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EFFECT OF COCONUT OIL ENRICHED CASSAVA STARCH BASED EDIBLE COATINGS ON QUALITY OF MINIMALLY STRAWBERRIES (*FRAGARIA ANANASSA*)

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ABSTRACT
The purpose of this work was to evaluate the effects of applying cassava starch coating with the addition of different concentrations of coconut oil in minimally processed strawberries. The strawberries were selected and sanitized, had their leaves and peduncles removed, and were submerged in the coatings (40ºC) for three minutes. Four treatments were obtained: T1 - control (strawberries without coating); T2 - coconut oil (1.0%) + cassava starch (3.0%); T3 - coconut oil (1.5%) + cassava starch (3.0%); T4 - coconut oil (2.0%) + cassava starch (3.0%). After receiving the coatings, the strawberries were placed in PET (polyethylene terephthalate) containers and stored at 5±1°C for 12 days. Physical, chemical, sensory analysis and microbiological evaluations were performed. T2 and T3 samples were more efficient in reducing mass loss (14.59% and 14.52%). They were also effective in maintaining texture and color for longer, as they influenced sensory and microbiological analysis, increasing shelf life and slowing growth, especially of molds and yeasts. The study may help small-scale establishments to increase the shelf life of minimally processed strawberries. The use of small concentrations of coconut oil prolonged the quality of strawberries during refrigerated storage.

1.Introduction

Strawberry (*Fragaria ananassa*) is a non-climacteric fruit containing a great variety of bioactive compounds including phenolic constituents, anthocyanins, vitamins and minerals (Giampieri *et al*., 2015; Pizato *et al.*, 2022). However, postharvest handling and storage of fresh strawberries is difficult mostly due to their high susceptibility to mechanical injury, water loss, microbial decay, physiologic al deterioration and high respiration rate (Liu *et al*., 2018).

Studies show the possibility of developing packaging or coatings using natural and biodegradable macromolecules, such as proteins, lipids and polysaccharides (Alves-Silva *et al*., 2022). There are numerous studies that reported the beneficial effects of edible coating on the minimally processed fruit and vegetables such pineapple (Pizato *et al*., 2019; Padrón-Mederos *et al*., 2020), papaya (Holsbach *et al*., 2019), broccoli (Pizato *et al*., 2020), guavas (Arroyo *et al*., 2020), strawberry (Martínez-González *et al*., 2020; Pizato *et al.*, 2022).

Starch is one of the most studied biodegradable polymers for obtaining films and coatings, and present low cost (Borges *et al*., 2015). It presents possibilities of chemical and physical modification for application in use as coatings (Holsbach *et al*., 2019). Starch is a biopolymer composed of several units of amylose and amylopectin, being classified as a polysaccharide (Oliveira *et al*., 2020).

Coconut oil is a natural food product rich in lauric acid. There is evidence that a part of this acid converts endogenously to monolaurin that is known to possess a broad spectrum of antiviral, antibacterial and antifungal activities (Liberman *et al*., 2006). Coconut oil coating closed the opening of stomata and lenticels thereby, reducing the transpiration and respiration rate and also reduce microbial activity (Nasrin *et al*., 2020).

Thus, the objective of the present work was to evaluate the effect of an edible coating based on cassava starch with the addition of coconut oil to increase the shelf life of minimally processed strawberries.

2. Materials and methods

2.1. Material

Fresh strawberries (*Fragaria ananassa*), cassava starch and coconut oil from the local market in Dourados-MS, Brazil, were used. The fruits were selected and classified according to their skin color, without physiological defects. The strawberries were transported to the bioengineering laboratory of the Federal University of Grande Dourados in plastic boxes, free of solar rays and at a temperature of approximately 10-12ºC. They were then stored at 5±1°C until processing.

2.2. Preparation of strawberries

The leaves and stalk of the strawberry were removed with the help of a stainless-steel knife, then they were sanitized in an organic chlorine solution at 2 $g.L^{-1}$, for 5 minutes, the water was drained for 2 to 3 minutes on sieves.

2.3. Preparation and application of coatings

The solutions were prepared according to the methodology of Chevalier *et al.* (2016), by slow homogenization of cassava starch (3%) in distilled water, until complete dissolution, followed by heating to 70ºC, for 20 minutes, and cooling to 40ºC. After this step, the coconut oil (Origin: Brazil; white colour at solid form but colourless above 30ºC with melting point in 25ºC and smoking point in 177ºC) was added according to the concentration established for each treatment.

The strawberries were totally submerged in the different coverings for three minutes and then drained with the help of sieves. Four treatments were obtained: T1 - control (strawberries without coating); T2 - coconut oil (1.0%) + cassava starch (3.0%); T3 - coconut oil (1.5%) + cassava starch (3.0%); T4 - coconut oil (2.0%) + cassava starch (3.0%). After applying the treatments, the strawberries were stored in a quantity of nearly 50 grams per package in PET (Polyethylene terephthalate), with lid (SANPACK) and with external measurements of 15x10x4 cm, and these packages were stored under refrigeration at 5±1°C for a period of 12 days.

2.4. Physical, chemical and microbiological analysis

The physical, chemical and microbiological analyses was performed in triplicate, on the day of processing, being considered as day 0 and after 1, 3, 5, 7, 9 and 12 days of storage.

2.4.1. Loss mass

The strawberries were stored at a cooling temperature of 5±1°C and UR of 60±2% and weighed in an analytical balance on days 0, 1, 3, 5, 7, 9 and 12 of storage. The loss of mass was obtained through the difference in the initial and final mass of the strawberry multiplied by 100 at each analysis. The results were expressed as a percentage of mass loss.

