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Short communication

# Exposure to ozone reduces postharvest quality loss in red and green chilli peppers

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ABSTRACT

The effect of continuous exposure to ozone at 0.45, 0.9 and 2 μmol mol$^{-1}$ on quality changes during the storage of red and green chilli peppers at 10 °C was investigated. Ozone at 0.45 and 0.9 μmol mol$^{-1}$ reduced disease incidence in red peppers, with no further benefits at 2 μmol mol$^{-1}$. Ozone at 0.9 μmol mol$^{-1}$ reduced weight loss during storage and improved firmness maintenance. Skin colour was bleached in red peppers exposed to ozone at 2 μmol mol$^{-1}$, and in green ones at all tested doses. Total phenolic content was not affected by ozone but antioxidant activity was reduced in green chilli peppers exposed to ozone at 2 μmol mol$^{-1}$, due to lower ascorbic acid content in those samples. Ozone at 0.9 μmol mol$^{-1}$ extended the shelf-life of chilli peppers.



## 1. Introduction

Chilli peppers' shelf life is limited by both, contamination with microorganisms, including human pathogens, e.g. *Escherichia coli* (Cerna-Cortes et al., 2012) and visual and textural quality loss (Nunes, Emond, Rauth, Dea, & Chau, 2009). Chlorine is the most common sanitiser used in the fresh produce industry (Gil, Selma, Lopez-Galvez, & Allende, 2009); however, there is increasing concern about chlorine being over-used and its real efficacy during storage. Thus, the advantages and limitations of numerous alternative methods, e.g. the use of hydrogen peroxide, organic acids, and UV radiation have been reviewed (Artes, Gomez, Aguayo, Escalona, & Artes-Hernandez, 2009; Ramos, Miller, Brandao, Teixeira, & Silva, 2013).

The interest in using ozone as a postharvest treatment of fruit and vegetables has recently increased (Glowacz, Colgan, & Rees, 2015a; Horvitz & Cantalejo, 2014; Miller, Silva, & Brandao, 2013) due to its potential to reduce microbial contamination of the produce, without any chemical residues being left (Khadre, Yousef, & Kim, 2001), and having no adverse effect on the product's quality, if used at the proper dose.

A number of authors (Alexandre, Santos-Pedro, Brandao, & Silva, 2011; Alexopoulos et al., 2013; Glowacz, Colgan, & Rees, 2015b; Horvitz & Cantalejo, 2012; Ketteringham, Gausseres, James, & James, 2006) studied the efficacy of ozone in reducing microbial counts on bell peppers, and a few (Glowacz et al., 2015b; Horvitz & Cantalejo, 2010a, 2010b, 2012) also assessed its effect on physicochemical properties. However, the information on the effects of ozone treatment on the postharvest quality of chilli peppers is scarce (Chitravathi, Chauhan, Raju, & Madhukar, 2015) and requires further investigation.

Microbial counts were found to be reduced on fresh-cut red bell peppers treated with gaseous ozone at 0.7 μmol mol$^{-1}$ for 1–5 min prior to storage (Horvitz & Cantalejo, 2010b, 2012) and on whole red bell peppers continuously exposed to ozone at 0.1 and 0.3 μmol mol$^{-1}$ (Glowacz et al., 2015b) during a 14-day storage period and with a more pronounced effect at the higher dose.

The efficacy of aqueous ozone in reducing microbial loads on fresh-cut red (Alexandre et al., 2011) and whole green (Alexopoulos et al., 2013) bell peppers was found to increase with increasing dose of ozone. However, Ketteringham et al. (2006) and Horvitz and Cantalejo (2010a) did not find positive effects of aqueous ozone treatment of fresh-cut peppers. Cut surfaces promote leaching of organic matter that reacts with ozone, thereby reducing its efficiency as an antimicrobial agent. Thus, it has been suggested to treat whole rather than pre-cut peppers.

In a recent study (Chitravathi et al., 2015), aqueous ozone treatment at 30 μmol mol$^{-1}$ for 10 min prior to storage reduced microbial counts on chilli peppers during subsequent storage at 8 °C. However, and to the best of our knowledge, there is no information in the literature on the effects of continuous exposure to gaseous ozone on the postharvest quality of chilli peppers. In the previous study (Glowacz et al., 2015b) no signs of rotting were observed in bell peppers continuously exposed to ozone at 0.3 μmol mol$^{-1}$,

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while the growth of fungi on the stem and peduncle was observed in 8.3% and 25% of the fruit continuously exposed to ozone at 0.1 μmol mol$^{-1}$ and untreated control, respectively. The objective of this study was to investigate the effects of continuous exposure to ozone at 0.45, 0.9 and 2 μmol mol$^{-1}$ on disease incidence and the physicochemical characteristics of red and green chilli peppers.

## 2. Materials and methods

### 2.1. Plant material and handling

Free from visible defects red and green chilli peppers (*Capsicum annuum* L.), varieties Serenade and Jalapeno, respectively, were supplied by Barfoots of Botley Ltd, West Sussex, UK.

Experiment design and ozone fumigation system set up was previously described by Glowacz et al. (2015b). Fruit were kept at 10 ± 1 °C, and continuously exposed to ozone at approximately 0.45 ± 0.10, 0.9 ± 0.10 and 2 ± 0.20 μmol mol$^{-1}$, using FPTU ozone generators (Onnic International, UK). Control chilli peppers were stored under air. Air was circulated to ensure even distribution of ozone and gas concentration was monitored periodically, on the sampling day before taking the produce out from the containers for subsequent assessment, with an L-106 Ozone Monitor (2B Technologies, US). Relative humidity inside the containers was maintained at 90 ± 3% and monitored using humidity loggers (Lascar Electronics Ltd, UK). Produce quality, i.e. weight loss, visual quality (signs of rotting, shrivelling, stem browning, skin colour), firmness, content of sugars, bioactive compounds and antioxidant activity, was assessed on arrival and after 7, 10 and 14 days of storage.

