Original Research Article

Pomelo (*Citrus maxima*) Peel Extract as Biopreservative Coating for Selected Fruits

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ABSTRACT

This study aimed to investigate the biopreservative potential of 0.5% (w/v) lyophilized pomelo (*Citrus maxima*) peel extract as a coating for selected fruits, namely: Philippine mangoes and Cavendish bananas. An experimental descriptive research design was employed to analyse the deviation of weight, pH and sensory evaluations (colour quality and firmness) on bananas and mangoes over 8 days. Moreover, the qualitative analysis of phytochemicals and titratable acidity as citric acid was conducted. Mean and standard deviation were used to obtain the key findings of the study. Results showed the detection of flavonoids, phenols and tannins at a high concentration. Titratable acidity as citric acid was determined with a concentration of 0.096%. The percentage weight loss showed an average percent actual weight loss of 9.93% and 14.26% for pomelo peel extract (PPE) coated mangoes and bananas respectively. The physiochemical characteristics of mangoes and bananas when treated with PPE solution, gave positive results in deviation of weight and pH during the 8-day observation period. The tests conducted for sensory evaluation were colour quality and firmness. Colour quality and firmness were more retained in the mango samples as they still had an acceptable colour quality after the 8-day observation period and maintained a sprung firmness. The extract was able to highlight successful biopreservation on the selected fruits in different levels of effectiveness as shown by the average weight reduction. The findings of the study show that pomelo peel extract has biopreservative properties in the selected parameters. However, more sensory tests and a higher concentration of the extract are needed to be sure.

Keywords: Food Chemistry, pomelo peel extract, fruit bio preservation, phytochemicals, citrus maxima, peel extract.

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1.0 Introduction

Sensory properties play a significant role in the likes and dislikes of consumers as they guide in making food-related decisions and intake behaviours (1). Several properties of food, such as texture and appearance can impact the desire of people to eat and have an appetite and are one of the factors that decide whether the food is unappetizing, stale, or even inappropriate to eat (2). Food is determined by physical properties and sensory attributes. Consumers have a high demand for quality food products as it reflects the value of the price to pay for them (3). Sensory properties play a large role in marketing, consumer decisions, and food distribution. When consumers refuse to think of certain foods as acceptable for consumption due to bad sensory properties, sales go down, and food spoilage increases.

Consumers have been demanding more "organic food," and using complex chemicals most people are not familiar with, as preservatives have become difficult. With this problem, the use of plant-based preservatives is best; as shown in a study using aloe ver*a* extract as a preservative for selected perishable fruits and vegetables, with the results showing suppression of weight loss, delayed ripening, delayed reduction of titratable acidity, and fewer changes in appearance, it is found in the study that with the use of soaking the fruits and vegetables in water containing 25-50% aloe vera extract, they were successfully preserved. Results showed the potential of biopreservative in preserving food (4). Additionally, a study conducted discovered the bio-preservative potential of plant-based edible coatings on the post-harvest quality of guava fruits. It was found that the guava fruits that were applied with the plant-based edible coatings incorporated with extracts showed a great number of preservative effects; these were observed through the decreased level of physiological weight loss, decreased amounts of total soluble solids, as well as the increase in juice pH (5).

Several plants have shown potential in having an application in food biopreservation in means to become a possible solution for food spoilage, one of these plants is pomelo. Pomelo (*Citrus maxima*) is a type of citrus fruit called shaddock or Chinese grapefruit. Pomelo is known to contain an extensive range of components, such as phytochemicals and essential oils, with various food applications. Pomelo peels account for 30% of the fruit's overall weight. They contain several phytochemicals contributing to their great potential as preservatives (6). It is predominantly grown in Southeast Asia and is mainly consumed in Southeast and East Asia. Other areas that grow pomelo include Mexico, Southern California, and Florida. It is known as the largest citrus fruit and is one of the known fruits with large amounts of agricultural residual waste. In the Philippines, specifically in Davao City, pomelo is abundant and the city is one of the world's largest producers and exporters of pomelo.

