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ORIGINAL RESEARCH

Impact of carboxymethyl cellulose based edible coating on storage life and quality of guava fruit cv. 'Allahabad Safeda' under ambient storage conditions

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Abstract
Edible coatings form a semi-permeable membrane film which retards the ripening and senescence. In this sight an research was investigated to study the effects of different concentrations of carboxymethyl cellulose (CMC; 1.0, 1.5 and 2.0 g L^{-1}) on the storage life and quality of guava fruit cv. 'Allahabad Safeda' under ambient storage conditions (24 ± 1 °C and 65 ± 5% RH) for up to 12 days. Determination of weight loss, decay, firmness, sugars; soluble solids content (SSC), reducing sugars (RS) and total sugars (TS), titratable acidity, ascorbic acid content, total phenol content and sensory attributes was done. Fruit coated with CMC (1.5 g L^{-1}) significantly showed reduced weight loss (3.95%) and decay (8.33%) besides maintaining higher firmness (41.68 N), sugars (SSC, RS and TSS; 11.32%, 2.98% and 7.79% respectively), titratable acidity (0.40%), ascorbic acid content (216.11 mg 100 g^{-1} pulp), total phenol content (113.90 mg 100 g^{-1} pulp) and sensory attributes (7.81) compared with control. Overall, coating with CMC (1.5 g L^{-1}) significantly extended the storage life and maintained the fruit quality of guava cv. 'Allahabad Safeda' for up to 12 days under ambient storage conditions. Further investigations would explore knowledge among growers for successful post-harvest application of CMC to extend the storability and marketability of guava fruit cv. 'Allahabad Safeda' under ambient storage conditions.

Keywords Edible coating · Shelf-life · Marketability · Fruit quality

Introduction

Guava (*Psidium guajava* L.), a premium fruit of tropics and subtropics and popularly known as '*Apple of Tropics*' is a plentiful source of health-promoting compounds such as ascorbic acid, phenolics and carotenoids [1]. Consuming guava fruits helps in reducing serum cholesterol, triglycerides and hypertension. Besides its fruit is rich in pectin content which reduces the risk of heart-attack [2]. The storage of guava fruit is not possible for more than 3 days under ambient storage conditions due to its climacteric nature and high perish ability [3]. Noble post-harvest techniques are required to reduce guava fruit losses and increase fruit marketability.

To date, different approaches such as coating with *Aloe vera* gel [4], chitosan [5, 6], essential oils [7] and cassava starch or rice bran, sunflower oil [8], dipping in sodium nitroprusside [9], ascorbic acid [10], calcium chloride or calcium nitrate or naphthalene acetic acid and/or salicylic acid [11] have been investigated to enhance the storability and maintaining the quality of guava fruit under ambient storage conditions but delivered in narrow success. The tendency for consuming chemical free horticultural crops is increasing due to health risks. Edible coating as generally recognized as safe (GRAS) treatment is one of the best alternatives for increasing storability and reducing post-harvest losses. Besides, they also increase high mechanical strength and are resistant to transpiration and respiration processes [12, 13].

CMC is a water-soluble derivative of cellulose which has been used as edible coating on many horticultural crops. It has a good film forming property which acts as a barrier for moisture and gases thereby delay the senescence [14]. Existing literature suggests that the post-harvest application

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of CMC significantly prolonged the storability besides maintaining the quality of several fruit crops such as 'Kinnow' mandarin [15], 'Eureka' lemon [16], and rambutan [17]. Previously, the post-harvest application of cashew gum (CG) + CMC significantly maintained the post-harvest quality of sliced guava cv. 'Kumagai' for up to 12 days under ambient storage conditions [18]. Vishwasrao & Ananthanarayan [19] also reported that the post-harvest application of hydroxypropyl methyl cellulose (HPMC) + palm oil (PO) significantly extended the storage life and maintained the fruit quality of guava cv. 'Lalit' for up to 12 days under ambient storage conditions. 'Allahabad Safeda' is one of the widely used commercial cultivars of guava all across the world which is popular for its unimpeachable quality fruits and has a large share in the guava industry of India. Due to lack of a suitable post-harvest approach the duration for marketability of this cultivar is limited only a few days. Thus, owing to cost effectiveness and biodegradable characteristics, CMC was selected to extend the marketability of guava fruit cv. 'Allahabad Safeda' under ambient storage conditions. To best of our knowledge no such previous reports are available on the influence of CMC coating on storage life and quality of guava fruit cv. 'Allahabad Safeda' under ambient storage conditions therefore justified to be investigated. Therefore, the aim of present investigation was to evaluate the effect of CMC coating on storage life and fruit quality of guava cv. 'Allahabad Safeda' under ambient storage conditions.

