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Impact of Edible-based Coatings on the Physico-chemical Properties of Bitter Gourd (*Momordica charantia L.*)

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ABSTRACT

Bitter gourd, known for its high nutritional value faces challenges due to its high perishability leading to senescence. Recently, there has been a growing interest in using edible-based coatings as a promising approach to delay the senescence of fruit and vegetables. The study was conducted to determine the optimal concentration of aloe vera gel, moringa leaf extract, ginger extract, and coconut oil + beeswax as edible-based coatings for bitter gourd fruits. Bitter gourd fruits treated with an 80 mL: 7 g coconut oil + beeswax composition exhibited superior visual quality, firmer texture, and lowest TSS value compared to other coatings. The 70 mL: 5 g coconut oil + beeswax coating demonstrated the highest percentage of titratable acidity (% TA), while also displaying the lowest respiration rate, correlating with minimal observed cumulative weight loss. Moringa leaf extract at a concentration of 20% effectively controlled color changes. No significant differences were observed in the bitter gourd fruits' dry matter content, pH, and shelf life. These findings underscore the potential of coconut oil and beeswax combinations, with specific ratios offering tailored benefits for short-term storage of bitter gourd (not beyond 8 days).

Keywords: bitter gourd, ginger, aloe vera, moringa, coconut oil, beeswax

INTRODUCTION

Bitter gourd (*Momordica charantia* L.) is a fruit of tropic origin locally known as ampalaya (Anbasaran & Tamilmani 2013). It is widely used in culinary and traditional medicine (Heiser 1979). Its leaves, roots, and fruits are well-known for various medicinal uses (Behera et al 2010). It has cucurbitacin-like alkaloid momordicine that causes bitter flavor but is rich in iron, phosphorus, and ascorbic acid (Jeffrey 1980; Okabe et al 1982).

Like any other vegetable, bitter gourd fruit undergoes physiological and biochemical changes during and after harvest. Different changes occur such as, but not limited to, decrease in organic acid concentration, increase in sugar, softening of tissues, degradation of chlorophyll (including the synthesis of anthocyanin or carotenoid upon maturation), loss and production of volatile flavor compound, reduction in amino acid and phenolics, and breakage of cells (Lin & Zhao 2007).

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Recently, there has been a growing interest in the application of edible-based coatings as postharvest treatments in delaying the physiological and biochemical changes of fruits and vegetables. Several studies have reported the usefulness of aloe vera (*Aloe barbadensis* Miller) gel in delaying the ripening of tomatoes (Jati et al 2022), mangoes (Suriati et al 2021), and guavas (Rehman et al 2020). Similar results have also been demonstrated by moringa leaf extract in the delay of fruit softening, maintenance of membrane integrity, and reduction of total sugar accumulation in mangoes (Bambalele et al 2021). Meanwhile, ginger extract with its antioxidant properties can fight off physiological stress and prevent damage to some fruit. Sedyadi et al (2018) claimed that tomato postharvest quality and shelf life were effectively maintained by ginger extract. Similarly, guava fruits treated with ginger extract at 20% concentration had the lowest non-reducing sugar content and had higher antioxidant activity, vitamin C content, total phenolics, and the highest flavonoid content (Zaidi et al 2023).

In the case of coconut oil, it contains anti-senescence properties that can reduce respiration and transpiration rates and slows down the process of ethylene biosynthesis (Lieberman et al 2006). The application of coconut oil at 100% concentration also paved the way for the reduction of respiration and transpiration rates and microbial activities in kagzi lime fruits because of the closing of stomata and lenticels (Bisen et al 2012). Moreover, waxes are widely known as commercial coatings. These can be based on paraffin wax or a combination of other waxes such as, but not limited to, carnauba or beeswax. Aside from improving appearance, waxes can also lessen weight loss, incidence of chilling injury, and shrinkage in fruits (Bajwa & Anjum 2007; Porat et al 2004). In recent years, fruits and vegetables have been treated with beeswax with the goals of extending shelf life, reducing product dehydration, halting the growth of mold, and improving the aesthetic of the treated produce (Amiray & Bar-Ilan 2012).

Based on the literature review, little to no studies have been conducted on the impacts of various concentrations of aloe vera gel, moringa leaf extract, ginger extract, and various ratios of coconut oil + beeswax on the postharvest physiology of bitter gourd fruits. Hence, this study was conducted to determine and evaluate the effect of various edible-based coatings on the postharvest physiology of bitter gourd fruits and determine the optimal concentration or ratio in delaying senescence and extending the shelf life of bitter gourd fruits.

MATERIALS AND METHODS

Fruit Sample Preparation

Freshly harvested bitter gourd fruits were procured in Mac Arthur, Leyte (10.8302° N, 124.9617° S). Fruits free from visible defects, disease symptoms, and insect infestations were carefully selected. These fruits were placed in plastic crates with corrugated cartoon liners and were carried out with care to minimize mechanical injuries and were immediately transported to the Crop Physiology Laboratory, Department of Horticulture, Visayas State University. The fruits were sorted upon arrival and the only good ones were used as experimental samples. Right after the application of treatments, the fruits were stored under ordinary room conditions with temperatures ranging from 24 to 28 °C and relative humidity ranging from 70 to 80%.

Edible-based Coatings Preparation

Aloe Vera Gel

To prepare for the aloe vera gel (10% & 20%), aloe vera leaves were cleaned of adhering small debris before extraction. Fresh aloe vera gel was prepared according to previous reports (Chrysargyris et al 2016). Briefly, for each leaf, the spines along the leaf margins were removed before longitudinally slicing to separate the rind from the inner leaf gel. The gel fillets were crushed to yield a mucilaginous gel which were filtered to discard the fibrous fraction.

