{a}	13.90 ± 0.77^{a}	14.79 ± 7.14^{c}
3 weeks	82.67 ± 1.40^{a}	14.48 ± 2.17^{a}	7.48 ± 3.27^{cd}
4 weeks	82.52 ± 1.62^{a}	14.48 ± 2.17^{a}	2.07 ± 0.65^{d}

Notes: values (mean ± SD) within a column followed by different superscripted lowercase letters are significantly ($p<0.05$) different

However, the capsaicin concentration considerably declined from 49.61 to 2.07 ppm. The occurrence of decomposition processes on red chilies during storage, resulting in a reduction in capsaicin content, enables these results conceivable.

3.5. Interaction of Ozone Solution Immersion and Storage Time Treatment

There was an interaction effect between the treatment with and without ozone-immersion and storage time on the capsaicin content of fresh red chilies, as shown in Figure 1. The treatment without ozone immersion resulted in a lower concentration of capsaicin than that of with immersion. In addition, the longer the storage duration, the greater the reduction in capsaicin content. The fact that red chilies undergo breakdown processes during storage, resulting a decrease in capsaicin concentration, provided these results feasible.

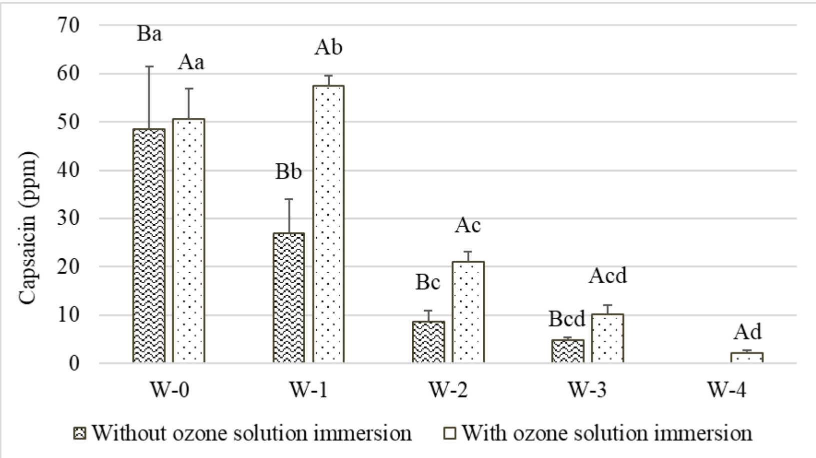

Figure 1. Capsaicin content of fresh red chilies during modified cold-storage

4.CONCLUSIONS

Ozone immersion treatment significantly affected the level of redness and yellowness of chilies, while storage period affected the hardness and color of fresh red chilies during modified cold-storage. The interaction of the two treatments affected the capsaicin content. Meanwhile, the water and vitamin C content remained stable without the influence of any treatment during storage. It is necessary to study further modifications and different treatments to maintain the capsaicin content of fresh red chilies.

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