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Effect of tragacanth gum (*Astragalus gummifer*) and melaleuca essential oil to extend the shelf life of minimally processed pineapples

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ABSTRACT. The consumption of minimally processed fruit is increasing due to its convenience, but its shelf life is reduced when compared to fresh fruit (*in natura*). The effects of using tragacanth gum (*Astragalus gummifer*) and melaleuca essential oil (*Melaleuca alternifolia*) as an edible coating on minimally processed pineapples (*Smooth cayenne*) were investigated in this study. The pineapples were sanitized, peeled, cut into standardized pieces, and immersed in the toppings, obtaining four treatments: T1 (control); T2 (0.5 tragacanth gum and 0.2% melaleuca essential oil); T3 (0.5 tragacanth gum and 0.3% melaleuca essential oil); T4 (0.5 tragacanth gum and 0.4% melaleuca essential oil), then drained and stored in PET (Polyethylene Terephthalate) containers with a lid, under refrigeration at 5±1°C for 12 days. Physicochemical and microbiological analyses were performed. The samples T2 and T4 obtained less mass loss and less decrease in total soluble solids content. The T2 sample also showed promising results by reducing the loss of texture and delaying the growth of mold and yeast in relation to the control sample over 12 days of storage. The use of tragacanth gum together with melaleuca essential oil was efficient in maintaining the quality of minimally processed pineapples for a longer time.

Keywords: tea tree; *Melaleuca alternifolia*; *Smooth cayenne*; edible toppings; natural gum.

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Introduction

The world production of fruit is high, with pineapple occupying 3% of this total. Brazil ranks third in the production of this fruit (Food and Agriculture Organization [FAO], 2020). The production of pineapples in Brazil was approximately 1.55 billion units in 2021 (Statista, 2022).

Pineapple (*Ananas comosus L. Merr.*) is a plant of the Bromeliaceae family (Hossain, 2016). Because it is a large fruit, minimal processing becomes a good reason to increase its consumption.

Minimally processed products are very perishable and have a very short shelf life (4 to 10 days) compared to fresh fruit (*in natura*) that has a shelf life of several weeks to months, as in the case of pineapple (Pizato et al., 2019; Basaglia et al., 2021). The cutting or slicing operations modify the metabolic process of vegetal tissue and increase its susceptibility to spoilage, inducing a reduction of the shelf life (Cortez-Vega, Pizato, Souza & Prentice, 2014).

The use of edible coatings may represent a promising alternative in the postharvest preservation of minimally processed fruits (Alikhani, 2014), and the addition of essential oil as an antimicrobial may help to improve food preservation (Debiagi, Kobayashi, Nakazato, Panagio, & Mali, 2014). Some authors have researched the effect of different types of coatings on various minimally processed fruits, such as papaya (Holsbach et al., 2019), guava (Arroyo et al., 2020), and pineapple (Padrón-Mederos, Rodríguez-Galdón, Díaz-Romero, Lobo-Rodrigo, & Rodríguez-Rodríguez, 2020; Prakash, Baskaran, & Vadivel, 2020; Zou et al., 2021). Edible coatings obtained from natural resources are environmentally friendly and are able to enhance the quality of produce (Pizato et al., 2019).

Tragacanth gum is a dried exudate that is obtained by cutting the stems of Asian Astragalus species (*Leguminosae*) (Azarikia & Abbasi, 2010). Tragacanth gum is a natural, non-toxic, and biocompatible polymer, and it is widely used as a natural emulsifier and thickener in the food industry. Its use is due to its stability over a wide pH range and its effectiveness as an emulsifying agent with a long shelf life (Mohamadnia, Zohuriaan-Mehr, Kabiri, & Razavi-Nouri, 2008; Mohebbi, Ansarifar, Hasanpour, & Amiryousefi, 2012).

The genus *Melaleuca* belongs to the Myrtaceae family, including approximately 100 species native to Australia and the islands of the Indian Ocean. *Melaleuca artenifolia* is commonly known as the 'Tea Tree' flourishing in swamp areas. Its oil is extracted from the plant by hydrodistillation. It has bactericidal and fungicidal activity and is presented as photochemical markers such as, α-Terpinene, ϒ-Terpinene, Terpinen-4-ol (Correa et al., 2020).

Therefore, this study aimed to evaluate the effects of using tragacanth gum (*Astragalus gummifer*) and melaleuca essential oil (*Melaleuca alternifolia*) as an edible coating in minimally processed pineapples (*Smooth cayenne*) stored at 5±1°C for 12 days.

