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Influence of ozone treatment on postharvest quality of stored summer squash

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ABSTRACT

This study was carried out to ascertain the effect of different concentrations of ozone (0.2, 0.4 and 0.6 ppm ozonated water) on postharvest quality of summer squash fruit during cold storage at 8 ± 2ºC temperature and 85-90% relative humidity. Various physico-chemical quality traits were recorded at a regular interval of 3 days upto 12 days of fruit storage. Among the applied doses of ozone, 0.4 ppm ozone concentration was found better in retaining higher fruit firmness (5.84 N) and maintaining lower weight loss (15.06%) over control fruits during storage of 12 days. However, total bacterial count (3.92 log cfu/g); yeast & mould count (3.65 log cfu/g) and decay incidence (%) were effectively controlled by 0.6 ppm ozone concentration. Contrast to these gainful impact of ozone application on firmness, physiology and microbial load; the colour of the stored fruit was masked even by 0.2 ppm ozone.

Key words: *Cucurbita pepo*, decay loss, yeast and mould count.

INTRODUCTION

Summer squash (*Cucurbita pepo* L.) is a cucurbitaceous vegetable of Mexican origin. It is a good source of carbohydrates, dietary fibres, minerals (like Ca, Mg, P, Zn *etc.*) and many essential vitamins. Yellow to pink fruit flesh are rich in vitamin A than green skin fleshed varieties. It is grown commercially in many countries like USA, Europe, China, Japan and India *etc*. In India, it is confined to a limited scale in states like Himachal Pradesh, Uttarakhand, Punjab, Haryana, Delhi and Western Uttar Pradesh. Squash is a quick growing short duration (time from flowering to harvest 45 to 60 days) vegetable, that's why most popular crop among farmers practising protected cultivation. Further, owing to short shelf-life and quality deteriorative phenomenon, summer squash cultivation is mainly concentrated in peri-urban areas. Thin, soft external rind and external glossiness are major indicators of a pre-maturity condition. Being a very soft rind vegetable, its handling transportation and storage requires specialized attention and quick disposal to the consumers. Among all cucurbits; squash is a highly perishable crop with shelf life upto 2-3 days under ambient storage conditions. Loss of fruit firmness and shrivelling are the serious common postharvest problems in summer squash. During storage, summer squash is severely affected by many postharvest storage diseases.

Ozone is a strong antimicrobial agent with high reactivity, penetrability and spontaneous decomposition to a non-toxic product (Kim *et al.*, 3). Primary advantages of ozone include fast decomposition in water to oxygen, no residual effect and improved microbial reduction efficacy against bacterial and fungal spores than hypochlorite. Ozone forms oxidated radicals in the presence of water that penetrate and act on cell membranes. Ozone is efficient at low concentrations, requires only a short contact times, does not generate hazardous residues on the treated product and rapidly auto decomposes (Pascual *et al.*, 8). Therefore, this study was undertaken which elucidate the impact of ozone on postharvest quality traits of summer squash.

MATERIALS AND METHODS

This study was conducted in the Division of Food Science & Postharvest Technology, ICAR-IARI, New Delhi-110012 during the year 2015. In this study, effect of different concentrations of ozone on summer squash fruits was observed on quality attributes during storage at 8 ± 2°C in a temperature controlled chamber. Freshly harvested summer squash fruits were dipped in different concentration of ozonated water for 30 minute, and then fruits were properly wiped out to remove free moisture from the surface followed by storage at 8 ± 2°C and 85-90% RH. Physical, physiological, biochemical and microbial changes in summer squash were recorded at 3 days interval with three replications. The details of the treatment are as follows: T_0= Control, T_1 = 0.2 μl l^{-1}, T_2 = 0.4 μl l^{-1} and T_3 = 0.6 μl l^{-1}. For the measurement of physiological loss in weight, the fruits were weighed during storage at regular intervals and expressed in percentage. Fruit firmness was determined by

