

Physicochemical evaluation of coated and interleaved cheeses with films of ripe banana peel and starch enriched with extract of loquat leaves



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ABSTRACT

This study aimed to evaluate the effect of edible coating and films based on ripe banana peel flour and cornstarch, with and without extract of loquat (*Eriobotrya japonica*) leaves, in sliced and cut mozzarella cheese during 28 days of storage at 4 °C. During storage, weight loss was observed across all treatments. Increase in pH and reduction in titratable acidity during storage were verified for all cheeses, although milder in those treated with edible formulations. The cheeses submitted to coating or film were less moist than the others. Cheeses treated with the formulation containing the extract were less light and had more intense yellowish coloring. The hardness of the evaluated cheeses did not change during storage. Therefore, the use of edible films and coatings of ripe banana peel flour and loquat leaf extract has potential as an alternative material for the conservation of cheeses.

1. Introduction

Perishable foods are traditionally conserved by refrigeration in petroleum-derived packaging, mainly plastics. The disadvantage of this packaging is related to its inadequate disposal in the environment: due to its resistance to degradation, it can generate serious environmental problems (Ma et al., 2017; Muscat et al., 2012). Several studies have been done on the partial or total replacement of these materials by edible films and coatings in recent years. These materials are one of the most economical and sustainable forms of food conservation, due to the use of renewable, biodegradable, and low-cost raw materials, such as fruit residues (Caetano et al., 2018; Cazón et al., 2017; Dehghani et al., 2018; Piñeros-Hernandez et al., 2017).

The difference between edible films and coatings is in how they are applied to food. Coatings are in liquid form and applied to food by immersion, spraying, or other methods, forming a coating around the product after drying. Films are formed as thin membranes after solvent evaporation, and applied between food components, on food surfaces, or sealing the food (Costa et al., 2018; Otoni et al., 2017). The application type depends on the food and storage conditions (Costa et al., 2018).

Edible films and coatings prepared with agri-food residues, such as banana peels, have potential use in the food industry due to their polymeric composition (Arquelau et al., 2019; Silva et al., 2020a,b). Furthermore, the addition of plant extracts can improve the functionality of these materials, mainly due to the presence of phenolics and antioxi-

dant and antimicrobial agents, which can contribute to a longer period of food conservation (Kontogianni et al., 2022; Piñeros-Hernandez et al., 2017; Silva et al., 2020b,c). Extracts of loquat (*Eriobotrya japonica* Lindl.) leaves are sources of these substances (Aziz et al., 2017; Delfanian et al., 2015; Silva et al., 2020c). Silva et al. (2020c) studied the loquat leaf extract, which showed antioxidant and antimicrobial activities, and 49 compounds were identified, including phenolic acids, carotenoid, flavonoids, phytosterol, and terpenes. In another study by these authors (Silva et al., 2020b), this extract was incorporated into edible films of ripe banana peel and starch, which showed antioxidant activity and the presence of phenolic compounds. Due to these characteristics, this extract was chosen to be used as an additive in films and coatings for cheese.

Among perishable foods, there are cheeses that have better conservation with edible films and coatings. Cheese is an ancient food widely consumed throughout the world, with different types and flavors. It is composed mainly of protein, lipids, carbohydrates, minerals, and water, being an appropriate medium for the growth of contaminant microorganisms that can cause unpleasant flavors and odors. Biochemical, physicochemical, and microbiological changes occur during its shelf life, which affects its composition, texture, color, and flavor. Therefore, the use of packaging is important to preserve the desirable characteristics of cheese and ensure food safety. Regarding sustainability, replacing non-degradable plastic packaging with edible films and coatings can be a good alternative for cheese (Cerqueira et al., 2010; Costa et al., 2018; Silva, 2016; Youssef et al., 2019; Zhong et al., 2014).

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The type of packaging can interfere with the physicochemical, sensorial, and microbiological characteristics of cheese, conservation, and consumer acceptability, which is why studies relating to the different packaging materials for each type of cheese are needed (Nogueira et al., 2021).

Studies using different edible coatings in different types of cheese were found. However, none of them used sliced and interleaved mozzarella cheese with edible films. Bonilla and Sobral (2019) evaluated sliced *prato* cheese, covered on both surfaces with films of chitosan, gelatin, and boldo extract. Cruz-Diaz et al. (2019) alternately stacked Manchego cheese slices with edible films from whey protein concentrate. Kontogianni et al. (2022) applied whey protein films incorporated with rosemary and sage infusion on the surface of soft cheese. Youssef et al. (2019) prepared a mixture of chitosan and polyvinyl alcohol loaded with titanium dioxide nanoparticles, which was then brushed onto the surface of *ras* cheeses, a hard cheese produced in Egypt. Zhong et al. (2014) tested four different coating methods (dipping, enrobing, spraying, and electrostatic spraying) and three types of filmogenic solution (chitosan, sodium alginate, and soy protein isolate) with mozzarella cheese. Mongolian cheeses were coated with starch–chitosan coating by brushing (Mei et al., 2013). The usage of edible coating on cheeses can manage the nutritional value, color and flavor, and has the advantage of being consumed together with the cheese, avoiding the generation of waste (Kontogianni et al., 2022).

Mozzarella cheese was chosen as a sample for film and coating application because it is one of the most produced and consumed cheeses in Brazil, equivalent to 65% of Brazilian production (Soares & Rodrigues, 2019). Furthermore, it exists in the market both in pieces and sliced and interleaved with plastic, thus being possible to evaluate its characteristics with the use of the coating and film, respectively.

