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USE OF CHITOSAN AND XANTHAN GUMS TO EXTEND THE SHELF LIFE OF MINIMALLY PROCESSED BROCCOLI (*Brassica oleracea L. Italica)*

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Abstract
The objective of this work was to apply edible coatings based on xanthan and chitosan gums in minimally processed broccoli and evaluate their physical, chemical, microbiological and sensory characteristics, during 12 days of refrigerated storage. The coatings were applied to the florets of broccoli. After the application of coatings, the broccoli heads were stored under refrigeration. 3 treatments were generated, being T1 the control treatment, T2 treatment with xanthan (1.5%) and T3 treatment with chitosan (1.5%). Of the evaluated treatments, the one which contained chitosan was the best in relation to the attributes of color, texture, loss of vitamin C and weight and also in relation to the sensory attributes when compared with the other treatments. The treatment containing xanthan was also efficient when compared with the control sample for all the performed analyzes. The presence of total coliforms and thermotolerant coliforms and *Escherichia coli*, as well as *Salmonella* for all evaluated treatments was not detected. Of the researched coatings, the treatment with chitosan, was the one that presented the best results, showing that they were able to reduce the microbial growth and extend the life-span of minimally processed broccoli for up to 12 days in refrigerated storage.

1. Introduction

Broccoli (*Brassica oleracea L. Italica*), are plant species with low calories, which contains a high content of components (Caleb *et al.*, 2016), but their metabolism is relatively high (Esturk *et al.*, 2014), causing them to be highly perishable after harvesting, and this can be noticed due to loss of green coloring and yellowing. Various types of storage and techniques of treatments have been tested with the aim of improving the quality of post-harvest and extend the broccoli's lifespan (Li *et al.*, 2014).

The production and consumption of minimally processed foods have become popular. Thus, fruits and vegetables have pleased consumers due to their interest in natural products and a change of life style (Yousuf and Srivastava, 2015).

Due to the increase in the preference of consumers in relation to food ready for consumption, the economic importance in the industries of fresh fruits has become increasingly significant. The main target of the fresh products technology is to provide consumers with ease and products with nutritional and sensory desirable characteristics (Yousuf *et al.*, 2018).

An alternative technology to increase the life-span of minimally processed vegetables is the employment of edible coatings. These coatings are not intended to replace the use of conventional materials of packaging or even permanently eliminate the use of low temperatures, but present a functional performance and supporting role, contributing to the preservation of the texture and nutritional value, reducing the gaseous exchange surface and the excessive loss or gain of water (Assis and Britto, 2014). Various materials have been used in the production of edible films, including gelatin, starch, gum, pectin and chitosan (Palou *et al.*, 2015).

Chitosan is a linear polysaccharide derived from the chitin deacetylation. This component can be used for the development of edible coatings at industrial level due to their biofuncional, biodegradable, biocompatible, non-toxic, film formator and antimicrobial characteristics (Sun *et al.*, 2016).

The xanthan gum is a high molecular weight polysaccharide obtained from the fermentation of bacteria *Xanthomonas campestris*. When added in aqueous medium gives stability to heat and the acidic and basic conditions, due to its rigid structure. The xanthan gum is an important component when mixed with other biopolymers due to the synergism of its viscosity as a result of intermolecular interaction with other materials (Bak and Yoo, 2018; Jo *et al.*, 2018).

Edible coatings could assist in the conservation of minimally processed vegetables. Thus, the objective of this work was to apply edible coatings based on xanthan and chitosan gums in minimally processed broccoli and evaluate their physical, chemical, microbiological and sensory characteristics, during 12 days of refrigerated storage at a temperature of 4 ±1 °C.

2. Material and methods

2.1. Material

The broccoli (*Brassica oleracea L.* var. *Italica*) used was purchased at local shops of the city of Dourados, MS, and was selected according to the weight (approximately 0.4 kg), color and appearance. The broccoli was transported in Styrofoam boxes, where they were stored at a temperature of 4±1 °C for 12 hours until the achievement of minimal processing.

