Effect of carnauba wax nanoemulsion coating on postharvest papaya quality

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Abstract

Papaya is a fruit of great economic importance worldwide, but still presents a high rate of postharvest losses. Among the different reasons explaining this phenomenom, intensive labor and inappropriate storage conditions are the main ones. Carnauba wax nanoemulsion (CWN) coating may be an alternative to this problem, preserving postharvest fruit quality. Therefore, an experimental CWN was developed and a set of three trials were conducted to evaluate its performance on storage of papaya fruits solo type. On the first trial, this coating was applied to the fruits at concentrations of 4.5, 9.0, 13.5 and 18.0% compared to control group (fruits coated with water). In a second trial, the best concentrations determined in the first one was used (13.5 and 18.0% respectively). On the last trial, CWN on a high concentration 18% was compared to commercially treated and untreated fruits. Fruits were stored for 12 to 20 days at 16 to 18°C and Relative Humidity upper to 70%. Physicochemical analyzes carried were soluble solids, titratable acidity, pH, weight loss, firmness, color and ethylene production, while postharvest disease incidence and severity was only performed on the last trial. Significant difference was observed on treatments with high CWN concentration (13.5 and 18.0%) in relation to reducing weight loss, delay ripening and decreasing ethylene production compared to untreated, commercial coating and even to low CWN concentrations. For disease severity it was observed a reduction on coated fruits with high CWN concentration when compared to control and commercial coating. CWN has a potential use for extending papaya postharvest shelf life.

Keywords: papaya, shelf life, nanotechnology, diseases

INTRODUCTION

Papaya fruit is considerably a perishable fruit (Hewajulige et al., 2018) with high economic value and importance in many tropical countries for domestic market and exportation. The total world production in 2016 was 13,050,749 metric tons (MT). The main producer countries are India, Brazil, Mexico, Indonesia and Dominican Republic, being Mexico the main exporter country and USA and European Community important importers (Agrianual, 2019). Postharvest losses and quality problems on papaya have been reported from harvest to consumer (Paull et al., 1997; Chonhenchob and Singh, 2005).

Edible coatings can be an alternative to improve fruit postharvest conservation (Flores-López et al., 2016) and reduce losses and improve all chain. Coatings have distinctive properties. They reduce fruits water loss and present antimicrobional action, and have been used for a number of produces and species for fruit conservation (Galus and Kadzińska, 2015). There are a considerable number of edible coatings on commercial use with distinctives properties, that alone or in conjugation can improve fruit conservation (Assis et al., 2008; Forato et al., 2011; Assis and de Britto, 2017). It is possible to highlight its use in non-climacteric fruit such as lemon (Caron et al., 2015) and orange (Njombolwana et al., 2013).

Nanotechnology can change actual food industry giving different approaches and applications (He and Hwang, 2016). Nanoemulsions can show new attributes and enhance some distinguish features that can contribute to improve fruit conservation (Flores-López et

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al., 2016; Acevedo-Fani et al., 2017). Carnauba wax has been used as fruit coating extensively for different fruits as principal or one of the emulsion constituents (De Freitas et al., 2019), however not many researches has paid attention on its use on papaya fruit post-harvest conservation. It has been some reports about the combination of carnauba wax – and essential oils (EO), as an EO nanoemulsion (Kim et al., 2013; Jo et al., 2014; Kim et al., 2014), but not only CWN by itself as a fruit coating. Acevedo-Fani et al., 2017 also reported that the main biopolymer matrix used for nanoemulsions applied for fresh cuts fruits were chitosan and alginate mainly associate to essential oils. Therefore, the main goal of this research was to evaluate the effect of a carnauba wax nanoemulsion in the post-harvest quality conservation on papaya (*Carica papaya* L.) setting the best emulsion concentration and comparing to a commercial coating.

