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Quality improvement and shelf life extension of minimally fresh-cut mango fruit using chemical preservatives

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ABSTRACT

Purpose: Mango is an invaluable and climacteric fruit with a short shelf life. Minimally fresh-cut mango fruit market is growing very fast, particularly in Europe and the United States, and recently in Asian countries and the Middle East. Consumers demand high quality in fresh-cut fruit. **Research method:** Effect of different post-cutting chemical treatments including calcium chloride ($CaCl_2$), ascorbic acid (AA), salicylic acid (SA), oxalic acid (OA) and citric acid (CA) on the quality maintenance and extending the shelf life of fresh-cut were evaluated. Treated slices were placed into the Polypropylene (PP) containers with lids (Passive MAP) and stored at 4±1 °C for two weeks. **Findings:** The results showed that the highest firmness (7.01 N) was recorded in $CaCl_2$ treated fresh-cut mangoes at the end of storage. The TSS significantly was lower in all treated fresh-cuts compared to the control. Besides, treated mango slices with AA, SA, and OA had a higher antioxidant activity than other treatments and control. Interestingly, mango slices that were treated with $CaCl_2$ had a higher texture (4.33) value compared to the control and other treatments. The AA and $CaCl_2$ treatments maintained the fresh-cut taste compared to the control and other chemical treatments after 14 days of cold storage. The highest shelf life was observed in $CaCl_2$ (17.5 days) and SA (17.0 days) treatments. The hue values were best maintained in OA and CA treatments. Moreover, the total aerobic mesophilic bacterial and fungal counts remained below detection limits at the end of storage. **Limitations:** No limitations were found to report. **Originality/Value:** In conclusion, $CaCl_2$, AA and SA were better treatments for fresh-cut mangoes because higher acceptability and sensorial quality and also longer shelf life.

INTRODUCTION

Minimally processed ready-to-eat fresh-cut fruits have been one of the fastest-growing segments of the food industry in European markets, and also in Asia and the Middle East countries (Huynh & Nguyen, 2020; Moradinezhad et al., 2020). Among different fruits, mango (*Mangifera indica* L.) is an invaluable tropical fruit and suitable for the ready-to-eat market. This is mainly due to their unique taste, aroma, and nutritional value high Vitamin C, β-carotene and mineral content (Tharanathan et al., 2006). Fresh-cut mangoes are processed as either diced chunks or sliced and packaged in polypropylene or polystyrene plastic containers under cold storage in some countries.

Mangos are climacteric fruits, and can undergo the normal ripening process after harvest (Kays, 1991). During ripening, significant changes in mango quality attributes can be categorized into three groups, textural changes, changes in pigmentation, and flavor (Kays, 1991). Textural changes are more important during mango ripening process result in fruit softening, which influence the eating quality and shelf life of the fruit.

Consumers demand high quality in fresh-cut fruit mangoes; however, there is a limitation to the shelf life of fresh-cut mangoes due to their perishability, which leads to tissue softening, browning, and flavor loss (Siddiq et al., 2013). Post-cutting life of fresh-cut mango is short about eight days at cold storage (Çandır, 2017). The shelf life of fresh-cut mango slices is also different in mango cultivars to some extent. For example, the shelf life is about 10 days for Tommy Atkins (Souza et al., 2005), and six days for Kent mangoes (Dea et al., 2010).

Besides, customer acceptance and spoilage associated with microbial contamination are essential issues in the fresh-cut industry. Hence, several studies on fresh-cut mango have been focused on the application of texture firming, anti-microbial agents, and also anti-browning treatments (Siddiq et al., 2013) to prolong the shelf life of fresh-cut mango. Cut fruits are exposed to environmental microbes in the processing facility. Reducing the contamination will be dependent on the use of the appropriate disinfectants and sanitizers. The high use of chlorine as a disinfectant is of great concern and is presently prohibited in some European countries due to issues of public health (Meireles et al., 2016). At the present time, alternative technologies for safety, improved quality of fresh-cut products have been developed. One of these technologies is application of organic acids and calcium salts for maintenance of firmness, and inhibition of enzymatic and non-enzymatic browning as well as in the prevention of microbial growth of fresh-cut products (Jideani et al., 2017).

