

Carboxymethyl Cellulose Based Chickpea (*Cicer arietinum* L.) Hull Polysaccharides Composite Coating Maintains the Quality of Cherry Tomatoes

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ABSTRACT

The efficiency of Carboxymethyl Cellulose (CMC) based Chickpea Hull Polysaccharides (CHPS) edible coating with regards to shelf life and physicochemical properties of cherry tomatoes were determined. Cherry tomatoes were coated with various CHPS concentrations (0.25, 0.50, 0.75 and 1.00%) to preserve cherry tomatoes during storage at 20°C. The CMC-incorporated CHPS coatings were found effective to reduce the respiration rate, weight loss, firmness, lycopene content, total soluble solid, vitamin C, total polyphenols, and to improve the overall likeness of fruit compared with the control. All these effects were noted to be dose-dependent. Taken together, using CMC-incorporated CHPS coatings could prolong the shelf life of cherry tomatoes.

Keywords: CMC, Edible coating, Edible films, Shelf life, *Solanum lycopersicum* L.

INTRODUCTION

The utilization of naturally grown fresh fruit and vegetables is becoming more popular to consumers. Consumers have a demand for food products with good quality, safe, increased shelf life with biodegradable packaging. These demands have led to renewed interest in the use of biodegradable material used for packaging of foods (Zhao, *et al.* 2010). For biodegradable packaging, proteins and polysaccharides are the best sources. Because of their, potentials these are being explored throughout the world for utilization in edible films and coatings. An edible film resembles plastic film wrap, but it is formed from edible protein and polysaccharides (Baldwin *et al.* 1995). The

basic and foremost purpose of developing edible coatings and films are to protect foods from oxygen intrusion, moisture change, loss of flavor and aroma, mechanical damage, and oil migration. Edible coatings and film based on polysaccharides have also been found to be excellent barriers to oxygen intrusion and aroma loss in foods. Polysaccharides, lipids, proteins and their combinations may be used as coating materials for fresh produce (Wu, and Chen 2013; Bal, 2013).

Carboxymethyl Cellulose (CMC) is water-soluble, linear, long-chain, a common derivative of cellulose and anionic polysaccharide. It is tasteless, cream-colored, free-flowing, odorless powder (Hadar *et al.* 2014). Its solution is nontoxic

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and has a good film-forming characteristics, thus it is utilized as an additive to improve the processing properties and the quality of product for food packaging materials (Ma *et al.* 2008). Although polysaccharides have been widely applied in food preservation field, Chickpea Hull Polysaccharides (CHPS) have not been studied before to develop the CMC-based edible coatings.

Cherry tomato (*Solanum lycopersicum* L) is very rich in vitamin C and β -carotene, thus one of popular vegetable in the world because of its fresh consumption (Ergun *et al.* 2006). They are being utilized either fresh as a salad or after cooking as snacks. Cherry tomato is known as the storehouse of antioxidants, such as ascorbic acid, carotenoids, and phenolic compounds, (Raffo *et al.*; Levy, and Sharoni, 2004) due to being rich in phytonutrients. It plays a vital role in human health (Giovannucci, 1999; Vecchia, 1998).

Cherry tomato is highly perishable owing to its richness in nutrients, hence, after harvest has a shelf life of only 5 to 7 days. Therefore, practical approaches to extend the shelf life of cherry tomatoes must be developed by applying edible coatings. Several preservation technologies such as cold storage, Ultraviolet radiation, (Choi *et al.*, 2015) modified atmosphere packaging (13), hot air treatment (Zamora *et al.* 2015), controlled atmosphere storage (Aquino *et al.* 2016), edible coating (Wu *et al.* 2016) for cherry tomato have long been developed as a mean to enhance shelf life by alleviating water stress, decreasing physiological activity, and reducing mechanical damage. Among them, the incorporation of the natural antimicrobial agents into edible films and coatings has been recommended to upgrade the quality of fruits and prolong their shelf life (Silva *et al.* 2017). Furthermore, the natural antimicrobial agents have been shown to lower environmental impact, good antimicrobial activities with low toxicity (Sivakumar and Banos, 2014).

The postharvest storage of fruits and vegetables has been prolonged by using

edible coatings (Raffo, 2002; Allegra, 2016; and Singh 2016). Therefore, the goal of the present study was to enlighten the CMC potential enriched with CHPS composite coatings to improve the quality of cherry tomatoes stored at 20°C and to minimize the cost of packaging and related packaging waste. Cherry tomatoes coated with five different types of coatings will be analyzed in terms of respiration rate, total soluble solids, decay percentage, firmness, lycopene content, total phenols, weight loss, vitamin C content and sensory evaluation.

MATERIALS AND METHODS

Sodium Carboxymethyl Cellulose (CMC) and Glycerol were purchased from Junsei Chemical Co., Ltd. (Tokyo, Japan). Glycerol was procured by Solarbio Science & Technology (Beijing, China). Cherry tomatoes (Alicante tomato) mature-red, were purchased from the local market (Nanjing, Jiangsu, China) and sorted on the basis of maturity, size, color, with no blemishes, and no mechanical damage. All other used reagents were of analytical grade.