Materials and methods

Fruit and treatment

Guava fruit cv. 'Allahabad Safeda' of uniform sized and without any incidence of disease were harvested at physiological maturity i.e., mature green stage from 8-year-old healthy trees maintained at fruit research farm of Lovely Professional University, Phagwara (31°15′N; 75°42′E). Immediately after harvest fruit were transferred to the post-harvest laboratory of Department of Horticulture at Lovely Professional University, Phagwara. Following sorting and grading operations, the fruit were disinfected with 0.01% chlorinated water (Sodium hypochlorite 4% @ 2.0 ml L^{-1}) and allowed to dry overnight at room temperature [20]. After drying operation, the fruit were separated into 4 groups of 30 fruit for each sampling time (3 replications of 10 fruit). The fruit were coated with 1, 1.5 and 2.0 g L^{-1} CMC by following procedures detailed in our previous investigation on cold-stored 'Kinnow' mandarin fruit [15]. After drying, the packing of fruit was done in corrugated fiber boxes (2 kg capacity) and stored under ambient storage conditions (24 ± 1 °C and 65 ± 5% RH). The coated and uncoated fruit were randomly selected after 4 days interval and analyzed for the following physico-chemical attributes for up to 12 days. Freshly harvested fruit were utilized for the quality analysis at the beginning of storage.

Estimation of weight loss, decay and firmness

Weight loss, decay and firmness were estimated by the following methods earlier described in our previous investigation [15]. Weight loss of both coated and uncoated fruit was determined at each sampling time and expressed in percentage. Fruit decay was determined by dividing the number of decayed fruits with fruit taken on the commencement of the experiment and expressed in percentage. The firmness of both the coated and uncoated fruit was estimated by penetrating the fruit from both sides using 8 mm stainless steel probe penetrometer (Model FT-327, USA) as outlined earlier in our previous investigation [15] and expressed in newton (N).

Estimation of SSC, RS and TS

For the estimation of SSC, hand refractometer (Erna, Japan) was used and the final values were expressed in percentage following temperature correction at 20 °C [21, 22]. To estimate the RS, fresh fruit pulp (5.0 g) was taken and after maceration volume was made to 50 ml using distilled water. For precipitation of unwanted material, 2.0 ml of lead acetate solution (45%) was added to the solution. After 10 min. 5.0 ml of potassium oxalate (22%) was added to solution to remove excess of lead and volume further made to 100 ml using distilled water. The filtrated was obtained and titrated against Fehling A + B (2.5 ml each) using methylene blue as an indicator. The end point was judged as appearance of brick red color and results were expressed in percentage [23].

For the estimation of TS, 25 ml of filtrate (previously made for the estimation of RS) was taken in 100 ml of volumetric flask. 20 ml of HCL (60%) was added to this solution and allowed to stand overnight for hydrolysis. Saturated NaOH solution was used to neutralize the excessive HCL and final volume was made to 100 ml using distilled water. Estimation of TS was made by titrating the hydrolyzed filtrate against the boiling mixture comprising 2.5 ml of Fehling A and B each, using methylene blue as an indicator until appearance of brick red color and the results were expressed in percentage [23].

Estimation of titratable acidity

To determine the TA, fresh fruit pulp (5.0 g) was macerated using distilled water and volume was made to 50 ml with distilled water. The aliquot was titrated against NaOH (0.1 N) using phenolphthalein as an indicator. The calculation was made using the formula as previous used by Gill et al. [24] and the obtained results were expressed in percentage.