Material and methods

Material

Pineapples (*Smooth cayenne*), tragacanth gum (*Astragalus gummifer*) (Aremsa S.A, Lima, Peru), and melaleuca essential oil (*Melaleuca alternifólia*) (Phytoterápica, São Paulo State, Brazil) were purchased from local commerce in the city of Dourados-MS (latitude 22° 13' 18.54" South and longitude 54° 48' 23.09" West). The pineapples were selected in relation to size, peel color with a maturation degree between 50 to 70%, without defects, injuries, or infections. The analyses were performed in the Bioengineering laboratory of the Federal University of Grande Dourados.

Pineapple preparation

The pineapples were transported at a temperature of approximately 25°C in thermal boxes to the Bioengineering laboratory of the Federal University of Grande Dourados, where they were washed and sanitized in an organic chlorine solution at 2 g L^{-1} for 10 min. Then they were peeled, and the core was removed manually, and then cut into standardized pieces of 2.0 x 2.0 cm in size.

Coating preparation and application

The coatings used were prepared based on tragacanth gum and melaleuca essential oil (100% pure). The percentage of gum tragacanth and tea tree essential oil used in this work were not previously tested, but when used as coatings on minimally processed pineapple pieces, they showed good coverage and odor. The tragacanth gum (TG) (0.5%) was dissolved slowly under stirring in distilled water for 30 min. until its complete dissolution at a temperature of 25°C using a propeller stirrer (Fisaton 313D, Fisaton, São Paulo State, Brazil), melaleuca essential oil (MEO) was added at the end of the process at the study concentrations while stirring for another 10 min.

The samples were divided into four treatments, namely: T1 (control - uncoated); T2 (0.5 TG and 0.2% MEO); T3 (0.5 TG and 0.3% MEO); T4 (0.5 TG and 0.4% MEO). The pineapple pieces were immersed in the coating solutions for 5 min. and then drained for 3 min. on sieves and packed in PET (polyethylene terephthalate) containers, with a lid (SANPACK), and stored under refrigeration at 5±1°C for 12days.

Physical, chemical, and microbiological analysis

The physical, chemical, and microbiological analyses were performed in triplicate on the day the samples were processed (day 0) and after 1, 3, 5, 7, 9, and 12 days of storage.

Mass loss

Mass loss was obtained between the initial weight of the minimally processed pineapple and the weight obtained at the end of each storage time, on an analytical scale (Mettler Toledo, ME204, Ohio, USA), according to the following equation (Alikhani, 2014):

$$Weight\ loss = \frac{initial\ mass - final\ mass}{initial\ mass} \times 100$$

The results were expressed in mass loss percentage.

pH analysis

The analysis was performed according to the method described by Association of Official Agricultural Chemists (AOAC, 2000). We used 20g of the crushed pineapple samples in 10mL of distilled water and then measured using a bench potentiometer (Marconi PA 200, São Paulo State, Brazil).

Total soluble solids content

The total soluble solids content was determined from the liquid extract obtained after grinding the samples. A bench refractometer was used (Abbé, Q767B, Tokyo, Japan). The results were expressed in °Brix according to AOAC (2000) methodology.

Color analysis

Color was evaluated using a Minolta colorimeter (Model CR-400, Osaka, Japan) with direct reading of the parameters: brightness (L*), from 0 (black) to 100 (white); Chroma a*, ranging from green (-60) to red (+60), and Chroma b* from blue (-60) to yellow (+60) (Basaglia et al., 2021). The total color difference (ΔE) was calculated according to the following equation (Simão et al., 2022).

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Texture analysis

The determination of the texture of minimally processed pineapples was obtained by cutting and shearing the samples, in a uniaxial way, with the help of a texturometer (Stable Micro Systems, TA-XT2i, Surrey, England), equipped with a cylindrical flat-bottom probe of 5 mm diameter. The test conditions were pre-test speed 2 mm s^{-1}, test speed 2 mm s^{-1}, post-test 10 mm s^{-1}, and penetration distance 10 mm (Pizato et al., 2019).

Microbiological analysis

The microbiological analyses performed were for *Escherichia coli*, *Salmonella ssp.*, and for molds and yeasts, using methodology described by American Public Health Association (Apha, 2001).

Statistical analysis

The analyses were performed in triplicate and the results expressed by the mean with standard deviation. The results obtained were statistically evaluated by analysis of variance (ANOVA) followed by Tukey's test at 5% significance using the Statistica 7.0 program (Statsoft Inc. 2004, Tulsa, OK).

