EFFECT OF GELATIN BASED EDIBLE COATINGS ON MINIMALLY PROCESSED CARROT (*DAUCUS CAROTA* L.) SLICES

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Abstract

Minimally processed carrots are an important segment in the food retail industry. Carrots are rich in bioactive compounds like polyphenols and other compounds having health promoting properties. Also, the shift of modern-day consumer towards fresh, minimally processed, conveniently prepared food is making freshly cut carrots more and more popular. But their highly perishable nature and leaching of nutrients entails good packaging which can also positively affect the appearance. Edible packaging could be a good solution for this problem, compared to traditional packaging materials. They are a continuous thin layer (≤ 0.6 mm) based primarily on hydrocolloids (proteins, carbohydrates, fats). Edible packaging as the name suggests, can be consumed with the food on which they are applied. They act as a barrier against water, gaseous and solute transfer and provide mechanical strength to the food product. To encounter the problems of environmental pollution and sustainable development created by presently used plastic packaging obtained from non-biodegradable resources, more emphasis is given to edible packaging. Moreover, edible packaging support circular economy.

The present research work discusses the effect of edible coatings made of gelatin, citric acid and glycerin. Two different concentrations of gelatin, 8% and 10% were used and their effect was seen on carrots against the control samples (carrot samples having no coating). The concentration of glycerin was 2% and ascorbic acid was 1% in both the coating solutions. Carrots were sliced having 7 mm thickness. Coating was applied using the dipping method. The control and coated samples were stored in ambient conditions. Total polyphenol content, Percent loss in weight, color values, textural analysis of sliced carrots were recorded for 5 days.

Key words: *freshly cut vegetables, carrots, biodegradable, edible packaging, gelatin, circular economy*

1. INTRODUCTION

It has been proven by numerous scientific studies that a good lifestyle and eating habits promote health. Due to the omnipresence of the internet, consumers can access all the information including health-related in a flash of a second. Thus, modern day consumer is much more aware, conscious and demanding. Moreover, the busy lifestyles, new habits and demand for ready to eat food has resulted in growth of minimally processed fruit and vegetable market (Algeria *et al.,* 2010). Minimally processed fruits and vegetables are more convenient, have fresh characteristics, and health benefits. Minimal processing can be any of these unit operations- washing, sorting, peeling, coring, slicing, etc. (Howard and Devi, 1996. But in the process, the integrity of fruits and vegetables is altered because of the wounding (Emmabux and Minnar, 2003). Carrots are among the top ten most popular minimally processed vegetables (Ragaert *et al.,* 2004). Total worldwide production of carrot in 2019 was 44.77MT including turnips (FAOSTAT 2020). Carrots are multi-nutritional vegetables. They are rich in natural bioactive compounds which are acknowledged for their nutraceutical and health benefits (Ahmed *et al.,* 2019). Carrots are an excellent source of ascorbic acid (vitamin-C), phenols and β- carotene. Phenols in carrots are responsible for color, bitterness and aroma (Zhang *et al.,* 2005). Different types of phytochemicals might be helpful against free radical scavengers, cancers, high blood pressure. They also play crucial role in enhancing the immune system (Sharma *et al.,* 2012). β- carotene is a precursor of vitamin A and is good for eyes.

Minimally processed carrots are prone to several physiological changes that reduce their shelf life and quality. The surface abrasion may accelerate the respiration of carrot tissues, resulting in elevated protein degradation, degradation of carbohydrates and lipids and development of off flavors (Li and Barth, 1998). The wounding during minimal processing is also known to commence a new protective layer which is known as 'white blush' (Boun and Huxoll, 1991a). White blush is not liked by consumers and limits the acceptability of minimally processed carrots.

A number of techniques have been applied to enhance the quality and shelf life of fresh cut carrots including modified atmosphere, use of electrolyzed water, use of essential oils (Dawange *et al.*, 2016; Ranjitha *et al.*, 2017; Koide *et al.*, 2011; Romeo *et al.*, 2010).

The present packaging material plastics are mainly produced from fossil fuels and may take thousands of years to biodegrade. Plastics are a menace to the environment and are hurdle in the sustainable development (Li *et al.*, 2016; Kedzierski *et al.*, 2020). Some new studies have found that plastics also lead to global warming as they produce methane and ethylene (Royer *et al.*, 2018)..