Estimation of ascorbic acid content

Estimation of ascorbic acid content of the fruit pulp was done by following Ranganna[25] procedures with minor changes. Accordingly, fresh fruit pulp (5.0 g) was macerated and added to 95 ml of 0.4% oxalic acid. 10 ml aliquot was taken from this prepared solution and titrated against 0.4% DPCIP dye till the appearance of the end point (pink color). The results were expressed in mg 100 g^{-1} pulp [24].

Estimation of total phenol content

To estimate the total phenol content from the fruit pulp methods were used detailed previously by Bray & Thorpe [26] with slight changes [24]. Accordingly, 1.0 g of fresh fruit pulp was macerated with 10 ml ethanol (80%). After filtration, 0.2 ml filtrate was taken into 25 ml test tube thereafter 1 ml of FC reagent (1 N) followed by 2.0 ml of Na_2Co_3 (20%) were added to test tube. The contents were thoroughly homogenized and heated in boiling water bath for 1 min and then cooled under running tap water. The final volume of the obtained solution was made to 25 ml with distilled water. After 30 min the absorbance was taken using micro-plate spectrophotometer (Epoch Biotech, USA) at 650 nm. The calculation of total phenol content was done against a standard curve of gallic acid and the results were expressed in mg 100 g^{-1} pulp [24].

Estimation of sensory attributes

To estimate the sensory attributes, a panel of 10 trained panelists were selected to evaluate the sensory attributes on the basis of taste, texture, aroma and overall appearance of the fruit using a 9-point 'Hedonic scale' [27]. Fruit which displayed the score between 0 and 6 were extremely unfit; 7 moderately fit; 8 very much fit and 9 extremely fit for consumption [24].

Experimental design and analysis

Two-way ANOVA was used to analyze the data using the methods of Statistical Analysis System 9.3 (S.A.S. Institute Inc., Cary, NC, USA). The effect of coating treatments and storage periods and interaction between coating treatments and storage periods were evaluated with ANOVA. Least significance difference (LSD) was used to compare means at a 5% level of probability.

Results

Influence of CMC coating and storage period on the weight loss

A rapid increase in weight loss was recorded with progress in storage period from day 4 to 12 (3.34–8.17%) in all the treatments. Nevertheless, coated fruit exhibited significantly ($P < 0.05$) reduced weight loss than that of control. After 12 days of storage fruit treated with CMC (1.5 g L^{-1}) resulted in significantly ($P < 0.05$) reduced weight loss (3.95%) compared with the control (7.55%) and other coating treatments. Weight loss was significantly ($P < 0.05$) influenced by the interaction between the coating treatments and storage time. In all the storage periods, fruit coated with CMC (1.5 g L^{-1}) resulted in significantly ($P < 0.05$) reduced weight loss as compared with the control and other coating treatments (Table 1).

Influence of CMC coating and storage period on the fruit decay

All treated and untreated fruit showed no significant ($P < 0.05$) disease symptoms up to 4 days of storage, but thereafter disease symptoms appeared. Overall, the fruit coated with CMC (1.5 g L^{-1}) showed the lowest decay (8.33%) compared with other coating treatments and control where decay was significantly ($P < 0.05$) highest (29.17%). Fruit decay was significantly ($P < 0.05$) affected by the interaction between the coating treatments and storage time. Fruit coated with CMC (1.5 g L^{-1}) exhibited significantly ($P < 0.05$) lowest decay in all the storage period as compared with the control and other coating treatments (Table 1).

Influence of CMC coating and storage period on the firmness

A significant decrease ($P < 0.05$) in firmness was observed with prolongation in storage period from day 4 to 12 (54.07–26.17 N, respectively). Overall, coating with CMC (1.5 g L^{-1}) exhibited significantly ($P < 0.05$) highest firmness (41.68 N) as compared with other coating treatments and control (34.79 N). Firmness was significantly ($P < 0.05$) influenced by the interaction between the different coating treatments and storage period. After 4 and 8 days of storage, fruit coated with CMC (1.5 g L^{-1}) manifested significantly ($P < 0.05$) highest firmness as compared with the control and all other coating treatments. Nevertheless, at the end of the storage period, fruit coated

