EFFECT OF COMPOSITE EDIBLE COATING FROM AMARANTHUS CRUENTUS FLOUR AND STEARIC ACID ON REFRIGERATED STRAWBERRY (FRAGARIA ANANASSA) QUALITY

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Abstract — A composite coating from Amaranthus cruentus flour and stearic acid (10 g stearic acid/100 g flour, 26 g glycerol/100 g flour and stirring speed at 12000 rpm) was applied on fresh strawberries in order to verify the effect on its quality. Other treatments were effected to comparison: PVC film, bi-layer coating of the optimized formulation, optimized formulation without stearic acid and a control group of fruits (not coated). Fruit quality was evaluated by weight loss, mold spoilage, firmness retention and surface color development. The weight loss increased with the storage time for all treatments and the firmness decreased, however, the optimized coating was the most effective for the firmness retention of fruits among the edible coatings studied (excepting PVC film). The same trend was observed for the surface color development; the optimized coating resulted in a minor increase in the ratio of chromatity parameters (a/b) as a function of storage time.

Keywords — edible coating, Amaranthus cruentus flour, stearic acid, strawberry quality.

I. INTRODUCTION

Edible coatings have long been known to protect perishable food products from deterioration by retarding dehydration, suppressing respiration, improving the textual quality, helping retain the volatile flavor compounds and reducing the microbial growth (Debeaufort et al., 1998). In this way, the application of edible coatings on fresh fruits like strawberries can provide an alternative method to extend the post-harvest life, reducing quality changes and quantity losses, and can also result in the same effect as modified atmosphere storage (Park, 1999).

The types of materials used to elaborate edible coatings include lipids, resins, polysaccharides and proteins (Krochta and Mulder-Johnston, 1997). Each group of material has certain advantages and disadvantages and, for this reason, many coatings are actually formulations of any or all of the above (Baldwin et al., 1997). The use of natural mixtures of protein, polysaccharides and lipids from agricultural sources, to take advantage of each of these components in a ready system, appears as a new opportunity of material in the area of edible films.

A. Raw material

Amaranth flour was prepared using the mature seeds of Amaranthus cruentus cultivar “BRS Alegria”, provided by Embrapa Cerrados (Brazilian Company of Agropecuary Research - Federal District - Brazil). After harvest the seeds were cleaned and stored at 20 °C in sealed containers until tested. Flour was obtained using the modification of the alkaline wet milling method of Perez et al. (1993), such as proposed by Tapia et al. (2005). Glycerol and all chemicals used were reagent grade and were purchased from Synth (São Paulo, Brazil).

B. Preparation of Coating Formulation

The composite coating from Amaranthus cruentus flour and stearic acid studied in this work was prepared from an optimized formulation defined previously by Colla et al. (2006), using an experimental design (Central Composite Rotatable Design - 2^5 with 6 axial and 3 central points, resulting in a sum of 17 experiments). The optimized parameters of this formulation were stearic acid concentration (10g/100g of amaranth flour), glycerol concentration (26 g/100g of flour) and stirring speed in the step of stearic acid incorporation on the amaranth flour suspension (12000 rpm). The coating suspension was prepared using the following procedure: amaranth flour and distilled water (4.0 g/100 mL solution) was
mixed until the temperature reached 50 °C; then, the pH was adjusted for proteins solubilization (10.7 adjusted with NaOH 1.0 N) and the heating process continued until 80 °C, when glycerol and stearic acid were added; after the lipid melting, the hot solution was immediately emulsified with an Ultra-Turrax homogenizer (IKA Works Brazil, model T18-Basic, Jacarepaguá, Brazil) for 3 min at 12000 rpm; the solution was cooled with an ice bath and kept under vacuum in order to remove air bubbles or any dissolved air, during approximately 3 h, before the application in the fresh strawberries.

C. Fresh Strawberries Preparation and Treatments
Strawberries (Fragaria ananassa) at commercial ripening stage, grown in greenhouses of a local farm, were harvested and immediately treated. Fruits of uniform size, free of physical damage and fungal infection were used. Strawberries were dipped in chlorinated water (0.25 g Cl2/L), dried, dipped in the formulated suspensions (coatings) at room temperature and dried again with air (20 °C and 85% RH). Five treatments were performed to coat fresh strawberries and to compare with the optimized coating formulation: 1 (control), the strawberries were dipped into distilled water for 1 min; 2 (PVC), fruits were individually covered with a thin amaranth flour film-forming solution at room temperature and dried again with air renewal and circulation with temperature and relative humidity controls (Marconi, model MA 415UR, Piracicaba, Brazil) at 7 ºC and 80% RH for 21 days. 3 (treatment 3) was opaque yellowish. Comparing the coatings were well adhered to the strawberry surfaces. Regarding the transparency, the coating elaborated without stearic acid addition was transparent but the coating elaborated with the optimized formulation (treatment 3) and the bilayer coating (treatment 4) was opaque yellowish. Comparing the control fruits (Fig. 1) and those coated with the bilayer treatment (Fig. 4), all the strawberries shrank and lost their brightness. The control fruits (Fig. 1) and those coated with the bilayer treatment (Fig. 4) presented the greater shrinking. For the strawberries coated with the optimized formulation (Fig. 3), the original initial size was kept by a longer time in comparison to the other treatments, exception for the PVC treatment (Fig. 2), which resulted in the minor strawberry shrinking. By the visual analysis was possible to verify that the best quality was maintained until the day 16, for the strawberries coated with the optimized formulation, what it can be an indicative of its efficiency to delay the senescence process of the strawberries. According to Han et al. (2004), the shelf-life of fresh strawberries at cold temperatures (0 - 4 ºC) is usually less than 5 days.

