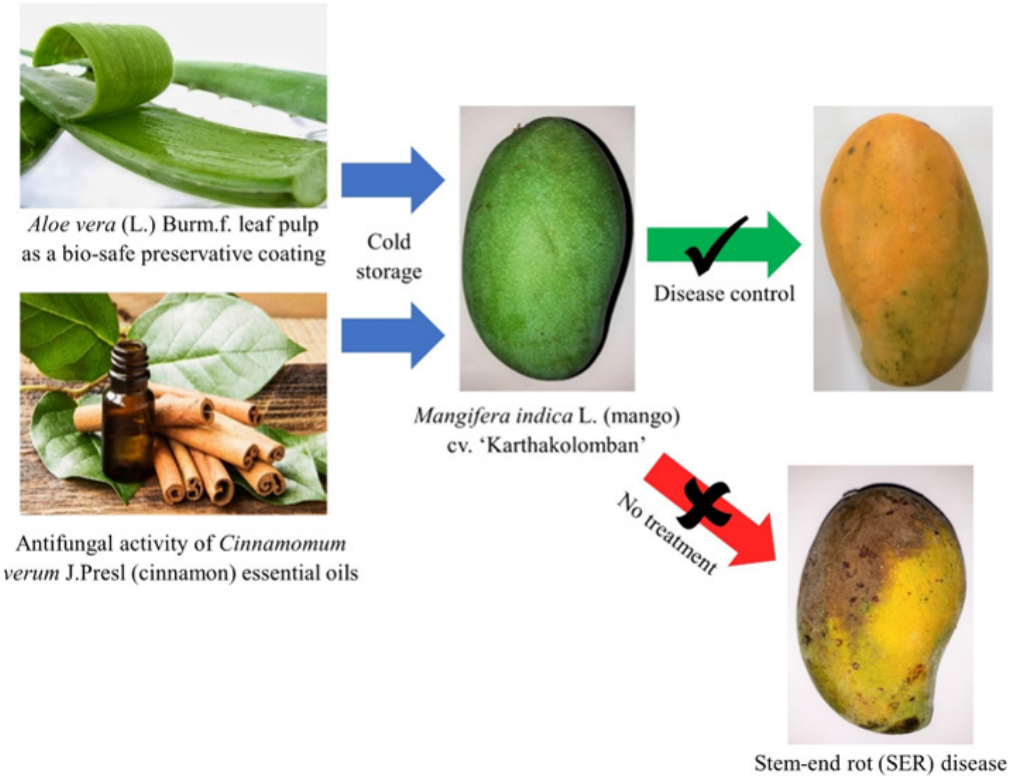
SHORT COMMUNICATION

Dip treatment of *Aloe vera* gel and *Aloe vera* in combination with cinnamon essential oils on stem-end rot of mango cv. 'Karthakolomban'

N.S.N. Karunarathna, K. Abeywickrama and T.D. Kodituwakku*



Highlights

- *Aloe vera* gel and cinnamon oils control stem-end rot of mango cv. 'Karthakoloban' stored at 12 - 14 ℃.
- *Aloe vera* gel coatings extend the storage life of mango cv. 'Karthakolomban' up to ten days.
- Treatments do not adversely affect the physicochemical and sensory properties.
- Treatments are harmless to the consumer as well as the environment.

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Dip treatment of *Aloe vera* gel and *Aloe vera* in combination with cinnamon essential oils on stem-end rot of mango cv. 'Karthakolomban'

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Abstract: This study was conducted to investigate the applicability of *Aloe vera* gel alone and mixed with cinnamon leaf and bark oil in controlling stem-end rot (SER) and extending the shelf life of mango cv. 'Karthakolomban'. Mangoes were subjected to dip treatments of *Aloe vera* gel and *Aloe vera* gel in combination with cinnamon bark oil (2.0 µL/mL) and cinnamon leaf oil (2.0 µL/mL) and their pathological, physicochemical, sensory properties, and percentage shriveling were evaluated after a 10 d storage period at 12-14 °C. Dip treatment of *Aloe vera* gel + cinnamon oils and *Aloe vera* gel reduced SER by 3.0 - 6.0%. Physicochemical and sensory properties did not show drastic alterations among all treatments and controls. Mangoes subjected to *Aloe vera* gel + cinnamon oil treatments demonstrated 0% shriveling. Uncoated fruits showed the highest shriveling. The findings highlight that *Aloe vera* gel may have a better prospect in the preservation and quality maintenance of mango in combination with cinnamon oils.