2.2 Methods

2.2.1. Preparation of samples and coatings

The processing was carried out at a temperature of approximately 10 °C, with the utensils previously sanitized in organic chlorine solution (sodium dichloroisocyanurate), at a concentration of 2 g L^{-1}. The broccoli was sanitized in organic chlorine solution at a concentration of 0.2 g L^{-1}, for 15 minutes and then the florets were cut using a stainless-steel knife. Then, the pieces were rinsed with chlorinated water (0.2 g L^{-1}) in order to eliminate the cellular overflowed juice. The water was drained for 2 to 3 minutes on sieves and the florets were reserved until the preparation of the coatings.

The coatings used were xanthan (Shandong Fufeng) and chitosan (Polymar®) gums.

For the xanthan-based coating, the same was dissolved slowly in the proportion of 1.5% in water at a temperature of 25 °C, under agitation, after its complete dissolution, it was heated at 60 °C for 20 minutes.

For the 1.5% chitosan-based coating, a dissolution in acetic acid solution 1% (v/v) was performed, and the same was agitated for 30 minutes at ambient temperature.

After the preparation of the coatings, the florets of broccoli were completely submerged in the solutions prepared for 5 minutes and then drained using sieves. They were waited to dry in an oven with air circulation at ambient temperature for 10 minutes. Then they were stored in PET packaging - Polyethylene terephthalate, with cover (SANPACK).

Three treatments were generated: T1 - control treatment (only the florets of broccoli without cover; T2 - Treatment using 1.5% xanthan gum and T3 - Treatment using 1.5% chitosan gum.

The packages were stored under refrigeration at 4±1 °C for a period of 12 days (day zero to day 12). Being that the physical, chemical, microbiological and sensory analyzes were performed at the time of storage 0, 1, 3, 5, 7, 9 and 12 days. Each day of analysis generated data independent of each other, following a normal distribution.

2.2.2. Physical, chemical and microbiological analysis

2.2.2.1. Texture analysis

The measures of texture of minimally processed florets of broccoli were determined using a texturometer (Stable Micro Systems model TA.XTplus), in accordance with the methodology of Chevalier *et al.* (2018).

2.2.2.2. pH analysis

For the pH analysis, approximately 20 g of samples were crushed in 100 mL of distilled water, and then the measurement was performed using a pHmeter Marconi (PA 200). The analysis was performed according to the official Method (AOAC, 2000).

2.2.2.3. Content of vitamin C

For the determination of the content of vitamin C the standard method of AOAC (2000) was used.

2.2.2.4. Loss of weight

For the loss of weight analysis, the methodology described by Cortez-Vega *et al.* (2014) was used.

2.2.2.5. Color analysis

The color analysis was determined according to the methodology of Chevalier *et al.* (2018), using a Minolta colorimeter (CR400) where random measures were taken on the external surface of the florets of broccoli. The parameters analyzed were luminosity (L*), Chromas a* and b*.

2.2.2.6. Microbiological analysis

Microbiological analyzes were performed for total coliforms and thermotolerant coliforms, *Escherichia coli*, *Salmonella*, aerobic mesophilic and molds and yeasts, during 12 days of storage following analytical methodology described by APHA (2001).

2.2.2.7. Sensory analysis

For the sensory analysis, the methodology described by Chevalier *et al.* (2018) was followed. 12 trained appraisers were used. For each treatment the following attributes were evaluated: texture, color, aroma and overall evaluation. It was established a scale that ranged from 5 to 3, where 5 meant sample of excellent quality (fresh, aromatic and without darkening); 4 meant regular (little fresh, less intense odor and moderate darkening); 3 the sample of poor quality (without freshness and intense odor and with a high degree of darkening and the presence of mold).

2.3. Statistical analysis

The research was carried out in a completely randomized design, with three treatments and twelve storage times. Data was subjected to an analysis of variance (ANOVA), with comparison of means by the Tukey test ($P < 0.05$), using the Statistica® 7.0 software (StatSoft, Inc., Tulsa, USA). All data was presented as mean ± standard error. All the assumptions of the analysis of variance were verified to ensure the validity of the statistical analysis.

3. Results and discussions

3.1. Physical and chemical analyzes

3.1.1. pH analysis

Table 1 presents the values of pH of minimally processed broccoli during storage for 12 days.