Despite the extensive literature on fruit extract-related preservatives, limited studies have been conducted about pomelo peels. In addition, this study aims to focus on the biopreservative effects of the peel extract on fruits, an area of limited research compared to previous studies focusing on meat. In addressing this research gap, this biopreservative had a significant practical impact in decreasing the global issue of food losing good sensory properties through preserving fruits and opens the potential to preserve other fruits using pomelo peel extract. Moreover, with this affordable approach to food preservation, fruits will have lower chances of losing quality due to decay of sensory properties which can benefit

fruit and vegetable farmers, distributors, and markets worldwide.

In this study, pomelo peels were extracted and analysed qualitatively for the presence of phytochemicals using various tests. The extract was utilized on the fruit samples as a coating to observe the extract's biopreservative potential and effects for 8 days in the following parameters: deviation in actual weight, deviation in pH, and sensory evaluation of colour and firmness. Preservatives are additives that hinder oxidation, which is one of the main steps and reason for rotting; this is done through either aerobic or anaerobic mechanisms (6).

2.0 Materials and Methods

2.1 Plant material

Pomelo, mangoes, and bananas were obtained from a local seller in Bankerohan, Davao City; the samples were chosen regardless of shape and size but were discarded if there was any sign of bruising and fungal infection. A botanist from the University of Southern Mindanao, North Cotabato, authenticated the collected plant sample. The authentication of the plant samples is important to ensure that the obtained peel extract is from the fruit peels of *Citrus maxima* and not another fruit, as well as it is to ensure that the selected fruits being tested are accurate.

2.2 Preparation of plant extract

Pomelos (*Citrus maxima*) were collected, hand-peeled, cut, and washed (5,7). The peels were then dried in a dehydrator for 30-45 minutes. A solution with a ratio of 1:8 was prepared (8). Specifically, 50g of the dried peels were mixed with 400 ml 95% ethanol (9) and macerated in a refrigerator for 7 days; when it was out of the refrigerator, it was manually shaken for a few minutes. The extract was then filtered using Whatman (No.1) filter paper and put into a rotary evaporator for 60 minutes at 40-60 ºC (10) or until the solvent had been completely evaporated to increase the extract concentration and remove the solvent. The crude extract is then dried using a freeze drier with temperatures between -34° and -45 °C and stored in the dark at 4 ºC in an airtight container until further use (11).

2.3 Phytochemical content and percent titratable acidity as citric acid of lyophilized pomelo peel extract

Plant extracts were tested for the presence of phytochemicals following the qualitative test (12-16) and the determination of citric acid content using titration was conducted (17). The titrant used was 0.5M sodium hydroxide (NaOH), 10ml of pomelo peel extract was used as an analyte and three drops of phenolphthalein with the addition of 30ml water. The endpoint was determined with a permanent appearance of pink colour. The percentage of citric acid in the sample was determined using the following formula:

$$Percent\ citric\ acid = \frac{Mass\ of\ citric\ acid}{Mass\ of\ PPE}\ x100$$

2.4 Preparation and application of pomelo peel extract coating, chitosan coating positive control, and uncoated negative control

The peel extract coating solution (0.5% w/v) was prepared by weighing 0.5g dry pomelo peel extract dissolved in 100 ml of deionized water. For the positive control, chitosan was used, and the concentration of the coating solution was 0.5% w/v chitosan. This is prepared by dissolving while vigorously

stirring 5g of chitosan powder into a solution that contains 0.5% (v/v) acetic acid with 25% glycerol (w/w chitosan), as a plasticizer. The resulting solution was then filtered to remove insoluble components and stirred again until it was completely homogenous while gradually adding 30 ml of 1N NaOH until it reached a pH of 6-7 (18). The pomelo peel extract solution was prepared without glycerol, acetic acid, and NaOH added to observe the potential of the pomelo peel extract alone.

The fruit samples were dipped in the pomelo peel extract solution for 1 minute and 30 seconds. Additionally, the fruit samples that represented the chitosan-positive control samples were dipped in the prepared chitosan coating solution for 1 minute and 30 seconds. The negative control samples were then dipped in distilled water. All the samples were observed at room temperature (5) with no form of packaging for 8 days while monitoring the preservative effects of the extract on the fruit samples every 2 days.