G. Surface Color Development

Strawberry surface color was evaluated with a Hunter Labscan colorimeter equipped with an optical sensor (ColorQuest II, Hunter Associates Laboratory, Fairfax, VA, USA) calibrated with an appropriate device to reduce sampling area. L* (lightness), a* (redness), and b* (yellowness) values were registered after 1, 3, 6, 10, 13, 16 and 18 days of storage. For each fruit, three different sites were measured. As the ratio of chromaticity parameters (a/b) has been commonly accepted for describing color changes on post-harvest fruits and vegetables (McGuire, 1992), it was also calculated and reported in this study.

III. RESULTS AND DISCUSSION

A. Visual Coating Characterization
The coatings were well adhered to the strawberry surfaces. Regarding the transparency, the coating elaborated without stearic acid addition was transparent (treatment 5), but the coating elaborated with the optimized formulation (treatment 3) and the bilayer coating (treatment 4) was opaque yellowish. Comparing the control and coated strawberries at 1 and 21 days of storage (Fig. 1 - 5), all the strawberries shrank and lost their brightness. The control fruits (Fig. 1) and those coated with the bilayer treatment (Fig. 4) presented the greater shrinking. For the strawberries coated with the optimized formulation (Fig. 3), the original initial size was kept by a longer time in comparison to the other treatments, exception for the PVC treatment (Fig. 2), which resulted in the minor strawberry shrinking. By the visual analysis was possible to verify that the best quality was maintained until the day 16, for the strawberries coated with the optimized formulation, what it can be an indicative of its efficiency to delay the senescence process of the strawberries. According to Han et al. (2004), the shelf-life of fresh strawberries at cold temperatures (0 - 4 ºC) is usually less than 5 days.
Figure 1. Strawberries not coated (Control) at 2 (a) and 21 days (b) of storage at 7 °C and 80% RH.

Figure 2. Strawberries coated with PVC film at 2 (a) and 21 days (b) of storage at 7 °C and 80% RH.

Figure 3. Strawberries coated with the Optimized formulation at 2 (a) and 21 days (b) of storage at 7 °C and 80% RH.

Figure 4. Strawberries coated with the Bilayer of Optimized formulation at 2 (a) and 21 days (b) of storage at 7 °C and 80% RH.
Figure 5. Strawberries coated with the Optimized without stearic acid formulation at 2 (a) and 21 days (b) of storage at 7 ºC and 80% RH.

B. Mold Spoilage of Fresh Fruits

The results observed for the mold spoilage of the strawberries stored at 7 ºC and 80% RH are shown in Fig. 6. Strawberries are highly perishable fruit and have high physiological post-harvest activities, presenting short time of useful life after the harvest, due to the fungal attack, that promotes the appearance of dark points and texture loss (softening) in the attacked zones (García et al., 1998; Ghaout et al., 1991). Strawberries are also susceptible to water loss, bruising and mechanical injuries due to their soft texture and lack of a protective rind (Hernández-Muñoz et al., 2006).

It can be seen in Figure 6 that all treatments protected fruits against mold until 3 days of storage. However, the better protection against mold during the total storage time was observed for the coating elaborated with the optimized formulation, which presented 44% of infected fruits. After 18 days of storage, the fruits coated with the without stearic acid treatment presented 50% of infected fruits, as well as the group of fruits not coated (control). The fruits coated with the bilayer treatment had 66% of contaminated fruits. These results were statistically different (Tukey test, p<0.05). The better efficiency of the optimized coating against the strawberries spoilage was probably due to its low permeability to the \( O_2 \) \( (2.36 \times 10^{-13} \text{ cm}^3/\text{m.s.Pa}) \), determined in a previous work (Colla et al., 2006).

According to Baldwin et al. (1995), the coating could affect the respiratory process of the fruits and water loss, through the reduction of the \( O_2 \) and \( CO_2 \) permeabilities (increase of the \( CO_2 \) concentration and reduction of the \( O_2 \) concentration) and consequent formation of an internal atmosphere in the fruits. Thus, the high rate of breath and production of ethylene of the fruits as the strawberries can be reduced by the application of half-permeable coatings. The half-permeability is an important characteristic that unable the formation of anaerobic conditions and development of capable microorganisms that grows in these conditions.

The application of the bilayer of optimized coating could have resulted in better conditions for mold growth (possible formation of cracks, increasing the contamination process); this could explain the greater percentage of infection for the fruits coated with this treatment.

