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Effects of Alginate-based Chitosan-Starch Coating on the Physico-Chemical Properties of Guapple (*Psidium guajava* L. cv. Queso de Bola)

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ABSTRACT

Because of its nutritious qualities and growing demands, an attempt to support the Philippine Guapple industry was enacted through edible coating. Especially those of starch and chitosan formulation, edible coatings are known to develop low-cost and biocompatible resistance from the drastic changes that commodities experience from their surroundings. Thus, becoming a low-cost technology to prevent yield losses and decrease rate of senescence for selected fruits. With the control treatment as the designated Treatment 1, Treatment 2 Guapples are treated with coating concentrations of 2% Alginate + 0.5% Chitosan, and Treatment 3 Guapples are those that have been treated with 2% Alginate + 0.5% Chitosan + 2% Starch. This setup identifies if the variations of Starch and Chitosan concentrations affect the overall postharvest qualities of Guapples. The physico-chemical parameters were measured through non-destructive and destructive tests, as they relate to the overall process of senescence. Replicated four times in ambient conditions (28°C, ~80% RH), the physico-chemical variables are recorded periodically in a span of one week. It was found that in moisture loss deterrence, the coating from Treatment 2 is the most effective, with significant moisture loss deterrence (vs. Control) found during Day 2. On the other hand, it was found that in preserving the Guapples from Browning, Treatment 3 does it slightly better. No other significant changes were found in terms of other chemical properties of Guapple such as Total Soluble Solids, Titratable Acidity, pH, Firmness, and Ripening Index. Furthermore, the consumer sensory evaluation suggests that they are unable to find any significant preferential difference, except for slight preferences in Visual Quality found in Guapples with Treatment 3. Moving forward, maintaining temperature in the laboratory is recommended as it is determined to be a confounding variable that may have affected results in a warm June climate.

Keywords: guapple, edible coating, alginate, chitosan, starch

INTRODUCTION

Despite the nutritious distinction of Guapples, also known as the 'Queso de Bola' variety of Guava (Psidium guajava L. cv. Queso de Bola), it remains one of the most underutilized fresh fruits in the Philippines (Rodeo et al., 2017; Shamshad et al., 2021), even with its annual production of 750,000 metric tons (FAO, 2021). Therefore, one of the challenges of food security is to ensure that industries like Guapple, with significant market potential, are developed and supported with sustainable technologies. According to Gustavsson et al. (2011), most food losses in developing countries can be attributed to inefficiencies at the production and distribution levels. Reliable postharvest handling is especially important in these countries, given that Guapples have only a 6-7 day ambient storage shelf-life (Zuniega & Esguerra, 2020). Innovative systems are required to counteract the extreme climatic conditions within a tropical country. In fact, postharvest losses of Guava can be as high as 40% in developing countries (Sharma, 2021). This further accounts for about 4.1% lost to improper storage and 3.7% lost to packaging and transportation (Yadav et al., 2022).

Current local and international studies surrounding Guapple and Guava include the use of Modified Atmospheric Packaging with optimized gas concentrations of 9% O_2 + 5% CO_2 in 50-µm LDPE bags (Antala et al., 2014) and exposure to 1-methylcyclopropene, which retains the physiological crunchiness of Guapple, prolonging its marketability (Zuniega & Esguerra, 2020; Iqbal et al., 2018). Although effective, these technologies may be difficult to acquire in some local regions within the country. Thus, exploring other sustainable and low-cost solutions is essential.

It has long been considered that food-safe edible coating, if applied correctly, can extend the post-harvest life of fresh fruits and vegetables (Sharma et al., 2019). These thin coatings can act as barriers against moisture and harmful contaminants during handling, extreme changes in temperature, and ultimately serve as immediate shielding for mechanical stresses (Yadav et al., 2022). Thus, preventing the conditions that may accelerate the deterioration of the fresh produce.

Most edible coatings carry active ingredients (e.g., antimicrobial) to maximize the preservation of the fruits. Zam (2019) used alginate-based chitosan edible coating integrated with olive leaves extracts in order to coat sweet cherries. Tabassum & Khan (2019), on the other hand, also utilized chitosan-coating as it is integrated with other naturally occurring essential oils, such as Thyme and Oregano inoculants. Several other studies use different proportions of ingredients to improve the food quality of chosen fruits. For the purpose of this study, it looked into the infusion of starch-based coating into the chitosan edible coating. Sapper & Chiralt (2018) stated that even though starch-based coatings exhibit several advantages, such as good filmogenic capacity and availability, it is still very limited by its weak water vapor barrier properties. Chitosan, on the other hand, avoids loss of water and improves firmness of the inoculated products (Tabassum & Khan, 2019). Furthermore, unlike chitosan, Starch-based coating effectively prevents anaerobic growth of microbes that are severely toxic for human consumption. Silva et al., (2021) saw the important characteristics of these two types of coating that they integrated the native cassava starch into the gelatin-based chitosan coating.

With the intention of filling the gap in alginate-based starch and chitosan research in Guapple production here in the country, it will look into several parameters such as physico-chemical properties, eventually affecting both its shelf life and quality. This ties back to the overall idea of supporting such an underutilized and nutritious fruit with an untapped market potential. Specifically, this study is intended to build on the studies of Zam (2019), Sapper & Chiralt (2018), and Silva et al. (2021), to investigate the effects of Chitosan and Starch coating as they are applied to the context of the Philippine Market – particularly the underutilized Guapple concurred by Rodeo et al. (2017) and Shamshad et al. (2021).

This study aimed to determine the effects of alginate -based chitosan starch coating to the overall physico

-chemical and sensory properties of Guapple. It determined the effects of different proportions of ingredients in the Alginate-based Chitosan coating as they are applied to the Guapple in terms of Total Soluble Solids, Titratable Acidity, pH, Ripening Index, Color, Firmness, and Moisture Loss. It also looked at the most appropriate proportions of ingredients in the Alginate-based Chitosan Coating, as they relate to the sensory properties such as Taste, Visual Quality, Crispness and Crunchiness, and Overall Assessed Rating.

MATERIALS AND METHODS

Fruit Preparation and Experimental Design

The preparation of the Guapples is consistent with the methodologies proposed by Silva et al. (2021), as each Guapple fruit is soaked and lightly rinsed in distilled water before the coating process. Then, they are air-dried at room temperature until such a time that the surface is dry enough to facilitate the application of formulated edible coating.

Figure 1. Guapple Soaked in Distilled Water

After the preparation process, the treated Guapples were separated into three sets depicting different proportions that aimed to answer the objectives of the study. The different proportions of ingredients are as follows: (1) Control Treatment - No Edible Coating was applied; (2) 2% Alginate + 0.5% Chitosan; and (3) 2% Alginate + 0.5% Chitosan + 2% Cornstarch.

Edible Coating Preparation and Application

The 1000 mL of Alginate-based Edible coating were prepared for each treatment. The said Alginate solution is formulated by dissolving the Food-grade Sodium alginate powder in hot water (~50°C) to create a solution with 2% (w/v) concentration. Simultaneously, the n% (w/v) Cornstarch powder is also dissolved within the same solution. After the addition of the cornstarch, the Alginate solution will be cooled down to room temperature. Then, the 1% (w/v) calcium chloride solution and 2% glycerol will be added to the coating as a firming and plasticizer agent, respectively.

