

The Effect of Packaging Materials on the Quality of Freshness of Longan Fumigated with Medium Concentration-ozone Gas

Saranyapak Chamnan¹, Jaturapatr Varith^{1*}, Somkiat Jaturonglumlert¹,
Pisuthi Klinkajorn¹ and Jakraphong Phimphimol²

¹Graduate Program in Food Engineering, Faculty of Engineering and Agro-industry, Maejo University, Chiang Mai 50290, Thailand.

²Program in Postharvest Technology, Faculty of Engineering and Agro-industry, Maejo University, Chiang Mai 50290, Thailand.

ABSTRACT

The objective of this research was to evaluate the performance of a medium concentration-ozone treatment in maintaining the quality of freshness of “Daw” longan packed in different types of packaging materials. For fumigation with ozone gas, a batch size of 3 kg of longan fruit was fumigated for 5 minutes at a concentration of 4,000 ppm. The longan was then packed in three different types of packaging- polyethylene (PE), polypropylene (PP) and wrap film (WF), and was then stored at 5°C for a shelf life of up to 36 days. Non-ozonated longan was kept as a control. The results showed that as storage time lengthened, the longan became more susceptible to disease incidences, pericarp browning, and weight loss under all treatments. During storage, the longan slightly changed in its firmness although there was

no significant difference ($p \geq 0.05$) among the three different types of packaging. The ozonated longan stored in PE, PP, WF, and those with no-packaging had more L^* and b^* values and a longer shelf life, than those of the control. Among the three different types of packaging, the ozone fumigated longan stored in PE yielded the longest storage time with a shelf life of up to 36 days; an extended 140% longer shelf life as compared to the control.

ARTICLE INFO

Article history:

Received: 24 October 2018

Accepted: 15 February 2019

Published: 21 June 2019

E-mail addresses:

saranyapak.cha@gmail.com (Saranyapak Chamnan)

varithj@maejo.mju.ac.th (Jaturapatr Varith)

yaidragon@mju.ac.th (Somkiat Jaturonglumlert)

psetton@hotmail.com (Pisuthi Klinkajorn)

jakrapho@mju.ac.th (Jakraphong Phimphimol)

* Corresponding author

Keywords: Fresh quality, longan, packaging materials, ozone fumigation, shelf life extension.

INTRODUCTION

One of the economically important fruits in the north of Thailand is longan (*Dimocarpus longan* Lour). China, Indonesia, Vietnam, Hong Kong and Malaysia are important trading countries of fresh longan fruit with Thailand (Department of International Trade Promotion, 2017). Unfortunately, longan rots easily in nature, rendering it susceptible to various postharvest pathogens intrusion which shortens the longan's shelf life at room temperature (Saengnil et al., 2014). This main problem results in restrictions on the export of longan to long distant markets due to rapid pericarp browning during storage (Sardsud et al., 1994).

Ozone is one of the powerful oxidants and has the strong capacity of disinfection and sterilization. It is a powerful germicide which destroys bacteria and fungi. Ozone gas has a longer half-life than in aqueous ozone solution (Gonçalves & Kechinski, 2011). Ozone has been confirmed as GRAS status, as a food processing aid and is compliant with the Environmental Protection Agency Disinfection by Products Rule (Ong et al., 2014). Ozone is an effective treatment for increasing shelf life and in decreasing fungal deterioration in the postharvest treatment of fresh vegetables and fruits such as tomatoes where its shelf life can be extended from 16 to 48 days (Zambre et al., 2010) as compared with control. Other fruits that yielded positive results after ozone treatment include stone fruit (Palou et al., 2002), strawberry (Thaer et al., 2013) and the papaya fruit (Ong et al., 2014), have been well documented.

