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APPLICATION OF EDIBLE COATINGS CONTAINING CINNAMON AND PEPPERMINT ESSENTIAL OIL TO MINIMALLY PROCESSED PUMPKIN

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ABSTRACT
Edible coatings have proven to be an alternative in the preservation of fruits and vegetables. The incorporation of active agents such as essential oil has been shown to be efficient in inhibiting microbial proliferation in minimally processed vegetables. The present study investigated the efficiency of chitosan-based coatings with cinnamon leaf and peppermint essential oils in the conservation of minimally processed pumpkins stored for ten days at 5 °C. A completely randomized experiment was carried out with four groups, a group of pumpkins treated with chitosan coating, a group with a chitosan coating and cinnamon essential oil, and a group with a chitosan coating and peppermint essential oil, in addition to the uncoated control group. Analyses were carried out to determine the loss of mass, firmness, pH, titratable acidity and content of total soluble solids during the storage period. The group with peppermint coating and oil showed higher efficiency in mass retention, firmness and pH value during the first five days of storage. The coating groups containing cinnamon oil and peppermint showed a similar reduction in mass loss at the end of the ten days of storage. The use of coatings based on chitosan and peppermint essential oil is a viable alternative for the conservation of processed pumpkin for a short storage period.

Keywords: Edible coatings, Chitosan, Essential oils.

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INTRODUCTION

Pumpkin (*Cucurbita moschata*) is a seasonal crop widely cultivated in tropical and subtropical countries, traditionally used for both human and animal food (Gomes, 2021). Although it is highly beneficial for health, the commercialization of pumpkins meets resistance due to the size of the vegetable and hardness of the skin, common characteristics in several species (Priore et al., 2018).

Such difficulties have led markets and consumers to turn to processed plant foods due to their practicality and society's current lifestyle. Thus, strategies have been adopted to reduce the waste of perishable foods, such as processing and applying edible coatings (Khan et al., 2021). When combined with low-temperature storage, this process extends shelf life and preserves the nutritive value of the food (Yousuf et al., 2021).

An edible coating can be defined as a thin layer of edible material applied to the surface of the vegetable, in order to completely cover it. Its function is to serve as a barrier to the surrounding environment during the storage, transport and commercialization of these vegetables (Sharma et al., 2018).

Numerous improvements have been reported in research on the elaboration and application of edible coatings. These include the addition of functional components such as antimicrobial substances, antioxidants, vitamins, and nutrients, to specific coatings for processed foods that prevent changes in the color, taste, and texture of the food (Sharma et al., 2019).

Chitosan is a chitin-derived polysaccharide capable of forming biofilms and coatings with good strength and adhesion on fruits and vegetables (Haghighi et al., 2020). Additionally, chitosan has antifungal and antibacterial properties, which makes it an attractive choice for edible coating application (Tahir et al., 2023).

Yousuf et al. (2021) mention that in recent years, there has been an increasing use of essential oils (EO) in edible coating formulations for minimally processed vegetables. Essential oils are naturally occurring volatile compounds, belonging mainly to the terpene and phenylpropanoid classes (Basak, Guha, 2018). They are widely used for their antibacterial, antifungal, and antioxidant properties, as well as being preferred by consumers looking to avoid synthetic additives (Yousuf et al., 2021).

The use of essential oils as preservation agents in edible coatings is mainly based on their natural origin and their functional characteristics that promote the extension of the product's shelf life, such as antimicrobial and antioxidant activity (Ju et al., 2018). Vegetable

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processing increases food oxidation by causing enzymatic browning, nutrient reduction, and flavor change (Khan et al., 2021).

The good acceptance in the market is also related to the consumer's familiarity with the aromas from condiments and herbs already known and appreciated. Peppermint (*Mentha piperita*) is a medicinal herb with a refreshing aroma coming from its essential oil that contains menthol and menthone in higher concentration (Beigi et al., 2018). Peppermint essential oil has relevant biological activities, such as antibacterial, antiviral, immunomodulatory and antioxidant (Zhao et al. 2022). Cinnamon leaf oil (*Cinnamomum zeylanicum*) is rich in eugenol, unlike cinnamon bark oil which has cinnamaldehyde as its main constituent (Wang et al., 2009). Eugenol has recognized antimicrobial activity (Carneiro et al., 2019). Although coatings containing cinnamon oil and peppermint have been studied before, no application studies in minimally processed pumpkin have been identified in the literature.

