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ORIGINAL ARTICLE

Effect of edible coatings on 'Misty' blueberry (*Vaccinium corymbosum*) fruits stored at low temperature

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Abstract

Blueberry fruits are modern remedy for different health complications, due to presence of different nutrients and antioxidants. Nutrient rich blueberry cannot to be stored for many days because of its poor shelf life of merely 2–4 days at ambient conditions. Hence, there is lack of strategy to extend their availability for longer time. To fill this gap, the use of edible coatings has come to the way to increase the freshness of fruits. Hence, we studied the effect of four edible coatings such as carboxy methyl cellulose (1%), xanthan gum (0.3%), guar gum (0.75%) and gum Arabic (10%) on the 'Misty' blueberry fruits stored at low-temperature condition (1 ± 1 °C and 85–90% RH). During storage, observations on different physical and functional attributes were recorded till 35th day of storage. Our results showed that all the coatings were effective in extension of shelf life of coated fruits but the CMC-coated 'Misty blueberry fruits exhibited 44% lesser weight loss and maintained 22% higher firmness over non-coated fruits. Similarly, such fruits maintained ~ 40% higher level of ascorbic acid, 16% total phenolic content, 14% total anthocyanin content and 13% antioxidant activity. Based on these findings, it can be concluded that under low-temperature storage condition, CMC (1%) was the most effective coating as it increased the shelf life of 'Misty' blueberry up to 35 days of storage while maintaining quality.

Keywords Blueberry · Edible coatings · Shelf life · Total phenolic content · Anthocyanin content · Antioxidant activity · LOX activity

Introduction

Blueberry is a prostrate shrub of perennial flowering bush, bears waxy coated purple berry fruits from May to August. Blueberry belongs to *Vaccinium* genus of Ericaceace family. Cultivation of blueberry is concentrated around North American region since ancient time. Its fruits are known for their rich antioxidant activity, dietary fibre, vitamin C and K content (Sharma and Krishna 2018). Due to its esteemed health benefits, fruits are used in many processed products such as ice cream and yoghurt as value added products. Considering its importance, blueberry varieties such as 'Misty', 'Sharp Blue', 'Biloxi', 'Jewel', 'Gulf Coast', 'Blue Crop', 'Star', and 'Legacy' have been introduced at few research stations in Kullu and Palampur (Himachal Pradesh). Of several varieties, 'Misty', 'Sharp Blue', 'Blue Crop', and 'Legacy' are gaining popularity (Sharma and Krishna 2018). Also in a many supermarkets, consumer sized fresh blueberry packages are available. This shows the growing importance of blueberry fruits in the modern era. Despite all its significance, the storage life of blueberry is very meagre and, therefore, prudent attention is required for extension of its shelf life.

For postharvest management of different fruits, several techniques, such as use of edible coatings (Navarro-Tarazaga et al. 2011; Jhalegar et al. 2015; Kowalczyk et al. 2018; Kumar et al. 2018a, b; Prasad et al. 2018), 1-MCP treatment (Sharma et al. 2013), novel molecule such as nitrous oxide (Sharma and Sharma 2016; Jayarajan and Sharma 2019), ethylene absorbents (Scott et al. 1984) and ozone treatment (Aafia et al. 2018) have been attempted with

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variable success. Among different techniques used for postharvest management and shelf life extension of fruits, use of edible coatings is gaining popularity day-by-day globally. The edible coatings are made from proteins, lipids, polysaccharides or from a mixture of different compounds (Dhall 2012). These coatings extend the shelf life of produce by reducing moisture loss, reducing decay and preserving the texture of produce. The coatings may be applied directly on the surface of produce by dipping or spraying.

The studies pertaining to use of edible coating had never been attempted on blueberry fruits in India, and considering the importance of edible coatings on shelf life extension of blueberry, we have selected variety 'Misty' because it has large fruit size, firm fruit texture and high nutraceutical values (Joseph et al. 2014). Our study focuses on use of economically viable and environmental friendly edible coatings for extension of shelf life of blueberry fruits.

