International Journal of Technology 11(1) 37-47 (2020)
Received June 2019 / Revised August 2019 / Accepted January 2020

International Journal of Technology

http://ijtech.eng.ui.ac.id

Quality Analysis of Chili Treated with Aqueous Ozone Treatment and Improved Transportation and Handling Technology

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Abstract. The objective of this research is to study the reduction of chili postharvest losses (PHL) after implementation of aqueous ozone treatment, perforated packaging and refrigerated transportation in inter-city distribution. The completely randomized design method was used in the research, with five levels of combination treatments of chili: (i) aqueous ozone treatment; refrigerated transportation; (ii) no ozone treatment; refrigerated transportation; (iii) aqueous ozone treatment; non-refrigerated transportation; (iv) no ozone treatment; non-refrigerated transportation; and (v) existing handling practice as a control treatment. The study was conducted on a large scale in order to imitate the practice of local traders when distributing chili to other cities, with three repetitions. Each repetition used 850 kg of chili, which was transported from Magelang District, Central Java to Bogor, West Java (541.5 km), a journey of approximately 15-17 hours. Temperature and relative humidity in the vehicles were monitored and recorded. Quality analysis included decayed/damaged chili and chili with inappropriate harvest age, grouped into four types, namely physical/mechanical, physiological, microbiological, and green chili; color and texture. The quantity parameter was determined by measuring weight loss. It was concluded that the implementation of aqueous ozone treatment and improved transportation handling technology using refrigerated vehicles could reduce the postharvest losses of chili by 60.61%. Quantity loss was reduced from 2.16% to 1.82% and quality loss from 6.70% to 1.68%. Moreover, the color and texture (hardness) of the chili was maintained, showing a preserved freshness, which is an important parameter in chili marketing.

Keywords: Aqueous ozone treatment; Chili; Postharvest losses; Quality analysis; Refrigerated transportation

1. Introduction

Postharvest losses (PHL) are a worldwide concern these days, in the light not only of unstable food prices, but also more importantly because of decreasing food availability. PHL reduction technology is considered to be a solution to help maintain the availability and quality of fresh produce (Kitinoja, 2013).

Chili is one of the primary commodities monitored by the Government of Indonesia,

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doi: 10.14716/ijtech.v11i1.3213

due to its integral part in the Indonesian diet and cuisine. Over the years, chili price volatility has increased, with price swings occurring more than once every year, resulting in price increases of over 100% in a 3-to 4-month period (Webb and Kosasih, 2011). It was reported internationally when the price of chili increased as much as 10-fold at the end of 2010, reaching a higher price than beef. Repeated high price increases drive up inflation and become a matter of national concern and source of debate at every level (Webb et al., 2012).

Unlike with other commodities, this price volatility cannot always be explained as a result of changes in consumer demand. Although it is used as a cooking condiment, and market demand is rather inelastic (other than in the Holy Month of Ramadhan, when a surge in demand takes place), the price swings of chili have been persistent during the last decade (Webb and Kosasih, 2011; Webb et al., 2012). It is reasonable to say that the price fluctuations are caused by the production and distribution system (Webb and Kosasih, 2011).

The level of chili productivity in Indonesia over the past 5 years has been around 6 tons/ha. The national production volume was 1,045,000 tons in 2016, which exceeded the total consumption of approximately 760,000 tons. However, two case studies in Payakumbuh, West Sumatra (Iswari and Srimaryati 2014) and in Magelang, Central Java (ICAPRD & PT. Agro Indo Mandiri, 2018), revealed that the loss of chili during the supply chain reached 38% and 17%, respectively. These data suggest a relatively high discrepancy between the amount of chili available in the market and the consumption rate of the community. This may explain the price fluctuations and the occurrence of negative trade balances of chili in the past, when import volume was comparably higher than export volume. This situation is likely to recur in the future if a PHL reduction effort is not made.