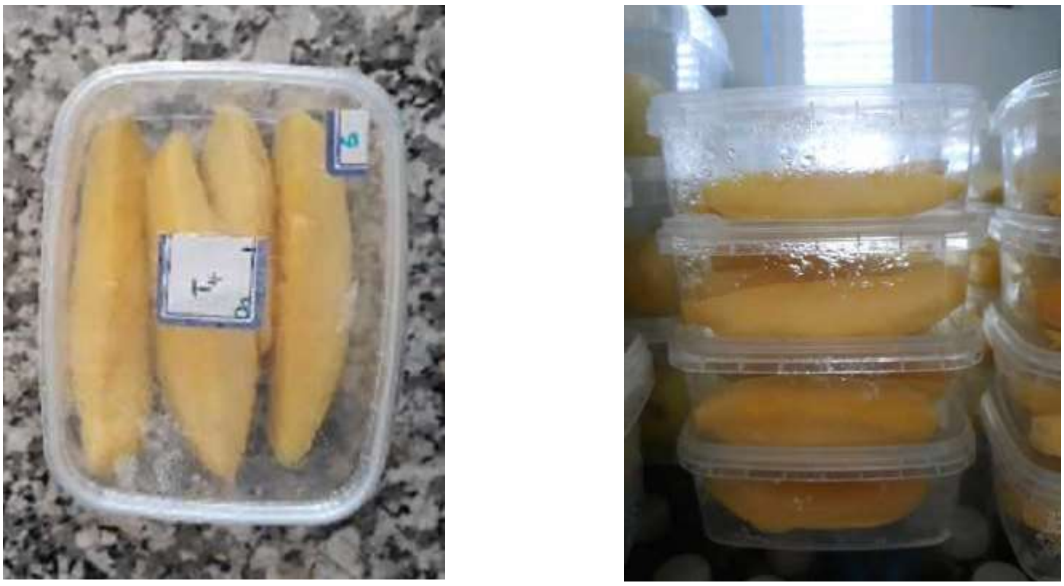
Post-cutting treatments can be used to slow the rate of softening or browning. Review of literature shows that the use of anti-softening chemical dips, anti-browning, and modified atmosphere packaging significantly extended the post-cutting life of fresh-cut fruits, including mango (Kader, 2008; Suttirak & Manurakchinakorn, 2011; Ngamchuachit et al., 2014). Also, previous studies indicated that antioxidants treatment inhibits color darkening in fresh-cut mangoes (Plotto et al., 2004; Robles-Sánchez et al., 2009; Siddiq et al., 2013). Recently, natural compounds with bioactive attributes such as citric acid, ascorbic acid, oxalic acid, and lactic acid are usually applied as a dip not only as anti-browning but also to prolong the shelf life of fresh-cut fruits (Ghidelli & Pérez-Gago, 2018). These are also antimicrobial agents against microorganisms (Bari et al., 2005; Velderrain-Rodríguez et al., 2015).

Nowadays, very few techniques are available in Iran to prolong the shelf life of fresh-cut mangoes. Moreover, no information is available regarding the effect of chemical treatments on the quality and postharvest life of fresh-cut mangoes cv. Sindhri, which cultivated in the southern areas of Iran. The objectives of this study, therefore, were to evaluate the effect of different post-cutting chemical treatments as antioxidants, antimicrobials, and firming agents including calcium chloride ($CaCl_2$), ascorbic acid (AA), salicylic acid (SA), oxalic acid (OA) and citric acid (CA) on the quality maintenance and to prolong the shelf life of fresh-cut mango cv. Sindhri packaged in polypropylene (PP) containers in refrigerated storage conditions to introduce a new product in the market using proper postharvest treatments and also to reduce postharvest losses of this valuable fruit in Iran.