Table 1. pH of minimally processed broccoli for the different treatments in 12 days at 4 °C

Parameter analyzed	Days	Treatments		
		T1	T2	T3
pH	0	5.83±0.15^{bA}	5.83±0.15^{cA}	5.83±0.15^{bA}
	1	5.87±0.41^{bA}	5.89±0.09^{bcA}	5.87±0.07^{abA}
	3	6.02±0.23^{bA}	5.93±0.22^{abcA}	5.89±0.21^{abA}
	5	6.38±0.11^{abA}	6.08±0.05^{abcB}	6.07±0.09^{abB}
	7	6.75±0.17^{aA}	6.31±0.17^{aA}	6.24±0.26^{abA}
	9	6.28±0.32^{abA}	6.24±0.14^{abA}	6.24±0.03^{abA}
	12	6.32±.016^{abA}	6.31±0.08^{aA}	6.30±0.15^{aA}

Equal lowercase letters in the column and equal uppercase letters in line does not present a significant difference at the level of 5% ($p<0.05$) by the Tukey test. (T1) control; (T2) 1.5% xanthan; (T3) 1.5% chitosan.

In Table 1 it is possible to observe that at the beginning of the experiment, the broccoli pH value was 5.83. Value close to that (6.08) was reported by Padula *et al.* (2006) in minimally processed organic broccoli.

Between the fifth and seventh day there were more accentuated increases in pH values for both treatments, being that the control treatment showed the largest increase (6.75). These high values of pH may be associated to the use of organic acids in excess as a respiratory substrate (Araújo and Shirai, 2016). Thus, it is possible to deduce that the xanthan and chitosan coatings were effective as a barrier to oxygen diffusion, therefore reducing the rate of breathing and maintaining a pH more stable until the seventh day of storage.

It was observed that after the seventh day, there was a decrease of pH to the control treatment, this can be related with the microbial growth and production of acids that may occur during the deteriorating period.

3.1.2. Loss of weight

Table 2 presents the loss of weight of minimally processed broccoli during storage, for the different treatments.

There was an increase in the loss of weight of minimally processed broccoli. The control treatment (T1) showed the greatest loss (17.41%), followed by the treatment T2 (14.63%) and finally with smaller loss of weight in 12 days of treatment T3 (11.57%). With this, it is realized that the treatments T2 and T3 were more efficient to reduce the permeability to water vapor of the product to the environment. In their work on the impact of edible coating and shocks of moderate heat on the quality of minimally processed broccoli, Ansorena *et al.* (2011) observed that the loss of weight of broccoli without the coating was significantly higher than the coated broccoli. This observation agrees with the present study, because the use of coatings significantly decreased the loss of weight of the coated samples.

Araújo and Shirai (2016) in their work on the application of chitosan coating in minimally processed broccoli also observed that during storage there was a gradual increase in the percentage of loss of weight of the treatments.

The broccoli coated with chitosan of those authors, had a smaller loss of weight in relation to other coatings used, agreeing with the values of loss of weight of this work, which was also lower than the control treatment or when xanthan was used.

Table 2. Loss of weight (%) of minimally processed broccoli with different treatments during storage

Parameter analyzed	**Days**	**Treatments**		
		T1	**T2**	**T3**
Loss weight (%)	0	$0±0.0^{fA}$	$0±0.0^{fA}$	$0±0.0^{gA}$
	1	$2.78±0.19^{eA}$	$1.31±0.07^{fB}$	$1.42±0.24^{fB}$
	3	$4.16±0.42^{eA}$	$3.27±0.16^{eA}$	$3.04±0.31^{eA}$
	5	$5.93±0.78^{dA}$	$5.78±0.71^{dA}$	$5.16±0.07^{dA}$
	7	$9.79±0.21^{cA}$	$8.65±0.15^{cB}$	$7.58±0.13^{cC}$
	9	$13.16±0.46^{bA}$	$12.03±0.31^{bAB}$	$9.68±0.09^{bB}$
	12	$17.41±0.33^{aA}$	$14.63±0.18^{aB}$	$11.57±0.27^{aC}$

Equal lowercase letters in the column and equal uppercase letters in line does not present a significant difference at the level of 5% ($p<0.05$) by the Tukey test. (T1) control; (T2) 1.5% xanthan; (T3) 1.5% chitosan.