The objective of this work was to coat pieces of mozzarella cheese with filmogenic solutions and to cover slices of mozzarella cheese with films, both based on ripe banana peel flour with and without loquat leaves extract. Furthermore, physicochemical characteristics during the shelf life of the cheeses were evaluated.

2. Materials and methods

2.1. Sampling

The peels of the *prato* banana (*Musa acuminata* × *Musa balbisiana*, AAB), at stage 7 of ripening, were collected in February 2018 (Belo Horizonte, Minas Gerais, Brazil). The peels were immersed in 0.5% (w/v) anhydrous citric acid solution, ground in a blender (Siemens, LS-04, Brusque, SC, Brazil), frozen, thawed, drained, and dehydrated in a ventilated oven (320-SE, Fanem, São Paulo, SP, Brazil) at 60 °C for 24 h. The dried peels were ground in the blender to pass through a 32-mesh screen (Silva et al., 2020a).

The loquat leaves (*Eriobotrya japonica* Lindl.) were collected in December 2019, in Belo Horizonte, Minas Gerais, Brazil. Then, they were washed with tap water, dried with absorbent paper and dehydrated in the oven at 40 °C for 46 h. Subsequently, the dried leaves were packed in plastic bags for storage at −18 °C until the moment of extract preparation.

Cornstarch (Maizena®, Unilever Brasil Industrial Ltda., Garanhuns, PE, Brazil), the mozzarella cheese in pieces (Cristaulat®, Cristaulat Laticínios, Belo Horizonte, MG, Brazil), and sliced and interleaved mozzarella cheese (Latelli®, Laticínios Exterkoetter Eireli, São Bonifácio, SC, Brazil) were purchased in markets in Belo Horizonte and Contagem, MG, Brazil. The cheeses were stored in a refrigerator (8 °C) until use.

2.2. Preparation of loquat leaf extract

For the extraction, the method described by Silva et al. (2020b) was used, where 10 g of dehydrated, crushed and sieved (16-mesh) loquat

leaves were mixed with 100 mL 50% ethanol, in vials capped and covered with aluminum foil. This mixture was sonicated using a digital ultrasonic washer (Sanders Medical, SoniClean 2, Santa Rita do Sapucaí, MG, Brazil) twice, for 20 min, with a 10 min interval between them. Then, filtration was carried out with qualitative filter paper, and the extract was evaporated in a rotary evaporator (Büchi, R-215, Valinhos, SP, Brazil) at 45 °C until alcohol removal.

2.3. Preparation of filmogenic solution

The formulations for the coating and for obtaining the films were prepared according to Silva et al. (2020b). The filmogenic solution was obtained by mixing 12 g of banana peel flour, 4.2 g of cornstarch, and 300 mL of distilled water, heated at 90 °C in a water bath for 30 min, and homogenized (Ultra Stirrer, Ultra 80-II, São Paulo, SP, Brazil) at 18,000 rpm for 5 min. Then, 2.28 g of glycerol were added and returned to heating (90 °C) for another 30 min. This preparation was done three times to obtain the amount of filmogenic solution necessary for the preparation of the films and the application on the cheeses. The samples were filtered using a gauze pad and the three preparations were mixed, obtaining the standard filmogenic solution (700 g). Part of this solution (350 g) was mixed with 14 g of loquat leaf extract (equivalent to 4%), obtaining the filmogenic solution with the extract.

2.4. Preparation of edible films

Two types of edible films were prepared by casting technique, one obtained from the standard filmogenic solution and the other from the filmogenic solution with loquat leaf extract. Therefore, production was exactly as described in the previous section. Each 180 g of these filmogenic solutions was cast onto polypropylene trays (215 × 295 mm) and dried at 40 °C for 24 h.

2.5. Edible coating application

Mozzarella cheese (3 kg) was cut into 20 × 20 × 20 mm pieces (approximately 6 g). They were then separated into three groups of 80 pieces each. One group was coated by immersion for 60 s in the standard filmogenic solution (CS), another in the filmogenic solution with extract (CE), and the last group in distilled water (control - CC), with the residual coating allowed to drip off. After, the cheeses from the three treatments were left overnight at 8 °C in a Bio-Oxygen Demand (BOD) incubator (SL-224, Solab, Piracicaba, SP, Brazil). Subsequently, five pieces were placed in polyethylene packaging identified according to treatment and analysis time, in triplicate, and stored for up to 28 days at 4 ± 1 °C in BOD.

2.6. Edible films application

Sliced mozzarella cheese was divided into smaller slices (30 × 30 × 2 mm, approximately 2 g), and edible films were placed on the surface of these samples, in the same way as the commercial product containing plastic film, i.e., as slice separator films. These cheeses and films were alternately stacked to form sets with 6 cheese slices and 5 separator films. For the cheese without film, only the slices of cheese were stacked. For this test, four treatments were carried out in triplicate: sliced cheese without film (WF), sliced cheese with commercial film (CF), sliced cheese with a standard film of banana peel flour (SF), and sliced cheese with the film containing the loquat leaf extract (EF). Then, the samples were placed in polyethylene packaging, identified according to treatment and time of analysis, and stored at 4 ± 1 °C in the BOD for up to 28 days.

2.7. Cheese analysis

The cheeses of all treatments were analyzed for moisture, colorimetric parameters, weight loss, hardness, pH, and titratable acidity on days

1, 7, 14, 21, and 28 of refrigerated storage. Except for the analysis of weight loss, commercial and edible films were removed from the surfaces of the sliced cheeses on each analysis day. Moisture was determined by drying in the oven at 105 °C for 24 h, in duplicate (Mei et al., 2013). The colorimetric parameters L* (lightness), a* (red to green), and b* (yellow to blue) of the cheeses were evaluated in a spectrophotometer (Konica Minolta, CM-2300d, Tokyo, Japan) equipped with the CIELab scale. From the values of a* and b*, the parameters h* (hue) and C* (chroma or color intensity) were calculated (Arquelau et al., 2019). Six measurements were done for the sliced cheeses and five for the cheeses in pieces for each treatment, and the average measurement was calculated.

