Effect of post harvest ozone fumigation on storage of onion

Abstract

The storage of commercial onions is essential to meet off-season demands; however, it often results in significant quality degradation and post-harvest losses, including physiological loss in weight , sprouting and rotting. Thus an attempt had been made to test efficacy of ozone fumigation on physical and quality attributes of onion cv. Nasik Red. Onions were fumigated with varying concentrations of ozone in airtight LDPE containers for specific duration followed by 2 hours exposure to atmospheric air to dissipate residual ozone. The treated onions were stored and examined for about 3 months. Among treatments, the onions treated with a lesser ozone concentration (3637.2µl L^{-1} ozone per 10 minutes) demonstrated superior results including significant reduction in physiological loss in weight, sprouting, rotting, black mold incidence with the highest percentage of marketable bulbs. These findings suggest that controlled ozone fumigation, particularly at lower concentration effectively preserve the onions quality during storage, offering promising post harvest management strategy.

Keywords: Ozone, post harvest, fumigation, storage of onion.

Introduction

The Onion (*Allium cepa* L.) is a member of the Alliaceae family, is one of the earliest vegetable crop cultivated and consumed by humankind. Known as the “queen of the kitchen," onion plays an indispensable role in culinary preparations due to their unique ability to enhance food flavour, taste and aroma. Globally, onion are integral to various cuisines, consumed in multiple forms such as raw salads, and cooked vegetables, soups, condiments and spices. Additionally onion serves as a base ingredient for value-added products like powders and flakes. The characteristic pungency of onions, attributed to the volatile compound allyl-propyl disulphide, distinguishes them as a staple in kitchen worldwide. Nutritionally, onions offer significant value, containing 88 % water and providing essential vitamins, minerals, energy, making them a vital dietary component (Obeng-Ofori *et al*., 2007).

India ranks as the second largest producer of onions after China, with cultivated area of 1.62 million hectares and an annual production of 26.64 million tonnes (Anon., 2021). Karnataka is one of the leading onion-producing states in India, contributing significantly to the country's overall production. Onion serves as a critical commercial crop, bolstering the state's agricultural economy. They are cultivated predominantly in the districts of Gadag, Chitradurga, Dharwad, Bijapur and Bagalkot. The strategic importance of onions in Karnataka lies not only in domestic consumption but also in their substantial contribution to the export market, which strengthens the national economy.

Despite their significance, the post-harvest management of onion remains critical challenge. Onions are inherently seasonal, requiring effective storage solutions to ensure their availability during off-season. Post-harvest physiological changes, such as transpiration and respiration, continue in the harvested bulbs, leading to weight loss and deterioration in quality. These processes coupled with environmental factors such as temperature, humidity, results in a decline in key quality parameters, including dry matter content and moisture levels. Such losses directly impact growers and retailers profit margins, necessitating the development of efficient storage technologies.

In Karnataka, the traditional storage practices for onions often involve ambient conditions, which although cost-effective, fail to mitigate physiological loss in weight, sprouting, and microbial decay effectively. Prolonged storage duration exacerbate these issues, making the development of the advanced technologies imperative. Among the emerging techniques, ozone fumigation has garnered attention for its potential to enhance storage duration by suppressing sprouting, rotting and microbial spoilage.

Ozone fumigation, an eco-friendly and non-residual technique, works by oxidizing gas that can have a dual effect by directly damaging microbial cell membranes, enzymes, and nucleic acids while also inducing a defence reaction in the tissues and slowing the biochemical reactions. It has demonstrated to be effective in mitigating spoilage in a variety of horticultural crops. However, its application in onions, particularly under Karnataka climatic and agricultural conditions, remains underexplored.

This study seeks to evaluate the impact of ozone fumigation on key quality parameters and physiological loss in weight (PLW) in onion bulbs stored for prolonged periods.

Materials and Methods

The present investigation was carried at University of Horticultural Sciences, Bagalkot by using Nasik red variety of onion. Post curing onions are subjected to ozone fumigation at varying concentrations in airtight LDPE containers. Following the treatment, the containers were unsealed and bulbs were exposed to atmospheric air for 2 hours to allow the dissipation of residual ozone, minimizing potential hazards during subsequent handling. Then the treated onions were stored in specialized storage structure designed for onions for 3 months and observations were recorded at 30 days interval (Fig. 1).