Edible films and coatings can be a good option, they have answer to all the problems created by the conventional packaging materials. They are made up of edible biopolymers and food grade additives. The biopolymers can be proteins, polysaccharides, lipids, or their mixture. Edible films are free standing structures and are applied to food after they are made but edible coatings are applied directly to the food stuff (Han, 2014).

Gelatin is natural water-soluble protein obtained by partial hydrolysis of collagen which is found in bones, skins, connective tissues and tendons of vertebrates and invertebrates (Shankar *et al.*, 2016). Gelatin has very good gelling, thickening and water binding capacity (Ramos *et al.*, 2016). Gelatin is also used as gelling, texturization, stabilization and emulsification agent in the food industry (Alfaro *et al.*, 2015). Instead of being dumbed as agro-industrial waste, gelatin can be revalorized from unused or partially used parts of animals and can be revalorized to make edible coatings for packaging of food commodities (Iahnke *et al.*, 2015). It can be a competitive alternative biopolymer as its use directly corelate to novel technologies. The major drawbacks of gelatin are mechanical and water barrier properties making it difficult to use in packaging (Jeya Shakila *et al.*, 2012).

Not much research has been done to see the effect of gelatin coatings on minimally processed carrots. Considering the above, the objective of present work was to develop edible coating based on gelatin, apply it to minimally processed carrot slices and evaluate shelf life of the product based on color, texture, percentage loss in weight and total polyphenol content for a period of 5 days at ambient conditions.

2. MATERIALS AND METHODS

2.1 Materials

Materials used were gelatin, citric acid, glycerin, carrots. Carrots were brought from local supermarket in Budapest.

2.2 Sample Preparation

Good quality fresh carrots were brought. They were peeled using a hand peeler and sliced using Robert Bosch (GmbH) FD8904 machine. The thickness of carrot slices was 7mm. After slicing they were washed thoroughly in potable running water. Afterwards, the carrot slices were divided in three different batches. No coating was applied to the first batch it was called control. The other two were treated with 2 different coatings.

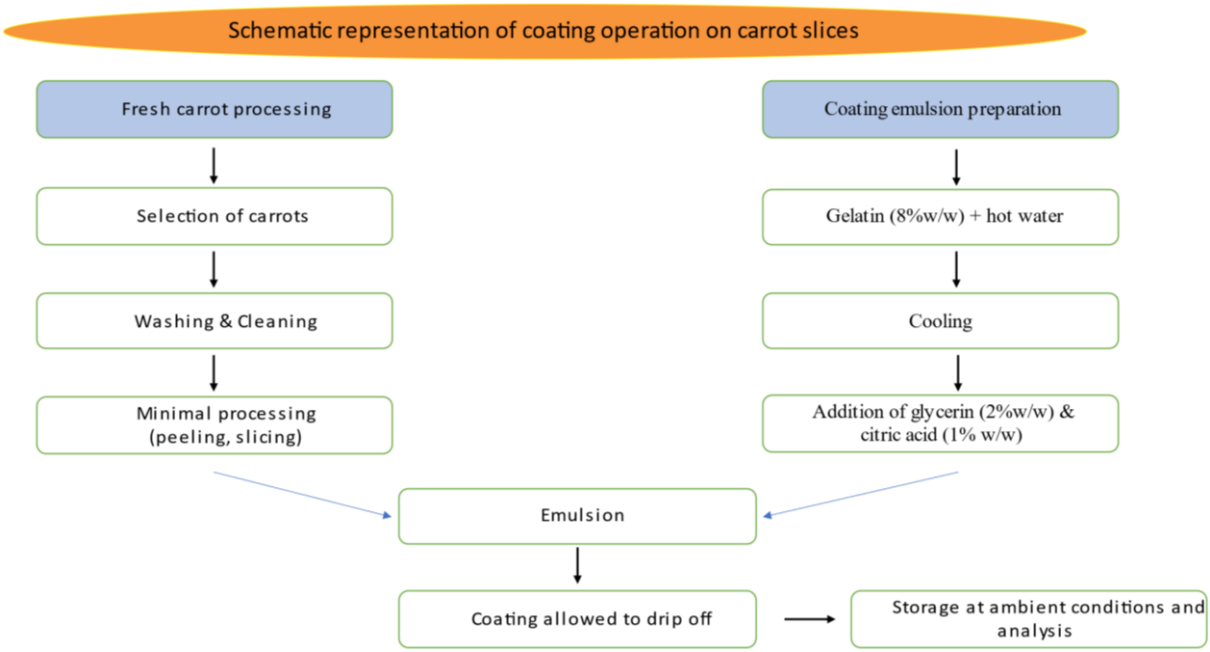
2.3 Preparation of Coatings

Two different coatings were made with 8 and 10% gelatin. For the first coating 8% gelatin was heated with distilled water for 5 minutes. After that, glycerin (2%) and citric acid (1%) were added. The solution brought to about 35-37℃ temperature. Same method was used to make the second coating, but the concentration of gelatin was 10%.