The evaluation of the weight loss percentage involved weighing the samples of each treatment, identified with time 5 (28th day), at the beginning of the experiment and during the other storage times, and subsequently calculating the weight loss using Eq. (1) (Molina-Hernández et al., 2020):

$$\text{Weight loss (\%)} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100 \quad (1)$$

Hardness was measured using a texture analyzer (TAXT2i, Stable Micro Systems, Surrey, UK), in rupture mode, with a 5 kg load cell for equipment calibration and a 4 mm diameter cylindrical probe. For the cheeses in pieces, the probe was placed at a distance of 20 mm from the base, and for those sliced at 5 mm, which moved perpendicularly to the surface of the cheese at a constant speed of 0.4 mm.s⁻¹ (Zhong et al., 2014) and a penetration depth of 15 mm and 5 mm, respectively. Five and four measurements were taken, respectively, for each treatment. The force x distance curve was generated using the Texture Expert Exceed software (Stable Micro Systems) to obtain the maximum force (N), equivalent to the hardness of the cheeses.

The preparation of the samples for the analysis of pH and titratable acidity (TA) was done as described by Pierro et al. (2011), with modifications. The cheeses were weighed (about 10 g), mixed with 50 mL of distilled water, and crushed with a mixer. Then, 40 mL of distilled water were added and heated at 40 °C, with agitation for 15 min. The samples were centrifuged (Jouan BR4) at 1792 x g for 10 min and filtered with filter paper. The supernatants were submitted to direct pH reading using a digital pH meter (Bante Instruments, 920, China). Subsequently, 25 mL of each supernatant was added in erlenmeyers for TA analysis with 0.1 N NaOH. TA (% w/w) was calculated according to Eq. (2), where V is the volume of NaOH (mL), C is the concentration of NaOH (N), and W is the weight of the cheese (g):

$$\text{TA} = \frac{V \times C}{W} \times 100 \quad (2)$$

2.8. Statistical analysis

Results were expressed with means of the replicates and their respective standard deviations. Data were analyzed using a split-plot design, with time and treatment as factors. The adjustment for multiple comparisons was made by the Sidak test, at a 5% significance level, using the software SPSS 15.0 for Windows (SPSS Inc., Chicago, IL, USA).

3. Results and discussion

3.1. Coated cheese

Perishable foods tend to lose weight throughout storage, mainly due to moisture loss (Wang et al., 2019). The behavior of the coated cheeses in pieces in relation to weight loss is shown in Fig. 1.

Weight loss increased for all treatments during storage time. For CC, it ranged from 0.20 to 0.73% (w/w); for CS, 0.13 to 0.67% (w/w); and for CE, from 0.13 to 0.45% (w/w). In general, CS and CE cheeses showed better performance in relation to weight loss when compared to the control cheese; however, there was no significant difference ($P > 0.05$) between cheeses coated with standard formulation and the control, on all

Table 1

Physicochemical characteristics of cheeses in pieces: control (CC), coated standard (CS), and coated with loquat leaf extract (CE) during storage days.