2.4.2. pH analysis

The analysis was performed according to the method described by AOAC (2000).

2.4.3. Total soluble solids content (ºBrix)

The total soluble solids content was determined using an Abbé bench refractometer, and the results were expressed in ºBrix (AOAC, 2000).

2.4.4. Titratable acidity

The titratable acidity was determined by titrating 10 mL of the sample (previously homogenized with 100 mL of distilled water) and phenolphthalein using 0.1 $mol.L^{-1}$ NaOH.

The results were expressed as a percentage of citric acid (AOAC, 2000).

2.4.5. Color measurement

The color measurements were made using a previously calibrated Konica Minolta colorimeter (Model CR-400/CR-410), using the CIE L*a*b* (Comission Internationale de L'Eclairage) system. The results were expressed as L*, a* and b* (Minolta, 1994).

2.4.6. Firmness measurement

The determination of the firmness of the strawberries was obtained by cutting and shearing the samples in a uniaxial way, with the aid of the texturometer (TA-TX Plus). The tests were performed with the aid of a 12 mm diameter cylindrical probe. The samples were centered on the slit of the blade, which was sheared at a speed of 2 mm s^{-1} uniaxially. The distance traveled was pre-fixed in 35mm and the complete shearing of the sample occurred. The shearing force was expressed in Newton (N) (AMSA, 2015).

2.4.7. Microbiological analysis

The microbiological tests performed were for molds and yeasts, psychrotrophic, *Salmonella* ssp, and *Escherichia coli*, following the methods described in APHA (2001).

2.4.8. Sensory evaluation

The sensory evaluation followed the methodology described by Chevalier *et al*. (2018), using 12 trained judges. For each treatment, attributes of texture, color, aroma and overall evaluation were evaluated only through sight, smell, and touch (under no hypothesis it was proven) during 12 days of storage at 5 ± 1°C, using a scale that ranged from 5 to 3, where 5 meant a sample of very good quality (fresh, aromatic, and without darkening); 4 meant regular (not very fresh, less pronounced aroma, and moderate darkening); 3 the sample of very bad quality (without freshness and aroma and with a high degree of darkening and presence of mold).

2.5. Statistical analysis

The analyses were realized in triplicate and the results expressed by the average. The results obtained were statistically evaluated through the Analysis of Variance (ANOVA) and Tukey's test at a 5% significance level, with the help of the STATISTICA® 7.0 program.

3.Results and discussions

3.1. Loss mass

Table 1 shows the values of loss of mass evaluated for strawberries over a period of 12 days stored at a temperature of 5±1ºC.

We can observe in Table 1 that T2 and T3 treatments had lower mass loss. The T4 treatment presented the highest mass loss (27.58%), values that were above those found by Martínez-González *et al*. (2020), who obtained values between 9.7% - 13.2% after eight days of storage, when they evaluated the effect of coatings with chitosan, chitosan nanoparticles and propolis on the behavior of ripening and antioxidant capacity of strawberries. As a non-climacteric fruit, strawberries have high water loss due to their considerable respiratory rate, in addition to being susceptible to mechanical damage and disease. All these factors lead the fruit to a rapid deterioration (Cunha Júnior *et al*., 2012). Mass loss increased significantly ($p>0.05$) during the entire storage period for all treatments. These results agree with those observed by Virgen-Ortiz *et al*. (2020), who evaluated the application of pectic oligosaccharides in different concentrations in the post-harvest quality of strawberries, where they found a 22.9% mass loss at the end of the storage period for untreated strawberries, while for strawberries coated with 9 g L^{-1} of pectic oligosaccharides the mass loss was 17.8%.

Table 1. Mass loss (%) of strawberries coated with cassava starch and different concentrations of coconut oil at 5±1ºC, for 12 days

Days	Treatments			
	T1	**T2**	**T3**	**T4**
0	0^{gA}	0^{gA}	0^{gA}	0^{gA}
1	$0.61±0.12^{fB}$	$1.22±0.23^{fA}$	$1.20±0.61^{fAB}$	$1.36±0.37^{fA}$
3	$2.10±0.16^{eB}$	$2.04±0.44^{eB}$	$2.01±0.08^{eB}$	$5.77±0.71^{eA}$
5	$5.59±0.21^{dB}$	$4.78±0.09^{dC}$	$4.17±0.17^{dD}$	$10.64±0.22^{dA}$
7	$11.80±0.43^{cB}$	$8.65±0.31^{cC}$	$7.98±0.32^{cC}$	$14.81±0.58^{cA}$
9	$16.53±0.11^{bA}$	$13.58±0.11^{bB}$	$12.12±0.09^{bC}$	$16.43±0.04^{bA}$
12	$23.38±0.94^{aB}$	$14.59±0.59^{aC}$	$14.52±0.06^{aC}$	$27.58±0.49^{aA}$

Averages of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and upper-case letter in the line do not differ by Tukey's Test ($p<0.05$): (T1) control (strawberry uncoated); (T2) 3.0% cassava starch and 1.0% coconut oil; (T3) 3.0% cassava starch and 1.5% coconut oil; (T4) 3.0% cassava starch and 2% coconut oil.

Mass loss over 10% is enough to compromise the strawberry's appearance, causing wrinkled and dull epidermis (Hernandéz-Muñoz *et al*., 2006). Until the seventh day, T2 and T3 presented values below 10%, while T4 treatment presented values above 10% from the 5th day of storage. These results are close to those found by Muley and Singhal (2020), who used chitosan conjugate coating and whey protein isolate in strawberries stored at 5±1ºC and 20 ±1ºC.