MATERIALS

Fruits

Papaya fruits, solo group, cultivar Golden, were carefully shipped from a commercial farm (Bahia State) to the postharvest laboratory, Embrapa Instrumentação, São Carlos, SP, and sanitized with specific detergent for fruits and chlorine dioxide. They were then selected by lacking of standard defects, size and maturity stage (stage 1 of maturation, less than 15% of skin surface covered by a yellow color) (Santamária Basulto et al., 2009).

Carnauba wax nanoemulsion

Carnauba wax nanoemulsion (CWN) was developed on oil phase and water phase using ammonia in a morpholine-free method adapted to this work (Hagenmaier and Baker, 1997) in a high-pressure process. CWN diameter size obtained was 44.1±7.6 nm, with a narrow polydispersion index (0.28) and zeta potential -43.8 mV, measured by Zetasizer Nano ZS (Malvern Instruments Inc., Westborough, MA, USA) (Miranda et al., 2019, manuscript submitted to publication).

METHODS

Trials were conducted in three steps. On the first one, CWN was applied to the fruits randomly divided into 5 treatments, as follows: CWN in four concentrations (4.5, 9.0, 13.5 and 18.0%) and control. In a second trial, the two best concentrations determined in the first one were used. On a third trial, CWN on a highest concentration was compared to a commercial coating (diluted to 1:1) and to untreated fruit.

In the first trial, the fruits were kept for 20 days in a cold chamber at 16°C. On the twentieth day of the experiment, the temperature chamber was changed to 22°C and thus maintained in the next 24 h until the beginning of the last analyzes, in order to accelerate the ripening in its final stage and to observe if there would still be considerable differences between the treatments. On the second step trials, the fruits were kept for 16 days in a cold chamber at 18°C. The last trial was stored for 12 days at 16°C. In all the trials humidity was kept above 70%. For replicates, it was 10 fruits for treatment for non-destructive analyses e 5 fruits for destructives.

Non-destructive analyses

The parameters evaluated were:

- Weight loss: At each sampling date, the same fruits were individually weight on a digital balance, model Marte AS 2000C.
- Skin color was measured with a colorimeter Minolta® CR-400 Chroma Meter (Minolta Camera Co., Osaka, Japan), using the CIELAB system: L* (lightness), a* (green-red) and b* (blue-yellow) values. In each fruit, three measurements were made in the equatorial region on equidistant sides at the same points throughout the treatment.
- Fruit Severity and Disease Incidence. On the third trial at the end of the storage period of 12 days at 16 C, fruits were visually evaluated for fruit rot severity and

incidence on a scale of 1 thru 5, being 1, less affected and 5 more affected using the Horsfall-Barret scale (Berry et al., 2004).

- Ethylene production: Two fruits of the same treatment were packed in pairs in hermetic glass jars with screw cap and held for two hours. At the end of this period, 1 mL of the headspace was collected through a rubber septum located on the cap. This volume was injected with Varian Gas Chromatograph model CP 3800, with TCD/FID detectors, in order to detect the peaks corresponding to ethylene. Results were expressed in $\mu g\ kg^{-1}\ h^{-1}$.

Destructive analyses

- Soluble solids (SS) were performed on a digital refractometer Atago RX-5000cx and results expressed in °Brix.
- Titratable acidity (TA) was determined using 10 g of homogenized fruit pulp diluted in 30 mL of distilled water by titration with NaOH 0.1 N until pH 8.1. Values expressed in in grams of citric acid ×100 mL^{-1}.
- pH values were determined using a bench-top potentiometer (PHS-3B). pH was performed on second trial.
- Flesh firmness was done using TA.XT Plus Texture Analyzer (Stable Micro Systems Ltd., Godalming, UK), evaluating maximum penetration force required for a 6 mm diameter probe to penetrate on a depth of 15 mm at a rate of 5 mm s^{-1} on four measurements on equatorial distance. The results were expressed in Newton (N). Firmness was done on first and second trial.

