Combination of ozone and packaging treatments maintained the quality and improved the shelf life of tomato fruit

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Abstract. Tomato is very important vegetable crop but has short shelf life. The objective of this research was to determine the effect of ozone and packaging combination treatment on the quality and the storage life of tomato fruit. There were six treatments including: control (without ozone and packaging); without ozone and packaged with polyethylene bag; without ozone and polyethylene terephtlate punnet; with ozone but without packaging; with ozone and packaged with polyethylene bag; and with ozone and polyethylene terephtlate punnet. Each treatment was made into 3 replications. Tomato samples were harvested at turning stage. Ozone treatment was applied for 60 seconds. Tomatoes were then treated with and without packaging. The fruit were then stored at room temperature for up to 12 days. The parameters for assessment were water content, color, texture, weight loss and the population of naturally contamination Escherichia coli. Each parameter was assessed on day 0, 6 and 12 of storage. The results indicated that combination of ozone and packaging treatments significantly affected physical and biochemical changes (water content, color, texture and weight loss) of the fruit, suppressed the microbiological contamination on the fruit and maintained fruit freshness or quality after 12 days of storage. The combination of ozone and perforated polyethylene packaging treatment was the best treatment to maintain the quality and prolonged the shelf life of tomato fruit to be 12 days at room temperature.

Keywords: Ozone, Packaging, Tomato, Quality

1. Introduction
Tomato (Lycopersicum esculentum) is one of the most widely grown horticultural crops in Indonesia including in West Nusa Tenggara. The production of tomato fruit in the last 5 years has steadily increased. For example, the production in 2012 was 25,045 tons which then increased to 28,839 tons in 2013 [1] and became 36,943 tons in 2015 [2].

Tomato fruit is a very important source of nutrition including vitamins and minerals such as vitamin C, pro-vitamin A and others. Most importantly, tomato fruit is rich of lycopene which is a strong antioxidant that very important for health [3]. The benefit of being rich of nutrition is the reason for high demand of fresh tomatoes. Therefore, sufficient amount of fruit production and continuous supply of fresh tomato fruits are very crucial in order to fulfil the demand.

On the other hand, tomato fruit is a perishable product and has limited shelf life after harvest. As the fruit is categorized into the climacteric vegetable-fruit crop, there is a huge change in the biochemical process in the fruit including high respiration rate, ethylene production and the degradation of some chemical compounds in the fruit. This is in turn not only caused changes in the physical characteristic of the fruit but also losses of nutrients such as vitamins. In addition, the
degradation of complex chemical compounds i.e. starch into simple sugar and high water content also provide suitable condition for microbial growth which then lead to fruit decay [4].

Therefore, it is very crucial to develop postharvest technology for fresh fruit to extend fruit shelf life. Creating optimal postharvest condition including low temperature storage, suitable packaging and waxing, are among the potential postharvest intervention methods that can be applied to maintain fruit quality and prolong storage life of the fruit. The use of ozone is another potential method for improving the postharvest life of fruits and vegetables.

Ozone (O3) is a strong oxidant that has potential role as disinfectant agent that can kill microorganisms including bacteria, virus and fungi. Ozone is also an environmentally safe technology that can be applied as postharvest control mean for handling fruits and vegetables [5]. The use of ozone in postharvest technology to improve postharvest storage life for fruits and vegetables has been developed and become more important in the last ten years. Several research have demonstrated that ozone treatment was able to maintain product quality [6]. Results from some research also show that ozone has an important role in reducing microorganism contamination and pesticide residual effect on fruits and vegetables. Other research also reported that treatment using ozone reduced fungal contamination on raspberries, strawberries and blueberries [7]. Ozone also was effective in suppressing Escherichia coli growth on chicken [8]. The mechanism of ozone in reducing microbial growth is through modifying cell wall permeability that may cause microbial cell lysis and resulted in microbial inactivation. The inactivation in turn prolong the shelf life of the products [9].