Table 1 Effect of CMC edible coating and storage period on the weight loss (WL), decay and firmness of guava fruit cv. 'Allahabad Safeda' stored under ambient storage conditions (24 ± 1 °C and 65 ± 5% RH)

WL (%)					Decay (%)				Firmness (N)			
Storage time (days)					Storage time (days)				Storage time (days)			
Treatment (T)	4	8	12	Mean (T)	4	8	12	Mean (T)	4	8	12	Mean (T)
CMC (1.0 g L^{-1})	2.37^{g}	4.15^{f}	7.40^{c}	4.64^{C} ± 0.74	0.00^{f}	12.50^{e}	41.66^{c}	18.05^{C} ± 6.18	54.19^{a}	40.38^{b}	28.16^{c}	40.91^{A} ± 3.80
CMC (1.5 g L^{-1})	1.69^{g}	3.94^{f}	6.21^{d}	3.95^{D} ± 0.65	0.00^{f}	0.00^{f}	25.00^{d}	8.33^{D} ± 4.17	56.15^{a}	41.16^{b}	27.73^{c}	41.68^{A} ± 4.15
CMC (2.0 g L^{-1})	3.94^{f}	4.25^{f}	8.96^{b}	5.72^{B} ± 0.82	0.00^{f}	12.50^{e}	54.16^{b}	22.22^{B} ± 8.20	54.97^{a}	38.51^{b}	27.24^{cd}	40.24^{A} ± 4.07
Control	5.38^{e}	7.14^{c}	10.13^{a}	7.55^{A} ± 0.70	0.00^{f}	25.00^{d}	62.50^{a}	29.17^{A} ± 9.10	50.96^{a}	31.85^{c}	21.56^{d}	34.79^{B} ± 4.34
Mean	3.34^{C} ± 0.43	4.87^{B} ± 0.40	8.17^{A} ± 0.46		0.00^{C} ± 0.00	12.50^{B} ± 2.67	45.83^{A} ± 4.30		54.07^{A} ± 0.86	37.97^{B} ± 1.19	26.17^{C} ± 0.87	
LSD ($P \leq 0.05$)	Treatment (T) = 0.35 days (ST) = 0.27 SI × T = 0.79				Treatment (T) = 1.82 days (ST) = 1.43 ST × T = 4.12				Treatment (T) = 2.57 days (ST) = 2.02 ST × T = 5.82			
Value for WL at harvest (day 0); 0.00					Value for spoilage at harvest (day 0); 0.00				Value for firmness at harvest (day 0); 71.54			

For each parameter, data with similar letters are not significantly different at $P \leq 0.05$ (n = 10)

Small letters indicate differences of interactions effects (treatments × storage times), and capital letters indicate differences of main effects (treatments or storage times)

with CMC (1.0 g L^{-1}) recorded significantly ($P < 0.05$) highest firmness as compared with the control and other coating treatments (Table 1).

Influence of CMC coating and storage period on the SSC, RS and TS

Sugars (SSC, RS and TS) significantly ($P < 0.05$) increased up to 8 days of storage then significantly ($P < 0.05$) declined till end of the storage. Nevertheless, fruit treated with CMC 1.5 (g L^{-1}) recorded significantly ($P < 0.05$) highest SSC, RS and TS (11.32%, 2.98% and 7.79% respectively) compared with the control (10.96%, 2.72% and 7.54% respectively) and other coating treatments. Sugars (SSC, RS and TS) were significantly ($P < 0.05$) influenced by the interaction between the coating treatments and storage period. Following 4 and 8 days of storage control fruit (uncoated) exhibited significantly ($P < 0.05$) highest SSC, RS and TS as compared with the control and all other coating treatments. Whereas fruit coated with CMC 1.5 (g L^{-1}) recorded significantly ($P < 0.05$) highest SSC, RS and TS at the end of the storage period as compared with the control and other coating treatments (Table 2).

Influence of CMC coating and storage period on the titratable acidity

TA significantly ($P < 0.05$) decreased with an advancement in storage time from day 4 to 12 (0.46–0.29%). However, the rate of decrease in TA was almost lower in all coating treatments. Fruit coated with CMC (1.5 g L^{-1}) had significantly ($P < 0.05$) highest TA (0.40%) as compared with the control (0.35%) and other coating treatments. TA was significantly ($P < 0.05$) influenced by the interaction between the coating treatments and storage time. Following 4, 8 and 12 days of storage period fruit coated with CMC (1.5 g L^{-1}) recorded the highest TA as compared with the control and other coating treatments (Table 3).

