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ORIGINAL ARTICLE

Potential of carboxymethyl cellulose coating and low dose gamma irradiation to maintain storage quality, inhibit fungal growth and extend shelf-life of cherry fruit

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Abstract Carboxymethyl cellulose (CMC) coatings alone and in combination with gamma irradiation was tested for maintaining the storage quality, inhibiting fungal incidence and extending shelf-life of cherry fruit. Two commercial cherry varieties viz. Misri and Double after harvest at commercial maturity were coated with CMC at levels 0.5–1.0 % w/v and gamma irradiated at 1.2 kGy. The treated fruit including control was stored under ambient (temperature 25 ± 2 °C, RH 70 %) and refrigerated (temperature 3 ± 1 °C, RH 80 %) conditions for evaluation of various physico-chemical parameters. Fruits were evaluated after every 3 and 7 days under ambient and refrigerated conditions. CMC coating alone at levels 0.5 and 0.75 % w/v was not found effective with respect to mold growth inhibition under either of the two conditions. Individual treatment of CMC coating at 1.0 % w/v and 1.2 kGy irradiation proved helpful in delaying the onset of mold growth up to 5 and 8 days of ambient storage. During post-refrigerated storage at 25 ± 2 °C, RH 70 %, irradiation alone at 1.2 kGy gave further 4 days extension in shelf-life of cherry varieties following 28 days of refrigeration. All combinatory treatments of CMC coating and irradiation proved beneficial in maintaining the storage quality as well as delaying the decaying of cherry fruit during post-refrigerated storage at 25 ± 2 °C, RH 70 % but, combination of CMC at 1.0 % w/v and 1.2 kGy irradiation was found significantly ($p \leq 0.05$) superior to all other treatments in maintaining the storage quality and delaying the decaying of cherry fruit. The above combinatory treatment besides maintaining storage quality resulted in extension of 6 days in shelf life of cherry varieties during post-refrigerated storage at 25 ± 2 °C, RH 80 % following 28 days of refrigeration. Above Combination treatment gave a maximum of 2.3 and 1.5 log reduction in yeast and mold count of cherry fruits after 9 and 28 days of ambient and refrigerated storage, thereby ensuring consumer safety.

Keywords Cherry · Edible coating · Gamma irradiation · Storage quality · Shelf-life extension

Introduction

Cherry is the first temperate non-climacteric stone fruit of Kashmir valley that flushes to the market after winter. Kashmir valley is the largest producer of cherry in India and its cultivation as niche cash crop has picked up at a faster rate. The commercially exploited varieties of cherry are 'Misri', 'Double' and 'Makhmali'. Cherry is harvested at full maturity to achieve maximum quality in terms of visual appearance, color, texture, flavor and nutritional value. It is highly perishable, susceptible to mechanical injury, physiological deterioration, water loss and has short life due to fast decay caused by fungal infections. The maximum shelf-life of Cherry at ambient (25 ± 2 °C, RH 80 %) and refrigeration temperatures (0–3 °C, RH 90 %) is around 5 and 14 days respectively. The short storage life of the cherry fruit makes its marketing a challenge, hence most of the fruit is consumed locally and around 1–2 % of

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the total produce is marketed to near distant domestic markets. The use of conventional chemicals as anti-ripening, anti-senescence and microbial fumigants has been phased out and restricted throughout the world. These chemicals pose serious health hazards and environmental effects (Cetinkaya et al. 2006). The adverse effects of these chemicals lower or limit the export capabilities of fresh as well as dried fruits. To overcome the adverse effects posed by the chemicals, extend the shelf-life and maintain storage quality, facilitate the marketing of fruit to places other than the local market, augment export trade and establishes price for the grower during the glut season, alternate processes are needed.

Gamma irradiation has become an effective means of processing and preserving food products (Molins 2001; Fan et al. 2003). The process is gaining much importance as it can be performed at room temperature; and due to its cold nature and high efficiency for inactivation of food borne pathogens and parasites (Bidawid et al. 2000). Irradiation has been recognized as an alternative to chemicals for treating fresh and dried agricultural products to overcome quarantine barriers in international trade, as a mode of decontamination, disinfestations, delaying the ripening and senescence of fruits and vegetables and for improving nutritional attributes and shelf-life (McDonald et al. 2012; Hong et al. 2008; Lacroix and Ouattara 2000; Hallman 2000). Literature review reveals that considerable research has been done on irradiation of stone fruits with respect to quality maintenance and postharvest shelf-life extension. According to McDonald et al. (2012), commercial scale irradiation of six peach varieties (Encore, Blaze Prince, July Prince, Red Globe, Flame Prince and August Lady) at targeted dose of 0.4 kGy did not adversely affect shelf life but enhanced the ripening process; however, this was perceived as positive change by the consumers. Kim et al. (2009) reported that peach varieties respond differently to irradiation, but the greatest impact seems to be on firmness. Hussain et al. (2008) observed a dose dependent loss of firmness and enhancement in anthocyanin accumulation of Elberta peaches irradiated at doses between 1 and 2 kGy. Hussain et al. (2013) in another study reported that dose range of 1.2–1.5 kGy significantly inhibited the decaying of plums Cv. Santaroza up to 16 days of ambient storage. Irradiation in combination with refrigeration prevented the decaying of plums up to 35 days as against the 12.5 % decay in un-irradiated control samples. However, the literature so far published regarding the radiation processing of cherry represent varying results. Drake and Neven (1997) reported that in 'Bing' and 'Rainier' sweet cherries irradiated in the dose range of 0.15–0.9 kGy, no change in total soluble solids, titratable acidity or flavor were noted at any of the irradiation doses. Our earlier study (Parveen et al. 2015) also confirmed that gamma irradiation at dose of 1.2 kGy was effective in inhibiting the decay of cherry and extending the storage life of fruit by 6 days at 25 ± 2 °C, RH 70 % following 28 days of refrigeration.

Edible coatings, a new strategy used to extend shelf-life and to improve food quality of whole as well as fresh-cut fruits has been applied to many products. Coating of fruits with edible materials acts as a barrier to moisture and oxygen during postharvest handling and storage (Petersen et al. 1999). Edible coatings can be used to protect perishable food products from deterioration by retarding dehydration, suppressing respiration, improving textural quality, helping retain volatile flavor compounds and reducing microbial growth (Lee et al. 2003). Edible coatings are also used to improve the fruit appearance and conservation due to their environmentally friendly nature, natural bacteriocide activity and creating of modified atmosphere packaging (Cha and Chinnan 2004). Edible coatings also act as a means of medium for incorporation of anti-microbial and anti-senescence compounds and serve as active packaging. Different compounds such as cellulose, alginate, chitosan, chitin, lipids, milk proteins, starch, wax and zein have been used as coating materials in fruits with varying success for extending shelf-life and maintaining fruit quality (Ahmed et al. 2009; Maftoonazad et al. 2008; Ribeiro et al. 2007; Valverde et al. 2005). Although waxes are the most widely used coating materials for fruits and vegetables, they are not so effective for a range of fruit crops (Cha and Chinnan 2004). Conforti and Totty (2007) reported that lipid based hydrocolloid coatings maintain consistent quality including firmness, crispness and juciness when applied on Golden Delicious apples. Edible coatings based on chitosan have also been reported to reduce postharvest decay in fruit crops (Romanazzi et al. 2003). Chiabrando and Giacalone (2013) reported that application of edible coatings based on sodium aliginate and chitosan could be used to reduce deteriorative processes, maintain quality and improve shelf-life of fresh-cut nectarine stored at 4 °C. Edible coatings of sodium aliginate and methylcellulose when applied on peaches resulted in shelf-life extension of 21 and 24 days at 15 °C, RH 40 % (Maftoonazad et al. 2008).

Combinatory treatments have also widely been investigated as they often result in synergistic effects. Earlier reports indicate that edible coatings in combination with radiation processing has shown significant delay in mold growth and microbial contamination level, leading thus to an improvement of the food shelf-life (Lacroix et al. 2002; Vachon et al. 2003; Zuniga et al. 2012). CMC based coatings can also be combined with gamma irradiation to obtain a synergistic effect with respect to storage quality and shelf-life of fresh fruits. The literature survey indicates that there hardly seems any information available till this date regarding the combinatory use of CMC coating and

gamma radiation to maintain quality of cherry fruit. Therefore, the present study was under taken to evaluate the combined effect of gamma irradiation and CMC coating on the storage equality and shelf-life extension of cherry. The assessment of the treatments is based on the evaluation of physicochemical parameters, microbial load and decay percentage.

Materials and methods

The study was conducted consecutively for two years during 2011–2013. Fruit selection was done from same orchard and harvesting was carried out in the first week of June for both the years of study. The results showed similar behavior for both the years and the data presented for each parameter is the average of the means of 2 years of study.

Raw material preparation

Cherry fruit of proper commercial maturity, uniform size and color and without any signs of damage or fungal decay was procured from the cherry orchards of Harwan, Kashmir. Selection of fruit was done from the same orchard and fruit was harvested during early morning hours. The harvested fruit was then transported to the Nuclear Research Laboratory and was kept at 2 °C in a cold storage room. The pre-cooled fruit was manually graded in order to have uniformity in size and color and any blemished or injured fruits present were discarded.

CMC coating

The coating treatment was given alone and in combination with gamma irradiation. The coating consisted of 0.5, 0.75 and 1.0 % (w/v) CMC. The formulations were prepared by dissolving the required quantity of CMC in distilled water under stirring and heating at 90 °C for 30 min. The solution was then cooled to room temperature. The fruits were dipped for 5–10 min at room temperature. The temperature of the coating solution was 10 ± 2 °C. After completion of the coating treatment, the samples were taken out and allowed to surface dry completely at 25 ± 2 °C using wall mounted fans. Following the CMC treatment, the fruits were packed in cardboard boxes of size 0.5 × 0.3 × 0.3 m^3. Three boxes each containing 250 g fruits were taken for each treatment per sampling period. Fruits neither CMC coated nor gamma irradiated served as control.

Gamma irradiation treatment

The packaged CMC coated fruit was subjected to gamma irradiation at 1.2 kGy using PANBIT irradiator (Isotope Division, BARC, Mumbai, India) having Co-60 as the gamma-ray source. The fruits were irradiated at minimum dose rate of 128 Gy/h. To ensure uniformity of dose, boxes were turned by180° half way through the irradiation time and the over dose ratio (Dmax/Dmin) was determined and found to be 1.6. The dose rate was determined by Ceric-Cereous dosimetry. To ensure that fruit receives the exact dose, the dosimeters were placed in each fruit box for each treatment at high as well as low dose spots. After completion of irradiation, separate batches of fruit either CMC coated only or CMC coated and gamma irradiated were kept under ambient (temperature 25 ± 2 °C, RH 70 %) and refrigerated (temperature 3 ± 1 °C, RH 80 %) storage conditions for periodic evaluation of physicochemical parameters. Prior to the measurement of quality parameters all refrigerated samples were allowed to attain the room temperature. Three boxes each containing 250 g of fruit were evaluated for each parameter and treatment after every 3 days in case of ambient storage and every 7 days in case of refrigerated storage.

Firmness measurement

Firmness was determined using the Universal TA-XT2 texture analyzer equipped with a 3 mm probe set at 10 mm/s and a penetration distance after contact of 7 mm and the values were expressed in Newton (N). Triplicate samples were used for determination of firmness and each replicate consisted of 25 fruits.

Total sugars

Total sugars were determined by modifying the method of Miller (1959) using 3,5-dinitrosalicylic acid reagent (DNSA). The fruits initially used for firmness measurement were subjected to juice extraction for estimation of total sugars. In principle, the reducing sugars reduce DNSA to 3-amino-5 nitrosalicylic acid resulting in the formation of reddish-orange coloration that is measured with a spectrophotometer at 540 nm. A total of 5 ml of filtered cherry juice was mixed with equal amount of DNSA solution and incubated on boiling water bath for 10 min. The mixture was allowed to cool at ambient temperature and diluted further with double distilled water if required. The absorbance of the solution was measured at 540 nm using an ultraviolet–visible spectrometer (HITACHI-330, Germany). Glucose solution of known concentration was used as standard for measuring the concentration of reducing sugars in the juice sample. The estimation of total sugars was performed following the inversion of sucrose (a non-reducing sugar) to reducing sugar. To 50 ml of cherry juice, 2 g citric acid was added and the mixture was incubated at 60 °C for 20–30 min for complete inversion

of sucrose to reducing sugars. The acid hydrolyzed solution was cooled to ambient temperature and neutralized by the addition of sodium hydroxide. From this hydrolyzed solution, 5 ml of the sample was taken for quantifying total sugars in terms of invert sugar as per the method described above. Measurements were performed in triplicates. Sucrose and total sugar concentrations in juice sample were calculated using the equations

$$\text{Sucrose } (\%) = (\text{Total invert sugar - Reducing sugar}) \times 0.95$$
$$\text{Total sugar}(\%) = \text{Reducing sugar}(\%) + \text{Sucrose}(\%)$$

Total anthocyanins

Total anthocyanins were determined according to the pH-differential method (Giusti and Wrolstad 2001). Homogenized fruit sample in triplicates were extracted using ethanol: 1 N HCl (85:15, v/v). Clear extract (1 ml) was placed into 25 ml volumetric flask, made up to a final volume with pH 1.0 buffer (1.49 g of KCl/100 ml water and 0.2 N HCl, with a ratio of 25:67) and mixed thoroughly. Another 1 ml of extract was also placed into a 25 ml volumetric flask, made up to a final volume with pH 4.5 buffer (1.64 g of sodium acetate/100 ml of water, adjusted to pH 4.5 with 0.2 N HCl) and mixed. Absorbance was calculated as $\Delta A = (A_{510\ nm} - A_{700\ nm})\ pH1.0 - (A_{510\ nm} - A_{700nm})\ pH4.5$ with a molar extinction coefficient of 26,900 for cyanidin-3-glucoside. Results were calculated using the following equation and expressed as mg of cyanidin 3-glucoside equivalents per 100 g of fresh sample.

$$\text{Total anthocyanins } (\text{mg}/100\,\text{g}) = (\Delta A/€L) \times MW \times D \times (V/G)$$

where ΔA is absorbance, € the cyanidin3-glucoside molar extinction coefficient (26,900), L the cell path length (1 cm), MW the molecular weight of anthocyanin (449.2), D a dilution factor, V the final volume (ml) and G the sample weight (g).