Baside ozone treatment, tomato fruit quality may be further improved with packaging treatment. As mentioned earlier, packaging is very important aspect in postharvest handling technique for fruits and vegetables as it can prevent or reduce damage both physical or mechanical and physiological damage for the product during postharvest handling [10].

Previous research indicated that combination of ozone treatment and packaging can extend product shelf life. Ozone treatment for 60 seconds and combined with polyethylene bag packaging maintained apple fruit quality for 21 days of storage period [11]. Handayani (2016) also reported that ozone treatment for 30 seconds and polietilen packaging treatment maintained chili quality [12]. Other research also shows that treating mango fruit with ozone for 5 minutes maintained fruit quality for 14 days at room temperature [13]. Previous research on tomato indicated that ozone treatment for 45 seconds extended the fruit shelf life for 10 days at 25°C [14]. More research on tomato fruit is needed especially for the room storage condition as a real condition during supply chain in tropical countries like Indonesia. Therefore, this research was carried out to determine the effect of ozone and packaging combination treatment on the quality and the storage life of tomato fruit.

2. Materials and Methods

2.1. Fruits

The tomato fruit cultivar of ‘Servo’ was harvested at turning stage [15] at the farmer’s field in Penedagandor village, East Lombok. The fruits were immediately transported to the Faculty of Food Technology and Agroindustry University of Mataram by road transportation. After arrival at the Quality Control laboratory, the fruits were cleaned and sorted based on the size, color and the present of defects or blemish. Uniform size and maturity level, and free of blemish or physical damage were used for the experiment. The fruits were divided into 18 units as there were 6 treatments (no ozone and no packaging; no ozone and Polietylene (PE) bag; no ozone and Polietylene Terephaltate (PET) punnet; with ozone no packaging; with ozone and PE; and with ozone and PET punnet) and each treatment was made into 3 replications.

2.2. Ozone treatment

Ozone treatment was applied using ozone generator (Tiens Fruit and Vegetable Cleaner, model TR-YCA, Output ozone 150 mg/h ± 20%, Tianjin Tianshi Biongfineering Co., Ltd, China). Nine units of the tomato samples were treated with ozone for 60 seconds. After treatment, the fruits were air dried.
2.3. Packaging treatment
Tomato samples (9 units) were either packed according to the treatments i.e. packing with Polietylene 0.05 mm bag (3 units) or Polietylene Terephltalate punnet 0.06 mm (3 units) or left unpacked (3 units). There were two lots of trial regarding the packaging. In the first trial, the packaging both PE bag and PET punnet were without perforation, whereas in the second trial all packaging were perforated (8 holes for each bag or punnet).

2.4. Storage and assessment
The treated and untreated tomato samples were stored at room temperature for up to 12 days for quality and shelf life assessment. The assessment was carried out at day 0, 6, dan day 12 of storage.

2.5. Parameter and statistical analysis
Parameters that were analyzed were water content [16], weight loss [17], texture using hand penetrometer [18], color using colorimeter (MSEZ User Manual) and accessed by panelists and the population of Escherichia coli using MPN method. The E. coli was assessed as it is one of the indicators for sanitation condition [19]. The data obtained from the trial were analyzed using Analysis of Variance at 5% significant level using Co-Stat software. When there was significant different, they were analyzed using honestly significant different test at the same significant level [20].