Preparation of CMC/CHPS Composite Coatings

Coating solution was prepared according to our reported method (Akhtar, 2018). Briefly, coating solution was produced by mixing 3 g (2% w/v) CMC and 0.9 g of glycerol used as plasticizer (30% of CMC weight) with 150 mL distilled water. For complete dissolving of the solution, it was heated at 90°C about 20 minutes. CHPS concentrations (0.25, 0.50, 0.75, and 1.00% based on CMC weight) with 150 mL distilled water were stirred at room temperature for 2 hours. The already prepared solution of CMC and glycerol were added to CHPS suspension and heated at 90°C for 20 minutes. The solutions were vacuum degasified to remove air bubbles for 1 hour.

Coating Application

Cherry tomatoes were immersed for 2 minutes in 2% sodium hypochlorite solution and then slowly dried. Fruits were considered as control without any treatment. Cherry tomato coated with CMC containing

The fruits were weighed by using electronic weighing scale before application of the treatment, which was used as the initial fruit weight. The weight loss was measured at the end of each storage interval and the final fruit weight was determined. The following formula was used to calculate the percentage weight loss:

$$\text{Weight Loss \%} = \frac{\text{Initial fruit weight} - \text{Fruit weight on the day of observation}}{\text{Initial fruit weight}} \times 100$$

different concentrations of CHPS (0, 0.25, 0.50, 0.75, and 1.00% hereafter referred to as CHPS1, CHPS2, CHPS3 and CHPS4) and were set at a tray (10 fruits per tray), respectively. During the coating process, cherry tomatoes were dipped in coating solutions for 30 seconds, the remaining solutions were dripped off and dried for 2 hours at ambient environment. Furthermore, the cherry tomatoes were placed in polypropylene plastic trays and stored at 20°C for 15 days. Each treatment for cherry tomato consisted of 15 fruits for non-destructive analysis (weight loss and color) and 15 fruits for destructive analysis.

Respiratory Rate

Stored cherry tomatoes were sampled to measure CO₂ production by following the method of (Kim, and Min, 2017). Respiratory rate of the control and treated fruits were determined by closed system. At the end of each storage period interval, three replicates were used from each group to analyze the CO₂ production. The samples used were first weighed and then kept in (100 mL) sealed jars. The CO₂ accumulated in the headspace atmosphere was evaluated by a portable gas analyzer (Check Point 2; PBI Dansensor, Ringsted, Denmark).

Weight Loss

Weight loss of cherry tomatoes was determined by following the method reported by (Moneruzzaman, *et al.* 2019).

Fungal Decay

The decay of cherry tomatoes for coated and uncoated (control) fruits was computed as the number of decayed fruit divided by total number of fruits multiplied by 100 (Elanany, 2009). For visual observation, the fruits were monitored daily by inspecting the signs of filamentous hyphae growth or black spots of botrytis. Tomatoes showing surface mycelial development were considered decayed.

Firmness

The cherry tomatoes were analyzed for firmness by using Texture Analyzer (Food Tech Corp., USA) with 5 kg load cell and 2 mm diameter probe flat head stainless steel cylinder, according to the procedure described by (Gourau, 2007) at room temperature. A single whole cherry tomato was placed under the probe and the force required to puncture was measured.

Internal Quality Assessment of Fruits

Total Soluble Solids (TSS)

Cherry tomatoes from each treatment groups were grounded in a blender and the



homogenized juice was utilized to measure the concentration of soluble solids. Total soluble solids were recorded by using hand held digital refractometer (°Brix) according to the procedure described by (AOAC. 1995). A drop of juice was used to measure TSS, and the values were described as °Brix.

Titrateable Acidity

Fifty-gram samples were blended with 150 mL distilled water, then, samples were titrated against 0.1N NaOH by using phenolphthalein indicator. The light pink color (end point) appearance was noted (pH 8.1). Acidity was calculated and expressed as percent of citric acid:

$$\text{Acid \%} = \frac{\text{Titre value} \times \text{Normality} \times \text{m. eq. wt. of acid}}{\text{volume of sample}} \times 100$$

Milli-equivalent weight of citric acid= 0.06404.

pH

Cherry tomato juice was used to measure the pH by using a pH-meter (320, Metler Toledo, Shanghai, China). Juice of four fruits from each treatment group was prepared and used. Triplicate readings were noted.