3.2. pH analysis

Table 2 presents the evaluated pH data for strawberries during a 12 days storage period.

The pH values observed on day 12 decreased in relation to day 0 of storage for all the evaluated treatments, and the T3 and T4 treatments presented the highest final values, statistically differing from the other treatments. This higher pH value verified along the storage days for the samples T3 and T4 was already expected, since these samples were the ones that received the highest concentration of coconut oil. According to Muley and Singhal (2020), non-volatile organic acids, especially citric acid formed during the storage of strawberries, contribute and regulate pH. These organic acids are consumed in various metabolic pathways associated with the ripening process of strawberries (Lan *et al*., 2019). In this study, pH decreases during storage, and Yan *et al*. (2019) report that this decrease is combined with storage conditions, such as temperature, relative humidity and light, storage life, and physiological conditions of the fruits.

Studies by Bose *et al*. (2019) observed a slight increase in pH values with the passing of the days of storage when they worked with strawberries coated with alginate. Similar effect was found in the pH values by Virgen-Ortiz *et al*. (2020), working with the application of pectic oligosaccharides in the concentration of 9 g/L in the post-harvest quality of strawberries, where they observed a variation from 3.49 to 3.77 in 14 days of storage. These works demonstrated that a greater consumption of organic acids and sugars occurred during the respiratory metabolism of the strawberry. These results disagree with the present study, because a decrease of the pH values was observed with the passing of the storage days.

Table 2. pH values of strawberries coated with different proportions of coconut oil and cassava starch at 5±1ºC for 12 days

Days	Treatments			
	T1	T2	T3	T4
0	3.83±0.04^{aA}	3.83±0.04^{aA}	3.83±0.04^{aA}	3.83±0.04^{aA}
1	3.83±0.02^{aA}	3.51±0.01^{bC}	3.74±0.03^{bB}	3.72±0.02^{bB}
3	3.29±0.02^{dC}	3.31±0.01^{dC}	3.44±0.05^{cB}	3.65±0.01^{cA}
5	3.27±0.03^{dA}	3.09±0.00^{eD}	3.17±0.00^{dB}	3.13±0.00^{fC}
7	3.46±0.04^{bcA}	3.29±0.02^{dB}	3.45±0.02^{cA}	3.27±0.02^{eB}
9	3.54±0.04^{bC}	3.54±0.01^{bC}	3.73±0.01^{bB}	3.84±0.00^{aA}
12	3.46±0.01^{cB}	3.45±0.00^{cB}	3.50±0.01^{cA}	3.50±0.00^{dA}

Averages of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and upper-case letter in the line do not differ by Tukey's Test ($p<0.05$): (T1) control (strawberry uncoated); (T2) 3.0% cassava starch and 1.0% coconut oil; (T3) 3.0% cassava starch and 1.5% coconut oil; (T4) 3.0% cassava starch and 2% coconut oil.

3.3. Total soluble solids content (ºBrix)

Table 3 presents the values of the total content of soluble solids found for strawberries over a period of 12 days stored at 5±1ºC.

Table 3. Values of total soluble solids (°Brix) of strawberries coated with different proportions of coconut oil and cassava starch at 5±1ºC, for 12 days

Days	Treatments			
	T1	T2	T3	T4
0	7.00±0.00^{aA}	7.00±0.00^{aA}	7.00±0.00^{aA}	7.00±0.00^{aA}
1	6.17±0.24^{bA}	6.00±0.00^{cA}	5.17±0.24^{bcB}	6.00±0.00^{bA}
3	5.50±0.41^{cB}	7.00±0.00^{aA}	5.00±0.01^{cB}	4.00±0.00^{eC}
5	5.00±0.00^{dB}	5.50±0.03^{dA}	5.00±0.00^{cB}	4.00±0.00^{eC}
7	5.50±0.16^{cB}	6.37±0.17^{bA}	5.40±0.14^{bB}	6.07±0.05^{bA}
9	5.33±0.24^{cAB}	5.30±0.14^{dAB}	5.50±0.24^{bA}	5.00±0.02^{dB}
12	5.13±0.03^{cC}	5.08±0.01^{eC}	5.77±0.21^{bA}	5.20±0.00^{cB}

Averages of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and upper-case letter in the line do not differ by Tukey's Test ($p<0.05$): (T1) control (strawberry uncoated); (T2) 3.0% cassava starch and 1.0% coconut oil; (T3) 3.0% cassava starch and 1.5% coconut oil; (T4) 3.0% cassava starch and 2% coconut oil.

There was a decrease in the values of soluble solids with the passing of the storage days for all the evaluated treatments: the T3 treatment presented the smallest decrease (17.57%) and the T1 and T2 treatments presented the largest reductions, 26.71 and 27.41%, respectively. According to Pelayo *et al.* (2003), the reduction of the total soluble solids occurs because of the hydrolysis of sucrose, which uses the respective sugars as a substrate for respiration.

Petriccione *et al.* (2015) found different results in strawberries covered with chitosan (1% and 2%) and non-covered, where the content of soluble solids increased gradually over nine days of cold storage. A study by Virgen-Ortiz *et al.* (2020) also observed an increase in the content of soluble solids in all treatments evaluated when they worked with the application of pectic oligosaccharides on strawberries. A possible explanation for this phenomenon is the solubilization of polyuronides and hemicelluloses present in the cell wall and also the loss of water due to the perspiration of the fruit (Nguyen *et al*., 2020).

3.4. Titratable acidity

Table 4 presents the results of titratable acidity found for strawberries during a period of 12 days stored at refrigerated temperature.

