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Research Article

Effects of Edible Coatings on Sensory Quality of Minimally Processed Carrot

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Abstract: The aim of this study was evaluate the effects of edible coatings on the sensory quality of minimally processed carrots. Minimally processed carrot samples were immersed in coatings prepared with yam starch (4%), glycerol (2%) and chitosan (0; 0.5; 0.75; 1.0 and 1.5%, respectively) for 3 min. Samples were conditioned in trays of expanded polystyrene and polyvinyl chloride films, stored at 8°C during 15 days. Color, flavor and whiteness index attributes were analyzed after 0, 5, 10 and 15 days by using a nine-point hedonic scale and colorimetry, respectively. The coated samples showed significant differences ($p<0.05$) regarding color, flavor and whiteness index. At time zero, the samples coated with starch, glycerol and chitosan obtained the highest hedonic notes, presenting a homogeneous and bright color. At day 15, samples coated with starch and glycerol, obtained the highest marks for color (7.4) and taste (6.5); while the control group (uncoated) and samples coated with starch, glycerol and chitosan had scores around 5. Samples coated with starch, glycerol and 1.5% chitosan had the lowest whitening index (37.6) compared to 44.2, obtained with the control group. Edible coatings based on starch and chitosan improved the sensory quality of the minimally processed sliced carrot, maintaining its color and delaying the whitening process.

Keywords: Biodegradable films, bleaching, chitosan, color, starch

INTRODUCTION

Sensory characteristics of foods are usually reflective of its quality, so it is important that these characteristics prevail during the time of storage of products. Films and edible coatings retain the sensory characteristics and texture properties of foods (Kester and Fennema, 1986; Guilbert *et al*., 1996; Gennadios *et al*., 1997; Mahalik and Nambiar, 2010; Mastromatteo *et al*., 2012; Duran *et al*., 2016).

Edible coatings on minimally processed vegetables provide a semi permeable barrier to gases and water vapor and reduce the respiration rate. In addition, they prevent water loss and color changes, improve texture and mechanical integrity, retain flavor and reduce microbial growth, thereby increasing the shelf life of the products (Baldwin *et al*., 1995; Baldwin *et al*., 1996; Lin and Zhao, 2007; Conte *et al*., 2009; Mastromatteo *et al*., 2011; Mastromatteo *et al*., 2012).

Gelatin-based edible coatings applied in minimally processed baby carrots at 5 and 10°C maintained color and flavor for longer. After 25 days of storage, it was verified that baby carrots coated and stored at 5°C were more accepted by consumers than the uncoated ones (Teixeira, 2004). Park *et al*. (1994) evaluated the sensory properties in zein coated tomatoes stored at 21°C; among the sensorial attributes studied by the authors, the acidity and flavor were not altered by the coating, whereas the zein coatings delayed ($p<0.05$) the maturation of the tomato, preserving firmness and color, which are the main attributes in the market.

Among the polysaccharides used to produce films and edible coatings, starch is the most commonly used natural biopolymer (Singh and Maitra, 2015). The use of starch can be an interesting alternative for the development of films and edible coatings considering its low cost, availability, biodegradability, efficacy and easy manipulation (Mali *et al*., 2002; Durango *et al*., 2006; Jiménez *et al*., 2012). Research has shown that starch-based coatings applied to strawberries can maintain their sensorial characteristics, as the coated fruits retain longer the firmness, aroma, color, weight and freshness (García *et al*., 1998; Henrique and Cereda, 1999).

Chitosan is another polysaccharide widely used in the composition of films and antimicrobial coatings, because, besides having good film-forming properties, it has a bactericidal and fungicidal action (Dutta *et al*., 2009; Moreira *et al*., 2011; Singh and Maitra, 2015). Wang and Gao (2013) demonstrated that chitosan coatings applied to strawberries delayed deterioration of this fruit during storage at 5 or 10°C. Studies have

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shown that chitosan-based coatings have the potential to increase the shelf life of fresh fruits and vegetables by inhibiting the growth of microorganisms (Durango *et al*., 2006; Friedman and Juneja, 2010; Kerch, 2015; Duran *et al*., 2016), reducing ethylene production and oxygen levels and increasing the internal concentration of carbon dioxide (Lazaridou and Biliaderis, 2002; Elsabee and Abdou, 2013; Petriccione *et al*., 2015).