2.4 Application of coatings

Coatings were applied using dipping method. Each carrot slice was coated three times and then observations were taken daily for 5 days. Control and coated carrot slices were stored in ambient conditions.

2.5 Schematic Representation



2.6 Analytical methods

2.6.1 Percentage weight loss

Weight of the samples were measured on each day of analysis using a laboratory scale high precision digital A & D company, FX3000i weighing balance with accuracy of 0.01g. Weight loss was then determined and expressed as percentage weight loss using the following formulae:

Weight loss (%) = $(W_i-W_f)/W_i * 100$

Where, W_i is the initial weight (g) on day 1 and W_f is the measured weight (g) of each sample on particular day of analysis during storage period.

2.6.2 Color values

Color measurements were performed by CIE Lab Color Measuring System with Konica Minolta CR 410 manual digital color meter. The results were expressed in the CIE LAB System with L* (the lightness coordinate), a* (red-green coordinate, with +a* indicating red and -a* indicating green) and b* (the yellow -blue coordinate, with +b* indicating yellow, and -b* indicating blue) colorimetric coordinates.

2.6.3 Texture Analysis

The texture analysis was performed using Brookfield LFRA Texture Analyser-6514933. A stainless-steel needle probe was used having 1.0mm diameter and 46mm length. The penetration depth was 4mm and speed of the probe was 1mm/s.

2.6.4 Total Polyphenolic Content

Extraction- 2 g of sample was dissolved in 20 mL of solution containing 80% methanol and 20% distilled water. The mixture was allowed to rest for two hours at room temperature. After the resting period, the mixture was filtered using filter papers and liquid solution was obtained to perform further analysis.

The spectrometric measurements were carried out with Hitachi U-2900 equipment (Hitachi High-Technologies Europe GmbH, Krefeld, Germany). All the reagents were purchased in analytical grade from Sigma-Aldrich Chemical Co. (3050 Spruce Street, St. Louis, MO 63103, USA).

Total Polyphenol Content (TPC) was determined using the method of (Singleton and Rossi, 1965). Samples were prepared with Folin Ciocalteu's reagent and sodium sulphate solution. The color change during the reaction was detected at 760nm by spectrophotometer and the results were expressed as gallic acid equivalent (μg Gallic Acid Equivalent (GAE) mL^{-1}).

2.6.5 Statistical Analysis

All the experiments were done in triplicates/more than triplicates. There were two fixed factors, treatment (edible coating with different concentrations of gelatin) and storage time (number of days). Treatment had three levels no coating, coating with 8% gelatin, coating with 10% coating represented as C, 8%G and 10%G respectively. Time factor had 5 levels 1,2,3,4 and 5 days. Assumptions for Normal distribution of data and homogeneity of variance were checked. Normality was proved by Kolmogorov-Smirnov test, D'Agostino Test and Chi square Test. Homogeneity of variance was checked by Leven's Test and ratio of maximum variance over minimum variance for each factor. Two factor complete randomized ANOVA was used for analysis since two factors were involved with one dependent variable, Tukey and Games-Howell post hoc test were run for significant variables. Statistical evaluation was done using IBM SPSS V25 in 95% confidence interval.

Values represent means of more than three replicates and their corresponding standard deviations. Superscripts with small case letters indicate significant differences by time along the rows. Superscripts with the uppercase letters indicate significant differences by treatment along the columns. 8%G, and 10%G represent 8%, and 10% concentrations of the gelatin in the edible coatings. C represents the control carrots without any coating or treatment.