Materials and methods

Description of experiment

The experiment was undertaken in the Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi-110012 during 2017–2018. The fruits of 'Misty' blueberry variety were harvested at purple colour break stage from a private orchard, located at Katrain, Kullu, Himachal Pradesh. Freshly harvested blueberry fruits were brought to the laboratory and treated with four different edible coatings as under.

Edible coating treatment

Four edible coatings namely carboxy methyl cellulose (CMC-1%), xanthan gum (0.3%), guar gum (0.75%) and gum Arabic (10%) were selected for the study. The said concentrations of different coatings were decided after reviewing the literature (Arnon et al. 2014; Khaliq et al. 2015). Different concentrations of the coatings such as CMC (1%), xanthan gum (0.3%), guar gum (0.75%) and gum Arabic (10%) were prepared by dissolving 2 g of CMC, 6 g xanthan gum powder, 15 g of guar gum powder and 200 g of gum Arabic powder, respectively, in 2 L of luke warm water whereas the untreated blueberries served as control. Freshly harvested blueberry fruits were dipped in the edible coating formulations separately for 10 min and after treatments, the fruits were dried under fan at the ambient room temperature followed by packing in plastic punnets (200 fruits per punnet) with four replications. After packaging, fruits were stored at low temperature (1 ± 1 °C and 85–90% RH). During storage, observations on different physical and functional attributes recorded at 7 days interval for 35 days.

Determination of physiological loss in weight (%) and fruit firmness (N)

Physiological loss in weight of 'Misty' blueberry fruits was determined by weighing the fruits at an interval of 7 days, with the help of an electronic digital balance and expressed in percentage (%):

$$\text{PLW}\ (\%) = \frac{\text{Initial weight} - \text{weight after storage} \times 100}{\text{Initial weight}}$$

Fruit firmness of blueberry fruits was determined by texture analyzer (model: TA + Di, Stable micro systems, UK) and expressed as maximum force (kgf) during the compression, in Newtons (N).

Determination of total soluble solids and ascorbic acid content

The total soluble solids of blueberry samples were measured using fisher hand refractometer (0–50) and the results were expressed as degree Brix (°B) at 20 °C (AOAC 1990). Ascorbic acid was estimated with the help of method proposed by Ranganna (1999) and calculated by the following formula and represented as mg of ascorbic acid per 100 g of sample:

$$\text{mg of ascorbic acid}/100\ \text{g sample} = \frac{\text{Titre value} \times \text{dye factor} \times \text{vol. made up} \times 100}{\text{Aliquot of extract} \times \text{volume of sample taken}}$$

Estimation of total phenolic and total anthocyanin content and antioxidant (AOX) activity

The total phenolic content in the fruits were determined and expressed as mg of gallic acid equivalents (GAE)/100 g of extract using method suggested by Singleton and Rossi (1965). The total monomeric anthocyanin content was determined using the method of Wrolstad et al. (2005) and expressed as mg/100 g of fruit weight. Antioxidant activity in the blueberry fruits was determined using CUPRAC (cupric reducing antioxidant capacity) method recommended by Apak et al. (2004) and expressed as μmol TE/g of fresh weight.

Estimation of lipoxygenase (LOX) activity

Lipoxygenase activity of stored blueberry fruits was determined using the method of Axelrod et al. (1981) and expressed as μmoles $\text{min}^{-1}\ \text{g}^{-1}$ fresh weight.

Determination of overall acceptability

Overall acceptance is the prominent criteria for the estimation of extent of acceptability of the coated and non-coated fruits to consumers using the methodology of Amerine et al. (1965). Semi-trained panellists had evaluated the samples on Hedonic scale (0–9) on the basis colour, flavour, texture, and taste at 7-day interval.

Statistical analysis

The experiment was designed in factorial CRD (Completely Randomised Design) with five treatments of four replications. The results were compared from ANOVA after extracting C.D. (Panse and Sukhatme 1984). The data were analysed using the SAS (Statistical Analysis System).