Influence of CMC coating and storage period on the ascorbic acid content

Ascorbic acid content decreased significantly ($P < 0.05$) with progress in storage period from day 4 to 12 (234.54–176.76 mg 100 g^{-1} pulp). However, CMC (1.5 g L^{-1}) coating resulted in significantly ($P < 0.05$) highest ascorbic acid content (216.11 mg 100 g^{-1} pulp) compared with control (195.40 mg 100 g^{-1} pulp) and other coating treatments. Ascorbic acid content was significantly ($P < 0.05$) influenced by the interaction between coating treatments and storage time. After 4 days of storage fruit coated with CMC (1.0 g L^{-1}) had significantly ($P < 0.05$) highest content of ascorbic acid compared with the control

Table 2 Effect of CMC edible coating and storage period on the soluble solids content (SSC), reducing sugars (RS) and total sugars (TS) of guava fruit cv. 'Allahabad Safeda' stored under ambient storage conditions (24 ± 1 °C and 65 ± 5% RH)

SSC (%)					RS (%)				TS (%)			
Storage time (days)					Storage time (days)				Storage time (days)			
Treatment (T)	4	8	12	Mean (T)	4	8	12	Mean (T)	4	8	12	Mean (T)
CMC (1.0 g L^{-1})	10.97^{a-d}	11.77^{abc}	10.81^{cde}	$11.18^{A} \pm 0.18$	2.30^{d}	3.23^{a}	2.80^{b}	$2.78^{B} \pm 0.14$	6.20^{c}	8.72^{a}	8.18^{ab}	$7.70^{A} \pm 0.40$
CMC (1.5 g L^{-1})	10.93^{bcd}	11.80^{ab}	11.23^{a-d}	$11.32^{A} \pm 0.16$	2.36^{cd}	3.39^{a}	3.18^{a}	$2.98^{A} \pm 0.16$	6.25^{c}	8.88^{a}	8.23^{ab}	$7.79^{B} \pm 0.41$
CMC (2.0 g L^{-1})	10.80^{de}	11.60^{a-d}	10.77^{de}	$11.06^{A} \pm 0.16$	2.18^{d}	3.18^{a}	2.66^{bc}	$2.67^{B} \pm 0.15$	6.18^{c}	8.58^{a}	8.08^{ab}	$7.61^{A} \pm 0.38$
Control	11.06^{a-d}	11.90^{a}	9.93^{e}	$10.96^{A} \pm 0.30$	2.44^{cd}	3.46^{a}	2.25^{d}	$2.72^{B} \pm 0.19$	6.40^{c}	8.98^{a}	7.24^{bc}	$7.54^{A} \pm 0.39$
Mean	$10.94^{B} \pm 0.08$	$11.77^{A} \pm 0.09$	$10.68^{B} \pm 0.16$		$2.32^{C} \pm 0.04$	$3.31^{A} \pm 0.05$	$2.72^{B} \pm 0.10$		$6.26^{C} \pm 0.08$	$8.79^{A} \pm 0.12$	$7.93^{B} \pm 0.15$	
LSD ($P \le 0.05$)	Treatment (T) = 0.43 days (ST) = 0.33 SI × T = 0.97				Treatment (T) = 0.15 days (ST) = 0.12 ST × T = 0.35				Treatment (T) = 0.50 days (ST) = 0.39 ST × T = 1.13			
Value for SSC at harvest (day 0); 9.00					Value for RS at harvest (day 0); 1.82				Value for TS at harvest (day 0); 5.68			

For each parameter, data with similar letters are not significantly different at $P \le 0.05$ (n = 10)

Small letters indicate differences of interactions effects (treatments × storage times), and capital letters indicate differences of main effects (treatments or storage times)

Table 3 Effect of CMC edible coating and storage period on the titratable acidity (TA), ascorbic acid content and total phenol content of guava fruit cv. 'Allahabad Safeda' stored under ambient storage conditions(24 ± 1 °C and 65 ± 5% RH)