### 2.2. Measurements

#### 2.2.1. Weight loss

Weight loss (%) was determined by comparing the weight of the fruit on the sampling day with their initial weight determined on day 0.

#### 2.2.2. Visual quality and firmness

Rotting, shrivelling and stem browning were recorded as a score (0 or 1 – no/signs of rotting, shrivelling and stem browning, respectively). The number of fruit with defects was recorded and calculated as % of the assessed sample population (30 chilli peppers from each replicate). Skin colour and fruit firmness were determined using a Minolta CR-400 chroma meter (Minolta, Japan) and a TA.XT plus Texture Analyser (Stable Micro Systems, UK), respectively, as previously described (Glowacz et al., 2015b).

#### 2.2.3. Biochemical analyses

Sugars, ascorbic acid (AsA) and total phenolic content were measured by methods given in Glowacz et al. (2015b), whereas antioxidant activity FRAP (ferric reducing antioxidant power) and the ability of fruit extracts to scavenge DPPH (2,2-diphenyl-1-picrylhydrazyl) free radicals was determined using the method previously described by Ali, Ong, and Forney (2014).

### 2.3. Statistical analyses

Chilli peppers were organised in 6 replicates of 90 peppers, for each variety. Data are presented as mean values from a fully randomised design. The significance of main effect was established using ANOVA. Tukey's test was used to compare individual treatment values. All statistical analyses were performed using GenStat 17th Edition software (VSN International Ltd, UK).

## 3. Results and discussion

### 3.1. Disease incidence

Red chilli peppers were found to be more prone to rotting, compared to green chilli peppers, in which rots were not observed during the storage period. Signs of rotting (primarily moulds) were observed on red chilli peppers after 7 days of storage on 11.1% and 2.8% of the control samples and those exposed to ozone at 0.45 μmol mol$^{-1}$ while no microbial growth was found on those peppers subjected to 0.9 and 2 μmol mol$^{-1}$ gaseous ozone. After 10 days, 16.7% of the control samples showed signs of rotting, whereas disease incidence was significantly reduced to 4.2% in chilli peppers exposed to ozone at 0.45, 0.9 and 2 μmol mol$^{-1}$, without any difference between doses. Finally, after 14 days of storage, 25% of the control samples where rotted, while signs of rotting were observed on 8.3, 8.3 and 16.7% of chilli peppers exposed to ozone at 0.45, 0.9 and 2 μmol mol$^{-1}$, respectively. Disease incidence was substantially reduced at both 0.45 and 0.9 μmol mol$^{-1}$. The highest dose of ozone used, probably led to tissue damage, thus facilitating fungal infection, in this way counteracting the beneficial antimicrobial action of ozone.

Reduced disease incidence in peppers exposed to ozone at 0.45 and 0.9 μmol mol$^{-1}$ is in agreement with the results observed by Glowacz et al. (2015b) and Horvitz and Cantalejo (2010b, 2012), who observed reduced microbial counts on whole red bell peppers continuously exposed to ozone at 0.1 and 0.3 μmol mol$^{-1}$ (Glowacz et al., 2015b) and fresh-cut red bell peppers treated with gaseous ozone at 0.7 μmol mol$^{-1}$ for 1–5 min prior to storage (Horvitz & Cantalejo, 2010b, 2012), respectively. On the other hand, it is also clear that the dose of ozone has to be appropriately adjusted for each commodity (Forney, 2003) to avoid unwanted tissue damage.

### 3.2. Weight loss, shrivelling and stem browning

Chilli peppers lost weight over the storage period. The weight loss was lower in both red and green chilli peppers exposed to ozone at 0.9 μmol mol$^{-1}$; however, this effect was lost after 14 days in ozone-exposed green chilli peppers (Table 1).

Shrivelling and stem browning are both indicators of reduced quality related to the loss of water. The appearance of signs of shrivelling was delayed in red chilli peppers exposed to ozone at 0.45 and 0.9 μmol mol$^{-1}$, while stem browning was significantly reduced only in samples exposed to ozone at 0.9 μmol mol$^{-1}$ up to 10 days of storage (Table 1). Green chilli peppers were more susceptible to shrivelling than red ones. Shrivelling was reduced up to 10 days of storage in green chilli peppers exposed to ozone at 0.9 μmol mol$^{-1}$ (Table 1). Increasing the dose from 0.9 to 2 μmol mol$^{-1}$, enhanced shrivelling, this suggests that the dose of ozone at 2 μmol mol$^{-1}$ was too high, and reduced visual quality of the produce.

Reduced weight loss has previously been observed in kiwi continuously exposed to ozone at 0.3 μmol mol$^{-1}$ for 5 months (Minas et al., 2012), cucumbers and courgettes continuously exposed to ozone at 0.1 μmol mol$^{-1}$ for 17 days (Glowacz et al., 2015b) and chilli peppers treated with aqueous ozone at 30 μmol mol$^{-1}$ for 10 min (Chitravathi et al., 2015). Water loss from chilli peppers occurs primarily through the cuticle (Kissinger et al., 2005), thus the amount of water loss during storage could be affected by its thickness and composition (Lara, Belge, & Goulao, 2014; Parsons et al., 2013). Thick cuticle makes the produce less susceptible to damage by preventing the epidermal tissues from ozone action (Ali et al., 2014). The mechanism of ozone action in chilli peppers may involve its effect, via reactive oxygen species (ROS) (Kangasjarvi, Jaspers, & Kollist, 2005), on the activity of lipoxyge-