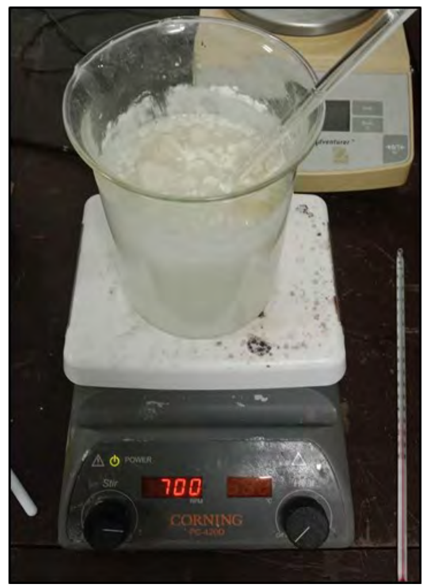

Figure 2. Formulation of Edible Coating

The 0.5% (w/v) chitosan particles were dispersed in a 0.5% (v/v) citric acid solution and agitated through magnetic stirring (700 rpm) for 4h. Then, both the alginate solution and chitosan solution are then combined until homogenized to create the final formulated product. By this time, the treated Guapples are then immersed in the combined filmogenic solution for 1 min and then dried in still-air room temperature as seen in **Figure 3**.

They are then stored in room temperature and relative humidity conditions (28°C, ~80% RH) for

Figure 3. Guapple Applied with Edible Coating

observation - to simulate the conditions that could be faced by Philippine Guava varieties in commercial environments (e.g., Wet Markets).

Moisture Loss Determination

The moisture loss was measured through the weight loss formula used by Lim et al. (2011) on their edible film research as presented below.

Equation 1

$$Moisture\ Loss\ (\%) = \frac{W_0 - W_1}{W_0}\ x\ 100\%$$

Wherein W_O is the initial weight of the treated Guapple, and is the weight at the time of measurement. The determination of weight loss is determined up until the terminal day of the experiment (Day 7), or until the Guapple Fruit is determined to be unfit for consumption. The regular measurement would be administered every two days and would be done through Nondestructive measurements aided by the OHAUS AR0460 Digital Weighing Scale.

TSS, TA, pH, and Ripening Index Determination

Every two days, the destructive determination of Total Soluble Solids (TSS) and pH are carefully executed. Fruit pulp is extracted from each of the Guapple fruits through a food-grade blender (Eureka EEB-1.25L). On the other hand, the Titratable Acidity and Ripening Index are only recorded at the Day 0 and terminal date of the experiment due to economic and time considerations.

To determine the TSS, 2 mL of the Guapple pulp would be fed to a hand-held refractometer. The instrument would automatically measure the TSS by Brix. On the other hand, the Digital Electrode pH meter would be used in 5 mL of Guapple extract to determine the pH of the fruit as the experiment progresses. Both instruments are calibrated before the experiment: with the refractometer using distilled water, and the pH meter using the pH-4 and pH-7 calibration liquid.

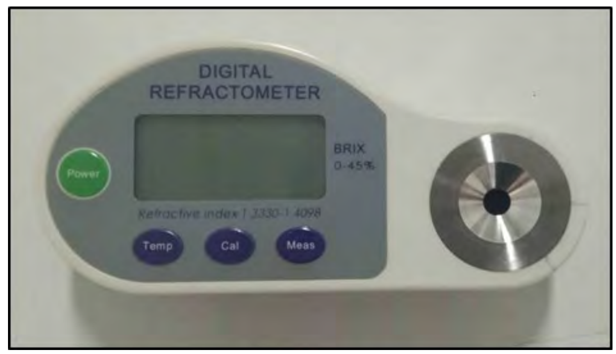

Figure 4. DBR 35 Digital Handheld Refractomer

Figure 5. Laqua Electrode pH Meter

To determine the Titratable Acidity (TA), the extracted pulps are sent to a third-party laboratory that is approved and recommended by both the Food and Drug Administration and the Department of Science and Technology. After the measurement of the Total Soluble Solids and Titratable Acidity, the Ripening Index was then calculated as the ratio between Total Soluble Solids and Titratable Acidity.

$$Ripening\ Index = TSS/TA$$ **Equation 2**

Color Indices and Firmness

The Color Indices were measured through the Konica Minolta CR-10 Colorimeter to get the objective measurement of the average lightness of the color (L*), average red color (a*), and average yellow color (b*). By nominating random sections in each Guapples, the color parameters were recorded to track the progression of the Guapple Fruit per two days. The calibration done on the Color meter is to use a standard white tile where the real L*, a*, b* values were derived.

Figure 6. Konica Minolta CR-10 Color Meter

In line with this, the Browning Index is then computed per each guapple fruit per day. This methodology is adapted from the study of Ding & Ling (2014), as they cite the study from Ruangchakpet and Sajjaanantakul (2007), in the mathematical expression to be used to ascertain the browning of several fruits as seen in the equation below:

$$BI = [100(x - 0.31)]/0.17$$ **Equation 3**

Wherein "x" is derived on the following formula proposed by Ruangchakpet and Sajjaanantakul (2007), as seen below:

Equation 4

$$x = (a^* + 1.75L^*)/(5.645L^* + a^* - 0.3012b^*)$$

Furthermore, to determine the objective Firmness of the Guapple Fruit, the use of a universal testing machine (Instron Series IX Tester) was executed. Using an 8-mm rounded tip plunger, with 10mm/ minute crosshead speed, the firmness of the Guapples were then measured. Upon the yielding of the Guapple Peel, the objective measurement of the texture of the Guapples was garnered.

Figure 7. Firmness Testing of Guapple Samples

Sensory Assessment

Finally, for the sensory evaluation of the Visual Quality, Taste, Crispiness, Crunchiness, and Overall Visual Rating: 12 untrained panelists were invited to rate the Guapple Fruit on the 6th day through a simple likert scale.

For both Visual Rating and Taste, the fruit slices were assessed based on the appeal of color and general satisfaction, with a scale of 1-5, with 5 being the most appealing. On the other hand, Guapple Samples are specifically subjected to hedonic ratings of Crunchiness and Crispiness, respectively. For the Crunchiness: 1 = Very Soft, 3 = Neither, and 5 = Very Crunchy. For the Crispiness: 1 = Very Leathery, 3 = Neither, and 5 = Very Crispy. Finally, the Overall Sensory Rating will be assessed through the following hedonic rating: 1 = Extremely Unacceptable, 2 = Unacceptable, 3 = Satisfactory, 4 = Appealing, and 5 = Very Appealing.

