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Effect of potassium permanganate on postharvest quality attributes of bitter gourd fruit

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Abstract

Bitter gourd is a widely consumed cucurbitaceous vegetable rich in several nutrients and phytochemicals. The fruit is also used in traditional medicine systems to cure a variety of ailments. However, bitter gourd fruit has a very short postharvest life of 3-4 days at ambient conditions, due to which it suffers significant loss after harvest. In the present study, with the aim to extend storage life, bitter gourd fruits were packed in corrugated fiberboard boxes along with sachets of potassium permanganate (KMnO4) granules @ 1.0, 2.0 and 3.0 g per kilogram of fruit; while control fruits were packed without KMnO4 sachets. The results revealed that during 8 days of storage at room temperature, fruits packed with 3.0 g/kg KMnO4 sachets had minimum deterioration in fruit quality compared to control, and also weight loss and decay loss was observed lowest. KMnO4 treated fruit @ 3.0 g/kg retained the highest chlorophyll content and lowest accumulation of carotenoid pigments in the fruit skin. These fruits also had maximum soluble solids, ascorbic acid, total phenolics content, antioxidant capacity and minimum accumulation of malondialdehyde up to 8 days of storage than other treatments.

Keywords: Bitter gourd, potassium permanganate, postharvest, shelf life.

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Introduction

Bitter gourd (*Momordica charantia* L.) is a highly prized tropical cucurbitaceous crop due to its rich nutritive value and health-promoting properties. The immature turgid fruits of bitter gourd are consumed as vegetables. Fruits are good source of carbohydrates (10.6%), proteins (2.9%), vitamins and minerals like iron, calcium, phosphorous, sodium, potassium, zinc, copper, etc. (Upadhyay *et al.* 2015, Behera 2008; Priyadarshi etal. 2021; Mehta *et al.* 2021). Bitter gourd has the highest nutritive value among the cucurbits, particularly iron and ascorbic acid (Behera 2004). Moreover, it has also been used in ancient traditional medicine systems since ages due to its antidiabetic, antimicrobial, antiviral, antioxidant, anti-hepatotoxic, antiulcer and anti-inflammatory properties (Abo *et al.* 2008, Nerurkar *et al.* 2010, Taylor 2002). Bitter gourd fruits are used as a natural remedy for diabetes due to its beneficial effects in reducing glucose level. This glucose level reduction is due to three bioactive compounds: charantin, polypeptide p (plant insulin) and alkaloids. Another compound, oleanolic acid glycoside, has been found to develop glucose tolerance (Mohammady *et al.* 2012). Liver damage has also been prevented with the consumption of fresh bitter gourd juice (Ahmad *et al.* 2016). The fruits of bitter gourd are harvested at the immature tender green stage. Harvesting is done at an interval of 2–3 days, as the fruit matures and ripens quickly (Desai and Musmade 1998). At a fully ripe stage, the fruit changes

color from green to yellow and becomes soft, the seed cavity becomes bright red and the arils become deep red, making it unfit for consumption or marketing (Hamissou *et al.* 2013). Harvested fruits are highly perishable and cannot be stored for more than 3–4 days at ambient conditions. The limited postharvest life of this fruit is due to its climacteric behavior causing rapid upsurge in respiration and ethylene production after maturity, with the onset of ripening (Kays and Hayes 1978). This also causes rapid softening of fruit during their storage. In addition, the presence of thin cuticle layer over the fruit surface causes high moisture loss from the fruit. Furthermore, the uneven exterior surface of the fruit is because of the continuous/discontinuous pattern of tubercles prone to physical injury, which ultimately increases the chances of microbial infection. Bitter gourd's high perishability and delicate nature is a major challenge for long-distance transportation and marketing.

Potassium permanganate ($KMnO_4$) is a stable chemical that acts as an ethylene absorber when placed inside a box containing fruits or vegetables. It oxidizes ethylene into carbon dioxide and water, thereby reducing the undesirable effects of ethylene on produce (Prasad and Kochhar 2014). It has been reported that $KMnO_4$ delays fruit ripening, softening and helps in increasing postharvest life (Akbari and Ebrahimpour 2014). The present study aims to investigate the effect of packaging of bitter gourd fruit with $KMnO_4$ sachets on extending storability and preserving fruit quality during storage at ambient conditions.