Total phenols

Total phenols were determined according to the Folin-Ciocalteu method as described by Waterhouse (2002) with minor modifications. Homogenized sample (3 g) was extracted three times with 80 % ethanol. The extracts obtained were centrifuged for 20 min and the supernatants collected were dried under nitrogen. The residue obtained was dissolved in 5 ml of distilled water followed by addition of 0.5 ml of Folin-Ciocalteu reagent. After 3 min, 2 ml of 20 % sodium carbonate solution were added. The mixture was mixed thoroughly, placed in boiling water for exactly 1 min, cooled and absorbance measured at 650 nm against a reagent blank. Total phenols were determined with the use of an external standard curve and expressed as mg gallic acid equivalents (GAE) per100 g.

Ascorbic acid content

Ascorbic and dehydroascorbic acid estimation was done by HPLC system of JASCO, Japan (model, LC-Net II/ADC), fitted with an automatic degassing unit,UV-2070 detector, PU-2080 pump and a HiQ-Sil C18 column (size 4.6 mm × 250 mm)using the method of Pasternak et al. (2005). Known weight of sample of cherry fruit in triplicates was extracted with 3 % meta-phosphoric acid. The extraction procedures were repeated three times. The extracts from each replicate were pooled and filtered through Whatman filter paper no.42. Filtrate obtained was evaporated approximately to one-fourth of volume under nitrogen. The resultant sample was then filtered through 0.22 mm membrane filters (Millipore). An aliquot of 20 ml sample was injected for estimation purposes in a C-18 column. Prior to analysis, the analytical column was thoroughly washed with methanol followed by mobile phase for 1 h. The mobile phase consisted of 2 % acetic acid and the run was isocratic. Flow rate of mobile phase was maintained at 0.5 ml/min. Detector wavelength was set at 254 nm. An external standard of $_{L}$-ascorbic acid and dehydroascorbic acid in 3 % meta-phosphoric acid was used for the identification and quantification of ascorbic and dehydroascorbic acid. Ascorbic and dehydroascorbic acid content in cherry samples was calculated from the standard curve of $_{L}$-ascorbic and dehydroascorbic acid.

Weight loss

Weight loss was determined by periodical weighing of samples. Triplicate samples each consisting of 45 fruits was used for each treatment including control. Weight loss was calculated from initial weight using the formula:

$$\text{Weight loss } (\%) = (\text{Wi} - \text{Ws}/\text{Wi}) \times 100$$

where Wi = initial weight; Ws = weight at sampling period.

Decay percentage

Decay percentage was determined visually from known number of fruits. Any fruit showing the signs of fungal growth and mealiness (extreme soft and oozing condition) was considered as decayed. Decay percentage was monitored under ambient (temperature 25 ± 2 °C, RH 70 %), refrigerated (temperature 3 ± 1 °C, RH 80 %) as well as post-refrigerated storage conditions (temperature

25 ± 2 °C, RH 70 %). Two replicates of known number of fruits were used for monitoring decay under ambient and refrigerated conditions for each treatment including control. For monitoring decay under post-refrigerated conditions, samples initially kept under refrigerated conditions were taken out from cold storage and stored under ambient conditions to monitor decay. Decay percentage was calculated as:

$$\text{Decay percentage} = (\text{No. of decayed fruits}/\text{Total number of fruits}) \times 100$$

Overall acceptability (OAA)

Overall acceptability based on colour, texture and taste was done by a trained panel of 5 judges on round table basis using 4 point scale where 4 = excellent, 3 = good, 2 = fair and 1 = poor. Out of the five judges, four were from the Division of Food Technology, Sheri Kashmir University of Agricultural Sciences and Technology, Kashmir (SKUAST-K) and one from our Nuclear Research Laboratory, having good experience in the sensory analysis of foods. Thirty to thirty-five fruits were selected randomly, coded and served to judges for evaluation of color, texture and taste. The limit of acceptability was kept as 2.5 and the samples whose acceptability values were below 2.5 corresponding the storage period were rated unacceptable. The testing was undertaken in a place free from extraneous odors and sound. Panelists were requested not to talk during the procedure. The panel test was carried out under normal light conditions. The temperature of the fruit during testing was the existing normal temperature. The panelists were instructed to evaluate the taste of the samples by eating the samples and assign the score as per the 4-point scale. The overall acceptability was reported as the mean of the triplicate values of colour, texture and taste. The overall acceptability of samples which exhibited retention in red colour, crisp texture and acceptable taste was rated higher than the samples which recorded darker colour, mealy like texture and bitter or insipid taste.

Yeast and mold count

Yeast and mold count was determined by pour plate technique using potato dextrose agar media (Aneja 1996). Triplicate samples were used for the determination of yeast and mold count. Fifteen fruits in triplicates were homogenized (HL–1631, Philips, India). One gram of homogenized sample was taken and dissolved in previously sterilized 9 ml of distilled water and kept in stirring condition for 30 min. One milliliter of this solution was further diluted by dissolving in 9 ml of sterilized distilled water. This way a dilution of 10^{-3} was obtained. One milliliter aliquot each of 10^{-3} dilution was pour plated in triplicates on potato dextrose agar media to determine yeast and mold count. The samples were incubated at 30 ± 2 °C for 5 days. The colonies so formed were counted and expressed as log cfu/g of sample.

Statistical analysis

The data was analyzed statistically using completely randomized design experiment (Cochran and Cox 1992). For each measurement, three replicates of samples were tested per treatment and mean ± standard deviation values were reported. Analysis of variance (ANOVA) of the data was performed using MINITAB statistical analysis software package (Minitab,version 11.12, 32 bit, Minitab,USA). Difference between means of data was compared by least significant difference (LSD) and Student's t test was applied to determine if the difference was statistically significant. Differences at $p \leq 0.05$ were considered to be statistically significant. Duncan's multiple range test was used to compare the mean values at each storage period.

Results and discussion

Firmness

Effect of individual and combination treatments of CMC coating and gamma irradiation on firmness of cherry fruit is presented in Table 1. The data on firmness indicated that out of the two varieties, firmness at harvest time was significantly ($p \leq 0.05$) higher in 'Double' compared to 'Misri'. Data analysis also revealed that there was no significant ($p \geq 0.05$) difference in firmness of cherry fruits treated either with CMC coating, irradiation or combination of CMC and gamma irradiation at first day of storage under both the storage conditions. Further it is clear from the Table 1 that firmness of cherry varieties decreased during the storage time. The decrease was significantly ($p \leq 0.05$) higher in samples kept under ambient conditions than refrigerated condition. Under refrigerated conditions, firmness decrease for both the varieties was statistically non-significant ($p \geq 0.05$) up to 7 days of storage in all treatments including control. Among coating treatments, 0.5 % w/v CMC had no significant effect on preventing firmness decrease of cherry varieties when compared with control irrespective of storage condition. Treatments of irradiation alone at 1.2 kGy, CMC coating above 0.5 % w/v and combination of irradiation (1.2 kGy) and CMC coating at levels 0.5–1.0 % w/v showed significant ($p \leq 0.05$) beneficial effects in maintaining the

Table 1 Firmness (N) of cherry fruits treated with combination of carboxymethyl cellulose and gamma irradiation during storage under ambient and refrigerated conditions

Treatments	Ambient storage (days)				LSD	Refrigerated storage (days)					LSD
	0	3	6	9		0	7	14	21	28	
(a) Misri											
T1	$6.7 \pm 0.03^{a,4}$	$5.1 \pm 0.03^{a,3}$	$3.6 \pm 0.04^{a,2}$	$2.5 \pm 0.02^{a,1}$	0.3	$6.6 \pm 0.04^{a,5}$	$5.7 \pm 0.04^{a,4}$	$4.3 \pm 0.07^{a,3}$	$3.3 \pm 0.06^{a,2}$	$2.3 \pm 0.04^{a,1}$	0.4
T2	$6.6 \pm 0.01^{a,4}$	$5.2 \pm 0.03^{a,3}$	$3.8 \pm 0.04^{a,2}$	$2.9 \pm 0.04^{b,1}$	0.2	$6.6 \pm 0.04^{a,5}$	$5.7 \pm 0.03^{a,4}$	$4.5 \pm 0.03^{a,3}$	$3.3 \pm 0.07^{a,2}$	$2.5 \pm 0.04^{a,1}$	0.3
T3	$6.6 \pm 0.03^{a,4}$	$5.3 \pm 0.02^{a,3}$	$3.8 \pm 0.03^{a,2}$	$3.1 \pm 0.03^{b,1}$	0.2	$6.5 \pm 0.03^{a,5}$	$5.6 \pm 0.03^{a,4}$	$4.7 \pm 0.04^{b,3}$	$3.6 \pm 0.05^{b,2}$	$2.9 \pm 0.01^{b,1}$	0.4
T4	$6.5 \pm 0.03^{a,4}$	$5.5 \pm 0.03^{b,3}$	$4.1 \pm 0.03^{b,2}$	$3.5 \pm 0.01^{c,1}$	0.3	$6.5 \pm 0.03^{a,5}$	$5.7 \pm 0.03^{a,4}$	$4.9 \pm 0.02^{b,3}$	$3.6 \pm 0.0^{b,2}$	$2.9 \pm 0.04^{b,1}$	0.3
T5	$6.5 \pm 0.03^{a,4}$	$5.8 \pm 0.03^{b,3}$	$4.5 \pm 0.01^{c,2}$	$3.9 \pm 0.02^{d,1}$	0.2	$6.6 \pm 0.03^{a,5}$	$5.4 \pm 0.02^{a,4}$	$4.9 \pm 0.07^{b,3}$	$4.3 \pm 0.04^{c,2}$	$3.4 \pm 0.03^{c,1}$	0.3
T6	$6.5 \pm 0.05^{a,4}$	$5.7 \pm 0.03^{b,3}$	$4.9 \pm 0.04^{d,2}$	$3.9 \pm 0.02^{d,1}$	0.3	$6.5 \pm 0.03^{a,5}$	$5.6 \pm 0.03^{a,4}$	$4.9 \pm 0.06^{b,3}$	$4.4 \pm 0.04^{c,2}$	$3.6 \pm 0.03^{c,1}$	0.2
T7	$6.5 \pm 0.05^{a,4}$	$5.8 \pm 0.03^{b,3}$	$5.2 \pm 0.04^{d,2}$	$4.4 \pm 0.02^{e,1}$	0.3	$6.5 \pm 0.03^{a,5}$	$5.6 \pm 0.03^{a,4}$	$5.1 \pm 0.06^{c,3}$	$4.7 \pm 0.04^{d,2}$	$3.6 \pm 0.03^{c,1}$	0.2
T8	$6.5 \pm 0.05^{a,4}$	$5.7 \pm 0.03^{b,3}$	$5.2 \pm 0.04^{d,2}$	$4.4 \pm 0.02^{e,1}$	0.3	$6.5 \pm 0.03^{a,5}$	$5.6 \pm 0.03^{a,4}$	$5.1 \pm 0.06^{c,3}$	$4.7 \pm 0.04^{d,2}$	$3.9 \pm 0.03^{d,1}$	0.2
LSD	0.2	0.3	0.3	0.3		0.2	0.3	0.2	0.2	0.3	
(b) Double											
T1	$7.7 \pm 0.04^{a,4}$	$6.4 \pm 0.02^{a,3}$	$4.2 \pm 0.05^{a,2}$	$3.1 \pm 0.03^{a,1}$	0.4	$7.8 \pm 0.05^{a,5}$	$6.6 \pm 0.01^{a,4}$	$5.3 \pm 0.03^{a,3}$	$4.2 \pm 0.03^{a,2}$	$2.9 \pm 0.03^{a,1}$	0.4
T2	$7.6 \pm 0.05^{a,4}$	$6.4 \pm 0.01^{a,3}$	$4.2 \pm 0.03^{a,2}$	$3.5 \pm 0.04^{b,1}$	0.2	$7.8 \pm 0.03^{a,5}$	$6.6 \pm 0.02^{a,4}$	$5.4 \pm 0.02^{a,3}$	$4.4 \pm 0.03^{a,2}$	$3.1 \pm 0.04^{a,1}$	0.4
T3	$7.6 \pm 0.01^{a,4}$	$6.6 \pm 0.03^{a,3}$	$4.4 \pm 0.05^{a,2}$	$3.6 \pm 0.02^{b,1}$	0.4	$7.7 \pm 0.03^{a,5}$	$6.6 \pm 0.03^{a,4}$	$5.5 \pm 0.01^{a,3}$	$4.5 \pm 0.03^{a,2}$	$3.3 \pm 0.03^{b,1}$	0.4
T4	$7.5 \pm 0.03^{a,4}$	$6.8 \pm 0.04^{b,3}$	$4.7 \pm 0.06^{b,2}$	$3.9 \pm 0.04^{c,1}$	0.3	$7.7 \pm 0.02^{a,5}$	$6.8 \pm 0.02^{a,4}$	$5.8 \pm 0.02^{b,3}$	$4.8 \pm 0.03^{b,2}$	$3.8 \pm 0.04^{c,1}$	0.4
T5	$7.4 \pm 0.04^{a,4}$	$6.9 \pm 0.03^{b,3}$	$5.2 \pm 0.04^{c,2}$	$4.5 \pm 0.03^{d,1}$	0.2	$7.5 \pm 0.01^{a,5}$	$6.9 \pm 0.01^{a,4}$	$6.2 \pm 0.03^{c,3}$	$5.2 \pm 0.01^{b,2}$	$4.3 \pm 0.05^{d,1}$	0.3
T6	$7.4 \pm 0.03^{a,4}$	$6.8 \pm 0.03^{b,3}$	$5.3 \pm 0.03^{c,2}$	$4.5 \pm 0.03^{d,1}$	0.3	$7.5 \pm 0.03^{a,5}$	$6.9 \pm 0.04^{a,4}$	$6.2 \pm 0.03^{c,3}$	$5.3 \pm 0.03^{c,2}$	$4.5 \pm 0.01^{d,1}$	0.2
T7	$7.4 \pm 0.03^{a,4}$	$6.9 \pm 0.03^{b,3}$	$5.7 \pm 0.03^{d,2}$	$4.9 \pm 0.03^{e,1}$	0.3	$7.5 \pm 0.03^{a,5}$	$6.9 \pm 0.04^{a,4}$	$6.5 \pm 0.03^{c,3}$	$5.6 \pm 0.03^{c,2}$	$4.9 \pm 0.01^{e,1}$	0.2
T8	$7.4 \pm 0.03^{a,4}$	$6.9 \pm 0.03^{b,3}$	$5.7 \pm 0.03^{d,2}$	$5.1 \pm 0.03^{e,1}$	0.3	$7.5 \pm 0.03^{a,5}$	$6.9 \pm 0.04^{a,4}$	$6.5 \pm 0.03^{c,3}$	$5.6 \pm 0.03^{c,2}$	$4.9 \pm 0.01^{e,1}$	0.2
LSD	0.3	0.3	0.2	0.3		0.3	0.3	0.3	0.4	0.3	