In the present work, two chitosan-based formulations were evaluated, one incorporated into cinnamon leaf essential oil and the other into peppermint essential oil, with the objective of analyzing the viability of these coatings in the conservation of minimally processed pumpkin (MPA) and stored under refrigeration.

MATERIAL AND METHOD

MATERIALS

The pumpkins used were purchased at the municipal market in the city of Balsas, Maranhão. Chitosan and microcrystalline cellulose were acquired from Cimed, glycerin and Tween 80 from Synth, glacial acetic acid from Dinâmica and sodium hydroxide from Isofar. The essential oil of cinnamon leaves (*Cinnamomum zeylanicum*) was obtained from Phytoterápica and the essential oil of peppermint (*Mentha piperita)* from Do Terra.

MINIMAL PUMPKIN PROCESSING

The pumpkins were carefully washed in drinking water and sanitized in an aqueous solution of 10% sodium hypochlorite and rinsed with distilled water. Then, the pumpkins were peeled and cut in order to obtain cubes of approximately 4 cm3. About 450 to 500 g of cubed pumpkin were used for each group evaluated. In all, there were four groups with 5 five replications each (Silva et al., 2013).

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PREPARATION OF COATING FORMULATIONS

The chitosan coating was prepared using 1% (w/v) chitosan, 0.3% (w/v) microcrystalline cellulose and 1% (v/v) acetic acid in deionized water. Homogenization was achieved with constant stirring for 3 hours, at a temperature of 60°C. After cooling the formulation in an ice bath, glycerin at 1% (w/w) was added, which resulted in the formulation of chitosan (SO). The formulations containing essential oil were produced with the SO formulation and addition of 1% cinnamon essential oil (w/w, OC) or 1% peppermint essential oil (w/w, OM) solubilized in *80 tween* at 1% (w/w) in the final formulation.

COATING APPLICATION

The application of the coating formulations was carried out by the immersion method also known as "*Dipping".* The processed pumpkins were immersed in one of the formulations, SO, OC and OM, and remained submerged for about two minutes. Subsequently, the pieces were deposited on a stainless steel screen and dried at 25°C for 6 hours. After drying, the pumpkins were grouped according to the SO, OC and OM formulations, resulting in 3 groups. A fourth group was formed by uncoated pumpkins to be the control group (SR). All groups were packed in polystyrene trays and polyvinyl chloride film and kept in a refrigerator at 5 °C for 10 days (Genevois, Pla, Flores, 2016)

EXPERIMENTAL ANALYSIS

To analyze the changes during the storage process, samples from the four groups were taken to determine the loss of mass, firmness, total soluble solids content, pH value and titratable acidity. The analyses were performed at 0, 5 and 10 days of sample storage. These analyses were conducted in duplicates or triplicates.

MASS LOSS

The mass loss of the pumpkin samples was determined by weighing on an analytical scale. All groups were weighed on day zero and on the days previously defined and established by the ratio between the initial weight (*wi*) of the samples and the final weight (*wf*). Weight loss was expressed as a percentage (Huynh, Nguyen, 2021) through equation 1:

$$\%\,Weight\ loss = \frac{(wi - wf)}{wi} \text{x } 100\% \quad (1)$$

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DETERMINATION OF FIRMNESS

The determination of the firmness of the pumpkin samples was performed in a portable and analog penetrometer model GY-3 (Soonda), with a cylindrical tip of 8 mm in diameter. The reading was recorded in Pascal units (105 Pa) and converted to values in Newton (N/m2) using the conversion 1x105 Pa = 1x105 N/m2 (adapted from Silveira et al. 2018).

TOTAL SOLUBLE SOLIDS CONTENT

The determination of the total soluble solids content was performed using a manual refractometer for the determination of sugars on a Brix scale (0-32% ºBrix, manufacturer ATC system), at a temperature of 25 ºC, where a drop of crushed pumpkin juice was inserted. The results were expressed in ºBrix, according to AOAC (2000). The refractometer was previously calibrated with distilled water (Silveira et al. 2018).

HYDROGEN POTENTIAL (PH) VALUE

The determination of the pH value was carried out through a potentiometer (Scientific Genesis) previously calibrated with standard solutions of 4.0 and 7.0. Two 10 g samples from each group were crushed in a blender and diluted in 100 ml of distilled water. pH was determined by the mean of the replicates (Silveira et al. 2018).