As with other horticultural products, chili tends to be perishable due to its high water content and continued active metabolism after harvest, raising challenges for those along the supply chain (farmers, traders and retailers) to maintain its postharvest quality and prevent losses (Mahajan et al., 2017). The value of commodities is also influenced by plant-disturbing organisms (Wijanarko et al., 2017). Various technologies had been developed by researchers to reduce PHL, including ozonation (Iswari and Srimaryati, 2014; Nurdjannah et al., 2014; Setyabudi et al., 2016; Asgar et al., 2017). Moreover, improved transportation conditions are necessary, especially in Indonesia, where chili must be distributed daily from production centers to different areas. However, only a few practitioners in the field had implemented these technologies, and combining postharvest technology and improved transportation for chili is unheard of. The lack of experiments using large scale and actual conditions from farm to market is one of the challenges to implementation by practitioners in their commercial activity. The objective of this research is to study the reduction of chili postharvest losses after implementation of aqueous ozone treatment, perforated packaging and refrigerated transportation in inter-city distribution. The postharvest handling activities in the study were conducted with the actual daily schedules, scales and conditions of the farmers.

2. Methods

The application of aqueous ozone technology and perforated packaging took place in Sugihmas Village, Grabag Subdistrict, Magelang District, Central Java, in cooperation with the Association of Farmers' Groups (Gapoktan), namely Maju Mandiri. This location was chosen based on recommendations from the Department of Agriculture and Food Crops of Magelang District. According to these, apart from Magelang being a production center of chili, supplying the crop to surrounding areas and near big cities, including Jogjakarta (+50 km), Semarang (+80 km), Jakarta (+500 km) and Tangerang (+550 km), it is also known to have an established mechanism of buying and selling chili with an auction method during the harvest season.

The activity was conducted three times, scheduled based on the local farmers' harvest times, which fell on Kliwon days, according to the traditional Java calendar system (at five-day intervals). The chili was harvested in the morning and sorting was done directly on the trees. Only chili with minimum red color of 50% was harvested. After harvesting, the chili was put into plastic crates and taken to the local packaging house operation unit (PHO) for treatment. The study was conducted on a large scale in an effort to imitate the practice of local traders when distributing chili to other cities. Each repetition used approximately 850 kg of chili, which was transported by road from Magelang District to Bogor, West Java (541.5 km, approximately 15–17 hours).

2.1. Aqueous Ozone Treatment

Aqueous ozone was prepared by an ozone generator (D'Ozone, Dipo Technology, Semarang, Indonesia). Ozone gas was pumped into water in a stainless steel tub (2,400 L, filled to two thirds level) for 1.5 hour in order to ensure a perfectly saturated ozone concentration in the water. The chili was placed in plastic crates (20 kg per crate) and soaked in the ozonized water for 15 minutes. It was then drained on draining tables prior to sorting. Subsequently, it was packed into cardboard boxes (two types) according to its respective treatment.

2.2. Determination of Packaging Perforation

Perforation is important in order to accommodate and anticipate the respiration and transpiration process of harvested chili. Determination of the placement of holes in the cardboard as perforation was modified from a previous study by Mandana et al. (2013), which recommended 3% perforation of the packaging surface area.

The dimension of the cardboard used in this study was 56 cm × 36 cm × 38 cm (length × width × depth). 36 holes were placed evenly on four sides of the cardboards (front, back, right and left), the obtained perforation being approximately 2.5% of the surface area.

2.3. Chili Distribution

The chili with the improved handling treatment was packed into perforated cardboard boxes with a capacity of 20 kg/box, while the untreated chili (existing practice) was packed into used cigarette cardboard cartons, as is the usual practice of the collectors/PHO. The chili was then transported from Magelang, Central Java to Bogor, West Java using a refrigerated truck and non-refrigerated truck. The temperature and relative humidity in the trucks during transportation were monitored using a Hygrochron temperature & humidity iButton (DS1923-F5#). Five boxes of each treatment were unloaded in Bogor as research samples for quality and quantity parameter observation.