Statistical Analyses

Two different statistical analyses were executed. For the measurement of statistical significance ($p <0.05$), both the Kruskal-Wallis Test and Analysis of Variance (ANOVA) were performed. Specifically, ANOVA was used to determine the significance of findings whose values are determined to be parametric, while Kruskal-Wallis was used for those with non-parametric values. Should there be any significant difference, the Tukey's Post hoc tests shall be executed. Before this, the normality and homogeneity are then assumed and tested ($p < 0.05$). Thus, the use of scales such as Shapiro-Wilk ($N < 30$) and Levene Statistics were utilized. Lastly, these statistical tests were conducted through the use of IBM SPSS Statistics 20 software to automate and prevent errors.

RESULTS AND DISCUSSIONS

Total Soluble Solids (TSS)

Seen in **Figure 8** is the variable movement of the Average Total Soluble Solids for the sets of Guapple Samples as the experiment continues. Total Soluble Solids are seen to have non-continuous increase and decrease as the timeline of the study prolongs; whereby significant increase is seen in Day 7 Treatment 2 versus the Control Samples.

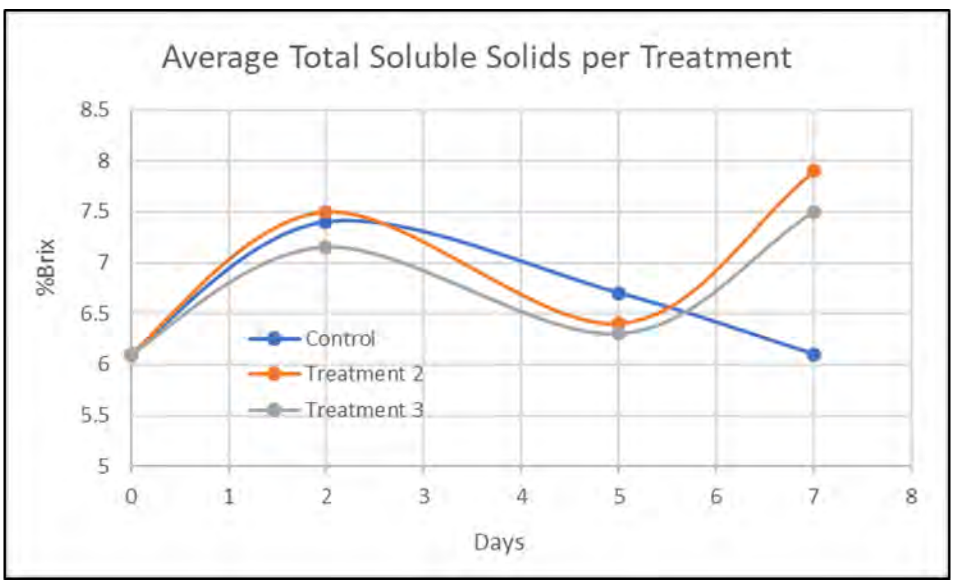

Figure 8. Average Total Soluble Solids for Guapple Samples

This behavior of the Guapple samples is consistent to the study of Silva et al. (2021), where the coated samples (specifically the chitosan and gelatin treatment) were seen to have significant increase in comparison to the control in terms of Total Soluble Solids on Day 7. On the other hand, the study of Nair et al. (2017) also observed this sudden increase on their study surrounding Alginate and Pomegranate Peel Extract as they are applied to Guava as an edible coating. The researcher explained that this increase is due to the delayed climacteric process. Consistent to Silva et al (2021), due to the delayed respiratory process brought by the coating, TSS peaks are found at the later stages of storage period – attributed to delayed conversion of some starches into much simpler sugars. Thus, it can be concluded that this increase in Total Soluble Solids is stimulated by the Chitosan and Alginate-based coating. However, a closer look into the other maturity index should be carried out in order to understand its overall effects and determine the relevance of said findings to its maturity.

Titratable Acidity (TA)

As seen in **Figure 9**, the Citric Acid concentration increased by about 0.2% to 0.3% for all the control and treated Guapples.

According to studies such as those from Patel et al. (2015), the general biochemical changes in Guava should precede the decrease of Titratable Acidity as it is consumed by respiration within the fruit ripening development. This claim is also consistent

Table 1. Total Soluble Solids of Treated Guapples in 7 days

DAYS	TREATMENT	Total Soluble Solids, % Brix			
		Mean		SD	
0	Reference	6.1	±	0.88	
2	Control	7.4	±	0.74	a
	Treatment 2	7.5	±	0.45	a
	Treatment 3	7.2	±	0.79	a
5	Control	6.7	±	0.91	a
	Treatment 2	6.4	±	0.49	a
	Treatment 3	6.3	±	0.44	a
7	Control	6.1	±	0.53	a
	Treatment 2	7.9	±	0.72	ab
	Treatment 3	7.5	±	1.22	a

Means in a group with a common letter do not differ with each other at Tukey's Post hoc test of 5% level of significant difference.