3. Results and Discussion
3.1. Effect of treatments on water content
Water content is a very important component of fruit and vegetables in general including in tomato fruits as it plays a significant role on product quality. Data obtained from this research indicated that the water content of tomato fruits was not altered by the treatment up to 6 days of storage period. In general, the water content of tomato samples was about 94%. However, as the storage prolonged to 12 days at room temperature, the ozone and packaging treatment had significant effect on water content. As shown in Table 1, tomato fruits treated with ozone and packaging either with PE or PET had higher water content compared to the untreated ozone and without packaging. Combination of ozone treatment and PE packaging performed the best result which maintained the fruit water content of 95.58% compared to the control (92.57%). Low water content of the untreated samples may possibly be associated with high water loss in the samples. Storing the fruit without packaging may create optimal atmosphere condition around the product which trigger high respiration rate [21]. Water produced from the respiration then evaporated through transpiration which lead to high water loss from the sample. With the use of packaging on the other hand, there may be relatively low oxygen concentration around the fruit which associated with the permeability of packaging film to oxygen, and therefore resulted in low respiration rate, which may then lead to low transpiration rate and water loss.

| Treatments                        | Water content (%) during storage |
|----------------------------------|---------------------------------|
|                                  | Day 0  | Day 6  | Day 12 |
|                                  | NP     | P      | NP     | P      | NP     | P      |
| No Ozone, no packaging (T1)      | 94.41  | 94.49  | 94.23  | 93.58  | 93.84b | 92.57b |
| No Ozone, PE (T2)                | 94.4   | 93.85  | 94.55  | 94.79  | 95.05a | 94.47ab |
| No Ozone, PET (T3)               | 93.60  | 94.08  | 94.4a  | 94.61  | 94.77ab| 94.03ab |
| Ozone + no packaging (T4)        | 94.36  | 93.82  | 94.35  | 94.65  | 94.07ab| 94.41ab |
| Ozone + PE (T5)                  | 94.06  | 94.31  | 94.83  | 94.99  | 94.84ab| 95.58a |
| Ozone + PET (T6)                 | 94.46  | 94.00  | 94.47  | 94.38  | 94.69ab| 94.68a |

Note: Numbers followed by the same letters in the same column were not significant different using HSD at 5% significant level.
3.2. Effect of treatments on weight loss

Weight loss is one of indicators that can be used to monitor changes in fruits and vegetable quality during storage. In general, weight loss occurs in all horticultural products during storage with different rate depending on the product characteristics and postharvest handling technique [21]. As can be seen in Table 2, the treatment of ozone and packaging with either PE or PET reduced weight loss of tomato fruit significantly compared to non-treated ozone and un-packed fruit.

| Treatments                        | Weight loss (%) during storage |
|-----------------------------------|-------------------------------|
|                                  | Day 6 | Day 12 |
|-----------------------------------|-------|-------|
| No Ozone, no packaging            | 11.71b| 14.12b|
| No Ozone, PE                      | 0.96c | 1.20c |
| No Ozone, PET                     | 1.86c | 3.01c |
| Ozone + no packaging              | 15.91a| 18.81a|
| Ozone + PE                        | 0.78c | 1.31c |
| Ozone + PET                       | 1.96c | 3.78c |

Note: Numbers followed by the same letters in the same column were not significant different using HSD at 5% significant level.

Data in Table 2 also show that there was an increase in the amount of weight loss when the storage period was prolonged. This may be associated with the changes in the cell wall permeability of tomato fruits [22]. As the fruit becomes ripe or even over-ripe which soon turn to the senescence stage, the cell wall is more permeable to oxygen, carbon dioxide and water vapor and cause higher transpiration rate which then lead to higher water loss from the fruit [23, 24]. Suitable postharvest handling technology is very important to suppress or delay water loss from the product. Packaging, for example, plays significant role in atmosphere modification around the products, thus can reduce the rate of respiration and transpiration in the fruit. As Purwadi et al. (2007) said that thicker packaging has lower permeability to oxygen, carbon dioxide and water vapor and cause low transpiration rate and lower water loss from the fruit [25].