Materials and Methods

Bitter gourd fruits were harvested at the marketable maturity stage and brought to the Postharvest Laboratory, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. Thereafter, uniform (maturity, size, color) fruits free from any disease, pest or injury were sorted out for conducting the experiment. This study divided fruits into four uniform lots (5 kg each) and packed in corrugated fiberboard boxes. For the treatments, three boxes consisted of sachets containing $KMnO_4$ granules @ 1.0, 2.0 and 3.0 g/kg fruit while, control fruits were packed without $KMnO_4$ sachets. All the boxes were then stored at room temperature (20°C). During storage, observations on the following physicochemical quality attributes were recorded at every 2 days after storage (DAS):

Weight loss and decay loss

The weight of bitter gourd fruits under different treatments was recorded with electronic balance at 2 days intervals. Fresh weight loss was determined by calculating the difference between initial and final fruit weight (sampling day) and expressed as percent weight loss. Decay loss was recorded by counting the fruit infected with spoilage-causing microorganisms regardless of its severity and expressed as a percent decay loss.

Total chlorophyll and carotenoid content

The fruit's total chlorophyll and carotenoid content were estimated following Arnon (1949) and Roy (1973) methods, respectively. Acetone was used for the extraction of pigments till the tissue became colorless. The samples were centrifuged for chlorophyll estimation and the absorbance was recorded at 645 and 663 nm in a spectrophotometer. For carotenoid estimation, the pigment was separated in petroleum ether and the absorbance of the sample was recorded at 452 nm in a spectrophotometer. Finally, the fruit's total chlorophyll and carotenoid content were calculated as mg/g fresh weight (FW).

Membrane lipid peroxidation and soluble solids content

To determine membrane lipid peroxidation, malondialdehyde content in bitter gourd fruit was estimated using trichloroacetic acid and thiobarbituric acid solutions (Zheng and Tian 2006). After centrifugation, the absorbance of the supernatant was recorded in a spectrophotometer at 450, 532 and 600 nm wavelengths and results were expressed as nmol/g FW. The soluble solids content (SSC) in bitter gourd fruit was estimated using a digital refractometer and results were expressed as a percent.

Ascorbic acid and total phenolics content

Ascorbic acid content was determined by titration method using 2,6-dichlorophenol indophenol dye (Jones and Hughes 1983). The homogenized sample in metaphosphoric acid solution was titrated with dye till the appearance of pink color persisted for 15 seconds. The ascorbic acid content was calculated as mg/100 g FW. The method of Singleton *et al.* (1999) was used for estimation of total phenolics content. The ethanolic sample extract was mixed with Folin-ciocalteu reagent and sodium carbonate solution. The sample was then centrifuged and absorbance was recorded at 760 nm. The results were expressed as gallic acid equivalent (mg GAE/100 g FW).

Antioxidant capacity

Total antioxidant capacity of bitter gourd fruit was determined following the method of Apak *et al.* (2008). The ethanolic sample extract was mixed with copper (II) chloride, neocuproine and ammonium acetate solutions. After the centrifuge, the absorbance of the supernatant was recorded at 450 nm. The results were expressed as trolox equivalent (µmol TE/g FW).

Statistical design and data analysis

The experiment was laid out in a factorial, completely randomized design (CRD), having 4 replications for each treatment. The data were subjected to analysis of variance (ANOVA) with treatments and storage duration as sources of variation. Mean comparisons between treatments were performed using the HSD Tukey's test. Statistical analysis was performed by SAS statistical system 9.2 and differences at $p \leq 0.05$ were considered statistically significant.