Values are mean ± SD, $n = 3$; LSD = least significant difference ($p \leq 0.05$)

Values within treatments with different superscript lowercase letters (a–e) in a column differ significantly ($p \leq 0.05$)

Values within storage periods with different superscript numerical (1–5) differ significantly ($p \leq 0.05$)

T1 = control; T2 = 0.5 % w/v CMC; T3 = 0.75 % w/v CMC; T4 = 1.0 % w/v CMC; T5 = 1.2 kGy; T6 = 0.5 % w/v CMC, 1.2 kGy; T7 = 0.75 % w/v CMC, 1.2 kGy; T8 = 1.0 % w/v CMC, 1.2 kGy

higher valves of firmness of cherry varieties under both the storage conditions. After 9 days of ambient storage, firmness decrease for control and 0.5–1.0 % w/v CMC coated fruits was of the order of 62.7 and 46.1–56.1 % for Misri variety and 59.7 and 48.0–53.9 % for Double variety respectively. On the other hand, the firmness decrease in samples treated with irradiation only at 1.2 kGy was 40.0 % for Misri variety and 39.2 % for Double variety. In fruits treated with combination of CMC coating (0.5–1.0 % w/v) and 1.2 kGy irradiation, firmness decrease after 9 days of ambient storage was 32.3–40.0 % for Misri variety and 31.1–39.2 % for Double variety. In case of Misri variety, firmness decrease after 28 days of refrigerated storage was 65.1 % for control, 55.4 % for 1.0 % w/v CMC coated fruits and 48.5 % for 1.2 kGy irradiated fruits. Cherry fruits of Misri variety treated with combination of CMC (1.0 % w/v) and 1.2 kGy irradiation recorded firmness decrease of 40.0 % over the same storage period. For Double variety, the firmness decrease after the end of 28 days of refrigerated storage was 62.8 % in control, 50.6 % in 1.0 % w/v CMC coated fruits and 42.7 % in 1.2 kGy irradiated fruits respectively. In fruits treated with combination of CMC (1.0 % w/v) and 1.2 kGy irradiation, the firmness decrease was significantly lower (34.7 %). During ripening and senescence, the activities of enzymes namely protopectinase and pectinmethyl esterase responsible for hydrolyzing and solubilization of pectic substances increases, thereby contributing to firmness decrease. Since irradiation is known to delay the ripening and senescence of fruits (Fan et al. 2003) and combination with methods like CMC coating gives a synergistic effect. Therefore, the significant retention of firmness in samples treated with combination of CMC (1.0 %w/v) and 1.2 kGy irradiation stored under either of the two conditions is attributed to the reduction in the enzymatic activity as a result of individual or synergistic effect of the treatment (Prakash et al. 2002; Hussain et al. 2008).

Total sugars

The data on total sugars, depicted in Table 2 indicated that out of the two varieties, total sugars at harvest time were significantly ($p \leq 0.5$) higher in 'Misri' compared to 'Double'. Data analysis also indicated non-significant ($p \geq 0.05$) difference of total sugars in cherry fruits treated individually or in combination with CMC and gamma irradiation at the first day of storage under both the storage condition. Under ambient conditions, significant increase in total sugars was observed up to 3 days of storage in both the varieties; beyond that a decreasing trend was recorded in both the varieties. However, the increase of total sugars after 3 days of storage was statistically marginal ($p \geq 0.05$) among the treatments for both the varieties. Similar trend in total sugars was observed in fruits kept under refrigerated conditions up to 7 days of storage. In cherry fruits stored under refrigerated conditions, the increase of total sugars in both the varieties was observed up to 14 days. With further advancement in storage, total sugars of cherry varieties decreased significantly; the decrease was higher in samples kept under ambient conditions than under refrigerated condition. Among individual treatments, irradiation at 1.2 kGy and CMC coating at 1.0 % w/v showed significant ($p \leq 0.05$) beneficial effects in maintaining the higher values of total sugars of cherry varieties under both the storage conditions. Among the combinatory treatments, CMC coating (0.75 and 1.0 % w/v) followed by irradiation at 1.2 kGy maintained significantly ($p \leq 0.05$) higher total sugars of cherry varieties under both the storage conditions. For Misri variety, after 9 days of ambient storage; the decrease in total sugars from the maximum value at 3 days; was of the order of 15.5 % in control and 6.2–14.9 % in 0.5–1.0 % w/v CMC coated fruits. Similarly for Double variety; the decrease was of the order of 13.4 and 7.6–13.4 % for the same treatments. On the other hand, the decrease in total sugars for samples treated with irradiation alone at 1.2 kGy was 6.1 % for Misri variety and 8.1 % and for Double variety. However, in fruits treated with combination of CMC coating (0.5–1.0 % w/v) and 1.2 kGy irradiation, decrease in total sugars was 4.0–6.7 % for Misri variety and 5.9–8.8 % for Double variety for the same storage period. In Misri variety, after 28 days of refrigerated storage, the decrease in total sugars from the maximum value at 14 days was 15.6 % for control, 12.1 % for 1.0 % w/v CMC coated fruits, 10.5 % for 1.2 kGy and 6.0 % for fruits treated with combination of 1.0 % w/v CMC and 1.2 kGy irradiation. For Double variety, the firmness decrease for the same treatments after the end of 28 days of storage was 19.4, 13.2, 8.9 and 6.1 % respectively. The initial increase in total sugars is attributed either to enzymatic conversion or radiation induced degradation of higher polysaccharides into simple sugars, where as the subsequent decrease is attributed to oxidation of sugars during respiration (Hussain et al. 2008). Among the treatments, combination of 0.75–1.0 % w/v CMC coating and 1.2 kGy irradiation proved effective in delaying the decrease in total sugars towards the end of storage compared to all other treatments under both the storage conditions, there by indicating a significant ($p \leq 0.05$) delaying effect on the processes of ripening, senescence and respiration.

Total ascorbic acid

Ascorbic acid is required for a range of essential metabolic reactions in all plants and animals. In living organisms, ascorbic acid works as an antioxidant by protecting the

Table 2 Total sugars (%) of cherry fruits treated with combination of carboxymethyl cellulose and gamma irradiation during storage under ambient and refrigerated conditions

Treatments	Ambient storage (days)				LSD	Refrigerated storage (days)					LSD
	0	3	6	9		0	7	14	21	28	
(a) Misri											
T1	$14.1 \pm 0.13^{a,2}$	$14.8 \pm 0.14^{a,3}$	$14.1 \pm 0.14^{a,2}$	$12.5 \pm 0.02^{a,1}$	0.4	$14.1 \pm 0.14^{a,3}$	$14.3 \pm 0.14^{a,3}$	$14.7 \pm 0.14^{a,4}$	$13.3 \pm 0.14^{a,2}$	$12.4 \pm 0.14^{a,1}$	0.4
T2	$14.3 \pm 0.11^{a,2}$	$14.8 \pm 0.13^{a,3}$	$14.1 \pm 0.14^{a,2}$	$12.6 \pm 0.04^{a,1}$	0.4	$14.3 \pm 0.14^{a,3}$	$14.5 \pm 0.13^{a,3}$	$14.8 \pm 0.14^{a,4}$	$13.3 \pm 0.13^{a,2}$	$12.6 \pm 0.14^{a,1}$	0.3
T3	$14.2 \pm 0.13^{a,2}$	$14.6 \pm 0.12^{a,3}$	$14.3 \pm 0.13^{a,2}$	$13.1 \pm 0.03^{b,1}$	0.3	$14.3 \pm 0.13^{a,3}$	$14.6 \pm 0.13^{a,3}$	$14.9 \pm 0.14^{a,4}$	$13.6 \pm 0.15^{a,2}$	$12.9 \pm 0.16^{b,1}$	0.4
T4	$14.2 \pm 0.14^{a,2}$	$14.5 \pm 0.13^{a,2}$	$14.3 \pm 0.13^{a,2}$	$13.6 \pm 0.01^{c,1}$	0.3	$14.3 \pm 0.13^{a,3}$	$14.6 \pm 0.12^{a,3}$	$14.9 \pm 0.12^{a,4}$	$13.6 \pm 0.15^{a,2}$	$13.1 \pm 0.14^{b,1}$	0.3
T5	$14.5 \pm 0.13^{a,2}$	$14.8 \pm 0.14^{a,2}$	$14.6 \pm 0.11^{b,2}$	$13.9 \pm 0.02^{c,1}$	0.4	$14.6 \pm 0.13^{a,3}$	$14.8 \pm 0.12^{a,3}$	$15.2 \pm 0.15^{b,4}$	$14.2 \pm 0.14^{b,2}$	$13.6 \pm 0.13^{c,1}$	0.3
T6	$14.5 \pm 0.15^{a,2}$	$14.9 \pm 0.14^{a,3}$	$14.6 \pm 0.14^{b,2}$	$13.9 \pm 0.02^{c,1}$	0.3	$14.5 \pm 0.12^{a,2}$	$14.8 \pm 0.12^{a,3}$	$15.2 \pm 0.16^{b,4}$	$14.4 \pm 0.14^{b,2}$	$13.6 \pm 0.15^{c,1}$	0.2
T7	$14.6 \pm 0.15^{a,1}$	$14.9 \pm 0.13^{a,2}$	$14.6 \pm 0.14^{b,1}$	$14.3 \pm 0.02^{d,1}$	0.4	$14.5 \pm 0.12^{a,2}$	$14.8 \pm 0.14^{a,3}$	$15.1 \pm 0.14^{b,4}$	$14.6 \pm 0.13^{c,2}$	$14.2 \pm 0.13^{d,1}$	0.2
T8	$14.5 \pm 0.15^{a,1}$	$14.9 \pm 0.14^{a,2}$	$14.6 \pm 0.14^{b,1}$	$14.3 \pm 0.02^{d,1}$	0.3	$14.6 \pm 0.13^{a,2}$	$14.8 \pm 0.14^{a,2}$	$15.1 \pm 0.15^{b,3}$	$14.6 \pm 0.13^{c,2}$	$14.2 \pm 0.14^{d,1}$	0.2
LSD	0.5	0.4	0.3	0.3		0.5	0.5	0.3	0.3	0.3	
(b) Double											
T1	$12.5 \pm 0.14^{a,2}$	$13.4 \pm 0.15^{a,3}$	$12.4 \pm 0.15^{a,2}$	$11.6 \pm 0.15^{a,1}$	0.4	$12.3 \pm 0.15^{a,2}$	$12.6 \pm 0.14^{a,3}$	$13.9 \pm 0.16^{b,4}$	$12.1 \pm 0.03^{a,2}$	$11.2 \pm 0.03^{a,1}$	0.4
T2	$12.6 \pm 0.15^{a,2}$	$13.4 \pm 0.15^{a,3}$	$12.4 \pm 0.13^{a,2}$	$11.6 \pm 0.14^{b,1}$	0.3	$12.5 \pm 0.13^{a,2}$	$12.8 \pm 0.14^{a,3}$	$13.9 \pm 0.16^{b,4}$	$12.2 \pm 0.03^{a,2}$	$11.2 \pm 0.04^{a,1}$	0.4
T3	$12.6 \pm 0.13^{a,2}$	$13.2 \pm 0.13^{a,3}$	$12.6 \pm 0.15^{a,2}$	$11.8 \pm 0.15^{a,1}$	0.4	$12.5 \pm 0.13^{a,2}$	$12.8 \pm 0.13^{a,2}$	$13.6 \pm 0.14^{b,3}$	$12.8 \pm 0.03^{b,2}$	$11.6 \pm 0.03^{a,1}$	0.4
T4	$12.5 \pm 0.13^{a,1}$	$13.2 \pm 0.14^{a,3}$	$12.6 \pm 0.16^{a,2}$	$12.2 \pm 0.14^{b,1}$	0.3	$12.4 \pm 0.14^{a,2}$	$12.8 \pm 0.13^{a,2}$	$13.6 \pm 0.14^{b,3}$	$12.8 \pm 0.03^{b,2}$	$11.8 \pm 0.04^{b,1}$	0.4
T5	$12.9 \pm 0.14^{a,2}$	$13.5 \pm 0.13^{a,3}$	$12.9 \pm 0.14^{b,2}$	$12.4 \pm 0.16^{b,1}$	0.2	$12.6 \pm 0.14^{a,2}$	$12.9 \pm 0.15^{a,2}$	$13.4 \pm 0.13^{a,3}$	$12.8 \pm 0.01^{b,2}$	$12.2 \pm 0.05^{b,1}$	0.3
T6	$12.9 \pm 0.16^{a,2}$	$13.6 \pm 0.15^{a,3}$	$12.9 \pm 0.13^{b\ 2}$	$12.4 \pm 0.15^{b,1}$	0.3	$12.5 \pm 0.14^{a,1}$	$12.9 \pm 0.14^{a,2}$	$13.2 \pm 0.13^{a,3}$	$12.6 \pm 0.03^{b,2}$	$12.2 \pm 0.01^{b,1}$	0.3
T7	$12.8 \pm 0.14^{a,1}$	$13.6 \pm 0.15^{a,3}$	$13.2 \pm 0.13^{b,2}$	$12.8 \pm 0.14^{c,1}$	0.3	$12.6 \pm 0.15^{a,1}$	$12.9 \pm 0.15^{a,2}$	$13.4 \pm 0.14^{a,3}$	$12.8 \pm 0.03^{b,2}$	$12.4 \pm 0.01^{c,1}$	0.3
T8	$12.9 \pm 0.13^{a,1}$	$13.6 \pm 0.14^{a,3}$	$13.2 \pm 0.14^{b,2}$	$12.8 \pm 0.14^{c,1}$	0.3	$12.7 \pm 0.15^{a,1}$	$12.9 \pm 0.15^{a,2}$	$13.2 \pm 0.13^{a,3}$	$12.8 \pm 0.03^{b,1}$	$12.4 \pm 0.01^{c,1}$	0.4
LSD	0.4	0.4	0.3	0.4		0.4	0.3	0.3	0.3	0.4	