Results and discussion

Mass loss

The results for mass loss (%) are presented in Table 1, for minimally processed pineapples during 12 days of storage.

Table 1. Mass loss values (%) for minimally processed pineapples with tragacanth gum and melaleuca essential oil stored at 5 ± 1°C for 12 days.

Days	Treatments			
	T1	T2	T3	T4
0	0^{fA}	0^{cA}	0^{fA}	0^{eA}
1	$1.81±0.70^{dA}$	$1.49±0.48^{cA}$	$1.28±0.50^{dA}$	$0.71±0.20^{eB}$
3	$5.44±0.90^{eA}$	$4.49±0.40^{bAB}$	$3.85±0.10^{eB}$	$2.14±0.50^{dC}$
5	$7.16±0.66^{cA}$	$5.07±0.81^{bB}$	$5.65±0.30^{cB}$	$3.43±0.19^{cC}$
7	$8.93±0.61^{bA}$	$7.52±0.15^{aB}$	$8.36±0.36^{bAB}$	$4.65±0.08^{bC}$
9	$10.22±0.12^{bA}$	$8.57±0.55^{aB}$	$9.07±0.38^{bAB}$	$5.77±0.60^{bC}$
12	$12.45±0.10^{aA}$	$8.89±0.80^{aC}$	$11.33±0.51^{aB}$	$7.83±0.62^{aC}$

The means of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and capital letter in the row do not differ by the Tukey test (p > 0.05). Where: T1 (control - uncoated); T2 (0.5 TG and 0.2% MEO); T3 (0.5 TG and 0.3% MEO); T4 (0.5 TG and 0.3% MEO); and T5 (0.5 TG and 0.3% MEO).

It can be seen that all treatments had mass loss over the days of storage. The sample T1 (control) showed the highest percentage of mass loss in 12 days of study. Treatments T2 and T4 with 0.2 and 0.4% melaleuca essential oil, respectively, obtained the lowest losses. The results found in the present study showed lower values of mass loss than those found by Basaglia et al. (2021), when they used chitosan and cinnamon essential oil in minimally processed pineapples stored for 15 days under refrigeration.

Mass loss occurs by two factors: transpiration or storage time (Carvalho & Lima, 2002). The mass loss results found in this work corroborate with the work of Pizato et al. (2019), where these authors also found lower mass loss values for samples coated with Tara gum (8.23%) compared to the control sample (27.31%), verifying then that the samples containing coatings delay mass loss and the natural aging of the fruit.

Also, Basumatary, Mukherjee, Katiyar, Kumar, and Dutta (2021) when evaluating the use of chitosan, aloe vera gel and zinc oxide in pineapples, stored at 25°C for 15 days, found that these coatings were effective in reducing mass loss, and that the setting was 11.40% in 15 days of study. These results collaborate with those obtained in the present study, which also demonstrated that the use of coatings is effective in reducing mass loss and, consequently, leaving the product ready to be consumed for a longer period.

pH analysis

Table 2 shows the pH values found for the minimally processed pineapples during the 12 days of storage.

A decrease of pH values was observed in all samples compared to the first and last days of analysis. The decrease in these values may be associated with the production of organic acids during storage due to biochemical reactions (Lima, Ramos, Marcellini, Batista, & Faraoni, 2005). There was a greater reduction in pH values for T4 treatment (13.56%). The final pH values found in this study are similar to those found by Zzaman, Biswas, and Hossain (2021) when they worked with applying immersion pretreatments and drying temperatures to improve the quality of pineapple slices.

Basaglia et al. (2021) found in their studies pH values between 3.11 and 3.42 in pineapples coated with chitosan and cinnamon essential oil, where an increase in pH was also found on the first days, reducing after day 5 of storage, as in the present work.

Buelvas-Caro, Polo-Corrales, and Hernandez-Ramos (2019), evaluated minimally processed pineapples with different treatments containing aloe-vera and cassava starch for 16 days. These authors also observed a drop in pH over the days of storage. The drop in pH found by these authors and by the present work may be related to the acidification of the cytoplasm, a production and partial dissolution of CO_2 in the water of cellular tissues, which causes a decrease in the pH of the medium (Sauceda, 2011). The increase in this variable is attributed to the senescence phase of the fruit, as it uses the organic acids present in it for respiration (Buelvas-Caro et al., 2019).