2.4. Quality and Quantity Parameter Observation

Examination of the decay and damage rate was made using the non-destructive method with subjective evaluation by trained staff (Mahajan et al., 2017). Decayed/damaged chili and chili with inappropriate harvest age was separated and weighed. The decay and damage were then identified and grouped into different types, i.e. physical (mechanical), physiological, microbiological and green chili, and each was weighed. Examination of the texture profile was conducted using a Texture Analyzer (Pro CT3, Brookfield) and of color (L, C and hue values) using a Chromameter (AMT501U, AMTAST). The quantity/weight loss was calculated as follows:

$$\text{Weight loss} = \frac{\text{initial weight} - \text{end weight}}{\text{initial weight}} \times 100\% \quad (1)$$

2.5. Data Processing and Statistical Analysis

The experiment employed completely randomized design, applying one factor and five levels of combination treatments of chili, including treatment with/without ozone and refrigerated transportation, and compared these with the existing practice. The applied treatments were: (i) aqueous ozone treatment, refrigerated transportation; (ii) no ozone treatment, refrigerated transportation; (iii) aqueous ozone treatment, non-refrigerated transportation; (iv) no ozone treatment, non-refrigerated transportation; and (v) existing handling practice as a control treatment. Each treatment was repeated three times, meaning there were 15 experimental units. Sample collection was conducted by taking five cardboards boxes of chili from each experimental unit, and sampling the chili from each cardboard boxes. The data were analyzed statistically using analysis of variance (ANOVA) and the Duncan multiple range test (DMRT).

3. Results and Discussion

3.1. Transportation Conditions

Upgraded value chain conditions, for example through cooling, have been found to be beneficial for small-scale postharvest technology to reduce losses in horticultural crops (Kitinoja, 2013). In this study, chili distribution was performed in two different conditions, refrigerated and non-refrigerated. The temperature and relative humidity (RH) of the environment during chili transportation using the refrigerated vehicle ranged from 17.61 to 26.11°C and from 82.71 to 90.28%, while for the non-refrigerated vehicle the figures were 23.09 to 30.59°C and 85.46 to 94.09% (Figures 1 and 2).

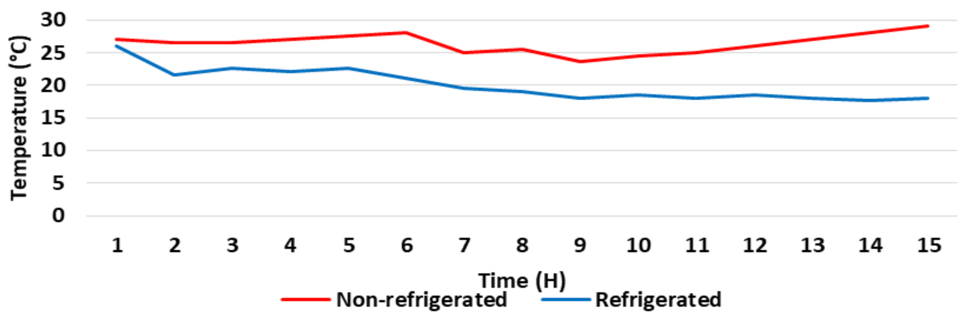

Figure 1 Temperature inside the refrigerated and non-refrigerated vehicles during chili transportation

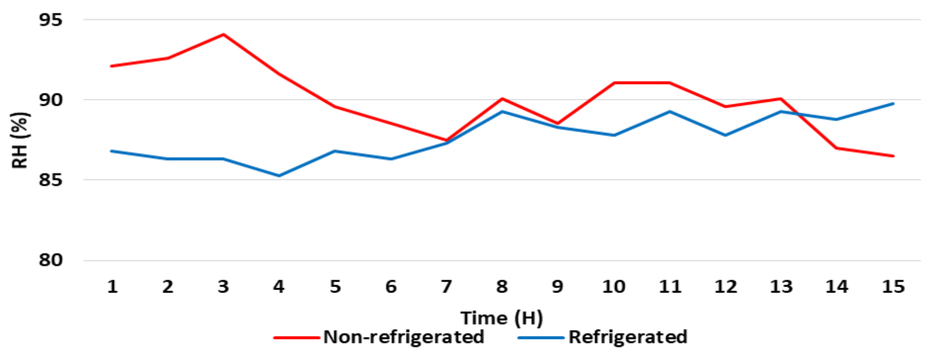

Figure 2 Relative humidity inside the refrigerated and non-refrigerated vehicles during chili transportation

