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1-Methylcyclopropene and Ethephon Effects on 'Carabao' Mango Fruits Harvested at Different Stages of Fruit Maturity

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Abstract. Three experiments were conducted using three different stages of fruit maturity (100, 105, and 110 DAFI or days after flower induction) of 'Carabao' mangoes harvested from the same set of trees. Fruits harvested were applied with 1-MCP [(dosage:0.5 µL/L) via gas exposure for 20 hours and spraying], and ethephon (dipping at 1ml/L of H2O) applied singly or in combination. Mangoes were then stored in ambient room conditions [29.2±1.6°C, 69.88±4.0% relative humidity (RH)]. Mango fruits with 1-MCP treatment applied through gas exposure at 0.5 µL/L consistently delayed the peel color change, firmness, and weight loss of harvested fruits at 100, 105 and 110 DAFI. These fruits held its shelf life for 15 (100 DAFI), 12 (105 DAFI) and 9 (110 DAFI) days compared to control with 12, 10 and 8 days respectively. Furthermore, all treatments showed varied effects on the visual quality of fruits regardless of its maturity. It also appeared that fruits at 105 DAFI treated with ethephon alone have better taste while other organoleptic attributes, chemical properties (TSS, TTA and pH), as well as the disease incidence and severity were found to be comparable. This further proved that 1-MCP delays ripening of fruits but could not prevent disease occurrence.

Keywords: chemical properties, climacteric fruits, Ethylene-action blocker, mango, shelf-life

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1. Introduction

Hailed as the "king of fruits", *Mangifera indica* L. or mango is one of the most recognized tropical fruits in the world [1]. The attractive and excellent flavor, fragrance, taste, and nutritional properties drove its prominence to international markets making it one of the most traded fruits worldwide [2]. Rightfully, mango was acclaimed as the national fruit of Asian countries such as India, Pakistan, and the Philippines, and acknowledged as Bangladesh' national tree [3].

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In the Philippines, mango ranks third after banana and pineapple among fruit crops reaching 711,659.89 MT in 2018 in terms of production volume [4]. Although there are several varieties of mango cultivated, 'Carabao' mango known internationally as 'Philippine Super Mango' is the leading variety grown and known for export [5]. 'Carabao' mangoes coming from the Philippines has established a good reputation in the international market. In fact, this variety was recorded in the Guinness Book of Records as the worlds' sweetest variety defeating other mango producing countries [6].

Mangoes are categorized as climacteric fruit which ripen speedily after harvesting, hence, to extend its shelf life, additional postharvest methods are required [7]. This high value crop is very delicate, highly perishable, and susceptible to postharvest diseases, extreme temperature, and physical injuries. Transport of fresh produce from producing fields to markets has been limited due to the perishable nature of the fruit, its sensitivity to low storage temperatures, and disease issues. According to Herianus et al. [8], the ripening process in mature green mango fruits comprises several biochemical processes. The short storage duration severely restricts long-distance commercial fruit shipment. Thus, mangoes are transported around the world on chilled container ships. Furthermore, there were other shelf life enhancing treatments which need further study to fully maximize and complement the potential of cold storage as a method for increasing the postharvest life of fresh mango fruits after harvest [9]. Most mangoes sent to distant markets around the world are exposed to different postharvest treatments, such as hot water treatment, wax coating, cold storage, modified and controlled atmospheres, thermal quarantine, and fungicidal sprays, due to their short shelf life. These procedures are carried out to extend the shelf life of fresh produce and to avoid the spread of invasive pests and diseases that threaten both the economy and the environment [10].

Due to the transitory surge in the production of ethylene during ripening of the fruit, the inhibition of ethylene production or its action has been viewed as a potential method of delaying the ripening process of the fruit [11]. Many well-known chemicals, such as 1-Methylcyclopropene (1-MCP) and Aminoethoxyvinylglycine (AVG), have been successfully utilized to block ethylene production in climacteric fruits. 1-MCP is a gas with a physical similarity to ethylene, allowing it to bind to ethylene receptors in fruits, blocking ethylene's usual function and extending the storage life of agricultural produce. It is an innocuous gas that inhibits ethylene function by inhibiting ethylene receptors when administered at very low concentrations [12]. 1-MCP is an efficient ethylene antagonist because it irreversibly binds to the receptors of ethylene and has a long-lasting action.

Although 1-MCP's ability to delay the ripening of the fruits of 'Carabao' mango has been thoroughly investigated over the years, varied results emerged due to multiple factors that need to be manipulated and considered which significantly affects its effectiveness. These factors include the fruit age or stage of fruit maturity 1-MCP concentration, storage temperature, period of gas exposure, method of application and preharvest cultural practices [13]. Many of these characteristics are expected to have an impact on 1-MCP's performance in other crops, including mangoes.