Statistical analysis

Analyses of the responses of the non-destructive longitudinal experiments were performed from some parameters estimated for each one of the replicates. Afterwards, for comparison of treatments, these parameters were submitted to analysis of variance and Duncan's multiple comparison test, when applicable. Weight loss and * a: angular coefficient of the adjusted linear regression models; L and b*: the vertex coordinates of the quadratic models adjusted by regression. To compare the distributions of the treatments, whose analyzes were destructive, nonparametric ANOVA and multiple comparisons test of Kruskal-Wallis were used. The level of significance was set at 0.05 for all analyzes and the software used was R version 3.5.2.

RESULTS AND DISCUSSION

Non-destructive analyses

1. Weight loss.

For weight loss (%) it was possible to observe during the storage period of 20 days at 16°C and also on the 21st day (Figure 1) for all CWN treatments a significant reduction on daily weigh loss rate than untreated fruits. As higher the CWN (%) concentration lower was the daily weigh loss rate, being the higher concentration (18%) the lowest weight loss rate. For the second and third trial (Figure 2) it was observed similar behavior than trial one, were the lowest fruit weight loss daily rate (%) was found for CWN 18%, but in this case, not significant different from commercial coating. Both were significant different from non-treated treatments. There are a number of articles indicating Carnauba Wax properties on reducing weight loss in other fruits, such as Guava (Jacomino et al., 2003), oranges (Malgarim et al., 2007), but not for papaya fruits (De Freitas et al., 2019). On the other hand, nanoemulsions studies have been carried out in distinctive fruits with Carnauba Wax and essential oil nanoparticulate (Kim et al., 2013, 2014; Jo et al., 2014). There is a very evident indication of a weight loss reduction on CWN.

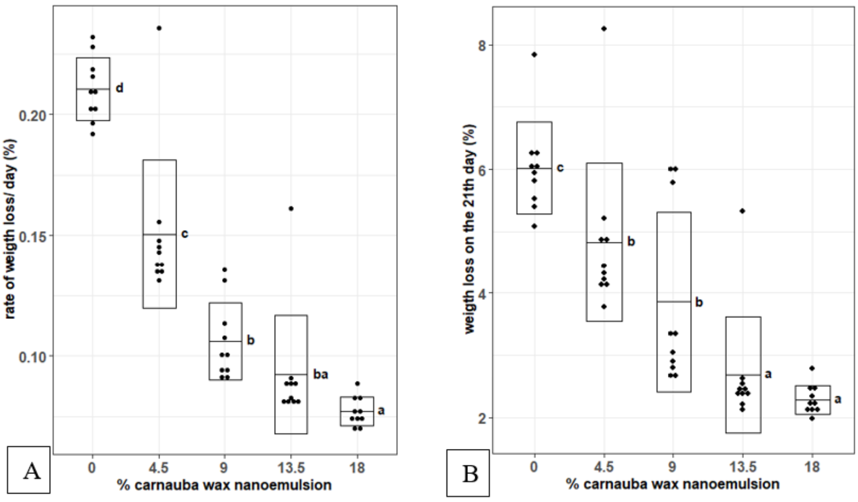

Figure 1. (A) Fruit weight loss daily rate (%) during storage for 20 days at 16°C and (B) on 21st day at 22°C on control and four CWN concentrations (4.5, 9.0, 13.5 and 18.0%).