Table 3. Content of ascorbic acid in minimally processed broccoli with different treatments during storage

Parameter analyzed	Days	Treatments		
		T1	T2	T3
Ascorbic acid content (mg/100g of broccoli)	0	117.14±0.57^{aA}	117.14±0.57^{aA}	117.14±0.57^{aA}
	1	101.25±0.71^{bB}	112.16±0.47^{bA}	113.48±0.37^{bA}
	3	70.18±0.83^{cC}	83.15±0.88^{cA}	80.98±0.22^{cB}
	5	68.51±0.24^{dB}	80.11±0.29^{dA}	80.08±0.17^{cA}
	7	65.48±0.32^{eB}	77.42±0.57^{eA}	76.92±0.41^{dA}
	9	60.17±0.42^{fC}	72.63±0.41^{fB}	76.03±0.18^{deA}
	12	58.65±0.16^{gC}	71.16±0.63^{fB}	75.59±0.47^{eA}

Equal lowercase letters in the column and equal uppercase letters in line does not present a significant difference at the level of 5% ($p<0.05$) by the Tukey test. (T1) control; (T2) 1.5% xanthan; (T3) 1.5% chitosan.

3.1.3. Analysis of content of vitamin C

Table 3 presents the variation of ascorbic acid (vitamin C) of broccoli, during refrigerated storage for 12 days.

In Table 3 it is possible to observe that in all treatments, there was a decrease in the content of vitamin C. This can be explained by the presence of oxygen, which, in contact with the broccoli, reduces the content of ascorbic acid (Qiu *et al.,* 2013).

The control treatment presented a greater loss of vitamin C with as the days passed by of storage 49.93%), followed by treatment with xanthan (39.25%).

The chitosan showed better retention of vitamin C than the other treatments. This indicates that the incorporation of this coating reduced the oxygen diffusion, preserving the contents of ascorbic acid (Qiu *et al.,* 2013). This behavior was similar to that found by Ansorena *et al.* (2011).

3.1.4. Texture analysis

Table 4 shows the results found for texture (N) in all the evaluated treatments.

Texture is an important factor at the time of purchase of certain products, because it is associated with the sensory factor. When there is loss of weight, contact with oxygen and temperature variation, the values of texture increase in relation to the fresh product, making the taste unpleasant. Checking the Table 4 it was realized that the values of texture increased at the days of storage went by, being that the control treatment presented a higher texture in 12 days of storage. This increase of the texture is related with the loss of weight of broccoli, and there was a greater loss of water and consequently leaving the tissue more rigid and thus increasing the florets texture. The T3 treatment showed the lowest variance (17.18%) of texture when compared to the other treatments.

Moreira *et al.* (2011) in their study on the effect of chitosan coating in broccoli observed that the application of chitosan coating did not affect the texture and inhibited the florets opening, this being an important advance in the quality of broccoli. The preservation of floret texture of broccoli was also observed in the present study when chitosan was used as coating.

Table 4. Values of texture (%) of minimally processed broccoli with different treatments during storage

Parameter analyzed	Days	Treatments		
		T1	T2	T3
Texture (N)	0	6.75±0.52^{dA}	6.75±0.52^{dA}	6.75±0.52^{cA}
	1	6.81±0.24^{dA}	6.8±0.17^{cdA}	6.81±0.18^{cA}

	3	7.19±0.15^{dA}	7.05±0.09^{cdA}	6.97±0.08^{bcA}
	5	8.72±0.54^{cA}	7.58±0.17^{bcB}	7.08±0.21^{bcB}
	7	9.55±0.11^{bcA}	8.04±0.25^{cB}	7.75±0.42^{abB}
	9	10.12±0.33^{bA}	9.08±0.41^{aB}	8.16±0.15^{aC}
	12	11.21±0.13^{aA}	9.85±0.22^{aB}	8.21±0.46^{aC}

Equal lowercase letters in the column and equal uppercase letters in line does not present a significant difference at the level of 5% (p<0.05) by the Tukey test. (T1) control; (T2) 1.5% xanthan; (T3) 1.5% chitosan.