Results and Discussion

Fresh weight loss

In the present study, regardless of treatments, bitter gourd fruits showed significant decline in fruit weight with the advancement of storage period (Table 1). However, the weight loss was much higher in control fruit on each sampling day, compared to the treated fruits. Among different ethylene absorbent treatments, fruits packed with $KMnO_4$ granule sachets @ 3.0 g/kg recorded lowest weight loss (16.18%) while, control fruit demonstrated maximum weight loss of 25.85% on the 8th day of storage. On this day, the effect of $KMnO_4$ sachets @ 2.0 and 3.0 g/kg in reducing weight loss of fruit was statistically at par. Rapid weight loss in bitter gourd fruit occurs after harvest owing to morphological factors such as thin cuticle, soft texture and high moisture, resulting in shriveling, loss of turgidity, and consumer acceptability. The prime cause of weight loss is metabolic processes like transpiration and respiration (Luo *et al.* 2011). In this study, a higher concentration of $KMnO_4$ effectively reduced the weight loss of fruit during storage by reducing the harmful effects of ethylene. As a result, delayed senescence and higher fruit firmness also reduced weight loss of fruit. The findings are in accordance with other vegetables like pointed gourd (Bhattacharjee and Dhua 2017a) and sweet pepper (Cerit and Demirkol 2020).

Decay loss

With the ongoing storage period, decay loss of bitter gourd fruit increased (Table 1). Up to 2 days, no decay incidence was noted in treated fruits except the control (1.41% loss). However, 4th day onward, decay incidence was observed in all the $KMnO_4$ treated fruits, but it was minimum (2.13%) in fruits packed with 3.0 g/kg $KMnO_4$ sachets while decay loss was maximum in control (8.58%) fruit. A similar result was also recorded on the last day of storage *i.e.* highest decay loss was in control fruits (27.34%) and the lowest (13.15%) was noted in fruits packed with 3.0 g/kg $KMnO_4$ granule sachets. The surface morphology of bitter gourd fruit such as thin cuticle and uneven skin makes it vulnerable to physical injury during harvesting, transportation and storage. Physical injuries cause effortless invasion of pathogens through the open wound, thereby causing decay. In the present investigation, minimum decay loss in $KMnO_4$-treated fruit might be attributed to the ethylene oxidizing property of $KMnO_4$ which in turn delayed softening of the fruit (Pangaribuan *et al.* 2003). Our findings were also supported by Nath *et al.* (2015) in tomato, Bhattacharjee and Dhua (2017a) in pointed gourd and Bhattacharjee and Dhua (2017b) in bitter gourd.

Total chlorophyll and carotenoid content

Total chlorophyll content in the bitter gourd fruit skin declined irrespective of treatments as the storage duration was prolonged (Table 2). After 8 days of storage, the lowest chlorophyll content was noted in control fruit (7.42 mg/g FW); while, it was maximum (10.53 mg/g FW) in fruits packed with 3.0 g/kg $KMnO_4$ granule sachets. On the contrary, an upsurge in total carotenoids was noted during storage in bitter gourd fruits (Table 2). However, this rise was profound

Table 1: Effect of potassium permanganate granules on weight loss and decay loss of bitter gourd fruit during storage

Treatments	*Weight loss (%)*				*Decay loss (%)*			
	2 DAS	*4 DAS*	*6 DAS*	*8 DAS*	*2 DAS*	*4 DAS*	*6 DAS*	*8 DAS*
Control	5.93 ± 0.14a	12.19 ± 0.49a	17.55 ± 0.39a	25.85 ± 0.44a	1.41 ± 0.49a	8.58 ± 0.56a	15.31 ± 0.81a	27.34 ± 0.79a
$KMnO_4$ (1.0 g/kg fruit)	4.49 ± 0.13b	8.84 ± 0.17b	12.53 ± 0.09b	17.79 ± 0.62b	0.00	6.54 ± 0.32b	9.45 ± 0.45b	19.21 ± 0.85b
$KMnO_4$ (2.0 g/kg fruit)	4.66 ± 0.20b	8.43 ± 0.11bc	12.55 ± 0.25b	17.46 ± 0.34bc	0.00	4.38 ± 0.41c	6.89 ± 0.34c	18.77 ± 0.54b
$KMnO_4$ (3.0 g/kg fruit)	4.29 ± 0.18b	7.66 ± 0.15c	11.86 ± 0.26b	16.18 ± 0.13c	0.00	2.14 ± 0.13d	5.16 ± 0.35d	13.15 ± 0.70c

Values are mean ± standard error of four replicate determinations (n=4). Treatment values followed by the same letters are not significantly different on each sampling day ($p < 0.05$).