Moreover, ripening of mango fruit also undergoes numerous biochemical modifications, including enhanced respiratory climate, endogenous ethylene manufacturing, softening of fruits, changes in carbohydrates, organic acids, phenolic compounds, and the manufacturing of compounds for volatile aroma. Changes in the endogenous level of plant growth regulators are thought to be a crucial influence in mango fruit ripening management [14]. Mangoes generate comparatively small concentrations of ethylene but react to exogenous applications of ethylene such as ethephon. Monitoring the accessibility of O_2 and CO_2 to the fruit during respiration can influence ripening and senescence rates in many climacteric plants, such as mangoes, and these two molecules can have a significant inhibitory effect on ethylene's ability to start ripening. To speed up the maturation process, ethylene must be applied artificially [15].

In this experiment, the postharvest quality of ‘Carabao’ mango at different stages of fruit maturity as influenced by 1-MCP as an ethylene-action-blocker and ethephon as a ripening-promoter under ambient storage condition were assessed. It specifically aimed to determine the best postharvest treatment for ‘Carabao’ mango at 100, 105 and 110 days after flower initiation (DAFI) using 1-MCP and ethephon applied singly or in combination.

2. Materials And Methods

2.1. Site and Duration

There were three experimental set ups conducted in this study. All experiments were conducted at the University of Southeastern Philippines (USEP) Tagum–Mabini Campus Chemistry and Food Tech Laboratory, Tagum City, Davao del Norte, Philippines from March to April 2019. The experimental treatments were kept under ambient room conditions [29.2 ± 1.6°C, 69.88 ± 4.0% relative humidity (RH)].

2.2. Experimental Design, Treatments, and Treatment Application

In this study, ‘Carabao’ mango fruits were harvested at three stages of maturity 100, 105 and 110 DAFI) from the same set of trees and utilized as the experimental samples. There were three experiments carried out in a single factorial trial arranged in a Completely Randomized Design (CRD). Each treatment was replicated three times with 20 mango fruits per replicate. The treatments were T1 = 1-MCP (gas exposure) alone; T2 = 1-MCP (gas exposure) + ethephon; T3 = 1-MCP alone (spraying method); T4 = 1-MCP (spraying + ethephon); T5 = ethephon alone; and T6 = control (no treatment).

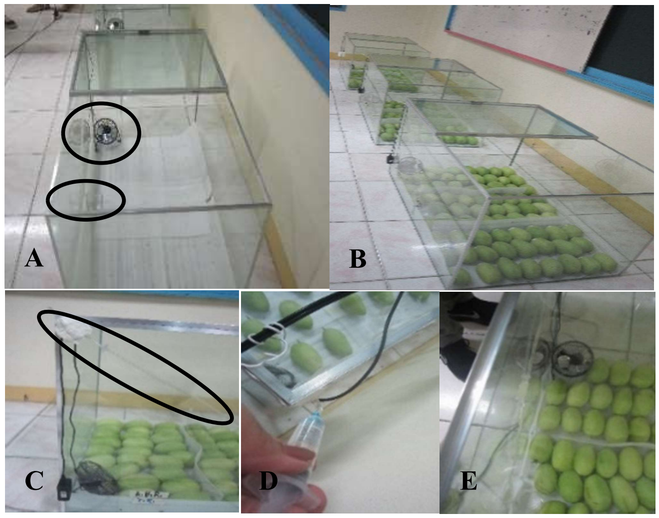

Figure 1. 1-MCP Application Through Gas Exposure Method. (A) Improvised Chamber Glass with Small Fan and Glass Container; (B) Arrangement of Mango Fruits; (C) Installation of Plastic Tube; (D) Addition of Distilled Water Using Syringe; (D) Small Fan Turned on After Sealing the Chamber

All sample fruits were subjected to standard hot water treatment, following the Hot water treatment facility protocol of USeP [16], for postharvest disease control at 52-55°C for 10 minutes prior 1-MCP and ethephon treatments. Fruits treated with 1-MCP through gas exposure were done by exposing the fruits to 1-MCP (dosage: 0.5 µL/L) inside an improvised air-tight chamber under ambient room [27.4 ± 2.1°C, 72.5 ± 3.0% relative humidity (RH)] condition (Figure 1). The chamber was equipped with a small fan to facilitate the circulation of 1-MCP gas. The formulation of commercial 1-MCP was 0.43% (SmartFreshTM powder, 0.14 g/kg active ingredient). A computed amount of 1-MCP powder based on its dosage and weight of fruits was placed in a 150 ml glass container. The container was positioned along with the fruits. A plastic tube was also installed connecting to the outer side portion of the glass container. Afterwards, the chamber was closed and sealed with molding clay. A 10 mL distilled water was then added using syringe through the tube. The water flowed towards the glass container which triggered the release of 1-MCP gas and instantaneously occupied the whole space of the chamber. While inside the chamber, the small fan was turned on and kept closed for 16 hours [17]. After 16 hours of exposure, the fruits exposed with 1-MCP was transferred to storage boxes and stored in an ambient room condition for further evaluation.