Treatment details

T_1- Control

T_2 - Ozone 3637.2 µl L^{-1} ozone/10min

T_3 - Ozone 5455.8 µl L^{-1} ozone/15min

T_4 - Ozone 7274.4 µl L^{-1} ozone/20min

T_5 - Ozone 9093.0 µl L^{-1} ozone/25min

T_6 - Ozone 10911.6 µl L^{-1} ozone/30min

Observations recorded

Rotting percentage

The percentage of rotting was calculated by weighing rotten bulbs from batch at particular intervals. The following formula was used to calculate the rotting percentage, which represented the weight of the bulbs that were rotten at 30, 60 and 90 DAS.

$$\text{Rotting percentage (\%)} = \frac{\text{Weight of the rotted bulbs}}{\text{Initial weight of bulbs}} \times 100$$

Incidence of black mould

Black mould, a serious storage disease caused by *Apergillus niger*, was monitored monthly over a period of three months. The prevalence of black mould was quantified and expressed as percentage.

Marketable bulbs

The weight of healthy bulbs was recorded after the separation of the rotted and sprouted bulbs at the end of each storage interval (*i.e.*, 30, 60 and 90 DAS). The recovery of marketable bulbs was calculated using following formula

$$\text{Marketable bulbs (\%)} = \frac{\text{Wight of the healthy bulbs obtained}}{\text{Initial weight of the bulbs}} \text{ x } 100$$

Dry matter

From each treatment, bulbs were chosen at random and chopped into small pieces using a stainless steel knife. A sample with a known weight was dried in a hot air oven at 55°C until a constant weight was attained. The formula below was used to compute the percent dry matter.

$$\text{Per cent dry matter (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

Total phenol content

The Folin Ciocalteau Reagent (FCR) method was used to calculate the sample's total phenol content (Sadasivam and Manickam, 2005). A pestle and mortar was used to crush 0.5 g of fresh tissue in 10 ml of 80 % ethanol. Using filter paper, the solution was filtered, and the filtrate was then allowed to evaporate. 5ml of distilled water are then added to the filter. A test tube holding 0.5 ml of the filtrate was placed into the mixture, which contained 2.5 ml of distilled water, 1 ml of FCR reagent, and 2 ml of sodium carbonate and it was heated in a water bath for 10 minutes. After cooling the test tube's contents, a spectrophotometer reading was taken at 650 nm. The amount of total phenol was calculated and reported in mg GAE per g of fresh weight using a common graph.

Pyruvic acid

The Ketter and Randle (1998) method was used to determine the amount of pyruvic acid present in the sample. A 0.0125 percent DNPH (2,4, Dinitrophenyl hydrazine) solution was created by dissolving 0.1625 g of wet DNPH powder in 1000 ml of 2N HCl. 1 ml of a diluted, filtered homogenate sample and 1 ml of a 0.0125 percent solution of DNPH were mixed in a test tube. After adding 5 ml of 0.6 N NaOH, the test tube was placed in a water bath at 37 °C for 15 minutes. A spectrophotometer set at 420 nm was then used to measure the absorbance. The sample's content of pyruvic acid was determined by applying the following formula to a graph made from standards made by sodium pyruvate.

µmoles of pyruvate/g tissue = µmoles/ml (read from standard curve) × Total dilution.

Results and Discussion

Rotting

In general, the post harvest losses in onions due to rotting were 8 to 12 per cent (Sharma *et al*., 2012). In the current experiment, bulb rotting exhibits a progressive increase at all subsequent storage period of 90 days. The mean per cent rotting was 4.41 per cent at 90 DAS (Table 1). Numerically least rotting was noticed in the treatment T_2 (Ozone 3637.2 µl L^{-1}) (1.59%) was followed by T_4 (Ozone 7274.4 µl L^{-1}) (2.39%) and T_3 (Ozone 5455.8 µl L^{-1}) (2.42%). The least rotting may possibly be due to the fact that the neck of the bulb was completely dried and closed, which helps in reducing the chances of micro-organisms entry into the bulbs and lower order of pathological decay of microorganisms because of anti-microbial property of ozone. Similar findings were observed by Lim *et al*. (2021) and Shelake *et al*. (2022). The maximum rotting was observed in bulbs of T_1 (Control) (5.22%) attributed to latent infection prevailing in bulbs resulting in rotting.