TOTAL TITRATABLE ACIDITY

The total titratable acidity was determined by a potentiometer previously calibrated with standard solutions of 4.0 and 7.0. Samples of 10 g of pumpkin were crushed in 100 mL of distilled water. The solution was filtered and titrated with a standardized solution of 0.05 N NaOH up to pH 8.2 (AOAC, 2000). The results of the TTA were expressed as a percentage of citric acid (Soares, 2015) according to Equation 2.

$$\%\ \acute{A}cido\ c\acute{\imath}trico = \frac{[\text{mL(NaOH) x } N(NaOH) \text{ x } 0{,}064]}{10} \text{x } 100\% \qquad (2)$$

STATISTICAL ANALYSIS

Single-factor analysis of variance was performed for the physicochemical analyses, firmness and mass loss, and Tukey's test for mass loss and firmness, with a significance level of 5%. The data were treated using the Microsoft Excel program.

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RESULTS AND DISCUSSION

MASS LOSS

The mass loss of the treated MPA samples and the control group was determined on the fifth and tenth days of storage, and mass losses with significant differences between the groups were identified for both days of analysis, as shown in Table 1.

Table 1. Effect of edible coating on coating groups with Cinnamon leaf EO coating peppermint (OM), coating without EO (SO) and uncoated group (SR) on the loss of mass, firmness, pH, titratable acidity and total soluble solids of minimally processed pumpkins during storage at 5°C.

Groups	Mass loss (%)	Firmness (N)	ph	Titratable acidity (%AC)	Soluble solids toast (°Brix)
	0 day storage				
Fresh Abóbora	0,00	10,23 ± 0,25	6,72 ± 0,17	0,06 ± 0,02	8,66 ± 2,08
	5 days storage				
SR	1,39 ± 0,35	10,00 ± 1,67	6,95 ± 0,09	0,07 ± 0,02	11,25 ± 0,25
SO	0,66 ± 0,55	8,08 ± 0,91	7,28 ± 0,04	0,05 ± 0,01	11,75 ± 0,25
OC	2,43 ± 0,64	7,83 ± 1,21	7,36 ± 0,14	0,06 ± 0,01	12,00 ± 0,50
TO	0,75 ± 0,24	9,58 ± 1,88	7,02 ± 0,21	0,09 ± 0,00	11,75 ± 1,25
F-significant	**	*	**	*	ns
	10 days storage				
SR	9,30 ± 1,40a	9,57 ± 0,46a	6,87 ± 0,22	0,09 ± 0,01	10,67 ± 2,52
SO	6,68 ± 0,25b	7,20 ± 1,33b	7,24 ± 0,05	0,09 ± 0,01	11,50 ± 2,60
OC	6,02 ± 1,33b	6,23 ± 1,51b	7,15 ± 0,27	0,09 ± 0,01	12,50 ± 2,18
TO	6,55 ± 0,83b	6,00 ± 0,64b	7,20 ± 0,14	0,10 ± 0,00	13,00 ± 2,18
F-significant	**	**	ns	ns	ns

(AC) citric acid, (ns) not significant, (*) significant at *P<0.05 or (**) significant at P<0.01.*

All groups showed mass loss up to the fifth day, ranging from 0.66 to 2.43%. The SO group (0.66 ± 0.55%) followed by OM (0.75 ± 0.24%) were the ones that lost the least mass in the five days of storage. On the tenth day, the difference in mass loss was smaller for the coated groups, with lower losses for the OC group (6.02 ± 1.33%). In Tukey's test, the treated groups differed from the control group only in the analysis of the tenth day.

The percentages of mass loss in the treated groups are lower than those obtained by Huynh and Nguyen (2021), with chitosan-coated pumpkins stored at 5°C for 12 days, but well above those obtained by Cortes-Vega et al. (2014) under similar storage conditions.

The large variation in the values of mass loss of minimally processed vegetables is related to several factors, as they include the metabolism of vegetable maturation, respiration rate, and surface area by volume (Sandhya, 2010; Choe et al. 2016). Regarding the losses due to increased surface area of AMP, Sasaki et al. (2006) report that the cube and flap cuts tend to have greater mass losses than the half-slice cut during the storage period.

