EFFECT OF CINNAMON ESSENTIAL OIL/β-CD AND LEMONGRASS ESSENTIAL OIL/β-CD INCLUSION COMPLEXES ON PRESERVATION OF PAPAYA FRUIT

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ABSTRACT

Papaya is a tropical and subtropical fruit that has a good taste and is nutritious. However, this fruit is susceptible to diseases caused by fungi, leading to the loss of the quality and quantity of papaya production. To overcome the problem, two inclusion complexes (ICs) of cinnamon essential oil and lemongrass essential oil with β-cyclodextrin (CEO-β-CD and LEO-β-CD), which demonstrated safe and well-researched methods for fruit preservation, are options. In this report, to extend the shelf-life of papaya and increase its physicochemical quality, two ICs (CEO-β-CD and LEO-β-CD) were used (each inclusion complex conducted at two doses of 2.5 mg and 10 mg per gram of fruit). The shelf-life of the papayas in five groups was determined. Moreover, every two days, the papayas were measured in physical and chemical properties. The results exhibited that the four treatment groups had prolonged the shelf-life and enhanced the physico-chemical properties of the papayas compared to those of the control group. Moreover, the CEO-β-CD inclusion complex at a dose of 10 mg per 1 g fruit had a better ability to preserve papaya fruit than others.

Keywords: *Cinnamon essential oil, lemongrass essential oil, inclusion complex, papaya fruit, preservative.*

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1. INTRODUCTION

Papaya (*Carica papaya*) is good tasting; it becomes a mouthwatering fruit when it is slightly firm and slightly soft of firmness, light yellow-green fruit color and a deep orange with yellow flesh color. Besides that, papaya has over 200% of the daily required amount of vitamin C and a rich amount of vitamin A, vitamin E, fiber and antioxidants that aid in everything from anti-aging to stress relief [1]. Papaya plants belong to the *Caricaceae* family. It comes from South America and is widely planted in tropical and subtropical regions with a harvested area of 460,000 hectares in 2019. The dominant area of papaya production is the Asian continent with 7,700,000 tons among 13,700,000 tons of the world's production in 2019 [2].

Despite its nutritional and economic importance, papaya is susceptible to the development of postharvest diseases caused by phytopathogenic fungi [3], such as anthracnose, *Fusarium* fruit rot, stem end rot, black and dry rot, *Rhizopus* soft rot, etc., which can drastically influence to both the quality and quantity of papaya production. Those diseases lead to a reduced shelf - life of papaya fruits, depicting them as unsuitable for consumption or sale, related to mycotoxins produced by fungi [4]. To tackle the challenge, synthetic fungicides are widely used for controlling post-harvest diseases, including benomyl, imazalil, and thiabendazole. However, the long-term use of fungicides could be toxic to human health, harmfully affect the environment and lead to resistant strains [5]. Thus, non-chemical fungicides to control post-harvest diseases need to be developed.

Essential oils (EOs) are secreted by aromatic plants and achieved by steam distillation of leaves, bark, buds, roots, fruits, flowers, seeds and whole plants. They are volatiles and odorous compounds that could be used for antifungal potential. Some studies have exhibited the effectiveness of EOs and their separated components on the preservation of fruits and vegetables [6 - 8]. However, EOs are not only volatile and aromatic but also sensitive to the effects of temperature, light, oxygen, etc. [9]. Therefore, inclusion complexes (ICs) of EOs with cyclodextrins (CDs) have been widely studied to protect EOs and sustain their release [10]. Two ICs of cinnamon essential oil (CEO) and lemongrass essential oil (LEO) with β-cyclodextrin (β-CD) demonstrated a preservation activity and prevented black spots on mango fruit [11].

This study aimed to evaluate the effect of the two ICs CEO - β - CD and LEO - β - CD on the preservation of papaya fruits.

2. MATERIALS AND EXPERIMENTS

2.1. Materials

The CEO-β-CD and LEO-β-CD inclusion complexes (ICs) were prepared following the procedure outlined in a previously reported method [11]. Their characterization was checked using powder x-ray diffraction (PXRD) and fourier transform infrared spectroscopy (FT-IR). Purified water for the experiments was obtained by distillation in the laboratory and all other materials and solvents used were of analytical grade.