Black mould

Black mould of onions is caused by the fungus *Aspergillus niger*. It is high temperature favouring fungus for its growth and optimum temperature range for growth is 28-34°C. Warmth and moisture favour development of the disease (Maude *et al*. 1984). Although the disease can occasionally be seen in the field at harvest, black mould is primarily a postharvest disease and can cause extensive losses in storage under tropical conditions (Thamizharasi and Narasimham, 1992).

In the present investigation, there was an enhancement in the incidence of black mould during storage of 90 days. The mean values for the disease incidence varies from 0.84 per cent to 3.36 per cent during the experiment (Table 1). The least mean values was recorded for the treatment T_2 (Ozone 3637.2 µl L^{-1}) (1.21%) followed by T_3 (Ozone 5455.8 µl L^{-1}) (1.39%), T_4 (Ozone 7274.4 µl L^{-}1) (1.94%) and T_5 (Ozone 9093.0 µl L^{-1}) (2.22%)(Fig.3). The least incidence of black mould in the treated bulbs might possibly due to disinfectant effect of ozone, which may have eradicated the prevailing microbial population on the bulbs. The decomposition of ozone generates free radicals, mainly reactive oxygen species (ROS) which exhibit potent antimicrobial activity. This antimicrobial activity mainly ascribed to succeeding reaction of the ozone decomposing molecules leading to the inactivation. Similar findings was observed by Lim *et al*. (2021) and Shelake *et al*. (2022) in onion. The maximum incidence of black mould was observed in T_1 (control) (3.43%) this may possibly due to latent infection carried by the bulbs from the field.

Marketable bulbs

Maximum availability of sound and healthy bulbs at the end of the storage period is crucial for a successful sale and to generate a profit. The amount of marketable bulb varies on a variety of factors, including cultivar and pre and post-harvest procedures. In the present investigation the quantity of the mean marketable bulb ranges from 92.37 per cent in the first 30 DAS to 81.28 per cent in the successive 90 DAS (Table 2). The maximum per cent marketable bulbsat the end of storage period was obtained in the treatment T_2 (Ozone 3637.2 µl L^{-1}) (88.58%) followed by T_3(Ozone 5455.8 µl L^{-1}) (87.89%) and T_4 (Ozone 7274.4 µl L^{-}1) (86.89%) (Fig.2).This may be attributed to minimum physiological loss in weight (%), per cent rotting and per cent sprouting in these treatments. These results are in conformity with the findings of Bansal *et al*. (2015).

Minimum per cent marketable bulbs were noticed in the treatment T_5 (Ozone 9093.0 µl L^{-1}) (85.37%) followed by T_1(Control) (85.44%) is mainly because of high rate respiration, moisture loss intern resulting maximum loss in weight, coupled with uncontrolled sprouting and rotting also might have been the possible cause for minimum per cent marketable bulbs (Patil *et al*., 2023).

Dry matter

Dry matter content is the key parameter of onion bulb quality which influences its pungency, stiffness and storage life (Sinclair *et al*., 1995). Onions with high dry matter content tend to be considerably firmer and store for longer periods before shoot growth and disease incidence diminish the quantity of marketable bulbs (Darbyshire and Henry, 1979; Rutherford and Whittle, 1982; Suzuki and Cutliffe, 1989). Dry matter composition varies during storage. The structural carbohydrates in onion comprise the reducing fructose and glucose and non-reducing sucrose and series of oligosaccharides called fructans (Darbyshire, 1978). These carbohydrates contribute for roughly 60 to 80 per cent of dry matter composition (Rutherford and Whittle, 1982).

In the present investigation, mean increase in dry matter content from 15.24 per cent to 18.57 per cent was observed during storage period of 90 days. The mean highest dry matter content was noticed in the treatment T_3 (Ozone 5455.8 µl L^{-1}) (17.33%) followed by T_2 (Ozone 3637.2 µl L^{-1}) (17.28%), T_4 (Ozone 7274.4 µl L^{-1}) (16.91%), T_5 (Ozone9093.0 µl L^{-1}) (16.87%) and T_6 (Ozone 10911.6µl L^{-1}) (16.85%) (Table 2). The increase in dry matter content during the storage period could be attributed to the increase in chemical constituents and also decrease in the moisture content of the bulbs. Reduction in moisture content of the bulb and thereby minimised the hydrolysis of sugar, ultimately resulting in highest dry matter content due to accumulation of more sugar. With the progress of storage, it shows similar pattern of change in dry matter. The results obtained in the present study are in agreement with the result obtained by Chang *et al*. (1987) in onion. The minimum dry matter content was found in T_1 (Control) (16.28%) this may possibly due to higher moisture content found in these bulbs.

