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Control of microbial growth and lipid oxidation on beef steak using a cashew nut shell liquid (CNSL)-based edible coating treatment

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Abstract

Evaluate of cashew nut shell liquid (alginate-CNSL) on TBARS, physicochemical attributes and microbial growing of beef steak was investigated. Three edible coating treatments were prepared: (1) control (uncoating); (2) sodium alginate coating (no additive); and (3) active coatings of sodium alginate added cashew nut shell liquid (alginate-CNSL) at 1% into. Color indexes and water holding capacity were not affected by coating treatments. The pH of the beef samples from the control treatment increased at storage time, and the beef involved with alginate-CNSL coating maintained a pH stable. Alginate-CNSL coating promoted cooking loss lower after 3rd day of storage. Alginate-CNSL coating promoted a lower shear force decrease compared at control and sodium alginate coating. Alginate-CNSL coating reduced lipid oxidation (TBARS) and microbial growing (mesophiles and psychrophiles counts) in beef compared others treatments. Active coating from CNSL (1%) improved the beef preservation, reducing lipid oxidation and microbial growing, until the 6th day of storage stability.

Keywords: *Anacardium occidentale;* antioxidation; bioactive packaging; meat; mesophiles.

Practical Application: The use of alginate-basis coating added with 1% of CNSL increases the shelf life of perishable foods widely consumed by individuals such as beef. In addition, it is indicated as replacement for conventional non-degradable packaging.

1 Introduction

Oxidative processes are one of the main causes of deterioration in meat during storage. In meat processing, both manufactures and researchers are focusing toward using natural antioxidant (NA) instead of synthetic one. Perishable foods, such as beefs, are much more susceptible to spoilage, through the oxidation of lipids and proteins, as well as microbial spoilage due to their intrinsic characteristics, such as moisture and pH, as well as extrinsic factors, such as packaging conditions, materials and storage. These factors change the perishability time of the food, known as shelf life (Özogul et al., 2017; Brasil, 2018; Lorenzo et al., 2018; Santos et al., 2022). Beef refrigeration at 4 °C has a short shelf life around 3-5 days (United States, 2019).

Nowadays, due to the increasing demand of consumers for safe products and the need to reduce food consumption, there has been an increase in the search for biodegradable packaging technologies that help reduce the negative impact of conventional packaging materials on the environment. In this sense, coatings are promising alternatives to help increase the shelf life of perishable foods. They are constituted as thin layers that are applied directly to the surface of the food even as a filmogenic solution and, after drying, leads to the formation of the film, aiming to coat the food in an integral or partial way, thus forming a barrier between this and the circulating environment with the objective of conservation (Milani & Maleki, 2012; Dehghani et al., 2018; Torusdağ et al., 2022).

The coatings consist of a macromolecular matrix responsible for their structures, and by the food-grade components and the plasticize incorporation, which aims to reduce fragility and increase flexibility, from the biopolymers with similar conditions than non-degradable plastics. According to Beristain-Bauza et al. (2017), the polymers most used as raw material for this purpose are polysaccharides.

Bioactive compounds, such as functional oils, have been often added to polysaccharide films increasing antioxidants and antimicrobial activities replacing synthetic plastics (Cazón et al., 2017) and minimizing or even interrupting deterioration processes and improving preservation of meat and meat products.

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In this sense, cashew nut shell liquid (CNSL) is a phenolic lipid that can appears as a functional oil, a by-product of cashew (*Anacardium Occidentale L.*). It is a dark, viscous liquid and a natural source of long-chain unsaturated phenol compounds, with great antioxidant properties, especially due to the high content of cardanol present in the technical CNSL (Kubo et al., 2006; Rodrigues et al., 2006; Lomonaco et al., 2009). Thus, exhibiting essential characteristics to be used as an additive in the production of films aimed at slowing the lipid oxidation process and consequently increasing the shelf life of food, because the incorporated active agents define the functionality packaging materials (Topuz & Uyar, 2020). Vasconcelos et al. (2021) observed that bioactive films containing CNSL have antimicrobial activity and excellent antioxidant properties, being believed to be a promising alternative to be used in the agri-food industry.