The results obtained of titratable acidity expressed in percentage (%) of citric acid show that there was a decrease in titratable acidity between day 0 and day 12 for treatments T1 (from 8.22 to 7.26), T2 (8.22-5.87) and T4 (8.22-6.31). According to Vargas *et al*. (2006), the enzymatic activity during storage is one reason why the decrease of fruit acids occurs. Taste and flavor are results of the presence of sugars and organic acids in the fruits, and many organic acids are secondary metabolites formed by the citric acid cycle that is used during breathing (Moshari-Nasirkandi *et al*., 2020). With this, it was perceived that the T1, T2 and T4 treatments went through a more accentuated respiratory process than the T3 treatment, because they obtained higher acidity losses in 12 days of storage.

Petriccione *et al*. (2015) found values close to the present study when working with strawberry chitosan coatings. These authors demonstrated that the acidity decreased significantly during the storage of strawberries at 2 ºC, with lower values in uncoated fruits compared with chitosan coated fruits. This work found final values of titratable acidity in treatments with less and more coconut oil (T2 and T4, respectively).

Table 4. Titratable acidity (citric acid %) of strawberries coated with different proportions of coconut oil and cassava starch at 5±1ºC, for 12 days

Days	Treatments			
	T1	T2	T3	T4
0	8.22 ± 0.33^{bA}	8.22 ± 0.33^{abA}	8.22 ± 0.33^{bcA}	8.22 ± 0.33^{bA}
1	4.59 ± 0.10^{dD}	6.11 ± 0.09^{dC}	6.88 ± 0.00^{dB}	7.45 ± 0.14^{cA}
3	7.26 ± 0.05^{cB}	8.41 ± 0.05^{aA}	8.60 ± 0.14^{abA}	7.45 ± 0.08^{cB}
5	9.36 ± 0.17^{aA}	7.93 ± 0.06^{bcC}	7.26 ± 0.05^{dD}	8.79 ± 0.05^{aB}
7	9.36 ± 0.19^{aA}	8.60 ± 0.08^{aB}	8.03 ± 0.08^{cC}	7.07 ± 0.21^{cD}
9	8.22 ± 0.12^{bA}	7.64 ± 0.12^{cB}	5.92 ± 0.12^{eC}	5.16 ± 0.14^{eD}
12	7.26 ± 0.19^{cB}	5.87 ± 0.09^{dD}	8.78 ± 0.09^{aA}	6.31 ± 0.29^{dC}

Averages of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and upper-case letter in the line do not differ by Tukey's Test ($p<0.05$): (T1) control (strawberry uncoated); (T2) 3.0% cassava starch and 1.0% coconut oil; (T3) 3.0% cassava starch and 1.5% coconut oil; (T4) 3.0% cassava starch and 2% coconut oil.

3.5. Color measurement

The results found for the color parameters L* (Brightness), a* (Chroma a*) and b* (Chroma b*) are shown in Table 5.

Through Table 5 it is possible to observe that the parameters were affected by the presence of 3% cassava starch coating and by the different concentrations of coconut oil studied, since significant differences ($p\geq0.05$) were observed between the samples with the passing of the storage days.

The parameter L* (luminosity) is an indicator of darkening of the fruit, expressing the change in color during the period of senescence, where the fruit tends to be darker and redder throughout storage (Borges *et al*., 2015). The use of the cover on strawberries did not show significant changes in the initial coordinates (day 0) of color of the fruit. With the passing of the storage days, a decrease of L* values were observed for all the evaluated treatments, tending to a darker coloration, and the T4 and T1 treatments were the ones that presented the smallest decrease of this parameter (20.72% and 19.77%, respectively), and the T3 treatment presented the smallest luminosity variation during the evaluated period (10.45%). The final values (days 12) of the highest brightness parameter of the treatments that the coverings (T2, T3 and T4) received occur by the cassava starch cover, together with different proportions of coconut oil that gave the strawberry a greater brightness.

Table 5. Color obtained from strawberries coated with cassava starch and different proportions of coconut oil at 5±1ºC for 12 days

Analyzed Parameters	Days	Treatments			
		T1	T2	T3	T4
L*	0	34.14±0.76^{aB}	37.42±0.87^{aA}	38.16±0.22^{aA}	38.64±0.82^{aA}
	1	33.94±1.12^{aB}	37.30±0.58^{aA}	38.06±0.19^{abA}	37.64±0.36^{abA}
	3	32.49±0.33^{abB}	36.19±1.12^{abA}	37.24±0.52^{abcA}	36.01±0.75^{bcA}
	5	31.50±1.23^{bcB}	36.05±0.09^{abA}	36.79±0.71^{bcA}	34.57±1.01^{cdA}
	7	30.31±0.45^{cdD}	35.11±0.47^{bcB}	36.12±0.09^{cdA}	33.14±0.26^{deC}
	9	29.72±0.61^{cdC}	34.30±0.08^{cdAB}	35.22±0.16^{deA}	32.07±0.06^{efB}
	12	28.18±0.24^{dC}	32.15±0.36^{dAB}	34.17±0.88^{dA}	30.63±0.34^{fB}
Chroma a*	0	29.48±0.18^{aA}	31.24±0.09^{aA}	31.89±0.14^{aA}	32.13±0.11^{aA}
	1	29.11±0.43^{aC}	31.16±0.15^{aB}	31.80±0.09^{abA}	31.02±0.07^{bB}
	3	27.70±0.65^{bC}	30.73±0.08^{aAB}	31.54±0.07^{bA}	30.48±0.09^{cB}
	5	26.11±0.58^{cC}	29.61±0.13^{aB}	30.98±0.11^{cA}	29.31±0.14^{dB}
	7	27.34±0.53^{bC}	29.14±0.05^{aB}	30.01±0.03^{dA}	28.55±0.17^{eB}
	9	26.03±0.12^{cD}	28.03±0.09^{aB}	29.79±0.12^{dA}	27.01±0.03^{fC}
	12	23.68±0.18^{dD}	27.41±0.27^{aB}	28.88±0.05^{eA}	26.41±0.07^{gC}
Chroma b*	0	25.03±0.59^{abB}	26.63±0.02^{aA}	26.78±0.12^{bA}	27.22±0.05^{aA}
	1	25.03±0.21^{abC}	26.24±0.14^{abB}	26.71±0.09^{bA}	27.04±0.19^{aA}
	3	24.36±0.76^{abB}	25.86±0.03^{abA}	26.25±0.05^{cA}	25.07±0.05^{bAB}
	5	26.04±0.64^{aA}	26.21±0.31^{abA}	27.08±0.13^{aA}	26.79±0.41^{aA}
	7	25.12±0.30^{abC}	25.85±0.30^{abB}	26.81±0.09^{abA}	25.35±0.07^{bBC}
	9	24.22±0.06^{bB}	25.71±0.02^{bA}	25.91±0.14^{dA}	25.01±0.22^{bAB}
	12	22.10±0.17^{cC}	25.56±0.09^{bA}	25.64±0.04^{dA}	24.84±0.09^{bB}