Moringa Leaf Extract and Ginger Extract

To prepare different concentrations of extract (10% & 20%), the already prepared powder of ginger rhizomes and moringa leaves were used according to the concentration for 10%, 50 g of powder was mixed with 450 mL of distilled water and for 20%, 100 g of powder were mixed with 400 mL of distilled water. Then, the extract was stored in a refrigerated cooler for 24 hours and then filtered using a cheesecloth. Afterward, the treatments were applied by dipping for 10 minutes with a solution of different plant extracts (Samad et al 2019). The bitter gourd fruits were air-dried at room temperature for 60 minutes before being placed in plastic crates.

Coconut Oil + Beeswax

To prepare for the coconut oil and beeswax, the two materials were placed in a beaker, then mixed and stirred in a hot water bath following the given ratio of mixtures (60 mL coconut oil + 3 g beeswax; 70 mL coconut oil + 5 g beeswax; 80 mL coconut oil + 7 g beeswax) until it melted and to obtain a homogenous mass that would become viscous upon cooling. A soft, clean brush was used to gently apply the coating material to the fruit's surface.

Experimental Design and Treatments

The experiment was laid out in Completely Randomized Design (CRD) with five (5) sample fruits in each treatment and replicated three (3) times. The treatments were as follows:

T_1 – Control (No treatment)
T_2 – 10% Aloe Vera Gel
T_3 – 20% Aloe Vera Gel
T_4 – 10% Moringa Leaf Extract
T_5 – 20% Moringa Leaf Extract
T_6 – 10% Ginger Extract
T_7 – 20% Ginger Extract
T_8 – 60 mL: 3 g Coconut Oil + Beeswax
T_9 – 70 mL: 5 g Coconut Oil + Beeswax
T_{10} – 80 mL: 7 g Coconut Oil + Beeswax

DATA GATHERED

Physical Analysis

Cumulative Weight Loss

Cumulative weight loss was determined by recording the initial weight of the fruits at the start of the experiment and subsequently at one-day interval until the termination of the study. This was done using a food weighing scale. The loss in weight was calculated following (Prashanth et al 2022) as:

$$\text{CWL}\ \% = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}}\ \text{x}\ 100$$

Visual Quality Rating

The physical appearance of each bitter gourd sample was evaluated using a visual quality rating (VQR) of Acedo (1999). The VQR of each fruit sample was assessed daily until the termination of the experiment:

VQR	DESCRIPTION
9	Excellent, no defects
7	Good, defects minor (yellowing, decayetc.)
5	Poor, defects serious, limit of marketability
3	Limit of edibility
2	Inedible under usual condition

Fruit Softening

Fruit softening was assessed by finger feel and was gathered every other day of storage using the following rating scale by Acedo (1999).

SOFTENING	DESCRIPTION
1	No symptoms
2	1-10% surface softening
3	11-30% surface softening
4	31-50% surface softening
5	Extensive softening, ripe-soft

Color Changes

The color changes were assessed using the following rating:

COLOR RATING	DESCRIPTION
1	Green
2	Breaker, definite break in color <10% of the surface
3	Turning, more green than yellow, orange, or red
4	More yellow, orange, or red than green
5	Yellow, orange, or red with little trace of green
6	Full yellow, orange, or red

Dry Matter Content

The dry matter content of bitter gourd fruits was determined using fruit samples from each treatment after 11 days of storage. Fifty grams (50 g) sample fruits were weighed using a weighing scale. The samples were oven dried at 105 °C for 24 hours until they reach a constant weight and then reweighed (Ileleji et al 2010). The remaining weight of the samples after drying was used to calculate the percent dry matter content, which was expressed as a percentage of the wet sample. The following formula was used:

$$\text{Dry Matter Content (\%)} = \frac{\text{Dry Weight}}{\text{Fresh Weight}} \text{ x } 100$$

Shelf Life

Five (5) sample fruits per treatment across three (3) replications were evaluated by exposing them to ordinary room conditions with temperatures ranging from 24 to 28 °C and recorded every other day until the termination of the study or the VQR of 5 is reached which limits marketability.

Chemical Analysis

Total Soluble Solid (°Brix)

Total soluble solids (TSS) measure the approximate sugar content of the fruits. A 50 gram of bitter gourd fruit flesh was prepared and was added with 50 mL distilled water and homogenized in the blender. The homogenate was filtered with a cloth to extract the bitter gourd fruit juice. Thereafter, TSS was measured using the digital refractometer with a range of 0 to 32 °Brix by placing 1 to 3 drops of clear juice on the prism potential for reading.

Titrable Acidity (% TA)

Titrable acidity was determined using a 5 mL juice extract (aliquot) of the bitter gourd fruits and was placed into a beaker added with 2 drops of 1% phenolphthalein indicator. This was titrated with 0.1 N sodium hydroxide (NaOH) until the pink color was observed in every sample through initial and final readings. Then the % TA of Malic acid as predominant acid in bitter gourd fruit was calculated using the formula below:

$$\text{\% TA malic acid} = \frac{\text{V x N x M}}{\text{W}} \text{ x } 100$$

where:

V = volume of NaOH added, mL
N = concentration of NaOH, normality (N)
M = milliequivalent weight of predominant acid, g/meq (malic acid-0.067)
W = weight of aliquot, g

$$\text{W} = \frac{\text{Weight of sample, g}}{\text{Wt. of sample + vol. of water added, mL}} \text{ x vol. of aliquot}$$

Potential Hydrogen

The pH was determined using a digital pH meter which was pre-calibrated using pH 4, pH 7, and pH 10 buffer solutions. A gram of bitter gourd fruits was blended and homogenized with 10 mL of distilled water, and filtered, and the pH of the filtrate was determined.