3. RESULTS

3.1 Weight loss of carrot slices

Weight loss occurred in all the carrot slices. The carrot slices lost weight because they were exposed to the environment (Olivas and Barbosa-Cánovas, 2005). The prime reason of weight loss was water evaporation facilitated by water vapor pressure gradient along with loss of carbon (lost during formation of CO_2 during respiration) (Kim *et al.*, 2006; Mohebbi *et al.*, 2012). As expected, the weight loss of coated samples was significantly less than non-coated (control) samples. The weight loss on initial day for C, 8%G and 10%G was 72.62%, 68.375 and 61.53% respectively, this gradually increased to 90.22%, 89.38% and 88.01% on last day of storage. Both the coating treatment and storage time had significant effects on the percentage loss in carrot weight. Coating treatment, $F(2, 30) = 65.832$, $P<0.001$ and storage time, $F(4, 30) = 634.200$, $P<0.001$. Moreover, there was a significant interaction between different coating treatment and storage on the percentage loss in the carrot, $F(8, 30) = 9.054$, $P<0.001$. Maximum weight loss was seen in control samples and control samples had lost all the probable free water by the 4^{th} day because the weight loss for 4^{th} and 5^{th} day was same for control samples. Among the coated samples, 10%G coated samples showed best results with minimum weight loss among the control and coated samples. 8%G coated samples showed better results than control samples but were outperformed by 10%G coated samples. The results for weight loss of carrot slices are assigned in Table 1.

Table 1. Effect of coating treatment and storage time (days) on percentage weight loss of the carrots.

% Weight loss in carrot slices					
Treatment	Time (Days)				
	1	2	3	4	5
10%G	61.53 ± 3.44 ^{a,A}	83.62 ± 1.27 ^{b,A}	83.33 ± 2.12 ^{b,A}	87.43 ± 0.56 ^{b,A}	88.01 ± 0.61 ^{b,A}
8%G	68.37 ± 0.88 ^{a,B}	88.08 ± 0.80 ^{b,B}	88.83 ± 0.63 ^{b,B}	89.27 ± .048 ^{b,B}	89.38 ± 0.66 ^{b,B}
C	72.62 ± 1.33 ^{a,C}	88.56 ± 0.41 ^{b,B}	89.83 ± 0.02 ^{b,C}	90.22 ± 0.03 ^{c,C}	90.22 ± 0.03 ^{d,B}

3.2 Color value of carrot slices

3.2.1. L color values*

Results for the L* color values are expressed in Table 2. Declining trend was seen throughout the storage. Control samples had highest L* values, 69.71 at day 1 and 65.00 at day 5. Both the coated samples had significantly less L* color values than the control ones. Both coating treatment and storage time had significant effects on the L* color values of carrot. Coating treatment, $F(2, 120) = 362.946$, $P<0.001$ and storage time, $F(4, 120) = 47.296$, $P<0.001$. Moreover, there was a significant interaction between different coating treatment and storage on the percentage loss in the carrot, $F(8, 120) = 12.181$, $P<0.001$. The results were commendable, both the coatings were able to reduce the whiteness index. Whiteness index is a limiting factor in the acceptance of the minimally processed carrots (Boun and Huxsoll, 1991b). Control samples had maximum value on day 1 (69.75) and on day 5 as well (65.00). 8% Gelatin coated samples showed mediocre values and the 10% Gelatin coated samples showed least values, 61.63 on day 1 and 50.03 on day 5.

Table 2. Effect of coating treatment and storage time (days) on L*color values of the carrots.

	days	C	8%G	10%G
	1	69.75 ± 1.81 ^{c,C}	58.54 ± 1.09 ^{b,A}	61.63 ± 1.96 ^{d,B}
	2	65.38 ± 0.66 ^{b,B}	53.89 ± 2.57 ^{a,A}	55.08 ± 1.04 ^{b,A}
L*	3	62.84 ± 2.14 ^{a,C}	54.38 ± 1.58 ^{a,A}	58.11 ± 2.50 ^{c,B}
	4	63.85 ± 1.09 ^{a,b,C}	55.77 ± 5.05 ^{b,B}	51.57 ± 1.37 ^{a,A}
	5	65.00 ± 0.86 ^{b,C}	54.58 ± 0.81 ^{a,B}	50.03 ± 1.51 ^{a,A}

3.2.2. a color values*

Coated samples showed higher a* color values compared to control ones. The results can be seen in Table 3. Both the treatment and storage time had significant effects on the a* color values of carrot slices. Coating treatment, $F(2, 120) = 30.763$, $P<0.001$ and storage time, $F(4, 120) = 11.836$, $P<0.001$. Moreover, there was a significant interaction between different coating treatment and storage on the percentage loss in the carrot, $F(8, 120) = 2.267$, $P<0.05$. Between the coated samples 10%G had higher values than 8%G coated samples during the entire storage period and values decreased during the course of time. For 10%G coated samples the values reduced from 22.5, day 1 to 17.54, day 5. 8%G coated samples had 21.95 on day 1 and 16.76 on day 5. Control samples had least values among the three categories. On day 1 the a* color values for control were 16.04 which rose to 18.32 on day 2 and then kept decreasing till 5th day ending on 15.59. greater a* color values in coated samples suggests that the intensity of red color was kept better in those samples than control.