Averages of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and upper-case letter in the line do not differ by Tukey's Test ($p<0.05$): (T1) control (strawberry uncoated); (T2) 3.0% cassava starch and 1.0% coconut oil; (T3) 3.0% cassava starch and 1.5% coconut oil; (T4) 3.0% cassava starch and 2% coconut oil.

The trend in the decrease of L* values found in this study were similar to those found by Virgen-Ortiz *et al*. (2020), when they worked with coverings in strawberries based on pectic oligosaccharides and also Garrido-Bigotes *et al*. (2018). These authors observed that the strawberries slowly darken during storage due to the induction of anthocyanin production. Furthermore, Perdones *et al*. (2012) found a decrease in luminosity values in uncoated strawberries coated with chitosan and essential oil of lemon, and those with the coating showed lower losses of luminosity at the end of storage.

The Chroma a* varies from negative to green and positive to red. Chroma a* is a measure of redness and is highly correlated with the anthocyanin concentration in strawberry (Virgen-Ortiz *et al*., 2020).

A decrease of a* values was observed with the passing of the storage days for all the evaluated treatments (Table 5). The control treatment (T1) presented the greatest decrease (19.67%), and the T3 treatment had the smallest decrease (9.43%) in 12 days of storage. Hernández-Muñoz *et al*. (2008), report that the decrease of Chromas indicates a change to less vivid colors. A study by Virgen-Ortiz *et al*. (2020) disagrees with the present study, because when they worked with coverings of pectic oligosaccharides in the concentration of 5 and 9 g/L, they observed an increase in the values of Chroma a* with the passing of storage days.

Regarding Chroma b*, it can be observed that a small decrease in values occurred when compared between day 0 and day 12 of storage, and the control treatment (T1) showed the largest decrease (11.70%), while treatment T2 showed the smallest decrease in parameter b* (4.01%), followed by treatment T3 (4.25%). However, T2 and T3 treatments showed no significant difference between them ($p \leq 0.05$) at the end of the days of storage.

3.6. Firmness measurement

Changes in the texture of the controlled and treated strawberries during storage at 5±1ºC are shown in Table 6.

It can be seen in Table 6 that the firmness has decreased with the passing of the storage days for all treatments. The control treatment was the one that presented a greater decrease in texture at the end of 12 days (49.33%), while the T2 and T3 treatments presented the smallest loss, 24.72% and 22.07%, respectively, not differing statistically between them at the end of the evaluated period. During fruit ripening, the loss of firmness is mainly associated with the rupture of the medium lamella and the modification of the composition and structure of the polymers existing in the primary cell wall (Luo, 2006), respiration, water loss, and damage to structural tissues caused by molds (Chu *et al*., 2020). The process of disassembling the cell wall involves the depolymerization of the xyloglucan-cellulose matrix and the solubilization of pectins, which contribute to the softening of the fruits (Posé *et al*., 2019). As a result, it can be seen that the use of covers helped to slow down the loss of firmness and were efficient in keeping the cell wall of the fruit stiffer for longer.

Table 6. Firmness (N) of strawberries coated with cassava starch and different proportions of coconut oil at 5±1ºC, for 12 days

Days	**Treatments**			
	T1	**T2**	**T3**	**T4**
0	4.50 ± 0.11^{aA}	4.53 ± 0.11^{aA}	4.53 ± 0.11^{aA}	4.51 ± 0.11^{aA}
1	3.63 ± 0.09^{bB}	4.35 ± 0.06^{aA}	4.42 ± 0.23^{aA}	4.15 ± 0.05^{bA}
3	3.11 ± 0.16^{cB}	4.19 ± 0.14^{abA}	4.21 ± 0.09^{abA}	3.85 ± 0.17^{cAB}
5	3.01 ± 0.10^{cC}	4.02 ± 0.07^{bA}	4.09 ± 0.11^{bA}	3.59 ± 0.09^{cB}
7	2.78 ± 0.02^{dC}	3.82 ± 0.05^{cA}	3.94 ± 0.02^{bA}	3.37 ± 0.03^{dB}
9	2.57 ± 0.04^{eC}	3.70 ± 0.03^{cA}	3.81 ± 0.03^{cA}	3.13 ± 0.04^{eB}
12	2.28 ± 0.12^{fC}	3.41 ± 0.07^{dA}	3.53 ± 0.32^{cA}	3.02 ± 0.06^{eB}

Averages of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and upper-case letter in the line do not differ by Tukey's Test ($p<0.05$): (T1) control (strawberry uncoated); (T2) 3.0% cassava starch and 1.0% coconut oil; (T3) 3.0% cassava starch and 1.5% coconut oil; (T4) 3.0% cassava starch and 2% coconut oil.