MATERIALS AND METHODS

Fruit preparation and treatments

Sixty mature green Sindhri mangoes (260-310 g) were harvested from a commercial orchard in Minab, Hormozgan province, Iran early in June 2018. The fruit was transported to the Postharvest Lab of the University of Birjand, Iran, on the same day. They were acquired next day. Damaged and defective fruits were eliminated. Selected fruits were then immersed in 100 ppm sodium hypochlorite for 3 min for surface disinfection. All cutting equipment like knives and cutting boards were immersed in a 200 ppm NaOCl solution to disinfection. The 60 selected mangos were completely peeled, and were then sliced from stem end to blossom end into four slabs. Treatments were dipping fresh-cut mango slices in different chemical solutions including 1% ($w.v^{-1}$) calcium chloride, 1% ($w.v^{-1}$) ascorbic acid, 1 $Mm.L^{-1}$ salicylic acid, 1% ($w.v^{-1}$) oxalic acid, and 1% ($w.v^{-1}$) citric acid for 3 minutes. Control slices were immersed in distilled water. Treated slices were then transferred to the Polypropylene (PP) containers with lids (TEB Plastic, Science-based Co., Iran) of 160 ml volume and the 0.5 mm thickness and stored at 4±1 °C (Fig. 1). Physico-chemical, sensorial quality and microbiological attributes of treated fresh-cut mangoes were determined after two weeks of cold storage.



a b

Fig. 1. Treated mango slices that were packed in polypropylene (PP) containers (a), and stored at 4±1 °C (b).

Physico-chemical assessments

Firmness

Fruit firmness was measured using a digital penetrometer (FHT 200, Extech Co., USA) and data showed as Newton.

Total soluble solid (TSS)

TSS in the extracted juice of each slab (one center section) was measured by a hand-held refractometer (RF 10, °Brix, 0–32%, Extech Co., USA).

Titratable acidity (TA)

To measure titratable acidity, 5 ml of extracted fruit juice (one center section) was titrated with 0.1 N sodium hydroxide. The TA was calculated as a percentage of citric acid.

Determination of total phenolic content

The total phenolic content of juice was determined by the Folin-Cicoalteu method at a wavelength of 725 nm and expressed as a percentage of Gallic acid (Chuah et al., 2008).

Determination of total antioxidant capacity

The antioxidant activity of juice was measured using the DPPH method base on the evaluation of the free radical scavenging capacities of juices as described by Turkmen et al. (2005).

Color attributes

Flesh color was evaluated in two different positions on each slab. The color was determined in terms of L^*, a^* and b^* values using a colormeter (TES-135 A, Taiwan). The chroma was obtained with the following equation (1):

$$\text{Chroma} = \sqrt{a^2 + b^2} \quad (1)$$

The hue angle is defined as follows (2):

$$\text{Hue angle(h)} = \tan^{-1}(b/a) \quad (2)$$

Sensorial quality

Sensory evaluation of samples was done by a panel of eight trained members, based on a 5-point hedonic scale on the twentieth day of cold storage. All the treatments were randomized at room temperature and panelists rated the texture, taste, visual appearance, and overall acceptability of fresh-cut mango slices on a five-point scale, 1= the extremely bad, and 5 = extremely good (2.5 and higher = acceptable) as described by Moradinezhad et al. (2018). The trained panelists evaluated the fresh-cut mango slices at room temperature (24°C).

Shelf life

Shelf life was determined based on the length of time (day) from the packaging of fresh-cut mango slices up to the time the slices become unacceptable in terms of appearance, microbial, and sensorial quality attributes.

Microbial quality

All samples were analyzed for numbers of aerobic mesophilic bacteria, yeasts and molds after two weeks of storage at 4 ± 1 °C. To determine the microbial load of samples, ten grams of each sample were used, as described by Caleb et al. (2013) method. To enumerate microbial load, 1.0 mL of each dilution was pour-plated in triplicate onto appropriate media, Plate Count Agar (01–161, Scharlau, Barcelona, Spain), (PCA) for aerobic mesophilic bacteria, and Potato Dextrose Agar (PDA) (01-483, Scharlau, Barcelona, Spain) for yeast and molds. Plates for aerobic mesophilic bacteria were incubated at 37 °C for 48 h and 25 °C for 72-120 h for yeast and molds.

Statistical analysis

The experiment design was a Completely Randomized Design (CRD) with six treatments and in four replications. The recorded data were subjected to analysis of variance (ANOVA) using the GenStat program (version 12, 2010, VSN International, Ltd., UK). LSD test at a 5% level of probability ($P \leq 0.05$) was used to compare of means of different treatments.