Ascorbic Acid

Ascorbic acid content of tomatoes was measured by using 2, 6-dichloroindophenol titration, following the method described by (AOAC. 1995). As much as 50 g of sample was weighed and extracted by using 50 mL metaphosphoric acid and acetic acid solution (*i.e.* 15 g of H₃PO₄ and 40 mL of CH₃COOH in 500 mL of distilled water) and was then filtered, diluted properly to a final concentration of 10-100 mg of ascorbic acid 100 mL⁻¹. Blank, standard, and three replicates of sample were titrated with the indophenol reagent (prepared by dissolving 50 mg of 2, 6-dichloroindophenol sodium salt and 42 mg of NaHCO₃ to 200 mL with distilled water) to a light rose pink endpoint

color lasting for at least 5 sec. Volume of indophenols for titration were used to calculate ascorbic acid content of tomato.

Lycopene

The whole fresh cherry tomato fruit was homogenized to extract the lycopene. The homogenized sample (5 g) was weighed into a 125 mL flask wrapped with aluminum foil to avoid light. Then, 50 mL mixture of hexane/acetone/ethanol (2:1:1, v/v/v) was added to solubilize the carotenoids (Sadler *et al.* 1990). Samples were kept on shaker for 30 min followed by the addition of 10 mL distilled water. The sample solution was kept to separate into two distinctive polar

(35 mL) and a non-polar (25 mL) layer, with the upper layer containing lycopene. The absorbance of the lycopene-hexane solution was measured at 472 nm to calculate the total lycopene content in the sample. The absorbance conversion into lycopene concentration depended on its specific Extinction coefficient (E%) of 3,450 in hexane (Sharma, and Maguer, 1996). The results were expressed in mg 100 g⁻¹ of fruit.

Total Polyphenols Content

Folin Ciocalteu procedure was followed to measure total poly phenols in cherry tomatoes (Singleton *et al.* 1999) with minor modifications. The 50 g sample was grounded and centrifuged for 15 minutes at 4°C and then filtration was carried out by using Whatman No. 1 filter. The supernatant 0.5 mL was mixed with 0.5 mL of Folin Ciocalteu solution. After keeping for 3 minutes, saturated sodium carbonate solution (10 mL) was mixed and the volume was made up to 25 mL by distilled water addition. The blue color absorbance that developed was measured at

725 nm after keeping for 30 minutes in dark. Phenolic compounds concentrations were calculated by the absorbance comparison of the samples with standards. Results were described as milligrams of Gallic acid in 100 g of fresh tomatoes.

Sensory Evaluation

Sensory characters of cherry tomatoes were determined by 10 panelist (Age range: 25-30 years old, 5 males and 5 females) from the Department of Food Science and Technology. The sensory quality parameters considered were color, taste, texture, flavor and overall acceptability and the evaluation was made after 15 days of storage. Ratings were presented by the scores (0-2= Dislike extremely, 3-4= Dislike slightly, 5= Fair, 6-8= Like moderately, and 9= Excellent) (Meilgaard, 2006).

Statistical Analysis

Data analysis was carried out by using ANOVA. Differences between means ($P < 0.05$) were measured by using Duncan's multiple range test. Statistical analyses were performed using SPSS software (version 16, SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

Respiration Rate of Cherry Tomatoes during Storage

During the storage, cherry tomatoes age and mature. Fruits and vegetables continuously utilize their nutrients for cellular respiration. At higher respiration rate, more nutrients are consumed, which ultimately lead to rapid aging and shorter shelf life. Cherry tomatoes are climacteric fruit; they go rapidly through a respiratory climacteric postharvest period under normal conditions of temperature, initially the respiration rate increases due to post-

maturation stage of cherry tomato, and the respiration intensity gradually reduces; ultimately, the cherry tomato rapidly becomes soft, undergoes senescence and decays thereafter (Yun *et al.* 2015). Figure 1-A exhibits the effects of different concentrations of CMC based CHPS coatings of cherry tomatoes on the respiration intensity during storage. The CMC based CHPS coatings could postpone the onset of respiration peak and decrease the respiration rate. The respiration rate after 9 days of storage in the control group was about 50% lower than in CMC based CHPS coated groups with different concentrations of CHPS. Thus, the coatings effectively inhibited the respiratory intensity of cherry tomatoes. The CMC-CHPS1 group reflected a lower inhibition degree on respiration rate, even though significant difference ($P < 0.05$) was noted between the CMC-CHPS1 and CMC-CHPS4 groups; however, the better overall effect was shown by CMC-CHPS2.

Weight Loss

Fruits and vegetables reduce their weight followed by loss of water via transpiration and respiration. Moreover, water loss lowers the gloss and plumpness of fruits and vegetables and, ultimately, affects its commercial value. Therefore, the rate of weight loss is the key factor to measure the degree of fruits and vegetables preservation. The results for weight loss are depicted in Figure 1-B. The weight loss of the tomatoes increased with the storage period, which was highest for the control, followed by the weight loss of the tomatoes coated with CMC only and different concentrations of CHPS. During the storage, gradual weight loss was noted in all the groups. Additionally, control group exhibited the increased rate of weight loss as compared to coated groups ($P < 0.05$), reflecting that coating significantly delayed water loss, thereby enhancing shelf life of the fruits. At the final 15th day of storage, maximum weight loss of 9 % was observed in CMC