Thus, considering the importance of researching alternatives that seek better biodegradable technologies, aiming to increase the shelf life of perishable foods and widely consumed by individuals such as beef, while promoting less environmental impact and better food quality for the final consumer. This study aimed to evaluate the effect of the alginate-basis coating added with 1% of CNSL on the beef quality and preservation.

2 Materials and methods

2.1 Preparation and applying of active coating with cashew nut shell liquid (CNSL)

Coating solution was prepared according to the methodology of Vasconcelos et al. (2021). Initially, a sodium alginate solution was prepared, purchased from Dinâmica Química Contemporânea® (Indaiatuba, São Paulo, Brazil), at a concentration of 3% (m/v). Subsequently, glycerol and polysorbate (Tween 80®) were added in a solution at 2 and 0.5% (w/w) concentrations, respectively. Then, the mixture was heated to 70 °C in a hot plate and stirred with a glass rod for 1 hour for total homogenization of the filmogenic solution. Then, the technical CNSL (containing 84.4% cardanol and 15.6% cardol), kindly provided by Amêndoas do Brazil® (Fortaleza, Brazil), was added to alginate coating solution for the respective inclusion levels: 0 and 1.0% (weight/weight), remaining under manual agitation (glass stick) for 20 min, until total homogenization.

Beef samples were prepared from the *longissimus dorsi* muscle was obtained from a single Nellore crossbred animal 24 h after slaughter, purchased at a commercial slaughterhouse located in the city of Patos-PB, inspected periodically and within the appropriate sanitary hygiene standards, according to the technical regulation of the manual of good practices for food services (Brasil, 2004). The muscle was cut into 45 uniform pieces, containing 10 × 6 × 2 cm and approximately 100 grams, which were randomly distributed among the different treatments tested, with five samples for each day of analysis per treatment.

Subsequently, pieces of beef were immersed in the edible coating for 2 min. and then dried with air flow, so that, after drying, the coating would form directly on the surface of the beef. Thus, three treatments were defined: without any coating solution (control); alginate sodium coating (alginate) and alginate coating added with 1% of cashew nut shell liquid (alginate-CNLS). The definition of the quantity of CNSL to be added to the film (1%) was based on the results obtained from the production and characterization of the biofilms described according to Vasconcelos et at. (2021). Then, all beef samples were stored at 4 ± 1 °C until analysis was performed for 6 days, at 3-time storage intervals: 0, 3, 6, according to the method-ology adapted from the study by Jridi et al. (2018), to assess the shelf life of the beef. During this period, physicochemical analyzes, lipid oxidation and microbiological analysis were performed.

2.2 Physicochemical analysis of meat after coatings application

The pH of beef was obtained at 20 °C with a digital skewer type probe (Testo 205®, São Paulo, Brazil), and calibrated with a buffer solution with between 4.0 pH 7.0 (Association of Official Analytical Chemists, 2012).

Beef color indexes were evaluated (Miltenburg et al., 1992) at the referred times from the standardization of the cuts of meat in a thickness of 15 mm, followed by exposure to air for 30 minutes in a refrigerated environment (4 °C) so that the readings could then be taken with the aid of a colorimeter (Konica Minolta, model CR-400), operating in the CIELAB system (L*, a* and b*), where L* is the luminosity, varying from black (0%) to white (100%); a* the intensity of the red color, varying from green (-a) to red (+a); and b* the intensity of the yellow color, varying from blue (-b) to yellow (+b). The aperture port was with glass cover and the beef samples were measured using illuminate D65. This device was calibrated before each analysis with a standard white tile. Three measurements were taken at different points on the beef, using the mean values to represent the color. The color saturation index (Chroma, C*) was determined by Hunt & King (2012) Equation 1:

$$Chrome\ (*C) = \left(a*^2 + b*^2\right)^{0.5} \quad (1)$$

The analyses of water-holding capacity (WHC) were performed in triplicate, to improve the accuracy, followed the pressure method (Sierra, 1973). It was used a 2.0 g meat sample, that was placed on a circular filter paper, between two acrylic plates, then a 3.4 kg equivalent force was put on the top of the paper for approximately 5 min. The difference between the weight before and after the process was calculated. The quantity of water loss observed in the sample was expressed as a percentage of water exuded by the sample in proportion to the samples' initial weight.