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using a texture analyzer and expressed in Newton (N). Peel colour was measured using Hunter Lab System. The colour value was expressed as L* and a*. Fruit decay incidence was calculated by counting the diseased and healthy fruit in each treatment and expressed as %. Total microbial load was recorded by standard plate count method and expressed as log CFU/g of fruit sample. Two way analysis of variance was performed on the data sets using SAS 9.3 software (2) and significant effects ($p<0.05$) were noted. Significant difference among the means was determined by Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Irrespective of treatments there was an increase in L^* value with the progress in storage period (Table 1). Hunter L^* value was found to be significantly ($P \leq 0.05$) affected with different treatments. Rate of increase of Hunter L* value was found to be highest (46.35) for 0.6 ppm ozone concentration followed by 0.4 ppm (45.26), while it was lowest (43.26) in control at the end of storage period. The obtained results proved that ozone treatments have bleaching effect on summer squash. In respect of Hunter a* value, all the treatments showed rapid increase till end, which indicated fadeness in green colour of fruits due to bleaching action of O_3 (Table 2). The green colour of the summer squash peel is imparted by chlorophyll concentration which is generally degraded with the onset of senescence through chlorophyllase mediated enzyme activity. The negative Hunter a* value may be due to suppression of chlorophyllase and other degrading enzymes by the virtue of ozone efficacy (Aguayo *et al*., 1; Singh *et al*., 9).

No significant difference in firmness among the treatments was observed up to 12th day of storage however, a marked decrease in fruit firmness was observed in control fruits. At the 12th day of storage, highest firmness (5.84 N) was recorded in 0.2 and 0.4 ppm ozone treated fruits while it was least (4.95 N) in control (Fig. 1). 0.4 ppm ozone treated summer squash fruits retained ≈18% higher firmness over control. The higher fruit firmness in ozone treated summer squash may be due the better retention of moisture content during storage or inhibition in the activities of cell degrading enzymes like polygalactouronase (PG) and pectin methyl esterase (PME). Similar findings were also reported by Aguayo *et al*. (1) and Escriche *et al*. (2).

In general, weight loss was significantly lower in ozone treated fruits compared with untreated fruits (Fig. 2). However, difference among the different ozone concentration was non-significant. All the concentration of ozone (0.2, 0.4 and 0.6 ppm) significantly lowered the weight loss over the control fruits during entire storage period. The medium concentration (0.4 ppm) of ozone was most suitable for retaining freshness comparing to its higher doses. Least water loss in ozonated fruits may be due to the higher firmness, which regulates and maintain the cell wall and membrane integrity during storage. Maguire *et al*. (6) on tomato and Palou *et al*. (7) on peaches also reported similar results. While, Liew and Prange (5) reported that ozone treated carrot exhibited higher weight loss during storage compared to untreated ones. The reasons for these contrary results have been explained with different metabolic pathway switch on during storage under different environmental conditions.

Up to 3rd day of storage no decay incidence was found in any of the treated fruits, later on, control summer squash exhibited decay incidence from 6 days of storage which further increased rapidly up to end of storage (Table 3). However, those fruits which were treated with 0.2, 0.4 and 0.6 ppm ozone concentration showed decay from 9th day onward.

Table 1. Impact of ozone treatments on Hunter L^* value of summer squash during storage at 8 ± 2°C and 85-90% RH.

Ozone (ppm)	Storage period (days)					
	0	3	6	9	12	Mean
0.0	32.89^{l}	34.29^{k}	36.30^{j}	39.89^{h}	43.26^{de}	37.32^{d}
0.2	32.89^{l}	36.28^{j}	39.36^{h}	42.42^{ef}	44.22^{cd}	39.03^{c}
0.4	32.89^{l}	37.96^{i}	41.01^{g}	42.90^{ef}	45.26^{b}	40.01^{b}
0.6	32.89^{l}	40.02^{gh}	42.25^{f}	44.34^{bc}	46.35^{a}	41.17^{a}
Mean	32.89^{e}	37.14^{d}	39.73^{c}	42.39^{b}	44.77^{a}	

*Means with same superscript letter are not significantly different

Table 2. Impact of ozone treatments on Hunter a* value of summer squash during storage at 8 ± 2°C and 85-90% RH.