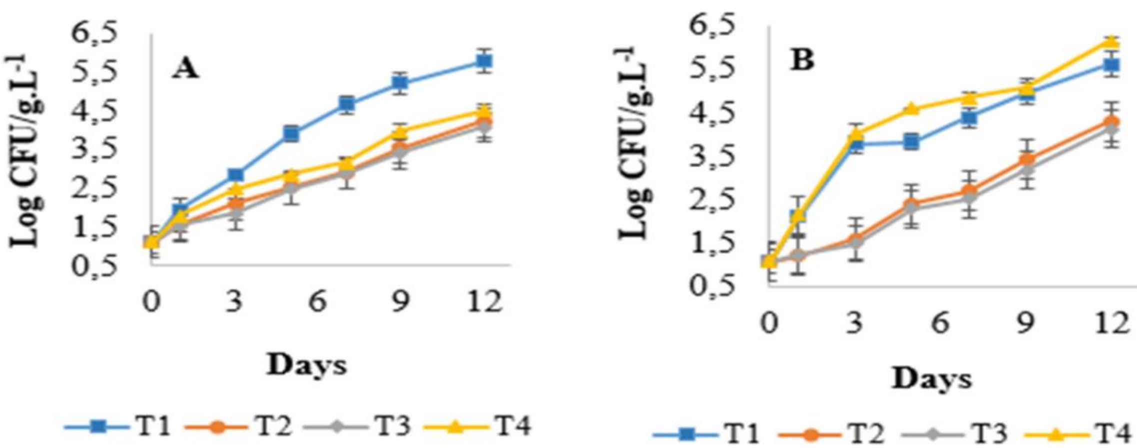
Some works found in the literature are in accordance with those observed in this study. Petriccione *et al*. (2015) demonstrated the efficiency of coatings to maintain the texture of strawberries for longer, when they worked with 2% chitosan in the coatings. When Martínez-González *et al*. (2020) studied the application of chitosan, along with nanoparticles of chitosan and propolis, in concentrations of 10% and 20%, they observed that at the end of eight days of storage the strawberries showed a greater firmness when compared to the control sample. These results are also in line with Restrepo and Aristizábal (2010), which reported higher firmness in strawberries covered with mucilaginous Aloe Vera gel and carnauba wax compared to the control sample. Ventura-Aguilar *et al*. (2018), in turn, evaluated the effect of chitosan and cinnamon essential oil applied to strawberries at 5 and 20ºC and observed a 33% higher firmness retention in the fruit treated with coatings compared to the control sample. Chitosan-based coatings plus oleic acid significantly reduced the rate of respiration and slowed the loss of strawberry texture (Vargas *et al*., 2006).

3.7. Microbiological analysis

No *Salmonella* ssp. and *Escherichia coli* were detected in the minimally processed strawberry samples. The minimally processed products must be similar to the fresh product, but with microbiological quality guaranteed by the reduction of pathogenic and deteriorating microorganisms. RDC Nº. 12 of 2001 (Brasil, 2001) establishes that for fresh fruit "*in natura*", prepared (peeled or selected or fractionated), sanitized, chilled, or frozen for direct consumption, the *Salmonella* ssp. bacteria must be absent in 25 grams of sample and that the maximum values of thermotolerant coliforms must be $5x10^2$ $CFU.g^{-1}$. Therefore, the present work is within these important specifications by legislation. Chevalier *et al*. (2018), when they studied the application of coatings obtained from protein isolate of tilapia (*Oreochromis niloticus*) in minimally processed melons did not observe the presence of *Salmonella* ssp. and *Escherichia coli*.

Figure 1 (A and B) shows the values of psychrotrophic and mold and yeast found for strawberries coated with cassava starch and coconut oil, stored for 12 days at controlled temperature (5±1ºC).

Figure 1. Psychrotrophic (A) and mold and yeast (B) found in strawberries coated with cassava starch and different proportions of coconut oil at 5±1ºC, for 12 days



Averages of three repetitions, expressed in colony forming unit per gram of sample: (T1) control (strawberry uncoated); (T2) 3.0% cassava starch and 1.0% coconut oil; (T3) 3.0% cassava starch and 1.5% coconut oil; and (T4) 3.0% cassava starch and 2% coconut oil.

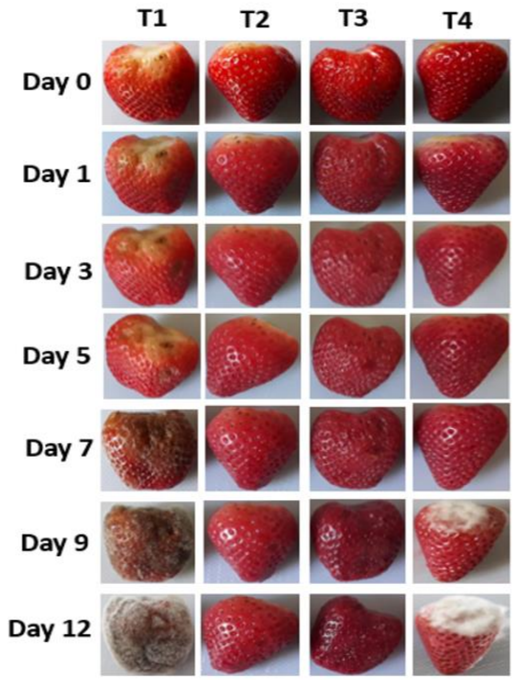


Figure 2. Appearance of strawberries without and with cassava starch-based coatings containing different concentrations of coconut oil over the days of storage

Figure 1 (A) shows the growth of psychrotrophic organisms during the 12 days storage period. As observed, there was an accentuated growth of these microorganisms with the passing of the storage days, and the control treatment (T1) presented a higher growth (5.5 log/CFU.g^{-1}), differing statistically from the others at the end of the experiment. The T2, T3 and T4 treatments did not differ from each other during the evaluated period.