Table 3 shows that all treatments presented an increase in soluble solids content, with a significant difference between the first and last day of storage for all treatments evaluated. Sharma, Saini, and Sharma (2018) stated that increases in soluble solids content should not occur as storage days pass, because pineapple is considered a non-climacteric fruit. However, Pizato, Cortez-Vega, Souza, Prentice-Hernandez, and Borges (2013) showed that mass loss of minimally processed fruits can lead to sugar accumulation and thereby increase the total soluble solids content over time.

Total soluble solids content (°Brix)

Table 3 shows the total soluble solids values of the samples during storage.

Table 2. pH values for minimally processed pineapple samples with tragacanth gum and different concentrations of melaleuca essential oil, stored at 5 ± 1°C for 12 days.

Days	Treatments			
	T1	T2	T3	T4
0	$3.63{\pm}0.05^{abA}$	$3.70{\pm}0.10^{aA}$	$3.70{\pm}0.10^{aA}$	$3.76{\pm}0.05^{aA}$
1	$3.64{\pm}0.05^{abA}$	$3.70{\pm}0.04^{aA}$	$3.64{\pm}0.01^{abA}$	$3.74{\pm}0.06^{aA}$
3	$3.67{\pm}0.04^{aAB}$	$3.72{\pm}0.02^{aA}$	$3.57{\pm}0.06^{abcB}$	$3.70{\pm}0.03^{aA}$
5	$3.50{\pm}0.03^{bcA}$	$3.61{\pm}0.08^{abA}$	$3.54{\pm}0.09^{bcdA}$	$3.51{\pm}0.03^{bA}$
7	$3.55{\pm}0.06^{abcAB}$	$3.64{\pm}0.04^{abA}$	$3.52{\pm}0.05^{bcdAB}$	$3.47{\pm}0.05^{bB}$
9	$3.53{\pm}0.02^{abcA}$	$3.52{\pm}0.05^{bA}$	$3.46{\pm}0.05^{cdA}$	$3.47{\pm}0.03^{bA}$
12	$3.44{\pm}0.11^{cAB}$	$3.50{\pm}0.05^{bA}$	$3.43{\pm}0.02^{dAB}$	$3.25{\pm}0.08^{cB}$

The means of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and capital letter in the row do not differ by the Tukey test ($p > 0.05$). Where: T1 (control - uncoated); T2 (0.5 TG and 0.2% MEO); T3 (0.5 TG and 0.3% MEO); T4 (0.5 TG and 0.3% MEO); and T5 (0.5 TG and 0.3% MEO).

Table 3. Total soluble solids values (°Brix) for minimally processed pineapple samples with tragacanth gum and different concentrations of melaleuca essential oil, stored at 5 ± 1°C for 12 days.

Days	Treatments			
	T1	T2	T3	T4
0	12.66±0.57^{bA}	10.33±0.57^{bB}	10.33±0.57^{cB}	12.66±0.57^{cA}
1	12.94±0.55^{abA}	11.10±0.45^{bB}	10.38±0.45^{cB}	12.88±0.57^{bcA}
3	13.50±1.50^{abA}	12.66±1.10^{aAB}	10.50±0.50^{cB}	13.00±0.50^{bcAB}
5	13.33±0.57^{abA}	12.83±0.03^{aAB}	12.16±0.28^{bB}	13.20±0.30^{abcA}
7	13.66±1.10^{abA}	13.00±0.50^{aA}	13.00±0.00^{abA}	13.33±0.54^{abcA}
9	14.50±0.80^{abA}	13.50±0.00^{aA}	13.33±0.57^{abA}	14.16±0.40^{abA}
12	15.00±0.57^{aA}	14.00±0.40^{aA}	14.00±0.60^{aA}	14.52±0.57^{aA}

The means of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and capital letter in the row do not differ by the Tukey test (p > 0.05). Where: T1 (control - uncoated); T2 (0.5 TG and 0.2% MEO); T3 (0.5 TG and 0.3% MEO); T4 (0.5 TG and 0.3% MEO); and T5 (0.5 TG and 0.3% MEO).

Treatments T2 and T3 showed the greatest increases in total soluble solids with 35.52%. Studies conducted by Chaves et al. (2011), with minimally processed pineapple observed final values of 11.75°Brix, which were lower than those found in this study. Basaglia et al. (2021) showed that treatments containing lower concentrations of chitosan and cinnamon essential oil had the lowest increase in soluble solids content (26.45%). In this study, the T4 treatment that had the highest concentration of melaleuca essential oil was the one that obtained the lowest increase in total soluble solids concentration.