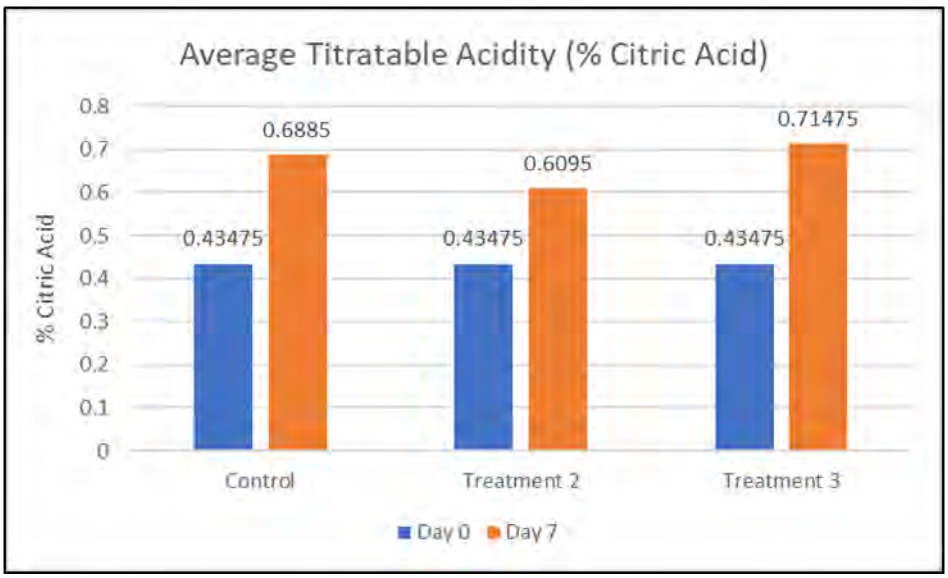

Figure 9. Average Titratable Acidity of Guapple Samples

with the findings of Bashir & Abu-Goukh (2003), where regardless of if the Guava has a pink or white flesh, the general trend is that it should decrease over time. However, in the case of the experiments of this study, all of the treatments, including the Control Treatments, had increased Titratable Acidity on Day 7. This can be attributed to the variability of Guapples as the values are seen to be analogous from the findings of Silva et al. (2021). And while statistical analyses point out that there are no significant differences for the means of Day 7 Guapple for all treatments, a slight increase of Titratable Acidity is seen in Treatment 3 as compared to the Control Treatments. This can be an indication of delayed maturation that is implicitly affected by Starches in the edible coating itself. These findings are consistent with the claims of Thakur et al. (2018) where their rice starch carrageenan study successfully delayed the biosynthesis of ethylene and respiration rates in Banana fruits. Thus, extending these findings to the Titratable Acidity properties of Guapple, the cornstarch in the edible coating is a viable rationale for the higher levels of Citric Acid. However, for the alginate-based chitosan coating it is simply not applicable. The higher levels of Total Soluble Solids indicate a consumption of metabolic acids into sugar as consistent to the study of Bashir and Abu-Goukh (2003) surrounding Guava, as well as those from the studies of Nair et al. (2017). Thus, the higher the total soluble solids, the lower the titratable acidity upon maturation. In the case of the experiments, the set of data had increased levels of TSS on Treatment 3 and higher than control levels of TA on the same treatment. If there really is an existence of delayed maturity index, then the TSS should have been lower with higher TA. However, since the former is the case, the analysis therefore points to the idea that the minute effects of Alginate + Chitosan + Starch is simply insignificant (in comparison to Control) to draw out substantial conclusions. And so, it can be deduced that the Alginate + Chitosan coating, and Alginate + Chitosan + Starch coating have not successfully delayed the senescence of the Guapples by basis of Titratable Acidity and Total Soluble Solids.

Table 2. Titratable Acidity of Treated Guapples in Day 0 and Day 7

DAYS	TREATMENT	Titratable Acidity, % Citric Acid Mean		SD	
0	Reference	0.43	±	0.09	
7	Control	0.69	±	0.14	a
	Treatment 2	0.61	±	0.20	a
	Treatment 3	0.71	±	0.10	a

Means in a group with a common letter do not differ with each other at Tukey's Post hoc test of 5% level of significant difference.

Guapple Pulp pH

After undergoing an electrode pH determination for the four replications of Guapple Extract, the results are then graphed to track its changes through **Figure 10.**

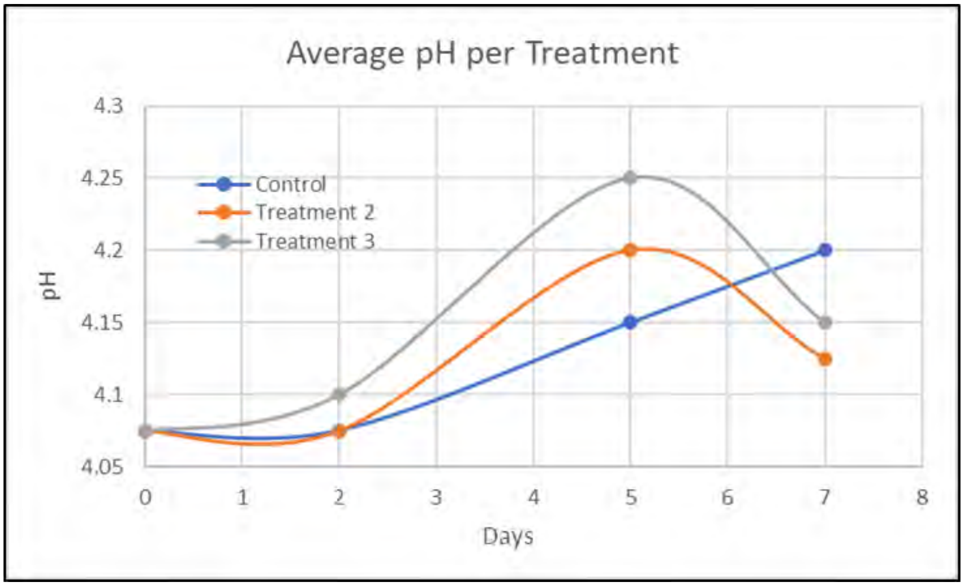

Figure 10. Average Titratable Acidity of Guapple Samples

Given the non-continuous and inconsistent behavior of pH of Guapple samples, the statistical analysis as it relates to the overall pH measurements per treatment were deemed to be insignificant. Even if the increase of Titratable Acidity is expectedly going to increase its acidity (or at least be maintained) the pH of the sample pulps was read to be almost the same as those in the Control samples. This line of results is also consistent with the studies of Silva et al. (2021), where the use of Chitosan and Starch coating have not significantly affected the pH of the treated samples. Furthermore, studies such as those from Rodeo et al. (2018), support the insignificant pH findings seen in this study. As control samples in previous literatures have a slightly increased acidity (characterized by the decrease in pH). Thus, the slight increase of acidity in this paper can be attributed to the normal biological processes of Guapples, such that the non-continuous increase and decrease of pH is not stimulated by any of the substances applied to the Guapple surfaces.

Ripening Index

From the calculations of the ratio of the Total Soluble Solids and Titratable Acidity, the Ripening Index for each fruit was measured, as depicted in **Figure 11**. Thus, it is seen that there are no significant differences for the Ripening Index of all Treated Guapples as they are compared to the Control Guapples. Since the variables to be considered are already statistically insignificant (Total Soluble Solids and Titratable Acidity) within each other, the said ratio is then also expected to be statistically insignificant. However, an important characterization is to be seen such that the Ripening

Table 3. pH of Treated Guapple Samples in 7 days

DAYS	TREATMENT	pH of Guapple Pulp				
		Mean		SD	Median	
0	Reference	4.08	±	0.13		
2	Control	4.08	±	0.05	4.10	a
	Treatment 2	4.08	±	0.05	4.10	a
	Treatment 3	4.10	±	0.00	4.10	a
5	Control	4.15	±	0.13	4.15	a
	Treatment 2	4.20	±	0.08	4.20	a
	Treatment 3	4.25	±	0.13	4.25	a
7	Control	4.20	±	0.08	4.20	a
	Treatment 2	4.13	±	0.10	4.15	a
	Treatment 3	4.15	±	0.06	4.15	a

Medians in a group with a common letter do not differ with each other at Kruskal-Wallis Test of 5% level

Table 4. Ripening Index of Treated Guapple Samples in Day 0 and Day 7

DAYS	TREATMENT	Ripening Index, TSS/ TA				
		Mean		SD	Median	
0	Reference	14.63	±	4.46		
7	Control	9.12	±	2.15	9.23	a
	Treatment 2	13.94	±	3.98	13.37	a
	Treatment 3	10.49	±	0.72	10.68	a

Medians in a group with a common letter do not differ with each other at Kruskal-Wallis Test of Significant Difference of 5% Level