Carrot (*Daucus carota* L.) is one of the most popular vegetables, but its commercialization is limited by rapid deterioration during storage due to physiological changes that shorten its shelf life (Li and Barth, 1998). The minimally processed carrot, during storage, rapidly loses its bright orange color and develops a whitish color on the surface, reducing its acceptability by the consumer (Boun and Huxsoll, 1991; Cisneros-Zevallos *et al*., 1995; Mastromatteo *et al*., 2012). Ranjitha *et al*. (2017) revealed that shelf-life of fresh-cut carrots can be extended to 12 days by coating carrot slices with pectin mainly through preventing the formation of white blush and the changes in color, texture and flavor during storage at 8°C. Avena-Bustillos *et al*. (1993, 1994) demonstrated that the use of sodium caseinate/stearic acid coatings on peeled carrots helps to maintain moisture and reduce whiteness. According to Tatsumi *et al*. (1991), whitening on the surface of minimally processed carrots is attributed to processing dehydration.

The aim of this study was to evaluate the effect of coatings based on starch and chitosan in the sensory quality of minimally processed carrot, including color, taste and whiteness index.

MATERIALS AND METHODS

The experiment was conducted in the Packaging Laboratory, Sensory Analysis and Minimum Processing Unit of the Federal University of Viçosa, Viçosa-MG, Brazil.

Minimal processing of carrot: Carrot (*Daucus carota* L.) variety Brasília were donated by the *Cooperativa agropecuária* do Alto Paranaíba (COOPADAP). Carrots were stored at 5±1°C until processing time. Carrots with medium size and free of mechanical injury were selected; they were washed with running water, peeled manually and cut into 5 mm thick slices in a vegetable processor (Robot Coupe CL50). Slices of carrots were immersed in sanitizing solution (200 mg/L of total residual chlorine) at 5°C for 10 min and rinsed (3 mg/L of total residual chlorine) at 5°C for 10 min. Subsequently, they were centrifuged at 800×g for 6 min in a domestic centrifuge (Arno).

Antimicrobial edible coating: The coatings were prepared with yam starch (*Dioscorea alata*) var. Caramujo with the registration BGH7270 in the Banco de Germoplasma of the UFV. The starch extraction was carried out in the Laboratory of Starch and Flour at the Federal University of Viçosa (Durango *et al*., 2009). Chitosan as an antimicrobial compound was purchased in PADETEC (Technological Development Park of the Federal University of Ceará, Brazil) with a degree of deacetylation above 85%.

Table 1: Composition of antimicrobial edible coatings used in minimally processed carrots

Coating	Starch (%)	Glycerol (%)	Chitosan (%)
1 (Control)*	0.0	0.0	0.00
2 (S+G)	4.0	2.0	0.00
3 (S+G+C)	4.0	2.0	0.50
4 (S+G+C)	4.0	2.0	0.75
5 (S+G+C)	4.0	2.0	1.00
6 (S+G+C)	4.0	2.0	1.50

*: Carrots immersed in distilled water; S: Starch; G: Glycerol; C: Chitosan (% calculated in w/w)

To prepare the coatings, it was used aqueous solutions containing starch (4%), glycerol (2%) and chitosan (0.5, 0.75, 1.0 and 1.5%, w/w, respectively) previously dissolved in glacial acetic acid (0.4% w/w). The suspensions were homogenized in Ultra Turrax T 18 basic at 10,000 rpm for 10 sec. The suspensions were gelatinized at 95°C (Durango *et al*., 2006). Starch coatings were also prepared without addition of chitosan (Table 1).

Application of coatings in minimally processed carrot and storage: Samples of minimally processed sliced carrots were immersed in the different coatings during 3 min. Afterwards, they were dried with air flow, at 20°C for 3 h. The control group (uncoated carrots) was immersed in sterilized distilled water under the same conditions. Samples (120 g slices of carrots) were packed in expanded-polystyrene trays and wrapped in 10 µm thick Polyvinyl Chloride (PVC) film. Samples were stored at 8±2°C and 58±2% relative humidity during 15 days.