Buelvas-Caro et al. (2019) also observed an increase in the soluble solids content over the days of storage in minimally processed pineapples containing coatings with aloe-vera and cassava starch. These authors reported that this is due to the effect of the coatings on delaying fruit respiration, being this variable dependent on the consumption of organic acids or other bioenergetic source that is used as a substrate. With that, as available, the substrate in the fruit is consumed during the metabolic process, thus increasing the °Brix progressively.

Color analysis

Table 4 presents the color values for the different treatments evaluated in pineapples minimally processed for 12 days. The luminosity parameter decreased with the passing of the days of storage, that is, a darkening was observed already on the first day of analysis, and on the last day of analysis, all samples were different in relation to the first day and also among themselves.

The sample T1 (control) showed L* of 70.26 on day 0 and 57.25 on day 12, similar to those found by Prakash et al. (2020), who studied citral nano emulsions in minimally processed pineapples, where they found a decrease in browning in 12 days of study.

The sample T3 (0.5% solution of tragacanth gum plus 0.3% melaleuca essential oil) showed the highest darkening among the samples, 27.87% in 12 days. The results obtained contradict those found by Basaglia et al. (2021), who obtained lower rates in browning for the samples with chitosan coating and cinnamon essential oil, being the highest for the control sample.

In relation to the a* parameter, all samples increased their values throughout the days of storage, but without differentiating among themselves until day 7. As of day 9, sample T1 (control) showed an increase in relation to the other samples. T3 obtained better results. Basaglia et al. (2021) also found an increase in chroma a* over the days of storage.

For the chroma b*, a reduction in values was observed for all treatments, meaning that there was oxidative browning, and T4, which had the highest amount of melaleuca essential oil, showed the most oxidative browning. This behavior was different from that found by Basaglia et al. (2021), where the sample with the highest concentration of essential oil showed a greater reduction in the b* value. Moreover, this same behavior was observed by Holsbach et al. (2019) when they worked with minimally processed papaya with starch coating and clove essential oil. Pan, Zhu, and Shouying (2015) also observed a decrease in b* values after 11 days in minimally processed pineapples.

There was an increase in the color difference (ΔE) as the storage period elapsed. The values for color loss (ΔE) showed significant variations ($p < 0.05$) with storage time. The degree of color difference between the samples was high, which means that the color stability of the minimally processed pineapples in this study was low. The trend towards color increase was less pronounced in uncoated pineapples (control). It should be noted that the color difference variable was obtained from the values of L*, a* and b*, in a given period of storage and from values corresponding to a pattern, which, in the present work, referred to the pieces of pineapple at the beginning of storage. Thus, a greater elevation of the color difference implies a more pronounced departure from the initial color (Simão et al., 2022), a behavior observed in pineapples coated with gum tragacanth and tea tree essential oil at all concentrations studied. Cserhalmi, Sass-Kiss, Tóth-Markus, and Lechner (2006) reported that the color change can be perceived by consumers depending on the ΔE value. Color difference is perceived by consumers when the ΔE value is greater than 1.5. The minimally processed pineapple samples quickly reached a ΔE value of 1.5 under all storage conditions, as shown in Table 4.

Table 4. Color values for minimally processed pineapple samples with tragacanth gum and different concentrations of melaleuca essential oil, stored at 5 ± 1°C for 12 days.