Results and discussion

Physiological loss in weight (PLW) and fruit firmness

Consumers like fresh fruits which are fully turgid and have no shrinkage. During postharvest handling and marketing, fresh produce always lose some amount of moisture which leads to shrinkage and decline in fruit firmness and thus lowers down the consumer acceptability. Hence, maintenance of weight loss and fruit firmness of the harvested produce by some means are always desirable. In this context, we observed in this study that PLW in CMC-coated blueberry fruits was ~44% less in comparison to non-coated (control) blueberry fruits (Fig. 1). In general, there was increase in weight loss with the increase in storage period, and it was the highest on 35th day of storage (12.9%) and lowest on 7th day of (1.5%) storage. The higher PLW in the non-coated blueberry fruits might be due to higher moisture loss compared to coated fruits. Edible coatings usually form a barrier between the fruit and surrounding environment, which reduce water and transpiration loss. Lower PLW in CMC-coated 'Misty' blueberry fruits over other coatings may be due to lower moisture loss as well as metabolic activities such as respiration and ethylene evolution rates. In a similar study, Perez-Gago et al. (2003) also reported a decrease in PLW of CMC-coated plums over other coatings or non-coated plums. Furthermore, Zhou et al. (2007) have also reported that edible coatings such as shellac, Semperfresh™ and CMC-coated 'Huanghua' pears exhibited reduced weight loss during storage than uncoated pears.

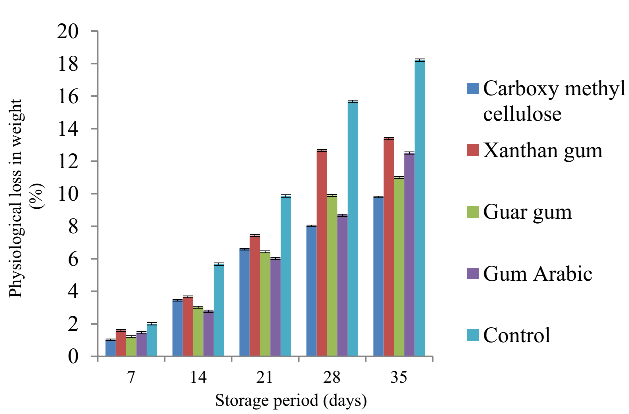

Fig. 1 Impact of edible coatings on PLW of 'Misty' blueberry stored at low-temperature condition (1 ± 1 °C and 85–90% RH)

The fruit firmness is an important attributes of freshness of a produce. The produce with better firmness is always preferred in the market. Hence, maintenance of better fruit firmness during storage is always desirable. In this study, we observed that the CMC-coated 'Misty' blueberry fruits maintained ~ 22% higher fruit firmness than non-coated (control) blueberry fruits and/or rest of the coatings (Table 1). Furthermore, the fruit firmness decreased with the progressive increase in storage period, being the highest on 7th day of storage (2.8 N) and the lowest on 35th day of storage (1.2 N). Less moisture loss and maintenance of membrane integrity by CMC coating might have reduced loss of fruit firmness during storage. Kumar et al. (2018a, b) had also reported that lac-based coatings maintained better firmness during storage of 'Santa Rosa' plums.

Quality parameters

Total soluble solids impart sweetness and palatability to the produce. However, these quality attributes usually decrease during the storage of produce due to different metabolic activities. Hence, effective strategies for preservation of these quality parameters are always required. In the present study, CMC-coated fruits maintained higher TSS (17.3°Brix) than non-coated blueberry fruits (17.1°Brix) (Fig. 2). Furthermore, the total soluble solid content increased with the increase in storage period, being the lowest on 7th day of storage (16.9°Brix) and the highest on 35th day of storage (17.8°Brix). Our research resembled the findings of Duan et al. (2011) who reported the potential effects of edible coatings such as Semperfresh, acid-soluble chitosan, water-soluble chitosan, calcium caseinate and sodium alginate on the total soluble solids of fresh blueberries during storage period. Similarly, Sogvar et al. (2016) also reported Aloe vera (AV) gel in combination with ascorbic acid maintained higher TSS and other quality attributes in strawberry fruits compared to untreated ones.