Table 2: Effect of potassium permanganate on total chlorophyll and carotenoids content of bitter gourd fruit during storage

Treatments	*Total chlorophyll content (mg/g FW)*				*Total carotenoids content (mg/g FW)*			
	2 DAS	*4 DAS*	*6 DAS*	*8 DAS*	*2 DAS*	*4 DAS*	*6 DAS*	*8 DAS*
Control	14.16 ± 0.38a	12.39 ± 0.44b	9.29 ± 0.38c	7.42 ± 0.34d	0.80 ± 0.02ab	0.98 ± 0.02a	1.13 ± 0.02a	1.31 ± 0.01a
$KMnO_4$ (1.0 g/Kg fruit)	15.13 ± 0.25a	13.92 ± 0.16a	11.37 ± 0.26cb	8.94 ± 0.29c	0.82 ± 0.03a	0.95 ± 0.04ab	0.99 ± 0.02b	1.16 ± 0.04b
$KMnO_4$ (2.0 g/Kg fruit)	15.01 ± 0.36a	14.12 ± 0.43a	11.91 ± 0.15ab	9.38 ± 0.37bc	0.75 ± 0.01bc	0.89 ± 0.02bc	0.96 ± 0.05b	1.13 ± 0.02bc
$KMnO_4$ (3.0 g/Kg fruit)	14.29 ± 0.32a	13.46 ± 0.22a	12.37 ± 0.23a	10.53 ± 0.26a	0.70 ± 0.02c	0.85 ± 0.03c	0.91 ± 0.03b	1.03 ± 0.04c
	Initial reading (day 0): 16.05 ± 0.54 mg/g FW				Initial reading (day 0): 0.63 ± 0.02 mg/g FW			

Values are mean ± standard error of four replicate determinations (n=4). Treatment values followed by the same letters are not significantly different on each sampling day ($p < 0.05$).

in control compared to the treated fruits. At the final day of observation, control fruits (1.31 mg/g FW) showed the highest carotenoids content while fruits stored with 3.0 g/kg $KMnO_4$ sachets was found most effective in limiting the rate of increase in carotenoid pigments (1.04 mg/g FW). The green skin color of bitter gourd fruit indicates its freshness and marketability depends upon its colour. The skin colour changes from green to yellow due tofruit ripening. Chlorophyll imparts green colour to the bitter gourd fruit. During storage, chlorophyll loss occurred due to the chlorophyllase enzyme's activity. Furthermore, being climacteric nature, the fruit produces ethylene which triggers the activity of chlorophyll degrading enzyme. In this study, $KMnO_4$ treatment documented lower chlorophyll degradation owing to its ethylene oxidizing property which delayed ripening, thereby reducing chlorophyllase activity and inhibiting the synthesis of carotenoids (Bhattacharjee and Dhua 2017b). Similar effects of $KMnO_4$ were also reported in other vegetables such as broccoli (DeEll *et al.* 2006) and pointed gourd (Bhattacharjee and Dhua 2017a).

Membrane lipid peroxidation

The malondialdehyde content in bitter gourd fruit showed upward trend with the storage duration (Table 3). Since 2nd day of storage, maximum malondialdehyde accumulation was recorded in control fruit (0.93 nmol/g FW), reaching up to 1.86 nmol/g FW after 8 days of storage. Minimum malondialdehyde accumulation occurred in 3.0 g/kg $KMnO_4$ treated fruit (1.58 nmol/g FW). However, there was no significant difference in malondialdehyde content between 2.0 and 3.0 g/kg $KMnO_4$ treated fruits. Malondialdehyde is produced as a product during membrane lipid peroxidation, which is often used as a marker of oxidative damage and senescence (Ohkawa *et al.* 1979). This oxidative damage is caused by reactive oxidative species (ROS) which initiates the hyper-peroxidation of fatty acids, thus producing free radicals. Furthermore, free radicals damage the cell membrane by initiating the process of lipid peroxidation (Rosahl 1996). In this study, lower membrane lipid peroxidation in $KMnO_4$ treated fruit might be attributed to delayed senescence in treated fruit owing to the oxidation of ethylene.