Values are mean ± SD, $n = 3$; LSD = least significant difference ($p \leq 0.05$)

Values within treatments with different superscript lowercase letters (a–d) in a column differ significantly ($p \leq 0.05$)

Values within storage periods with different superscript numerical (1–4) differ significantly ($p \leq 0.05$)

T1 = control; T2 = 0.5 % w/v CMC; T3 = 0.75 % w/v CMC; T4 = 1.0 % w/v CMC; T5 = 1.2 kGy; T6 = 0.5 % w/v CMC, 1.2 kGy; T7 = 0.75 % w/v CMC, 1.2 kGy; T8 = 1.0 % w/v CMC, 1.2 kGy

body against oxidative stress and also works as a cofactor in several vital enzymatic reactions. Total ascorbic acid content of cherry varieties is presented in Table 3. Data revealed that ascorbic acid was significantly ($p \leq 0.05$) higher in 'Double' variety compared to 'Misri'. It is seen from the Table 3 that treatment of irradiation either alone or in combination with CMC coating resulted in non-significant ($p \geq 0.05$) decrease in ascorbic acid content when compared with control and CMC coated samples just after the treatment. During storage significant ($p \leq 0.05$) decrease in ascorbic acid was recorded in all the treatments under both the storage conditions for both the varieties. Decrease was significantly ($p \leq 0.05$) higher in fruits stored under ambient condition compared refrigerated condition. After 3 days of ambient storage; there was no significant ($p \geq 0.0$) difference in total ascorbic acid content of control fruits and those treated with individual treatments of 0.5–1.0 % (w/v) CMC and 1.2 kGy irradiation. Comparison of the treatments based on statistical analysis revealed that combination treatment of CMC (0.75–1.0 % w/v) and 1.2 kGy was significantly effective in maintaining the higher ascorbic acid content of cherry samples of both the varieties under both the storage conditions towards the end of storage. Percentage decrease of ascorbic acid content in Misri variety after 9 days of ambient storage was 77.3 % in control; 71.6–75.4 % in 0.5–1.0 % w/v CMC coated fruits, 63.5 % in 1.2 kGy irradiated fruits and 53.9–59.7 % in fruits treated with combination of CMC coating and irradiation respectively. For Double variety, the ascorbic acid decrease for the same treatments after the end of 9 days of ambient storage was 75.6, 69.2–75, 62.2 and 48.6–53.4 % respectively. Under the refrigerated conditions after 7 days of storage, there was no significant ($p \geq 0.05$) difference of ascorbic acid content in both the varieties for all the treatments including control. However, after 28 days of refrigerated storage, significant ($p \leq 0.05$) differences in ascorbic acid existed among the treatments and the levels were significantly ($p \leq 0.05$) higher in fruits treated with combination of CMC coating (1.0 % w/v) and irradiation at 1.2 kGy. In Misri variety, ascorbic acid decrease after 28 days of refrigerated storage was 79.4 % in control; 66.2–72.3 % in 0.5–1.0 % w/v CMC coated fruits, 55.6 % in 1.2 kGy irradiated fruits and 30.1–51.6 % in fruits treated with combination of CMC coating and irradiation respectively. For Double variety, the ascorbic acid decrease for the same treatments after the end of 28 days of refrigerated storage was 78.9, 69.2–75.6, 63.5 and 40.5–56.2 % respectively. Thus it can be inferred that main loss of ascorbic acid is because of storage rather than irradiation. The ascorbic acid loss during storage is known to be because of its antioxidant activity especially under postharvest storage conditions (Davey et al. 2000). Also, the lower ascorbic acid found just after irradiation, in fruits treated with 1.2 kGy irradiation alone and in combination with coating seems to indicate that radiolysis could accelerate the conversion of ascorbic acid to dehydroascorbic acid (DHA). That is, ascorbic acid which is the reduced form and the one with a higher vitamin C activity can be rapidly and reversibly oxidized to DHA, which is biologically active but to a less extent. Wong and Kitts (2001) suggested that the decrease in ascorbic acid in food during ionization can be attributed to two mechanisms: the first occurring by the direct oxidation of ascorbic acid through the action of OH radical generated by the water radiolysis in the fruits and the second by the oxidation of ascorbic acid, as it is consumed during the treatment to protect other compounds against the oxidative damage induced by the ionization. The higher retention of ascorbic acid in cherries subjected to combination of CMC coating and irradiation during storage is because of synergistic effect of the treatments on delaying the process of respiration and senescence.

Total anthocyanins

The data on total anthocyanins revealed that 'Misri' variety had significantly ($p \leq 0.05$) higher anthocyanins than 'Double' (Fig. 1). Among treatments including control for both the varieties, there was no significant ($p \geq 0.05$) difference in anthocyanin content at zero days of storage. During storage, the anthocyanins recorded a decreasing trend in both the varieties irrespective of storage condition and treatment; however, the decrease was higher under ambient storage compared to refrigerated storage. Data analysis revealed that after 9 days of ambient storage, the anthocyanin content was significantly ($p \leq 0.05$) higher in cherries treated with combination of CMC (0.75 and 1.0 % w/v) and 1.2 kGy for both the varieties. Similar observation was recorded in fruits kept under refrigerated conditions after 28 days of storage. For Misri variety after 9 days of ambient storage; the anthocyanin content decreased by 29.5 % in control and 21.6–29.0 % in 0.5–1.0 % (w/v) CMC coated fruits. In fruits treated with irradiation alone and in combination with CMC, the decrease was 16.1 and 6.4–18.7 % respectively. In case of Double variety; after 9 days of ambient storage, the decrease in anthocyanins was 44.7 % in control and 31.9–40.6 % in 0.5–1.0 % (w/v) CMC coated fruits. Decrease of 26.5 and 10.2–27.4 % was recorded in fruits treated with irradiation alone and in combination with CMC coating. Under refrigerated conditions after 28 days of storage; the anthocyanin decrease in Misri variety was 25.8 % in control and 16.1–24.6 % in 0.5–1.0 % (w/v) CMC coated fruits. Decrease of 14.9 % was recorded in 1.2 kGy irradiated fruits compared to 6.3–10.4 % in fruits treated with combination of CMC and irradiation. In case

Table 3 Total ascorbic acid (mg/100 g) content of cherry fruits treated with combination of carboxymethyl cellulose and gamma irradiation during storage under ambient and refrigerated conditions

Treatments	Ambient storage (days)				LSD	Refrigerated storage (days)					LSD
	0	3	6	9		0	7	14	21	28	
(a) Misri											
T1	$6.6 \pm 0.11^{a,4}$	$4.3 \pm 0.14^{a,3}$	$2.1 \pm 0.14^{a,2}$	$1.5 \pm 0.12^{a,1}$	0.4	$6.8 \pm 0.14^{a,5}$	$5.6 \pm 0.14^{a,4}$	$4.1 \pm 0.14^{a,3}$	$3.3 \pm 0.14^{a,2}$	$1.4 \pm 0.14^{a,1}$	0.4
T2	$6.5 \pm 0.12^{a,4}$	$4.3 \pm 0.13^{a,3}$	$2.1 \pm 0.14^{a,2}$	$1.6 \pm 0.13^{a,1}$	0.3	$6.5 \pm 0.14^{a,5}$	$5.5 \pm 0.13^{a,4}$	$4.1 \pm 0.14^{a,3}$	$3.3 \pm 0.13^{a,2}$	$1.7 \pm 0.14^{a,1}$	0.3
T3	$6.5 \pm 0.13^{a,4}$	$4.5 \pm 0.12^{a,3}$	$2.4 \pm 0.13^{a,2}$	$1.9 \pm 0.13^{a,1}$	0.3	$6.5 \pm 0.13^{a,5}$	$5.6 \pm 0.13^{a,4}$	$4.3 \pm 0.14^{a,3}$	$3.6 \pm 0.15^{a,2}$	$1.9 \pm 0.16^{b,1}$	0.4
T4	$6.7 \pm 0.12^{a,4}$	$4.8 \pm 0.13^{a,3}$	$2.7 \pm 0.13^{b,2}$	$1.9 \pm 0.11^{a,1}$	0.3	$6.8 \pm 0.13^{a,5}$	$5.6 \pm 0.12^{a,4}$	$4.6 \pm 0.12^{b,3}$	$3.6 \pm 0.15^{a,2}$	$2.3 \pm 0.14^{b,1}$	0.3
T5	$6.3 \pm 0.13^{a,4}$	$4.8 \pm 0.14^{a,3}$	$3.1 \pm 0.11^{b,2}$	$2.3 \pm 0.12^{b,1}$	0.4	$6.3 \pm 0.13^{a,5}$	$5.8 \pm 0.12^{a,4}$	$4.9 \pm 0.15^{b,3}$	$4.2 \pm 0.14^{b,2}$	$2.8 \pm 0.13^{c,1}$	0.3
T6	$6.2 \pm 0.12^{a,4}$	$4.9 \pm 0.14^{b,3}$	$3.1 \pm 0.14^{b,2}$	$2.5 \pm 0.12^{b,1}$	0.3	$6.4 \pm 0.12^{a,5}$	$5.8 \pm 0.12^{a,4}$	$4.9 \pm 0.16^{b,3}$	$4.4 \pm 0.14^{b,2}$	$3.1 \pm 0.15^{c,1}$	0.2
T7	$6.3 \pm 0.14^{a,4}$	$5.3 \pm 0.13^{b,3}$	$3.9 \pm 0.14^{c,2}$	$2.9 \pm 0.13^{c,1}$	0.4	$6.3 \pm 0.12^{a,5}$	$5.8 \pm 0.14^{a,4}$	$5.3 \pm 0.14^{c,3}$	$4.8 \pm 0.13^{c,2}$	$3.9 \pm 0.13^{d,1}$	0.3
T8	$6.3 \pm 0.13^{a,4}$	$5.3 \pm 0.14^{b,3}$	$3.9 \pm 0.14^{c,2}$	$2.9 \pm 0.13^{c,1}$	0.3	$6.3 \pm 0.13^{a,3}$	$5.8 \pm 0.14^{a,2}$	$5.3 \pm 0.15^{c,2}$	$4.8 \pm 0.13^{c,1}$	$4.4 \pm 0.14^{e,1}$	0.4
LSD	0.5	0.5	0.4	0.4		0.5	0.4	0.3	0.4	0.3	
(b) Double											
T1	$7.8 \pm 0.14^{a,4}$	$5.3 \pm 0.14^{a,3}$	$3.1 \pm 0.15^{a,2}$	$1.9 \pm 0.15^{a,1}$	0.4	$7.6 \pm 0.12^{a,5}$	$6.1 \pm 0.14^{a,4}$	$4.2 \pm 0.16^{a,3}$	$3.3 \pm 0.03^{a,2}$	$1.6 \pm 0.03^{a,1}$	0.4
T2	$7.6 \pm 0.15^{a,4}$	$5.4 \pm 0.13^{a,3}$	$3.4 \pm 0.13^{a,2}$	$1.9 \pm 0.14^{a,1}$	0.3	$7.8 \pm 0.13^{a,5}$	$6.4 \pm 0.14^{a,4}$	$4.2 \pm 0.16^{a,3}$	$3.6 \pm 0.03^{a,2}$	$1.9 \pm 0.04^{a,1}$	0.4
T3	$7.6 \pm 0.13^{a,4}$	$5.3 \pm 0.13^{a,3}$	$3.6 \pm 0.15^{b,2}$	$2.4 \pm 0.15^{b,1}$	0.4	$7.5 \pm 0.13^{a,5}$	$6.3 \pm 0.13^{a,4}$	$4.8 \pm 0.14^{b,3}$	$3.8 \pm 0.03^{b,2}$	$1.9 \pm 0.03^{a,1}$	0.4
T4	$7.8 \pm 0.13^{a,4}$	$5.5 \pm 0.14^{a,3}$	$3.9 \pm 0.16^{b,2}$	$2.4 \pm 0.14^{b,1}$	0.3	$7.8 \pm 0.14^{a,5}$	$6.5 \pm 0.13^{a,4}$	$4.8 \pm 0.14^{b,3}$	$4.2 \pm 0.03^{c,2}$	$2.4 \pm 0.04^{b,1}$	0.4
T5	$7.4 \pm 0.14^{a,4}$	$5.5 \pm 0.13^{a,3}$	$4.1 \pm 0.14^{c,2}$	$2.8 \pm 0.16^{b,1}$	0.5	$7.4 \pm 0.14^{a,4}$	$6.5 \pm 0.15^{a,3}$	$4.8 \pm 0.13^{b,2}$	$4.6 \pm 0.01^{d,2}$	$2.7 \pm 0.05^{b,1}$	0.3
T6	$7.3 \pm 0.13^{a,4}$	$5.9 \pm 0.12^{b,3}$	$4.4 \pm 0.13^{c,2}$	$3.4 \pm 0.15^{c,1}$	0.5	$7.3 \pm 0.14^{a,5}$	$6.5 \pm 0.14^{a,4}$	$5.4 \pm 0.13^{c,3}$	$4.6 \pm 0.03^{d,2}$	$3.2 \pm 0.01^{c,1}$	0.3
T7	$7.4 \pm 0.14^{a,4}$	$5.9 \pm 0.12^{b,3}$	$4.6 \pm 0.13^{d,2}$	$3.8 \pm 0.14^{c,1}$	0.4	$7.4 \pm 0.13^{a,5}$	$6.6 \pm 0.15^{a,4}$	$5.6 \pm 0.14^{c,3}$	$4.9 \pm 0.03^{d,2}$	$3.8 \pm 0.01^{d,1}$	0.3
T8	$7.4 \pm 0.13^{a,4}$	$5.9 \pm 0.14^{b,3}$	$4.6 \pm 0.14^{d,2}$	$3.8 \pm 0.14^{c,1}$	0.4	$7.4 \pm 0.13^{a,4}$	$6.6 \pm 0.15^{a,3}$	$5.6 \pm 0.13^{c,2}$	$4.9 \pm 0.03^{d,1}$	$4.4 \pm 0.01^{e,1}$	0.5
LSD	0.5	0.4	0.3	0.4		0.6	0.5	0.4	0.3	0.4	