3.1.5. Color analysis

Table 5 presents the parameters of color evaluated for minimally processed broccoli during storage for 12 days.

There was an increase in the values of brightness as the storage days passed by. The higher the value of L* the clearer the sample, and thus it is possible to notice that the control sample showed a higher brightness (48.91) with 12 days of storage (44.11), presenting a coloring that was previously dark green to a color tending to be yellowish. Whereas the treatment with chitosan showed the smallest increase of this parameter, showing that it was capable of retaining to retain the broccoli original color for more time.

Regarding the parameter Chroma a*, all samples showed negative values, showing the green color of broccoli, but as time went by, there was a tendency for loss of green, being that in the control treatment there was a tendency in 12 days for positive values. The treatment T2 and T3 had final values closer to the beginning of the study and showed no significant difference between them in 12 days of storage.

The Chroma b* values also declined as time of storage went by and the treatments T2 and T3 presented smaller yellowing of the florets. The T3 treatment showed stability of values in 12 days of storage, which did not differ among themselves during this evaluated period, which demonstrates a better efficiency of treatment with chitosan as coating.

Araújo and Shirai (2016) found that the color parameters to evaluate the effect of acetic acid and chitosan in relation to the control group, showed no significant variation (p<0.05) in 10 days of storage. These results disagree with the present study, because the use of chitosan as coating was effective to preserve the florets of broccoli color for a longer time. The results found in this study agree with Ansorena *et al.* (2011), who once worked with broccoli coated with carboxymethyl cellulose and chitosan and they kept the green color and the degradation of chlorophyll occurred in lower proportion when compared with the control sample.

Table 5. Parameters of color of minimally processed broccoli with different treatments during refrigerated storage

Parameter analyzed	**Days**	**Treatments**		
		T1	**T2**	**T3**
L*	0	30.19±0.88^{dA}	30.19±0.82^{eA}	30.19±0.82^{cA}
	1	30.27±1.09^{dA}	30.31±0.44^{eA}	30.45±0.53^{cA}
	3	35.57±2.13^{cA}	33.11±0.65^{dA}	32.71±1.79^{bcA}
	5	39.21±1.45^{cA}	37.92±1.53^{cAB}	35.38±0.77^{bB}
	7	42.87±0.35^{bA}	40.33±0.55^{bcB}	39.38±1.56^{aB}
	9	43.23±1.17^{bA}	41.71±1.17^{bAB}	40.22±1.07^{aB}
	12	48.91±1.41^{aA}	45.07±0.96^{aAB}	44.11±0.49^{aB}
	0	-8.86±0.52^{aA}	-8.86±0.52^{aA}	-8.86±0.52^{aA}

Chroma a*	1	-8.88±0.29^{aA}	-8.79±0.19^{aA}	-8.89±0.41^{aA}
	3	-8.11±0.44^{aA}	-8.65±0.22^{aA}	-8.80±0.73^{aA}
	5	-7.65±1.02^{aA}	-8.03±0.58^{aA}	-8.06±0.34^{abA}
	7	-6.16±0.23^{bB}	-7.11±0.33^{bA}	-7.57±0.12^{bA}
	9	-5.31±0.17^{bB}	-6.91±0.72^{bA}	-7.31±0.40^{bA}
	12	-5.09±0.24^{bB}	-6.54±0.17^{bA}	-6.97±0.21^{bA}
Chroma b*	0	32.56±1.28^{aA}	32.56±1.28^{aA}	32.56±1.28^{aA}
	1	32.49±0.76^{abA}	29.65±3.46^{abcA}	28.89±4.58^{aA}
	3	33.38±1.22^{aA}	30.21±1.54^{abA}	31.82±1.48^{aA}
	5	31.05±0.55^{abA}	29.89±0.67^{abcA}	30.11±0.48^{aA}
	7	27.57±2.73^{bcA}	28.02±1.67^{abcA}	29.41±1.37^{aA}
	9	23.88±3.13^{cdA}	26.56±1.44^{bcA}	27.09±2.55^{aA}
	12	19.57±0.96^{dB}	25.07±0.77^{cA}	26.89±3.54^{aA}

Equal lowercase letters in the column and equal uppercase letters in line does not present a significant difference at the level of 5% ($p<0.05$) by the Tukey test. (T1) control; (T2) 1.5% xanthan; (T3) 1.5% chitosan.