Soluble solids content

In this investigation, SSC in control fruit increased up to the 4 days of storage, thereafter, it declined whereas, in $KMnO_4$ treated fruits. SSC increased up to 6 days following which it declined (Table 4). After 4 day of storage, maximum SSC was recorded in control fruit (5.32%) while minimum (4.9%) was noted in fruits packed with 3.0 g/kg $KMnO_4$ granule sachets. Thereafter, on 8th day of storage, SSC content in $KMnO_4$ treated and control fruit was noted statistically at par. The initial rise in SSC in bitter gourd fruit might be due to the breakdown of starch into simple sugars due to activity of hydrolytic enzymes. However, the decline in SSC thereafter took place owing to the utilization of sugars in respiratory pathways, which in turn symbolizes fruit senescence. In this study, packing of bitter gourd fruit with potassium permanganate significantly reduced the progressive

Table 3: Effect of potassium permanganate on malondialdehyde content of bitter gourd fruit during storage

Treatments	*Malondialdehyde content (nmol/g FW)*			
	2 DAS	*4 DAS*	*6 DAS*	*8 DAS*
Control	0.93 ± 0.02a	1.17 ± 0.04a	1.58 ± 0.04a	1.86 ± 0.02a
$KMnO_4$ (1.0 g/Kg fruit)	0.85 ± 0.02a	1.17 ± 0.02b	1.40 ± 0.02b	1.80 ± 0.02a
$KMnO_4$ (2.0 g/Kg fruit)	0.79 ± 0.004ab	1.08 ± 0.02b	1.40 ± 0.03b	1.63 ± 0.04b
$KMnO_4$ (3.0 g/Kg fruit)	0.82 ± 0.03b	1.00 ± 0.03b	1.34 ± 0.03b	1.59 ± 0.02b
	Initial reading (day 0): 0.69 ± 0.06 nmol/g FW			

Values are mean ± standard error of four replicate determinations (n=4). Treatment values followed by the same letters are not significantly different on each sampling day ($p < 0.05$).

Table 4: Effect of potassium permanganate on soluble solids and ascorbic acid content of bitter gourd fruit during storage

Treatments	*Soluble solids content (%)*				*Ascorbic acid content (mg/100 g FW)*			
	2 DAS	*4 DAS*	*6 DAS*	*8 DAS*	*2 DAS*	*4 DAS*	*6 DAS*	*8 DAS*
Control	4.15 ± 0.12a	5.32 ± 0.05a	4.92 ± 0.12a	4.47 ± 0.08a	79.18 ± 1.95a	66.09 ± 2.15a	50.75 ± 1.03b	41.03 ± 0.93b
$KMnO_4$ (1.0 g/Kg fruit)	4.00 ± 0.24a	5.05 ± 0.06ab	5.40 ± 0.19a	4.65 ± 0.13a	81.82 ± 2.30a	69.36 ± 0.66a	59.65 ± 2.52a	44.31 ± 1.23ab
$KMnO_4$ (2.0 g/Kg fruit)	4.10 ± 0.11a	5.02 ± 0.14ab	5.20 ± 0.16a	4.77 ± 0.11a	82.35 ± 1.02a	72.35 ± 1.43a	59.19 ± 1.50a	47.09 ± 2.07a
$KMnO_4$ (3.0 g/Kg fruit)	3.92 ± 0.11a	4.87 ± 0.11b	5.22 ± 0.12a	4.92 ± 0.16a	83.26 ± 1.36a	73.26 ± 2.26a	61.98 ± 1.65a	48.22 ± 1.49a
	Initial reading (day 0): 3.55 ± 0.10 %				Initial reading (day 0): 88.99 ± 2.64 mg/100 g FW			

Values are mean ± standard error of four replicate determinations (n=4). Treatment values followed by the same letters are not significantly different on each sampling day ($p < 0.05$).

Table 5: Effect of potassium permanganate on total phenolics content and total antioxidant capacity of bitter gourd fruit during storage