3.3. Effect of treatments on texture

Texture of fruits and vegetables in general, is closely associated with the metabolism reaction and biochemical degradation of certain chemical compounds (non-soluble pectin into the soluble form) in the fruit after harvest and during ripening process. The texture of mature fruit that is usually firm or hard becomes soft when the fruit start to ripen. Modification of environmental condition around the fruit such as the use of packaging or managing the condition that prevent or reduce the biochemical reaction rate may delay the change in fruit texture. Result from this trial indicated that the combination of ozone and packaging treatment significantly affected tomato fruit texture after 112 days at room temperature storage (Table 3). Ozone treated and packaging with either PE bag or PET punnet had firmer texture of the samples indicated by higher retention value from the penetrometer reading compared to the untreated ozone and without packaging of tomato samples. As mentioned earlier, packaging may provide lower gas environmental condition around the fruit which lead to lower respiration rate and other biochemical degradation in the fruit especially the chemical compounds related to the texture of the fruit. This may then resulted in firmer texture of the ozone treated and packed fruits than the untreated fruit.
Color is an important indicator of fruit ripening stage and product quality. Measuring tomato sample color using Colorimeter provide information on the L*, a*, and b* which represent the lightness and the changes in the degree of green to red color of the fruit. Results from this research showed that there was no significant different of the lightness and °Hue value (obtained from a* and b* value) of the samples from all treatments. However, after 12 days storage the ozone treated and packaging either PE or PET tend to have lower L value which may related to the lightness degree of red color on the samples. Results from the organoleptic test for the color change (Table 4) also indicated that ozone treated fruit packed with PE packaging had relatively lower score (3.0-3.2 = reddish yellow) compared to the untreated ozone and no packaging treatment (3.4-3.5 = red). In general, there was huge change on color of the fruit during storage from yellowish green (score around 2) to reddish yellow or red color (score of 3.5). This may be associated with the degradation of chlorophyll which represents green color on the fruit and the synthesis of lycopene and other compounds that resulted in red color as the fruit ripen [26].

**Table 3. Effect of ozone and packaging on the texture (kg/cm²) of tomato fruits during storage**

| Treatments                  | Texture (kg/cm²) | Day 0 | Day 6 | Day 12 |
|-----------------------------|------------------|-------|-------|--------|
|                             | NP   | P    | NP   | P    | NP   | P   |
| No Ozone, no packaging      | 1.45 | 1.30 | 0.45 | 0.73 | 0.32b | 0.28b|
| No Ozone, PE                | 1.42 | 1.70 | 0.63 | 1.06 | 0.55a | 0.70a|
| No Ozone, PET               | 1.45 | 0.89 | 0.60 | 0.82 | 0.58a | 0.58ab|
| Ozone + no packaging        | 1.40 | 1.53 | 0.59 | 1.31 | 0.57a | 0.73a|
| Ozone + PE                  | 1.55 | 1.63 | 0.53 | 0.76 | 0.52a | 0.90a|
| Ozone + PET                 | 1.20 | 1.45 | 0.60 | 0.82 | 0.60a | 0.73a|

Note: Numbers followed by the same letters in the same column were not significant different using HSD at 5% significant level.

3.4. **Effect of treatments on fruit color**

Color is an important indicator of fruit ripening stage and product quality. Measuring tomato sample color using Colorimeter provide information on the L*, a*, and b* which represent the lightness and the changes in the degree of green to red color of the fruit. Results from this research showed that there was no significant different of the lightness and °Hue value (obtained from a* and b* value) of the samples from all treatments. However, after 12 days storage the ozone treated and packaging either PE or PET tend to have lower L value which may related to the lightness degree of red color on the samples. Results from the organoleptic test for the color change (Table 4) also indicated that ozone treated fruit packed with PE packaging had relatively lower score (3.0-3.2 = reddish yellow) compared to the untreated ozone and no packaging treatment (3.4-3.5 = red). In general, there was huge change on color of the fruit during storage from yellowish green (score around 2) to reddish yellow or red color (score of 3.5). This may be associated with the degradation of chlorophyll which represents green color on the fruit and the synthesis of lycopene and other compounds that resulted in red color as the fruit ripen [26].