A fluctuation in temperature occurred in the refrigerated truck, which was suspected to be a technical problem. However, the lowest temperature of 17.61°C was achieved around half way through the trip (at midnight), which stabilized somewhat further into the journey. On the other hand, the temperature in the non-refrigerated truck was more stable in the first half of the trip, but started to increase after sunrise. This observation shows that it is important to schedule transportation at night, to help maintain the temperature and avoid more damage if a technical problem occurs. Such problems may be caused by the required amount of energy needed to achieve the targeted temperature, which in turn is influenced by the ambient air temperature and humidity, the age of the vehicle and of the refrigerant used, and the specific refrigeration technology used (Budiyanto and Shinoda, 2017).

3.2. Quality Analysis

3.2.1. Quality deterioration

Quality losses were defined as deterioration due to mechanical damage, microbiological damage, physiological damage or inappropriate harvest age. The quality losses in the chili are shown in Table 1. The implementation of all the technology interventions resulted in the lowest quality loss compared to other treatments.

Mechanical losses between treatments showed no significant difference, i.e. 1.02-2.10%, a very low figure according to ICAPRD and PT. Agro Indo Mandiri (2018) reported chili mechanical losses as high as 14.79 % between harvest by farmers and involvement of large scale collectors and traders, due to the use of used fertilizer plastic sacks. In this study, this practice was replaced by using plastic crates. Kitinoja (2013) found that the use of plastic crates can reduce damage by 30 to 60% and improve market value by 40 to 140% per kg.

In this research, physiological losses were identified by visual assessment, i.e. sorting the withered and wrinkled chilis. The data show that all treatments had an insignificant difference on physiological losses, as the transportation duration was probably not long enough to make a difference. However, the data tendency indicates that the use of refrigerated transportation did lower physiological damage compared to non-refrigerated transportation.

Mahajan et al. (2017) elaborate that temperature management has been a focus in the efforts to improve the marketing of fruit and vegetables. This includes minimizing delays between harvest and cooling time, and trading and distribution. Temperature management should cover the supply chain, applying techniques from rapid cooling to controlled temperature at retail storage sites. Transportation with refrigerated temperatures is considered to be a necessary part of temperature management.

The microbiological safety of fresh produce has become a concern in communities today. Contamination can occur along the farm-to-kitchen value chain and is feared to be a source of foodborne pathogens (Mahajan et al., 2017). Observation of microbiological damage to the chili samples showed more differences between treatments. The lowest microbiological damage was found in the ozone-treated and refrigerated-distributed chili, while the existing practice resulted in the highest.

The reduction in microbiological causes of postharvest losses on horticultural crops by ozone treatment has also been observed by previous studies (Ong et al., 2013; Alwi and Asgar, 2014). These studies revealed the inhibition of *Escherichilia coli* O157, *Listeria monocytogenes*, *Salmonella enterica* sv. Typhimurioum and anthracnose caused by *Colletotrichum gloeosporioides* fungus populations.

Anthracnose disease is a great concern in chili farming in Indonesia. Ozone exposure has excellent potential to inhibit the growth of mycelia growth and conidia germination.

Ozonation has been proven to be a method to degrade and reduce the toxicity level of organic and inorganic compounds (Karamah et al., 2019). Moreover, ozone has fungitoxic and fungistatic activity, which is suitable for controlling anthracnose in papaya (Ong et al., 2013) and has also been observed in this study to have the same potential in chili.

In vitro and in vivo assay results reported by Alwi and Asgar (2014) show that the effectiveness of ozone exposure increased with exposure duration, supported by a high bacterial death rate. However, after a certain duration of exposure, the death rate reached a plateau due to protection from dead cells or tissue from the oxidative properties of ozone. Furthermore, Glowacz and Rees (2016) explain that a higher dose of ozone may cause tissue damage, allowing fungal infection and thus a higher risk of disease incidence.