Ascorbic acid is known for its potential antioxidant activity which is responsible for free radical scavenging and thereby protects the fruits from degradation. Its content undergoes loss during storage, hence the technique

Table 1 Effect of edible coatings on fruit firmness of 'Misty' blueberry stored at 1 ± 1 °C and 85–90% RH

Treatment	Fruit firmness (*N*)						Mean
	Storage period (days)						
	0	7	14	21	28	35	
Carboxy methyl cellulose	3.4	3.2	2.7	2.5	1.5	1.3	2.2
Xanthan gum	3.4	3.0	2.5	2.2	1.3	1.1	1.9
Guar gum	3.2	2.8	2.6	2.2	1.2	1.1	2.0
Gum Arabic	3.2	2.9	2.6	2.3	1.3	1.2	2.1
Control	3.4	2.2	2.4	2.0	1.3	1.1	1.8
Mean	3.3	2.8	2.6	2.3	1.3	1.2	
C.D. (0.05)	Treatment (T) = 0.16; storage days (S) = 0.16; $T \times S$ = N/A						

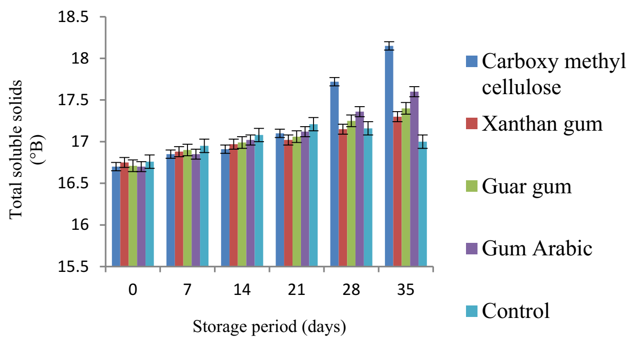

Fig. 2 Total soluble solids (TSS) of 'Misty' blueberry affected by edible coatings at low-temperature storage condition (1 ± 1 °C and 85–90% RH)

for its restoration is most appreciable. In this context, our research recorded that CMC-coated 'Misty' blueberry fruits exhibited ~ 67% higher ascorbic acid content over non-coated blueberry fruits (Table 2). The ascorbic acid content decreased with the increase in storage period, being the highest on 7th day of storage (19.0 mg/100 g) and the lowest on 35th day of storage (11.7 mg/100 g). Higher ascorbic acid content in CMC-coated blueberry fruits may be due to low moisture loss and lower rates of respiration in such fruits. Navarro-Tarazaga et al. (2011) have observed that hydroxypropyl methylcellulose (HPMC) edible film helped in maintaining higher ascorbic acid content over non-coated plums during the storage. Similarly, Soradech et al. (2017) have also reported that shellac and gelatine-coated banana fruits have higher ascorbic acid content than non-coated ones.

Functional attributes

Phenolic compounds are secondary metabolites which protect us from various ailments by scavenging free radicals from our body. In this study, we observed ~ 16% higher total phenolic content in CMC-coated fruits in comparison to non-coated blueberry fruits (Table 3). Higher phenolic content in CMC-coated blueberry fruits over other coatings may be due to less transpiration and respiration rate which might have reduced the ripening process and thereby retard the phenolic content degradation. Our results are in contradiction with that of Saba and Sogvar (2016) who reported that CMC coatings reduced the total phenolic in apple during storage.

Anthocyanins belong to flavonoid group of compounds which are responsible for imparting colour to food but being water soluble, these are susceptible to great loss during storage. Hence, in this study, we evaluated the effect different

Table 2 Variation in ascorbic acid content of 'Misty' blueberry stored at 1 ± 1 °C and 85–90% RH

Treatment	Ascorbic acid content (mg/100 g)						Mean
	Storage period (days)						
	0	7	14	21	28	35	
Carboxy methyl cellulose	24.0	22.5	21.3	20.2	18.6	17.3	20.0
Xanthan gum	24.2	17.5	15.3	13.5	11.8	9.9	13.6
Guar gum	24.0	18.5	16.3	15.7	13.3	11.6	15.1
Gum Arabic	24.2	19.6	18.2	16.5	14.5	12.4	16.3
Control	24.0	16.6	14.4	11.6	9.9	7.6	12.0
Mean	24.1	19.0	17.1	15.5	13.6	11.7	
C.D. (0.05)	Treatment (T) = 0.16; storage days (S) = 0.16; $T \times S$ = 0.35						