3.1.6. Microbiological analysis

The obtained results showed that the presence was not detected of total coliforms and thermotolerant coliforms and *Escherichia coli* (<10^2 CFU.g^{-1}), as well as of *Salmonella* (absence in 25g) in samples of minimally processed broccoli, confirming the effectiveness of hygienic care and action of the organic chlorine in the samples disinfection.

In Brazil, there is no specific legislation for minimally processed vegetables with tolerated limits of counts. However, there is legislation for fresh products, in natura (peeled or selected or fractionated), sanitized, refrigerated or frozen, establishing maximum values of thermotolerant coliforms of 5×10^2 CFU/g and the absence of *Salmonella* spp. in 25 g of sample (Brasil, 2001). The present study is, therefore, within these specifications imposed by the legislation.

Figure 1 shows the growth curve for mesophilic aerobic microorganisms.

There was an increase in the growth of mesophilic aerobic microorganisms as the days went by being that the control treatment presented a higher growth, significantly differing from the other treatments. The T3 treatment was the one that showed the lowest growth over 12 days of storage, showing that chitosan is a good barrier to microbial growth. More homogeneous edible coatings are desirable because they provide a more effective barrier between the plant and the external environment (Tezotto-Uliana *et al.*, 2014), thus hindering the transfer and microorganisms respiratory activity (Aquino *et al.*, 2015).

Moreira *et al.* (2011), researching the impact of edible coatings together with different thermal shocks on quality of minimally processed broccoli during refrigerated storage, observed that the chitosan did not act effectively against the mesophilic aerobic microorganisms. The present study demonstrated the contrary, because chitosan used in the proportion of 1.5% was effective to retard the growth of this microorganism.

Figure 2 presents the microbial growth for molds and yeasts, for florets of broccoli minimally processed during 12 days in refrigerated storage.

At the end of 12 days it was observed that there was significant difference among all the evaluated treatments. There was a greater growth of yeasts and molds in the treatment without coating (T1), and lower growth in the treatment with chitosan. This may be related to the fact that chitosan due to having a high content of deacetylation presents a greater antimicrobial power (Dutta *et al.*, 2009). Because the same acts against bacteria through their positive charges in the molecule allows the interaction and formation of polyelectrolyte complexes and surface polymers of bacterial cell (Durango *et al.*, 2006).

Ansorena *et al.* (2011), in their work with edible coating of chitosan and different levels of thermal shock, also found a reduction in the growth of yeasts and molds.