Ozone (ppm)	Storage period (days)					
	0	3	6	9	12	Mean
0.0	-7.45^{c}	-6.11^{bc}	-5.20^{bc}	-4.33^{bc}	-3.24^{b}	-3.87^{a}
0.2	-7.45^{c}	-5.49^{bc}	-4.94^{bc}	-3.72^{bc}	-2.92^{aa}	-4.90^{a}
0.4	-7.45^{c}	-5.39^{bc}	-4.78^{bc}	-3.47^{bc}	-2.66^{a}	-4.75^{a}
0.6	-7.45^{c}	-5.22^{bc}	-4.33^{bc}	-3.23^{b}	-2.47^{a}	-4.54^{a}
Mean	-7.45^{c}	-5.55^{b}	-3.06^{a}	-3.69^{a}	-2.82^{a}	

*Means with same superscript letter are not significantly different

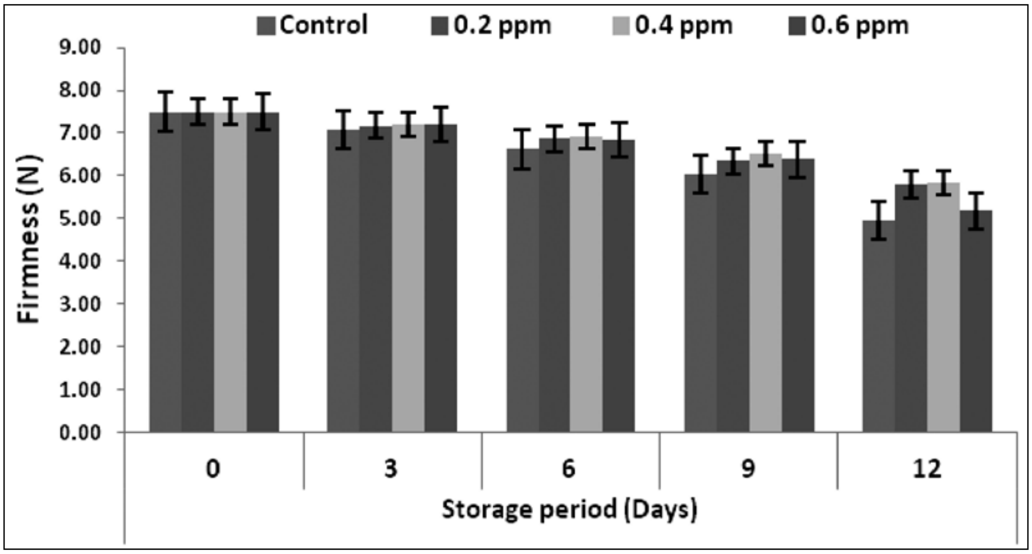

Fig. 1. Impact of ozone treatments on firmness of summer squash during storage at 8 ± 2°C and 85-90% RH.