Sensory analysis: To evaluated the acceptability of minimally processed carrots, color and flavor were measured after 0, 5, 10 and 15 days of storage by 31 consumers (ages between 18-45 years), using a nine-points hedonic scale. The value nine was attributed as like extremely and the value one attributed as disliked extremely. Untrained taster simultaneously received the six samples (uncoated carrot, starch-coated carrot, starch-coated carrot + 0.5% chitosan, 0.75, 1 and 1.5%, respectively).

Whiteness index: The Whiteness Index (WI) was determined on the Color Reader Mod. CR-10 (Minolta COLTD, Osaka/Japan) after 0, 5, 10 and 15 days of storage, respectively. This parameter was estimated using the formula described by Avena-Bustillos *et al*. (1994):

$$WI = 100 - [(100 - L)^2 + a^2 + b^2]^{½}$$

where,

L = Luminosity or brightness (light/dark)
a = Chromaticity in the axis of the green color (-) to red (+)
b = Chromaticity in the axis of the blue color (-) to yellow (+)

Experimental design and statistical analysis: A completely randomized design was applied with an arrangement in Split-plots and three replications. The treatments were control, starch coatings + glycerol and starch + glycerol + chitosan in concentrations of 0.5, 0.75, 1.0 and 1.5 Subplots were: 0, 5, 10 and 15 days, respectively. Statistical analyzes were performed with the aid of the Statistical Analysis System software licensed for use by UFV. The Analysis of Variance (ANOVA) for subdivided plots was applied, also Tukey test and regression analysis at a significance level of 5%.

RESULTS AND DISCUSSION

Color acceptability: For color, there were significant differences between treatments and their interactions ($p<0.05$), but time hat not significant differences ($p>0.05$) (Table 2).

The control group (uncoated samples) from the beginning of storage had the lowest color acceptance scores (Fig. 1), ranging from 4.0 to 4.7, which corresponds to the term disliked slightly. The limit value of a note for acceptance of an attribute is 6. This indicates that the samples from the control group were rejected by consumers from the beginning of storage. This result was expected since the carrot minimally processed with the storage time develops a whitish color, which gives it an aged and unattractive appearance. Several studies have reported that the whitish color of the carrot is due to the dehydration of the superficial cells as a result of the damage caused by the processing (Boun and Huxsoll, 1991; Tatsumi *et al*., 1991; Howard and Griffin, 1993; Avena-Bustillos *et al*., 1994; Moreira *et al*., 2011; Mastromatteo *et al*., 2012).

At the zero storage time, the highest hedonistic scores for the color attribute were obtained by the samples coated with starch + chitosan, which presented bright with a homogeneous orange color, in relation to the control, which showed to be opaque and without shine. Han *et al*. (2004), also observed, on the first days of storage, that chitosan coatings better controlled the color of strawberries, which can be attributed to the interactions between anthocyanin and chitosan. Anthocyanins, such as chitosan, are positively charged. The positive charges of chitosan can stabilize the anthocyanins charges leading to stability in the color of the fruits, but this effect has been decreasing with the storage time. In this study, chitosan could stabilize the carotenoids, responsible for the color in the carrot. The notes on the samples coated with chitosan varied between "liked slightly" and "indifferent" throughout the storage period.

From the 5th day of storage, samples coated with starch and glycerol (coating 2) showed the highest scores for the color attribute. Acceptance test of minimally processed sliced carrots without coatings reported a hedonic note of 3.7 for the color attribute after 14 days of storage at 7°C (Resende *et al*., 2004). Pilon (2003) reported a note of 5.45 for minimally processed cube carrots after 14 days of storage at 1°C. The advantage of edible coatings, of maintaining longer color in fruits and vegetables, has been reported by other researchers (García *et al*., 1998; Henrique and Cereda, 1999; Mchugh and Senesi, 2000; Teixeira, 2004; Mastromatteo *et al*., 2012; Pushkala *et al*., 2012; Han *et al*., 2014; Petriccione *et al*., 2015; Duran *et al*., 2016).