Values are mean ± SD, $n = 3$; LSD = least significant difference ($p \leq 0.05$)

Values within treatments with different superscript lowercase letters (a–e) in a column differ significantly ($p \leq 0.05$)

Values within storage periods with different superscript numerical (1–5) differ significantly ($p \leq 0.05$)

T1 = control; T2 = 0.5 % w/v CMC; T3 = 0.75 % w/v CMC; T4 = 1.0 % w/v CMC; T5 = 1.2 kGy; T6 = 0.5 % w/v CMC, 1.2 kGy; T7 = 0.75 % w/v CMC, 1.2 kGy; T8 = 1.0 % w/v CMC, 1.2 kGy

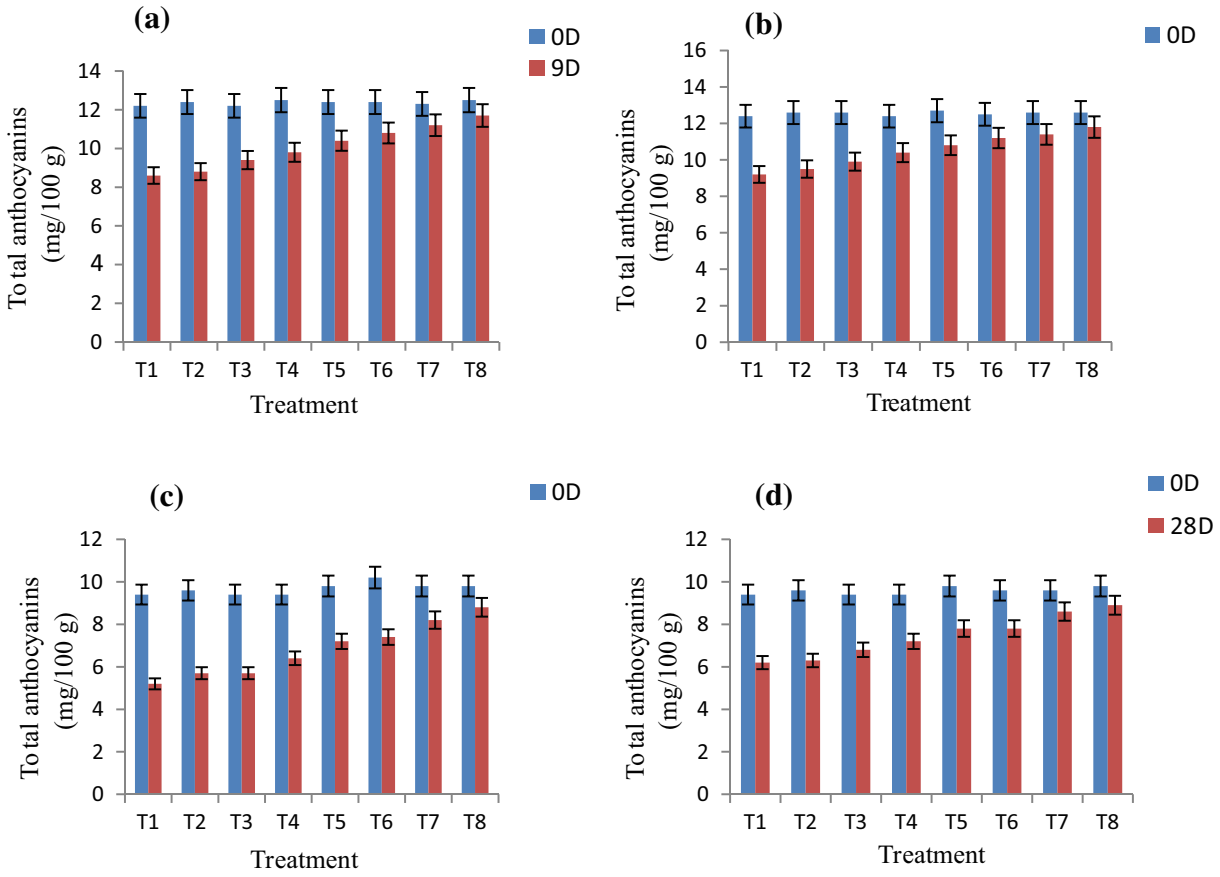

Fig. 1 Total anthocyanin content of cherries varieties treated with CMC and gamma irradiation. T1 = control; T2 = 0.5 % w/v CMC; T3 = 0.75 % w/v CMC; T4 = 1.0 % w/v CMC; T5 = 1.2 kGy; T6 = 0.5 % w/v CMC, 1.2 kGy; T7 = 0.75 % w/v CMC, 1.2 kGy; T8 = 1.0 % w/v CMC, 1.2 kGy. **a** Misri; ambient storage, **b** Misri; refrigerated storage, **c** Double; ambient storage, **d** Double; refrigerated storage

of Double variety, decrease of 34.0 % was recorded in control compared to 23.4–34.4 % in 0.5–1.0 % (w/v) CMC coated fruits. Fruits subjected to irradiation alone and in combination with CMC coating recorded a decrease of 20.4 and 9.2–18.7 % respectively. This lower decrease in anthocyanins in samples irradiated combination of CMC and irradiation is attributed to the synergistic inhibitory effect of treatment on the rate of anthocyanin degradation (Hussain et al. 2012).

Total phenols

Phenolics are reported to reduce the risk of cancer, heart disease and other age related degenerative diseases. They have an antioxidant action and scavenge reactive oxygen species or quench singlet oxygen (Patel et al. 2011). The present study revealed that total phenols were significantly ($p \leq 0.05$) higher in Misri compared to Double (Fig. 2). There was no significant difference in total phenols of control and CMC treated fruits of both the varieties just after treatment. However, an increase in total phenol content of both the cherry varieties was observed in samples treated with irradiation alone or in combination with CMC just after treatment. During storage, total phenols exhibited a decreasing trend in both the varieties irrespective of treatment and storage condition. Decrease was significant ($p \leq 0.05$) in samples kept under ambient storage compared to refrigerated storage. During further storage, significant differences existed in total phenols among treatments. Combination treatment of 1.0 % (w/v) CMC and 1.2 kGy irradiation proved significantly ($p \leq 0.05$) effective in maintaining the higher total phenol content throughout the storage for both the varieties. Data analysis indicated that percentage decrease of total phenol content in Misri variety after 9 days of ambient storage was 82.1 % in control and 67.2–77.7 % in 0.5–1.0 % (w/v) CMC coated fruits. Decrease of 64.4 % and 48.3–59.9 % was recorded in fruits treated with irradiation alone and in combination with CMC. For Double variety, total phenol decrease after the end of 9 days of ambient storage was 86.1 % in control and 69.6–80.3 % in 0.5–1.0 % (w/v) CMC coated fruits. In fruits treated with irradiation alone

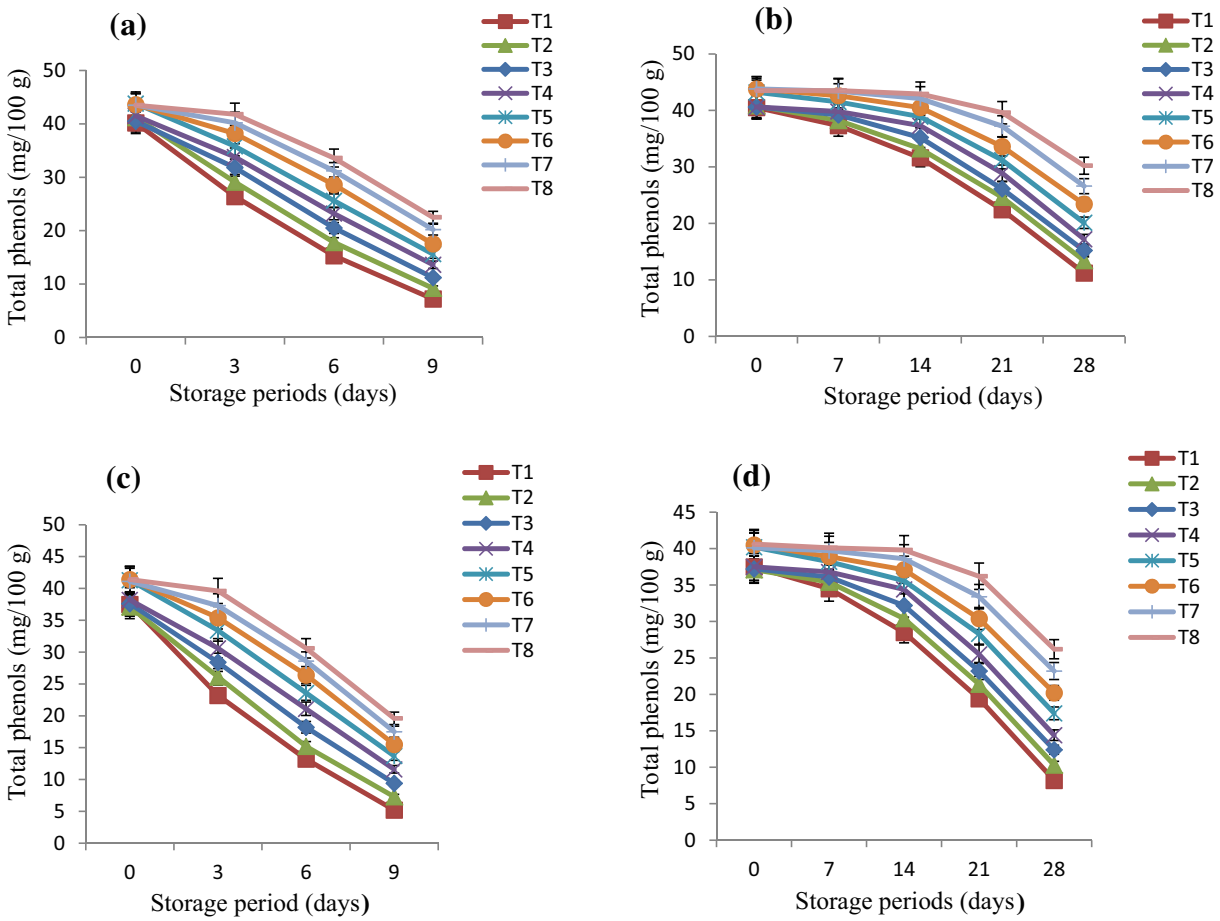

Fig. 2 Total phenols of cherries varieties treated with CMC and gamma irradiation. T1 = control; T2 = 0.5 % w/v CMC; T3 = 0.75 % w/v CMC; T4 = 1.0 % w/v CMC; T5 = 1.2 kGy; T6 = 0.5 % w/v CMC, 1.2 kGy; T7 = 0.75 % w/v CMC, 1.2 kGy; T8 = 1.0 % w/v CMC, 1.2 kGy. **a** Misri; ambient storage, **b** Misri; refrigerated storage, **c** Double; ambient storage, **d** Double; refrigerated storage

and in combination with CMC, decrease in total phenol content was 66.8 and 52.6–62.6 % respectively. Under refrigerated conditions after 28 days of storage, total phenol decrease in Misri variety was 72.3 % in control and 57.6–67.1 % in 0.5–1.0 % w/v CMC coated fruits. Decrease of 53.8 % was recorded in 1.2 kGy irradiated fruits compared to 30.1–46.6 % in fruits treated with combination of CMC coating and irradiation. For Double variety, the decrease in total phenolics after 28 days of refrigerated storage was 78.1 % in control and 61.6–72.2 % in 0.5–1.0 % (w/v) CMC coated fruits. Decrease of 61.6 and 35.5–50.1 % was recorded in fruits treated with irradiation alone and in combination with CMC. The increase in total phenols in samples treated with irradiation alone and in combination with coating is explained by the release of phenolic compounds from glycosidic compounds and degradation of larger phenolic compounds into smaller ones by irradiation (Stajner et al. 2007). The ability of gamma irradiation to increase phenolic compounds has also been observed in soya bean and peach samples treated with irradiation at levels ranging from 0.05 to 0.15 kGy and 1 to 2 kGy (Variyar et al. 2004; Hussain et al. 2010). The decrease in total phenolics during storage is attributed to poplyphenol oxidase (PPO)-catalyzed oxidation of phenolic compounds. During storage, process of senescence, solubilisation of cell wall pectic substances and microbial infestation result in sub cellular decompartmentation, disruption of membrane integrity and oxygen penetration, thereby leading to enhanced activity of PPO responsible for oxidation of phenols. It is usually believed that senescence or injury results in destruction of the biological barrier between PPO and polyphenols, and the enzyme is active only when it unites with its phenolic substrates (Barrett et al. 1991; Murata et al. 1997). Moreover, quinones formed during PPO oxidation reactions may undergo redox recycling; thereby generate free radicals that are neutralized at the expense of phenols (Felton et al. 1992). Because irradiation as well as coating treatment has

an inhibitory effect on the rates of respiration and senescence responsible for oxidative breakdown of phenolics; hence, combinatory treatment of CMC coating and irradiation maintained higher phenols in cherry fruits towards the end of storage (Hussain et al. 2010).