2.2. Experiments

Plant material: Uniform papayas in color, shape and weight (~800 grams) were bought from the local market (Da Nang, Vietnam), and washed under tap water, then wiped with ethanol for anti-fungi and then allowed to air-dry. The papayas were randomly divided into five groups, including four IC groups (two ICs at two doses of 2.5 mg per gram and 10 mg per gram of fruit) and a control group for comparison.

For each treatment group, three fruits were placed into a carton box with dimensions of 45 × 25 × 15 cm^3 and a sachet with 6 or 24 grams of ICs was hung inside the box and far from the fruits. One side of the box was transparent for observation. The control group contained three fruits without sachet. The boxes were placed in room conditions.

Estimation of shelf-life of papaya fruit

In this experiment, the shelf-life of a papaya fruit was the period from the beginning of the application of treatment to the point at which the fruit indicated spoilage with a rotten area beyond 21%. The rotten area of the fruit was quantified using ImageJ version 8 software (National Institutes of Health, Java). Two boxes with six fruits per group were used for this study.

Determination of physical quality of papaya: Peel color, weight loss and firmness

A colorimeter (model CS-210; CHN SPEC, China) was used to measure the peel color of the papaya, which recorded values were L*, a*, b*, and h*. Three different positions on the papaya were assessed for average values.

A digital balance (DIGI-DS, Japan) was used to record the weights of the papayas. The weight loss was the percentage loss of the initial weight.

A fruit hardness tester (FR-5120, Lutron, Taiwan) was used to determine the firmness of the papayas. A 6 mm cylindrical probe was pressed into the fruit to a depth of 8 mm. Three different positions on the papaya were measured, and the results were shown in Newtons (N).

Determination of chemical quality: Total soluble solid (TSS) and vitamin C content

A refractometer Atago Master-500 (Atago Co., Ltd., Japan) was used to measure the TSS of fruits at room temperature and expressed as % of dry matter.

Vitamin C (Ascorbic acid) content was determined by colorimetry using 2,6 - dichlorophenolindorhenol titration (according to the AOAC method, 1984) [12].

The quality of papaya was analyzed on days 2, 4, 6, 8, and 10 of the storage time.

Statistical analysis

All data were analyzed by one-way ANOVA. Mean separation was performed by Duncan's multiple range tests, with significance level ($p \leq 0.05$). Statistical analysis was carried out by using GraphPad Prism 6 software (Version 6.0, GraphPad Software, USA).

3. RESULTS AND DISCUSSION

3.1. Shelf-life of papaya fruit

Figure 1 shows the percentage of unrotted papayas in five groups in the storage time. The results revealed notably significant variations in the shelf-life of papayas attributed to diverse treatments. The papaya of the control group started rotting from day 5, and on day 6, all six fruits rotted. In contrast, papayas of two CEO-β-CD groups rotted from day 7, almost all fruits rotted on day 8, and the last rotted on day 9. Regarding two LEO-β-CD groups, fruits just prolonged unrotting to 8 days.

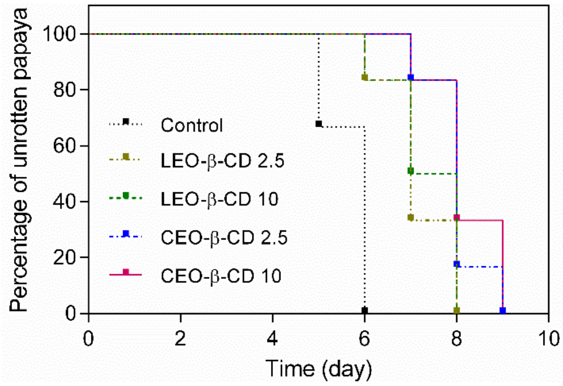

Figure 1. Percentage of unrotten papaya in storage time

Table 1. Shelf-life of papaya of five groups

Group	Control	LEO-β-CD 2.5	LEO-β-CD 10	CEO-β-CD 2.5	CEO-β-CD 10
Shelf-life (days)	6.0 ± 1	7.0 ± 1.5	7.5 ± 1	8.0 ± 1	8.0 ± 1.5