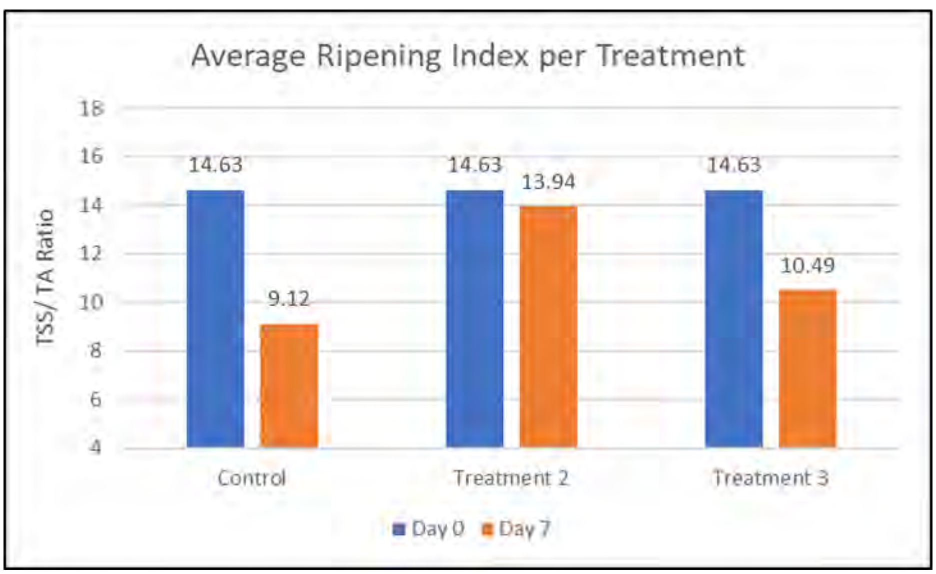

Figure 11. Average Day 7 Guapple Ripening Index

Index is lower in Day 0 than in Day 7 for all the Treatments including the Control. This can be traced back to the variability of Guapple fruits as they are tested for Titratable Acidity. Furthermore, even though these findings are deviations from the compositional changes claimed by Bashir & Abu-Goukh (2003), they are still adjacent to the values found by Silva et al. (2021) as it deviates from the findings that are normally found in such an experiment. Therefore, it is very important to note that the higher Ripening Index in Treated Guapples is not indicative of a delayed/ accelerated ripening. The conclusion then states that the Edible Coating simply has no effect on the Ripening Index of Guapples being experimented on as it is statistically insignificant for Day 7.

Color Index Determination

For the purpose of this study, one of the factors that was looked at is the enzymatic browning experienced by fleshy fruits such as Apples, Guapples, etc. Thus, using the data that is garnered through the Konica Minolta Color Reader (CR-10), the browning of the Guapples is tracked through the earlier stated formula from Ruangchakpet and Sajjaanantakul (2007). This Browning Index formula was used to graph the following figure.

Based on the illustration seen in **Figure 12**, the browning and peel discoloration started at the 2nd Day of the experiment and continued to increase as the timeline of the experiment proceeds. This behavior is also consistent in the study of Rodeo et al. (2018), where the peels of the Guapple are seen to have browning spots even as early as Day 2 and Day 3 under ambient storage conditions whereby significantly affecting their general consumer visual quality. Even though there are no statistical significances for the difference of Browning for all treatments, **Figure 12** shows Treatment 3 as having the most resilient samples against browning as seen by the decreased levels of browning versus control. This can be attributed to the paper-like coating of the Guapples with Treatment 3 (Alginate + Chitosan + Starch).

According to Jiang (2016), enzymatic browning occurs in fruit that gets sliced, pared, mechanically damaged, or even exposed to abnormal conditions as they mature. This is usually catalyzed by the exposure of surfaces of fruits in the atmosphere (e.g., oxygen) creating a brownish pigment seen in most commercial fruits. As described earlier, the browning is least seen in the edible coating with starch (Treatment 3). Thus, the resiliency in browning can be immediately tied to the inoculation of Starch to the Guapple Treatments and edible coating in general. In studies such as those by Coelho et al. (2017), enzymatic browning in Cassava when they are processed with starchy edible coating is effectively delayed in the process. Landrigan et al. (1996), discussed the effects of reduced browning in Rambutan fruits (Nephelium lappaceum L.) due to increased relative humidity of the surroundings. Decreased moisture loss decreases incidence of browning due to the declined concentration of total phenolic compounds in the pericarp or fruit surface. Furthermore, and while it is not statistically significant, the browning of Guapples under Treatment 2 is also seen to be slower than in the Control Guapples. This behavior of Alginate-based Chitosan coating is consistent to the studies of Nair et al. (2017), where the chitosan coating had also limited the direct contact of Guapple peels to its surroundings. However, in terms of visual analysis, the starch coating certainly

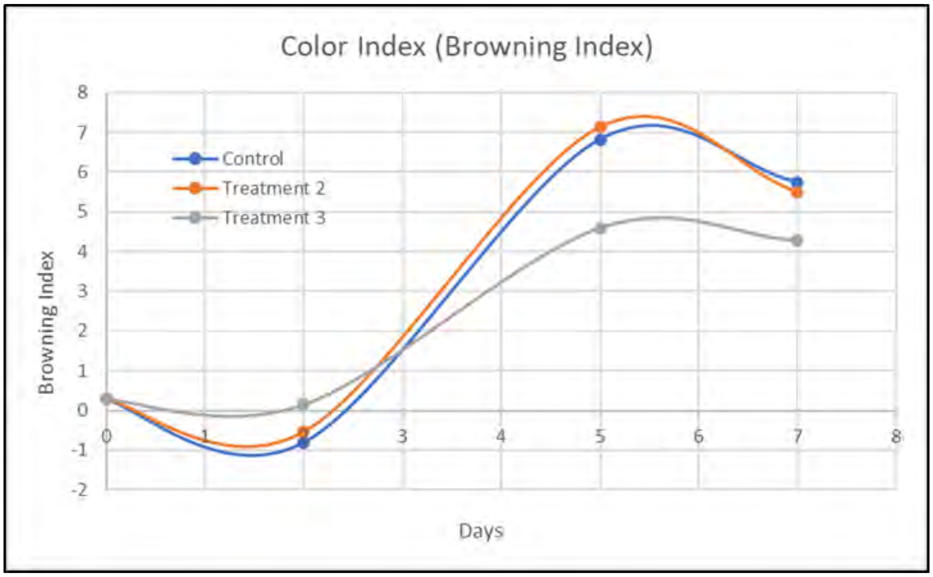

Figure 12. Average Browning of Guapple Samples per Day

Table 5. Browning Index of Treated Guapple Samples in 7 days

DAYS	TREATMENT	Browning Index Mean		SD	Median	
0	Reference	0.28	±	1.41		
2	Control	-0.80	±	5.24	-2.25	a
	Treatment 2	-0.55	±	3.82	-2.01	a
	Treatment 3	0.14	±	8.39	-1.56	a
5	Control	6.82	±	10.49	3.78	a
	Treatment 2	7.13	±	10.90	3.07	a
	Treatment 3	4.59	±	13.49	-0.89	a
7	Control	5.74	±	2.47	6.20	a
	Treatment 2	5.50	±	3.09	6.63	a
	Treatment 3	4.28	±	3.27	3.94	a

Medians in a group with a common letter do not differ with each other at Kruskal-Wallis Test of Significant Difference at 5% Level delays the said browning process much more effectively given the slight whitish tint in its immediate peel.

Firmness Determination

As seen in **Figure 13**, the Firmness of Guapple Samples are relatively close with each other as it is probed through the use of the Universal Testing Machine.