**Table 4. Effect of ozone and packaging on the color (Lightness and Hue) of tomato fruits during storage**

| Treatments | Lightness (L*) | °Hue | Color (score) |
|------------|----------------|------|---------------|
|            | Day 0          | Day 6| Day 12        | Day 6| Day 12| Day 0 | Day 6| Day 12|
| T1         | 64.24          | 63.97| 64.07         | 74.30| 73.27| 72.28| 2.8  | 3.4  | 3.5  |
| T2         | 64.41          | 63.87| 61.18         | 74.03| 74.12| 69.73| 2.2  | 2.9  | 3.2  |
| T3         | 65.29          | 66.18| 64.39         | 111.72| 73.81| 71.35| 2.4  | 3.0  | 3.0  |
| T4         | 62.87          | 62.09| 61.29         | 115.49| 70.98| 68.99| 2.6  | 2.8  | 3.4  |
| T5         | 64.99          | 62.94| 58.85         | 174.33| 74.31| 64.87| 2.3  | 2.7  | 3.0  |
| T6         | 59.53          | 57.19| 56.72         | 113.53| 64.12| 61.64| 2.5  | 2.4  | 3.3  |

3.5. **Effect of treatments on the population of Escherichia coli**

Free of microbial contamination is a very crucial aspect in food quality. Keeping tomato fruits in unsuitable condition such as excessive humidity will trigger microbial growth which lead fruit decay and not safe for the consumers [27]. Fruit may also be contaminated by microorganism through soil in the field or contaminated water used for cleaning the fruits. Some research have demonstrated that ozone treatment has powerful effect in reducing microbial contamination on foods including fruits and vegetables [28, 29, 30]. Results from this research also proved that ozone treatment combined with packaging treatment were effective in reducing *E. coli* contamination on tomato fruit as indicated in Table 5.
4. **Conclusion**

Ozone and packaging have an important role in postharvest handling of fruit and vegetables including tomatoes. Based on the results from this research the combination of ozone and perforated polyethylene (PE) bag was the best treatment to maintain the quality and prolonged the shelf life of tomato fruit to about 12 days at room temperature. Future research need to be focused on the effect of ozone on pesticide residual level on tomato fruits.

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**References**

[1] Badan Pusat Statistik NTB 2014 *NTB Dalam Angka* (Mataram: Badan Pusat Statistik NTB)

[2] Manurung S 2015 Handling of tomato (Lycopericum escusien Mill) post-harvest to increase the profit in Parahyangan peasent partners Cianjur Regency, West Java (Politeknik Pertanian Negeri Payakumbuh) (In Bahasa Indonesia)

[3] Rahmawati IS et al 2011 The effect of concentration Calsium Chloride (CaCl₂) treatment and the storage period of ascorbic acid content of tomato (*Lycopersicum esculentum* Mill.) *J. Buletin Anatomi dan Fisiologi* 29 (1) (In Bahasa Indonesia)

[4] Purwadi A et al 2007. The effect of ozonization period on storage period of tomato (*Lycopersicum esculentum* Mill.). *Prosiding PPI-PDIPTN* (Yogyakarta) (In Bahasa Indonesia)

[5] Asgar A et al 2015 Ozonization technology to preserve the freshness of Kencana cultivars chilli during storage *J. Penelitian Pascapanen Pertanian* 12(1) pp 20-26 (In Bahasa Indonesia)

[6] de Candia S et al 2014 Antimicrobial efficacy of gaseous ozone on berries and baby leaf vegetables *Proceeding of International Conference on Antimicrobial Research* (Madrid: Spain)

[7] Hecer C et al 2007 The Effects of Ozone and Chlorine Applications on Microbiological Quality of Chickens During Processing *J. BIOL. ENVIRON. SCI.* 1(3) pp 131-138

[8] Asgar A 2014 Ozonization technology to clean vegetables *Iptek Hortikultura* 10 (In Bahasa Indonesia)