Parameters	Days	Treatments			
		T1	T2	T3	T4
L*	0	$70.26±0.55^{aA}$	$62.24±0.44^{aC}$	$68.53±0.44^{aB}$	$68.54±0.35^{aB}$
	1	$68.68±0.03^{bA}$	$58.89±0.28^{bC}$	$63.73±0.12^{bB}$	$65.02±1.23^{bB}$
	3	$65.54±0.16^{cdA}$	$52.19±0.16^{cD}$	$54.14±0.70^{cC}$	$57.98±0.16^{cB}$
	5	$66.10±0.16^{cA}$	$52.03±0.90^{cC}$	$52.83±0.23^{dC}$	$57.60±0.68^{cB}$
	7	$64.76±0.52^{dA}$	$52.26±0.36^{cC}$	$52.04±0.14^{dC}$	$57.53±0.48^{cB}$
	9	$60.10±0.68^{eA}$	$49.45±0.19^{dC}$	$49.48±0.59^{eC}$	$54.55±0.88^{dB}$
	12	$57.25±0.38^{fA}$	$47.16±0.93^{eD}$	$49.43±0.84^{eC}$	$53.19±0.27^{dB}$
a*	0	$-1.89±0.24^{cA}$	$-2.06±0.05^{cAB}$	$-2.62±0.24^{bB}$	$-2.44±0.27^{cAB}$
	1	$-1.60±0.28^{cA}$	$-1.70±0.08^{bcA}$	$-2.01±0.22^{bA}$	$-2.07±0.02^{bcA}$
	3	$-1.02±0.37^{bcA}$	$-1.00±0.23^{abA}$	$-0.79±0.23^{aA}$	$-1.34±0.44^{abA}$
	5	$-0.64±0.44^{bA}$	$-0.76±0.11^{bA}$	$-0.68±0.11^{aA}$	$-1.05±0.40^{abA}$
	7	$-0.34±0.06^{bA}$	$-0.68±0.34^{bA}$	$-0.38±0.27^{aA}$	$-0.99±0.48^{abA}$
	9	$0.89±0.26^{aA}$	$-0.40±0.32^{aB}$	$-0.42±0.50^{aB}$	$-0.82±0.62^{aB}$
	12	$1.43±0.45^{aA}$	$-0.44±0.66^{aB}$	$-0.37±0.90^{aB}$	$-0.31±0.08^{aB}$
b*	0	$14.58±0.44^{bA}$	$14.95±0.99^{aA}$	$14.53±0.46^{aA}$	$14.18±0.89^{aA}$
	1	$14.45±0.56^{bA}$	$13.28±0.52^{aA}$	$13.49±1.40^{aA}$	$12.70±1.30^{aA}$
	3	$14.21±0.83^{bA}$	$9.95±0.91^{bB}$	$9.64±0.90^{bB}$	$9.75±0.44^{bB}$
	5	$14.32±1.09^{bA}$	$8.95±0.83^{bB}$	$9.41±0.90^{bB}$	$8.24±0.26^{bcB}$
	7	$14.91±0.92^{abA}$	$8.54±1.10^{bB}$	$9.30±0.57^{bB}$	$7.47±0.33^{cB}$
	9	$16.15±1.40^{abA}$	$9.56±0.19^{bB}$	$9.16±0.80^{bBC}$	$7.21±0.21^{cC}$
	12	$17.30±0.80^{aA}$	$9.21±0.85^{bB}$	$7.56±0.89^{bBC}$	$6.53±0.95^{cC}$
ΔE	0	-	-	-	-
	1	$1.60±0.25^{eC}$	$3.76±0.12^{eB}$	$4.94±0.22^{eA}$	$3.84±0.15^{eB}$
	3	$4.81± 0.47^{dC}$	$11.27±0.20^{dB}$	$15.30±0.44^{dA}$	$11.50±0.45^{dB}$
	5	$4.35±0.15^{dC}$	$12.50±0.30^{cB}$	$16.62±0.12^{cA}$	$12.50±0.10^{cB}$
	7	$5.72±0.18^{cC}$	$11.90±0.25^{cB}$	$17.40±0.20^{bA}$	$13.00±0.70^{cB}$
	9	$10.30±0.22^{bD}$	$13.97±0.40^{bC}$	$19.90±0.42^{aA}$	$15.70±0.25^{bB}$
	12	$13.30±1.02^{aC}$	$16.20±1.25^{aB}$	$20.45±0.30^{aA}$	$17.30±0.60^{aB}$

The means of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and capital letter in the row do not differ by the Tukey test (p >.05). Where: T1 (control - uncoated); T2 (0.5 TG and 0.2% MEO); T3 (0.5 TG and 0.3% MEO); T4 (0.5 TG and 0.3% MEO); and T5 (0.5 TG and 0.3% MEO). L*: luminosity; a*: chroma a; b*: chroma b; ΔE: color difference.

Texture analysis

Figure 1 shows what was evidenced in the color analysis, where the samples presented greater darkening as the days of storage went by.

Table 5 shows the values found for texture (N) in the minimally processed pineapple samples stored for 12 days of analysis.

The values for texture differed significantly from each other from the ninth day of analysis on the four treatments. On the last T1 (control) day, the greatest increase occurred, presenting a texture of 10.22N. This increase in texture is related to the mass loss of the pineapple, consequently making the tissue stiffer.

T2 obtained the lowest increase at the end of the 12 days of analysis, with 9.17N; therefore, coating showed the best results and the least changes in the structure of the minimally processed pineapple.