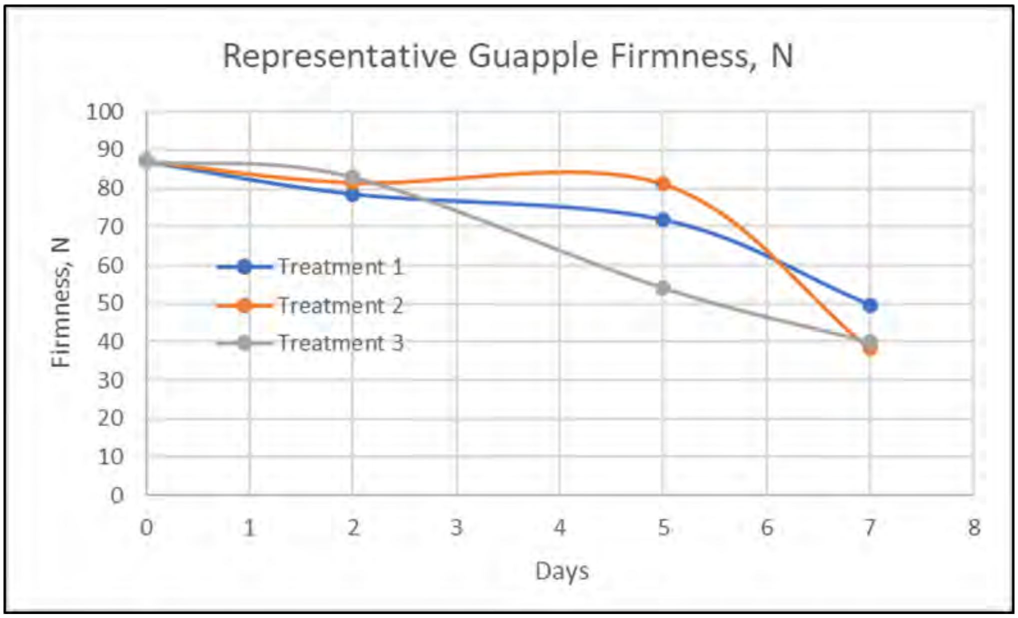

Figure 13. Representative Firmness of Guapple Samples

Table 6. Firmness of Treated Guapple Samples in 7 days

DAYS	TREATMENT	Firmness, N Mean		SD	
0	Reference	72.03	±	16.98	
2	Control	71.28	±	5.64	a
	Treatment 2	70.85	±	9.74	a
	Treatment 3	80.43	±	6.05	a
5	Control	66.35	±	26.56	a
	Treatment 2	55.73	±	33.11	a
	Treatment 3	51.78	±	4.62	a
7	Control	73.03	±	18.21	a
	Treatment 2	40.63	±	31.52	a
	Treatment 3	59.13	±	14.46	a

Means in a group with a common letter do not differ with each other at Tukey's Post hoc test of 5% level of significant difference.

In the studies of Bashir & Abu-Goukh (2003), the general behavior of Guava fruit as it ripens and further matures is to decrease its flesh firmness and eventually give in to the mechanical pressure of the ambient surroundings. This behavior is also mapped out by Rodeo et al. (2018) as they recorded the firmness to intensely decline in the 4th and 5th day of storage in its ambient conditions, which is conclusively consistent to the study of Braga et al. (2017) where the firmness of the Guava is seen to decrease intensely by the same timeline. And so, even if the said behavior is only seen in representative samples of Guapples in this paper, it is still a significant index to understand the relationship of other metabolic compounds in the cellular structure of the commodity. As seen in the statistical demonstration of this paper, there are no significant differences between the Firmness of each treatments including the control. According to Li et al. (2018), Firmness is one of the most important maturity indices as the cellular structure of any commodity is highly dependent on its chemical properties such as the Titratable Acidity and Total Soluble Solids. Water loss at the later stages of senescence accelerates texture change attributed to firmness as fruit cell wall disintegrates (Lufu et al., 2020; Paniagua et al., 2012). Given this claim, since the TSS and TA have no significant differences with each other – including the Ripening Index – the Firmness is also expected to have no significant differences with each other per Treatment. Such that the metabolism of acids into sugar are not that significant in comparison to their treatments to truly see the difference as they relate to its cellular structure. Thus, the behavior of the Guapples in this experiment to simply have no significant differences with each other is a causation of formulated edible coatings having no effects in its other chemical properties.

Moisture Loss Determination

For the duration of the experiment (from Day 0 to Day 7), the weight of the Guapples were recorded to track their moisture loss. From this, the moisture loss by wet basis is computed for all Day 0 to Day 7.

As exhibited in the statistical analyses, the study shows significant differences in Moisture Loss in Day 2 – particularly Treatment 2 vs. Control Guapples. And while these significant differences did not continue until the terminal date of the study,