Respiration Rate

This was measured using a CheckPoint 3 portable CO_2 and O_2 Gas Analyzer (Mocon) at the Postharvest Technology Laboratory, Department of Horticulture, Visayas State University. After allowing the bitter gourd fruits to respire for one hour, the rubber tubing from the CO_2 and O_2 analyzer was inserted into the glass tubing of the respiration jars with a volume of 3100 ml and the CO_2 reading was recorded. Respiration rate was calculated as follows (Acedo 1999):

$$\text{Respiration rate } (\text{mg } CO_2 \text{ kg}^{-1}\text{h}^{-1}) = \frac{C_1 - C_0}{100} \text{ x V x } \frac{1}{(t)(w)} \text{ x } \frac{44 \text{ mg } CO_2}{24 \text{ ml } CO_2}$$

where:

C_1 - % CO_2 after a time interval
C_0 - % CO_2 at zero time, 0.03%
V – Headspace volume, ml = vol. of respiration jar – vol. of commodity
t – time interval, hour
w – weight of commodity, hr

Statistical Analysis

Data was tabulated and analyzed using the software, Statistical Tool for Agricultural Research (STAR) version 2.0.1. The differences between the treatments were determined using Analysis of Variance (ANOVA). A post-hoc analysis was conducted using a pairwise comparison procedure, specifically the Tukey's Honest Significant Difference (HSD) test at the 5% level of significance.

RESULTS AND DISCUSSION

Physical Properties

Cumulative Weight Loss

Edible-coating materials are essential for creating a modified environment that lowers weight loss and water permeability. Throughout storage, weight loss increased gradually and peaked after 11 days (Figure 1). Notably, there was a significant difference by 2-fold between the control and the other treatments (10% & 20% aloe vera gel, 10% & 20% moringa leaf extract, and 10% & 20% ginger extract), as the treatments utilizing coconut oil + beeswax (60 mL: 3 g coconut oil + beeswax, 70 mL: 5 g coconut oil + beeswax, 80 mL: 7 g coconut oil + beeswax). The fruits that were treated with coconut oil and beeswax had the lowest weight loss after 11 days. According to Zhu et al (2008), respiration and transpiration reduce the moisture content causing weight loss of fruits and vegetables. Fruit weight loss during storage is mainly caused by oxidation, humidity transfer, and the respiratory process (Ayranci & Tunc 2003).

Coconut oil is known for its anti-senescence properties, which effectively lower respiration and transpiration rates, also inhibiting ethylene biosynthesis (Lieberman et al 2006). In contrast, beeswax contains a combination of long-chain alcohols and fatty acid esters, with monoester peaking at a concentration of 35% (Brativic et al 2016). These lipid components exhibit hydrophobic characteristics that enhance the water barrier, thereby reducing water loss (Diyana et al 2021). These findings were also consistent with the research of Arfin et al (2020), who observed that lemons treated with beeswax, either individually or in conjunction with coconut oil, experienced a significant decrease in respiration and were effectively shielded from weight loss.

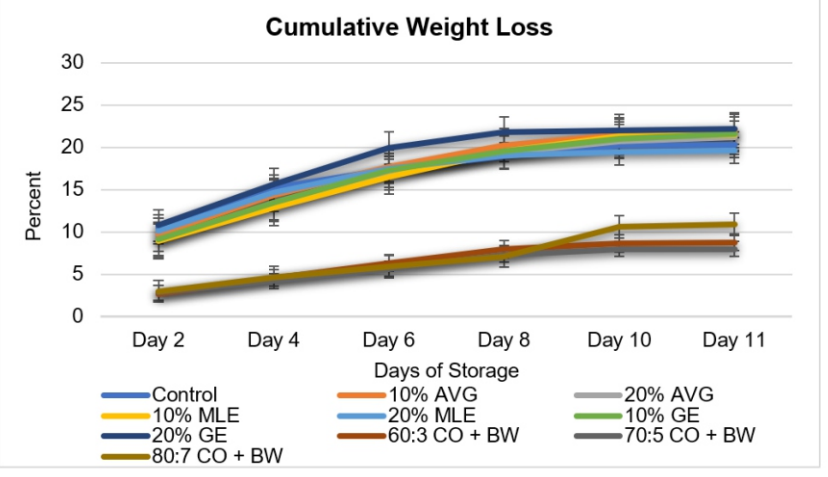

Figure 1. Cumulative weight loss of bitter gourd (*Momordica charantia* L.) as impacted by edible-based coatings.

Visual Quality Rating

Visual quality rating (VQR) stands as a pivotal characteristic influencing consumer selection. Figure 2 presents the impact of edible-based coatings on the VQR of bitter gourd. The VQR of bitter gourd demonstrated significant variation based on the different edible-based coatings applied. Notably, fruits coated with coconut oil + beeswax (60 mL: 3 g coconut oil + beeswax, 70 mL: 5 g coconut oil + beeswax, 80 mL: 7 g coconut oil + beeswax) exhibited the highest VQR compared to both the control and other treatments (10% & 20% aloe vera gel, 10% & 20% moringa leaf extract, 10% & 20% ginger extract).