Moreover, table 1 exhibits the shelf-life of papayas in five groups. The results showed that the longest recorded shelf-life of 8.0 days was evident in the fruit treated with CEO-β-CD, while the control group exhibited the shortest shelf-life of 6.0 days. Two groups treated with LEO-β-CD also showed a longer shelf-life with 7.0 and 7.5 days for the doses of 2.5 and 10 g kg^{-1}. These results reveal the efficacy of the CEO-β-CD inclusion complex compared to other groups in prolonging the shelf-life of papaya.

Based on the disease symptoms appearing on the skin of the papayas (Figure 2), some main reasons inducing the rotting of the papaya may be anthracnose, fusarium fruit rot, or rhizopus rot that are caused by *Colletotrichum gloeosporioides*, species of *Fusarium* or *Rhizopus stolonifera,* respectively [3]. ICs could release EOs over time, and in fact, they can inhibit the development of fungi and prevent disease [13 - 15]. Therefore, the ICs at a higher concentration might lead to higher anti-fungal ability and thus might result in longer shelf-life of papaya fruit in the treatment groups than the control group. Moreover, cinnamon essential oil has a higher anti-fungal ability on *Colletotrichum gloeosporioides* fungus than lemongrass essential oil [16], resulting in a respective ability of ICs. Indeed, the results illustrated that CEO-β-CD could preserve postharvest papaya fruit, and extend the shelf - life by 33% compared to the control samples. All the physical and chemical parameters of the papayas in the following experiments were analyzed on the days of fruit spoilage, specifically on day 6 and day 8 for the control group and the treatment groups, respectively.

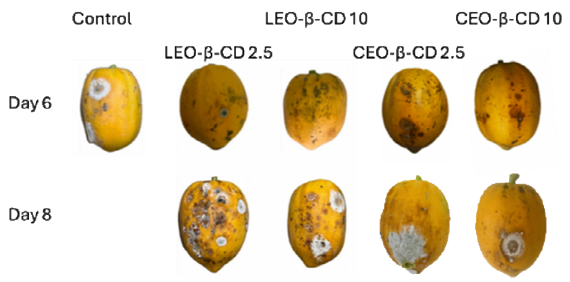

Figure 2. Papaya on day 6 and day 8 of storage time

3.2. Physical quality of the papaya fruit: weight loss, peel color and firmness

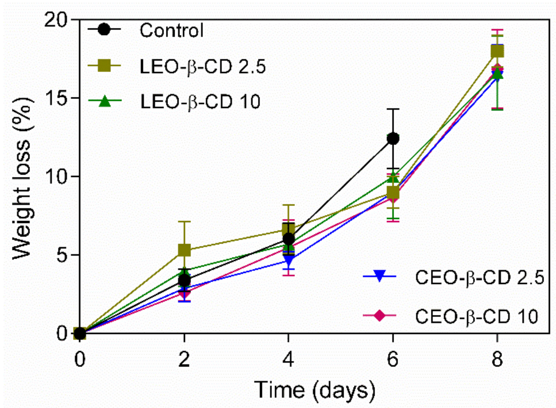

Figure 3. The weight loss of the papaya fruits during storage time

Weight loss

The weight loss of the papaya fruits gradually rose in five groups during storage time due to its natural ripening process (Figure 3). By day 6, the average weight loss of the treatment groups was still under 10% of the initial weight, while that of the control group was about 12%. During the storage period, the temperature induced the release of some molecules such as water, ethylene, or carbon dioxide from the flesh to the peel, leading to weight loss [17]. On day 8, the weight loss of the treatment groups significantly increased, which might be due to the rotten process of papaya.