TA (%)					Ascorbic acid (mg 100 g^{-1} pulp)				Total phenol (mg 100 g^{-1} pulp)			
Storage time (days)					Storage time (days)				Storage time (days)			
Treatment (T)	4	8	12	Mean (T)	4	8	12	Mean (T)	4	8	12	Mean (T)
CMC (1.0 g L^{-1})	0.45^{b}	0.38^{d}	0.31^{e}	$0.38^{B} \pm 0.02$	238.00^{a}	210.00^{bcd}	191.33^{de}	$213.11^{A} \pm 7.21$	149.89^{a}	117.50^{b}	68.60^{cd}	$112.00^{A} \pm 11.89$
CMC (1.5 g L^{-1})	0.49^{a}	0.38^{d}	0.33^{e}	$0.40^{A} \pm 0.02$	235.00^{a}	214.67^{abcd}	198.67^{cd}	$216.11^{A} \pm 5.81$	153.07^{a}	116.87^{b}	71.77^{cd}	$113.90^{A} \pm 11.84$
CMC (2.0 g L^{-1})	0.47^{ab}	0.36^{d}	0.28^{f}	$0.37^{B} \pm 0.03$	228.67^{ab}	219.33^{abc}	172.67^{e}	$206.89^{A} \pm 8.98$	140.37^{a}	118.14^{b}	67.96^{d}	$108.82^{A} \pm 10.79$
Control	0.42^{c}	0.37^{d}	0.25^{g}	$0.35^{C} \pm 0.02$	236.50^{a}	205.31^{bcd}	144.38^{f}	$195.40^{B} \pm 13.72$	151.48^{a}	81.93^{c}	49.54^{e}	$94.32^{B} \pm 15.09$
Mean	$0.46^{A} \pm 0.008$	$0.37^{B} \pm 0.003$	$0.29^{C} \pm 0.0009$		$234.54^{B} \pm 2.53$	$212.33^{C} \pm 2.61$	$176.76^{D} \pm 6.55$		$148.70^{B} \pm 2.12$	$108.61^{C} \pm 4.78$	$64.47^{D} \pm 2.72$	
LSD ($P \le 0.05$)	Treatment (T) = 0.013 days (ST) = 0.010 SI × T = 0.029				Treatment (T) = 10.82 days (ST) = 8.49 ST × T = 24.50				Treatment (T) = 6.06 days (ST) = 4.75 ST × T = 13.72			
Value for TA at harvest (day 0); 0.64					Value for ascorbic acid content at harvest (day 0); 252.00				Value for total phenol content at harvest (day 0); 182.93			

For each parameter, data with similar letters are not significantly different at $P \le 0.05$ (n = 10)

Small letters indicate differences of interactions effects (treatments × storage times), and capital letters indicate differences of main effects (treatments or storage times) and other coating treatments. However, following 8 days of storage fruit coated with CMC (2.0 g L^{-1}) had significantly ($P < 0.05$) highest ascorbic acid content compared with the other coating treatments and control. Nevertheless, fruit coated with CMC (1.5 g L^{-1}) had the highest ascorbic acid content after 12 days of storage period (Table 3).

Influence of CMC coating and storage period on the total phenol content

Total phenol content significantly ($P < 0.05$) declined with progress in storage period from day 4 to 12 (148.70–64.47 mg 100 g $^{-1}$ pulp). Overall, fruit coated with CMC (1.5 g L^{-1}) contained significantly ($P < 0.05$) highest total phenol content (113.90 mg 100 g-1 pulp) compared with the control (94.32 mg 100 g-1 pulp) and other coating treatments. Total phenol content was significantly ($P < 0.05$) affected by the interaction between coating treatments and storage time. Fruit coated with CMC (1.5 g L^{-1}) recorded significantly ($P < 0.05$) highest content of total phenol in 4 and 12 days of storage. Although, following 8 days of storage, fruit coated with CMC (2.0 g L^{-1}) contained significantly ($P < 0.05$) highest content of total phenol (Table 3).