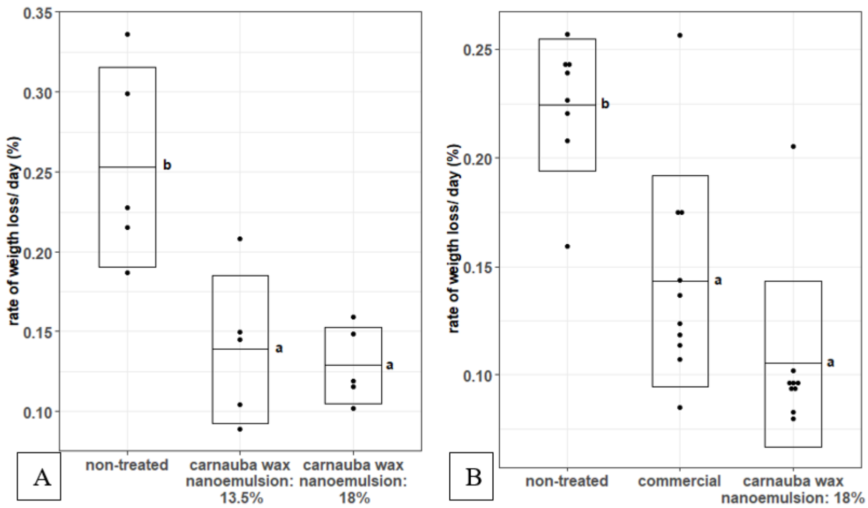

Figure 2. (A) Fruit weight loss daily rate (%) during storage for 16 days at 18°C (Control, CWN 13.5% and CWN 18%) and (B) fruits stored at 12 days at 16°C (Control, Commercial and CWN 18%).

2. Skin color.

L, a* and b*.*

With the CWN coating, it can be noticed a reduction on color daily change based on a* value, especially on the high concentrations (Figure 3A), that can also be visualized after storage for 21 days (Figure 3B), which the treatment with the highest CWN (18%) concentration showed a better skin color conservation, low a* value, than the other treatments and control. For L and b* value (Figure 4), it is possible to observe skin color maintenance for the highest CWN concentration (13.5 and 18%) after storage for 21 days. High L values show clear color, then can indicate delay on ripening, and similar situation was noticed for b* value. On second and third trial, it was also showed significant differences among treatments, being control with the highest a* daily rate change, significantly different to the other two treatments (13.5 and 18%) (Figure 5A) and similar results were found on third trial (Figure 5B) were CWN (18%) showed the lowest a* daily rate change, significant different from control, but not from commercial coating. There have been a number of articles for climacteric fruits that Carnauba Wax is able to maintain skin color and consequently delay ripening in persimmons (Silva et al., 2011) and mango (Dang et al., 2008). This feature was also clearly noticed here on nanoemulsions.

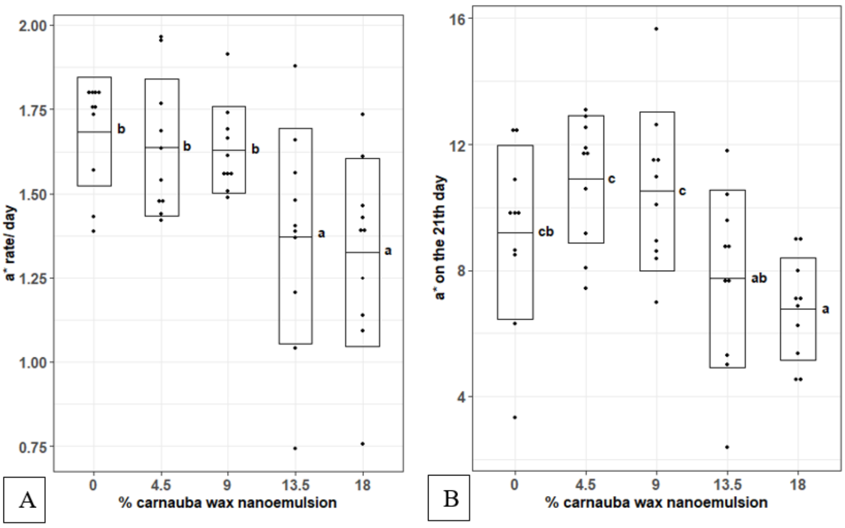

Figure 3. (A) a* daily rate change (%) during storage for 20 days at 16°C and (B) a* on 21th day at 22°C on control and four CWN concentrations (4.5, 9.0, 13.5 and 18.0%).