The analysis of cooking weight loss (CWL) used two beef samples (2.5 cm thick), free of subcutaneous fat. The samples were placed on a grill (George Foreman Jumbo Grill GBZ6BW, Rio de Janeiro, Brazil) to cook, also was used a Specialized thermometer for cooking meat (Acurite®, Sao Paulo, Brazil), in triplicate, and inserted in the beef to monitor the temperature of each steak until it reached 71 °C at the geometric center of the sample. Afterward, the steaks were removed from the cook apparat and then were exposed to room temperature, to temperature stabilized. The steaks were then weighed again. Finally, the CWL of each sample was obtained by the difference

in weight of the samples (before and after cooking), with values described as percentage of exudate (Duckett et al., 1998).

The shear force (SF) was determined according to Shackelford et al. (1999) using a texture analyzer (model TX-TX2, Mecmesin, Nevada, United States) with a set cross head space at 20 cm/min and fitted with a 25 kgf load cell. For each beef, three samples with 1.27 cm in diameter and 2.0 cm in length were taken using a cork borer cut. The SF values obtained were expressed in Newtons (N) according to the standard procedure recommended by the Meat Animal Research Center (Shackelford et al., 1999).

2.3 Lipid oxidation of beef

The lipid oxidation indicator was performed from thiobarbituric acid reactive substances (TBARS), according to the methodology of Witte et al. (1970), in which the value of substances that react to TBA (TBARS) was calculated using a standard curve of malonaldehyde (MDA). For this, five grams of meat from each sample (triplicate) were mixed with 20 mL of trichloroacetic acid (5%), homogenized for 5 minutes and centrifuged at 12,000 g for 10 minutes. Then 4 mL of the supernatant was mixed with 4 mL of 0.02 M TBA and incubated in a water bath at 100 °C for 60 minutes. Absorbance was measured at 532 nm and the results expressed in mmoles of MDA/g of meat.

2.4 Microbiological analysis of beef

Beef samples (in triplicate) with 25 g of with and without coatings in all storage times were collected in sterilized bottles containing 225 mL of maximum recovery diluent [0.1% (w/v) of peptone in 0.9% NaCl solution (w/v)], and then homogenized for 5 minutes at each proposed shelf time. In a sterile environment, dilutions from 10-1 to 10-5 were made using the maximum recovery diluent. One milliliter of each dilution was added to sterile Petri dishes, then approximately 15 mL of plate count agar culture medium at 40 °C was added. The plates were carefully shaken and incubated at 30 °C and 4 °C for 3 days and 7 days, respectively, for the counting of mesophilic and psychrophilic microorganisms (Silva et al., 2018).

2.5 Statistical analysis

Beefs were randomly distributed in a completely randomized design arranged in a factorial scheme 3 × 3 with three treatments (control; alginate coating only and alginate-CNSL coating) as and three beef storage times (0, 3 and 6 days) and the replicates according to analyses realized. The following statistical model was used (Equation 2):

$$Yijk = u + Ci + Tj + (CT)ij + Eijk \quad (2)$$

where: u is the overall mean, *Ci* is the effect of coating adding, *Tj* is the effect of shelf time or storage, *(CT)ij* is the interaction between coating adding and shelf life, and *Eijk* is random error. Results were expressed as mean ± standard deviation. Means were compared using one-way analysis of variance (ANOVA) followed by Tukey. Statistical data were considered significant with $p < 0.05$.

3 Results

There was no statistical difference ($p > 0.05$) for the coordinates of L* (lightness) and b* (yellowness), over the storage time. When analysing the redness (a*) and saturation index or Chrome (C*) indexes of the beef, there was a significant difference ($p < 0.05$) at 3 days of storage in relation to 0-time day, stabilizing at 6th day (Table 1). The inclusion of the coating, at time 0-day, did not affect ($p > 0.05$) the color parameter of the beefs.