RESULTS AND DISCUSSION

Firmness

Firmness significantly increased in all treatments compared to the control, except treated fruit with OA. The highest firmness (7.01 N) was recorded in $CaCl_2$ treated fresh-cut mangoes (Table 1), which was two-fold more than control (3.25 N). Chantanawarangoon and Kader (2000) stated that $CaCl_2$ (1%) dip maintained firmness of fresh-cut mango cubes and extending their post-cutting life compared with the control. AA, $CaCl_2$ and CA were shown to inhibit loss of firmness in fresh-cut apples at cold storage for 5–10 days (Chiabrando & Giacalone, 2012). The AA, CA and $CaCl_2$ were found to be the best treatments to maintain firmness and color of fresh-cut Tommy Atkins mangoes stored at cold storage for 12 weeks (Siddiq et al., 2013).

TSS and TA

The TSS significantly was lower in all treated fresh cuts compared to the control (Table 1). The fact that chemical dip treatments presented lower TSS than control suggests the efficacy of these chemicals in the reduction of respiration rate and also the ripening process in treated fresh-cut mango slices. Similarly, Bico et al. (2009) stated higher TSS in control than dip treatment at the end of storage on the fresh-cut banana. Chemical treatments had no significant effect on the TA of fresh-cut mangoes, except CA treated samples that significantly reduced TA compared to the control (Table 1). Reduced respiration rate may be reflected in lower changes in TA and TSS (Olivas & Barbosa-Cánovas, 2005).

Total phenol content

Total phenol content of fresh-cut mango slices did not affect by dipping treatments (Table 1).

Antioxidant activity

Antioxidants significantly increased in all treatments compared to the control (Table 1). However, treated fresh-cut mangoes with AA, SA, and OA had a higher antioxidant activity than other treatments and control. Robles-Sánchez et al. (2009) found that AA combined with CA or $CaCl_2$ dip promoted significant increases in antioxidant activity of fresh-cut Kent mangoes kept at cold storage. Also, Salinas-Roca et al. (2018) indicated that edible coated mango slices with $CaCl_2$, malic acid, and alginate individually or in combination treatment resulted in higher antioxidant capacity at the end of the storage. Similarly, Cefola et al. (2014) reported that AA dipping increased antioxidant capacity in nectarine. Our results are in agreement with the findings of the studies as mentioned earlier.

Color

Chemical dipping treatments did not effect on *L**, *a**, *b**, and chroma values of fresh-cut slices (Table 2). However, chemical treatments significantly affected the hue value of fresh-cut mangoes. The hue value represents true color, and the hue values for mango slices are presented in Table 2. The highest hue values were obtained in OA and CA treatments compared to control. The lower hue values in other treatments and control samples indicating surface browning occurred during storage. This indicates that OA and CA are effective anti-browning inhibitors for mango slices. Pace et al. (2020) reported that OA and CA dipping treatments preserved the quality of fresh-cut lettuce, and the hue values were higher than control. Besides, the AA, $CaCl_2$, and CA were shown to inhibit color deterioration in apple cubes kept at cold storage for 5–10 days (Chiabrando & Giacalone 2012). Pear slices that were dipped in a solution of Ca additives such as $CaCl_2$, Ca ascorbate, Ca lactate and Ca propionate had better color than the control (Gomes et al., 2010). Treated fresh-cut apples with different chemicals showed that 1% OA had the highest inhibitory activity on browning, followed by 1% CA and 1% AA, respectively (Son et al., 2001). On the contrary, no difference was observed among 1% AA, 1% CA, and 1% OA treatments in terms of banana slices color (Apintanapong et al., 2007).

Table 1. Effect of post-cutting treatments on physico-chemical properties of fresh-cut mangoes slices after 2 weeks of storage at 4 ± 1 °C

Post-cutting treatment	Firmness (N)	TSS (ºBrix)	TA (%)	Total Phenols (mg Gallic acid.100 g^{-1} FW)	Antioxidant activity (%)
Control	3.25c	15.67a	4.08a	63.66a	84.0d
$CaCl_2$ (1%)	7.01a	13.33b	5.01a	63.27a	91.01c
Ascorbic acid (1%)	5.77ab	11.67c	5.06a	63.49a	97.49a
Salicylic acid (1 mM)	5.53b	11.33c	4.85a	63.45a	95.19ab
Oxalic acid (1%)	3.15c	11.67c	4.49ab	63.98a	96.05ab
Citric acid (1%)	5.20b	12.0c	3.98b	63.61a	93.48bc
SE	0.64	0.54	0.27	0.13	1.31

In each column, similar letters indicates no significant difference at 5% level of probability using LSD.