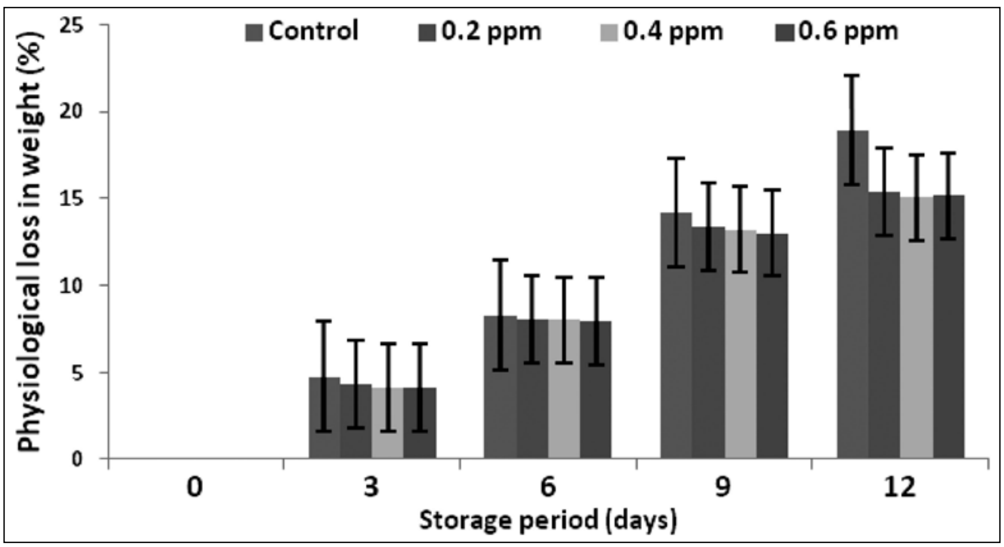

Fig. 2. Impact of ozone treatments on PLW (%) of summer squash during storage at 8 ± 2°C and 85-90% RH.

Table 3. Impact of ozone treatments on decay incidence (%) on summer squash during storage at 8 ± 2°C and 85-90% RH.

Ozone (ppm)	Storage period (days)					
	0	3	6	9	12	Mean
0.0	0.00^{h}	0.00^{h}	5.33^{f}	13.67^{c}	20.33^{a}	7.87^{a}
0.2	0.00^{h}	0.00^{h}	0.00^{h}	7.33^{e}	15.83^{b}	4.63^{b}
0.4	0.00^{h}	0.00^{h}	0.00^{h}	4.33^{fg}	13.50^{c}	3.57^{c}
0.6	0.00^{h}	0.00^{h}	0.00^{h}	3.33^{g}	10.83^{d}	2.83^{d}
Mean	0.00^{d}	0.00^{d}	1.33^{c}	7.17^{b}	15.13^{a}	

*Means with same superscript letter are not significantly different

After the 12 days of storage, control showed 20.33% decay incidence, while it was least (10.83%) in 0.6 ppm ozone, followed by 0.4 ppm O_3 concentration (13.50%). At the end of storage, decay incidence was ≈ 47% lower in 0.6 ppm ozone treated fruits of summer squash. Ozone forms oxidative free radicals in the presence of water that penetrate and act on cell membranes of microorganisms. Inactivation of microorganism by ozone is a complex process that attacks various cell membrane and cell wall constituents (*e.g.* unsaturated fats) and cell content constituents (enzymes and nucleic acids). The micro-organisms are killed by cell envelope disruption or disintegration leading to leakage of the cell contents

(Kim *et al*., 4). Higher concentration of ozone reduced the mycelium growth, spore formation and lesion diameter of decay causing microorganisms like gray mould and bacterial soft rot, which are the main decay causing microorganisms in summer squash. Our results are in consent with the Palou *et al*. (7), who reported that ozone at higher concentration reduced the aerial mycelium of moulds.

After ozonation, more than 50% bacterial population was decreased as it was reported initially. At the termination of experiments on 12th day, 0.6 ppm ozone treatment had ≈ 57% less bacterial colonies on fruit surface followed by 0.4 ppm ozone (43.41%) compared to control (Fig. 3). At the final day of storage, the highest yeast and mould population count (5.82 log cfu g^{-1}) was recorded in control fruits, which was without any treatment while it was lowest (3.65 log cfu g^{-1}) in 0.6 ppm ozone treated fruits followed by 0.4 ppm (3.86 log cfu g^{-1}) treated fruits (Fig. 4). At the end of experiment 0.6 ppm treated summer squash fruits had 37.29% less yeast and mould count followed by 0.4 ppm (33.68%) ozone compared to control. Reduction in microbial population by ozone treatment is a complex process in which cell membrane and cell wall constituents like unsaturated fatty acid, enzymes and nucleic acids of microbes are broken by generation of free radicals. Our results are in agreement with the findings of Kim *et al*. (4), who reported that the ozone was more effective against total bacterial population than yeast and mould population.