Influence of CMC coating and storage period on the sensory attributes

An identical change in sensory attributes were observed with progress in storage period from day 4 to 12 (7.90–6.10). Overall, fruit coated with CMC (1.5 g L^{-1}) resulted in significantly ($P < 0.05$) highest mean score for sensory attributes (7.81) compared with the control (7.04) and other coating treatments. A significant ($P < 0.05$) influence on sensory attributes is due to an interaction between different coating treatments and storage time. Fruit coated with CMC (1.5 g L^{-1}) recorded significantly ($P < 0.05$) highest sensory score in all storage period except day 4 where control fruit registered the highest sensory score (Fig. 1 Effect of CMC edible coating and storage period on the organoleptic sensory attributes (Hedonic scale 1–9) of guava fruit cv. 'Allahabad Safeda' stored under ambient storage conditions (24 ± 1 °C and 65 ± 5% RH).

Discussion

Guava fruit weight loss is due to both transpiration and high respiration due to its climacteric nature [28]. Reduced weight loss in CMC coated fruit can be ascribed to the formation of hydrogen bond inside the coating matrix and with the cuticle on the fruit surface due to the action of carboxylic group of CMC [29]. Earlier, the post-harvest coating with cashew gum + CMC significantly delayed the weight loss in sliced guava cv. 'Kumagai' for up to 12 days under ambient storage conditions [18]. Recently, the post-harvest application with CMC (1%) also resulted in reduced weight loss in 16 days cold-stored strawberry fruit [30]. Similar results were also reported in our previous investigation on 75 days cold-stored 'Kinnow' mandarin fruit [15]. Edible coatings delay the decay may be due to the fact that coating prolong the weight loss thus delay the senescence and consequently suppress the growth of micro-organisms [31, 32]. Recently, coating with CMC (1%) significantly delayed the decay in 16 days cold-stored strawberry fruit [30]. Likewise, in our previous investigation the post-harvest application of CMC (2.0 g L^{-1}) significantly delayed the decay in 75 days cold-stored 'Kinnow' mandarin fruit [15]. Fruit firmness is one of the major factors influences the post-harvest quality of horticultural crops [33]. Fruit firmness is mainly influenced by enzymes involved in pectin and some polysaccharides

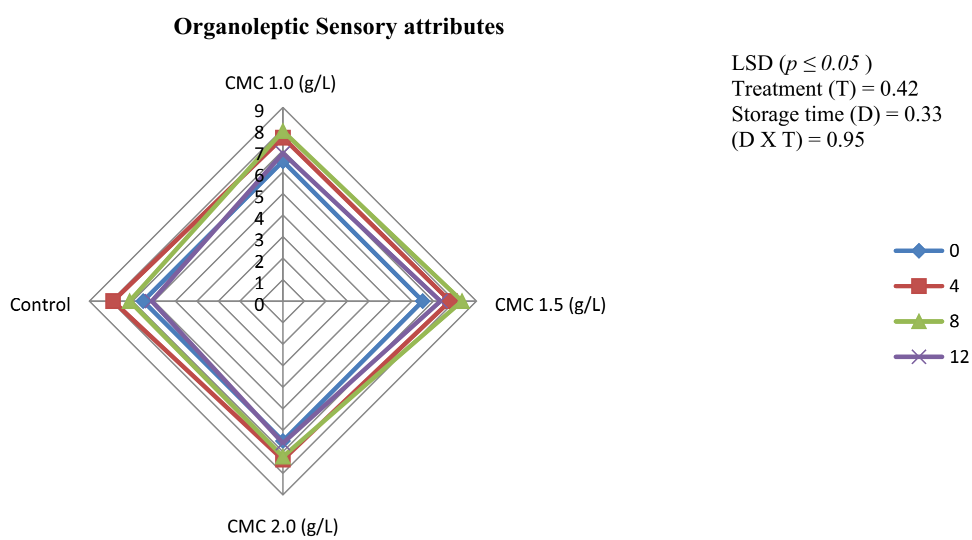

Fig. 1 Effect of CMC edible coating and storage period on the organoleptic sensory attributes (Hedonic scale 1–9) of guava fruit cv. 'Allahabad Safeda' stored under ambient storage conditions (24 ± 1 °C and 65 ± 5% RH)