However, by day 8, a noteworthy discrepancy emerged, with T10 (80 mL: 7 g coconut oil + beeswax) showing significant divergence from T8 (60 mL: 3 g coconut oil + beeswax) and T9 (70 mL: 5 g coconut oil + beeswax). This divergence can be correlated to the results of the study by Nasrin et al (2020) that lemons coated with coconut oil + beeswax (90 mL: 10 g coconut oil + beeswax and 80 mL: 20 g coconut oil + beeswax) kept in MAP were green and shiny throughout storage period of 18 days. This is also in conjunction with the claims by Bisen et al (2012) that coconut oil application closes the stomates and lenticels thereby reducing respiration and transpiration rates, while beeswax enhances fruit appearance (Bajwa & Anjum 2007; Porat et al 2004).

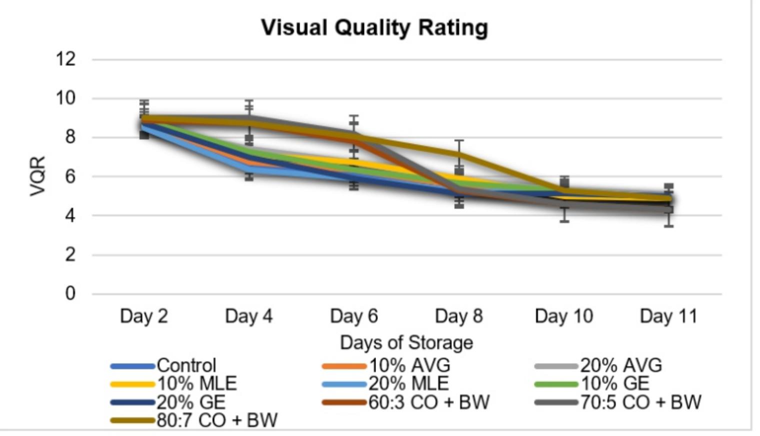

Figure 2. Visual quality rating of bitter gourd (*Momordica charantia* L.) as impacted by edible-based coatings

Fruit Softening

During the ripening process of bitter gourds, cell walls play a crucial role in facilitating the activity of various enzymes, including polygalacturonase and pectin methyl esterase These enzymatic activity leads to the softening of the entire fruit by breaking down structural components necessary for cell layer strength and bonding (Amanullah et al 2016).

Figure 3 illustrates the effect of edible-based coatings on the softening index of bitter gourd. The application of different coatings significantly influenced the firmness of the fruits. A gradual decrease in firmness was observed from day 2 to day 11. The control bitter gourds had the highest mean score, indicating the most significant softening from day 4 to day 11 compared to other treatments.

Changes in the makeup of the cell wall in terms of strength and adhesion, are pivotal influences contributing to firmness loss in on-tree ripening or post-harvesting. This phenomenon is attributed to the action of the hydrolyzing enzymes in the cell wall, which elevate ethylene levels in climacteric fruits (Valero et al 2013; Valero & Serrano, 2010).

The treatments involving coconut oil and beeswax, 60 mL: 3 g coconut oil + beeswax (T8), 70 mL: 5 g coconut oil + beeswax (T9), and 80 mL: 7 g coconut oil + beeswax (T10) proved effective in either preventing or delaying the softening of bitter gourd fruits. This efficacy can be attributed to the hydrophobic properties of beeswax (Diyana et al 2021) combined with coconut oil, which reduced the rate of transmission of the water vapor with the formation of a barrier around the fruit. This barrier impedes texture reduction, as water plays a vital role in maintaining cell turgor (Perez-Gago et al 2010).

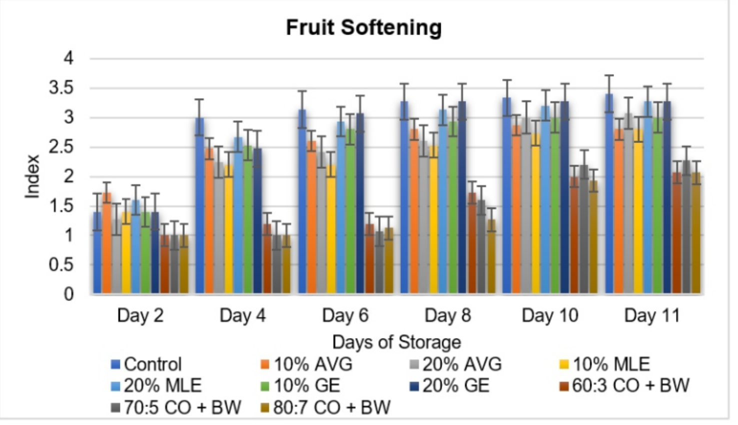

Figure 3. Fruit softening of bitter gourd (*Momordica charantia* L.) as impacted by edible-based coatings

Color Changes

As fruits ripen, they undergo several biochemical changes, including chlorophyll breakdown leading to changes in color, making the fruit less appealing to consumers (Cubero et al 2011; Maleki et al 2018).

Figure 4 outlines the color changes observed in bitter gourd fruits. On days 10 and 11, T5 (20% Moringa Leaf Extract) effectively preserved the green hue of the bitter gourd fruits. This finding aligns with the results of a study by Mthembu et al (2019), which demonstrated that moringa leaf extract (MLE) infused into edible carboxyl methylcellulose (CMC) successfully delayed color development in tomato fruits.