Treatments	*Total phenolics content (µg GAE/g FW)*				*Total antioxidant capacity (µmol TE/g FW)*			
	2 DAS	*4 DAS*	*6 DAS*	*8 DAS*	*2 DAS*	*4 DAS*	*6 DAS*	*8 DAS*
Control	590.50 ± 5.11a	530.00 ± 4.56b	471.50 ± 4.44c	398.00 ± 5.15d	2.33 ± 0.02b	1.76 ± 0.05c	1.39 ± 0.06c	1.13 ± 0.03c
$KMnO_4$ (1.0 g/Kg fruit)	603.75 ± 10.08a	550.00 ± 4.71ab	492.50 ± 3.5bc	418.75 ± 5.54c	2.39 ± 0.03b	1.88 ± 0.03b	1.59 ± 0.10bc	1.14 ± 0.05c
$KMnO_4$ (2.0 g/Kg fruit)	599.25 ± 4.23a	559.25 ± 13.24a	509.50 ± 5.11ab	442.50 ± 6.61b	2.52 ± 0.02a	2.27 ± 0.04a	1.80 ± 0.05ab	1.30 ± 0.04b
$KMnO_4$ (3.0 g/Kg fruit)	608.75 ± 15.60a	562.50 ± 4.79a	525.75 ± 12.20a	468.75 ± 4.27a	2.50 ± 0.05a	2.28 ± 0.02a	1.91 ± 0.06a	1.48 ± 0.06a
	Initial reading (day 0): 645.00 ± 11.90 µg GAE/g FW				Initial reading (day 0): 2.63 ± 0.04 µmol TE/g FW			

Values are mean ± standard error of four replicate determinations (n=4). Treatment values followed by the same letters are not significantly different on each sampling day ($p < 0.05$).

increase in SSC during storage as it reduced undesirable effects of ethylene in fruit, which in turn prohibited sucrose phosphate synthetase enzyme activity. Meanwhile, the respiratory activity of fruit also might have declined. Similar to this finding, tomato treated with $KMnO_4$ also maintained high soluble solids during storage (Kostekli *et al.* 2016, Nath *et al.* 2015, Mujtaba *et al.* 2014 and Salamanca *et al.* 2014).

Ascorbic acid content

Significant difference in ascorbic acid content was not observed up to 4 days of storage between $KMnO_4$ treated and control fruit (Table 4). However, as the duration of storage was prolonged, the ascorbic acid content in control fruit declined sharply from 88.99 to 41.03 mg/100 g FW after 8 days. Similarly, the ascorbic acid content in fruit packed with $KMnO_4$ sachets also decreased, but a minimum decrease in this context was recorded in fruits packed with 3.0 g/kg $KMnO_4$ granule sachets (48.21 mg/100 g FW) after 8 days of storage. Nevertheless, a significant difference in the level of ascorbic acid was not recorded among different $KMnO_4$ treatments. The ascorbic acid content in fruits and vegetables depletes during postharvest storage as it exports electrons to oxidants, neutralizing free radicals (Smimoff 1995). Depletion of ascorbic acid might be due to its utilization as a respiratory substrate in the respiratory pathway during later storage periods. This decline in ascorbic acid becomes more prominent when fruits become over-ripe, concurrently with the enhancement in softening of fruit tissues. Furthermore, role of phenol oxidase and ascorbate oxidase have also been reported in the decomposition of this vitamin during ripening (Seymour *et al.* 2013). In the present study, higher ascorbic acid in $KMnO_4$-treated fruit may be ascribed by limiting the ascorbate oxidase enzyme's activity, which subsequently maintained a higher level of ascorbic acid during storage (Bal 2018). Various other vegetables reported similar pattern after treatment with $KMnO_4$ such as tomato (Nath *et al.* 2015), *Cucumis* (Silva *et al.* 2013) and sweet pepper (Cerit and Demirkol 2020).

Total phenolics content

A downfall in total phenolics content was registered in bitter gourd fruit with the advancement of storage period irrespective of treatments (Table 5). Since the beginning day (day 0), control fruit exhibited maximum downfall in phenolics content from 645.0 to 398.0 µg GAE/g FW on the final day of storage (day 8). On 8th day of storage, 3.0 g/kg $KMnO_4$ granule treatment was found most effective in retaining maximum total phenolics (468.75 µg GAE/g FW), which was followed by 2.0 g/kg $KMnO_4$ treated fruit (442.5 µg GAE/g FW). Different phenolic acids found in bitter gourd fruit are gallic acid, caffeic acid, ferulic acid, chlorogenic acid, catechin and *p*-coumaric acid. Among these, gallic acid is predominant, which is followed by caffeic acid and catechin (Kubola and Siriamornpun 2008). Polyphenol oxidase (PPO) enzyme is associated with the oxidation of phenolics to quinines in the presence of oxygen (Newman *et al.* 2011). Analysis of the present investigation showed that control fruit exhibited lower phenolics content at the final day of storage compared to treated fruit due to rapid degradation. Applying KMnO4 produced inhibitory action against ethylene, probably leading to slower activity of PPO, thereby maintaining higher phenolic compounds in treated fruit compared to the control (Cerit and Demirkol 2020). Likewise, higher phenolics content was also maintained in tomato (Mujtaba *et al.* 2014) and pepper (Cerit and Demirkol 2020) stored with $KMnO_4$.