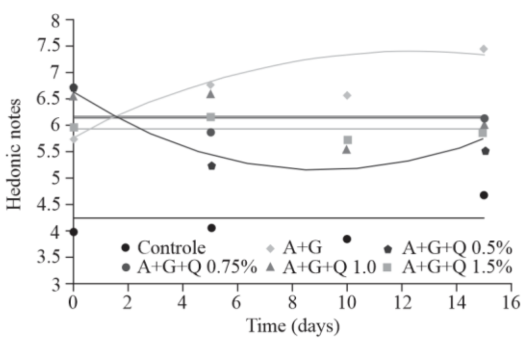

Fig. 1: Effect of the coatings on the color attribute of the minimally processed slice carrots stored at 8±2°C and 58±2% relative humidity for 15 days
♦: control; Δ: S+G; ×: S+G+C 0.5%; ◊: S+G+C 0.75%; ▲: S+G+C 1.0%; □: S+G+C 1.5%

Table 2: Summary of the variance analysis of the effect of coatings on color acceptability in minimally processed slice carrot

Source of variation	Degree of freedom	M.S.
Treatment	5	92.4927*
Error a	180	3.6827
Time	3	2.3168 n.s
Time*treatment	15	8.5307 *
Error b	540	3.7043

M.S.: Mean squares; *: Significant at 5% probability; n.s: Not significant at 5% probability

Acceptability of flavor: For the flavor attribute, coatings were significant ($p<0.05$), but time and interaction were not significant ($p>0.05$) (Table 3).

In this study, samples with the starch and glycerol coating (coating 2) were the only ones that presented a

Table 3: Summary of the variance analysis of the effect of coatings on flavor acceptability in minimally processed carrot

Source of variation	Degree of freedom	M.S.
Treatment	5	15.7078*
Error a	180	4.0155
Time	3	6.1698n.s
Time*treatment	15	3.1967n.s
Error b	540	3.7839

M.S.: Mean squares; * Significant at 5% probability; n.s Not significant at 5% probability

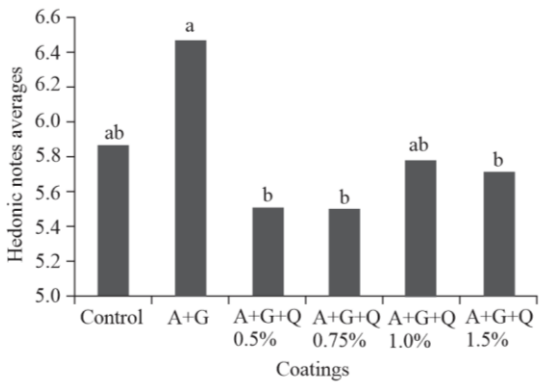

Fig. 2: Effect of the coatings on the flavor attribute in the minimally processed carrot
Means followed by the same letter do not differ by Tukey test at 5% probability (p>0.05); S: Starch; G: Glycerol; C: Chitosan

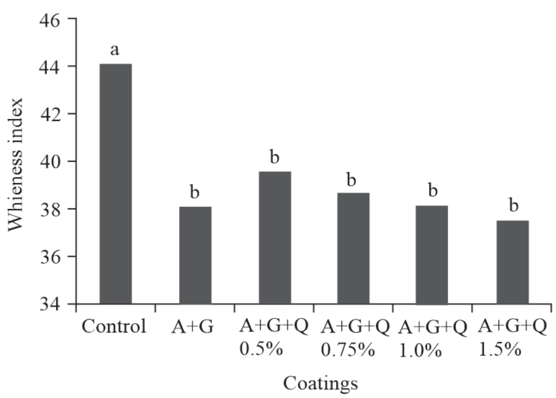

Fig. 3: Effect of the coatings on the whiteness index in the freshly processed carrot after 15 days of storage at 8±2°C and 58±2% relative humidity
Means followed by the same letter do not differ by Tukey test at 5% probability (p>0.05); S: Starch; G: Glycerol; C: Chitosan