| Analysis | Days | Treatment | | |
|------------------------|------|----------------------------|-----------------------------|----------------------------|
| | | CC | CS | CE |
| pH | 1 | 5.64 ± 0.01 ^{ac} | 5.61 ± 0.03 ^{abc} | 5.58 ± 0.05 ^{bd} |
| | 7 | 5.64 ± 0.02 ^c | 5.63 ± 0.02 ^c | 5.62 ± 0.02 ^c |
| | 14 | 5.63 ± 0.02 ^c | 5.61 ± 0.02 ^c | 5.63 ± 0.02 ^c |
| | 21 | 5.71 ± 0.02 ^b | 5.70 ± 0.02 ^b | 5.70 ± 0.02 ^b |
| | 28 | 5.91 ± 0.05 ^a | 5.89 ± 0.05 ^a | 5.82 ± 0.05 ^a |
| Titratable acidity (%) | 1 | 1.73 ± 0.10 ^c | 1.76 ± 0.03 ^b | 1.69 ± 0.04 ^c |
| | 7 | 1.91 ± 0.06 ^a | 1.94 ± 0.06 ^a | 1.83 ± 0.03 ^{bb} |
| | 14 | 1.84 ± 0.03 ^{bb} | 1.91 ± 0.02 ^{na} | 1.89 ± 0.04 ^a |
| | 21 | 1.59 ± 0.06 ^{bd} | 1.57 ± 0.05 ^{bc} | 1.67 ± 0.06 ^{ac} |
| | 28 | 1.51 ± 0.08 ^{bd} | 1.57 ± 0.04 ^{bc} | 1.66 ± 0.06 ^{ac} |
| Moisture (%) | 1 | 40.85 ± 0.41 ^{ab} | 40.11 ± 0.39 ^b | 40.04 ± 0.19 ^b |
| | 7 | 41.80 ± 0.29 ^a | 40.65 ± 0.33 ^b | 40.48 ± 0.40 ^b |
| | 14 | 41.77 ± 0.16 ^a | 40.42 ± 0.24 ^b | 40.04 ± 0.20 ^b |
| | 21 | 41.81 ± 0.43 ^a | 40.35 ± 0.62 ^b | 40.34 ± 0.31 ^b |
| | 28 | 41.67 ± 0.20 ^a | 40.31 ± 0.44 ^b | 40.47 ± 0.28 ^b |
| Lightness (L*) | 1 | 76.18 ± 4.33 | 74.94 ± 4.93 | 74.31 ± 4.30 |
| | 7 | 76.38 ± 1.42 ^a | 74.97 ± 2.08 ^{ab} | 74.49 ± 1.04 ^b |
| | 14 | 77.78 ± 1.69 ^a | 76.73 ± 1.34 ^a | 74.87 ± 1.52 ^b |
| | 21 | 77.36 ± 1.43 ^a | 76.63 ± 1.63 ^{ab} | 75.21 ± 1.68 ^b |
| | 28 | 76.98 ± 1.02 ^a | 75.70 ± 0.96 ^b | 74.08 ± 1.33 ^c |
| Hue (h°) | 1 | 89.61 ± 1.30 ^{AB} | 89.07 ± 1.07 ^{AB} | 89.22 ± 0.93 ^A |
| | 7 | 90.10 ± 0.26 ^A | 89.50 ± 0.39 ^A | 88.86 ± 0.79 ^A |
| | 14 | 89.60 ± 0.29 ^a | 88.65 ± 0.42 ^{bb} | 88.73 ± 0.59 ^a |
| | 21 | 89.50 ± 0.43 ^{ab} | 88.78 ± 0.62 ^{abc} | 87.84 ± 1.33 ^{bb} |
| | 28 | 88.91 ± 0.62 ^{ab} | 87.99 ± 0.62 ^{bc} | 87.21 ± 1.37 ^{bb} |
| Chroma (C*) | 1 | 33.32 ± 1.48 ^{ba} | 35.47 ± 1.92 ^a | 35.36 ± 1.71 ^a |
| | 7 | 31.09 ± 0.87 ^{bb} | 31.67 ± 0.90 ^{bb} | 33.08 ± 1.51 ^{ab} |
| | 14 | 30.99 ± 0.79 ^{bb} | 31.71 ± 0.74 ^{bb} | 32.88 ± 1.09 ^{ab} |
| | 21 | 30.59 ± 0.94 ^{bb} | 31.37 ± 0.84 ^{bb} | 32.89 ± 0.86 ^{ab} |
| | 28 | 29.23 ± 0.66 ^{bc} | 29.25 ± 1.61 ^{bc} | 31.78 ± 1.49 ^{ab} |
| Hardness (N) | 1 | 5.261 ± 0.011 | 5.265 ± 0.011 ^{AB} | 5.257 ± 0.012 |
| | 7 | 5.259 ± 0.005 | 5.261 ± 0.010 ^B | 5.258 ± 0.005 |
| | 14 | 5.268 ± 0.011 | 5.272 ± 0.009 ^A | 5.268 ± 0.010 |
| | 21 | 5.264 ± 0.010 | 5.268 ± 0.011 ^{AB} | 5.266 ± 0.012 |
| | 28 | 5.260 ± 0.011 | 5.263 ± 0.011 ^B | 5.262 ± 0.009 |

Mean values ± standard deviation. Different lowercase letters in the same row indicate significant differences ($P < 0.05$) between treatments for the same storage time using the Sidak test. Different capital letters in the same column indicate significant differences ($P < 0.05$) between times for the same treatment using the Sidak test. The absence of letters indicates that the effect was not significant ($P > 0.05$).

the days evaluated. Furthermore, CE presented a lower percentage loss (0.35 and 0.45%, respectively) on days 21 and 28, differing statistically ($P < 0.05$) from CS (0.54 and 0.67% cheeses, respectively) and CC (0.65 and 0.73%, respectively). This may be due to the lower water vapor permeability of the film containing extract (Silva et al., 2020b), which minimized the transfer of water from the cheese to the environment.

Other authors obtained similar behaviors for cheddar cheese coated with whey protein isolate nanofibers and carvacrol (Wang et al., 2019), *coalho* cheese coated with an alginate/lysozyme nano-laminate coating (Medeiros et al., 2014), and Mongolian cheese coated with water chestnut starch-chitosan formulation (Mei et al., 2013). On the other hand, Zhong et al. (2014) observed that the weight loss of uncoated mozzarella cheese was lower than the cheese coated by electrostatic spraying with soy protein isolate.

The pH values for cheese samples in pieces remained constant until the 14th day of storage, with no significant difference ($P > 0.05$) between treatments, except for CE on the first day of analysis, whose pH was lower ($P < 0.05$) than the control (Table 1). From day 21 onwards, there was an increase in pH, probably due to microbial contamination, because of the storage temperature (4 °C) and the high moisture of the mozzarella, around 40%. This is because visually, on day 21 of the study, small white dots were observed, and on day 28, greenish spots also appeared on the surface of some pieces of cheese, in all three treatments, indicating possible contamination by yeasts and fungi. The filmogenic