Pyruvic acid content

The substances like sugars and organic acids are contributing to the organoleptic taste and add to the distinctive flavour and aroma of onion. Pungency level and total soluble sugars are essential qualitative features of onion bulbs. The ingredients of soluble carbs contribute to onion sweetness (Simon, 1995). Many of such compounds can be chemically quantified. Thus an attempt has been made to estimate the pungency in the present investigation and the results obtained are briefly discussed.

In general, the pyruvic acid content showed decreasing trend as the storage period progressed. The mean value ranges between 8.66 µmoles/g to 7.23 µmoles/g. The mean value of pyruvic acid content is found to be maximum in treatment T_2 (Ozone 3637.2 µl L^{-1}) (8.92 µmoles/g) followed by T_4 (Ozone 7274.4 µl L^{-}1) (8.63 µmoles/g**)** and T_3 (Ozone 5455.8 µl L^{-1}) (8.53 µmoles/g).These results are in conformity with the findings of Aslam *et al*. (2022) and Shelake *et al*.(2022). The minimum pyruvic acid content was observed in T_6 (Ozone 10911.6µl L^{-1}) (6.65 µmoles/g) followed by T_1 (Control) (7.60 µmoles/g) (Table 3).The genetic regulation of flavour in onions is not understood (Ketter and Randle, 1998).

Total phenol content

The chemical composition of the onion varies and relies on cultivar, ripening stage, environment and agronomic circumstances (Hamilton *et al*., 1998; Randle and Bussard, 1993; Randle and Lancaster, 2002). Polyphenols are the natural chemicals in plants that are antioxidants with the ability to protect the body from some ailments. Previous research demonstrated that the main phenolics present in onion are quercetin, gallic acid, ferulic acid and their glycosides (Singh *et al*., 2009; Perez-Gregororio *et al*., 2010). Specifically, onion has been characterized for its flavanol, quercetin and quercetin derivatives (Roldan-Marin *et al*., 2009).