such as cellulose depolymerization [15]. Lower firmness in control fruit may be due to fruit softening which is strongly associated with the amount of ethylene produced under ambient storage conditions. It has been reported that the maximum amount of ethylene production occurs in 4–6 days after harvesting [34]. Earlier, the post-harvest coating with cashew gum + CMC exhibited significantly higher firmness in sliced guava fruit cv. 'Kumagai' under ambient storage conditions for up to 12 days [17]. Recently, the post-harvest application with CMC (1%) recorded significantly higher firmness in 16 days cold-stored strawberry fruit [30]. Similar results were also reported in our previous investigation on 75 days cold-stored 'Kinnow' mandarin fruit [15]. CMC coated fruit significantly delayed a rise in sugars may be due to the fact that coating retards the post-harvest ripening and delay the senescence and consequently delays the starch-sugar conversion [35]. Rapid initial post-harvest ripening of control fruit may be due to the dry atmosphere around the fruit led to the rapid conversion of starch into sugars [36]. Though, a delayed decline in sugars can be ascribed to usages of starch as substrate during the ripening process [15]. Recently, the combined post-harvest application of CMC + guar gum based silver nanoparticles (1:1) recorded significantly higher levels of sugars in 28 days cold-stored mango fruit cv. 'Seddik [37]. Likewise, in our previous investigation on 75 days cold-stored 'Kinnow' mandarin fruit, the post-harvest application of CMC (2.0 g L^{-1}) resulted in a gradual rise in sugars [15]. TA is strongly associated with the degree of post-harvest ripening, therefore used as maturity index in numerous horticultural crops [38]. Coated fruit significantly delayed a decrease in TA may be due to slow ripening process and a retarded starch-sugar conversion [15]. Recently,coating with CMC + guar gum based silver nanoparticles (1:1) exhibited significantly higher TA in cold-stored mango fruit cv. 'Seddik' [37]. Earlier, in our previous investigation the post-harvest application of CMC (2.0 g L^{-1}) exhibited significantly higher TA in 75 days cold-stored 'Kinnow' mandarin fruit [15]. Ascorbic acid content and total phenol content involve in antioxidant activity which restricts the formation of free radicals during oxidative stress. Coated fruit maintained significantly higher ascorbic acid and total phenol content may be due to the fact that CMC retards the O_2 supply which is responsible for enzymatic oxidation of antioxidant compounds such as ascorbic acid and total phenol content [39]. Recently, the post-harvest application with CMC (1%) resulted in significantly higher levels of ascorbic acid and total phenol in 16 days cold-stored strawberry fruit [30]. Our results are in tune with the previous findings of Ali et al. [40] and Baswal et al. [15] who reported that coating with CMC significantly maintained higher ascorbic acid content and total phenol content in cold-stored 'Kinnow' mandarin fruit. Fruit coated with CMC exhibited significantly higher score for sensory attributes as it is speculated that coatings modify internal atmosphere of the fruit which results in the development of acceptable flavor [41]. Recently, coating with CMC (1%) exhibited significantly higher scores for sensory attributes in 16 days cold-stored strawberry fruit [30]. Similarly, in our previous investigation the post-harvest treatment with CMC (2.0 g L^{-1}) exhibited significantly higher score for sensory attributes in 75 days cold-stored 'Kinnow' mandarin fruit [15]. Overall, the beneficial effects of edible coatings on sensorial properties and storage life of food stuffs may could be attributed to their suppression effects on micro-organisms such as bacteria [42] which is similar to some active packagings [43–45].

Conclusions

CMC (1.5 g L^{-1}) could be a potential treatment for maintenance of quality and reducing post-harvest losses in guava fruit. The treatment significantly delayed the weight loss and decay besides maintaining higher firmness, sugars, titratable acidity, ascorbic acid content, total phenol content and sensory attributes in guava fruit cv. 'Allahabad Safeda' for up to 12 days under ambient storage conditions. Furthermore, the obtained results from the present investigation assist us to investigate the effect of CMC coating on the dynamics of cell wall deteriorating enzymes and other bioactive compounds of guava cv. 'Allahabad Safeda' under ambient storage conditions in future.

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