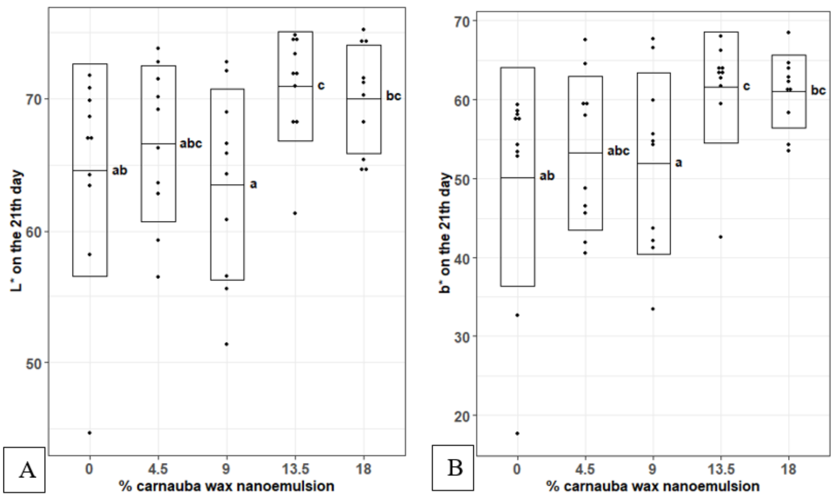

Figure 4. (A). L* and b* (B) on the 21th day at 22°C on control and four CWN concentrations (4.5, 9.0, 13.5 and 18.0%).

Fruit severity and disease incidence

CWN (18%) showed lower disease severity than other treatments (Figure 6A), 67% on scores 0-2, different from control and commercial, 44 and 33%, respectively of scores 0-2. For disease intensity (Figure 6B), commercial coating showed the highest incidence, 89% of scores 3-5. Control and CWN (18%) showed similar disease incidence, what was not noticed on severity. The use of Carnauba wax inhibited fungi growth (*Monilinia fructicola* and *Rhizopus stolonifera*) in vitro and in vivo trials for nectarine and plum (Gonçalves et al., 2010), indicating a possible antimicrobial action of carnauba in this work.

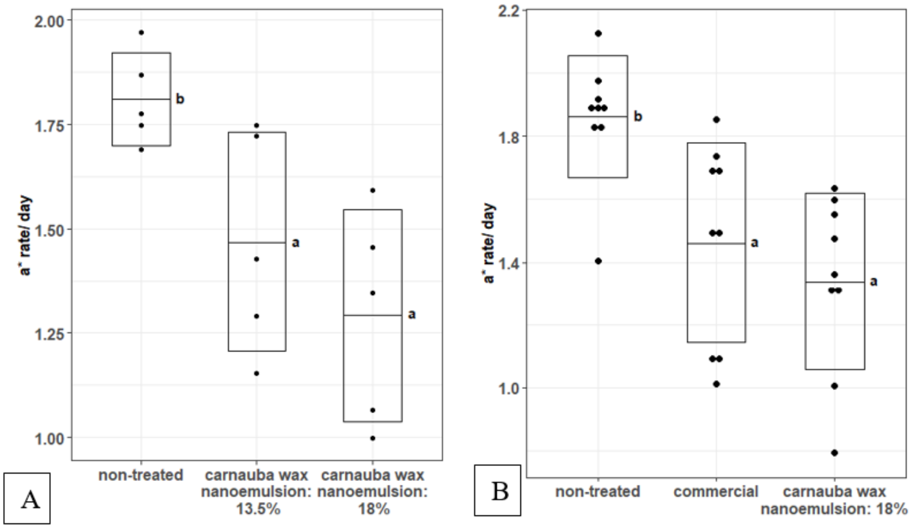

Figure 5. (A) a* daily rate during storage for 16 days at 18°C (Control, CWN 13.5% and CWN 18%) and (B) fruits stored at 12 days at 16°C (Control, Commercial and CWN 18%).