Table 2. Effect of post-cutting treatments on color attributes of fresh-cut mangoes slices after 2 weeks of storage at 4 ± 1 °C

Post-cutting treatment	*L**	*a**	*b**	Chroma	Hue°
Control	23.0a	8.02a	6.6a	10.38a	39.35bc
$CaCl_2$ (1%)	26.0a	4.5a	4.4a	6.25a	44.12b
Ascorbic acid (1%)	21.7a	6.63a	3.6a	7.54a	28.36c
Salicylic acid (1 mM)	25.9a	9.30a	6.7a	11.46a	35.75bc
Oxalic acid (1%)	26.4a	3.58a	5.3a	6.39a	55.95a
Citric acid (1%)	26.4a	6.07a	10.8a	12.38a	60.53a
SE	4.12	3.3	7.8	5.2	10.2

In each column, similar letters indicates no significant difference at 5% level of probability using LSD.

Table 3. Effect of post-cutting treatments on sensorial attributes and shelf life of fresh-cut mangoes slices stored at 4 ± 1 °C

Post-cutting treatment	Texture	Taste	Appearance	Overall acceptability	Shelf life (Day)
Control	2.6bc	2.33bcd	1.67d	2.20b	9.3c
$CaCl_2$ (1%)	4.33a	3.0b	3.33b	3.52a	17.5a
Ascorbic acid (1%)	3.0b	4.33a	4.67a	4.0a	14.3b
Salicylic acid (1 mM)	2.67bc	2.67bc	5.0a	3.55a	17.0a
Oxalic acid (1%)	2.0cd	2.0cd	2.33cd	2.14b	13.3b
Citric acid (1%)	1.67d	1.67d	3.0bc	2.10b	15.0b
SE	0.37	0.38	0.84	0.76	1.01

In each column, similar letters indicates no significant difference at 5% level of probability using LSD.

Sensorial quality

Quality considerations in the fresh-cut fruit industry are mainly based on appearance like surface color, and visible microbial growth, which highly likely affecting consumer decision of purchasing the product, and the texture and flavor properties will influence the evaluation of the consumer during consumption.

$CaCl_2$ significantly preserved texture quality of fresh-cut fruit compared to the control (Table 3). Fresh cut mangoes treated with $CaCl_2$ had a higher texture (4.33) value compared to the control and other treatments. Ngamchuachit et al. (2014) suggested $CaCl_2$ dip treatment for Tommy Atkins and Kent mango cubes to retain quality and consumer acceptance during nine days of cold storage. Alandes et al. (2009) have reported that Ca lactate treatment improved the texture of fresh-cut pears during three weeks of cold storage.

The highest taste (4.33) of treated fresh-cut mangoes was found in AA treatment, followed by $CaCl_2$ (3.0) (Table 3). AA and $CaCl_2$ maintained the fresh-cut mango taste compared to the control and other chemical treatments after 14 days of cold storage. The appearance quality of treated fresh-cut mangoes significantly increased in all treatments compared to the control, but OA treatment. The highest appearance quality was obtained in SA (5.0), followed by AA (4.67). Overall acceptability was higher in AA (4.0), SA (3.55), and $CaCl_2$ (3.50) compared to the control and other chemical treatments.

AA and Ca propionate treatments effectively maintained quality and inhibit browning of fresh-cut apple slices for five weeks during cold storage with no microbial growth (Buta et al., 1999). $CaCl_2$ and AA treatments improve the taste, firmness, and also reduce the browning in fresh-cut pineapple (Latifah et al., 2010).

Shelf life

The shelf life of fresh-cut mangoes significantly affected by chemical dipping treatment compared to the control (Table 3). The highest shelf life was observed in $CaCl_2$ (17.53 days) and SA (17.0 days) treatments, which was approximately doubled compared to the control (9.0 days) at 4 °C. In agreement with our results, the AA dip treatment significantly extended shelf life of the pear slices (Gorny et al., 2002) and pomegranate arils (Moradinezhad et al., 2020). Besides, in treated Keitt mango cubes that were dipped in CA (0.5%, $w.v^{-1}$), and AA (0.5%, $w.v^{-1}$), and packed in MAP retained quality attributes longer than the control samples (Liguori et al., 2018).