2.5 Quality of mango and banana post treatment with lyophilized plant extract over eight-day period

Selected ripe fruits were collected regardless of size. Three trials were done with the pomelo-treated samples, chitosan-treated positive control samples, and non-treated negative control samples. The fruits were kept in plastic trays for the duration of the observation phase, and all observations were conducted at room temperature. A representative sample from each group were tested prior to treatment and the results indicated a 0-day treatment. For the deviation in actual weight -the changes in deviation in actual weight were monitored and recorded in percent weight loss to determine the changes in physical weight as the fruit samples aged. There were three representative samples for this test; this was tested by weighing the sample every 2 days using an analytical balance (8,19). The results were calculated using the following formula:

$$Percent\ Weight\ Loss\ (\%WL) = \frac{(Initial\ Weight - Final\ Weight)}{Initial\ Weight}(100)$$

For deviation of pH-, the pH levels of the fruit samples were monitored and recorded to determine the changes in basicity and acidity levels. There were three representative samples for this test. The pH was determined by analysing the fruit pulp juice. This was prepared by weighing 10 g of fruit pulp and blended with 100 ml distilled water using Thermo Scientific: Eutech pH 150 pH meters.

During 8 days, sensory evaluations of colour quality and hardness were conducted every two days. The colour of the peel was checked and subjectively observed following the 1-5, rating scale in the study of Nunes et al. (20).

2.6 Statistical analysis

Data were expressed as mean ± standard deviation.

3.0 Results

3.1 Phytochemical content and percent titratable acidity as citric acid of lyophilized pomelo peel extract

The phytochemicals present in lyophilized pomelo peel extract were shown in Table 1. The pomelo peel extract (PPE) also gave positive results for the presence of citric acid, with a content of 0.096%. Citric acid is one of the main organic acids of citrus fruits.

Table 1: Phytochemical content of lyophilized PPE

Phytochemicals	Concentration in Extract Solution
Flavonoids	Positive
Phenolic	Positive
Saponins	Negative
Tannins	Positive

3.2 Quality of mango and banana post treatment with lyophilized plant extract over eight-day period

The biopreservative effects were observed in three trials for 8 days, with testing being done every 2 days. The following results were obtained and presented in Table 2.

Table 2: Deviation in actual weight and pH of mango and banana post treatment PPE over 8-day period

Fruit	Treatment	Average % Loss in Actual Weight
Mango	PPE	9.93% ± 0.48, Acceptable
	PC	14.16% ± 0.76, Acceptable
	NC	14.27% ± 0.71, Acceptable
Banana	PPE	14.26% ± 0.67, Acceptable
	PC	14.12% ± 0.61, Acceptable
	NC	14.94% ± 0.77, Acceptable

The average weight reduction percentage for bananas and mangoes over the course of eight days is the percentage value.
According to a study by Opara et al., a product is deemed overripe if its weight decreases by less than 21% within 8 days of room storage (21).
PPE – Pomelo peel extract
PC-Positive control
NC – Negative control

The pH levels of mangoes and bananas changed over the course of an 8-day observation period, as seen in Figure 1 and Figure 2; sensory assessment is shown in Table 3.

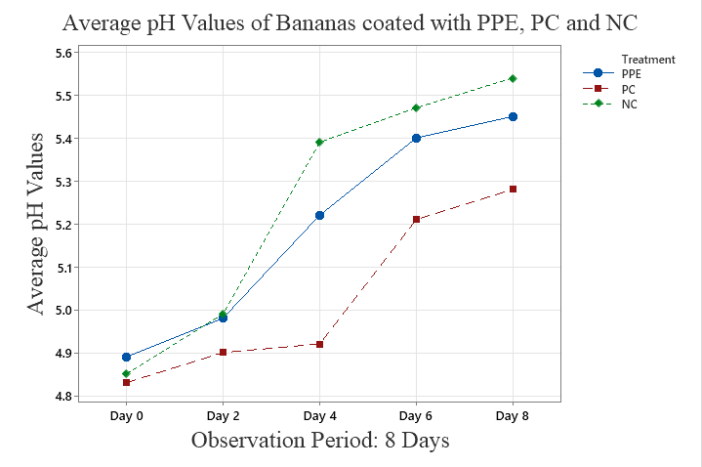

Figure 1: Average pH values of bananas coated with PPE (pomelo peel extract), PC (Chitosan) and NC (distilled water).