Figure 2. 1-MCP Application Through Spraying Method. (left) Spraying of Fruits; (center) Enclosure of Sprayed Fruits Using Plastic Cellophane; (right) Enclosed Treated Fruits Queued for 2 Hours

For fruits treated with 1-MCP through spraying, an aqueous spray solution was made where 0.5 μL/L of 1-MCP powder was added in l L of distilled water. The solution was evenly treated to the fruits using hand sprayer immediately after preparation. The fruits were then enclosed in transparent plastic bags for 2 hours after spraying allowing binding of 1-MCP gas. Afterwards, treated fruits were transferred and arranged in a storage box. Each box was labelled with treatment codes and positioned on its corresponding storage area (Figure 2).

Fruits subjected to ethephon treatment were dipped in an Ethrel® SL480 (0.48 kg/L ethephon) solution for 2–3 seconds, following the manufacturers' recommendation at 1ml of ripening solution diluted in 1L of water. The fruits were air-dried and neatly arranged in such a way that the mangoes should not touch each other. For fruits receiving combined treatments, 1–MCP was applied first prior to ethephon application. After treatment, all sample fruits were stored under normal room temperature storage.

2.3. Data Gathered

Ripening changes [peel color change, sensory firmness, total soluble solids (TSS), total titratable acidity (TTA), pulp pH and Organoleptic Attributes], shelf-life, visual quality rating (VQR), cumulative weight loss and postharvest disease assessment (incidence and severity) were gathered appropriately. Peel color change was monitored through visual evaluation throughout storage period using the standard scale of 1-6 (1-fully green; 2-breaker, not more than 10% yellow; 3-more green than yellow; 4-more yellow than green; 5-yellow with traces of green; and 6-fully yellow) which represent six ripening stages of mango fruits as described by Silva et al. [18]. The fruit firmness of each mango was assessed by applying a gentle hand pressure using a rating scale 1-5 (1 = fully soft; 2 = advanced softness; 3 = first softening; 4 = firm on touch; and 5 = very firm on touch) as described as by Jacob-Wilk et al. [19]. TSS, TTA, and pH of mangoes were measured from its pulp juice. Digital hand-held refractometer (ATAGO, RS-5000 Atago, Japan) was used to determine the TSS content and were reported in degree brix, while TTA content was analyzed following a titration method. 10 mL of mango juice was mixed with 90 mL of distilled water and 1-2 drops of 1% phenolphthalein indicator. Using 0.1 N NaOH, the mixed sample was titrated until the end point (pink colour) [20]. Final data were calculated using the formula below. pH on the other hand was evaluated using a digital pH meter (Kombucha Philippines). The sensory qualities (pulp color, taste, aroma, and overall acceptability) of mango fruits at peel color indicator 6 were assessed by a panel of 20 evaluators. This was evaluated employing the 9-point hedonic scale of 1-9 (9-extremely liked; 8-liked very much; 7-moderately liked; 6-slightly liked; 5-neither liked nor disliked; 4-slightly disliked; 3-moderate disliked; 2-disliked very much; and 1-extremely disliked). Moreover, the shelf life was measured by determining the number of days when the fruits reached VQR 3. VQR, on one hand, was monitored using the rating scale of 1-9 (9, 8-excellent, field fresh; 7, 6-good, with minor defects; 5, 4-fair, with moderate defects; 3-poor, with serious defects, limits marketability; 2-limit of edibility; and 1-non-eatable under usual condition). For cumulative weight Loss, digital weighing scale was employed and calculated as percentage of weight lost from initial. Each fruit was weighted at the beginning which served as initial weight (W_0) and during interval days (W_n). Weight loss was determined by computing: *Weight loss* (%) = [(W_0- W_n) / W_0] x 100. Finally, incidence of mango fruit showing symptoms of anthracnose in the fruit such as irregular, dark brown to black lesions form anywhere on the fruit, was calculated by counting number of fruits that were infected out of the total samples. The result was reported as mean percentage of disease incidence [21]. The severity shown as mean percentage lesion area on the fruit surface was evaluated from visible lesions and decided by following rating scale based on the method of Jongsri et al. [21] using 0-7 scale [0-no disease (0%);1-slightly infected (1-2% disease); 2-mildly infected (5% disease);3-minor infection (10% disease); 4-moderately infected (20% disease); 5-slightly severe (40% disease); 6-severely infected (60% disease); and 7-extremely severe (more than 80% disease).