As much as there are no standards in psychrotrophic bacteria and for mold and yeast in Brazil, it has been suggested that foods with populations above 10^5 and 10^6 CFU.g^{-1} (Verzeletti *et al*., 2010) may be unsuitable for humans due to loss of nutritional value, organoleptic changes, and risk of deterioration and infection (Lima *et al*., 2011). In this study, only the control treatment was above these limits from the 9th day of storage, demonstrating that the use of coatings was efficient to reduce the growth of psychrotrophic microorganisms. Similar results were observed by Chevalier *et al*. (2018), when they worked with coatings based on protein isolate of tilapia applied on minimally processed melons, and the control treatment also showed values above 10^5 from the 9th day of storage, and the treatments with protein isolate only exceeded this limit on the 12th day of storage.

Figure 1 (B) shows the growth of molds and yeasts in strawberries minimally processed during 12 days of storage. There was an increase in mold and yeast growth for all the evaluated treatments, and the T1 and T4 treatments showed the highest growth over the days of storage and at the end of 12 days these treatments did not differ statistically. For the treatments T2 and T3 an increase was also observed, but less than the control treatment and the treatment with cassava starch and 2% coconut oil.

The high growth for molds and yeasts presented by the T4 treatment can be explained by the fact that this treatment has the highest concentration of coconut oil, which may have caused a higher humidity of the sample and thus contributed to a significant increase of these microorganisms. On the other hand, the T2 and T3 treatments that presented lower concentration of coconut oil (1.0% and 1.5%, respectively) left the strawberries with lower humidity, contributing to a lower growth of molds and yeasts.

When Perdones *et al*. (2012) worked with chitosan along with lemon essential oil; they obtained a positive effect in reducing the fungal activity in strawberries stored at 5ºC. Moreover, Vu *et al*. (2011) reported a higher antifungal effect of limonene with chitosan in strawberries in 12 days of storage compared to the control sample. These studies present similar results to the present study, where low concentrations of coconut oil were effective for lower microbial growth throughout the days of analysis.

Figure 2 shows the appearance of strawberries over the days of storage. As we can see, the strawberries developed a darker color (redder) with the passing of the days of storage; besides, the T1 and T4 treatments showed apparent mold growth (days 9 and 12). These observations can be confirmed when we evaluate Figure 1 (B), in which there was greater growth of mold and yeast for these treatments and also when we analyze the data obtained during the sensory analysis (Table 7), in which the judges provided grades between 3 (which was considered as the limit grade for fruit acceptability) or below this value from the ninth day for T1 and T4.

3.8. Sensory evaluation

Table 7 presents the data obtained for the sensory evaluation of strawberries coated with different proportions of coconut oil together with cassava starch, stored for 12 days at controlled temperature.

There was a significant difference in all samples and attributes evaluated after 12 days of storage. The treatments that received coverage with cassava starch and coconut oil were equal to or greater than 3 at the end of 12 days, and are therefore considered acceptable.

It can be observed that for all the evaluated attributes there was loss of visual acceptance with the passing of the days of storage. On the days 0 and 1 of storage there was no preference for coated fruits, since the average scores of acceptances did not differ significantly between treatments. Hernández-Muñoz *et al*. (2008), when evaluating chitosan and calcium-coated strawberries, obtained a higher acceptance of coated strawberries. These authors explain that the brilliance conferred by the use of this coating was attributed by the tasters for its greater initial acceptance. This observation was not a differential for the present study, since the marks attributed by the judges did not differ between the treatments at the beginning of the evaluation days.

T1 treatment presented the biggest reduction, and from the ninth day it had already surpassed the stipulated minimum value of quality (except for the aroma attribute). Hernández-Muñoz *et al*. (2008) observed that from the sixth day of storage, the control strawberries (without coatings) had already exceeded the stipulated limit, but it is worth noting that these authors were working with a storage temperature of 10ºC. The T2 and T3 treatments presented the highest acceptability at the end of 12 days of storage, and at the end of this period; they were still with values above 3.

Restrepo and Aristizábal (2010) found that the strawberry control sample had a higher odor in 5 days of storage when compared to the samples containing edible carnauba wax-based coating and also mucilage. They attributed this to the fact that the coatings used acted as a barrier that reduced the passage of aromatic compounds by reducing the perception of odor by the judges. This was not observed in this study, since when the aroma attribute was evaluated, it was verified that the samples that received the cassava starch coating with different concentrations of coconut oil presented higher values for this attribute at the end of 12 days of storage.