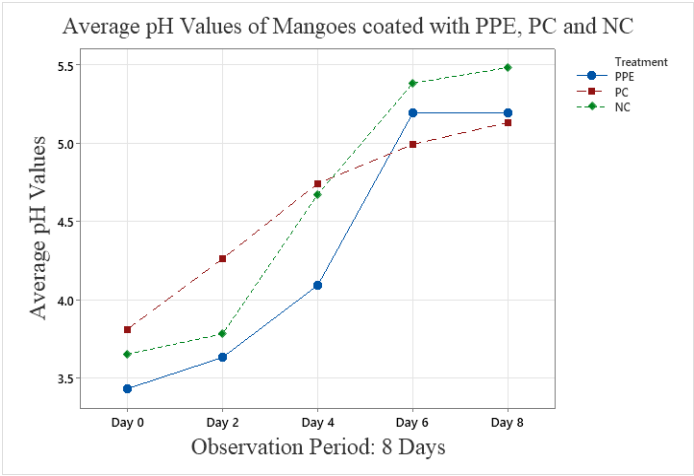

Figure 2: Average pH values of mangoes coated with PPE (pomelo peel extract), PC (Chitosan) and NC (distilled water).

Table 3: Sensory assessment using the mean colour quality and firmness after eight days of treatment

Fruit	Treatment	Color Quality	Firmness
Mango	PPE	2	2
	PC	1	3
	NC	1	3
Banana	PPE	1	3
	PC	2	3
	NC	1	4

Peel colour evaluation following the scores and description in the study of Nunes et al. through a 1-5 scale of colour, 1- full yellow, flecked with brown spots (very poor), 2- full yellow (poor), 3- more yellow than green (acceptable), 4- half green and half yellow (good) and 5- light green ripening process just began (excellent) (20).

The firmness was determined and monitored using the method in the study of Rahman et al. through a 1-5 scale of firmness, 1 = hard, 2 = sprung, 3 = slightly soft, 4 = eating soft and 5 = over soft (19).

4.0 Discussion

The phytochemical analysis revealed that the pomelo peel extract contains high concentrations of flavonoids, phenolic compounds, and tannins, particularly flavonoids and phenolics. This indicates that various phytochemicals with various bioactive qualities that aid in food preservation are abundant in the pomelo peel extract. These include the antioxidants found in phenolic, which can help postpone enzymatic browning. The findings are consistent with the study which found that flavonoids, the active ingredients in pomelo peels, are present (22). Furthermore, the study supports the findings that citrus fruits contain flavonoids, which may be identified by their aroma (23).

The findings also support the research which found that pomelo peels contain phenolic chemicals in both the albedo and flavedo regions (19). Furthermore, result of the study claims that pomelo peel contains these phytochemicals (24, 25). The study's findings are also consistent with the results wherein tannins were present in the pericarp of pomelo grown in the Philippines (26, 22).

With a level of 0.096%, the PPE likewise produced positive results for the presence of citric acid. One of the primary organic acids found in citrus fruits is citric acid that is used as natural preservative. The findings support the study that the citric acid in pomelo contributes to its sour flavour (27).

For weight loss, the maximum acceptable percentage weight loss of banana is 21% until it is considered overripe in a span of 8-days in room storage conditions. The PPE coated mangoes showed an average percent actual weight loss of 9.93%, meanwhile the positive control (PC) and negative control (NC) coated bananas have an average percent weight loss of 14.16 % and 14.27% respectively. Moreover, the PPE coated bananas have an average percent weight loss of 14.26%, the second lowest compared to the positive control which had the lowest amount of weight lost 8 days after treatment.

Overall, PPE produced favourable findings, particularly in samples treated with mango, which had the least amount of weight loss over the course of the observation period, demonstrating the biopreservative benefits. The findings are consistent with a study showing that banana extracts may maintain the weight of banana samples, with the bananas that received no treatment losing weight the quickest (19).

Furthermore, the results align with the study in which they utilize the bioactive properties of the pomegranate peel extract to maintain the quality attributes and characteristics of mangoes (28). Moreover, the results obtained also conform to the mango weight loss that was also remarkably reduced with the addition of Guar-based

edible coatings enriched with *Spirulina platensis* and *Aloe vera* extract (29).