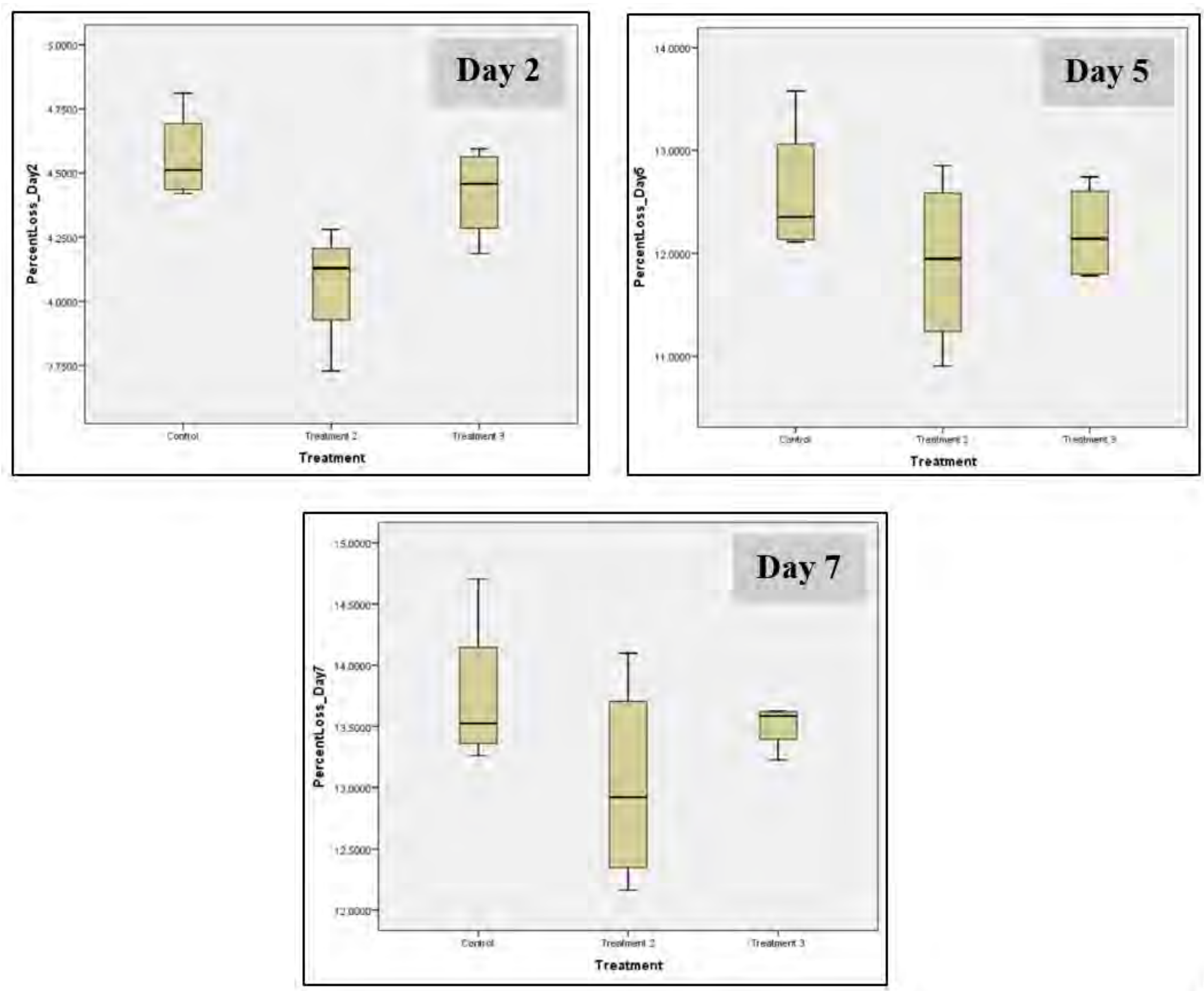

Figure 14. Percent Moisture Loss per Treatment (Wet basis) on Day 2 – Day 7

the cumulative moisture loss is still lower in Guapples that were treated with the edible coating. According to Silva et al. (2021), the existence of edible coating effectively deters the respiration and transpiration process of commodities as seen in their Guava samples with 0.5% Chitosan as integrated with the Starch ingredient. However, the chitosan and alginate-based coatings alone is already enough in deterring the moisture loss for Guava as seen in the study of Nair et al. (2018). To recall the reference from Versino et al. (2016), the integration of Starch in edible coatings inherently affects its overall water vapor gradient flows. Thus, the efficacy of moisture loss deterrence is expected to be lower in Treatment 3 than in Treatment 2. These findings explain the lower cumulative moisture loss in Treatment 3 than in Treatment 2 and is overall lower for Treated Guapples than the control. In conclusion, the edible coatings are truly much more effective in deterrence of moisture loss, particularly the Chitosan + Alginate coating in ambient conditions.

Table 7. Moisture Loss of Treated Guapple Samples in 7 days

DAYS	TREATMENT	Browning Index			
		Mean		SD	
2	Control	4.56%	±	0.15%	a
	Treatment 2	4.07%	±	0.20%	ab
	Treatment 3	4.42%	±	0.16%	a
5	Control	12.60%	±	0.59%	a
	Treatment 2	11.91%	±	0.74%	a
	Treatment 3	12.20%	±	0.42%	a
7	Control	13.75%	±	0.56%	a
	Treatment 2	13.03%	±	0.74%	a
	Treatment 3	13.51%	±	0.16%	a

Means in a group with a common letter do not differ with each other at Tukey's Post hoc test of 5% level of significant difference.

Sensory Evaluation

On the 6th day of the experiment, 12 untrained panelists were asked to evaluate the 0.3 cm thick Guapple slices representing the different Treatments in the study, specifically Control, Treatment 2, and Treatment 3. The Visual Quality, Taste, Crispiness and Crunchiness, and Overall Appeal.

After peeling and removing the skin of the Guapple, the 0.3 cm slices are examined by 12 untrained panelists. Each Treatments (including both of the Control samples) have managed to garner a satisfaction rating of 4 and above. And although the statistical significance says the opposite, there are some important observations found in the study. It is seen that the Visual Quality Rating of the Day 6 Treatment 3 Guapples scored higher than the Control Guapples for both Day 0

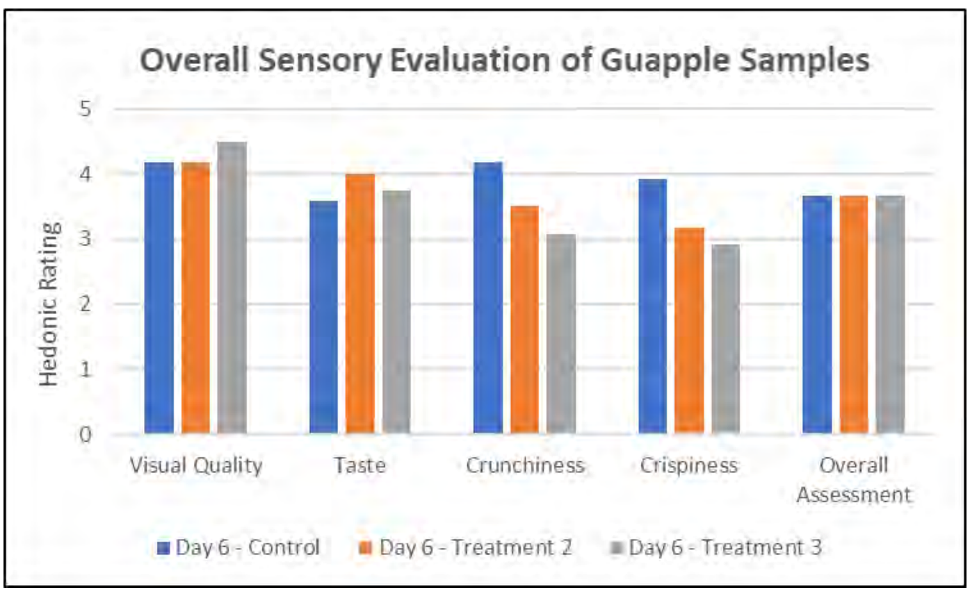

Figure 15. Overall Consumer Evaluation of Guapples at Day 6

and Day 6. On the other hand, no notable changes in the flesh are seen when Treatment 2 was further examined in comparison to the Control Treatment. This is related to the idea of Browning Index stated earlier, in that the higher level of Titratable Acidity and overall deterrence to the immediate atmosphere operationalizes the slower browning rates experienced by Guapples. Furthermore, for Total Soluble Solids and Ripening Index, this claim simply does not correlate immediately. And so, these were deemed inconclusive. However, this spike in Visual Quality may be drawn back to the claims of Silva et al. (2021) on visual quality changes. Thus, for Visual Quality alone – Treatment 3 is recommended in maintaining the overall Visual Quality of the Guapples.