Table 1 Quality losses of chili with various treatments

Treatment	Quality Losses (%)				
	Mechanical	Micro-biological	Physio-logical	Green Chili	Total
Ozone – refrigerated	1.02 a	0.16 c	0.50 a	0.00 b	1.68 c
Non-ozone – refrigerated	1.03 a	1.41 b	0.26 a	0.03 ab	2.75 b
Ozone – non-refrigerated	2.05 a	0.60 bc	0.64 a	0.00 b	3.29 b
Non-ozone – non-refrigerated	1.06 a	1.40 b	1.02 a	0.04 ab	3.53 b
Existing practice	2.10 a	3.77 a	0.75 a	0.09 a	6.70 a

Note: the same letters in the same column indicate no significant difference in the Duncan multiple range test level of 5%

Green or immature chili is considered underqualified due to its greater susceptibility to damage (O'Donoghue et al., 2018) and lower selling price in the market. Therefore, during sorting, green chili is removed and weighed as quality losses. This is consistent with the sorting practice of traders, who discount green chili and reduce payment to farmers. Farmers often harvest green chili due to a lack of knowledge of appropriate harvesting techniques and to increase the volume of the harvest (ICAPRD PT. Agro Indo Mandiri, 2018).

Capsicum sp. fruits are best harvested with a minimum 80% color coverage, when development can continue, including that of color. However, it has been found that the green parts seen at harvest tend to change into a darker color. Harvest at full red color is the preferred method (O'Donoghue et al., 2018).

Overall, based on Table 1, improved handling technology for chili, with a combination of aqueous ozone exposure and refrigerated transportation or single treatment, has been shown to be able to reduce quality losses by 74.92%, while ozone exposure reduced these by 50.89% and refrigerated transportation by 58.95%.

3.2.2. Color

Color is one of the parameters that determine the quality and price of chili. The results of color measurement using the Chroma-meter show that brightness was not significantly different across treatments. However, ozone treatment combined with refrigerated transportation showed the highest brightness value, while existing packing house operation (PHO) practice gave the lowest value (Table 2). Based on the Chroma value (C), chili from existing PHO practice had a duller color than with other treatments, as indicated by the lowest C value. Regarding color angle (Hue/^{o}H), existing PHO practice resulted in the lowest hue angle and was significantly different from other treatments. Chili from existing

PHO practice had a purplish red color based on L, C, and H in Chroma-meter diagrams, being darker than other treatments.

Although ozone treatments have been reported to affect the surface color of some horticultural crops, treatments with low concentration and duration have shown no negative influence on crop appearance, including color (Ong et al., 2013). Moreover, Glowacz and Rees (2016) observed that the concentration and exposure of ozone did not have a significant effect on the color of red chili in terms of L, C and H values. In this study, the initial color (degree of redness) and physiological activity of the chili may have affected the color of the samples after treatment. The existing practice by farmers does not include washing of the chili, and there is no effort to control the respiration rate during transportation, hence the results of the color measurement parameters of brightness, C value and color angle (Hue).

Table 2 Effect of different handling treatments on chili color

Treatment	Color Parameters		
	L (brightness)	C (chrome)	Hue (color angle)
Ozone – refrigerated	40.17 [a]	55.30 [a]	23.60 [a]
Non-ozone – refrigerated	39.90 [a]	54.18 [a]	23.08 [a]
Ozone – non-refrigerated	39.13 [a]	52.51 [a]	22.49 [a]
Non-ozone – non-refrigerated	38.51 [a]	51.19 [a]	21.46 [a]
Existing practice	37.78 [a]	50.51 [a]	10.34 [b]

Note: the same letters in the same column indicate no significant difference in the Duncan multiple range test level of 5%

3.2.3. Texture

Damage to chili may be indicated by the measure of hardness. An increased press value shows higher texture changes, which indicates that the chili's firmness had decreased, or that it has become wrinkled or dehydrated. Wall (2010) states that firmness is one of the primary indicators of chili quality. Glowacz and Rees (2016) had also reported that chili softens during storage. Exposure to ozone was observed to maintain its firmness and that the difference between treated and untreated chili was more pronounced after 10 days of storage. They suggest that ozone treatment can significantly reduce water loss during storage, therefore maintaining firmness.