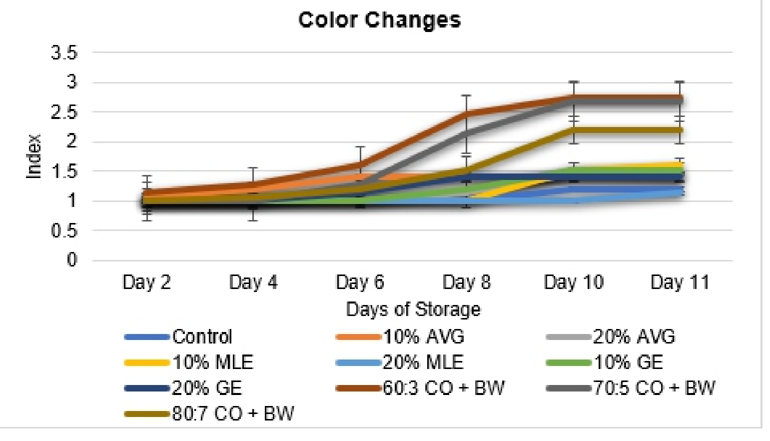

Figure 4. Color changes of bitter gourd (*Momordica charantia* L.) as impacted by edible-based coatings

Figure 5. Color changes of bitter gourd (*Momordica charantia* L.) as impacted by edible-based coatings at day 11. T_1 – Control; T_2 – 10% Aloe Vera Gel; T_3 – 20% Aloe Vera Gel; T_4 – 10% Moringa Leaf Extract; T_5 – 20% Moringa Leaf Extract; T_6 – 10% Ginger Extract; T_7 – 20% Ginger Extract; T_8 – 60 mL: 3 mg Coconut Oil + Beeswax; T_9 – 70 mL: 5 mg Coconut Oil + Beeswax; T_{10} – 80 mL: 7 mg Coconut Oil + Beeswax

While the bitter gourd fruits treated with moringa leaf extract at 20% concentration (T5) was statistically significant among other treatments, it can be interpreted in the graph above that the different mixtures of coconut oil and beeswax (60 mL: 3 g coconut oil + beeswax, 70 mL: 5 g coconut oil + beeswax, and 80 mL: 7 g coconut oil + beeswax) had observable signs yellowing as early as 8 days.

Dry Matter Content and Shelf Life

The dry matter content and shelf life of bitter gourd fruit as affected by edible-based coatings are presented in Table 1.

Table 1. Dry matter content and shelf life of bitter gourd (*Momordica charantia* L.) as impacted by edible-based coatings

TREATMENT	DRY MATTER CONTENT (%)	SHELF LIFE (days)
Control (No Treatment)	4.67a	7.13ab
10% Aloe Vera Gel	5.33a	8.00ab
20% Aloe Vera Gel	6.00a	8.40ab
10% Moringa Leaf Extract	5.33a	8.60ab
20% Moringa Leaf Extract	4.00a	6.67b
10% Ginger Extract	4.67a	8.20ab
20% Ginger Extract	6.00a	6.87ab
60:3 Coconut Oil + Beeswax	4.00a	7.93ab
70:5 Coconut Oil + Beeswax	5.33a	8.47ab
80:7 Coconut Oil + Beeswax	6.00a	8.93a
Initial Data	4.00	-
CV (%)	15.91	9.31

Means within the same column followed by a common letter and/or without letter designation are not significantly different from each other at 5 % level of significance.

The dry matter content was not significantly affected by edible-based coatings after 11 days of storage. The low dry matter content could be attributed to the high inherent moisture content of bitter gourd which contains more than 90% moisture (Yan et al 2019).

In terms of shelf life, no significant differences were observed between the coated fruits and the control fruits. Numerically, the highest shelf life was attained by 80 mL: 7 g coconut oil + beeswax (T10) however, signs of yellowing were observable on the 8th day (Figure 4) thereby limiting its marketability (Figure 2).

Chemical Characteristics and Respiration Rate

Total Soluble Solids

TSS is the percentage of dissolved solids containing amounts of sugars, acids (amino acids and ascorbic acids), and minerals in fruits and vegetables (Beckles 2012; Kader 2008). It can be noted in Table 2 that the TSS levels among treatments increased in correspondence to the increase in storage time. Initially, the TSS was 1.30 Brix at harvest. Albanese et al (2007) and Benitez et al (2013) claimed that due to the ripening process, the total soluble solid content generally increases over the storage period.

The results revealed significant differences among treatments. It was observed that bitter gourd fruits coated with 70 ml: 5 g coconut oil + beeswax (T9) and 80 ml: 7 g coconut oil + beeswax (T10) had the lowest TSS compared to other treatments after 11 days of storage. The rise in the concentration of the TSS in the sample can be ascribed to the increase in the loss of water throughout storage (Beckles 2012; Kader 2008). As the storage period increases, starch conversion into sugar happens in the fruit tissues, indicating an increase in TSS (Bourtroom 2008; Moalemiyah & Ramaswamy 2012).

Moreover, the increase in TSS during storage can be attributed to carbohydrate and pectin breakdown, incomplete hydrolysis (breaking down the bonds due to water) of protein, and the decay of glycosides in very small units through gaseous exchange (Togrul & Arslan 2004). However, it was evident in the study that edible-based coatings, 70 ml: 5 g coconut oil + beeswax (T9) and 80 ml: 7 g coconut oil + beeswax (T10) slightly reduced the changes in TSS levels. Edible-based coating postpones this process as coating slows down the internal metabolism with the reduction in the rate of respiration; thus, a drastic reduction of soluble solid content is avoided (Saha et al 2016) in coated bitter gourd fruits as compared to the control (uncoated). This suggests that changes in TSS levels in coated fruits were slower than in the control fruits.

Titratable Acidity

The results for the titratable acidity revealed significant differences among treatments. This suggests that the application of different coatings has been proven to be effective in retaining titratable acidity after 11 days of storage. With the values herein presented, the T9 (70 ml: 5 g coconut oil + beeswax) treatment had the highest titratable acidity.