2.4. Statistical Analysis

ANOVA or Analysis of Variance was used to analyzed the data while Tukey's Honest Significant Difference (HSD) test at 5% level of significance were used to compare the variations among the treatment means using Statistical Tool for Agricultural Research.

3. Results and Discussion

3.1. Ripening Changes

3.1.1. Peel color change

Peel color change of 'Carabao' mango fruit is an indicator of the progress of its ripening process. It indicates that the fruit has attained its desirable flavour, palatable nature and other textural properties that determines quality. Results of this study revealed that the treatments significantly influenced the peel color change for both harvested 'Carabao' mangoes at 100, 105 and 110 DAFI under ambient condition (Figure 3). For fruits harvested at 100 DAFI, it appeared that fruits applied with 1-MCP alone via gas exposure (T1) consistently showed significant delay in the peel color change of 'Carabao' mango fruits through-out its storage period (Figure 4). Conversely, fruits treated with ethephon alone (T5) significantly developed advance yellowing as manifested on day 2 of storage onwards.

Similarly, fruits harvested at 105 DAFI applied with 1-MCP alone via gas exposure (T1) consistently delayed its changes in peel color throughout its storage period compared to other treatments. However, T1 appeared to be comparable with T2 at day 2, T6 at day 6 and T3 at day 10. On the third experiment, all fruits without ethephon application (T1, T3 and T6) constantly showed significant delay on peel color change during storage.

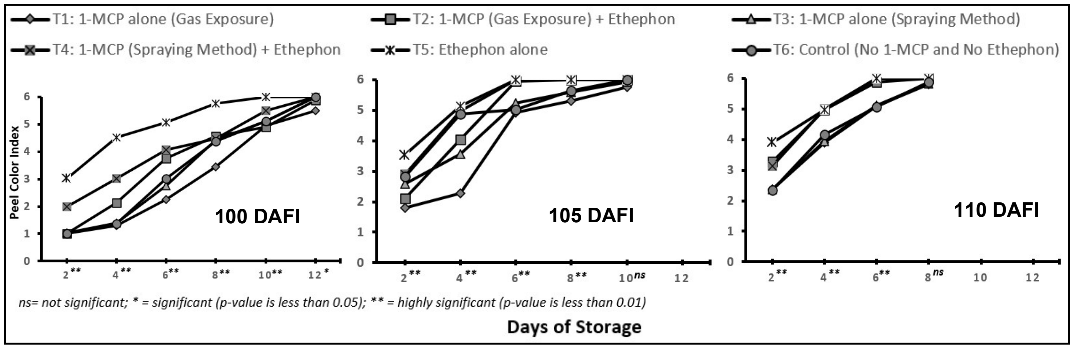

Figure 3. Peel color Change of Harvested 'Carabao' Mango Fruits at Three Stages of Fruit Maturity as Influenced By 1-MCP And Ethephon Application

Figure 4. 'Carabao' Mango Fruits (100 DAFI) Treated with 1-MCP and Ethephon Manifesting Different Peel Color Indices at Day 8 of Storage Under Ambient Condition. Fruits Under T1 Showed More Green Peel Color Than Yellow, while Those Under T2, T3, T4 and T6 Exhibited More Yellow Than Green. Majority of the Fruits in T5 Already Reached Full Yellow Peel Color

The results of the three conducted experiments validated the findings of other published research that 1-MCP significantly postponed the changes in peel color of mango. The three stages of maturity of the fruit being used on the experiments manifested different peel color change behaviour. Similarly, the delay in peel color development initiated by 1-MCP were also detected in other mango cultivars such as 'Guifei' and 'Nam dokmai' [22]. Likewise, in the study of Abu-Goukh et al. [23], gas exposure method was also commended as an effective method in applying 1-MCP for mango.

1,000 ppb concentration of 1-MCP0020prolonged the changes of peel and pulp color of 'Namh-dawg-mai-sri-tong' cultivar of mango [24]. Moreover, Ngamchuachit et. al. [25] concluded that treatment of 1-MCP prior to HWT appeared to have a more capability to lessen the rate of softening of the fruit when contrasted with 1-MCP application following hot water treatment or HWT. Their results revealed that 1-MCP treatments alone delayed the days to full-ripeness to 13 days as compared to 11 days for the control or untreated fruit.