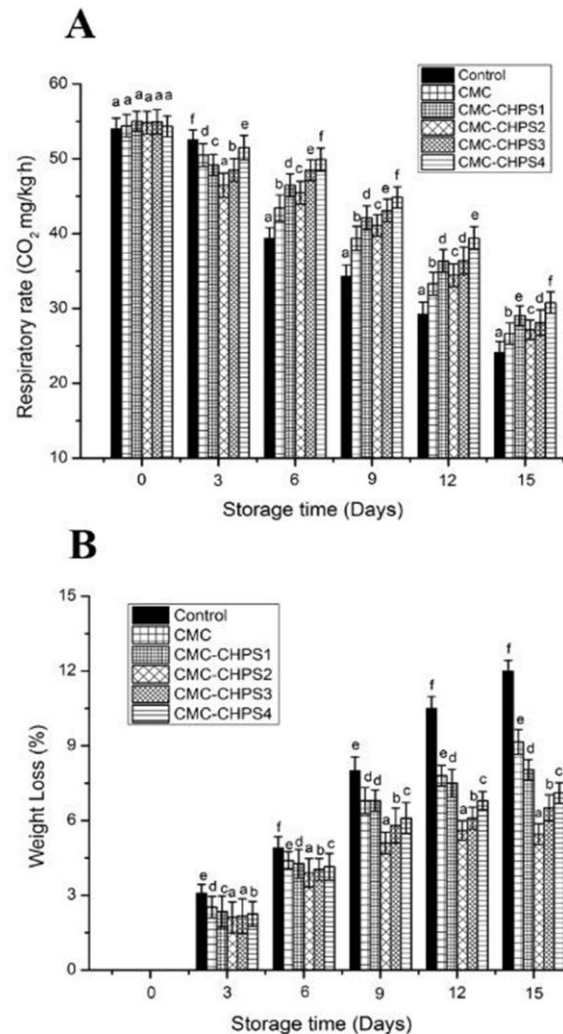


Figure 1. (A) Respiration rate and (B) Weight loss of cherry tomatoes coated with different coatings during storage.

coated fruits while that of the control fruit was 12%. CMC based CHPS coatings exhibited reduction in weight loss, which was 8.04, 7.11, 6.51 and 5.45% for the CMC-CHPS1, CMC-CHPS2, CMC-CHPS3 and CMC-CHPS4, respectively, with significant differences ($P < 0.05$). Weight loss contributed by respiration is a result of carbon atoms, in the form of carbon dioxide molecules, leaving the fruits (Dashipour *et al.*, 2015). Presence of edible coating increased the moisture surrounding the tomato, so, it decreased moisture gradient between inside and the surrounding of the

fruit. Results indicated that edible coatings based on CMC and CHPS effectively decreased weight loss of cherry tomatoes during storage.

Decay Percentage

To record decay percentage, the coated and uncoated cherry tomatoes were continuously monitored for fungal growth sign during the whole storage period. Fungal growth (Development of black spot and tiny white mass of filamentous hyphae near stem

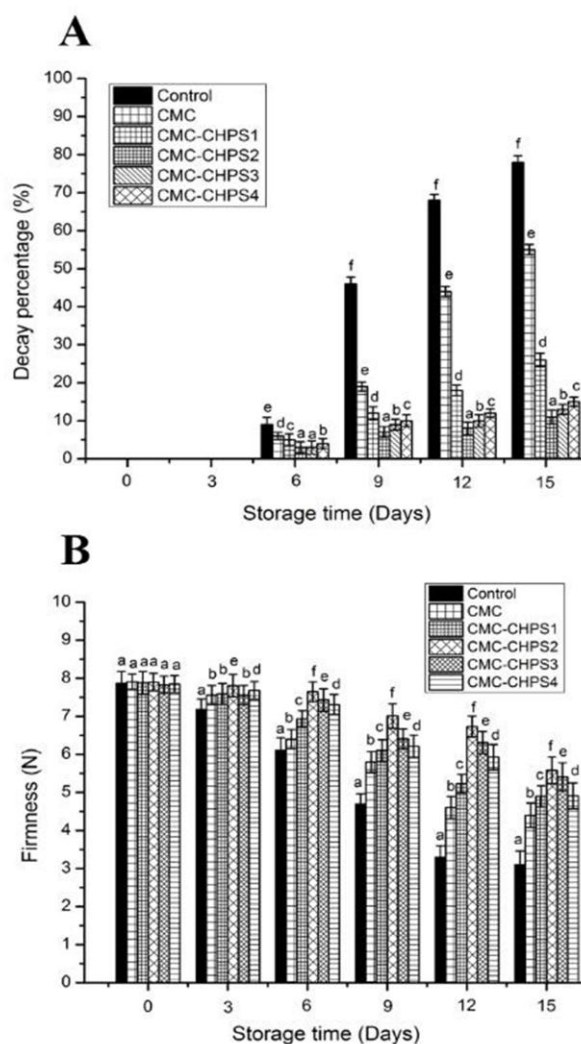


Figure 2. (A) Decay percentage and (B) Firmness of cherry tomatoes coated with different coatings during storage.