edible coatings on anthocyanin content in blueberry fruits, and we observed that CMC coating achieved ~ 14% better retention of anthocyanin content in comparison to non-coated blueberry fruits (Table 4). The total anthocyanin content decreased with the increase in storage period and it was the highest on 7th day of storage (129.6 mg/100 g) and lowest on 35th day of storage (98.5 mg/100 g). CMC-coated blueberry maintained higher levels of anthocyanin content primarily because of less degradation. In a similar study, Kalt et al. (1999) reported that anthocyanin content in blueberry decreased with the increase in storage period. Similarly, Kumar et al. (2017) also recorded increase in anthocyanin content in chitosan-coated 'Santa Rosa' plums.

Antioxidant activity is responsible for retardation of free radical activity and strengthening immune response of fruits. To maintain higher antioxidant activity in 'Misty' blueberry fruits during storage, we attempted different edible coatings. It was observed that CMC-coated fruits exhibited quite higher antioxidant activity (~13% higher) than non-coated blueberry fruits (Table 5). The antioxidant activity decreased with the increase in storage period, being the highest on 7th day of storage (20.2 µmol TE/g) and the lowest on 35th

Table 3 Influence of edible coatings on total phenolic content of 'Misty' blueberry during storage at 1 ± 1 °C and 85–90% RH

Treatment	Total phenolic content (mg GAE/100 g)						Mean
	Storage period (days)						
	0	7	14	21	28	35	
Carboxy methyl cellulose	154.8	149.3	142.6	135.6	129.5	122.5	139.0
Xanthan gum	154.6	147.6	139.4	126.4	117.4	95.5	130.2
Guar gum	154.4	145.5	135.4	129.5	118.6	106.4	131.7
Gum Arabic	154.5	142.3	137.4	127.5	121.7	115.2	133.1
Control	154.6	135.5	130.5	121.5	92.4	82.1	119.4
Mean	154.6	144.0	137.1	128.1	115.9	104.3	
C.D. (0.05)	Treatment (T) = 1.28; storage days (S) = 1.40; $T \times S$ = 3.14						

Table 4 Impact of edible coatings on total anthocyanin content of 'Misty' blueberry fruits during cold storage (1 ± 1 °C and 85–90% RH)

Treatment	Total anthocyanin content (mg/100 g)						Mean
	Storage period (days)						
	0	7	14	21	28	35	
Carboxy methyl cellulose	138.6	132.4	126.6	122.4	118.6	120.4	126.5
Xanthan gum	138.4	128.4	121.3	117.4	105.4	87.4	116.4
Guar gum	138.5	130.4	125.5	119.4	105.5	98.6	119.7
Gum Arabic	138.6	131.4	127.4	120.4	115.4	107.5	123.4
Control	138.5	125.4	121.5	115.3	87.4	78.4	111.1
Mean	138.5	129.6	124.5	119.0	106.5	98.5	
C.D. (0.05)	Treatment (T) = 1.29; storage days (S) = 1.41; $T \times S$ = 3.16						

Table 5 Antioxidant activity of 'Misty' blueberry fruits as influenced by edible coatings during storage at 1 ± 1 °C and 85–90% RH

Treatment	Antioxidant activity (µmol TE/g)						Mean
	Storage period (days)						
	0	7	14	21	28	35	
Carboxy methyl cellulose	22.6	21.4	18.4	15.3	13.4	12.4	17.2
Xanthan gum	22.6	19.6	17.6	14.2	11.4	8.9	15.7
Guar gum	22.5	20.1	18.1	12.5	11.5	9.6	15.1
Gum Arabic	22.4	20.4	18.4	16.3	12.5	11.4	16.9
Control	22.5	19.4	17.4	14.5	10.5	7.5	15.3
Mean	22.5	20.2	18.0	14.6	11.9	9.9	
C.D. (0.05)	Treatment (T) = 1.27; storage days (S) = 1.39; $T \times S$ = N/A						