Materials used for food packaging are essential to prevent physical damage to the product in order to obtain optimal shelf life. In addition, proper packaging has the proper characteristic of permeability, where a desirable equilibrium could modify the atmosphere when the rate of gas (oxygen and carbon dioxide) transmission permeating the packaging and thus balancing the respiration rate of the fruit (Kartal et al., 2012). Most packaging of fresh fruit uses polyethylene (PE) and polypropylene (PP) bags because of low water vapour permeability (Ščetar et al., 2010). Similarly, Sahoo et al. (2015) reported that the shelf life of pointed gourds packed in PP film and under refrigerated condition lasted for up to 16 days, while the shelf life of pointed gourds packed in LDPE film under ambient conditions could extend up to 4 days. The packaging of pointed gourds created a suitable headspace environment with low oxygen and high carbon dioxide concentrations. Chillies packed in microporous, PE-LD, polyolefin and anti-fog films had a shelf life of 16, 18, 22 and 28 days, respectively. In addition, control samples had shelf life of 15 days (Chitravathi et al., 2015).

Since ozone exhibits a high potential to extend shelf life of agricultural products, it can be used in combination with the proper packing material to prolong the shelf life of longan.

Thus, the objective of this study is to evaluate the effectiveness of fumigation with gaseous ozone, and the suitability in packaging, on the quality of freshness of longan during cold storage which could prevent desiccation, and which prolongs the shelf life of longan fruit.

MATERIALS AND METHODS

Longan Fruit Sample

Longan (*Dimocarpus longan* Lour.) cv. “Daw”, harvested in less than 3 days from the orchards in Chiang Mai, Thailand, was used in this study. The fruit was graded for uniformity of size (grade AA with a size of 30 mm. in diameter), color and non-disease appearance.

Ozone Fumigation System

The ozone fumigation system consisted of a corona discharge ozone generator from purified oxygen gas. The generator connected with the control system using a Labview™ program access through a wireless network. The system connected to a fumigation chamber of 0.4×0.4×1.2 m³. The system conveyed ozone gas by silicone tube. The optimum flow rate of ozone gas was 7.5 L/min and back pressure 12 kPa. The output of generating ozone gas was 5.5 g/h (Changchai et al., 2015). Ozone concentration was measured by an ozone gas sensor connected with a data logger. This data logger was calibrated by an ozone gas-sampling pump with a detector tube (Gastec Model GV-100, Japan).

Ozone Fumigation Treatment and Quality Evaluation

Longan fruit with a batch size of 3 kg was filled in a polycarbonate container. For fumigation process, the longan sample was fumigated with ozone gas at a concentration of 4,000ppm and held under pressure for 5 minutes. Longan fruit with and without fumigation were of packed size of 200g per pack. Accordingly, the longans were packed using 3 different types of packaging, namely, polyethylene (PE), polypropylene (PP) and foam tray wrap with film (WF), and stored at 5°C 95% RH until the end of shelf life. Treatments according to packaging type were defined by codenames as follows:

Untreated with gaseous ozone:

NC = control without packaging

NP = packed with PP

Treated with ozone gas:

OC = control without packaging

OP = packed with PP

NE = packed with PE

NF = packed with WF

OE = packed with PE

OF = packed with WF

The properties of these films used for packaging experiments are given in Table 1. The fruit was determined for its quality analysis immediately after fumigation and every

three days for disease incidence, pericarp browning, weight loss, firmness, color and shelf life evaluation.

Table 1

Permeability of gas through plastic films (Hernandez, 1997)

Permeability	PE	PP	WF
Water (g·µm/m ² ·d·kPa) at 37.8°C	66-99	16.5-26	330-2,000
Oxygen (cc(STP)·µm/m ² ·d·kPa) at 25°C	1,940	622	389-3,900
Carbon dioxide (cc(STP)·µm/m ² ·d·kPa) at 25°C	10,490	2,100	1,170-2,330

Determination of Disease Incidence

Disease incidence was assessed by measuring lesion area of fungal infection on each fruit's surface. Disease incidence was scored into levels as: Level 0 = no disease; Level 1 = 1-20%; Level 2 = 21-40%; Level 3 = 41-60%; Level 4 = 61-80%; and Level 5 = 81-100%. Longan fruit evaluated at a score > 0.20 were considered unacceptable for marketing.