Weight loss

Weight loss is a major cause of quality deterioration in fresh horticultural crops after harvest. Effect of individual and combinatory treatments of CMC coating and gamma irradiation on weight loss of cherry fruits is shown in Fig. 3. The data indicated that weight loss was significantly ($p \leq 0.05$) higher in 'Double' variety as compared to 'Misri. The data analysis also revealed that for 'Misri' variety after 3 days of ambient storage, there was no significant difference in weight loss between control, 0.5 and 0.75 % w/v CMC treated fruits. Similar trend was recorded in fruits treated with individual treatments of 1.0 % w/v CMC and 1.2 kGy irradiation. The weight loss of fruits treated with combination of CMC coating (0.5–1.0 % w/v) and 1.2 kGy was also marginally different with respect to each other but, significantly ($p \leq 0.05$) lower compared to all other treatments after 3 days of ambient storage. Almost similar trend of weight loss was recorded among treatment for Double variety also after the same storage period. After 9 days of ambient storage, weight loss was significantly higher in control and 0.5 % w/v CMC coated fruits for both the varieties compared to all other treatments. The combinatory treatments in particular 1.0 % w/v CMC and 1.2 kGy irradiation proved highly effective in reducing the weight loss of cherry fruits of both the varieties after the end of storage. Under refrigerated conditions the weight loss was significantly ($p \leq 0.05$) lower compared to ambient storage irrespective of the treatments, which is attributed to the delayed effect of low temperature on the

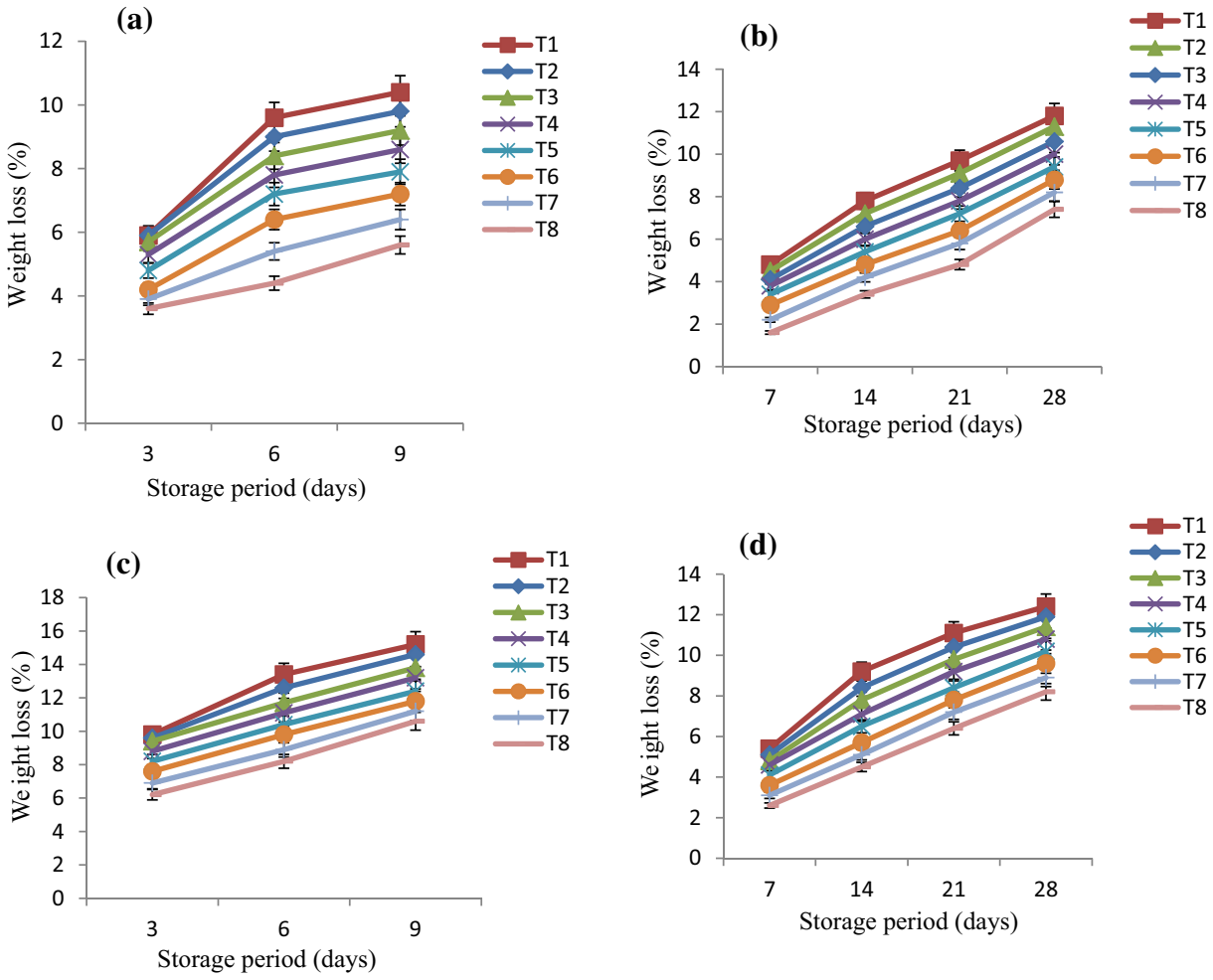

Fig. 3 Weight loss of cherry varieties treated with CMC and gamma irradiation. T1 = control; T2 = 0.5 % w/v CMC; T3 = 0.75 % w/v CMC; T4 = 1.0 % w/v CMC; T5 = 1.2 kGy; T6 = 0.5 % w/v CMC, 1.2 kGy; T7 = 0.75 % w/v CMC, 1.2 kGy; T8 = 1.0 % w/v CMC, 1.2 kGy. **a** Misri; ambient storage, **b** Misri; refrigerated storage, **c** Double; ambient storage, **d** Double; refrigerated storage

rates of transpiration and respiration responsible for weight loss. However, after 7 days of storage; weight loss of control samples was significantly ($p \leq 0.05$) higher compared to individual as well as combinatory treatments of CMC coating and gamma irradiation. Data analysis also revealed that among the coating treatments, weight loss increased inversely with increase in coating concentration. The reduction in weight loss in cherry fruits treated with coating followed by irradiation is because of the effect of the combinatory treatment on the respiration rate and in delaying the process of senescence. Further coatings are clearly effective in conferring a physical barrier to moisture loss, and therefore retarding dehydration and fruit shriveling (Almenar et al. 2006).

Overall acceptability (OAA)

Overall acceptability based on color, texture and taste of the cherry fruits treated with CMC coating and irradiation is shown in Table 4. Data analysis indicated that among treatments including control, there was no significant ($p \leq 0.05$) in overall acceptability of cherry varieties up to 3 days of ambient storage. Similar trend was also observed up to 7 days of refrigerated storage. In case of Misri variety, after 6 days of ambient storage; overall acceptability of control and 0.5–1.0 % (w/v) CMC coated fruits differed marginally ($p \geq 0.05$) with respect to each other and was significantly ($p \leq 0.05$) lower compared to fruits treated with irradiation alone and in combination with CMC. This trend in overall acceptability was observed even after 9 days of ambient storage. For Double variety, the overall acceptability of control and 0.5 % w/v CMC coated fruits was below the acceptable limit after 6 days of ambient storage. In fruits treated with CMC coating (0.75, 1.0 % w/v), 1.2 kGy irradiation and combination of coating and irradiation (0.5 % w/v CMC, 1.2 kGy); overall acceptability was below the acceptable limit after 9 days of ambient storage. Under refrigerated conditions for Misri variety; overall acceptability was significantly above the acceptable limit in all the treatments including control up to 21 days of storage. On the other hand, in Double variety; overall acceptability was below the acceptable limit in control and 0.5 % w/v CMC coated fruits over the same storage period. Statistical analysis of the data revealed that after 28 days of refrigerated storage, overall acceptability of fruits of both the varieties treated with irradiation alone and in combination with CMC coating (0.5–1.0 % w/v) was above the acceptable limit when compared with individual treatments of CMC and control respectively. Among the combinatory treatments, 1.0 % w/v CMC followed by irradiation at 1.2 kGy was significantly ($p \leq 0.05$) effective in maintaining the higher overall acceptability of cherry varieties under both the storage conditions. The fast decrease in overall acceptability of control and CMC coated samples (0.5–1.0 % w/v) is related to the decrease in texture, color and loss of volatile as perceived by the panelists because of rapid ripening, senescence and fungal decay. The synergistic effect of combinatory treatment of coating and irradiation on inhibition of fungal growth and retention of texture and color proved significantly beneficial ($p \leq 0.05$) in maintaining higher overall acceptability of cherries during storage (Hussain et al. 2010).

Microbial load

Effect of individual and combination treatments of CMC coating and radiation processing on microbial load as yeast and mold count of cherry varieties during storage under ambient and refrigerated conditions is shown in Table 5. Data pertaining to microbial load revealed that irradiation treatment alone and in combination with CMC coating decreased significantly ($p \leq 0.05$) the yeast and mold count of Misri and Double cherries under both the storage conditions. In samples treated with irradiation (1.2 kGy) alone and in combination with CMC coating at 0.5–1.0 % w/v, no microbial load was detected up to 3 and 6 days of ambient storage for both the cherry varieties. After 9 days of ambient storage, gamma irradiation treatment alone at 1.2 kGy resulted in 1.9 and 1.8 log reduction in microbial load in Misri and Double cherries respectively. Combination treatment of CMC coating and irradiation resulted in 2.0 and 2.2 log reduction in microbial load in Misri and Double cherries when compared with control. Treatment of CMC coating at 0.5, 0.75 and 1.0 % w/v gave 0.1, 0.6 and 1.3 log reductions in yeast and mold count of Misri variety and 0.5, 0.7 and 1.3 log reductions for Double variety after 9 days of ambient storage. Under refrigerated conditions, individual treatments of CMC coating at 1.0 % w/v and 1.2 kGy irradiation inhibited the occurrence of yeast and mold growth up to 7 days of storage. Combination of 0.5 % w/v CMC and 1.2 kGy irradiation inhibited the occurrence of yeast and mold growth up to 14 days of storage for both the varieties. Combination of CMC coating (0.75, 1.0 % w/v) and 1.2 kGy irradiation proved significantly ($p \leq 0.05$) effective in inhibiting the microbial growth up to 21 days of storage. The results of the present study confirmed that the combination treatment of edible coating (1.0 % w/v CMC) and irradiation (1.2 kGy) was more effective means of reducing the fungal decay of cherry fruit than the individual treatments of coating and irradiation. The significant ($p \leq 0.05$) reduction in fungal decay of cherry varieties treated with combination treatment of coating and irradiation appeared to be related to the yeast antagonistic and fungi static effect of the treatment (Zhang et al. 2003). Our results are in agreement with the previous works reporting the delay in mould

Table 4 Overall acceptability score of cherry fruits treated with combination of carboxymethyl cellulose and gamma irradiation during storage under ambient and refrigerated conditions