Total antioxidant capacity

With the progressive increase in the storage period, the antioxidant capacity of bitter gourd fruit decreased gradually (Table 5). Total antioxidant capacity in untreated bitter gourd fruit declined very fast compared to fruit packed with $KMnO_4$ sachets. On the final day of storage (day 8), untreated and fruit packed with 1.0 g/kg $KMnO_4$ sachets registered lowest antioxidant capacity *i.e.* 1.13 and 1.14 µmol TE/g FW, respectively. On the same day, bitter gourd fruit packed with 3.0 g/kg $KMnO_4$ granule sachets registered maximum antioxidant capacity (1.48 µmol TE/g FW). One of the most common changes that occur during senescence is oxidative damage because of reactive oxidative species (ROS), resulting in deterioration of produce quality. These ROS initiate the peroxidation of polyunsaturated fatty acids, resulting in cellular injuries. Several bioactive compounds in bitter gourd fruit have been reported, including

alkaloids, glycosides, phenolic compounds, flavonoids, and carotenoids, which exhibit antioxidant capacity (Lee *et al.* 2017). The results indicated that $KMnO_4$ treated fruit maintained higher antioxidant potential with respect to control. The increasing trend of antioxidant capacity in $KMnO_4$ treated fruit might be associated with the higher accumulation of phenolic compounds and delaying the subsequent senescence after storage (Mir *et al.* 2018). Pepper (Cerit and Demirkol 2020) stored with $KMnO_4$ were also reported to maintain higher antioxidant values during the entire period of storage compared to the control.

Conclusion

In conclusion, packing of bitter gourd fruit in corrugated fiberboard boxes along with $KMnO_4$ granule sachets @ 3.0 g/kg fruit proved beneficial in extending storability and preserving the quality of bitter gourd fruit after harvest. The finding has the potential to store bitter gourd fruit up to 8 days at room temperature. The study may benefit both the farmers and the vendors for long-distance transport and extended marketability of bitter gourd fruit.

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सारांश

करेला कुकुरबिटेसी कुल की लोकप्रिय सब्जी है। विभिन्न औषधीय और स्वास्थ्य वर्धक गुणों के कारण इसका उपयोग परम्परागत औषधियों में भी होता है। करेला का सामान्य तापक्रम पर भण्डारण अवधि बहुत कम होती है। इसमें तुड़ाई उपरान्त क्षय जल्दी होता है जिससे उत्पादकों को आर्थिक हानि तो होती ही है, साथ ही उच्च पोषण और गुणवत्ता से भरपूर करेले का उचित उपयोग भी नही हो पाता है। इस अध्ययन में भण्डारण अवधि को बढ़ाने के लक्ष्य से करेले को सी.एफ.बी. डिब्बों में इथीलीन अवशोषक पोटैशियम परमैंगनेट की पोटली (क्रमशः 1, 2 व 3 ग्राम/किग्रा.) के साथ रखा गया। अनुपचारित करेले को बिना किसी इथीलीन अवशोषक के पोटली में रखा गया। परिणामों से स्पष्ट हुआ कि 8 दिनों की सामान्य भण्डारण अवस्था में करेला जो 3 ग्राम/किग्रा. इथीलीन अवशोषक के साथ पैक किये गये, अन्य उपचारों और अनुपचारित की तुलना में अच्छी अवस्था में पाया गया। भार में कमी और क्षति भी इसमें कम पायी गयी। इस उपचार से फलों में अधिक क्लोरोफिल और न्यूनतम कैरोटीनॉइड देखी गयी। विटामिन 'सी', फिनोलिक्स, कुल विलेय ठोस पदार्थ और एंटी ऑक्सीडेन्ट क्षमता इन फलों में अधिक पायी गयी।