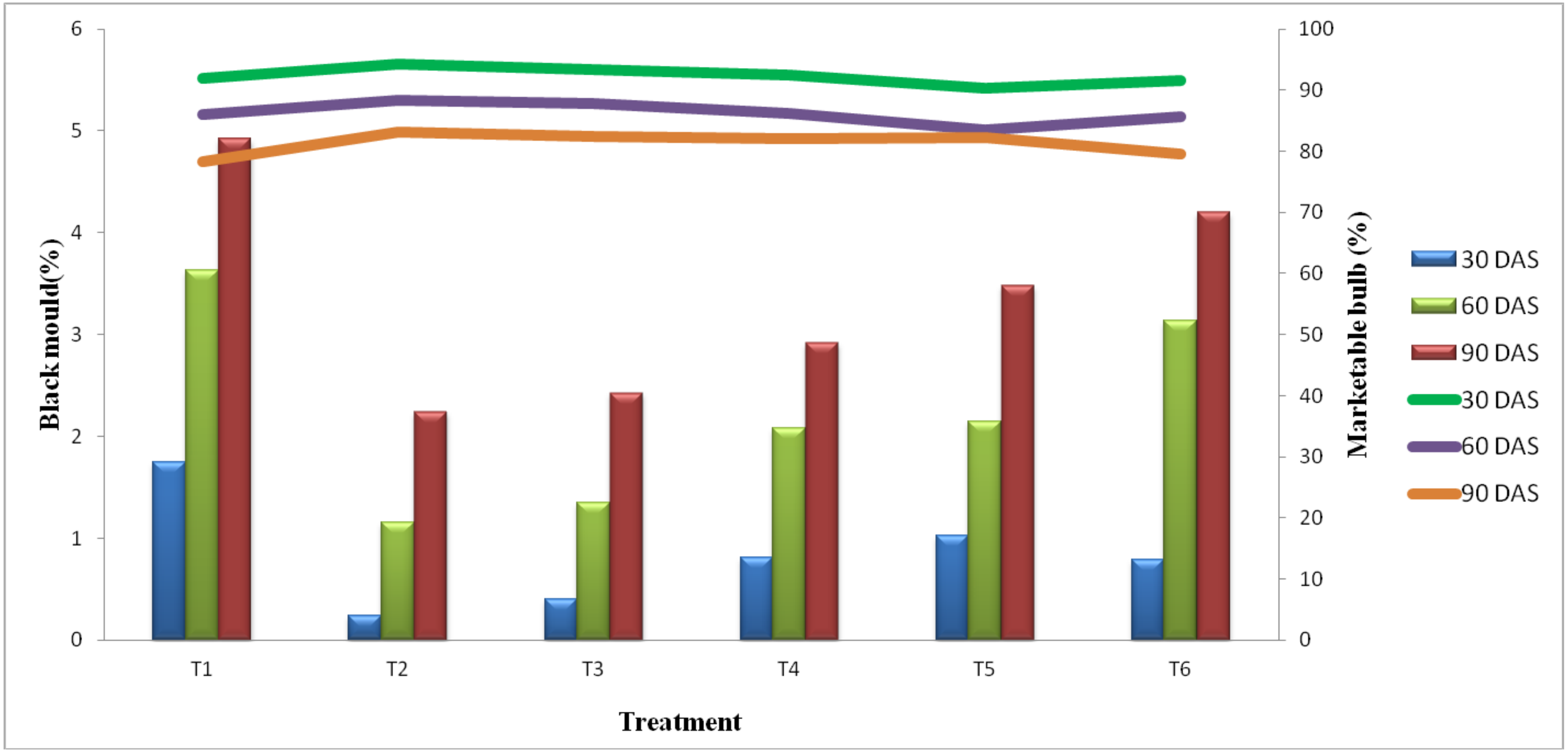
In the present investigation, with advancement in storage period phenolics content decreased gradually in all the treatment. However, relatively less decrease was observed in treatment T_2 (Ozone 3637.2 µl L^{-1}) (11.97 mgGAE/g) followed by T_5 (Ozone 9093.0 µl L^{-1}) (11.68 mgGAE/g) and T_4 (Ozone 7274.4 µl L^{-1}) (11.21 mgGAE/g). Results are in conformity with the findings Han *et al*. (2017). The least TPCwas observed in T_6 (Ozone 10911.6µl L^{-1}) (10.44 mgGAE/g), T_3 (Ozone 5455.8 µl L^{-1}) (10.70 mgGAE/g) followed by T_1 (Control) (10.82 mgGAE/g) (Table 3). The decrease in TPC at the later stage of storage might be due to enzymatic activities and senescence of tissues.

Conclusion

The findings of the study indicate that lower ozone concentrations, particularly treatment T_2 (Ozone: 3637.2 µl L^{-1}), demonstrated superior efficacy in preserving the quality of onion bulbs during a three-month storage period under ambient conditions. This treatment resulted in the lowest physiological loss in weight (PLW), minimal sprouting and rotting, reduced black mould incidence, while maximum percentage of marketable bulbs, enhanced bulb firmness, dry matter content, and pyruvic acid levels compared to other treatments. These results underscore the potential of optimized ozone fumigation as a sustainable and effective post-harvest strategy for improving onion storage outcomes.