Determination of Pericarp Browning

Pericarp browning was determined by estimating the browning area that appeared on each fruit's pericarp due to deterioration of the longan's shelf life during storage. The measurement was scored into 5 levels with respect to its browning area as Level 1 (0 - 20%), Level 2 (21 - 40%), Level 3 (41 - 60%), Level 4 (61- 80%) and Level 5 (81- 100%)

Determination of Weight Loss

Two batches of 200g treated samples were weighed for weight loss using 2 digits digital balance with ± 0.01g accuracy (model CP3202S, Sartorius, Germany). After weighing, the fruit was returned to storage cabinet at 5°C and 95%RH. The same batch of treated fruit was repeatedly weighed throughout storage time. Weight loss was expressed as Equation 1.

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

Determination of Firmness

Firmness analysis of 5 longan fruits from each treatment was selected at random where each fruit was penetrated on one side using a Texture Analyzer with ±0.1 g accuracy (model TA.XT-PLUS, Stable Micro Systems, UK). The firmness test applied a cylinder plunger SMS-P/2 probe (2 mm diameter), compressed by 20% strain using cross-head speed of pre-test, test, and post-test speed of 3 mm/s, 1 mm/s and 10 mm/s, respectively.

Determination of Color

The color of longan fruits was measured on the surface using a spectrophotometer with ± 5 nm accuracy (model Mini Scan XE PLUS 45/0-S, Hunter Lab, USA). The means of L^* (lightness) and b^* (yellowness and blueness) were reported according to the consumer preference on visual appearance of longan fruit with a yellow to light brown color (Jiang et al., 2002).

Determination of Shelf Life Evaluation

The shelf life of longan fruit was determined by disease incidence, immediately after fumigation and every 3 day-intervals during storage. The fruit was considered to be at the end of its shelf life when disease incidence of the fruit was evaluated with score > 0.20 .

Experimental Design and Statistical Analysis

The experiment was designed using factorial experimental design in a randomized complete block design (RCBD). Data were statistically analyzed by analysis of variance (ANOVA), and was carried out using SPSS 16.0. Duncan's Multiple Range Tests (DMRT) at a significance level of 0.05. Among the various treatments, the p-value less than 0.05 was considered as a significant difference.

RESULTS AND DISCUSSION

Effects on Disease Incidence

The first parameter related with the shelf life of the fruit can be defined as disease incidence. For Figure 1A, disease incidence of longan all treatments increased when storage time increased. The disease incidence of NC sample increased rapidly in 18 days. Longan treated with gaseous ozone exhibited less disease incidence than those of untreated samples when stored at 5°C. This corresponds with Ong et al. (2013) who found that ozone treatment reduced disease incidence up to 40% in papaya fruit. Other researchers also reported that ozone fumigation reduced the microorganism population in fruits such as longan fruit (Whangchai et al., 2006), date fruit (Habibi & Haddad, 2009), strawberry (Aday & Caner, 2014) and table grapes (Gabler et al., 2010) because it destroyed microorganisms by oxidizing the cellular components of cell fruit (Victorin, 1992). In our study, longan fruit packed in PE exhibited the least disease incidence when compared to PP, WF and without packaging. Since PE had more carbon dioxide (CO_2) permeability than other films (Table 1), it is possible that CO_2 might permeate to environment easier than those packed in other packaging. As a result, the ozonated longan packed in PE emerged less disease incidence than the others. The low percentages of diseases incidence in PE also slow down the rate of pathological disorder in PE films as well.

Effects on Pericarp Browning

The pericarp browning of longans under all treatments increased throughout shelf life (Figure 1B). At day 0, the longan fruit fumigated with gaseous ozone significantly exhibited less pericarp browning than that of non-fumigate longan fruit ($p < 0.05$). When stored for 15 days, the OE sample exhibited the least pericarp browning score of 1.80, whereas the NC sample exhibited the highest pericarp browning score of 4.40. Correspondingly, Whangchai et al. (2006) reported that with the increase of storage time, longan fruit treated with low concentration ozone showed an increase in pericarp browning because of the time limit in ozone efficiency to inhibit browning of longan fruit.