When water evaporates from chili tissue, the turgor pressure decreases and the cells begin to shrink and become damaged, so the fruit loses its freshness (Pangidoan, et al., 2014). During respiration, a large amount of water may be lost, causing withering and wrinkling, hence a harder chili texture. The chili respiration process rate increases during transportation because of the high temperature and humidity, impact and friction.

Ozone and cold transportation had an effect on hardness value. As shown in Table 3, this value in existing PHO practice is higher than with other treatments, although no statistical difference was observed. The tendency shows that untreated chili loses more freshness during the transportation process than with other treatments.

3.3. Quantity Losses

Quantity losses in this study were defined as losses in volume or weight, including losses due to technology implementation (e.g. scattered during aqueous ozone treatment) and transportation (end weight compared to initial weight). Quantity losses may also occur due to the respiration and transpiration processes of chili. Ethylene, a natural ripening hormone in fruits, causes softening during the fruit ripening process. The physiological process leads to a decrease in chili moisture content, resulting in the withering process (Wall, 2010).

Table 3 Effect of different handling treatments on the chili hardness value

Treatment	Hardness (gf)
Ozone – refrigerated	656.33[a]
Non-ozone – refrigerated	629.65[a]
Ozone – non-refrigerated	657.79[a]
Non-ozone – non-refrigerated	658.74[a]
Existing practice	666.65[a]

Note: the same letters indicate no significant difference in the Duncan multiple range test level of 5%

A comparison of the quantity losses of chili with technology intervention and existing practice showed no significant differences (Table 4). This indicates that the treatments did not have enough impact on the loss of moisture content in the chili during the 15 to 17 hour transportation process (night transportation). A longer transportation time or storage may have more impact, with the technology showing a more positive influence. Moreover, Glowacz and Rees (2016) elaborate that although the influence of ozone exposure on chili weight loss was reduced after 14 days of storage, the appearance indicators of weight loss, i.e. shrivelling and stem browning, were reduced and delayed.

Table 4 Quantity losses of chili with various treatments

Treatment	Quantity Losses (%)
Ozone – refrigerated	1.82 [ab]
Non-ozone – refrigerated	1.42 [b]
Ozone – non-refrigerated	1.79 [ab]
Non-ozone – non refrigerated	1.86 [ab]
Existing practice	2.16 [a]

Note: the same letters indicate no significant difference in the Duncan multiple range test level of 5%

According to Table 4, the combination of ozone treatment and refrigerated transportation was effective in reducing quantity losses by 15.74%. Without refrigerated transportation, ozone treatment reduced quantity losses by 50.89%, while refrigerated transportation without ozone treatment reduced quantity losses by 34.26%. These results show that single handling technology improvement may be sufficient to reduce quantity losses.

The rate of quantity losses has been shown to be related to temperature and relative humidity. Lower temperature and higher relative humidity during storage and transportation, combined with cultivar selection, has been shown to give a longer shelf life and lower postharvest loss (Samiran et al., 2013). However, the insignificant differences observed in this study may be caused by the similar environmental conditions of chilli distribution using refrigerated and non-refrigerated vehicles, as presented in Figures 1 and 2. The study by Wall (2010) found that the optimum temperature for chili storage is 7–10°C, with chili stored in box for a week, resulting in a daily weight loss of around 3.5% at 24°C, and only 0.5% at 8°C. According to Nurdjannah et al. (2014), storage at low temperature is effective in reducing chili losses.

Postharvest losses (PHL) were calculated by combining both quantity and quality losses. The PHL reduction was then calculated by comparing the PHL of untreated samples with that of the treated samples. The results of the calculation show that combination of technology intervention gave the highest reduction in PHL (60.61%) (Table 5). Moreover, simply replacing used cardboards with perforated ones (without ozone treatment and without refrigerated transportation) succeeded in reducing PHL by 39.16%. This was a promising result, and proves that simple improvements can help to reduce PHL, especially for local supply provision, where extended shelf life may not be very necessary. A simple change in practice like this has been shown to be more successful in implementation by small scale farming businesses (Kitinoja, 2013).

Nurdjannah et al. (2014) suggest that the packaging material significantly influences the respiration rate of chili during transportation. Perforated cardboard allows more oxygen into the packaging and prevents the accumulation of carbon dioxide. The modified gas concentration helps inhibit decay caused by enzymes, therefore prolonging the freshness of the chili and reducing losses.