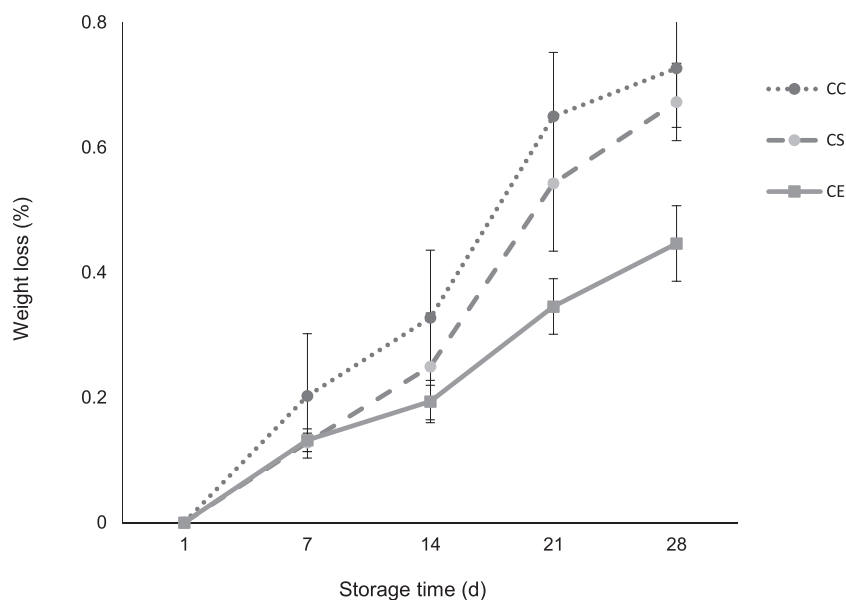


Fig. 1. Weight loss (%) of cheese in pieces during the storage. The error bars indicate the standard deviation of the mean ($n = 4$). CC: control cheese; CS: coated cheese with standard filmogenic solution; CE: coated cheese with filmogenic solution with loquat leaf extract.

solutions presented pH around 4.8 and, therefore, it is believed that there is no influence on the pH of coated cheeses, since they are close to those of the control cheese.

High pH during storage was also observed in other studies with coated cheeses. Medeiros et al. (2014) found that *coalho* cheese stored at 8 °C and coated with alginate/lysozyme nano-laminate increased in pH from day 12. Martins et al. (2010) observed an increase in pH from the 7th day of storage at 4 °C in ricotta cheese coated with a formulation made of galactomannans from *Gleditsia triacanthos* and nisin.

The values of titratable acidity increased until day 7 for CC and CS and until day 14 for CE, then reduced (Table 1), corroborating the pH result. The decrease in acidity was less intense for CE. Medeiros et al. (2014) also found a smaller reduction for coated *coalho* cheese when compared to uncoated cheese. Silva (2016) observed that the titratable acidity of mozzarella cheese remained constant for 60 days at 7 °C.

The low pH values, around 5, and the presence of organic acids and other compounds of microbial origin in cheeses hinder the growth of pathogens (Nunez et al., 2020). Therefore, the application of edible coatings that reduce the pH of the food surface can minimize microbial proliferation (Guilbert & Gontard, 2005). Thus, the coating with the formulation containing the loquat leaf extract caused a greater acidity to the cheese, which makes it a better choice for this purpose.

Mozzarella cheeses presented moisture content at around 40%, being classified as medium moisture (36.0 to 45.9%), according to Brazilian legislation (Brasil, 1996). As the weight loss of cheeses was very small, less than 1%, no large variation in moisture was observed during storage, especially for coated cheeses ($P > 0.05$), which presented lower moisture than the control at all times evaluated. This may be due to the immersion of the control cheese in distilled water, which provided a higher moisture content in this sample. Soleimani-Rambod et al. (2018) also verified that cheddar cheese coated with flaxseed mucilage or xanthan gum presented lower moisture than the control, at 60 and 90 days of storage (8 °C). According to these authors, coatings with high hydrophilic properties cause greater water absorption, leading to a reduction in moisture content in coated food.

The colorimetric analysis is shown in Table 1. Lightness, which defines the sample between the dark (0) and white (100) colors, did not differ significantly ($P > 0.05$) between the periods for each treatment, and the values for all samples lean towards a lighter color, which is desirable for mozzarella cheese. On the first day of analysis, the cheeses did not differ in lightness ($P > 0.05$). However, on the seventh day, CE

became less clear than the control cheese, while such behavior only occurred on day 28 for CS.

Contrary to what was obtained, Zhong et al. (2014) found that mozzarella cheeses coated with sodium alginate were lighter ($L^* = 80.3$ to 81.7) than the control cheese ($L^* = 76.8$), and that after 14 days of storage, all samples became darker ($L^* = 62.6$ to 75.4 and L^* control = 57.7). This variation between studies depends on the characteristics of the milk used in the production of the cheese as well as the coloring of the coating solution.

The hue values of treated cheeses are between 87 and 90, that is, they are close to the angle of 90°, indicative of yellow coloration (Konica Minolta, 2015), which comes from the β -carotenes existing in milk (Silva, 2016). The hue of the samples decreased slightly during storage, with a greater reduction for coated cheeses from day 14 onwards.

Chroma is related to color intensity. All cheeses showed a reduction of this parameter from the 7th day of storage, remaining constant until the end for CE. For CC and CS, there was another significant reduction ($P < 0.05$) on day 28. However, CE was the one that exhibited the highest color intensity. According to a previous study by our group (Silva et al., 2020b), the film with 4% extract presented a higher chroma value, so some compounds present in the extract may have been transferred to CE. Therefore, these results indicate that the coating containing loquat leaf extract interfered the most with the color of the cheese.

Silva (2016) investigated the colorimetric parameters of mozzarella cheese without application of a coating over 60 days of storage at 7 °C, and verified a reduction in lightness (from 60.39 to 53.98) and chroma (from 18.29 to 16.46), while the hue varied little (87.66 - 86.74). The lightness and chroma were lower than those of the cheeses of the present study, indicating that the type of milk has a strong influence on these parameters.

The texture of cheese is mainly influenced by the distribution of fat globules in the protein matrix (Lobato-Calleros et al., 2007). To assess any change in this characteristic, the most evaluated parameter is hardness, which is the force used to cause deformation, and is related to proteolysis and cheese water content (Molina-Hernández et al., 2020). The hardness of the cheeses remained practically constant during storage, with little differentiation for CS ($P < 0.05$), and no significant difference between storage days for CC and CE. Moreover, the values between treatments did not differ either.