scar) on day 6 was shown more clearly on the control group than on other treated cherry tomato groups (Gallaher and Mahajan, 2013). Decay percentages of cherry tomatoes are shown in Figure 2-A in all treatment groups. No significant decay was observed during the initial 6 days of storage. But, after that, the decay percentage was increased with increase in storage days in all treatments; however, the CMC based CHPS composite coatings decreased significantly the decay of cherry tomatoes compared with control ($P < 0.05$). The initial and final decay percentage in control fruit was 9 and 78%, respectively. At 15 days of storage, the decay percentage of fruits

treated with CMC (55%), CMC-CHPS1 (26%), CMC-CHPS2 (11%) and CMC-CHPS3 (13%) and CMC-CHPS4 (15%) were still significantly less than that of the control ($P < 0.05$). It has been concluded that CMC-based CHPS composite coatings were more effective in decreasing the decay compared with the control and other coatings (CMC only). The reduction in decay percentage might be due to coating effect to delay senescence, which actually makes the fruits more vulnerable to pathogens due to loss of their cellular tissue (Palmu, and Grosso, 2005). It was found by Bai *et al.* (Bai *et al.* 2003) that 'Gala' apples coated with 10% zein preserved the quality



and prolonged the shelf life of apple compared with the control fruits. A possible interpretation for these results could be a strong interaction developed between CMC and CHPS concentration due to the cross-linking effect.

Firmness

The firmness results of cherry tomato are shown in (Figure 2-B). Texture loss is one of the distinctive factors that limit quality of fruit and vegetables and the postharvest shelf lives. Therefore, texture is a fundamental quality parameter for cherry tomatoes. The fruit firmness in all groups gradually decreased with increase in storage time. The firmness decrease was rapid in the control group as compared to treated groups, suggesting that CMC based CHPS incorporated coatings effectively inhibited the tissue softening process. At the end of storage period, control fruit clearly exhibited the lowest value of firmness. CMC-CHPS2 treated cherry tomatoes maintained the maximum firmness during the entire storage period. These results might be linked to low water loss rate due to coatings on fruit surface. The firmness of all cherry tomatoes was significantly lower among the non-coated samples compared with the coated fruit ($P < 0.05$). The fruit softening is caused by cell wall composition, intracellular materials and deterioration in the cell structure (Seymour, 1993), which is a biochemical process involved in the hydrolysis of starch and pectin by enzymes e.g. wall hydrolases. Depolymerization or shortening of chain length of pectin substances occurs as fruit ripening process progresses with an increase in polygalacturonase and pectinesterase activities (Yaman, and Bayoindirli 2002). High level of CO_2 and low level of O_2 inhibit the enzyme activities and retain the firmness during the storage (Salunkhe, 1991). In this study, CMC based CHPS coatings maintained the firmness, hence indicating

that it might be an alternative method to hinder fruit softening.

Internal Quality

Total Soluble Solid (TSS)

Coatings reduce the respiratory and metabolic rates and thereby delay the consumption of organic acids. The respiratory intensity could be reduced by applying the chemical treatment to control the atmospheric composition, which could further delay organic acids utilization during enzymatic reaction of respiration (Bico, 2009). Total Soluble Solids (TSS) of cherry tomato was initially increased due to post maturation stage of cherry tomato and some differences could be observed in all coated groups as shown in Figure 3-A. In the present study, TSS decreased significantly ($P < 0.05$) with the passage of time during storage. CMC-based CHPS composite coatings treatment had TSS variation as compared to untreated and treated with CMC only. During the entire period of storage (15 days), the TSS content of fruits in the control was 4%, whereas fruits treated with CMC-CHPS2 showed the maximum TSS content of 5.6%. The noted results are also aligned with the previous results described by Park *et al.* (Park, 1994) that TSS of tomato fruits are significantly reduced during storage. But the declining of TSS in CMC based CHPS treated tomato fruits were most likely the result of retardation of respiratory and metabolic activity, ultimately delaying the process of ripening. Biquet and Lubza (Biquet, and Labuza, 1988) also pointed out similar results where they used chocolate films as an edible moisture barrier.