***Keywords*:** *Aloe vera*; cinnamon oils; mango; stem-end rot; storage life.

INTRODUCTION

Stem-end rot (SER) is a major postharvest disease associated with mango cv. 'Karthakolomban' which reduces the fruit quality and shortens storage life (Bally *et al*., 2009). Currently, the postharvest diseases of mango are controlled using synthetic fungicides. Due to the health and environmental hazards of pesticides, the scientific community is looking for safer alternative products from plants for effective control of disease causative agents during storage (Wilson *et al*., 1994).

Aloe vera gel is an eco-friendly preservative coating for different types of fruits, because of its film-forming properties, antimicrobial actions, biodegradability, and, biochemical properties. *Aloe vera* gel has the ability to lengthen the shelf life of fresh produce by reducing the rate of respiration and maintaining quality attributes (Ajeethan and Mikunthan, 2016). Essential oils play a substantial role in the protection of plants as antibacterial, antiviral, antifungal, and insecticidal agents. Different studies on essential oils of *Cinnamomum verum* J.Presl (cinnamon) have revealed that it has fungistatic and fungicidal properties against pathogenic fungi. Kodituwakku *et al*. (2020a) reported that cinnamon leaf and bark oils effectively inhibited SER causing fungal pathogens of mango cv. 'Karthakolomban'.

The objectives of this research were to investigate the (i) applicability of *Aloe vera* gel coatings (ii) cinnamon oil incorporated *Aloe vera* gel coatings in controlling SER in mango cv. 'Karthakolomban' to extend postharvest storage life.

MATERIALS AND METHODS

Mature green color fruits of mango cv. 'Karthakolomban', of medium size (90 d old) with no record of preharvest fungicide treatments were obtained from orchards and home gardens in the Gampaha district in Sri Lanka. Each mango fruit was washed with running tap water and in 1% (w/v) alum (potassium aluminum sulfate) (Assay > 99.5%) (Devi Trading Company, Colombo, Sri Lanka). Fruits were surface sterilized using 0.1% (w/v) sodium hypochlorite followed by washing in sterilized distilled water. All fruits were allowed to dry for 30 min on a laboratory bench (Kodituwakku *et al*., 2020b).

Preparation of treatments

Mature leaves of *Aloe vera* plants obtained from the Botanic Garden of the Department of Plant and Molecular Biology, University of Kelaniya, Sri Lanka were used to prepare the gel. Modified method of Martínez-Romero *et al*. (2018), was adopted. Leaves were washed with tap water, followed by 70% (v/v) alcohol to sterilize the surface. The gel was separated from the outer cortex of the leaf and the colorless pulp was ground using a small blender (Black and Decker, BX 250, Hunt Valley, USA) without adding water for two minutes. Pulp was poured through a clean muslin cloth to obtain a clear juice. *Aloe vera* gel (300.0 mL) was mixed with gelatin (6.0 g). The mixture was heated in a water bath at 70 °C until gelatin was completely dissolved and subsequently allowed to cool. Cinnamon leaf and bark oils purchased by Kodituwakku *et al*. (2020b) from Citro Essential Oils (Pvt.) Ltd., Mt. Lavinia, Sri Lanka were used for this study. Two treatments were prepared as *Aloe vera* gel with cinnamon bark oil (2.0 µL/ml) and *Aloe vera* gel with cinnamon leaf oil (2.0 µL/mL), by adding respective volumes of test oils as described by Kodituwakku *et al*.

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(2020b) to *Aloe vera* preparations. *Aloe vera* gel without any cinnamon oil served as another treatment. Distilled water was used as negative control (I) whereas gelatin (6.0 g) dissolved in distilled water (300.0 mL) was used as negative control (II)]. Carbendazim (Hayleys Agriculture Holdings Ltd., Colombo, Sri Lanka) (0.1% w/v) was used as the positive control (Martínez-Romero *et al*., 2018).

Application of treatments

Mangoes were dipped separately in negative controls, positive control, and each treatment for three minutes. All treated and control samples were placed in plastic trays (35×25×8 cm^3) separately. Each tray contained three replicate fruits and each treatment comprised three trays. All treatments and controls were stored at 12 - 14 ℃ in a walk-in cold room (Iceman Technologies (Pvt.) Ltd., Wattala, Sri Lanka) with relative humidity (RH) of 85-90%. The experiment was repeated once under identical conditions (Kodituwakku *et al*., 2020b).