Although it is seen that there is no statistical difference between the Taste Scores of all three experimental sets, as all of the treatments achieved a generally satisfying taste of 3 and up, a notable difference is still agreeable. According to the study of Dabiré et al. (2021), the Ripening Index (TSS/TA Ratio) serves as an important parameter in identifying the taste acceptability of commodities – as per their case tomato fruits. In this manner, as seen in **Figure 15**, the Taste Scores of Treatments 2 is seen to be the most superior in comparison to even the Control Guapples on Day 0. The consumers report a slight tinge of sweetness which is brought by the higher total soluble solids. And while it is conclusively defined that there are no significant differences between each of the treatments in terms of actually effecting changes in Total Soluble Solids, Titratable Acidity, pH, and Ripening Index, the Treatment 2 edible coating is slightly better in improving the marketable characteristic of Tastes seen in the consumer interviews done in this section.

Based on **Figure 15**, the perception of Crispiness of the Guapples is higher in the Control samples than those of Treated Guapples. This is also consistent with the findings realized when the Crunchiness variables are measured with the untrained panelists. However, these differences are not statistically significant enough to evaluate a conclusion. Chauvin et al. (2008) described Crispiness as the one-time fractured sensation of fruit flesh "upon-bite" which generally gets affected by the incisor of the mouth. Consistent to the study of Zuniega & Esguerra (2020), the crispiness of fruits generally depreciates as the experimental procedure moves on. And so, these are seen in the deterioration of Crispiness when Day 0 and Day 6 Guapples are directly compared. And while there are slight differences in the responses of the consumer, which is likely due to the structural metabolism of a commodity with slightly higher TSS, these are not enough to draw out conclusions. Thus, the Crispiness of Guapples have not been affected by the differences of edible coating treatment.

Overall, it was found that all of the Guapple Samples (including the control) have higher than satisfactory ratings for consumer preferences. An important note in these findings is how the Mean and Median (excluding the Standard Deviation) are equal to each other. This means that despite the characteristics that some sets of Guapple that are deemed to be important to the market, the consumer could not distinguish the difference of each treatment. Thus, this justifies the non-statistical significance of each marketable characteristic earlier.

Table 8. Sensory Evaluation from 12 Panelists (Kruskal-Wallis Test)

TREATMENT	Median Sensory Assessmentss									
	Visual Quality		Taste		Crunchiness		Crispiness		Overall	
Day 6 - Control	5.0	a	4.0	a	4.0	a	4	a	4	a
Day 6 - Treatment 2	4.0	a	4.0	a	3.0	a	3	a	4	a
Day 6 - Treatment 3	4.5	a	4.0	a	3.5	a	3	a	4	a

Medians in a group with a common letter do not differ with each other at Kruskal-Wallis Test of Significant Difference at 5% Level

SUMMARY AND CONCLUSION

Because of the underutilization of Guapples (Psidium guajava L.) in the country and the lack of postharvest infrastructures to support the handling of such highly perishable crops, the researcher has manufactured edible coating with different proportions of Chitosan and Starch to understand their effects in the physico-chemical properties of such a commodity. The experimental set-up calls for the 4 Replications of Guapples multiplied on a 2–3-day basis, specifically monitoring the Day 0, 2, 5, and 7. From this, the treatments that were made consisted of the Control Guapples – or the untreated Guapples, Treatment 2 Guapples – or the Guapples with 2% Alginate (w/v) + 0.5% Chitosan (w/v), and Treatment 3 Guapples – the Guapples with 2% Alginate (w/v) + 0.5% Chitosan (w/v) + 2% Starch (w/v). After each experimental day, the said properties are then measured, specifically the following: Total Soluble Solids, Titratable Acidity, pH, Ripening Index, Firmness, Browning Index, and Moisture Loss. Other sensory properties were also measured to determine the consumer preferences of 12 untrained panelists – including Visual Quality, Taste, Crunchiness, Crispiness, and Overall Assessed Quality.

The determination of Total Soluble Solids was executed in that it yielded a generally increasing behavior that is stimulated by the Ripening of the Guapple Samples for all treatments. Other measurements include pH, Ripening Index, and even Titratable Acidity yieled no significant results in the application of edible coating in the study. And so, even though there is a significant difference between TSS of Treatment 2 and Control other chemical properties point to the opposite wherein it is not significant enough to conclude that the delay/ acceleration of ripening is brought by the Edible Coatings inoculated to the Guapples.

One of the measurements that were notable in the study is the findings in the Moisture Loss of the Guapples. It is found that there are significant differences in the Moisture Loss of Treatment 2 since Day 2. Even through Disease Incidence, the Treatment 2 Guapple samples can significantly prevent cumulative moisture loss by about 5.55% in comparison to Control Samples. Meanwhile, Treatment 3 Guapples were able to prevent moisture loss only by about 1.82%. As discussed, these differences can be traced back to the moisture loss deterrence of the edible coating and even the water vapor gradient that starch coating allows. Furthermore, given the indifferences of selected chemical properties, the physical property of Firmness is also found to be non-significant as it is highly reliant on the interaction of sugars and metabolic acids within the Physiology of the Guapple fruit – where there is almost no difference found. Finally, in comparison to other Treatments, the edible coating that was integrated with starch has been found to reduce the incidence of browning as seen in the lower Browning Index for Treatment 3. This can be attributed to the paper film of the Guapple in Treatment 3 and the reduced moisture loss affecting concentration of total phenolic compounds in fruit pericarp consistent with other studies.

In the second part of the experiment is the consumer analysis of the study, Treatment 2 was found to be slightly more appealing in terms of Taste in comparison to other treatments. This can be traced back to the slight sweetness found in said Guapple Samples. Consistent to the findings on Color Index, Treatment 3 was found to have a slightly more appealing score in terms of Visual Quality, which can be traced back to its effective inhibition of browning spots. And while the Crunchiness and Crispness rating is slightly higher in the Controlled Guapples, this is related to the slightly increased findings in Total Soluble Solids which may have affected its overall texture, but not necessarily its Firmness. On the other hand, the overall assessment of consumers on Treated Guapples was almost equal to the Control based on Means and Medians (as per the Kruskal-Wallis Test). Thus, the consumers find that there is no significant difference in terms of marketable qualities when Guapples are applied with the edible coating. Finally, based on the economic analyses of the study, edible coating offers a low-cost avenue to improve certain commercial parameters such as moisture retention and even visual quality, depending upon the target consumers.

This study is able to reveal that in terms of Moisture Loss Deterrence and Visual Improvement, Guapples that are treated with Alginate and Chitosan Coating alone is found to be the most effective. On the other hand, in terms of increasing the Visual Appeal (both the Browning Index and Consumer Preferences) and Moisture Loss Deterrence, the Treatment 3 is found to be the most effective. Furthermore, other chemical properties such as Total Soluble Solids, Titratable Acidity, pH, and Ripening Index, were not seen to have a relationship within the application of the edible coatings in the experiment.

RECOMMENDATIONS

For future studies, the paper recommends the following: (1) test alginate-based chitosan coating on controlled climate environments to prevent confounding variables such as temperature and humidity in stimulating metabolic activities that affect physico-chemical properties; (2) measurement of L* a* b* area of incidence through an image processing software to truly quantify browning across the Guapple surface; (3) consideration of aromatic essential oils as a probable added ingredient in the study; (4) understand how other variables such as Phenolic Compounds and Ascorbic Acid of the Guapples are affected.

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