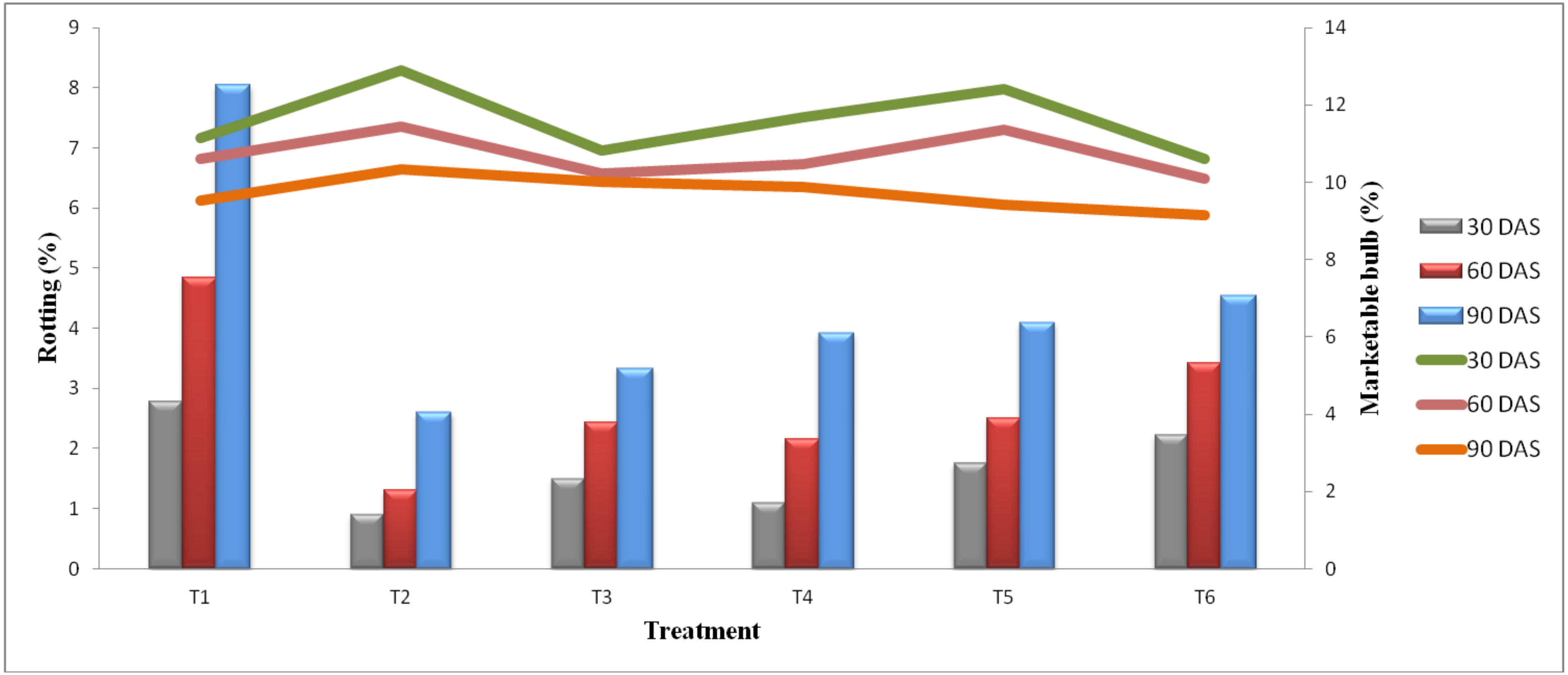
Fig 1: Procedure of Ozone fumigation of onions

Plate 4: Procedure of ozone fumigation of onions



T_1 - Control; **T_2**- Ozone 3637.2 µl L^{-1}; **T_3** - Ozone 5455.8 µl L^{-1}; **T_4** - Ozone 7274.4 µl L^{-1}; **T_5** - Ozone 9093.0 µl L^{-1}; **T_6** - Ozone 10911.6µl L^{-1}

Fig. 2: Effect of post harvest ozone fumigation on black mould (%) and marketable bulbs (%) of onion under ambient conditions (29±1°C and 43±1% RH)



T_1 - Control; **T_2**- Ozone 3637.2 µl L^{-1}; **T_3** - Ozone 5455.8 µl L^{-1}; **T_4** - Ozone 7274.4 µl L^{-1}; **T_5** - Ozone 9093.0 µl L^{-1}; **T_6** - Ozone 10911.6µl L^{-1}

Fig. 3: Effect of post harvest ozone fumigation on rotting (%) and marketable bulb (%) of onion under ambient conditions (29±1°C and 43±1% RH)

Table 1: Effect of post harvest ozone fumigation on rotting (%) and black mould (%) of onion under ambient storage condition (29±1°C and 43±1% RH)