These results were higher than those found by Basaglia et al. (2021) who showed lower final texture values for the coated samples than in the control treatment. This means that samples coated with gums added with essential oils behave more promisingly than uncoated samples. The decrease in firmness in pineapples that had coatings is related to the lower enzymatic hydrolysis of cell-wall components (Guerreiro, Gago, Miguel, Faleiro, & Antunes 2016). We can say that the migration of moisture in the sample is reduced when you have the addition of coatings, thus obtaining better results (Glicerina et al., 2019).

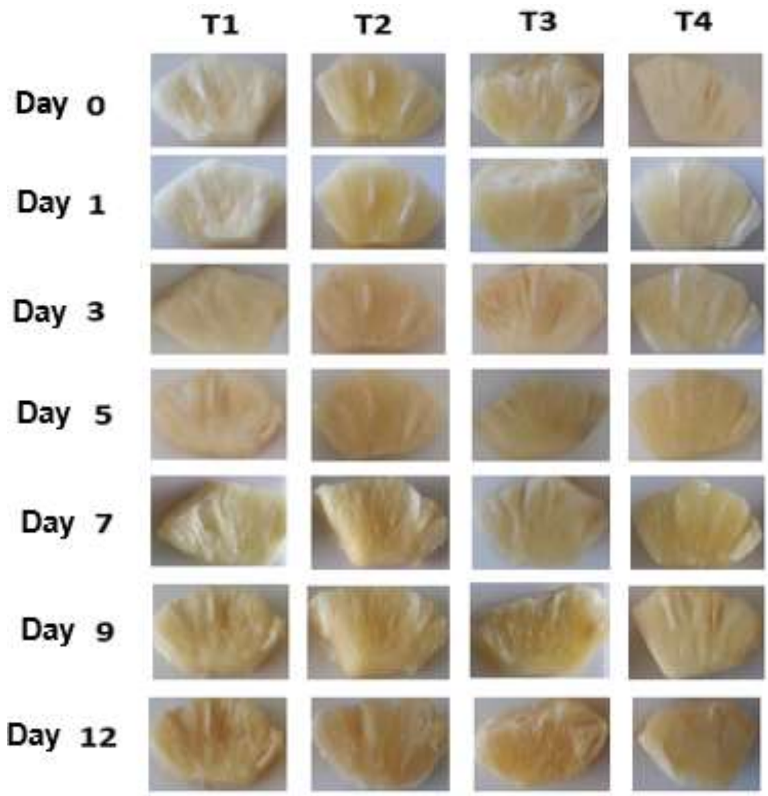

Figure 1. Appearance of pineapples coated or uncoated with different concentrations of melaleuca essential oil over storage days.

Table 5. Texture values (N) for minimally processed pineapple samples with tragacanth gum and different concentrations of melaleuca essential oil, stored at 5 ± 1°C for 12 days.

Days	Treatments			
	T1	T2	T3	T4
0	7.00±0.20^{bA}	7.56±0.45^{aA}	7.56±0.45^{aA}	7.56±0.45^{bA}
1	7.53±0.85^{bA}	8.30±0.57^{aA}	7.82±0.98^{aA}	7.76±0.80^{abA}
3	7.87±0.89^{bA}	8.58±0.54^{aA}	8.34±1.43^{aA}	8.16±0.43^{abA}
5	7.90±0.14^{bB}	8.63±1.80^{aAB}	9.30±0.70^{aA}	8.68±0.54^{abB}
7	8.30±1.30^{abA}	9.20±1.05^{aA}	9.12±1.80^{aA}	8.97±0.82^{abA}
9	8.60±0.75^{abAB}	9.19±0.20^{aA}	9.86±0.96^{aA}	8.56±0.17^{abB}
12	10.22±0.21^{aA}	9.17±0.11^{aBC}	9.77±0.77^{aAB}	9.26±0.31^{aBC}

The means of 3 repetitions ± standard deviation, followed by the same lower-case letter in the column and capital letter in the row do not differ by the Tukey test (p > 0.05). Where: T1 (control - uncoated); T2 (0.5 TG and 0.2% MEO); T3 (0.5 TG and 0.3% MEO); T4 (0.5 TG and 0.3% MEO); and T5 (0.5 TG and 0.3% MEO).