Firmness

The firmness of the papaya in five groups decreased from day 2 (Figure 4). After two days of storage, the firmness of the fruits in the control group showed a noticeable decrease compared to that of the treatment groups, by approximately 60% and 30%, respectively. Subsequently, the firmness of the fruits rapidly decreased in all five groups throughout the storage period. On day 8, the firmness of fruits of the CEO-β-CD at the dose of 10 g kg^{-1} group was highest, followed by CEO-β-CD at the dose of 2.5 g kg^{-1}, LEO-β-CD at the dose of 10 g kg^{-1} and LEO-β-CD at the dose of 2.5 g kg^{-1} groups. The above results could be ascribed to changes in the contents of some compounds in the papaya flesh, such as polysaccharides, pectin, or starch, resulting in the firmness decline of the papayas over time [17].

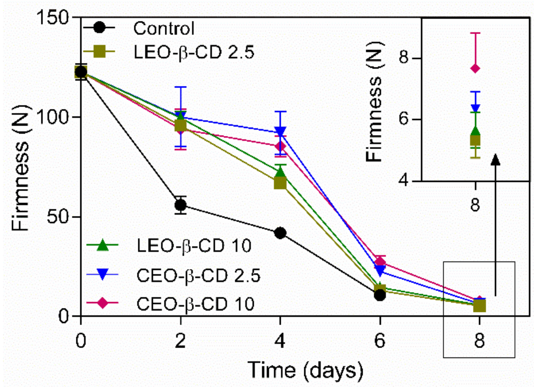

Figure 4. The firmness of the papaya fruits during storage time

Peel color

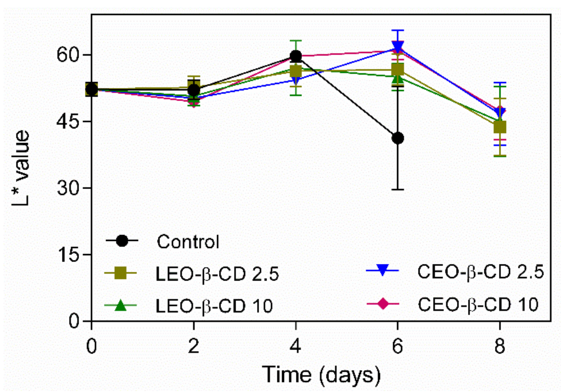

Figure 5. The L* value of peel color of the papaya fruits during storage time

Figure 5 and 6 demonstrated the change in peel color of papayas during treatment with ICs. The L* values of the papayas in all five groups leveled off in the first two days of the storage time, then increased and then decreased. This decrease can be attributed to the appearance and spread of black spots on the skin of the fruits (Figure 2). On day 8, the L* values of two CEO-β-CD groups exhibited a higher data than that of the LEO-β-CD groups. The h* value (hue angle) (Figure 6) showed a reducing trend in the five groups. These values of the five groups were about 110 on day 0 and decreased to 80 on day 6, and then on day 8, these values of the CEO-β-CD and LEO-β-CD groups were about 70 and 65, respectively.

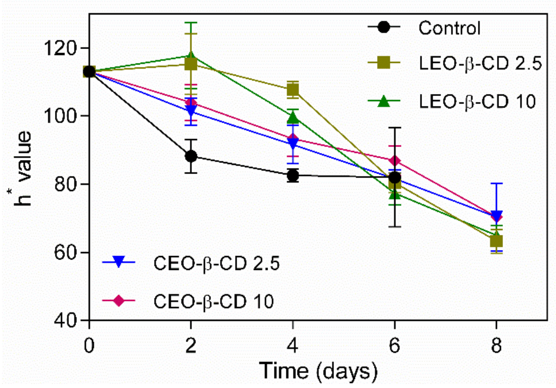

Figure 6. The h* value peel color of the papaya fruits during storage time

3.3. Chemical quality of papaya fruit: Total soluble solid (TSS) and vitamin C content

Total soluble solid (TSS)