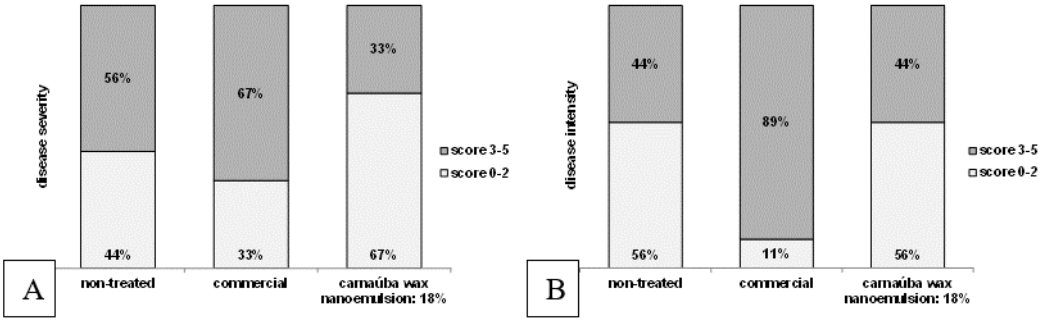

Figure 6. Fruit severity (A) and Disease Incidence (B) evaluation at the end of the storage period of 12 days at 16 C for non-treated, commercial and CWN (18%) on a scale of 0 thru 5, being low score less a high score more affected using the Horsfall-Barret scale (Berry et al., 2004).

Ethylene production

On first trial was shown a decrease in ethylene production over storage, extremely high on CWN treatments, especially in high concentrations (CWN 13.5 and 18%) (Figure 7). For second and third trial date was not conclusive and was not shown. During ripening process there is an increase in ethylene production in papaya. As ethylene production increases, firmness decreases (Fabi et al., 2007). Besides not significantly different, fruits with higher CWN concentration showed higher firmness.

Destructive analyses

SS, TA and pH analyses were only performed for second trial, and for SS (°Brix) and TA were not found significant differences among treatments. On the other hand, CWN treatments showed significantly higher pH than control (data not shown), which can be an indication of besides retarding skin color changes (Figure 3), ripening was not affected. For firmness in the first trial fruit firmness on control and CWN (4.5%) was different from the others, especially on higher concentration, but not significantly. There were also not found significant differences for firmness on this second trial (data not shown).

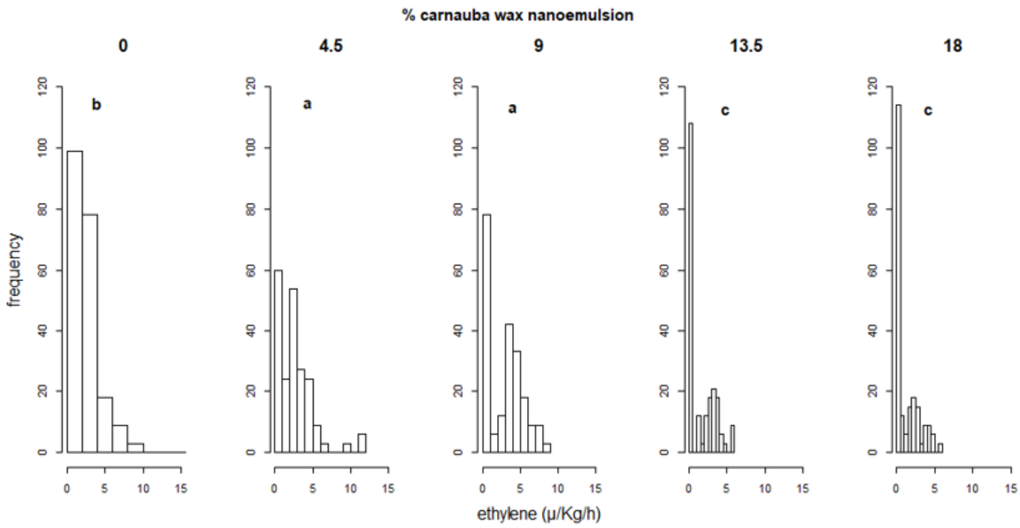

Figure 7. Ethylene production after 20 days at 16°C and at 21th day at 22°C on control and four CWN concentrations (4.5, 9.0, 13.5 and 18.0%).

CONCLUSIONS

Carnauba nanoemulsion has a potential use for extending papaya postharvest shelf life, reducing weight loss and delaying ripening.

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