In general, as fruit maturation sets in, fruit acidity tends to decline and conversely, a rise in sugar content (Raffo et al 2002). A decrease in total acidity is common in fleshy fruits like bitter gourd during post-harvest storage and this can be ascribed to the utilization of organic acids as substrates for respiratory metabolism in harvested fruits. The applied edible-based coatings served as a fruit's protective layer causing it to accumulate less acid (Diaz-Mula et al 2012; Valero & Serrano 2010). Moreover, Zapata et al (2008) recounted that the loss vegetable acidity is correlated to the reduction of quality during postharvest storage of vegetables while the retention of acidity is contributory to the preservation of shelf life of cucumber.

Table 2. Chemical characteristics and respiration rate of bitter gourd (*Momordica charantia* L.) as impacted by edible-based coatings

TREATMENT	TSS	TA	pH	Respiration Rate
	^{0}Brix	%	pH	mg CO_2/kg^{-1} hr^{-1}
Control (No Treatment)	3.38abc	0.23d	7.48	62.68ab
10% Aloe Vera Gel	4.22a	0.03g	7.07	53.73b
20% Aloe Vera Gel	3.22abcd	0.15ef	7.01	41.87bc
10% Moringa Leaf Extract	2.15def	0.18de	7.22	43.84bc
20% Moringa Leaf Extract	3.55ab	0.20de	7.14	62.71ab
10% Ginger Extract	2.42cde	0.08fg	7.23	56.91b
20% Ginger Extract	2.88bcd	0.50c	7.30	86.60a
60:3 Coconut Oil + Beeswax	3.05bcd	0.58b	7.24	37.39bc
70:5 Coconut Oil + Beeswax	1.48ef	0.78a	7.18	17.09c
80:7 Coconut Oil + Beeswax	1.32f	0.55bc	7.30	36.08bc
Initial Data	1.30	0.87	6.48	14.18
CV (%)	13.44	7.59	3.05	18.86

Means within the same column followed by a common letter and/or without letter designation are not significantly different from each other at 5 % level of significance.

Potential Hydrogen

The pH of the bitter gourd fruits statistically increased in all treatments after 11 days of storage as compared to the initial reading of 6.48, which means that as the storage period increased, the fruits became more alkaline (Table 2). The results were non-significant at a 5% level of significance. The lowest pH value was observed in T3 (20% Aloe Vera Gel). The increase in pH can be credited to the use of organic acids in the respiration process at storage (Nazoori et al 2020). As the storage period increases, senescence occurs in fruits and consequently, there is an increase in the pH value.

Radi et al (2017) claimed that, during ripening, organic acids are used as substrates in respiration metabolism: thus, TA decreases and pH and TSS increase. Since organic acids (e.g., malic acid or citric acid) are the primary substrates in the process of respiration, acidity decrease, and pH increase are anticipated in highly respiring fruit (Yaman & Bayoindirli 2002). In addition, the rise in pH can be attributed to the different biochemical, physiological, and structural changes happening during respiration (Ullah et al 2017).

Respiration Rate

Respiration rate is an important indicator of fruit quality. The lower the respiration rate, the better, for the fruit can stay fresh longer.

Results revealed that the respiration rate was lower after 11 days of storage as compared to the initial, higher reading. Notably, the rate of respiration was significant at 11 days of storage (Table 2). T9 (70 mL: 5 g coconut oil + beeswax) had comparable respiration rates with T3 (20% aloe vera gel), T4 (10% moringa leaf extract), T8 (60 mL: 5 mg coconut oil + beeswax), and T10 (80 mL: 7 g coconut oil + beeswax) by resulting in a reduced respiration value compared to other treatments.

Reduction of the rates of respiration through various treatments (coating, chemically derived technology, and modified atmosphere packaging) can be attributed to the delay of the utilization of organic acids in the enzymatic reactions of respiration (Bico et al 2009). Coatings reduce the rates of respiration and metabolism and thereby delay the utilization of organic acids (Baraiya et al 2012).

CONCLUSION

The different ratios of coconut oil and beeswax yielded the most favorable outcomes as compared to the control group. Bitter gourd fruits treated with 80 mL: 7 mg coconut oil + beeswax demonstrated superior visual quality, firmer texture, and lowest TSS value compared to other coatings. The 70 mL: 5 g coconut oil + beeswax coating exhibited the highest percentage of titratable acidity (% TA) and lowest respiration rate which correlates with the minimal observed weight loss. The color changes were effectively controlled by moringa leaf extract at a concentration of 20%. No significant differences were observed in the dry matter content and the pH of bitter gourd fruits, and the shelf life was not significantly affected by the coatings.

REFERENCES

Acedo A Jr. 1999. Postharvest physiology of perishable crops. Laboratory Manual in Horticulture 111. Department of Horticulture, College of Agriculture, Visayas State University, Visca, Baybay, Leyte, Philippines

Albanese D, Cinquanta L & Di Matteo M. 2007. Effects of an innovative dipping treatment on the cold storage of minimally processed Annurca apples. *Food Chemistry* 105(3):1054-1060

Amanullah S, Jahangir MM, Ikram RM, Sajid M, Abbas F & Mallano AI. 2016. Aloe vera coating efficiency on shelf life of eggplants at differential storage temperatures. *Journal of Northeast Agricultural University (English Edition)* 23(4):15-25

Amirav A and Bar-ilan I. 2012. Beeswax in fruit and vegetables analysis and the emerging challenge of material identification. *Advanced GC-MS Blog Journal* 1:1-2

Anbasaran A and Tamilmami C. 2013. Effect of calcium pectate on the physicochemical changes during the ripening of bitter gourd (*Momordica charantia* L.. Var-Co-1). *Asian Journal of Plant Science and Research* 3(4):51-58

Arfin M, Islam N, Nasrin T, Rahman A & Ullah A. 2020. Effect of novel coconut oil and beeswax edible coating on postharvest quality of lemon at ambient storage.