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The OC and OM groups showed similar or greater mass loss than the SO group. The OC group had a high mass loss in the first five days of storage, this result may be related to a coating with a porous surface capable of allowing gas exchange more easily. Chitosan films containing thyme and clove essential oils showed cracks in their microstructure shown by scanning electron microscopy (Hosseini et al., 2009). These results are also consistent with those of other researchers (Peng et al., 2013; Perdones et al., 2014; Xavier et al., 2020). Zhang et al. (2021) have reported that chitosan-based films and coatings that incorporate essential oils may exhibit heterogeneous microstructure and reduced mechanical strength of the coating.

FIRMNESS

The determination of the firmness of all coated MPA groups decreased in relation to the control group, on both days of analysis, with significant differences. In the EO coated groups, there was a greater variation in the firmness value, with the OM group having the highest firmness on the fifth day, and the OC group on the tenth day. The statistical difference between treated MPA and control was also observed in Tukey's test for the analysis on the tenth day. These results are in agreement with data from the literature for MPA and coated (Huynh, Nguyen, 2021). The SR group showed an increase in firmness throughout the storage period, but the result may have been caused by the drying of the fruit surface in a refrigerated environment, a similar effect was observed by Cortes-Veja et al. (2014).

The loss of firmness in minimally processed vegetables during the storage period can be attributed to the hydrolysis of polysaccharides present in the pumpkin cell wall, which occurs due to the action of enzymes (Melo, Vilas Boas, 2007; Nascimento et al., 2014).

TOTAL SOLUBLE SOLIDS (TSS) CONTENT

The values of total soluble solids of all groups did not show significant differences for the analyses of the fifth (11.25 to 12 °Brix) and tenth (10.66 to 13 °Brix) days, but there was an increase when compared to the value obtained for fresh pumpkin (8.7 °Brix). Russo et al. (2014) report increased SST content during storage of pumpkins in modified atmosphere. The absence of significant differences in TSS content, regardless of the coating, was also observed by Soares (2015), however the mean TSS value was 8.2 °Brix.

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In MPA and PVC packed, at 10 °C, the TSS values ranged from 9.83 to 10.38 °Brix (Silva et al., 2009). Several authors report a natural tendency to increase the TSS content throughout the storage period, due to the senescence metabolism of the plant that promotes the conversion of polysaccharides into simple sugars (Chitarra; Chitarra, 2005; Benítez et al. 2013).

pH AND TITRATABLE ACIDITY

The pH and titratable acidity showed the same statistical behavior in the analyses of the fifth and tenth days. The difference in pH of the treated and control pumpkins was significant and revealed a slight increase in the pH of the treated groups in relation to the control in the analysis of the fifth day. On the tenth day, the pH ranged from 6.87 to 7.24, with no significant differences between the groups. Russo et al. (2014) also observed a slight increase in pH in pumpkins stored in different packages for 9 days. This result is desirable for minimally processed and stored vegetables and has been associated with the respiration metabolism of vegetables (Lucera et al., 2012). Titratable acidity showed significant differences between the groups only on the fifth day, with a decrease in the percentage of citric acid in the SO and OC groups, and an increase in the OM group in relation to the control group. On the tenth day, the percentage of citric acid increased in all groups, with no significant differences between the groups. These results are in agreement with the literature (Russo et al., 2014), where a slight increase in acidity in vegetables during the storage period is natural. Acidity is related to metabolic reactions that lead to the formation of organic acids (Utama, Pramata, Pramesi, 2022). However, it is desirable that the total titratable acidity does not increase too much so as not to influence the sensory characteristics of the product and reduce its shelf life (Santos et al., 2016).

CONCLUSION

The study showed that edible coatings based on chitosan and cinnamon and peppermint essential oils favored the preservation of minimally processed pumpkins. However, the mass losses were higher than those reported in the literature, possibly due to porous microstructures that facilitated gas exchange for both coatings with essential oils.

The coatings used were not able to retain firmness in the MPAs satisfactorily, but left them with a desirable appearance, even after 10 days of storage. The content of total soluble solids, pH and titratable acidity showed expected variations for minimally processed vegetables during storage, which are in line with the literature.

Further studies are still needed to verify the decrease in senescence of coated MPAs regarding the loss of pigments and nutrients during the storage period, as well as to evaluate the microbiology inhibition by essential oils. Additional studies to improve the formulation in order to reduce the formation of micropores are also needed.

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