Treatments	Ambient storage (days)				LSD	Refrigerated storage (days)					LSD
	0	3	6	9		0	7	14	21	28	
(a) Misri											
T1	$3.8 \pm 0.11^{a,3}$	$3.3 \pm 0.14^{a,3}$	$2.5 \pm 0.14^{a,2}$	$1.4 \pm 0.12^{a,1}$	0.5	$3.9 \pm 0.14^{a,4}$	$3.6 \pm 0.14^{a,4}$	$3.1 \pm 0.14^{a,3}$	$2.6 \pm 0.14^{a,2}$	$1.7 \pm 0.14^{a,1}$	0.4
T2	$3.7 \pm 0.12^{a,3}$	$3.3 \pm 0.13^{a,3}$	$2.5 \pm 0.14^{a,2}$	$1.5 \pm 0.13^{a,1}$	0.4	$3.8 \pm 0.14^{a,4}$	$3.5 \pm 0.13^{a,4}$	$3.1 \pm 0.14^{a,3}$	$2.6 \pm 0.13^{a,2}$	$1.7 \pm 0.14^{a,1}$	0.3
T3	$3.8 \pm 0.13^{a,3}$	$3.5 \pm 0.12^{a,3}$	$2.8 \pm 0.13^{a,2}$	$1.8 \pm 0.13^{a,1}$	0.3	$3.8 \pm 0.13^{a,4}$	$3.6 \pm 0.13^{a,4}$	$3.3 \pm 0.14^{a,2}$	$2.9 \pm 0.15^{a,2}$	$2.1 \pm 0.16^{b,1}$	0.4
T4	$3.7 \pm 0.12^{a,3}$	$3.5 \pm 0.13^{a,3}$	$2.8 \pm 0.13^{a,2}$	$1.8 \pm 0.11^{a,1}$	0.3	$3.8 \pm 0.13^{a,3}$	$3.6 \pm 0.12^{a,3}$	$3.6 \pm 0.12^{b,3}$	$3.2 \pm 0.15^{b,2}$	$2.3 \pm 0.14^{b,1}$	0.3
T5	$3.7 \pm 0.13^{a,3}$	$3.5 \pm 0.14^{a,3}$	$2.9 \pm 0.11^{b,2}$	$2.2 \pm 0.12^{b,1}$	0.4	$3.9 \pm 0.13^{a,3}$	$3.7 \pm 0.12^{a,3}$	$3.5 \pm 0.15^{b,2}$	$3.2 \pm 0.14^{b,2}$	$2.6 \pm 0.13^{c,1}$	0.3
T6	$3.7 \pm 0.12^{a,3}$	$3.7 \pm 0.14^{a,3}$	$3.1 \pm 0.14^{b,2}$	$2.5 \pm 0.12^{b,1}$	0.3	$3.8 \pm 0.12^{a,3}$	$3.8 \pm 0.12^{a,3}$	$3.6 \pm 0.16^{b,2}$	$3.4 \pm 0.14^{b,2}$	$2.6 \pm 0.15^{c,1}$	0.2
T7	$3.8 \pm 0.14^{a,3}$	$3.7 \pm 0.13^{a,3}$	$3.1 \pm 0.14^{b,2}$	$2.5 \pm 0.13^{b,1}$	0.4	$3.9 \pm 0.12^{a,2}$	$3.6 \pm 0.14^{a,2}$	$3.5 \pm 0.14^{b,2}$	$3.2 \pm 0.13^{b,1}$	$2.9 \pm 0.13^{d,1}$	0.4
T8	$3.8 \pm 0.13^{a,2}$	$3.7 \pm 0.14^{a,2}$	$3.1 \pm 0.14^{b,1}$	$2.8 \pm 0.13^{c,1}$	0.3	$3.9 \pm 0.13^{a,2}$	$3.6 \pm 0.14^{a,2}$	$3.5 \pm 0.15^{b,2}$	$3.3 \pm 0.13^{b,1}$	$2.9 \pm 0.14^{d,1}$	0.4
LSD	0.2	0.4	0.3	0.4		0.3	0.3	0.3	0.3	0.2	
(b) Double											
T1	$3.8 \pm 0.14^{a,4}$	$3.1 \pm 0.14^{a,3}$	$2.1 \pm 0.15^{a,2}$	$1.1 \pm 0.15^{a,1}$	0.5	$3.8 \pm 0.12^{a,3}$	$3.4 \pm 0.14^{a,3}$	$2.9 \pm 0.16^{a,2}$	$2.1 \pm 0.03^{a,1}$	$1.7 \pm 0.03^{a,1}$	0.4
T2	$3.6 \pm 0.15^{a,3}$	$3.1. \pm 0.13^{a,3}$	$2.2 \pm 0.13^{a,2}$	$1.1 \pm 0.14^{a,1}$	0.5	$3.8 \pm 0.13^{a,3}$	$3.4 \pm 0.14^{a,3}$	$2.9 \pm 0.16^{a,2}$	$2.2 \pm 0.03^{a,1}$	$1.8 \pm 0.04^{a,1}$	0.4
T3	$3.8 \pm 0.13^{a,3}$	$3.4 \pm 0.13^{a,3}$	$2.7 \pm 0.15^{b,2}$	$1.5 \pm 0.15^{b,1}$	0.4	$3.8 \pm 0.13^{a,3}$	$3.5 \pm 0.13^{a,3}$	$3.1 \pm 0.14^{a,2}$	$2.6 \pm 0.03^{b,1}$	$2.3 \pm 0.03^{b,1}$	0.3
T4	$3.8 \pm 0.13^{a,3}$	$3.5 \pm 0.14^{a,3}$	$2.9 \pm 0.16^{b,2}$	$1.8 \pm 0.14^{b,1}$	0.5	$3.8 \pm 0.14^{a,3}$	$3.5 \pm 0.13^{a,3}$	$3.1 \pm 0.14^{a,2}$	$2.6 \pm 0.03^{b,1}$	$2.3 \pm 0.04^{b,1}$	0.3
T5	$3.8 \pm 0.14^{a,3}$	$3.5 \pm 0.13^{a,3}$	$3.1 \pm 0.14^{c,2}$	$2.3 \pm 0.16^{c,1}$	0.3	$3.7 \pm 0.14^{a,2}$	$3.5 \pm 0.15^{a,2}$	$3.3 \pm 0.13^{b,2}$	$2.9 \pm 0.01^{b,1}$	$2.6 \pm 0.05^{b,1}$	0.4
T6	$3.8 \pm 0.13^{a,3}$	$3.5 \pm 0.12^{a,3}$	$3.1 \pm 0.13^{c\ 2}$	$2.4 \pm 0.15^{c,1}$	0.3	$3.7 \pm 0.14^{a,2}$	$3.5 \pm 0.14^{a,2}$	$3.3 \pm 0.13^{b,2}$	$2.9 \pm 0.03^{b,1}$	$2.6 \pm 0.01^{b,1}$	0.4
T7	$3.8 \pm 0.14^{a,2}$	$3.5 \pm 0.12^{a,2}$	$3.2 \pm 0.13^{c,1}$	$2.8 \pm 0.14^{d,1}$	0.4	$3.8 \pm 0.13^{a,2}$	$3.6 \pm 0.15^{a,2}$	$3.4 \pm 0.14^{b,2}$	$3.1 \pm 0.03^{c,1}$	$2.9 \pm 0.01^{c,1}$	0.4
T8	$3.7 \pm 0.13^{a,3}$	$3.5 \pm 0.14^{a,3}$	$3.2 \pm 0.14^{c,2}$	$2.8 \pm 0.14^{d,1}$	0.2	$3.8 \pm 0.13^{a,2}$	$3.6 \pm 0.15^{a,2}$	$3.4 \pm 0.13^{b,2}$	$3.1 \pm 0.03^{c,1}$	$2.9 \pm 0.01^{c,1}$	0.4
LSD	0.2	0.4	0.3	0.3		0.2	0.3	0.3	0.3	0.3	

Values are mean ± SD, $n = 3$; LSD = least significant difference ($p \leq 0.05$)

Values within treatments with different superscript lowercase letters (a–d) in a column differ significantly ($p \leq 0.05$)

Values within storage periods with different superscript numerical (1–4) differ significantly ($p \leq 0.05$)

T1 = control; T2 = 0.5 % w/v CMC; T3 = 0.75 % w/v CMC; T4 = 1.0 % w/v CMC; T5 = 1.2 kGy; T6 = 0.5 % w/v CMC, 1.2 kGy; T7 = 0.75 % w/v CMC, 1.2 kGy; T8 = 1.0 % w/v CMC, 1.2 kGy

Table 5 Effect of gamma irradiation and carboxymethyl cellulose treatments on yeast and mold count (log cfu/g sample) of cherry varieties (Misri, Double) during storage under ambient and refrigerated conditions

Treatments	Ambient storage (days)				LSD	Refrigerated storage (days)					LSD
	0	3	6	9		0	7	14	21	28	
(a) Misri											
T1	$3.6 \pm 0.20^{b,1}$	$4.2 \pm 0.10^{c,2}$	$4.9 \pm 0.22^{d,3}$	$5.5 \pm 0.12^{d,4}$	0.4	$3.6 \pm 0.10^{b,1}$	$3.8 \pm 0.11^{b,2}$	$4.1 \pm 0.11^{c,3}$	$4.3 \pm 0.22^{c,4}$	$4.5 \pm 0.13^{c,5}$	0.1
T2	$3.6 \pm 0.10^{b,1}$	$4.2 \pm 0.20^{c,2}$	$4.9 \pm 0.23^{d,3}$	$5.4 \pm 0.13^{d,4}$	0.4	$3.5 \pm 0.10^{b,1}$	$3.8 \pm 0.11^{b,2}$	$3.9 \pm 0.13^{b,2}$	$4.2 \pm 0.21^{c,3}$	$4.3 \pm 0.12^{c,4}$	0.1
T3	$3.1 \pm 0.11^{a,1}$	$3.7 \pm 0.14^{b,2}$	$4.4 \pm 0.22^{c,3}$	$4.9 \pm 0.12^{c,4}$	0.5	$3.1 \pm 0.11^{a,1}$	$3.3 \pm 0.13^{a,2}$	$3.6 \pm 0.12^{b,3}$	$3.9 \pm 0.13^{b,4}$	$4.1 \pm 0.13^{b,5}$	0.1
T4	ND	$3.3 \pm 0.13^{a,1}$	$3.8 \pm 0.13^{b,2}$	$4.2 \pm 0.22^{b,3}$	0.3	ND	ND	$3.2 \pm 0.12^{a,1}$	$3.6 \pm 0.11^{b,2}$	$3.8 \pm 0.12^{b,3}$	0.1
T5	ND	ND	$3.1 \pm 0.13^{a,1}$	$3.6 \pm 0.21^{a,2}$	0.4	ND	ND	ND	$3.1 \pm 0.15^{a,1}$	$3.4 \pm 0.12^{a,2}$	0.2
T6	ND	ND	$3.1 \pm 0.13^{a,1}$	$3.6 \pm 0.21^{a,2}$	0.4	ND	ND	ND	$3.1 \pm 0.15^{a,1}$	$3.4 \pm 0.12^{a,2}$	0.2
T7	ND	ND	ND	$3.2 \pm 0.13^{a,1}$	–	ND	ND	ND	ND	$3.1 \pm 0.15^{a,1}$	–
T8	ND	ND	ND	$3.2 \pm 0.13^{a,1}$	–	ND	ND	ND	ND	$3.1 \pm 0.12^{a,1}$	–
LSD	0.4	0.3	0.3	0.3		0.3	0.3	0.3	0.4	0.3	
(b) Double											
T1	$3.5 \pm 0.23^{b,1}$	$4.3 \pm 0.11^{c,2}$	$4.9 \pm 0.22^{d,3}$	$5.4 \pm 0.11^{e,4}$	0.3	$3.5 \pm 0.21^{b,1}$	$3.8 \pm 0.22^{b,2}$	$4.1 \pm 0.11^{c,3}$	$4.4 \pm 0.12^{d,4}$	$4.7 \pm 0.21^{d,5}$	0.2
T2	$3.3 \pm 0.22^{a,1}$	$3.9 \pm 0.22^{b,2}$	$4.3 \pm 0.21^{c,3}$	$4.9 \pm 0.11^{d,4}$	0.2	$3.4 \pm 0.23^{b,1}$	$3.6 \pm 0.22^{a,2}$	$3.9 \pm 0.14^{b,3}$	$4.1 \pm 0.13^{c,4}$	$4.5 \pm 0.16^{d,5}$	0.1
T3	$3.1 \pm 0.21^{a,1}$	$3.7 \pm 0.23^{b,2}$	$4.1 \pm 0.22^{c,3}$	$4.7 \pm 0.12^{d,4}$	0.3	$3.1 \pm 0.12^{a,1}$	$3.4 \pm 0.12^{a,2}$	$3.7 \pm 0.12^{b,3}$	$3.9 \pm 0.14^{c,3}$	$4.2 \pm 0.11^{c,4}$	0.2
T4	ND	$3.3 \pm 0.21^{a,1}$	$3.7 \pm 0.31^{b,2}$	$4.1 \pm 0.12^{c,3}$	0.2	ND	ND	$3.1 \pm 0.13^{a,1}$	$3.5 \pm 0.11^{b,2}$	$3.7 \pm 0.21^{b,3}$	0.1
T5	ND	ND	$3.2 \pm 0.32^{a,1}$	$3.6 \pm 0.11^{b,2}$	0.2	ND	ND	ND	$3.2 \pm 0.13^{a,1}$	$3.4 \pm 0.21^{a,2}$	0.1
T6	ND	ND	$3.2 \pm 0.32^{a,1}$	$3.6 \pm 0.11^{b,2}$	0.2	ND	ND	ND	$3.2 \pm 0.13^{a,1}$	$3.4 \pm 0.21^{a,2}$	0.1
T7	ND	ND	ND	$3.2 \pm 0.21^{a,1}$	–	ND	ND	ND	ND	$3.2 \pm 0.13^{a,1}$	–
T8	ND	ND	ND	$3.2 \pm 0.21^{a,1}$	–	ND	ND	ND	ND	$3.2 \pm 0.15^{a,2}$	–
LSD	0.2	0.3	0.3	0.2		0.2	0.2	0.3	0.2	0.2	

Values are mean ± SD, $n = 3$; LSD = least significant difference ($p \leq 0.05$); ND = not detected

Values within treatments with different superscript lowercase letters (a–e) in a column differ significantly ($p \leq 0.05$)

Values within storage periods with different superscript numerical (1–5) differ significantly ($p \leq 0.05$)

T1 = control; T2 = 0.5 % w/v CMC; T3 = 0.75 % w/v CMC; T4 = 1.0 % w/v CMC; T5 = 1.2 kGy; T6 = 0.5 % w/v CMC, 1.2 kGy; T7 = 0.75 % w/v CMC, 1.2 kGy; T8 = 1.0 % w/v CMC, 1.2 kGy

Table 6 Effect of gamma irradiation and carboxymethyl cellulose treatments on decay percentage of Cherry (Cv. Misri and Double) during ambient (25 ± 2 °C, RH 70 %) storage