[9] Sembiring N 2009 The effect of types of packaging on product quality of red chilli (*Capsicum annum* L.) (*Universitas Sumatera Utara: Medan*) (In Bahasa Indonesia)

[10] Isyuniarno and Purwadi A 2007 The effect of using ozone oxidant in polyethylene plastic packaging to store Manalagi Apple (*Malus syvlesis* M.) (*PTAPB-BATAN. Yogyakarta* X (1)
[11] Handayani 2016 The effect of ozone combination and packaging on physical characteristics and microbiology of chilli (Capsicum frutescens L.) during storing (Universitas Mataram: Mataram)

[12] Yasa WS, Zainuri and Zaini A 2013 Keefektifan Teknologi Ozon Dalam Perbaikan Mutu Buah Mangga Gedong Gincu Lokal Lombok Laporan Penelitian (Universitas Mataram: Mataram)

[13] Purwadi A, Usada W and Isyuniarno 2007 Pengaruh Lama Ozonisasi Terhadap Umur Simpan Buah Tomat (Lycopersicum esculentum Mill.) Prosiding PPI-PDIPTN (Pustek Akselerator dan Proses Badah. Batan. Yogyakarta)

[14] Cantwell M 2008 Impact of Ripening & Storage Conditions

[15] Sudarmadji S, Haryono B and Suhardi 2002 Analysis procedure for food and agriculture (Yogyakarta: Liberty) (In Bahasa Indonesia)

[16] Widyastuti S et al 2015 Practicum guide of physiology and post harvest technology. Fakultas Teknologi Pangan dan Agroindustri (Universitas Mataram: Mataram)

[17] Muchtadi 1992 Post harvest physiology of fruits and vegetables. (Departemen Pendidikan dan Kebudayaan Direktorat Jenderal Pendidikan Tinggi Pusat Antar Universitas Pangan dan Gizi Institut Pertanian Bogor: Bogor) (In Bahasa Indonesia)

[18] Marriott NG and Gravani RB 2006 Principle of Food Sanitation Fifth Edition (New York, USA: Springer)

[19] Hanafiah KA 2003 (Mataram: PT. Raja Grafindo Permata)The

[20] Lizada C 1993 Mango The Biochemistry of Fruit Ripening Ed Seymour GB, Taylor JE and Tucker GA (London: Chapman & Hill)

[21] Wills R et al 1998 Postharvest An Introduction to the Physiology and Handling of Fruit, Vegetables and Ornamentals (Adelaide, South Australia: UNSW Press)

[22] Hadiwiyoto S and Soehardi 1981 Penanganan Lepas Panen (Jakarta: Departemen Pendidikan dan Kebudayaan)

[23] Syarief R and Irawati A 1988 Pengetahuan Bahan Untuk Industri Pertanian (Jakarta: Mediyatama Sarana Perkasa)

[24] Purwadi A, Usada W and Isyuniarno 2007 The effect of ozonization period on storage period of tomato (Lycopersicum esculentum Mill.) Prosiding PPI-PDIPTN (Pustek Akselerator dan Proses Badah. Batan. Yogyakarta)

[25] Fantastico ER 1993 Fisiolegi Pascapanen, Penanganan dan pemanfaatan Buah-buahan dan Sayur-sayuran Tropika dan Subtropika Translated by Kamariyani (Yogyakarta: Gajah Mada University Press)

[26] Parnell TL 2004 Tomatoes: Safe methods to store, preserve and enjoy (Division of Agriculture and Natural Resources University of California)

[27] Kim JG, Yousef AE and Dave S 1999 Application of ozone for enhancing the microbiological safety and quality of foods: A Review J Plant Prot 62(9) pp 1071-1087

[28] Khadre MA, Yousef AE and Kim JG 2001 Microbial aspects of ozone appliation in food: A review J. Food Sci 66(9) pp 1242-1252

[29] Wani S et al 2015 Effect of ozone treatment on inactivation of Escherichia coli and Listeria sp. On spinach Agriculture 5 pp 155-169