Titrateable Acidity (TA)

Changes in acidity are significantly influenced by metabolism rate, especially respiration. Respiration process utilizes the

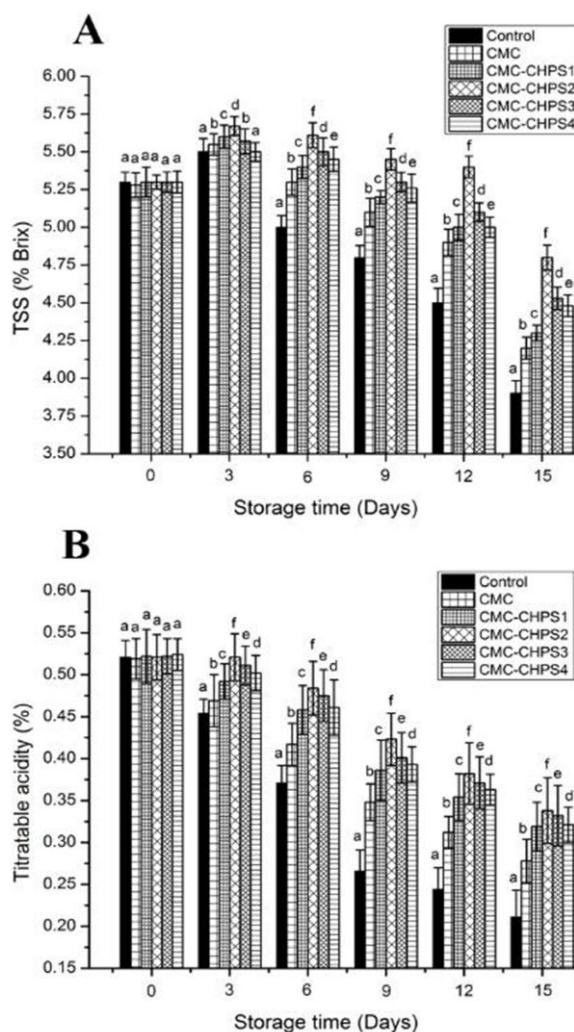


Figure 3. (A) TSS and (B) Titratable acidity of cherry tomatoes coated with different coatings during storage.

organic acids and, therefore, acidity declines during storage, which is also the important and main cause of fruit senescence (Lubna *et al.*, 2012). Titratable Acidity is one of pivotal indicator for fruit and vegetables preservation. During the storage, the differences in TA of cherry tomato are presented in Figure 3-B. The gradual decrease in TA was observed with the storage time in each group, the control group had faster reduction rate ($P < 0.05$) than the treated one, which may be linked to the metabolism in the fruit. In fruits and vegetables, the metabolic activities occur continuously. During the respiration, organic

acids are not only the major source of ATP but also intermediate source of metabolites for various types of biochemical reactions; consequently, the amount of TA decreases during storage. After coating, respiration rate of cherry tomatoes was significantly inhibited; hence, the organic acid metabolism was reduced. Coatings with CMC-CHPS2 showed the highest content, which was superior to the CMC only. These results demonstrate that the CMC based CHPS incorporated coatings could delay the nutrients consumption and enhance the shelf life of fruits. CMC-CHPS2 significantly ($P < 0.05$) prolonged cherry tomatoes

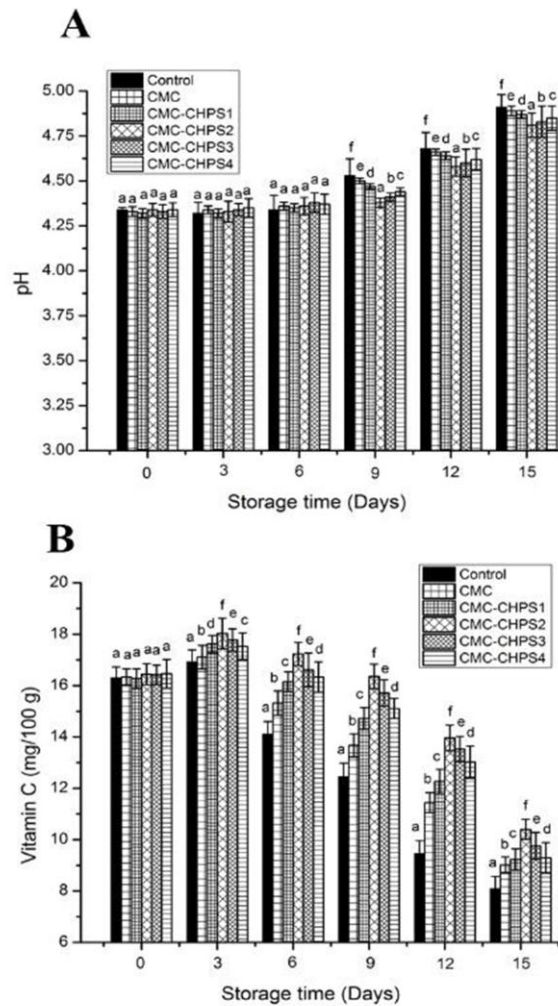


Figure 4. (A) pH and (B) Vitamin C content of cherry tomatoes coated with different coatings during storage.

preservation as observed in the slow rate of TA reduction.

pH

Changes in pH coated and uncoated cherry tomatoes are shown in Figure 4A. During the storage, this parameter increased significantly, which is related to fruit senescence, due to organic acids consumption during respiration (Yaman, and Bayoindirli, 2002). pH difference between 0 and day 6 was not statistically significant ($P > 0.05$) for all treatment groups including CMC-based CHPS coating. Cherry tomatoes

pH increased at the end of storage period for the control as well as the coated tomatoes. Furthermore, during the comparison, control group had more increased pH than the treatment groups. The pH values of cherry tomatoes coated with CMC, CMC-CHPS1, CMC-CHPS2, CMC-CHPS3 and CMC-CHPS4 were significantly different than the pH of uncoated samples at day 0 and day 15.