Treatments	Variety	TF	Decay percentage									
			Storage period (days)									
			3	4	5	6	7	8	9	10	11	12
T1	V1	45	10.8 ± 1.2^{b}	18.2 ± 1.4^{b}	32.6 ± 2.2^{b}	46.7 ± 2.5^{c}	59.1 ± 3.1^{c}	75.2 ± 3.2^{c}	89.3 ± 3.1^{d}	FD		
T2	V1	45	10.8 ± 1.1^{b}	17.2 ± 1.2^{a}	32.4 ± 1.6^{b}	45.5 ± 2.2^{c}	58.6 ± 2.5^{c}	74.3 ± 3.1^{c}	88.5 ± 3.2^{d}	FD		
T3	V1	45	6.5 ± 1.2^{a}	15.5 ± 1.1^{a}	29.3 ± 1.2^{a}	41.5 ± 2.2^{b}	55.5 ± 2.1^{b}	70.4 ± 2.6^{b}	81.2 ± 2.2^{c}	91.3 ± 2.2^{d}	FD	
T4	V1	45	ND	ND	ND	4.1 ± 1.1^{a}	11.6 ± 2.1^{a}	18.2 ± 2.2^{a}	28.4 ± 2.4^{b}	39.6 ± 2.1^{c}	53.6 ± 2.1^{c}	73.6 ± 2.1^{d}
T5	V1	45	ND	ND	ND	ND	ND	ND	5.3 ± 1.2^{a}	11.6 ± 2.1^{b}	21.2 ± 2.2^{b}	32.2 ± 2.2^{c}
T6	V1	45	ND	ND	ND	ND	ND	ND	5.3 ± 1.2^{a}	11.6 ± 2.1^{b}	21.2 ± 2.2^{b}	30.2 ± 2.2^{c}
T7	V1	45	ND	ND	ND	ND	ND	ND	ND	4.3 ± 1.2^{a}	10.6 ± 2.1^{a}	18.2 ± 2.2^{b}
T8	V1	45	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.3 ± 1.2^{a}
LSD			2.3	2.1	2.5	3.1	2.4	3.1	2.3	3.5	2.6	3.3
T1	V2	45	11.6 ± 1.2^{b}	20.6 ± 1.4^{a}	35.6 ± 2.2^{b}	51.7 ± 2.5^{c}	64.1 ± 3.1^{c}	79.2 ± 3.2^{c}	93.3 ± 3.1^{d}	FD		
T2	V2	45	11.2 ± 1.1^{b}	20.2 ± 1.2^{a}	35.4 ± 1.6^{b}	50.5 ± 2.2^{c}	63.6 ± 2.5^{c}	77.3 ± 3.1^{c}	92.5 ± 3.2^{d}	FD		
T3	V2	45	7.9 ± 1.2^{a}	18.5 ± 1.1^{a}	32.3 ± 1.2^{a}	46.5 ± 2.2^{b}	59.5 ± 2.1^{b}	73.4 ± 2.6^{b}	86.2 ± 2.2^{c}	93.3 ± 2.2^{d}	FD	
T4	V2	45	ND	ND	ND	7.1 ± 1.1^{a}	15.6 ± 2.1^{a}	23.2 ± 2.2^{a}	33.4 ± 2.4^{b}	44.6 ± 2.1^{c}	59.5 ± 2.1^{c}	73.4 ± 2.6^{d}
T5	V2	45	ND	ND	ND	ND	ND	ND	9.3 ± 1.2^{a}	18.5 ± 1.1^{b}	31.3 ± 1.2^{b}	44.5 ± 2.2^{c}
T6	V2	45	ND	ND	ND	ND	ND	ND	10.3 ± 1.2^{a}	18.5 ± 1.1^{b}	31.3 ± 1.2^{b}	44.5 ± 2.2^{c}
T7	V2	45	ND	ND	ND	ND	ND	ND	ND	6.3 ± 1.2^{a}	19.6 ± 2.1^{a}	34.2 ± 2.2^{b}
T8	V2	45	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.9 ± 1.2^{a}
LSD			2.5	2.3	2.1	2.6	2.6	3.2	3.2	3.5	4.2	3.8

Values are mean ± SD, $n = 3$; LSD = least significant difference ($p \leq 0.05$); V1 = Misri; V2 = Double; ND = no decay; FD = fully decayed; TF = total fruits; DOR = days of refrigeration

Values within treatments with different superscript lowercase letters (a–d) in a column differ significantly ($p \leq 0.05$)

T1 = control; T2 = 0.5 % w/v CMC; T3 = 0.75 % w/v CMC; T4 = 1.0 % w/v CMC; T5 = 1.2 kGy; T6 = 0.5 % w/v CMC, 1.2 kGy; T7 = 0.75 % w/v CMC, 1.2 kGy; T8 = 1.0 % w/v CMC, 1.2 kGy

Table 7 Effect of gamma irradiation and carboxymethyl cellulose treatments on decay percentage of Cherry (Cv. Misri and Double) during refrigeration and post-refrigerated storage at 25 ± 2 °C, RH 70 %

Treatments	Variety	TF	Decay Percentage									
			14 DOR	21 DOR	28 DOR	Post-refrigerated Storage (days) at temperature 25 ± 2 °C, RH 70 %.						
						1	2	3	4	5	6	7
T1	V1	45	17.8 ± 1.2^{c}	29.2 ± 1.4^{c}	45.6 ± 2.2^{d}	56.7 ± 2.5^{d}	66.1 ± 3.1^{d}	75.2 ± 3.2^{d}	84.3 ± 3.1^{c}	91.3 ± 2.5^{d}	FD	
T2	V1	45	12.8 ± 1.1^{b}	16.2 ± 1.2^{b}	32.4 ± 1.6^{c}	45.5 ± 2.2^{c}	62.6 ± 2.5^{c}	71.3 ± 3.1^{c}	81.5 ± 3.2^{c}	89.2 ± 3.5^{d}	FD	
T3	V1	45	6.5 ± 1.2^{a}	11.5 ± 1.1^{a}	16.3 ± 1.2^{b}	24.5 ± 2.2^{b}	33.5 ± 2.1^{b}	41.4 ± 2.6^{b}	49.2 ± 2.2^{b}	60.3 ± 2.2^{c}	71.8 ± 2.6^{c}	83.6 ± 2.2^{d}
T4	V1	45	ND	ND	5.6 ± 1.1^{a}	12.1 ± 1.1^{a}	19.6 ± 2.1^{a}	28.2 ± 2.2^{a}	35.4 ± 2.4^{a}	49.6 ± 2.1^{b}	61.3 ± 2.5^{b}	72.4 ± 2.6^{c}
T5	V1	45	ND	ND	ND	ND	ND	ND	ND	5.6 ± 1.2^{a}	12.1 ± 1.1^{a}	19.6 ± 2.1^{b}
T6	V1	45	ND	ND	ND	ND	ND	ND	ND	5.3 ± 1.2^{a}	10.1 ± 1.1^{a}	17.6 ± 2.1^{b}
T7	V1	45	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.3 ± 1.2^{a}
T8	V1	45	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.3 ± 1.2^{a}
LSD			4.1	4.5	5.2	5.5	3.4	3.6	3.1	5.2	4.6	3.5
T1	V2	45	20.8 ± 1.2^{c}	32.2 ± 1.4^{c}	48.6 ± 2.2^{d}	61.7 ± 2.5^{d}	69.1 ± 3.1^{c}	78.2 ± 3.2^{d}	88.3 ± 3.1^{c}	95.3 ± 2.5^{d}	FD	
T2	V2	45	14.8 ± 1.1^{b}	19.2 ± 1.2^{b}	35.4 ± 1.6^{c}	49.5 ± 2.2^{c}	67.6 ± 2.5^{c}	74.3 ± 3.1^{c}	85.5 ± 3.2^{c}	93.2 ± 3.5^{d}	FD	
T3	V2	45	10.5 ± 1.2^{a}	15.5 ± 1.1^{a}	27.3 ± 1.2^{b}	36.5 ± 2.2^{b}	43.5 ± 2.1^{b}	51.4 ± 2.6^{b}	69.2 ± 2.2^{b}	78.3 ± 2.2^{c}	85.8 ± 2.6^{c}	93.6 ± 2.2^{d}
T4	V2	45	ND	ND	6.8 ± 1.1^{a}	13.4 ± 1.2^{a}	21.6 ± 1.1^{a}	31.1 ± 1.1^{a}	41.6 ± 2.1^{a}	51.2 ± 2.2^{b}	69.4 ± 2.4^{b}	78.6 ± 2.1^{c}
T5	V2	45	ND	ND	ND	ND	ND	ND	ND	8.3 ± 1.2^{a}	15.4 ± 2.4^{a}	22.6 ± 2.1^{b}
T6	V2	45	ND	ND	ND	ND	ND	ND	ND	7.3 ± 1.2^{a}	14.4 ± 2.4^{a}	21.6 ± 2.1^{b}
T7	V2	45	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.5 ± 1.2^{a}
T8	V2	45	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.3 ± 1.2^{a}
LSD			3.3	3.4	5.2	4.8	4.1	3.1	3.5	4.5	5.2	4.4

Values are mean ± SD, $n = 3$; LSD = least significant difference ($p \leq 0.05$); V1 = Misri; V2 = Double; ND = no decay; FD = fully decayed; TF = total fruits; DOR = days of refrigeration

Values within treatments with different superscript lowercase letters (a–d) in a column differ significantly ($p \leq 0.05$)

T1 = control; T2 = 0.5 % w/v CMC; T3 = 0.75 % w/v CMC; T4 = 1.0 % w/v CMC; T5 = 1.2 kGy; T6 = 0.5 % w/v CMC, 1.2 kGy; T7 = 0.75 % w/v CMC, 1.2 kGy; T8 = 1.0 % w/v CMC

development in coated fruits. Fan et al. (2009) reported that the combination of *Cryptococcus laaurentii* with sodium alginate coating reduced mould by approximately 20 and 30 % compared with the control at 4 and 5 days, respectively.

Decay percentage

Effect of individual and combination treatments of CMC coating and radiation processing on decay percentage of cherry varieties during ambient, refrigerated and post-refrigerated storage at 25 ± 2 °C, RH 80 % is shown in Tables 6 and 7 respectively. Data on decay percentage indicated that under ambient condition; control, 0.5 and 0.75 % w/v CMC coated samples of both the varieties started decaying after 3 days and were almost fully decayed after 10 and 11 days of storage. Fruits treated with CMC coating at 1.0 % w/v started decaying after 5 days of ambient storage. Irradiation alone and in combination with CMC coating proved significantly ($p \leq 0.05$) effective in delaying the onset of decay in cherry fruits stored under ambient conditions. In fruits treated with irradiation alone at 1.2 kGy and in combination with CMC at 0.5, 0.75 and 1.0 % w/v, no decay was recorded in both the varieties up to 8, 9 and 11 days of ambient storage. Under refrigerated conditions after 21 days of storage, no decay was recorded in fruits treated either with individual treatments of CMC coating (1.0 %w/v), 1.2 kGy irradiation or combination of CMC coating and irradiation. Control fruits of Misri variety and those coated with CMC at 0.5 and 0.75 % w/v were decayed to the extent of 29.2, 16.2 and 11.5 % respectively. Whereas, control fruits of Double variety and those treated with CMC at 0.5 and 0.75 % w/v were decayed to the extent of 32.2, 19.2 and 15.5 % respectively. After 28 days of storage, no decay was recorded in fruits of both the varieties treated with irradiation alone and in combination with CMC coating compared to individual treatments of CMC coating at 0.5–1.0 % w/v. After 28 days of refrigeration, fruits were taken out and kept under ambient conditions (25 ± 2 °C, RH 80 %) to monitor decay. Control and 0.5 % w/v CMC coated fruits of both the varieties were almost fully decayed after 6 days of storage. Fruits of Misri variety treated with 0.75 and 1.0 % w/v CMC coating were decayed to the extent of 83.6 and 72.4 % up to 7 days of additional ambient storage. On the other hand, fruits of Double variety treated with 0.75 and 1.0 % (w/v) CMC were decayed to the extent of 93.6 and 78.6 % up to 7 days of additional ambient storage following 28 days of refrigeration. Gamma irradiation alone and in combination with 0.5 % w/v CMC delayed the onset of decay in cherry fruits up to 4 days of additional ambient storage following 28 days of refrigeration. Among the treatments, combination of CMC coating (0.75 and 1.0 % w/v) and 1.2 kGy irradiation was effective in delaying the decay of cherry fruits up to 6 days of storage at 25 ± 2 °C, RH 80 % following 28 days of refrigerated storage. Thus, the synergistic effect of gamma irradiation and CMC coating in delaying physiological processes and microbial proliferation responsible for decay has resulted in extending the shelf life of cherry fruits under ambient, refrigerated and additional ambient storage following refrigeration (Hussain et al. 2015).

Conclusion

The investigation showed that CMC coating alone at levels 0.5 and 0.75 % w/v was not found effective with respect to mold growth inhibition under either of the two conditions. Individual treatment of CMC coating at 1.0 % w/v and 1.2 kGy irradiation proved helpful in delaying the onset of mold growth up to 5 and 8 days of ambient storage. Following post refrigerated storage under ambient conditions, irradiation alone at 1.2 kGy resulted in 4 days extension in shelf-life of cherry varieties. All combinatory treatments of CMC coating and irradiation proved beneficial in maintaining the storage quality as well as delaying the decaying of cherry fruit during post-refrigerated storage at 25 ± 2 °C, RH 80 %. However, combination of CMC at 1.0 % w/v and 1.2 kGy irradiation was found significantly ($p \leq 0.05$) superior to all other treatments. The above combinatory treatment besides maintaining storage quality resulted in extension of 6 days in shelf life of cherry varieties during post-refrigerated storage at 25 ± 2 °C, RH 80 % following 28 days of refrigeration. Combination treatment of irradiation and 1.0 % w/v CMC coating gave a maximum of 2.3 and 1.5 log reduction in yeast and mold count of cherry fruits after 9 and 28 days of ambient and refrigerated storage, thereby ensuring consumer safety. Therefore, combinatory treatment of coating (1.0 % w/v CMC) and irradiation (1.2 kGy) can help to greater extent in facilitating the marketing of the fruit to distant markets other than local markets thereby benefiting the growers.

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