Table 3. Effect of coating treatment and storage time (days) on a* color values of the carrots.

	days	C	8%G	10%G
	1	16.04 ± 6.26 ^{a,A}	21.95 ± 1.69 ^{d,B}	22.50 ± 1.69 ^{c,B}
	2	18.32 ± 1.38 ^{b,A}	20.29 ± 0.74 ^{b,c,B}	19.58 ± 2.07^{a,b,A,B}
a*	3	16.62 ± 0.99 ^{a,A}	20.62 ± 2.26 ^{c,B}	20.83.11 ± 1.30 ^{b,c,B}
	4	15.31 ± 1.02 ^{a,A}	17.87 ± 3.13^{a,b,A,B}	18.87 ± 2.51 ^{a,b,B}
	5	15.59 ± 0.46 ^{a,A}	16.76 ± 1.5607^{a,A,B}	17.54 ± 1.26 ^{a,B}

3.2.3. b color values*

The results for b* color values were similar to a* color values, the coated samples had higher b* color values than control. The results are compiled in Table 4. Both treatment and storage time had significant effects on the b* color values of carrot slices. Coating treatment, F (2, 120) = 12.104, P<0.001 and storage time, F (4, 120) = 20.490, P<0.001. Moreover, there was a significant interaction between different coating treatment and storage on the percentage loss in the carrot, F (8, 120) = 4.676, P<0.001. 10%G coated samples had maximum values on both initial and last day. It showed 28.80 on day 1 and 21.01 on day 5. 8%G had lesser values than 10%G coated samples. These samples had 27.87 value on day 1 and then decreased up to 18.53 on the last day of the storage. The control samples had the least values throughout the storage period. The values were 20.37 on day 1 then increased to 23.23 on day 2 after that they keep falling to 18.55 on the last day of the storage.

The results of color values of the slices were in accordance with the results of (Boun and Huxsoll, 1991b).

Table 4. Effect of coating treatment and storage time (days) on b* color values of the carrots

	days	C	8%G	10%G
	1	20.37 ± 8.53 ^{a,A}	27.87 ± 2.06 ^{b,B}	28.80 ± 1.47 ^{c,B}
	2	23.23 ± 0.63 ^{c,A}	21.58 ± 2.27 ^{a,A}	22.80 ± 1.46 $^{a,b\ A}$
b*	3	21.43 ± 1.92 ^{b,A}	21.54 ± 1.93 ^{a,A}	24.62 ± 1.39
	4	19.91 ± 1.45 ^{a,A}	19.27 ± 3.64 ^{a,A}	20.94 ± 1.74 ^{a,A}
	5	18.55 ± 0.58 ^{a,A}	18.53 ± 2.28 ^{a,A}	21.01 ± 1.68 ^{a,B}

3.3 Texture analysis

The hardness and gumminess of the of the coated carrot slices was found to be more than control samples. Both treatment and storage time had significant effects on the hardness of carrot slices. Coating treatment, F (2, 120) = 37.166, P<0.001 and storage time, F (4, 120) = 45.333, P<0.001. Moreover, there was a significant interaction between different coating treatment and storage on the percentage loss in the carrot, F (8, 120) = 6.069, P<0.001. Similarly for gumminess, both treatment and storage time had significant effects on the hardness of carrot slices. Coating treatment, F (2, 120) = 16.743, P<0.001 and storage time, F (4, 120) = 18.798, P<0.001. Moreover, there was a significant interaction between different coating treatment and storage on the percentage loss in the carrot, F (8, 120) = 2.911, P<0.05. The results can be seen in Table 5, they were in accordance with the findings of (Lafortune *et al*., 2005).