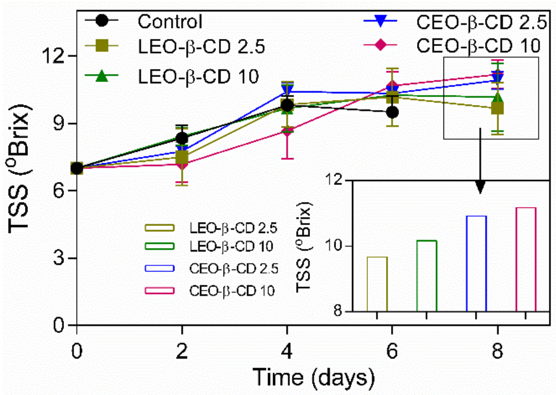

Figure 7. The TSS of the papaya fruits during storage time

The TSS of papaya fruits increased during the ripening process, as shown in Figure 7. The TSS of the papayas in five groups started at 7 °Brix on day 0, then increased fast in the first six days, and then almost leveled off on day 8. In detail, the TSS of fruits of the control group rose steadily to 11°Brix on day 6. While the TSS of the fruits of the LEO-β-CD groups exhibited a slight decrease on day 8. In contrast, the TSS values for the fruits of CEO-β-CD groups still rose to about 11.0 and 11.2°Brix on day 8. Moreover, in these four treatment groups, the TSS of the papayas of the CEO-β-CD 10 group presented a gradual increase from day 0 to day 8 and the highest TSS value at the end of the storage period.

Vitamin C

Figure 8 reveals the vitamin C content in the fruits during the storage time with various IC treatments. In the first two days, the vitamin C content of the fruits in all five groups increased, followed by a significant decrease. Among the five groups, the control group exhibited the fastest reduction in the vitamin C content of values of 0.14 mg/100 g of fruit flesh on day 2 and approximately 0.06 mg/100 g of fruit flesh on day 6. The four treatment groups had the same trend as the control group but a slower decrease. By the end of the storage period, the vitamin C in 100 g of flesh for the four treatment groups was around 0.037 mg. These results align with the natural degradation of the vitamin C compound in fruits over time [18]. Furthermore, on day 8, the vitamin C content of fruits of the CEO-β-CD 10 group was the highest compared to that of the other groups.

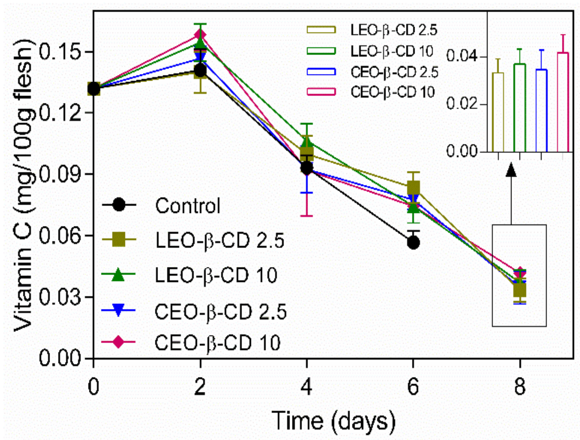

Figure 8. The vitamin C content of the papaya fruits during storage time

The changes seen in the physico-chemical parameters of papayas can be linked to their ripening and subsequent decay after being stored for six days. In the control group, the fruits started decaying by the fourth day, which led to reduced levels of TSS and vitamin C. Additionally, the ICs steadily released EOs over time, which helped to prevent fungal diseases. This resulted in higher TSS and vitamin C levels in the treated groups, particularly notable in the CEO-β-CD 10 group. The EOs from the ICs were instrumental in preserving the fruit and maintaining its chemical parameters during the storage period.

4. CONCLUSIONS

In summary, both CEO-β-CD and LEO-β-CD inclusion complexes were effective in extending the shelf-life and improving the quality of papayas. Notably, the CEO-β-CD inclusion complex demonstrated a pronounced ability to preserve papayas, especially at a concentration of 10 mg/g. This effectiveness was marked by prolonged the shelf-life of papayas by 25%, reduced disease symptoms, increased fruit firmness, stable peel color, elevated levels of total soluble solids, and enhanced vitamin C content, outperforming other treatments. These results suggest that the CEO-β-CD inclusion complex, at a dosage of 10 mg per gram of fruit, is a potent preservative for maintaining the quality of papayas post-harvest.

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