Induced ripening of mango

After cold storage of 10 d, mangoes were subjected to induced ripening at room temperature (28 ± 2 ℃) by exposing to ethylene derived from Ethephon (2-chloroethyl phosphonic acid) (Ester, Summer Field Chemicals Pvt. Ltd., Sri Lanka) for 2 d until mango attained the fully ripe stage (Kodituwakku *et al*., 2020b).

Assessment of pathological properties

Stem-end rot severity of each fruit was visually recorded using an SER disease severity index for mango (cv. Karthakolomban) developed at the Department of Plant and Molecular Biology, University of Kelaniya (Kodituwakku *et al*., 2020b).

Assessment of physicochemical properties

Five randomly selected ripened mango fruits from each treatment were analyzed for physicochemical properties. Total soluble solids (TSS) (°Brix) of the filtrates of fruit pulp were determined using a hand-held refractometer (ATC-1E, ATAGO Co. Ltd., Japan). Titratable acidity (TA) (% citric acid) was assessed by titration of the filtrates with 0.1 M NaOH using phenolphthalein as the indicator. The pH of the filtrates was measured using a portable pH meter (PC 510, EUTECH Instruments, Singapore). The firmness of the fruit pulp was measured using a fruit firmness tester (FT 011, QA Suppliers, Italy) (Kodituwakku *et al*., 2020b).

Assessment of weight loss

The initial weight of mangoes in each treatment and final weights were recorded using an electronic balance (Citizen Scale, USA). Percentage weight loss was obtained using the following equation (Ajeethan and Mikunthan, 2016).

$$\text{Percentage weight loss} = \frac{\text{Initial weight - Final weight}}{\text{Final weight}} \times 100$$

Assessment of peel color

Peel color was visually assessed using a peel color index for mango cv. 'Karthakolomban' developed by Kodituwakku *et al*. (2020b) (1 = Fully green, 2 = Breaker, 3 = More green than yellow, 4 = More yellow than green, 5 = Fully yellow).

Assessment of percentage shriveling

The percentage shriveling of each mango fruit was visually recorded using a shriveling index for mango cv. 'Karthakolomban' developed by Karunarathna (2019).

Assessment of sensory properties

Three randomly selected ripened fruits from each treatment and controls were provided to a ten-member untrained sensory panel to evaluate flesh color, aroma, texture, taste, flavor, and overall acceptability. Each sensory parameter was scored as follows: excellent = 9-10, good = 6-8, fair = 4-5, poor = 1-3 (Kodituwakku *et al*., 2020b).

Statistical analysis

Statistical analysis of results was carried out using MINITAB 18 statistical software. Data with respect to physicochemical properties were analyzed using One-way ANOVA and Tukey's pairwise comparison test. Kruskal Wallis non-parametric test was used to analyze data with respect to pathological, shriveling, sensory properties and peel color (Kodituwakku *et al*., 2020b).

RESULTS AND DISCUSSION

Pathological properties

Mango treated with distilled water and distilled water + gelatin displayed relatively higher SER severity values (*i.e.* 19.0% and 18.0% respectively) compared to other treatments, after storage at 12 - 14 ℃ for 10 d and induced ripening. *Aloe vera* gel, *Aloe vera* gel + cinnamon oil treatments reduced SER disease severity at a range of 3 - 6% which was lower than the SER severity in control fruits. No SER was observed in mango fruits treated with 0.1% (w/v) carbendazim. SER severity of mango subjected to *Aloe vera* gel and cinnamon oil treatments and those treated with carbendazim was significantly different in comparison to the negative controls ($p < 0.05$). Mango treated with *Aloe vera* gel only, *Aloe vera* gel + cinnamon bark oil, and *Aloe vera* gel + cinnamon leaf oil showed very low disease severity with good visual appeal as shown in Figure 1.

According to Kodituwakku *et al*. (2020b), 2.0 µL/mL cinnamon leaf oil and 1.6 µL/mL cinnamon bark oil effectively controlled SER disease of mango cv. 'Karthakolomban' during a spray treatment for up to eight days. Therefore, the present study is in accordance with Kodituwakku *et al*. (2020b), since both treatments with cinnamon oils at lower concentrations and *Aloe vera* gel controlled the SER disease successfully. Further, the present results are in conformity with Ajeethan and Mikunthan (2016), as they have revealed that *Aloe vera* gel coatings could delay the ripening of mango cv. 'Ampalavi' up to twelve days.