Journal of Agriculture and Food Research 2:1-2

Ayranci E and Tunc S. 2003. A method for the measurement of the oxygen permeability and the development of edible films to reduce the rate of oxidative reactions in fresh foods. *Food Chem*. 80: 423-431

Bajwa B and Anjum F. 2007. Improving storage performance of *Citrus reticulata Blanco mandarins* by controlling some physiological disorders. *Int. J. Food Sci. Technol.*42(2007):459-501

Bambalele N, Mditshwa A, Magwaza L & Tesfay S. 2021. The effect of gaseous ozone and moringa leaf–carboxymethyl cellulose edible coating on antioxidant activity and biochemical properties of 'Keitt' mango fruit. *Coatings* 11(11):1406

Baraiya NS, Gol NB & Rao TR. 2012. Influence of polysaccharide-based edible coatings on the shelf life and nutritional quality of tomato fruit. *Food* 6(1):22-27

Beckles DM. 2012. Factors affecting the postharvest soluble solids and sugar content of tomato (*Solanum lycopersicum* L.) fruit. *Postharvest Biol. Technol.* 63:129–140

Behera TK, Behera S & Bharathi LK. 2010. Bitter Gourd: Botany, Horticulture, Breeding (eds). Wiley-Blackwell Publishing, MA

Benítez S, Achaerandio I, Sepulcre F & Pujolà M. 2013. Aloe vera based edible coatings improve the quality of minimally processed 'Hayward 'kiwi fruit. *Postharvest Biology and Technology* 81:29-36

Bico SLS, Raposo MFJ, Morais RMSC & Morais AMMB. 2009. Combined effects of chemical dip and/or carrageenan coating and/or controlled atmosphere on quality of fresh-cut banana. *Food Control* 20(5):508-514

Bisen A, Pandey S & Patel N. 2012. Effect of skin coatings on prolonging shelf life of kagzi lime fruits (*Citrus aurantifolia* Swingle). *Journal of Food Science and Technology* 49(6):753-759

Bourtroom T. 2008. Edible films and coatings: characteristics and properties. *Int Food Res J.*15(3):237-248

Brativic A, Jasic M, Odobasic S & Sestan I. 2016. Physical-chemical properties and application of beeswax. In Book of abstracts and full papers from congress of beekeeping and bee products: Proceedings from the First Congress on Beekeeping and Bee Products, Tuzla, July 2016. University of Tuzla, Bosnia and Herzegovina

Chrysargyris A, Nikou A & Tzortzakis N. 2016. Effectiveness of *Aloe vera* gel coating for maintaining tomato fruit quality. *New Zealand Journal of Crop and Horticultural Science* 44(3):203-217

Cubero S, Aleixos N, Moltó E, Gómez-Sanchis J & Blasco J. 2011. Advances in machine vision applications for automatic inspection and quality evaluation of fruits and vegetables. *Food and Bioprocess Technology* 4: 487–504

Das R and Medhi G. 1996. Physico-chemical changes of pineapple fruit under certain postharvest treatments. *South Indian Hort. J.* 44(1-2):5-7

Diaz-Mula HD, Serrano M & Valero D. 2012. Alginate coatings preserve fruit quality and bioactive compounds during storage of sweet cherry fruit. *Food and Bioprocess Technol* 5:2990-2997

Diyana Z, Jumaidin R, Selamat M & Suan M. 2021. Thermoplastic starch/beeswax blend: Characterization on thermal mechanical and moisture absorption properties. *International Journal of Biological Macromolecules* 190:224-232

Heiser CB. 1979. The gourd book. University of Oklahoma Press, Norman, OK

Ileleji K, Garcia A, Kingsly A & Clementson C. 2010. Comparison of standard moisture loss-on-drying methods for the determination of moisture content of corn distillers dried grains with solubles. *J AOAC Int.* 293:825–832

Jeffrey C. 1980. A review of the Cucurbitaceae. *Botanical Journal of the Linnean Soc* 81:233-247

Kader AA. 2008. Flavor quality of fruits and vegetables. J. *Sci. Food Agric*. 88:1863–1868

Lieberman S, Enig MG, Preuss HG. 2006. A review on monolaurin and lauric acid: Natural virucidal and bactericidal agents, alternative and complementary therapy. *Alternative and Complementary Therapies* 12(6): 310-314

Lin D and Zhao Y. 2007. Innovations in the development and application of edible coatings for fresh and minimally processed fruits and vegetables. *Comprehensive Reviews in Food Science and Food Safety* 6(3):60-75

Maleki G, Sedaghat N, Woltering EJ, Farhoodi M, & Mohebbi M. 2018. Chitosan-limonene coating in combination with modified atmosphere packaging preserve postharvest quality of cucumber during storage. *Journal of Food Measurement and Characterization* 12(3): 1610–1621

MlMLadenoska I. 2012. The potential application of novel beeswax edible coatings containing coconut oil in the minimal processing of fruits. *Adv. Technolog.* 1(2):26-34

Moalemiyah M and Ramaswamy HS. 2012. Quality retention and shelf-life extension in Mediterranean cucumbers coated with a pectin-based film. *Journal of Food Research* 1(3):159