Table 7. Sensory evaluation of strawberries coated with cassava starch and different proportions of coconut oil at 5±1ºC, for 12 days

Analyzed Parameters	Days	Treatments			
		T1	**T2**	**T3**	**T4**
Texture	0	5.00±0.00^{aA}	5.00±0.00^{aA}	5.00±0.00^{aA}	5.00±0.00^{aA}
	1	4.72±0.00^{bA}	4.81±0.18^{abA}	4.83±0.14^{aA}	4.84±0.00^{aA}
	3	4.41±0.15^{cA}	4.43±0.23^{bcA}	4.71±0.12^{abA}	4.43±0.13^{bA}
	5	4.00±0.00^{dC}	4.34±0.14^{cAB}	4.43±0.09^{bA}	4.20±0.00^{cBC}
	7	3.29±0.05^{eB}	4.11±0.18^{cdA}	4.02±0.13^{cA}	3.34±0.07^{dB}
	9	2.85±0.12^{fB}	3.89±0.01^{dA}	3.79±0.20^{cA}	3.14±0.15^{deB}
	12	2.60±0.00^{gC}	3.29±0.05^{eA}	3.14±0.13^{dAB}	3.00±0.00^{eB}
Color	0	5.00±0.00^{aA}	5.00±0.00^{aA}	5.00±0.00^{aA}	5.00±0.00^{aA}
	1	4.88±0.00^{aA}	4.87±0.09^{aA}	4.95±0.22^{aA}	4.71±0.15^{bA}
	3	4.51±0.02^{bB}	4.80±0.05^{abA}	4.81±0.12^{abA}	4.60±0.02^{bB}
	5	4.14±0.15^{cC}	4.50±0.00^{bAB}	4.55±0.10^{bA}	4.30±0.05^{cBC}
	7	3.00±0.00^{dC}	4.08±0.25^{cAB}	4.12±0.10^{cA}	3.75±0.04^{dB}
	9	2.87±0.15^{dB}	3.98±0.19^{cA}	4.0±0.05^{cA}	3.00±0.00^{eB}
	12	2.62±0.08^{eC}	3.45±0.00^{dA}	3.43±0.10^{dA}	2.80±0.00^{fB}
Aroma	0	5.00±0.00^{aA}	5.00±0.00^{aA}	5.00±0.00^{aA}	5.00±0.00^{aA}
	1	4.70±0.00^{bA}	4.71±0.05^{bA}	4.73±0.13^{abA}	4.70±0.00^{bA}
	3	4.21±0.08^{cB}	4.59±0.12^{bA}	4.48±0.06^{bcA}	4.43±0.13^{cAB}
	5	4.00±0.00^{dB}	4.45±0.09^{bA}	4.43±0.09^{cdA}	4.23±0.03^{dAB}
	7	3.29±0.15^{eB}	4.12±0.03^{cA}	4.14±0.07^{deA}	4.00±0.00^{eA}
	9	3.05±0.00^{fB}	3.81±0.15^{dA}	3.75±0.13^{efA}	2.98±0.00^{fB}
	12	2.67±0.00^{gC}	3.54±0.12^{eA}	3.43±0.10^{fA}	2.90±0.05^{gB}
Overall evaluation	0	5.00±0.00^{aA}	5.00±0.00^{aA}	5.00±0.00^{aA}	5.00±0.00^{aA}
	1	4.85±0.02^{aA}	4.87±0.02^{abA}	4.87±0.00^{aA}	4.86±0.03^{aA}
	3	4.57±0.10^{bA}	4.63±0.08^{bA}	4.71±0.10^{abA}	4.54±0.04^{aA}
	5	3.86±0.15^{cB}	4.29±0.10^{cA}	4.43±0.07^{bcA}	4.00±0.08^{bB}
	7	3.00±0.00^{dC}	4.00±0.12^{cdA}	4.16±0.23^{cdA}	3.40±0.00^{cB}
	9	2.85±0.15^{dB}	3.73±0.19^{dA}	3.82±0.05^{dA}	3.00±0.0^{dB}
	12	2.15±0.04^{eD}	3.05±0.01^{eB}	3.14±0.04^{eA}	2.85±0.03^{eC}

Averages of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and upper-case letter in the line do not differ by Tukey's Test ($p<0.05$): (T1) control (strawberry uncoated); (T2) 3.0% cassava starch and 1.0% coconut oil; (T3) 3.0% cassava starch and 1.5% coconut oil; (T4) 3.0% cassava starch and 2% coconut oil.

Mendonça *et al*. (2020) also obtained a decrease in the sensory attributes evaluated when they studied the use of microemulsions, microemulsions with citronella essential oil, microemulsions with avocado oil, and emulsion of avocado oil with water in minimally processed strawberries. These authors observed that in 11 days of storage at 4 ºC, the appearance, color and odor attributes presented by the control sample and the sample that received the emulsion prepared with avocado oil with water were classified as good by the judges. In turn, samples that had microemulsions along with citronella essential oil and microemulsions with avocado oil were classified as regular and the sample containing only microemulsions was considered bad at the end of 11 days of storage. This work demonstrated that the use of oils together with the microemulsions were efficient to maintain the sensory characteristics of strawberries for longer. In the present study, it was also verified that the use of coconut oil together with cassava starch was promising for a longer sensorial life of minimally processed strawberries.

4. Conclusions

Of the evaluated treatments, T2 (1% coconut oil) and T3 (1.5% coconut oil) were the most efficient treatments in the conservation of minimally processed strawberries, when compared to the control sample and also the sample that presented the highest concentration of coconut oil in the formulation (T4).

The T2 and T3 treatments proved to have great potential to be applied as coatings as they reduced mass loss by approximately 85%, maintained physical and chemical characteristics, and reduced microbiological changes, especially in mold and yeast growth.

However, the use of coconut oil in low concentrations (1% and 1.5%), kept the minimally processed strawberries safe for consumption for a longer time when stored at 5 ± 1 ºC.

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