The antifungal efficacy of cinnamon oils is mainly due to the presence of eugenol and cinnamaldehyde

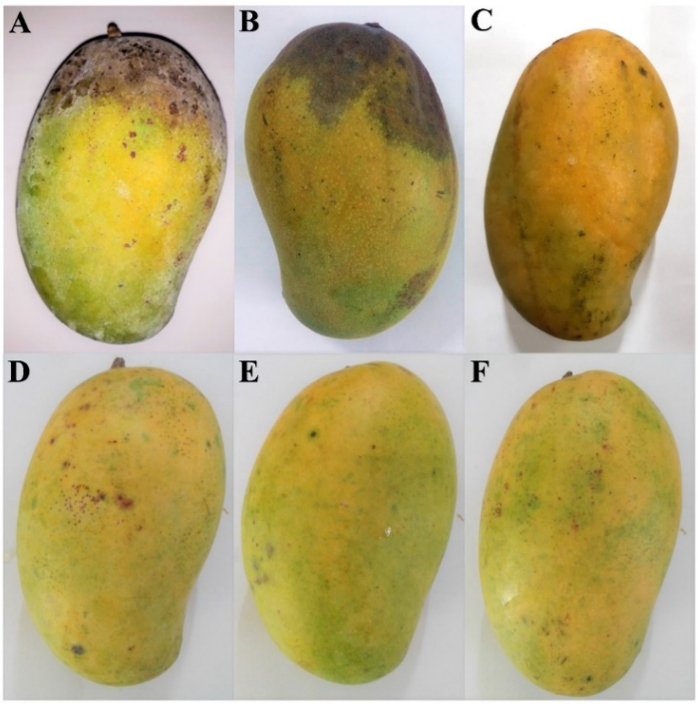

Figure 1: Appearance of mango cv. 'Karthakolomban' subjected to dip treatments, stored at 12 - 14 ℃ for 10 d and after induced ripening. A. distilled water B. distilled water + gelatin C. 0.1% carbendazim D. *Aloe vera* gel E. *Aloe vera* gel + 2.0 µL/mL cinnamon leaf oil F. *Aloe vera* gel + 2.0 µL/mL cinnamon bark oil.

as major constituents in cinnamon leaf and bark oils respectively (Abeywickrama, 2009). According to a recent gas chromatography-mass spectroscopy (GC-MS) analysis, cinnamon leaf oil mainly consisted of eugenol (63.76%), benzyl benzoate (3.61%), β-caryophyllene (2.48%), eugenol acetate (2.27%), (E)-cinnamaldehyde (1.37%), linalool (1.27%), and cinnamyl acetate (1.08%) (Kodituwakku *et al*., 2020a). GC-MS analysis of cinnamon bark oil showed a higher percentage of (E)-cinnamaldehyde (72.18%) followed by cinnamyl acetate (5.16%), eugenol (4.82%), β-caryophyllene (3.95%), linalool (3.69%), and benzyl benzoate (1.51%) as major constituents (Kodituwakku *et al*., 2020a). Hong *et al*. (2015) reported that cinnamaldehyde and linalool inhibited the mycelial growth of *Colletotrichum gloeosporioides* effectively. According to Marei and Abdelgaleil (2018), cinnamaldehyde was found to be antifungal against *Colletotrichum gloeosporioides*, *Botrytis cinerea*, *Aspergillus niger*, and *Penicillium digitatum*. Eugenol is one of the major antifungal components in cinnamon oils found to be effective against *Colletotrichum musae*, *Fusarium proliferatum*, and *B. cinerea* (Herath and Abeywickrama, 2008). *Aloe vera* gel contain anthraquinones (*i.e.* aloe-emodin, aloetic acid, anthranol, aloin A and B, isobarbaloin, emodin, and ester of cinnamic acid) which are found to be responsible for its antifungal activity (Misir *et al*., 2014). The synergistic effect of many antifungal components present in a plant extract at different proportions may inhibit the growth of fungal pathogens (Anthony *et al*., 2004).