The pH values of control treatment (uncoated) increased ($p < 0.05$) over the storage times analyzed, while the beefs conserved with alginate-CNSL coating remained pH stable during the storage period, as well as within the considerable normal standards for avoid meat spoilage (Table 2). Water holding capacity (WHC) did not show significant differences ($p > 0.05$) between the storage period, as well as between coating. However, for cooking loss (CL) of beef, it was observed that the control presented highest losses ($p < 0.05$) compared to alginate-CNSL coating until the 3rd day of storage, with a significant increase ($p < 0.05$) from 6th storage day.

Table 1. Active coating with cashew nut shell liquid (CNSL) on coloration parameters of beef during storage stability times (4 ± 1 °C).

Color Index	Active coating	Storage stability time (days)		
		0	3	6
Luminosity (L*)	Control	35.85 ± 1.29^{aA}	36.83 ± 1.29^{aA}	35.23 ± 0.94^{aA}
	Alginate coating	35.45 ± 0.67^{aA}	34.39 ± 0.96^{aB}	36.08 ± 1.29^{aA}
	Alginate -CNSL coating	35.26 ± 1.75^{aA}	35.73 ± 1.67^{aA}	34.10 ±1.30^{aB}
Redness (a*)	Control	18.90 ± 0.63^{aA}	13.56 ± 1.93^{bA}	15.16 ± 1.46^{bA}
	Alginate coating	18.56 ± 1.16^{aA}	14.09 ± 0.55^{bA}	16.38 ± 1.32^{bA}
	Alginate -CNSL coating	18.10 ± 1.34^{aA}	14.99 ± 2.28^{bA}	15.44 ± 2.3^{bA}
Yellowness (b*)	Control	2.63 ± 0.74^{aA}	1.33 ± 0.35^{bA}	1.66 ± 0.30^{bA}
	Alginate coating	1.93 ± 0.50^{aA}	1.27 ± 0.62^{aA}	1.89 ± 0.35^{aA}
	Alginate -CNSL coating	2.45 ± 1.42^{aA}	1.76 ± 0.79^{aA}	1.70 ± 0.80^{aA}
Chrome (C*)	Control (without film)	19.08 ± 0.77^{aA}	13.63 ± 0.92^{bA}	15.25 ± 1.46^{bA}
	Alginate coating	18.66 ± 1.11^{aA}	14.15 ± 0.95^{bA}	16.49 ± 0.99^{bA}
	Alginate -CNSL coating	18.27 ± 1.23^{aA}	15.09 ± 1.92^{bA}	15.53 ± 2.02^{bA}

Different lowercase letters in the row represent significance for CNSL level film application and different uppercase letters in the column represent significance for shelf life from Tukey test when $p < 0.05$.

Table 2. Active coating solutions added cashew nut shell liquid (CNSL) on physicochemical parameters of beef during storage stability times (4 ± 1 °C).

Variables	Active coating	Storage stability time (day)		
		0 d	3 d	6 d
pH	Control	5.59 ± 0.03^{bAB}	5.78 ± 0.06^{aA}	5.84 ± 0.07^{aA}
	Alginate coating	5.65 ± 0.02^{aA}	5.79 ± 0.07^{aA}	5.70 ± 0.02^{aA}
	Alginate -CNSL coating	5.77 ± 0.08^{aA}	5.71 ± 0.03^{aA}	5.71 ± 0.05^{aA}
WHC[1] (%)	Control	28.53 ± 6.28^{aA}	27.53 ± 3.42^{aA}	31.38 ± 3.95^{aA}
	Alginate coating	25.70 ± 0.82^{aA}	27.38 ± 2.49^{aA}	22.76 ± 6.06^{aA}
	Alginate -CNSL coating	26.09 ± 1.54^{aA}	19.81 ± 2.17^{aA}	28.46 ± 4.65^{aA}
Cooking loss (%)	Control	18.66 ± 1.21^{aA}	28.08 ± 4.73^{bB}	37.54 ± 2.95^{cA}
	Alginate coating	32.94 ± 3.25^{aB}	30.10 ± 5.61^{aB}	35.51 ± 2.98^{aA}
	Alginate -CNSL coating	31.74± 2.91^{aB}	24.17 ± 1.34^{aA}	37.63 ± 3.85^{bA}
Shear force (N/cm^2)	Control (without film)	24.32 ± 0.10^{aA}	5.49 ± 0.08^{bB}	5.30 ± 0.05^{bB}
	Alginate coating	20.10 ± 0.21^{aB}	5.79 ± 0.12^{bB}	8.24± 0.11^{bA}
	Alginate -CNSL coating	22.06 ± 0.08^{aAB}	10.59 ± 0.18^{bA}	8.43 ± 0.14^{bA}