C. Weight Loss

Normally, the weight loss occurs during the fruits storage due to its respiratory process, the transference of humidity and some processes of oxidation (Ayranci and Tunc, 2003). It can be observed in Fig. 7 that the weight loss increased with the storage time, for all treatments. However, the PVC and the optimized formulation coating significantly reduced the weight loss of strawberries during the storage period, compared to the control.
(p<0.05). In this way, the film formed on the surface of fruits delayed moisture migration from the fruits into the environment, thus reducing weight loss during the storage. The maximum weight loss observed for the strawberries coated with the optimized formulation was ~23%, after 18 days of storage. García et al. (1998) observed a similar result (~21% of weight loss) for strawberries coated with high amylose corn-based coating, after 30 days of storage at 0ºC.

Figure 7. Effect of coatings studied on weight loss of fresh strawberries stored at 7 ºC and 80% RH. Vertical bars indicate standard deviation.

The bilayer coating treatment resulted in higher weight loss in comparison to the fruits coated with a single layer of the optimized formulation, after 11 days of storage (means statistically different, p<0.05). This result was unexpected, but could be explained by the possible formation of cracks in the coating, increasing the water vapor transference. The fruits coated without stearic acid presented similar weight loss compared with the control fruits (p>0.05) (~35% after 18 days of storage). Based on this result it can be suggested that the stearic acid had an important function in the coating, improving the barrier properties, especially the water vapor barrier, which can be confirmed by the results obtained with the optimized coating (~23% of weight loss after 18 days of storage). It must be pointed out that the water vapor permeability of the optimized films, determined in a previous work (Colla et al., 2006), was 0.32 g.mm/m².h.kPa, which can be considered effectively as low, and could explain the better effect of the optimized coating in reducing the weight loss of the strawberries.

D. Firmness

Loss of texture is one of the main factors limiting quality and the postharvest shelf-life of fruit and vegetables. Strawberries soften considerably during ripening which mainly occurs as a result of degradation of the middle lamella of the cell was of cortical parenchyma cells (Hernández-Muñoz et al., 2006). Changes in the firmness between control and treated fruits during the storage time at 7 ºC are shown in Fig. 8. Initial firmness values were similar for control and treated samples (p>0.05). Increasing the storage time, the firmness decreased for both control and coated fruits, but in a higher degree for the fruits treated with the optimized without stearic acid coating and for the control group. As can be seen in Fig. 8, the optimized and bilayer coatings were efficient to promote the firmness retention of the strawberries during the storage time; the results at the end of storage time (18 days) were similar to those obtained for the PVC treatment (p>0.05).

The rate and extension of firmness loss during ripening of soft fruits like strawberries is the main factor to determine fruit quality and post-harvest shelf life. According to García et al. (1998), the texture modifications in fruits and vegetables are related to the composition of cell wall, enzyme activity, metabolic changes and water content.

In the same way for the weight loss, the strawberries coated without stearic was not effective in retaining the firmness, in comparison to the control fruits, as can be seen in Fig. 8. This behavior was expected, since it was observed a high weight loss for this treatment, what is an indicative of the water loss of the fruit and consequently texture modification. The break forces of the strawberries coated with PVC remained almost constant until 16 days of storage (p>0.05). The optimized coating, as well as observed for weight loss results, was more effective in retaining the firmness of the strawberries, among the coatings studied. This result proved that the coating prepared from optimized conditions controlled the migration of moisture from the fruits, thus controlling the integrity and texture of the strawberries during cold storage.

Figure 8. Effect of coatings studied on the firmness (peak force) of fresh strawberries stored at 7 ºC and 80% RH. Vertical bars indicate standard deviation.

E. Surface Color Development

The modification of the color occurs during the postharvest ripening and the fruits becomes redder and darker along the storage time, due to the synthesis of anthocyanins, a pigment contributing to the red color in strawberries (Han et al., 2004; Holcroft and Kader, 1999). The color changes of the coated strawberries and
control fruits were evaluated by the chromaticity parameters \((a/b)\) ratio in function of storage time. As can be seen in Figure 9, the control fruits presented higher values of \(a/b\) than the coated fruits. The optimized coating was the most efficient to avoid the \(a/b\) ratio increase, between the coatings studied. Thus, the senescence delay, evidenced by the decrease in color changes, demonstrates the effectiveness of this coating.

![Figure 9](image-url)

**Figure 9.** Effect of coatings on the surface color development \((a/b)\) ratio of fresh strawberries stored at 7 °C and 80% RH. Vertical bars indicate standard deviation.

### IV. CONCLUSIONS

The application of the optimized formulation coating elaborated from *Amaranthus cruentus* flour and stearic acid to strawberry fruits were shown to be beneficial in retarding the senescence process. This coating reduced the weight loss and the external color changes, and was effective in retaining the firmness of the refrigerated strawberries. In this way, Amaranth flour seems to be a very interesting source of raw material for coatings for- mulations, following the actual trends in to use natural mixtures of protein, starch and lipids, to reach the desired properties for edible films.

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### VI. REFERENCES


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