Physicochemical properties

Dip treatment of *Aloe vera* gel and *Aloe vera* gel + cinnamon oils did not adversely affect the physicochemical properties of mango. Slight changes in physicochemical properties could be observed in fresh commodities due to the variation in their postharvest behavior (Anthony *et al*., 2003). TSS values of mango subjected to different treatments (*Aloe vera* gel only, *Aloe vera* gel + cinnamon bark oil, and *Aloe vera* gel + cinnamon leaf oil) (*i.e.* 12.8-14.5 °Brix) were slightly lower than the negative control (distilled water) (*i.e.* 15.9 °Brix) and carbendazim treatment (*i.e.* 15.7 °Brix). Present results are in accordance with Ajeethan and Mikunthan (2016), who reported that the TSS value of mango fruits coated with 100% *Aloe vera* gel (*i.e.* 18.03 °Brix within 12 d) was significantly lower than uncoated control fruits (*i.e.* 20.77 °Brix within 12 d). TA of treated and control samples varied between 0.01 - 0.02%. TA values from all treatments were not significantly different from the controls, according to the ANOVA and Tukey's pairwise comparison test ($p > 0.05$). Present results are not in accordance with Ochiki *et al* (2015), who tested four concentrations of *Aloe vera* gel (0, 25, 50, 75%) and chitosan 1% to determine their effect on postharvest quality of mango cv. 'Ngowe' to control anthracnose disease. According to their study, 50% *Aloe vera* gel concentration treated mango contained the highest titratable acidity while negative control gave the lowest titratable acidity at a twenty-day storage period. Present results are in accordance with Kodituwakku *et al.* (2020b) who reported, spray treatment of essential oils [basil oil (1.6 µL/mL), clove oil (2.0 µL/mL), cinnamon leaf oil (2.0 µL/mL), and cinnamon bark oil (1.6 µL/mL)] did not adversely affect physicochemical properties of Karthakolomban mango fruits. Thus TSS, and TA values of essential oil-treated mango fruits were not significantly different from control fruits retaining their physicochemical qualities. Further, pH values and firmness of each treatment did not

show a significant difference with respect to the negative controls ($p > 0.05$) which were at a range of 3.11-3.60 and 0.49-0.59 respectively. According to the study by Ajeethan and Mikunthan (2016), pH values of *Aloe vera* gel-coated mango were comparatively lower than uncoated fruits. Firmness values of essential oil-treated mango and control reported by Kodituwakku *et al.* (2020b) were within the range of 0.39-0.54 indicating the compatibility of the results with the present research. Percentage weight loss of mango subjected to different treatments (*i.e.* 3.32% - 6.82%) and carbendazim (*i.e.* 6.14%) were comparatively lower than control I (distilled water) (*i.e.* 7.19%), control II (distilled water + gelatin) (*i.e.* 8.17%). Ajeethan and Mikunthan (2016) reported that uncoated mango fruits showed higher weight loss in comparison to *Aloe vera*-coated fruits. This observation is in accordance with the present study. Possible reasons for this observation are, that weight loss mainly occurs due to water loss by transpiration and loss of carbon reserves due to respiration. The rate at which water is lost depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere. *Aloe vera* gel coating acts as a barrier, thereby, restricting water transfer. According to the study carried out by Brishti *et al* in 2013, *Aloe vera* gel (100%) has been used to preserve papaya fruit at room temperature (25 - 29 ℃) and 82 - 84% RH. All samples showed a gradual loss of weight during storage. Throughout storage, the weight loss of uncoated fruit (sample) was significantly greater than that of *Aloe vera* gel-coated fruit. At the end of the storage, uncoated papaya showed a 22.5% loss in weight, whereas the weight loss of samples coated with *Aloe vera* gel was 7.93%. Therefore, papaya research results are compatible with current mango research data. All physicochemical parameters, except TSS and % weight loss, were not significantly different in comparison to the controls ($p > 0.05$).

Peel color

All treated and control mango fruits stored at 12 - 14 ℃ were "fully green" (index value = 1) or at the "color break" stage (index value = 2) after ten days. After induced ripening peel color of the mango changed into "more yellow than green" (index value = 4) or "fully yellow" (index value = 5). There was no significant difference in the mean peel color of all ripened mango ($p > 0.05$). Present results are in accordance with Kodituwakku *et al*. (2020b), who have reported that peel color of mango cv. 'Karthakolomban' subjected to spray treatment of essential oils was almost "fully yellow" after induced ripening.

Percentage shriveling

Mango treated with distilled water demonstrated the highest percentage shriveling value (*i.e.* 1.60%). A percentage shriveling value of 8.0% was observed in mango treated with distilled water + gelatin. Notably, there was no shriveling in mango treated with *Aloe vera* gel + cinnamon oils and carbendazim. However, a significant difference in % shriveling of treated mango with respect to the controls could not be identified ($p > 0.05$). It is worthwhile noting that fruits of control I (Figure 2A) and control II (Figure 2B) displayed some shriveling whereas, fruits subjected to *Aloe vera* gel, *Aloe vera* gel + cinnamon leaf oil, and *Aloe vera* gel + cinnamon bark oil treatments did not show shriveling when compared to the control fruits.