Effects on Weight Loss

Gaseous ozone treatments did not significantly affect ($p \geq 0.05$) the weight loss of longan fruit, however, type of packaging significantly did ($p < 0.05$). During 15 days in storage, longan fruits with no packaging gained more weight loss than those packed in WF, PE, and PP, respectively. The NC sample had the highest weight loss of 9.39% in 15 days. These results agreed with Mistriotis et al. (2016) who suggested that unwrapped samples (cherry tomatoes and peaches) had more weight loss than samples packed in PLA and OPP film. When storage time lengthened, longan fruit under all treatments was susceptible to weight loss. The OE sample had the highest weight loss of 13.42% in 36 days, as shown in Figure 1C. An increase in weight loss of longan is normally due to evaporation and respiration (water and heat production), but under different packaging types, it yielded different responses (Chitravathi et al., 2015).

Effects on Firmness

Firmness can be defined as the parameter which is related to cell wall strength and intercellular adhesion (Toivonen & Brummell, 2008). In Figure 1D, gaseous ozone treatments and packaging types did not significantly affect ($p \geq 0.05$) the firmness of the longan fruit. During storage at 5°C, the firmness of longan was within a range of 9.98 to 10.04 N. Longan fruit changed slightly in firmness but with no significant difference ($p \geq 0.05$). The firmness did not change. This may be due to lesser loss of moisture from the surface of longan fruit. In contrast to other fruits, Aday and Caner (2014) reported that significant difference in firmness values was observed between ozone treated and ozone untreated strawberries. All treated strawberries had higher firmness values than the control group. Pointed gourd in all packaging types had peak force decreased during storage under ambient and refrigerated storage condition (Sahoo et al., 2015).

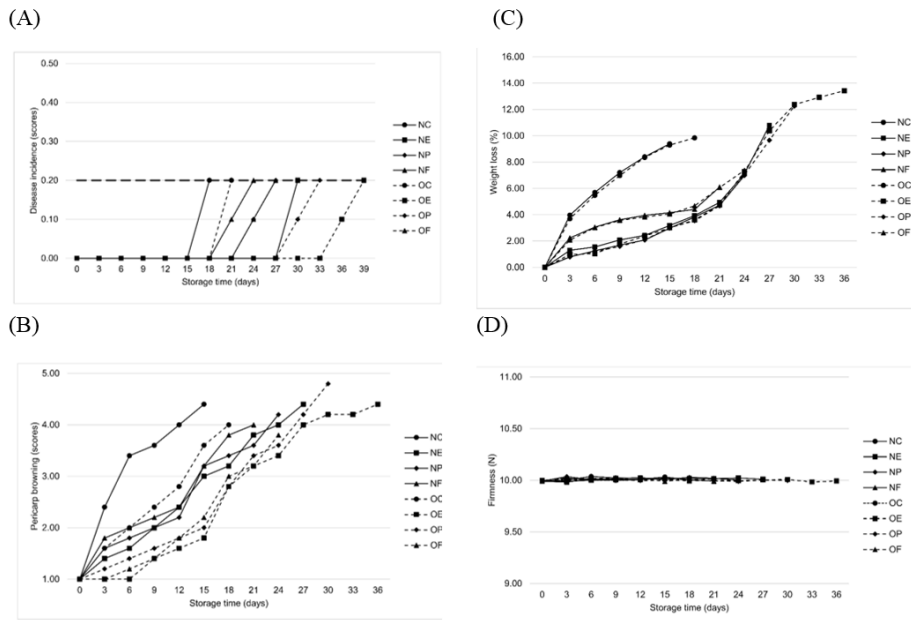


Figure 1. Effect of ozone fumigation and packaging materials on physicochemical properties of longan fruit during storage at 5°C: (A) disease incidence, (B) pericarp browning, (C) weight loss, and (D) firmness. Each data point represents a mean of three replicates (n=3)

Effects on Color

Color is the one factor in deciding visual attributes for buying and selling of longan fruit (Apai, 2010). At day 0, longan fruit without ozone fumigation possessed the L^* and b^* of 49.80 and 28.64. When fumigated with ozone gas, the longan had increased in L^* and b^* to 52.64 and 30.29, respectively. Ozone may cause an increase in L^* of longan due to the bleaching effect (Forney, 2003). During storage at 5°C, the ozonated longan stored in PE, PP, WF and without packaging had more L^* and b^* (light yellow-brown color) as well as a longer shelf life than those of the untreated longan (dark brown color), as shown in Figure 2A and 2B. Similar trend was also observed by Aday and Caner (2014) who suggested that strawberries with ozone treatments and storage times were significant factors affecting the L^* .