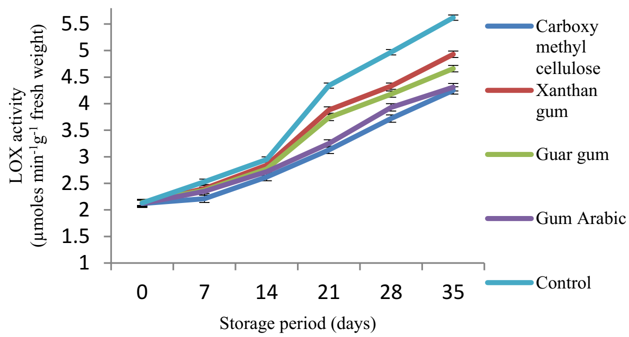

Fig. 3 Influence of edible coatings on LOX activity of 'Misty' blueberry stored at low temperature (1 ± 1 °C and 85–90% RH)

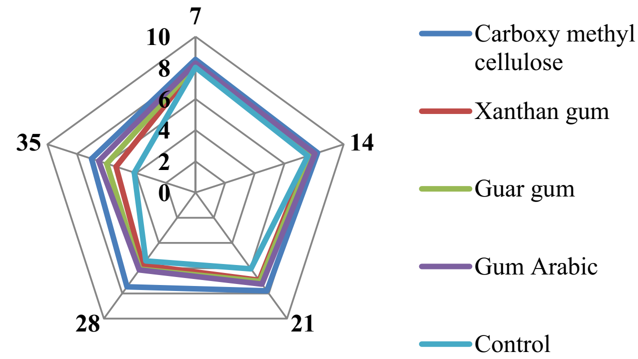

Fig. 4 Overall acceptability of 'Misty' blueberry fruits as influenced by edible coatings during storage at low-temperature conditions (1 ± 1 °C and 85–90% RH)

day of storage (9.9 µmol TE/g). The higher AOX activity in CMC-coated blueberry might be due to higher levels of total phenolic content, anthocyanins and ascorbic acid in such fruits. In a similar finding, Sanchez-Gonzalez et al. (2011) observed that hydroxypropyl methyl cellulose (HPMC) or chitosan coatings significantly increased the antioxidant activity of the grapes during storage.

Lipoxygenase (LOX) activity

Lipoxygenase enzyme is responsible for weakening of cell wall which thereby leads to senescence and reduction in the shelf life of fruits. Hence, reduction in LOX activity helps in enhancement of shelf life of fruits. In this study, we observed that CMC-coated fruits exhibited ~ 28% lower LOX activity compared to untreated fruits (Fig. 3). Further, the LOX activity gradually increased with increase in storage period, being the lowest on 7th day of storage (2.4 µmol min^{-1} g^{-1} FW) and the highest on 35th day of storage (4.8 µmol min^{-1} g^{-1} FW). Constant metabolic rate and retention of high stored energy in CMC-coated stored fruits might have provided resistance against the LOX activity during storage. Petriccione et al. (2015) have also revealed less LOX activity in chitosan-coated strawberry fruits over untreated ones.

Overall acceptability of fruits

Whatsoever treatment is given to any fresh fruits, it is overall acceptability of the produce which decides the effectiveness or recommendation of the treatment. Our study elucidated the significant effect of edible coating on overall acceptability of 'Misty' blueberry fruits, being the highest in CMC-coated fruits (7.8), and the lowest in non-coated blueberry fruits (6.3) (Fig. 4). The better ability of CMC coating in maintaining fruit texture, PLW, and overall fruit quality during storage might have helped for retaining better sensory attributes than other coatings and untreated fruits. Trevino-Garza et al. (2017) also studied the positive effects of edible coating on sensory attributes such as colour, odour, flavour, texture and overall acceptance of pineapples and they concluded that the coatings enhanced the overall acceptability of pineapples.

From this study, we can draw a conclusion that different edible coatings were effectively responsible for enhancing the shelf life of 'Misty' blueberry fruits which will be helpful in increasing its availability in the market. Among the coatings, the CMC coating was proved to be the best as it increased storage life of 'Misty' blueberry up to 35 days at low-temperature condition along with the retention of different quality attributes in a better way than other coatings or non-coated fruits.

Author contribution statement MGT and RRS executed the work. Analysis of data and rough draft of the article was prepared by MGT. RRS did editing and final correction in the article.

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