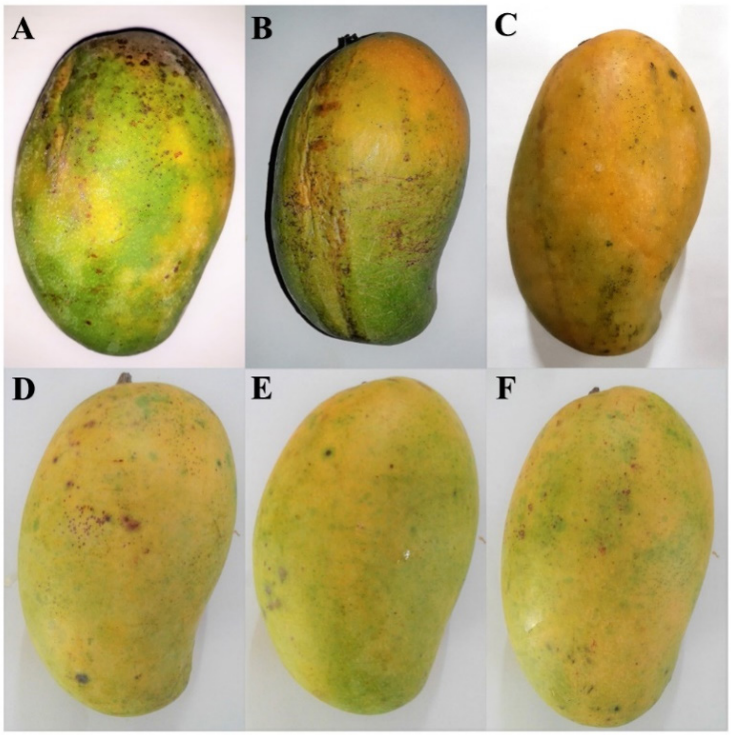

Figure 2: Shriveling of mango cv. 'Karthakolomban' subjected to dip treatment stored at 12 - 14 ℃ for 10 d and after induced ripening. A. Control I (distilled water) B. Control II (distilled water + gelatin) C. 0.1% carbendazim D. *Aloe vera* gel E. *Aloe vera* gel + 2.0 µL/mL cinnamon leaf oil F. *Aloe vera* gel + 2.0 µL/mL cinnamon bark oil.

Major reasons for the shriveling of mango are rapid water loss and postharvest diseases. *Aloe vera* gel coating was effective in controlling water loss from fruits. This positive effect in terms of reduction of moisture loss may be due to the hygroscopic properties of *Aloe vera* gel that allow the formation of a water barrier between the fruit and the surrounding environment (Misir *et al*., 2014). Therefore, *Aloe vera* gel-coated mango may exhibit comparatively lower shriveling values than uncoated mango sustaining the market quality of fruits.

Sensory properties

All sensory scores were within 6-8 which indicates a satisfactory level of the sensory properties (flesh color, aroma, texture, taste, flavor) of mango subjected to different treatments. Sensory properties, except texture, of mango treated with *Aloe vera* gel, *Aloe vera* gel + cinnamon oils, and carbendazim were not significantly different from the controls ($p > 0.05$). Hence, the treatments carried out have not drastically affected the sensory attributes when compared to the controls. This is in accordance with Kodituwakku *et al*. (2020b), who obtained the same result for mango subjected to basil oil, clove oil, cinnamon leaf oil, and cinnamon bark oil treatments previously (without *Aloe*).

CONCLUSIONS

Dip treatment of *Aloe vera* gel, *Aloe vera* gel + cinnamon leaf oil (2.0 µL/mL), and *Aloe vera* gel + cinnamon bark oil (2.0 µL/mL) effectively controlled SER disease of mango stored at 12-14 ºC and extended the storage life up to 10 d without adversely affecting physicochemical and sensory properties. *Aloe vera* gel coating in combination with cinnamon oils is a safe measure of extending the storage life since treatments are harmless to the consumer as well as the environment. Treatment strategies tested during this research study could be commercialized as environmentally sound, low-cost SER control methods for transportation and storage of mango within a period of 10 d from treatment.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest to report.

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