Effects on Shelf Life

The shelf life of longan fruit due to effects of ozone treatment and storage packaging type was determined by disease incidence, as shown in Figure 1A and Table 2. Longan fumigated with ozone gas had a longer shelf life than untreated samples. The ozonated longan packed in PE had a longer shelf life than that of PP, WF and those with no packaging when stored at 5°C. Among three different types of packaging, the ozone fumigated longan stored in PE

yielded the longest storage time up to 36 days, equivalent to 140% longer shelf life than that of the control. According to Zambre et al. (2010), tomatoes treated with ozone gas and stored at 15°C had a prolonged shelf life of tomato by 22 days. The longer shelf life of longan was possibly due to a reduction in the surface microbial count in combination with proper modified atmosphere effect inside the package. The modified gaseous composition in the different packaging created a suitable headspace with low oxygen and high carbon dioxide, which resulted in maintaining the quality and marketability of vegetables (Sahoo et al., 2015). Our results also agreed with that of Mangaraj et al. (2012) who found that the modified atmosphere packaging extended shelf life of the litchi fruit from 100 to 150% compared with unpackaged fruits.

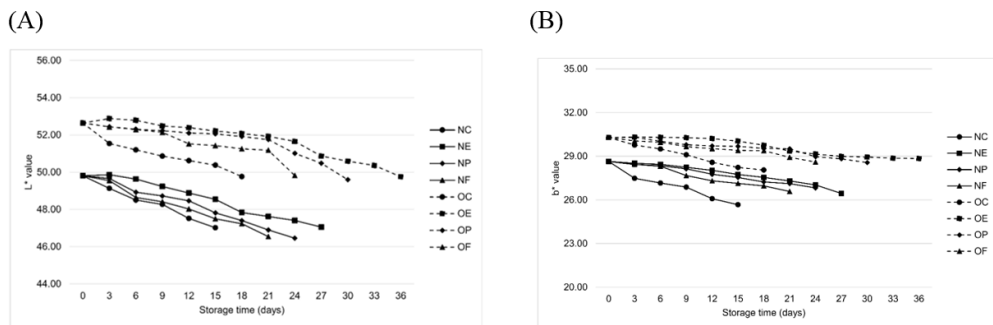


Figure 2. Effect of gaseous ozone and packaging type on color; (A) L* value and (B) b* value of longan fruit during storage at 5°C

Table 2

Shelf life at various treatment of longan fruit during storage at 5°C

Non-Ozone Treatment	Shelf life (days)	Ozone treatment	Shelf life (days)
NC	15	OC	18
NE	27	OE	36
NP	24	OP	30
NF	21	OF	24

CONCLUSION

Gaseous ozone treatment and the type of storage packaging materials are two important factors affecting the quality of freshness of the longan fruit. Without ozone fumigation, longan fruit had more incidences of disease, pericarp browning, and weight loss, with less L* and b* in storage for 15 days. With ozone fumigation, the disease incidences, weight

loss and shelf life of the longan fruit yielded positive effects, depending upon on the type of packaging materials. Using ozone fumigation combined with PE packaging was the optimum treatment that resulted in a storage shelf life up to 36 days. It is suggested that a combined treatment of a varied concentration of ozone fumigation, with more variety of packaging materials and storage conditions, can be further studied to improve the shelf life of fresh longan.

ACKNOWLEDGEMENTS

This research was supported by the Food Engineering Program, Faculty of Engineering and Agro-industry, Maejo University, Chiang Mai, Thailand. The authors gratefully acknowledge Assist. Prof. Dr. Kanda Whangchai at the Department of Biology, Faculty of Science, Chiang Mai University, Thailand, for providing the ozone calibration equipment.

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