Microbiological analysis

Salmonella sp. (absence in 25 g) and *Escherichia coli* (< 10^2 CFU g^{-1}) were not detected in the minimally processed pineapple samples. This evidences the efficient action of the organic chlorine used in the sanitization of both the fruits and the utensils employed in this study and also the use of good practices applied throughout the processing. In Brazil, there is no specific legislation for minimally processed fruits and vegetables regarding microbiological standards; however, there is legislation for fresh prepared product (peeled and sliced), sanitized, refrigerated, or fruits ready for consumption that establishes the presence of fecal coliforms of up to $5x10^2$ CFU g^{-1} and absence of *Sallmonella sp.* in 25 grams of sample (Brasil, 2001; Basaglia et al., 2021).

Figure 2 shows the growth of molds and yeasts found on the minimally processed pineapple samples coated with tragacanth gum and different concentrations of melaleuca essential oil, stored at 5 ±1°C for 12 days.

As can be observed, mold and yeast growth occurred over the days of storage on the minimally processed pineapples. The treatments containing the coatings with tragacanth gum and melaleuca essential oil showed less mold and yeast growth at 12 days of refrigerated storage, differing significantly from the control treatment (uncoated). Treatment T2 (0.5% tragacanth gum and 0.2% melaleuca essential oil) showed the lowest mold and yeast growth and also differed significantly from the other treatments at the end of the study.

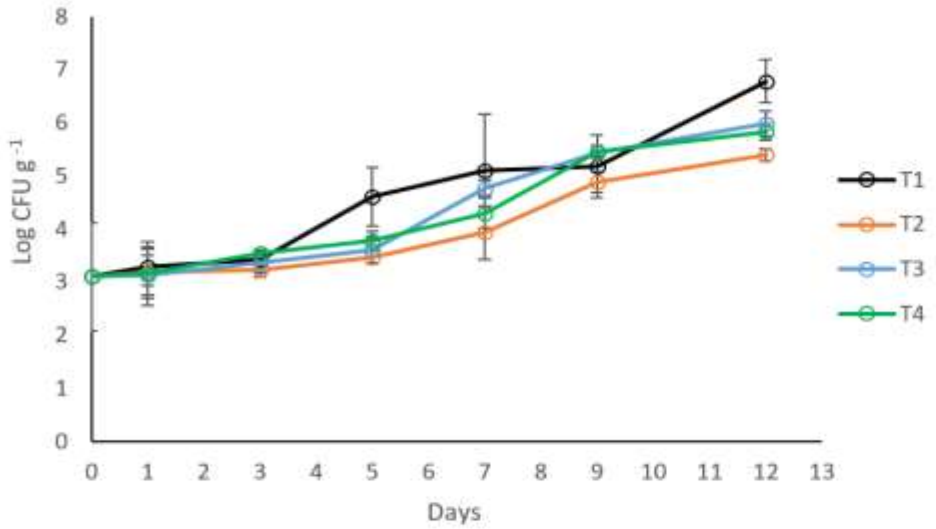

Figure 2. Mold and yeast growth on minimally processed pineapples with tragacanth gum and different concentrations of melaleuca essential oil.

Cheng and Shao (2011) and Shao, Wang, Xu, and Cheng (2013) demonstrated that melaleuca essential oil showed antifungal activity on strawberries. Yue et al. (2020) found that the use of encapsulated melaleuca essential oil showed antifungal activity on cherry tomatoes. These works agree with the present study that found a reduction in the growth speed of molds and yeasts when melaleuca essential oil and tragacanth gum were added to the treatments. Basaglia et al. (2021) also found that the use of cinnamon essential oil at the concentration of 0.5 and 1% was effective in slowing mold and yeast growth in minimally processed pineapple.

In fact, melaleuca essential oil impaired ergosterol component of the cell membranes of molds, synthesis and induced cell membrane rupture (Chidi, Bouhoudan, & Khaddor, 2020). In the other hand, Cox et al. (2001) interprets the action of essential oil by the penetration of terpinene-4-ol through the cell wall and the structures of the cell membrane leading to cell death.

Emamifar and Bavaisi (2017) when studying the addition of tragacanth gum as coatings on strawberries, observed that the use of 0.6% of this gum slowed mold growth (2.08 log CFU g^{-1}) compared to other concentrations used in 12 days of storage. In this study, despite using tragacanth gum (0.5%) together with melaleuca essential oil, more mold growth was observed at the end of 12 days of storage for both treatments used.

Conclusion

The use of tragacanth gum and melaleuca essential oil was efficient in reducing mass loss and total soluble solids content.

Regarding pH and microbiological analysis, T2 (0.5 tragacanth gum and 0.2% melaleuca essential oil) showed the best results.

T2 sample also showed better texture parameters, as it was the sample that maintained better firmness throughout the experiment.

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