Mthembu S, Tesfay S, Mditshwa L & Magzawa L. 2019. Efficacy of moringa leaf extract and carboxymethyl cellulose on optimizing postharvest quality of tomato fruit (*Solanum lycopersicum*) harvested at different maturity stages. *Acta Horticulturae*

Nazoori F, Poraziz S, Mirdehghan SH, Esmailizadeh M & Zamanibahramabadi E. 2020. Improving Shelf Life of Strawberry Through Application of Sodium Alginate and Ascorbic Acid Coatings. *International Journal of Horticultural Science and Technology* 7(3):279-293

Okabe HY, Miyahara T, Yamauchi K, Mirahara & T Kawasaki. 1980. Studies on the constituents of *Momordico charantia* L. 1. Isolation and characterization of momordicosides A and B, glycosides of a pentahydroxy-cucurbitane triterpene. *Chem. Thorne. But.* 28:2753-2762

Peedikayil F, Sreenivasan P & Narayanan A. 2015. Effect of coconut oil in plaque related gingivitis—A preliminary report. *Niger Med. J.* 56(2):143-147

Perez-Gago MB, Gonzalez-Aguilar GA & Olivas GI. 2010. Edible coatings for fruits and vegetables. *Stewart Postharvest Rev*. 6:1-14

Porat R, Weiss B, Cohen L, Dausand A & Aharoni N. 2004. Reduction of postharvest rind disorder in citrus fruit by modified atmosphere packing. *Postharvest Biol. Technol.* 33:35-43

Prashanth A, Kiran K, Rajkumar M & Aparna K. 2022. Studies on Postharvest Quality and Shelf Life of Pink Fleshed Dragon Fruit (*Hylocereus spp.*) Coated with Chitosan and Stored at Ambient Temperature. *Biological Forum – An International Journal* 14(3):340-347

Radi M, Firouzi E, Akhavan H & Amiri S. 2017. Effect of gelatin-based edible coatings incorporated with Aloe vera and black and green tea extracts on the shelf life of fresh-cut oranges. *Journal of Food Quality*

Raffo A, Leonardi C, Fogliano V, Ambrosino P, Salucci M, Gennaro L & Quaglia G. 2002. Nutritional value of cherry tomatoes (*Lycopersicon esculentum cv.* Naomi F1) harvested at different ripening stages. *Journal of Agricultural and Food Chemistry* 50(22):6550-6556

Rehman M, Asi M, Hameed A & Bourquin L. 2020. Effect of postharvest application of aloe vera gel on shelf life, activities of anti-oxidative enzymes, and quality of 'Gola' guava fruit. *Foods* 9(10):1361

Saha A, Tyagi S, Gupta RK & Tyagi YK. 2016. Guar gum-based edible coating on cucumber (Cucumis sativus L.). *European Journal of Pharmaceutical and Medical Research* 3(9):558-570

Samad M, Sajid M, Hussain I, Samad N & Jan N. 2019. Influence of herbal extract and storage duration on fruit quality of china lime. *Horticult Int J*. 3:(3) 153-158

Sedyadi E, Sulistyowati A, Kusumawati M, Nugraha I & Prabawati S. 2019. Utilization of ginger extract (*Zingiber Officinale*) and turmeric extract (*Curcuma longa*) as edible tomato-packing film. In Journal of Physics: Proceedings from the 2nd International Conference on Mathematics, Science and Computer Science, Novotel Balikpapan Hotel, 24 October 2018. Balikpapan Indonesia

Suriati L, Candra I & Supardika I. Aloe-gel coating for delaying physiochemical changes of fresh-cut mango. *Sustainable Environment Agricultural Science (SEAS)* 05(01):58-65

Togrul H and Arslan N. 2004. Carboxylmethyl cellulose from sugar beet pulp cellulose as a hydrophilic polymer in coating of mandarin. *J Food Eng* 62:271-279

Ullah A, Abbasi NA, Shafique M &. Qureshi AA. 2017. Influence of edible coatings on biochemical fruit quality and storage life of bell pepper cv. "Yolo Wonder". *Journal of Food Quality*

Valero D and Serrano M. 2010. Postharvest biology and technology for preserving fruit quality. CRC-Taylor & Francis, Boca Raton, USA

Valero D, Díaz-Mula HM, Zapata PJ, Guillén F, Martínez-Romero D, Castillo S & Serrano M. 2013. Effects of alginate edible coating on preserving fruit quality in four plum cultivars during postharvest storage. *Postharvest Biology and Technology* 77:1-6

Yaman O and Bayoindirli L. 2002.Effects of an edible coating and cold storage on shelf-life and quality of cherries. *Lebnsm. -Wiss. Und. Technol.* 35:146–150

Yan JK, Wu LX, Qiao ZR, Cai WD & Ma H. 2019. Effect of different drying methods on the product quality and bioactive polysaccharides of bitter gourd (*Momordica charantia* L.) slices. *Food Chem* 271:588-596

Zaidi M, Akbar A, Ali S, Akram H, Ercisli S, Ilhan G, Sakar E, Marc R, Sonmez D, Ullah R, Bari A & Anjum M. 2023. Application of plant-based edible coatings and extracts influences the postharvest quality and shelf-life potential of "Surahi" guava fruits. *ACS Omega* 8(22):19523–19531

Zapata PJ, Guillén F, Martínez-Romero D, Castillo S, Valero D & Serrano M. 2008. Use of alginate or zein as edible coatings to delay postharvest ripening process and to maintain tomato (*Solanum lycopersicon* M.) quality. *J Sci FoodAgric* 88:1287-1293