From the above study, it can be concluded that ozone treatments in the form of ozonated water concentration of 0.4-0.6 ppm proved the best in term of retaining postharvest quality, minimizing decay incidence (> 47%) and extending the shelf life.

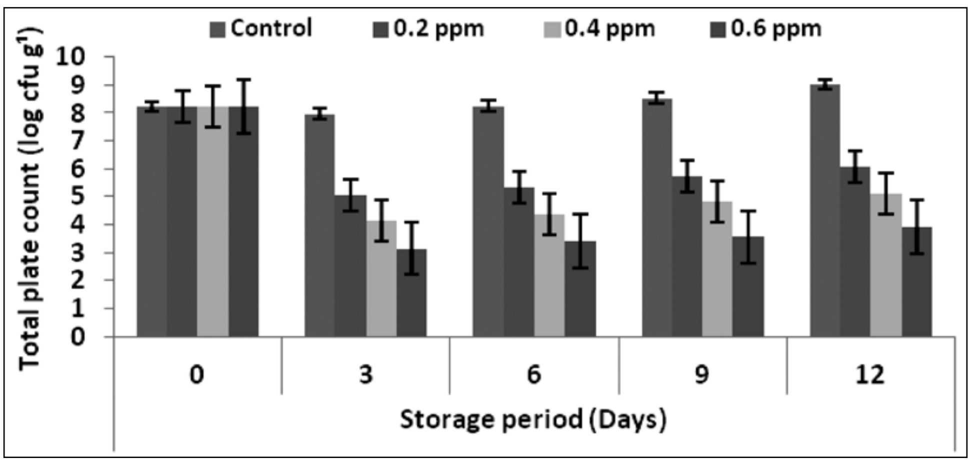

Fig. 3. Impact of ozone treatments on total plate count of summer squash during storage at 8 ± 2°C and 85-90% RH.

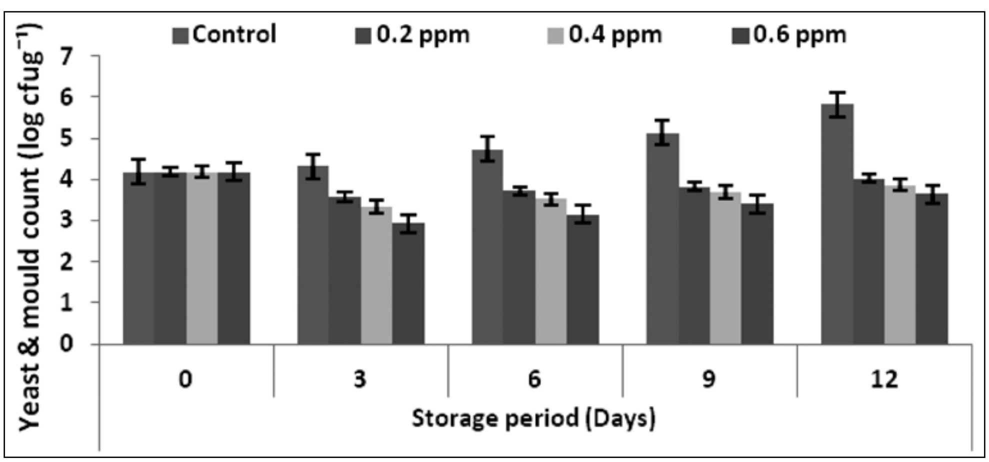

Fig. 4. Impact of ozone treatments on yeast and mould count of summer squash during storage at 8 ± 2°C and 85-90% RH.

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