Table 5. Effect of coating treatment and storage time (days) on hardness and gumminess of the carrot slices.

	days	C	8%G	10%G
Hardness	1	$89.11 \pm 17.78^{a,b,A}$	$72.39 \pm 11.45^{a,A}$	$113.11 \pm 25.75^{b,A}$
	2	$227.17 \pm 79.30^{a,B}$	$176.11 \pm 34.58^{a,b,C}$	$206.22 \pm 59.00^{b,D}$
	3	$273.22 \pm 78.37^{a,C,D}$	$362.44 \pm 225.15^{a,b,B,D}$	$694.89 \pm 271.88^{b,B}$
	4	$399.39 \pm 152.64^{a,C,D}$	$629.67 \pm 396.36^{a,b,C}$	$915.00 \pm 203.94^{b,C}$
	5	$225.79 \pm 136.62^{a,D}$	$757.44 \pm 561.88^{a,b,C}$	$1298.11 \pm 355.17^{b,C}$
Gumminess	1	$27.26 \pm 14.45^{a,A,C}$	$22.41 \pm 09.58^{a,A}$	$30.60 \pm 9.22^{a,A}$
	2	$33.95 \pm 20.28^{a,A,C}$	$47.95 \pm 16.63^{a,b,D}$	$63.29 \pm 16.89^{b,D}$
	3	$62.10 \pm 23.28^{a,B}$	$118.74 \pm 100.85^{a,b,A,B,C}$	$175.64 \pm 76.71^{b,B,C}$
	4	$76.74 \pm 43.32^{a,B}$	$200.33 \pm 183.56^{a,b,B,C}$	$342.25 \pm 210.25^{b,B,C}$
	5	$112.83 \pm 100.95^{a,C}$	$219.70 \pm 169.20^{a,b,D}$	$384.04 \pm 229.29^{b,C}$

3.4 Total Polyphenol Content (TPC) of carrot slices

Changes in TPC for C, 8%G and 10%G are shown in Table 6. Both the coating treatment and storage time had significant effects on the total polyphenol content of the carrots. Coating treatment, $F(2, 30) = 46.271$, $P<0.001$ and storage time, $F(4,30) = 298.169$, $P<0.001$. Moreover, there was a significant interaction between coating treatment and storage on the total polyphenol content of the carrot slices, $F(8, 30) = 23.242$, $P<0.001$. The results show that TPC increased during the storage period in coated as well as control samples. However, the accumulation rate of TPC was higher in coated samples. For control samples TPC increased initially till the 4th day (131.89) and dipped to 124.05 on 5th day. Similar trend was seen in 8%G coated samples TPC was 46.72 on first day and rose up to 141.89 on 3rd day but it dipped to 120.67 on 4th day and furthermore on 5th day to 98.61. On the other hand, in the 10%G samples TPC kept increasing from 33.44 on first day to 109.67 on day 5. Polyphenols accumulate during the storage of minimally processed carrots (Hoeard and Griffin, 1993; Klaiber *et al.*, 2005). Accumulation of polyphenols is induced by wounds created during minimal processing of carrots(Kenny and O'Beirne, 2010). Accumulation of polyphenols is directly proportional to wounding intensity. These have wound repair effect on carrots (Heredia and Cisneros-Zevallos, 2009).

Table 6. Effect of coating treatment and storage time (days) on total polyphenol content of the carrots.

Total Polyphenol Content (TPC) (μg GE mL^{-1})					
Treatment	Time (Days)				
	1	2	3	4	5
10%G	$33.44 \pm 1.89^{a,A}$	$76.67 \pm 2.03^{b,e,B}$	$83.33 \pm 2.12^{b,c,A}$	$96.44 \pm 4.73^{d,c,A}$	$109.67 \pm 14.97^{e,f,B,B}$
8%G	$46.72 \pm 1.92^{a,C}$	$61.34 \pm 2.55^{b,A}$	$141.89 \pm 4.29^{c,C}$	$120.67 \pm 2.05^{d,B}$	$98.61 \pm 2.12^{e,A}$
C	$39.83 \pm 1.73^{a,B}$	$87.17 \pm 4.5^{b,C}$	$115.78 \pm 5.95^{c,B}$	$131.89 \pm 8.81^{c,B}$	$124.05 \pm 8.72^{c,C}$

4. DISCUSSION

Our experiments showed that the samples coated with new edible coatings based on the gelatin containing citric acid and glycerin performed better than control samples. The edible coatings reduced the weight loss very efficiently. The total polyphenol content of coated samples was significantly less than the control samples. The color values of the control and coated carrot slices revealed that coated samples were able to retain their color better than control ones. The results also suggests that coatings were able to arrest the white color formation on the surface of carrot slices. The results of texture analysis showed that coated samples had retained their hardness and gumminess till the end of storage period. Thus, the new coatings proved to be better barrier for moisture, oxygen and can also arrest respiration. Also, the coatings containing 10% gelatin showed more promising results than 8% gelatin. Therefore, it can be concluded that new gelatin-based coatings have extensive application prospects in preservation of minimally processed carrots.

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