Fig. 2. Effect of post-cutting dip solutions on the growth of microorganisms on the fresh-cut mango slices after 2 weeks of storage at 4 ± 1 °C

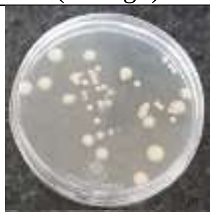
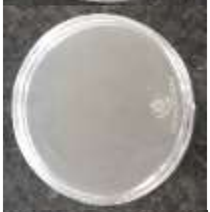
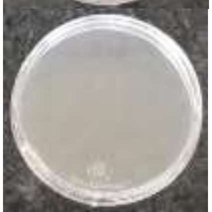
Post-cutting treatments	Total aerobic mesophilic bacterial (CFU.g^{-1})	Yeast and mold growth (CFU.g^{-1})
Control		
$CaCl_2$ (1%)		
Ascorbic acid (1%)		
Salicylic acid (1 mM)		
Oxalic acid (1%)		
Citric acid (1%)		

Table 4. Effect of post-cutting treatments on the growth of aerobic mesophilic bacteria, yeast and mold in fresh-cut mangoes slices after 2 weeks of storage at 4 ± 1 °C

Post-cutting treatments	Total aerobic mesophilic bacterial (CFU.g^{-1})	Yeast and mold (CFU.g^{-1})
Control	3.5×10^2	2.5×10^2
$CaCl_2$ (1%)	3×10^3	5×10^3
Ascorbic acid (1%)	5×10^2	5×10^2
Salicylic acid (1 mM)	<100	<100
Oxalic acid (1%)	4×10^3	4×10^3
Citric acid (1%)	4×10^2	4×10^2

In each column, similar letters indicates no significant difference at 5% level of probability using LSD.

Microbial quality

Dipping in chemical treatments reduced the numbers of aerobic mesophilic bacteria, yeasts and molds of fresh-cut mangoes (Table 4). The influence of different chemical treatments on the growth of aerobic mesophilic bacteria, yeast and mold populations after 14 days of storage at 4 ± 1 °C are shown in Figure 2. As can be seen, the lowest aerobic mesophilic bacteria count (<100 log $CFU.g^{-1}$), and mold growth (<100 log $CFU.g^{-1}$) were observed at SA treated fresh-cut mango slices (Table 4). However, no significant differences were found at the end of the storage time among the treatments. The total aerobic mesophilic bacterial and fungal counts remained below detection limits until day 14 of cold storage in all treatments and ranged from <100 to 5×10^3 log $CFU.g^{-1}$. The critical limits for important spoilage microorganisms is 10^8 $CFU.g^{-1}$ for aerobic mesophilic bacteria in fresh-cuts, and the critical limit for yeasts and molds is 10^6 $CFU.g^{-1}$ (Jacxsens et al., 2002). So, both of them were not exceeded at the end of cold storage. Compared to AA and glutathione, CA treatment at 1.5% significantly inhibited the growth of microorganisms in fresh-cut mangoes cv. 'Nam Dok Mai' as indicated by total plate count (Techavuthiporn & Boonyaritthonghai, 2016). It has been proved that one effective way of limiting microbial growth is to increase the acidity of a food by adding an acidifier. Organic acids traditionally applied in food industry, since pH reduction has a great impact on the growth and survival of different microorganisms, particularly bacteria. Similarly, calcium solution dip for one min maintained firmness, acceptable flavor, and microbial quality in fresh-cut melons kept at cold storage for 10 days under a passive MAP (Silveira et al., 2011). The result of the current study is in agreement with the findings of Silveira et al. (2011) on the fresh-cut of melon.

CONCLUSION

This study indicates that post-cutting chemical treatments of fresh-cut mango slices with $CaCl_2$, AA, and SA preserved the firmness, antioxidant activity, taste, and overall sensorial quality attributes of fresh-cut mango slices compared to the control after two weeks of cold storage with non-significant microbial load. However, the hue was best maintained in OA and CA treatments. Therefore, $CaCl_2$ (1%), AA (1%) and SA (1 mM) chemical treatments are recommendable for further studies on fresh-cut mango slices as they are also able to extend the shelf life of fresh-cut mangoes at cold storage condition.

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