Vitamin C

Ascorbic acid is very important in maintaining physiological functions in the human body, and is also considered as a

measure of fruit freshness. Vitamin C in cherry tomatoes is higher than in most other fruits and vegetables, thus, there is a high demand for cherry tomatoes. Figure 4-B reflects the effect of different concentrations during the storage of CMC based CHPS coatings on Vitamin C content. In the present study, samples coated with CMC-CHPS2 showed better results as compared with the control sample. In the present study, Vitamin C content was initially increased, and then gradually decreased. That could be due to post maturation stage of the cherry tomato used in this study, which was purchased from the local market (Hou, *et al.*, 2015). These results could be associated with the fact that the highest amount of Vitamin C was attained at the early ripening stage, which then further ameliorated the nutritional value of the tomato. However, Vitamin C concentration declined due to oxidation. Vitamin C decreased at lower rate in the treated groups compared with the control, reflecting the role of CHPS incorporated CMC coating on vitamin C content ($P < 0.05$). The edible film could delay gas exchange between environment and tissues, which decreases O_2 concentration that oxidizes vitamin C. Thus, Vitamin C oxidation was efficiently inhibited, thereby high concentration of Vitamin C was maintained in the coated fruits.

Lycopene Content

Deep red color of ripe tomato fruits is principally due to lycopene pigment. Lycopene is one of most abundant carotenoid in ripe tomatoes, containing approximately 80 to 90% of the pigments present (Agarwal, and Rao, 1998). Normally, 100 g of tomato fruit contain about 3 to 5 mg of lycopene (Sulaeman, *et al.* 2001; Hart and Scott, 1995). Lycopene is an effective antioxidant, which quenches highly reactive singlet oxygen radicals that ultimately acts to prevent cancer (Akanbi, and Oludemi, 2004). Lycopene needs to be

protected from extreme pH and excessive heat conditions, oxygen and lipid degrading enzymes, and exposure to light in order to avoid its isomerization and oxidation (Shi, and Maguer, 2000). The results of the present study on lycopene content are shown in Figure 5-A, which reflects the significant differences in lycopene content among all the treatment groups compared with the control. In the present investigation, during the initial days of storage, lycopene content increased. Afterwards, it decreased significantly ($P < 0.05$), which could be due to the type of cherry tomato fruit used in this study: 60-90 % of it had red color that, in post maturation stage, turned into deep red color (90%) (Helyes *et al.* 2006). The lycopene content in the control group decreased more rapidly compared to CMC only and other treatment groups. The treatment groups delayed the decrease of lycopene content. This can be attributed to delay in ripening due to reduced respiration rate. Overall, the group treated with CMC-CHPS2 showed better results as compared to other treatment groups. These results are in agreement with (Causse, *et al.* 2002; Brandt *et al.* 2003).

Total Polyphenols

The total polyphenols were expressed as mg of gallic acid equivalents per 100 g of fruit sample. It showed an increasing trend to a peak value and then declined, but the decrease in the control group was more compared to the coated groups (Figure 5-B). The total polyphenols of CMC based CHPS coated cherry tomatoes increased to peak value of 56.9 mg on day 3, after which it dropped to 34 mg/100 gm on day 15. The edible coatings acted as a potential sealing barrier for the fruits, thereby resulting in the production of secondary metabolites like phenols, etc. The overall decrease in phenolic compounds could be linked to cell structure breakdown as the fruit senesced (Fagundes, *et al.*, 2013). During the storage, the fruits in CMC-CHPS2 showed high

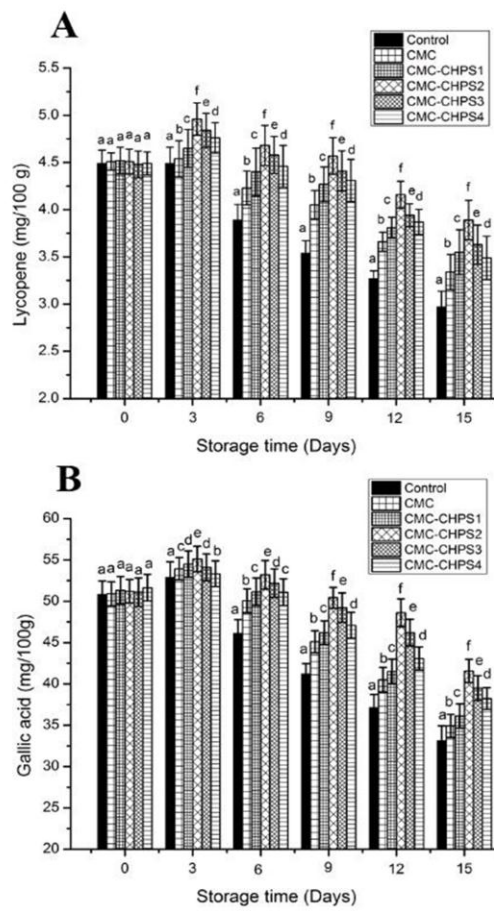


Figure 5. (A) Lycopene content and (B) Total polyphenols of cherry tomatoes coated with different coatings during storage.