Treatment Details	Rotting (%)			Mean	Black mould(%)			Mean
	Storage days				Storage days			
	30	60	90		30	60	90	
T_1 - Control	2.78	4.84	8.03	**5.22**	1.75	3.63	4.92	**3.43**
T_2- Ozone 3637.2 µl L^{-1}	0.90	1.31	2.58	**1.59**	0.24	1.16	2.24	**1.21**
T_3 - Ozone 5455.8 µl L^{-1}	1.50	2.43	3.32	**2.42**	0.40	1.35	2.43	**1.39**
T_4 - Ozone 7274.4 µl L^{-1}	1.10	2.16	3.91	**2.39**	0.81	2.08	2.92	**1.94**
T_5 - Ozone 9093.0 µl L^{-1}	1.75	2.51	4.08	**2.78**	1.03	2.15	3.48	**2.22**
T_6 - Ozone 10911.6µl L^{-1}	2.22	3.42	4.53	**3.39**	0.79	3.14	4.20	**2.71**
Mean	**1.71**	**2.78**	**4.41**	**2.97**	**0.84**	**2.25**	**3.36**	**2.15**
SEm (±)	0.10	0.13	0.09	0.11	0.07	0.12	0.12	**0.10**
CD@1%	**0.75**	**1.00**	**0.71**	**0.82**	**0.55**	**0.87**	**0.92**	**0.78**

Table 2: Effect of post harvest ozone fumigation on marketable bulb (%) of onion under ambient storage (29±1°C and 43±1% RH)

Treatment Details	Marketable bulb (%)			Mean	Dry matter(%)				Mean
	Storage days				Storage days				
	30	60	90		Initial	30	60	90	
T_1 - Control	92.00	85.95	78.38	**85.44**	14.40	15.54	16.85	18.37	**16.28**
T_2- Ozone 3637.2 µl L^{-1}	94.28	88.33	83.14	**88.58**	15.65	16.72	17.52	19.25	**17.28**
T_3 - Ozone 5455.8 µl L^{-1}	93.39	87.90	82.40	**87.89**	15.82	16.68	17.95	18.88	**17.33**
T_4 - Ozone 7274.4 µl L^{-1}	92.54	86.12	82.02	**86.89**	15.68	16.25	17.13	18.58	**16.91**
T_5 - Ozone 9093.0 µl L^{-1}	90.36	83.51	82.24	**85.37**	15.03	16.48	17.63	18.35	**16.87**
T_6 - Ozone 10911.6µl L^{-1}	91.62	85.64	79.50	**85.58**	14.88	16.57	17.90	18.05	**16.85**
Mean	**92.37**	**86.24**	**81.28**	**86.63**	**15.24**	**16.37**	**17.50**	**18.57**	**16.92**
SEm (±)	0.16	0.15	0.17	**0.16**	0.06	0.03	0.06	0.09	**0.06**
CD@1%	**1.17**	**1.12**	**1.31**	**1.20**	**0.43**	**0.23**	**0.48**	**0.71**	**0.46**

Table 3 : Effect of post harvest ozone fumigation on pyruvic acid (µmoles/g) and total phenol content (mgGAE/g) of onion under ambient storage condition (29±1°C and 43±1% RH)

Treatment Details	Pyruvic acid(µmoles/g)				Mean	Total phenol (mgGAE/g)				Mean
	Storage days					Storage days				
	Initial	30	60	90		Initial	30	60	90	
T_1 - Control	8.30	7.99	7.30	6.82	**7.60**	12.00	11.15	10.60	9.53	**10.82**
T_2- Ozone 3637.2 µl L^{-1}	9.50	9.13	8.90	8.16	**8.92**	13.22	12.90	11.43	10.33	**11.97**
T_3 - Ozone 5455.8 µl L^{-1}	9.10	8.93	8.28	7.83	**8.53**	11.76	10.82	10.23	10.01	**10.70**
T_4 - Ozone 7274.4 µl L^{-1}	9.30	9.12	8.67	7.44	**8.63**	12.80	11.69	10.48	9.88	**11.21**
T_5 - Ozone 9093.0 µl L^{-1}	8.50	8.03	7.54	7.12	**7.79**	13.55	12.41	11.35	9.43	**11.68**
T_6 - Ozone 10911.6µl L^{-1}	7.23	6.95	6.37	6.06	**6.65**	11.92	10.60	10.10	9.15	**10.44**
Mean	**8.66**	**8.36**	**7.84**	**7.23**	**8.02**	**12.54**	**11.65**	**10.69**	**9.72**	**11.15**
SEm (±)	0.12	0.08	0.14	0.08	**0.10**	0.08	0.07	0.06	0.06	**0.07**
CD@1%	**0.88**	**0.59**	**1.05**	**0.57**	**0.77**	**0.63**	**0.58**	**0.45**	**0.47**	**0.53**

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