Hardness is correlated with weight and moisture loss, and, in this study, the variation of these three parameters was small. Although CS and CE presented lower moisture in relation to CC, the hardness did

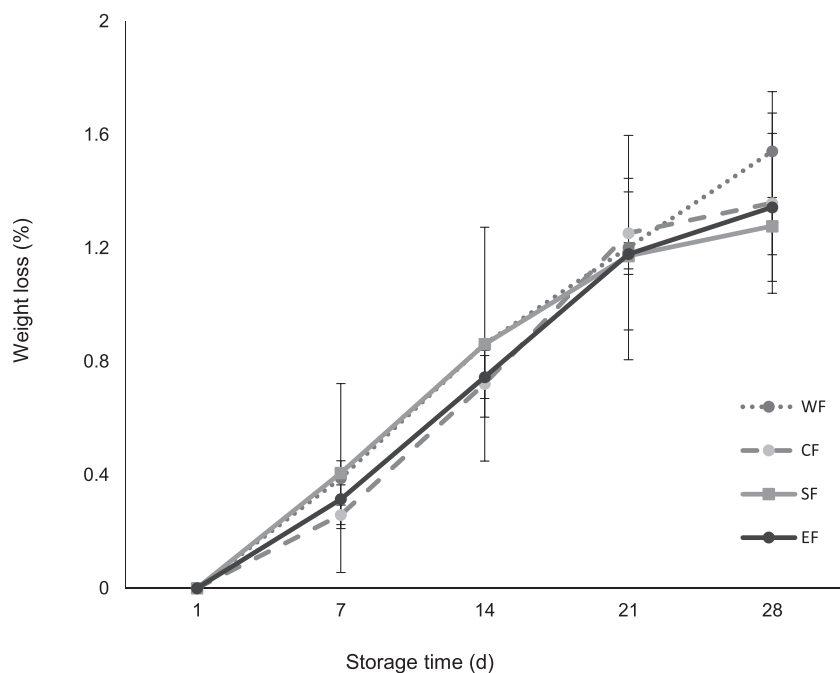


Fig. 2. Weight loss (%) of sliced cheeses during the storage. The error bars indicate the standard deviation of the mean ($n = 3$). WF: sliced cheese without film; CF: sliced cheese with commercial film; SF: sliced cheese with standard film of banana peel flour; EF: sliced cheese with the film containing the loquat leaf extract.

not change. Therefore, the coating did not influence the hardness of mozzarella cheese in pieces, so the cheeses, including the control, maintained the characteristic texture of mozzarella during the 28 days of analysis, which is desirable. Contrary to what was reported in this study, [Zhong et al. \(2014\)](#) observed increased hardness during storage for 14 days of control mozzarella cheese and coated mozzarella cheese with different formulations due to water evaporation. Moreover, most of these samples had lower hardness values than uncoated cheese. According to these authors, the application of the coating hydrated the cheeses, causing this reduction.

3.2. Sliced and interleaved cheeses

Weight loss of sliced cheeses ([Fig. 2](#)) increased during storage. For WF, it ranged from 0.39 to 1.54%; for CF, from 0.24 to 1.36%; for SF, from 0.41 to 1.28%; and for EF, from 0.31 to 1.34%, with no significant difference between treatments ($P > 0.05$) on all days evaluated. Therefore, both commercial and edible films did not affect weight loss when compared to cheeses without film, differing from the behavior observed for coated cheeses.

The pH values of sliced cheeses ([Table 2](#)) increased for all treatments during storage, being higher in WF and CF cheeses on most days analyzed. Therefore, the edible films were more protective of the cheeses, minimizing the pH elevation. This was also observed by acidity analysis ([Table 2](#)), whose values decreased from the 14th day for all samples, but for cheeses with edible films, the acidity was slightly higher ($P < 0.05$) when compared to WF and CF, on most days. This data is consistent with the result for cheeses in pieces. This behavior may be due to the probable microbial contamination, as on day 28 the cheeses of all treatments presented white spots on the surface and the sides of the slices, and on some slices of WF and CF cheeses, greenish spots were observed, probably of fungal colonies. Thus, by visual evaluation, it may be that the edible films (SF and EF) exerted some antimicrobial effect.

The pH increase was also observed by [Bonilla and Sobral \(2019\)](#) from the 3rd day of storage onwards, in sliced *prato* cheese covered with gelatin-chitosan-boldo extract edible film stored at 4 °C.

Regarding moisture, the same behavior observed for cheeses in pieces was verified in sliced cheeses. There was little variation during

the 28 days of analysis (37.94 to 42.28%), differing significantly ($P < 0.05$) only in the samples of days 1 and 21, for most cheeses. In addition, cheeses with edible films showed lower moisture content than WF and CF. Edible films may have absorbed water from cheeses during storage, due to their hydrophilicity. This can be advantageous because lower moisture in food can minimize microbial contamination. Different from the result found in this study, [Bonilla and Sobral \(2019\)](#) observed that sliced *prato* cheeses covered with chitosan-gelatin-boldo extract film, stored at 4 °C for 10 days, presented higher moisture content than the control, possibly due to the low permeability to water vapor of this type of film.

In some types of cheese, the high reduction in moisture content can increase hardness, impairing quality ([Costa et al., 2018](#)). The presence of water molecules in cheese causes the weakening of the protein matrix, resulting in unfirm cheese, however, when this water is reduced, this process is minimized, causing increased hardness ([Mohammed et al., 2019](#)). As hardness remained constant during storage, and there was no significant difference between the treatments ($P > 0.05$) ([Table 2](#)), the lower moisture obtained in SF and EF cheeses did not affect this quality parameter. This result was similar to those of cheeses in pieces.