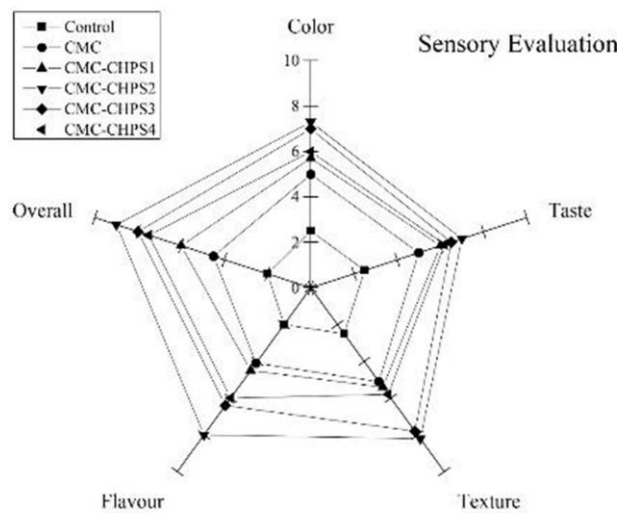


Figure 6. Sensory evaluation of cherry tomatoes coated with different coatings during storage.

levels of phenols, which could be due to the fact that CMC-CHPS2 provided a dense coating. The reason is that it possibly sealed the fruit to provide a preventive barrier against oxygen supply for enzymatic oxidation of phenolic compounds (Hernandez, 2006). (Dashipour *et al.* 2015) have also reported that the coating of CMC enriched with the *Z. multiflora* essential oil showed better effect on antioxidant activity while 3% *Z. multiflora* proved highest total phenolic contents.

Sensory Evaluation

Sensory evaluation of coated and uncoated cherry tomato fruits exhibited significant ($P < 0.05$) differences at the end of the storage period. The coated fruits had overall best scores in acceptability. The results are presented in Figure 6. After 5 days of storage, overall likeness of uncoated (control) group declined steadily, while the overall likeness for all the other fruits was stable during the initial 6 days of storage. The cherry tomato fruits in the control decayed and exhibited poor appearance. These observations reflect that CMC based CHPS incorporation might be utilized successfully as an edible coating for enhancing the shelf life and improving the quality of cherry tomatoes. Similar observations were reported by (Elanany *et al.*, 2009) who improved the shelf life of 'Anna' apples by applying edible coating.

CONCLUSIONS

The present results suggest that CMC application in combination with CHPS seem to have beneficial impact on the decay percentage, weight loss, firmness, TSS, TA and had positive effects on maintaining higher amount of Vitamin C, Lycopene, and total phenols of cherry tomatoes. By considering all these results, CMC-CHPS2 composite coating showed the best quality of cherry tomatoes compared with other

treatments. Therefore, CMC-CHPS composite coatings can be useful and an alternative method to improve cherry tomatoes postharvest quality.

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حفظ کیفیت گوجه فرنگی گیلاسی با پوشش کربوکسی متیل سلولز مبتنی بر کامپوزیت پلی ساکارید پوسته نخود (*Cicer arietinum* L.)

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چکیده

در این پژوهش، کارایی کربوکسی متیل سلولز (CMC) مبتنی بر کامپوزیت پلی ساکارید پوسته نخود (CHPS) به عنوان یک پوشش خوراکی (edible coating) در مورد انبارداری و خواص فیزیکوشیمیایی گوجه فرنگی گیلاسی بررسی شد. به این منظور، گوجه فرنگی های گیلاسی با غلظت های مختلف CHPS (شامل ۰/۲۵٪، ۰/۵۰٪، ۰/۷۵٪، ۱٪) پوشش داده شد تا از آنها در ماندگاری (دوره انبارداری) در حرارت ۲۰ درجه سانتیگراد حفاظت شود. نتایج حاکی از این بود که پوشش CHPS حاوی CMC در مقایسه با تیمار شاهد موثر بود و موجب کاهش فرایند تنفس، کاهش وزن، سفتی، محتوای لایکوپن، کل جامدات محلول، ویتامین C، فنول کل، و بهبود پسند کلی (overall likeness) میوه شد. نیز، مشاهده شد که همه این اثرها وابسته به درج بود. به طور کلی، کاربرد پوشش CHPS حاوی CMC می تواند ماندگاری گوجه فرنگی گیلاسی را طولانی کند.