Table 5 Postharvest loss reduction of chili with various treatments

Treatment	Total Losses (%)	Loss Reduction (%)*
Ozone – refrigerated	3.49	60.61
Non-ozone – refrigerated	4.17	52.93
Ozone – non-refrigerated	5.08	42.66
Non-ozone – non-refrigerated	5.39	39.16
Existing practice	8.86	-

Note: Loss reduction was calculated by comparison with existing PHO practice

4. Conclusions

A large-scale experiment was conducted on chili using aqueous ozone treatment and improved transportation conditions with refrigerated vehicles (length of transportation was 541.5 km, taking 15–17 hours). The combination of aqueous ozone treatment and improved transportation handling technology was able to reduce the quality losses (a 74.92% loss reduction) and quantity losses (a 15.74% loss reduction) of chili. Ozone treatment accounted for the decrease in chili microbiological losses, while improved packaging prevented high mechanical losses, as well as damage due to physiological reasons. Moreover, refrigerated transportation also helped with physiological losses, by allowing better respiration for the chili. Single handling technology improvement is also applicable to the reduction of postharvest losses to meet the different needs according to the length of transportation distance and duration. Ozone treatment without refrigerated transportation reduced quality losses by 50.89% and quantity losses by 17.13%, while refrigerated transportation without ozone treatment reduced quality losses by 58.95% and quantity losses by 34.26%. Aqueous ozone treatment did not alter the color or texture of the chili.

Acknowledgments

The authors would like to thank the Association of Southeast Asian Nations (ASEAN) and Japan-ASEAN Integration Fund (JAIF) for providing research funding for this work, as well as PT. Agro Indo Mandiri for their cooperation in conducting the work.

References

Alwi, N.A., Asgar A., 2014. Reduction of Escherichia Coli O157, Listeria Monocytogenes and Salmonella Enterica Sv. Typhimurium Populations on Fresh-cut Bell Pepper using Gaseous Ozone. *Food Control*, Volume 46, pp. 304–311

Asgar, A., Musaddad, D., Setyabudi, D.A., Hasan, Z.H., 2017. *Teknologi Ozonisasi untuk Mempertahankan Kesegaran Cabai Cultivar Kencana Selama Penyimpanan* (Ozonation Technology to Maintain Freshness of Chili Cultivar Kencana during Storage). *Jurnal Penelitian Pascapanen Pertanian,* Volume 12(1), pp. 20–26

Budiyanto, M.A., Shinoda, T., 2017. Stack Effect on Power Consumption of Refrigerated Containers in Storage Yards. *International Journal of Technology,* Volume 8(7), pp. 1182–1190

Glowacz, M., Rees, D., 2016. Exposure to Ozone Reduces Postharvest Quality Loss in Red and Green Chilli Peppers. *Food Chemistry*, Volume 210, pp. 305–310

ICAPRD., PT. Agro Indo Mandiri., 2018. Final Report of ASEAN-JAIF Pilot Activities of Reduction of Postharvest Losses, Case of Indonesia: Red Curly Chili

Iswari, K., Srimaryati., 2014. *Pengaruh Giberelin dan Jenis Kemasan untuk Menekan Susut Cabai Kopay Selama Pengangkutan Jarak Jauh* (The Effect of Gibberellins and Types of Packaging to Suppress Kopay Chili Shrinkage During Long Distance Transportation). *Jurnal Penelitian Pascapanen Pertanian*, Volume 11(2), pp. 89–100

Karamah, E.F., Anindita, L., Amelia, D., Kusrini, E., Bismo, S., 2019. Tofu Industrial Wastewater Treatment with Ozonation and the Adsorption Method using Natural Zeolite. *International Journal of Technology*, Volume 10(8), pp. 1498–1504

Kitinoja, L., 2013. Innovative Small-scale Postharvest Technologies for Reducing Losses in Horticultural Crops. *Ethiopia Journal of Applied Science and Technology,* Volume 15(1), pp. 9–15