The lightness values of WF and CF increased over storage days ([Table 2](#)), while cheeses with edible films showed an initial increase with subsequent reduction, from day 21 for SF and day 14 for EF. In addition, these cheeses were darker than the others, during the whole period. [Bonilla and Sobral \(2019\)](#) observed little variation of L^* (84.6 to 86.6) in both control sliced *prato* cheeses and in those containing edible films. The short storage time (10 days) used in the study of these authors may not have been enough to cause a greater change in lightness.

The hue values of sliced cheeses are close to 90°, as observed for cheeses in pieces, indicating that they are yellow, with little variation during storage. The EF cheese had the lowest hue value, especially from the 14th day, differing significantly ($P < 0.05$) from the others, leaning towards a darker yellow color.

As for chroma, it increased after the first day for cheeses with edible films, with little change between the 7th and 28th days. The FFE cheese, from the 14th day, exhibited the highest chroma values, corroborating the tonality data, presenting a more intense yellow coloration.

Table 2

Physicochemical characteristics of sliced cheeses without film (WF), with commercial film (CF), with standard film of banana peel flour (SF), and with film containing loquat leaf extract (EF) during storage days.

| Analysis | Days | Treatment | | | |
|------------------------|------|-----------------------------|----------------------------|------------------------------|----------------------------|
| | | WF | CF | SF | EF |
| pH | 1 | 5.79 ± 0.04 ^{aC} | 5.81 ± 0.05 ^{aC} | 5.70 ± 0.07 ^{bC} | 5.67 ± 0.03 ^{bD} |
| | 7 | 5.69 ± 0.01 ^{abD} | 5.71 ± 0.05 ^{aD} | 5.60 ± 0.02 ^{cD} | 5.65 ± 0.03 ^{bD} |
| | 14 | 5.81 ± 0.03 ^{aC} | 5.79 ± 0.02 ^{aC} | 5.69 ± 0.01 ^{cC} | 5.74 ± 0.02 ^{bC} |
| | 21 | 5.86 ± 0.02 ^B | 5.86 ± 0.03 ^B | 5.84 ± 0.02 ^B | 5.83 ± 0.03 ^B |
| | 28 | 6.21 ± 0.07 ^{aA} | 6.09 ± 0.03 ^{bA} | 5.95 ± 0.03 ^{cA} | 5.93 ± 0.04 ^{cA} |
| Titratable acidity (%) | 1 | 2.01 ± 0.04 ^{BA} | 1.96 ± 0.21 ^{BA} | 2.26 ± 0.04 ^{AA} | 2.25 ± 0.08 ^{AA} |
| | 7 | 2.00 ± 0.05 ^{CA} | 1.99 ± 0.06 ^{CA} | 2.34 ± 0.11 ^{AA} | 2.14 ± 0.08 ^{BA} |
| | 14 | 1.78 ± 0.07 ^{BB} | 2.03 ± 0.03 ^{AA} | 2.06 ± 0.07 ^{AB} | 2.09 ± 0.08 ^{AB} |
| | 21 | 1.55 ± 0.07 ^{BC} | 1.50 ± 0.05 ^{BB} | 1.79 ± 0.12 ^{AC} | 1.69 ± 0.04 ^{AC} |
| | 28 | 1.19 ± 0.05 ^{DD} | 1.44 ± 0.13 ^{EB} | 1.73 ± 0.06 ^{AC} | 1.61 ± 0.06 ^{BC} |
| Moisture (%) | 1 | 41.22 ± 0.58 ^{BB} | 42.08 ± 0.27 ^{AA} | 37.84 ± 0.07 ^{DB} | 39.10 ± 0.33 ^{CA} |
| | 7 | 41.55 ± 1.10 ^{AB} | 41.67 ± 0.24 ^{AB} | 38.99 ± 1.00 ^{BAB} | 39.01 ± 1.45 ^{BA} |
| | 14 | 41.31 ± 0.99 ^{AB} | 40.61 ± 1.15 ^{AB} | 39.02 ± 0.44 ^{BAB} | 39.17 ± 0.46 ^{BA} |
| | 21 | 42.28 ± 0.39 ^{AA} | 41.22 ± 0.79 ^{AB} | 39.38 ± 0.10 ^{BA} | 39.23 ± 0.68 ^{BA} |
| | 28 | 41.80 ± 0.48 ^{AB} | 40.94 ± 0.57 ^{AB} | 38.81 ± 0.44 ^{BAB} | 38.99 ± 1.36 ^{BA} |
| Lightness (L*) | 1 | 72.88 ± 1.53 ^{bC} | 74.96 ± 0.68 ^{aC} | 70.81 ± 1.86 ^{CD} | 71.11 ± 2.20 ^{CD} |
| | 7 | 79.89 ± 1.02 ^{AB} | 78.44 ± 0.96 ^{BB} | 77.68 ± 1.50 ^{bCAB} | 76.74 ± 1.44 ^{EB} |
| | 14 | 79.76 ± 0.82 ^{AB} | 80.48 ± 1.06 ^{AA} | 77.91 ± 0.81 ^{BB} | 78.04 ± 1.43 ^{BA} |
| | 21 | 81.48 ± 1.06 ^{AA} | 80.24 ± 1.86 ^{BA} | 78.84 ± 0.70 ^{CA} | 75.99 ± 1.55 ^{DB} |
| | 28 | 81.31 ± 0.61 ^{AA} | 78.76 ± 1.54 ^{BB} | 74.09 ± 1.50 ^{CC} | 73.53 ± 2.06 ^{CC} |
| Hue (h°) | 1 | 87.12 ± 0.40 ^{BB} | 88.16 ± 0.41 ^{AA} | 86.54 ± 1.11 ^{bcA} | 86.27 ± 0.87 ^{CA} |
| | 7 | 85.38 ± 0.57 ^{bC} | 86.71 ± 0.49 ^{AB} | 86.58 ± 0.98 ^{AA} | 85.67 ± 1.36 ^{BA} |
| | 14 | 87.95 ± 0.52 ^{AA} | 88.55 ± 0.42 ^{AA} | 86.85 ± 0.48 ^{BA} | 85.15 ± 1.59 ^{EB} |
| | 21 | 88.23 ± 0.32 ^{AA} | 88.62 ± 0.52 ^{AA} | 86.56 ± 0.60 ^{BA} | 84.98 ± 1.50 ^{EB} |
| | 28 | 87.53 ± 0.32 ^{AB} | 88.36 ± 0.58 ^{AA} | 85.44 ± 0.86 ^{BB} | 82.82 ± 1.95 ^{CC} |
| Chroma (C*) | 1 | 35.98 ± 1.22 ^{aC} | 32.94 ± 2.21 ^{BB} | 30.47 ± 2.50 ^{CB} | 33.32 ± 2.91 ^{BC} |
| | 7 | 36.64 ± 1.47 ^{bBC} | 36.93 ± 1.29 ^{BA} | 43.04 ± 1.47 ^{AA} | 44.30 ± 3.60 ^{BB} |
| | 14 | 38.62 ± 1.57 ^{cAB} | 36.94 ± 2.33 ^{CA} | 42.42 ± 1.10 ^{BA} | 46.30 ± 3.55 ^{AA} |
| | 21 | 36.36 ± 0.32 ^{cC} | 36.21 ± 2.20 ^{CA} | 41.61 ± 1.52 ^{BA} | 45.16 ± 4.46 ^{AB} |
| | 28 | 39.00 ± 1.64 ^{CA} | 35.45 ± 1.47 ^{DA} | 42.28 ± 1.29 ^{BA} | 46.14 ± 4.10 ^{AB} |
| Hardness (N) | 1 | 5.263 ± 0.007 | 5.259 ± 0.005 | 5.259 ± 0.004 | 5.258 ± 0.003 |
| | 7 | 5.259 ± 0.012 | 5.259 ± 0.010 | 5.257 ± 0.009 | 5.256 ± 0.006 |
| | 14 | 5.264 ± 0.012 | 5.267 ± 0.011 | 5.267 ± 0.006 | 5.265 ± 0.008 |
| | 21 | 5.264 ± 0.012 | 5.262 ± 0.008 | 5.260 ± 0.008 | 5.261 ± 0.005 |
| | 28 | 5.265 ± 0.007 | 5.267 ± 0.008 | 5.264 ± 0.011 | 5.264 ± 0.009 |