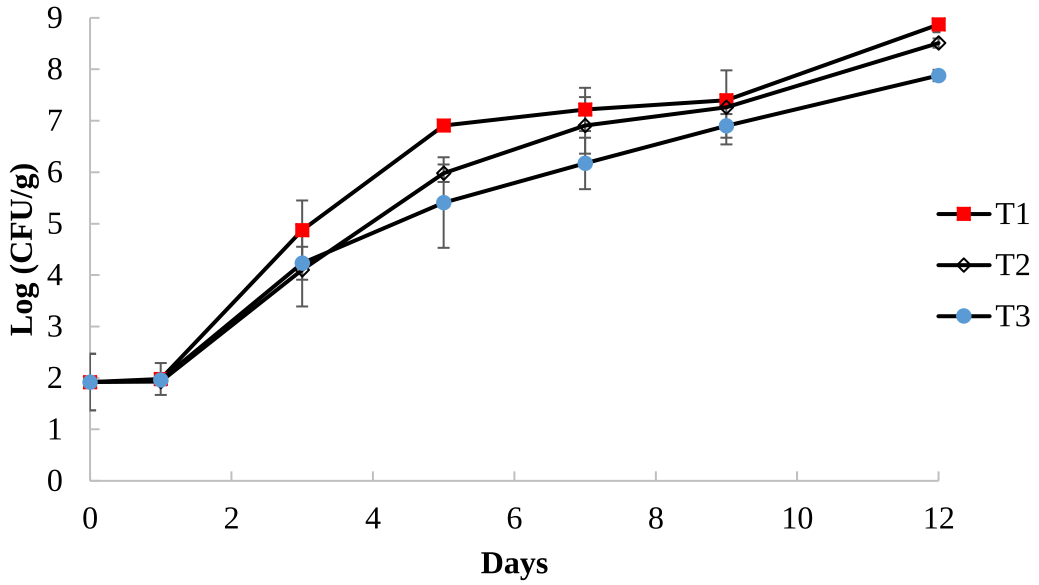

Figure 1. Growth of mesophilic aerobic microorganisms in minimally processed broccoli for 12 days
Where: (T1) control; (T2) 1.5% xanthan; (T3) 1.5% chitosan.

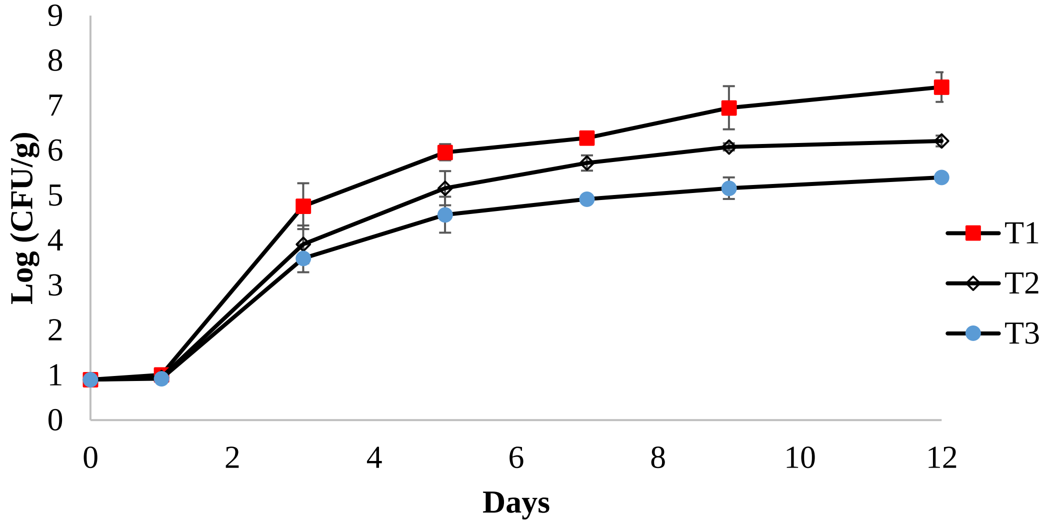

Figure 2. Growth of molds and yeasts in florets of broccoli minimally processed over 12 days
Where: (T1) control; (T2) 1.5% xanthan; (T3) 1.5% chitosan.

3.1.7. Sensory analysis

Table 6 shows the values of the sensory analysis found for minimally processed broccoli and stored at 4±1 °C for a period of 12 days.

It can be observed in Table 6, that in all the evaluated attributes, there was a decrease of acceptability by the appraisers, and the control treatment was the one that presented a greater reduction of values as the evaluation days

passed by, showing a significant difference in relation to the treatments T2 and T3.
During the storage some reactions occurs which affect the structure of the plants cell wall. For the texture attribute, the treatments T2 and T3 were above the value 3, which was established as a minimum limit of acceptability, demonstrating that the pectin and chitosan were capable of maintaining the texture for a longer time. This reduction of the texture during storage, can be explained due to the hydrolysis of pectic acids of the cell wall caused by the action of the enzymes pectinase, cellulase, β-galactosidase and glycosidases (Chitarra and Chitarra, 2005).

In relation to the parameter of color, odor and overall evaluation, a reduction was observed in these attributes in all the samples during storage. A greater variation was observed in the treatment T1, being that it differed significantly from the other treatments for the evaluated attributes, demonstrating that the xanthan gum (T2) and chitosan (T3) succeeded in delaying the changes that degrade and diminish the quality of minimally processed broccoli.