[1]Water holding capacity (WHC). Different lowercase letters in the row represent significance for CNSL level film coating application and different uppercase letters in the column represent significance for shelf life from Tukey test when $p < 0.05$.

Shear force (SF) reduced ($p < 0.05$) with the storage time increasing, however, it was observed that the beef conserved with alginate and alginate-CNSL coating, the SF reduction was lower compared to control (uncoating), especially at 3rd and 6th day (Table 2), characterizing it as a protective and stabilizing factor to sample degradation.

A significant increasing ($p < 0.05$) of malonaldehyde values in coating control beefs was observed in alginate-CNSL coating, preserved the oxidation process during the analyzed storage times (Figure 1). In addition, at 6th day storage, it was observed a stability in the peroxidation during the storage time compared to uncoating beef (control), as well as in relation to the only alginate coating. It was also observed that at time 0-day the alginate-CNSL coating had the highest peroxidation values, believing that this is due to the fact that CNSL initially reacts, even if in a small proportion with TBA, as noted in laboratory analysis, for the purpose of answers regarding this result.

There was a significant difference ($p < 0.05$) in mesophilic (Figure 2a) microbial growth in the control and sodium alginate only coating, when compared to the alginate- CNSL coating, especially at 6th storage day. It is observed that alginate had higher microbial growth than the control. Regarding to growth of psychrophilic microorganisms (Figure 2b), it was observed that the beefs with alginate-CNSL coating obtained microbial growth similar to the uncoating control group (uncoated) during the entire storage time, with no statistical differences observed ($p > 0.05$). Showing that for this type of microorganism, the coating did not have an antimicrobial activity. Beefs coated with the sodium alginate alone had the highest microbial growth.

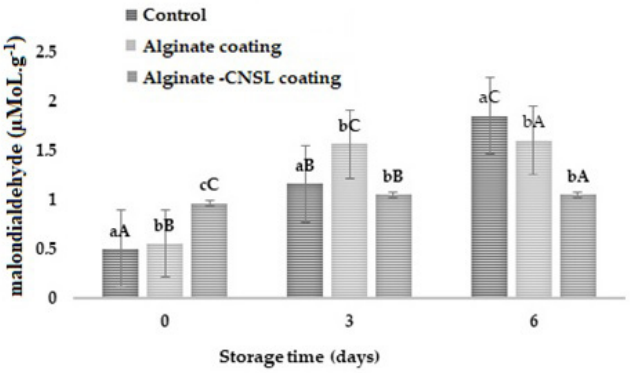

Figure 1. Active coating solutions with cashew nut shell liquid (CNSL) on lipid oxidation (TBARS values, µMoL malondialdehyde/g meat) of beef during storage stability times (4 ± 1 °C). Bars with different lowercase letters represent significance for CNSL level film application and different uppercase letters represent significance for storage time from Tukey test when $p < 0.05$.

4 Discussion

Meat color, mainly redness index (a*), is an important and influencing aspects considered by consumers at purchasing decisions, in addition to being greatly affected by shelf time. The decreasing in the a* values was observed over the storage period until 3rd day, stabilizing at 6th day, however without coating effect. It is believed that this was due to the protein oxidation of myoglobin and subsequent conversion into metmyoglobin, the result of growth and deterioration by microorganisms, thus resulting in a darker/brown meat (Faustman et al., 2010; Kaewprachu et al., 2017).