score above 6 (Fig. 2). This fact can be attributed to glycerol, which gave a sweet taste in the samples (appreciation of some consumers). Statistically, control samples, those coated with starch + glycerol + chitosan (1%) showed no differences (p>0.05). Similar results were obtained with freshly processed uncoated slide carrot samples stored at 7°C during 14 days (Resende *et al*., 2004). Scores obtained by the samples tested with starch + chitosan ranged from 5.5 to 5.8, corresponding to the term "indifferent". This result may be related to the fact that chitosan increases the levels of 6-Methoximelein, the main phytoalexin of the carrot, besides increasing the activity of essential enzymes in the synthesis of phenolic compounds (Romanazzi *et al*., 2002). Six-MM is an extremely bitter compound and these phenolic compounds have been associated with an increase in the perception of sour taste and may alter the perception of sweet taste in carrot (Talcott *et al*., 2001).

Table 4: Summary of the variance analysis of the effect of the coatings on the whiteness index in the minimally processed carrot

Source of variation	Degree of freedom	M.S.
Treatment	5	46.4986*
Error a	6	2.0495
Time	3	2.8131n.s
Time*treatment	15	3.8832n.s
Error b	18	2.2607

M.S.: Mean squares; *: Significant at 5% probability; n.s.: Not significant at 5% probability

Fig. 4: Minimally processed carrots stored at 8±2°C for 15 days (A) Carrots coated with starch + glycerol (coating 2), (B) Control group (coating 1)

Whiteness index: The effect of the coatings on the whitening index of the carrots was significant (p<0.05), as opposed to the time. There was no significant interaction between the coatings and the time (Table 4).

The whiteness indexes in the coated samples were statistically different from the control (Fig. 3) and statistically equal between them (p>0.05).

After 15 days of storage at 8±2°C, the carrots of the control group had the highest whiteness index (44.2), which was in agreement with the results obtained by the acceptance test for the color attribute, where the control group had the lowest scores during storage. These facts indicate a positive correlation between the subjective evaluation of the acceptance test and the instrumental measurement of color. While the lowest whiteness indices (38 and 40) were observed in the coated samples, which indicates the ability of the coatings to avoid or delay the loss of water from the samples to the environment. These results are similar to those of Izumi *et al*. (1996), Avena-Bustillos *et al*. (1994), Li and Barth (1998), Vargas *et al*. (2009), Pushkala *et al*. (2012), Ranjitha *et al*. (2017) and Song *et al*. (2017).

In this study, the whiteness of the carrot surface was significantly delayed by application of the edible coatings and samples presented a fresh appearance at the end of the storage period (Fig. 4A). In contrast, in the uncoated samples, the whitening process occurred with greater intensity (Fig. 4B). According to Avena-Bustillos *et al*. (1993), coatings of hydrophilic materials help to maintain moisture on the surface of the carrot, thereby reducing the formation of whitish color. These results reinforce the fact that the formation of whitish color in carrots is related to surface dehydration, as reported by Den Outer (1990), Tatsumi *et al*. (1991), Vargas *et al*. (2009), Pushkala *et al*. (2012) and Song *et al*. (2017).

The control group presented the highest whiteness index, due to the fact that the carrots developed whitish color as a result of the dehydration of the superficial tissues during storage (Tatsumi *et al*., 1991; Avena-Bustillos *et al*., 1994; Vargas *et al*., 2009), or lignification (Boun and Huxsoll, 1991; Howard and Griffin, 1993; Song *et al*., 2017).

CONCLUSION

Edible coatings based on starch and chitosan offered a beneficial effect on the sensorial quality of minimally processed sliced carrots, preserving color and delaying the appearance of whitening. After 15 days of storage at 8±2°C, the starch-glycerol coating was the most efficient to preserve color and taste in minimally processed slice carrots. The whiteness index was lower in the coated samples than the control, which presented the highest value after 15 days (44.2).

CONFLICT OF INTEREST

The authors declare no conflict of interests of any nature.

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