Mean values ± standard deviation. Different lowercase letters in the same row indicate significant differences ($P < 0.05$) between treatments for the same storage time using the Sidak test. Different capital letters in the same column indicate significant differences ($P < 0.05$) between times for the same treatment using the Sidak test. The absence of letters indicates that the effect was not significant ($P > 0.05$).

The color intensity of FSF and FFC cheeses showed little variation over and between days.

The cheeses with the edible films showed an increase in chroma after the first day, with little change between the 7th and 28th day. The EF, from day 14, exhibited the highest chroma values, corroborating the hue result, presenting a more intense yellow coloration. The color intensity of WF and CF cheeses showed little variation during storage and little variation between them. Considering the yellow-brown color, these data, in general, may indicate that edible films had an effect on cheeses. There may have been a transfer of compounds to the cheeses, especially those from the leaf loquat extract, since EF cheese differed the most from WF and CF. Therefore, for the cheeses in pieces, the formulation with leaf loquat extract significantly influenced their color.

4. Conclusion

The application of edible coating on mozzarella cheeses in pieces was advantageous by minimizing weight loss and acidity reduction, especially the formulation containing the loquat leaf extract, whose weight loss values ranged from 0.13 to 0.45% and pH ranged from 5.58 to 5.82, between days 1 and 28. However, this coating promoted a more intense yellowish coloration to the cheeses, showing chroma values between 35.36 and 31.78. For hardness, the coatings had no influence during shelf life.

For sliced cheeses, pH and titratable acidity were the only parameters in which the application of edible films was beneficial, causing less re-

duction of acidity. For cheeses with SF, pH ranged from 5.60 to 5.95 and TA ranged from 2.34 to 1.73% (w/w). While for cheeses with EF, these values varied from 5.65 to 5.93 and 2.25 to 1.61% (w/w), respectively. In addition, the cheeses containing the edible films presented the same validity period as those with the commercial film, which is desirable, indicating that the synthetic film can be replaced by a biodegradable material such as the edible film of banana peel flour.

The use of edible films and coatings on cheeses, prepared from agri-food residue and the addition of vegetable extract, is promising and can be an alternative material for the food industry, considering environmental and food safety aspects.

Declaration of Competing Interest

The authors report no declarations of interest.

CRediT authorship contribution statement

Viviane Dias Medeiros Silva: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft. **Amanda Neris dos Santos:** Methodology, Investigation. **Maria Clara Coutinho Macedo:** Methodology, Investigation. **Camila Gonçalves Rodrigues:** Investigation. **Vinicius Tadeu da Veiga Correia:** Investigation. **Inayara Cristina Alves Lacerda:** Writing – review & editing, Supervision. **Camila Argenta Fante:** Writing – review & editing, Supervision, Project administration.

Data availability

No data was used for the research described in the article.

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