Mahajan, P.V., Caleb, O.J., Gil, M.I., Izumi, H., Colelli, G., Watkins, C.B., Zude, M., 2017. Quality and Safety of Fresh Horticultural Commodities : Recent Advances and Future Perspectives. *Food Packaging and Shelf Life*, Volume 14, (Part A), pp. 2–11

Mandana, G.O., Utama, I.M.S., Yulianti. N.L., 2013. *Pengaruh Larutan Disinfektan dan Pengemasan Atmosfer Termodifikasi Menggunakan Film Plastik Terperforasi Terhadap Susut Bobot dan Mutu Buah Cabai Merah Besar selama Penyimpanan* (The Influence of Disinfectan Solution and Modified Atmosphere Packaging using Perforated Plastic Film on Weight Loss and the Quality of Red Chili during Storage). *Jurnal Biosistem Dan Teknik Pertanian*, Volume 1(1), pp. 1–10

Nurdjannah, R., Purwanto, Y.A., Sutrisno., 2014. *Pengaruh Jenis Kemasan dan Penyimpanan Dingin terhadap Mutu Fisik Cabai Merah* (The Effect of Packaging Types and Cold Storage on the Physical Quality of Red Chili). *Jurnal Penelitian Pascapanen Pertanian*, Volume 11(1), pp. 19–29

O'Donoghue, E.M., Brummell, D.A., McKenzie, M.J., Hunter, D.A., Lill. R.E., 2018. Sweet Capsicum: Postharvest Physiology and Technologies. *New Zealand Journal of Crop and Horticultural Science*, Volume 46(4), pp. 269–297

Ong, M.K., Kazi, F.K., Forney, C.F., Ali, A., 2013. Effect of Gaseous Ozone on Papaya Anthracnose. *Food and Bioprocess Technology,* Volume 6, pp. 2996–3005

Pangidoan, S., Sutrisno., Purwanto, Y.A., 2014. *Transportasi dan Simulasinya dengan Pengemasan Curah untuk Cabai Keriting Segar* (Transportation and Its Simulation using Bulk Packaging for Fresh Curly Chili). *Jurnal Keteknikan Pertanian*, Volume 2(1), pp. 23–30

Samira, A., Woldetsadik, K., Workneh, T.S., 2013. Postharvest Quality and Shelf Life of Some Hot Pepper Varieties. *Journal of Food Science and Technology*, Volume 50(5), pp. 842–55

Setyabudi, D.A., Broto, W., Jamal, I.B., 2016. *Pengaruh Pencelupan dalam Larutan Benomyl terhadap Kesegaran Cabai* (*Capsicum Annum* L. Var. Kencana) *pada Penyimpanan Suhu Rendah dan Ruang* (The Effect of Dipping in Benomyl Solution on The Freshness of Chili (Capsicum Annum L. Var. Kencana) in Room and Low Temperature Storage). *Jurnal Penelitian Pascapanen Pertanian*, Volume 13(2), pp. 53–62

Wall, M.M., 2010. *Postharvest Handling of Fresh Chiles*. Guide H-235. New Mexico State University

Webb, A.J., Kartikarsari, F.G., Kosasih, I.A., 2012. Do Chili Traders Make Price Volatility Worse ? A Qualitative Analysis of East Java Trading Practices. *SSRN Electronic Journal.* Available Online at SSRN: http://ssrn.com/abstract=2176153, Accessed on March 19, 2019

Webb, A.J., Kosasih, I.A., 2011. Analysis of Price Volatility in the Indonesia Fresh Chili Market. Paper presented to the Annual Meeting of the International Agricultural Trade Research Consortium, December 11-13, 2011, Tampa FL, USA. Available Online at https://iatrc.umn.edu/wp-content/uploads/2011Dec-AWebb_paper.pdf

Wijanarko, A., Nur D.F., Sahlan, M., Afnan, N.T., Utami, S.T., Hermansyah, H., 2017. Production of a Biopesticide based on a Cysteine Protease Enzyme from Latex and Papaya (Carica Papaya) for Spodoptera Litura in Red Chili Peppers (Capsicum Annum). *International Journal of Technology*, Volume 8, pp. 1455–1461