For the average pH, level of bananas and mangoes increased over time during observation. The negative control had the highest average pH change for the bananas and mangoes. The PPE for the banana pH showed positive results in slowing down pH change but had a large difference compared to the positive control. Meanwhile, the mango pH showed positive results in slowing the pH change. The results show that the average banana pH of the PPE-treated banana samples gave positive results for the biopreservative effect of the plant extract.

The increase in the pH level indicates the lowering of the stability of the fruit, which is causing the decay. Findings confirm the results of a study wherein treated samples are the samples with the lower pH level and the samples that have been preserved based on the other supporting tests done in the study (30). This increase in pH is due to the loss of acids in the fruit, such as citric acid.

The results also conform to the study that used the combination of lemon peel extract and calcium chloride on the dessert banana (31). This is because the pH of the bananas increased uniformly, but despite that, the pH of the treated bananas was lower compared to the control. Moreover, the results also align with a study regarding the effects of bio-based coatings on the ripening and quality attributes of tomato fruits, as the study also ended with similar results, in which the pH of the control was also higher compared to the treated fruit samples (32).

For the colour, using the visual observation of the fruit peel, at the end of the observation period, the PPE extract was not able to retain the colour of the banana peel as much, resulting in a very poor colour sensory evaluation and lack of biopreservative effects. On the other hand, for PPE -treated mangoes, the PPE treatment was able to retain the mango sample's colour, making it still have a colour that is acceptable after the 8-day observation period. These results show that the mango was able to retain more of its colour during the observation period, highlighting the PPE treatment's biopreservative effects. However, for banana, the positive control is better compared to the PPE-treated and negative control.

The results obtained align with the results of a study wherein one of the key tests and indicators for preservation was the resistance to colour change, pH alterations, and weight loss (33). This is observed in the extension of the postharvest shelf life of strawberries using a coating of chitosan-whey protein isolate conjugate. Where they observed that the coated strawberries that resisted colour change, also increased in shelf life, resulting in preservation.

The results of the study also confirm the colour variation that is found in a study about the efficacy of antioxidant extract from lemon by-products on preservation of minimally processed radish (34). This study has a similar aim in using food-grade antioxidants to extend the shelf life of radishes. It is shown in the study that the radishes that were treated by the extract had minimal colour variation, which aligns with the results of the study, as colour variation is minimal when colour and/or hue have minimal changes as well. Moreover, the results of the study further confirm the results of the study wherein the effects of pomegranate peel extract and/or lactic acid as a natural preservative for date fruits (35).

For firmness, it was tested using a scale of 1-5. The PPE-treated bananas gave a value of 3 in firmness, being the middle value between the positive and negative control. This resulted in the firmness of the PPE-treated bananas to be soft by description. Meanwhile the PPE treated mangoes gave a result of 2, Overall having the lowest firmness value compared to

the positive control and negative control with the value 3.00 interpreted as very sprung firmness. PPE in mangoes highlighted the bio preservative properties of the PPE treatment, by having a lower value than the positive control. Additionally, the banana-treated samples highlighted bio preservative effects when compared to the negative control with a firmness description of eating soft by the end of the observation period, a value that is closer to being over ripened or spoiled.

The findings are consistent with a study where strawberries lose firmness with age, fruits coated with chitosan-hawthorn leaf extract showed increased firmness, further supporting the study's findings that samples treated with natural extracts and bioactive compounds can maintain a fruit's firmness (36). Additionally, a study found out that edible coatings with antioxidant or anti-browning properties preserved the sensory qualities of fresh cut pears (37).

5.0 Conclusion

The PPE showed biopreservative effects on selected fruits based in different levels of effectiveness among the different tests conducted. The physiochemical characteristics of mangoes and bananas when treated with PPE solution gave positive results in deviation of weight and pH, and an acceptable colour quality and retention after the 8-day observation period. Thus, with all the observed effects, PPE is a good natural preservative. However, for a larger scope and data on the sensory property retention of the PPE, sensory evaluation on taste and smell may be conducted.

Authorship contribution statement

MLC: Visualization, Methodology, Experimented, Data analysis, Writing-original draft. **GMZ:** Visualization, Draft corrections, Writing- review and editing.

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Conflict of Interest

The authors declared that they have no conflicts of interest to disclose.

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