Another essential parameter in the impact on meat quality is the pH, since it is directly linked to the degree of protein denaturation (the lower the greater the denaturation), endogenous proteolysis and muscle contraction (Ramos & Gomide, 2007). It was observed that the beef samples from the control (uncoating) treatment showed a gradual pH increasing when storage time increased, while alginate-CNSL coating maintained a stable pH, presenting pH values within the normal interval (range 6.0 to 6.4) for beef steak consumption (Brasil, 2017). This was due to the fact that, with increasing storage time, microbial enzymes tend to degrade meat protein (myoglobin), forming nitrogenous compounds, such as ammonia and trimethylamine, causing pH values to increase and, consequently, there is an increasing in

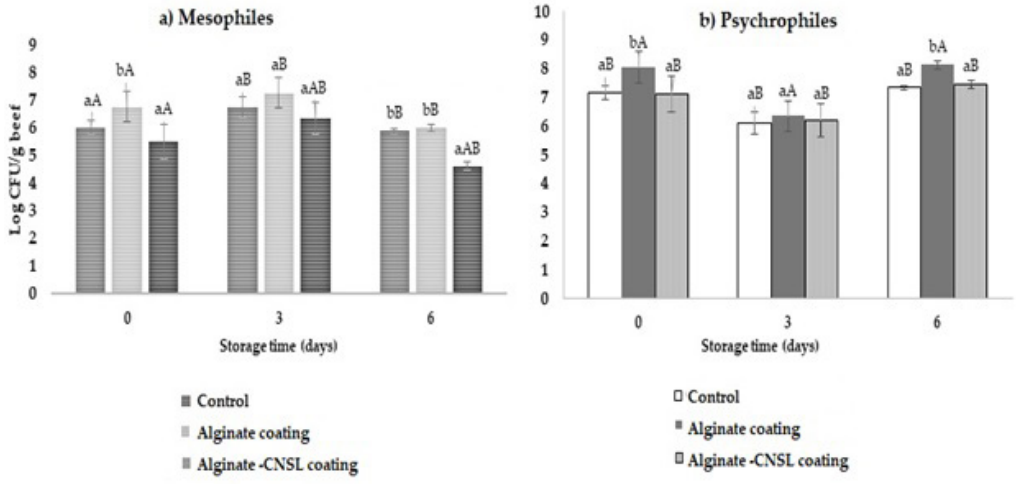

Figure 2. Active coating solutions with cashew nut shell liquid (CNSL) on total count of colony forming units (CFU) of (a) mesophiles and (b) psychrophiles of beef during storage stability times (4 ± 1 °C). Bars with different lowercase letters represent significance for CNSL level film application and different uppercase letters represent significance for storage time from Tukey test when $p < 0.05$.

the growth of microbial strains (Behbahani & Imani Fooladi, 2018; Ghani et al., 2018). It is noticed that the preservation of pH was the result of the ability of CNSL, rich in antioxidant and antimicrobial compounds, thus helping to reduce microbial growth and proliferation, which are inhibited at pH lowest (Behbahani et al., 2017).

In general, the WHC parameters did not show any significant difference over the days of storage. Regarding CL, it was possible to verify that the control beefs presented the highest losses in relation to those that contained bioactive coating based on CNSL, improving the post-cooking loss until the 3rd day. In addition, greater CL at storage time 0-day is justified due to the inclusion of the coating that, throughout the storage period, was incorporated into the sample. It is likely that from the 3rd day onwards, this film decreased its efficiency, which was expected, considering that the inclusion of CNSL, as a hydrophobic component, affected the hydrophilic property of the films (Catarino et al., 2017; Feng et al., 2019), leading to a decrease in affection between the film by water, thus increasing its permeability (Hosseini et al., 2009; Ghasemlou et al., 2013; Mahcene et al., 2020).