Pizarro *et al.* (2006) working with different plastic packages found values of odor lower to the other treatments in comparison with the control sample. These results are not in agreement with the present study, because higher values were found on the last day of storage for the remaining treatments (T2 and T3) in relation to the control sample. Chevalier *et al.* (2018) when worked with the application of Whitemouth croaker protein isolate in minimally processed melon, also managed to maintain the sensory characteristics of this fruit for more time.

Table 6. Evaluation of the sensory attributes of texture, color, aroma and overall evaluation of minimally processed broccoli, stored at 4 ºC for 12 days

Sensory attributes	**Days**	**Treatments**		
		T1	**T2**	**T3**
Texture	0	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}
	1	4.9 ± 0.0^{bB}	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}
	3	4.6 ± 0.1^{cB}	4.9 ± 0.1^{aA}	4.9 ± 0.1^{aA}
	5	3.8 ± 0.1^{dB}	4.5 ± 0.1^{bA}	4.6 ± 0.1^{bA}
	7	3.4 ± 0.1^{eB}	4.2 ± 0.1^{cA}	4.2 ± 0.1^{cA}
	9	2.2 ± 0.1^{fB}	3.6 ± 0.1^{dA}	3.8 ± 0.1^{dA}
	12	1.5 ± 0.1^{gB}	3.1 ± 0.1^{eA}	3.2 ± 0.1^{eA}
Color	0	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}	5.0 ± 0.1^{aA}
	1	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}
	3	4.5 ± 0.1^{bB}	4.8 ± 0.1^{bA}	4.9 ± 0.1^{aA}
	5	3.9 ± 0.1^{cB}	4.6 ± 0.1^{bA}	4.6 ± 0.1^{bA}
	7	2.8 ± 0.1^{dB}	3.6 ± 0.1^{cA}	3.8 ± 0.1^{cA}
	9	2.1 ± 0.1^{eB}	3.1 ± 0.1^{dA}	3.3 ± 0.1^{dA}
	12	1.4 ± 0.1^{fB}	2.5 ± 0.1^{eA}	2.7 ± 0.1^{eA}
Aroma	0	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}
	1	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}
	3	4.3 ± 0.1^{bB}	4.9 ± 0.1^{aA}	4.9 ± 0.1^{aA}
	5	3.8 ± 0.1^{cB}	4.5 ± 0.1^{bA}	4.6 ± 0.1^{bA}

	7	3.2 ± 0.1^{dB}	4.1 ± 0.1^{cA}	4.2 ± 0.1^{cA}
	9	2.3 ± 0.1^{eC}	3.0 ± 0.1^{dB}	3.3 ± 0.1^{dA}
	12	1.3 ± 0.1^{fC}	2.7 ± 0.1^{eB}	3.0 ± 0.1^{dA}
Overall Evaluation	0	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}
	1	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}	5.0 ± 0.0^{aA}
	3	4.4 ± 0.1^{bB}	4.9 ± 0.1^{aA}	4.9 ± 0.1^{aA}
	5	3.9 ± 0.1^{cB}	4.6 ± 0.1^{bA}	4.6 ± 0.1^{bA}
	7	3.0 ± 0.1^{dB}	4.0 ± 0.1^{bA}	4.1 ± 0.1^{cA}
	9	2.2 ± 0.1^{eC}	3.0 ± 0.1^{cB}	3.4 ± 0.1^{dA}
	12	1.3 ± 0.1^{fB}	2.8 ± 0.1^{dA}	3.0 ± 0.1^{eA}

Equal lowercase letters in the column and equal uppercase letters in line does not present a significant difference at the level of 5% ($p<0.05$) by the Tukey test. (T1) control; (T2) 1.5% xanthan; (T3) 1.5% chitosan.

4. Conclusions

The different coatings used in this study were efficient in the conservation of minimally processed broccoli, when compared to the control sample.

The use of xanthan and chitosan showed great potential to be applied as edible coatings for delaying the changes in coloring, maintain physical and chemical characteristics and reduce the microbiological changes.

However, the use of chitosan was more efficient in increasing the shelf life, leaving the minimally processed broccoli safe for consumption for more time.

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