The texture aspect of the meat, evaluated through the SF, is one of the main parameters influencing the quality of the meat. In which a progressive decrease was observed over the storage time, for all treatments, especially the control beefs and alginate coating, respectively. Where beef samples conserved with the alginate-CNSL coating presented the smallest decreases, due to the fact that the larger the bacterial population, the greater the softness index. Thus, the antimicrobial capacity of the CNSL caused the beefs to have a lower bacterial proliferation and, consequently, the softness index of these beefs was lower. Thus, this result is beneficial, considering the ability of the functional oil to delay myofibrillar protein degradation, according to the lower active microbial activity in meat (Krzywdzińska-Bartkowiak et al., 2016; Ghani et al., 2018; Behbahani et al., 2020).

When evaluating the lipid oxidation process of the beefs, through the TBA method, by quantifying the levels of malondialdehyde (MDA), a byproduct of the peroxidation reactions, it was observed that the control treatment reached the highest values in the TBARS and therefore, they suffered greater oxidation throughout the storage period. The best results related to lower MDA formation came from the beef conserved with the alginate-CNSL coating, with its incorporation being largely responsible for the promising results, since the CNSL, characterized by the presence of non-isoprenoid phenolic compounds and lipids long and unsaturated chain, with the presence of aromatic rings (Mazzetto et al., 2009; Balachandran et al., 2013). This gives it the capacity of hydrogen proton donor for the peroxyl radical, acting as a free radical inhibitor and as a primary antioxidant (Barreiros et al., 2006; Andrade et al., 2011). Which its efficiency could be observed through the monitoring of oxidation, which allows to evidence the capacity of phenolic compounds (Socrier et al., 2019). Furthermore, bioactive films based on CNSL at the 1% inclusion level have high antioxidant activity (Vasconcelos et al., 2021).

Through the microbiological evaluation of the analyzed beefs samples, it was also possible to observe that, the contamination observed from storage time 0 day, it is probably the result of inadequate hygienic sanitary conditions at the place of acquisition, which is confirmed from the lower CFU indices of meat in this time. It can be observed that over the storage period, microbial growth was significantly lower in the beefs involved with alginate-CNSL coating for the group of mesophilic microorganisms, characterizing it as a protective and stabilizing factor related to microbiological degradation. Which already it was expected, due to the antimicrobial characteristic of the CNSL used (technical), attributed to the presence of cardanol, which, in addition to presenting potent antioxidant activity, also has antimicrobial potential, even if inferior to anacardic acid, presenting only when CNSL *in natura*. In addition, the chemical structure of technical CNSL, rich in phenolic compounds s and terpenoids, as well as their interaction between them, also give it

this characteristic (Himejima & Kubo, 1991; Mazzetto et al., 2009; Osmari et al., 2015). It is noteworthy that mesophilic bacteria, that is, those whose ability is to multiply at higher temperatures (20 to 45 °C), have an important agriculture food influence, as a large part of the bacteria belonging to this group are associated to food-borne illnesses (Forsythe, 2016).

Its antimicrobial potential can be confirmed in the study by Vasconcelos et al. (2021), in which antimicrobial activity was observed from the inclusion of 1% of CNSL in film *against P. aeruginosa, L. monocytogenes, B. cereus* and *S. aureu*s bacteria, with greater efficiency for gram-positive bacteria, to the detriment of the negative ones. According to Atarés & Chiralt (2016), lipid sources with similar characteristics to CNSL can affect microbial cells through several mechanisms, including attacking the phospholipid bilayer of the cell membrane, interrupting enzymatic systems and compromising the genetic material of bacteria, releasing active compounds by coming into contact with the food surface and consequently helping to inhibit/delay bacterial proliferation (Guo et al., 2017).

5 Conclusions

The use of the alginate-based bioactive coating added 1% of CNSL for beef conservation, decreased the oxidative process and, consequently, promoted lipid stability, in addition to providing lower microorganisms proliferation, among which, there are several bacteria of important agri-food impact, presenting, therefore, promising characteristics for the preservation of perishable foods and could be used as a replacement for conventional packaging, taking into account the biodegradable and ecologically correct.

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