Significantly, the storage temperature and RH played an essential role in the course of peel color change of 'Carabao' mango fruits. Those harvested at 100, 105 and 110 DAFI without 1-MCP application altered its color dramatically, taking into account that the storage temperature ranged at 27–30 °C and RH of 60–80 % which promoted changes on biochemical and physiological activities of most climacteric fruits including mangoes. Response of 1-MCP varies on species of fruits, vegetables and other horticultural crops which could either delay the change of peel color of the commodity. 1-MCP retarded peel color change of tomato, a climacteric fruit, it reduces browning of eggplant, a non-climacteric horticultural crop [26].

Ethylene induced fruits through ethephon application synchronized its peel color appearance compared to the natural ripening or no ethephon application. The skin color is enhanced by ethylene treatment by increasing degreening [27]. This revealed that the role of ethylene in climacteric fruits such as mangoes significantly influence the ripening process.

On the other hand, Silva et al. [18] reported mangoes with 1-MCP treatment reached its full color change with desirable appearance. Hence, the result on the peel color change of this study further shows that 'Carabao' mango fruits harvested at 100 DAFI when treated with 1-MCP through gas exposure, can be stored, or displayed on markets with a maximum day of twelve (12). 1-MCP application through gas exposure performed better compared to spraying method which only delays up to ten (10) days. This trend has similar manifestation on 105 and 110 DAFI.

3.1.2. Sensory firmness

As the fruit ripens, the softening of fruits is correlated with the changes in its chemical components. Figure 5 shows the sensory firmness (assessed by hand pressure) of 'Carabao' mango fruits harvested at 100, 105 and 110 DAFI. For fruits harvested at 100 DAFI, fruits with 1-MCP treatments alone (T1 and T3) as well as control (T6) have firmer pulps than fruits with 1-MCP treatment but treated with ethephon (T2 and T3) as manifested on days 4 and 6 of storage. However, on day 12, fruits on T1 and T3 have firmer sensory firmness than other treatments.

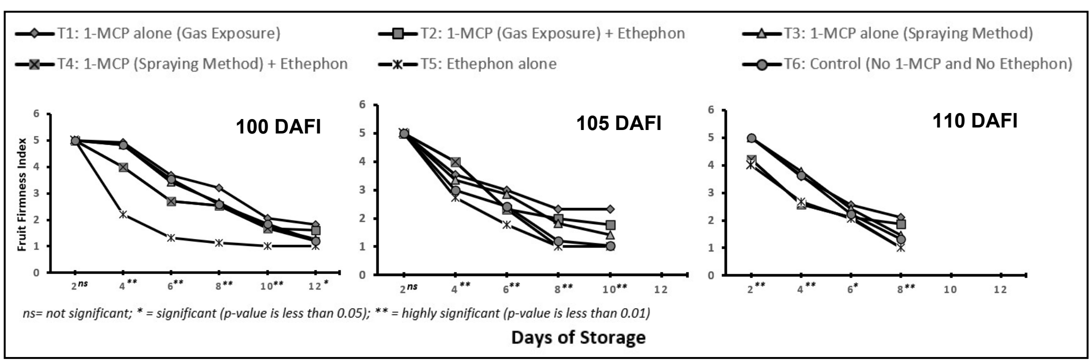

Figure 5. Sensory Firmness of Harvested 'Carabao' Mango Fruits at Three Stages of Fruit Maturity as Influenced By 1-MCP and Ethephon Application

For fruits harvested at 105 DAFI, it appeared that T1 or fruits applied with 1-MCP alone by gas exposure method gained firmer pulps as exhibited on days 6, 8 and 10 of storage. Mango fruits applied with1-MCP through spraying but with subsequent ethephon application (T4) as well as fruit applied with ethephon alone (T5) developed advance softening compared to other treatments as exhibited on days 8 and 10 of storage. This manifestation was probably due to the significant amount of exogenous ethylene that improved chemical changes in the fruit which eventually affects the firmness.

On the third experiment where fruits harvested at 110 DAFI were used, 1-MCP also showed desirable result in terms of fruit firmness. Fruits with 1-MCP treatment alone via gas exposure (T1) and spraying (T3) methods have consistently delayed softening of fruits as exhibited on days 2, 4 and 6 of storage. It can also be noted in this experiment that fruit age also affects the softening of mango fruits. Fruits harvested at 110 DAFI softened earlier that those harvested at 100 and 105 DAFI.

Experimental results showed that treatment of 1-MCP on 'Carabao' mango fruits delay softening of the fruits with respect to its fruit age. It appeared that fruits harvested at 100 DAFI responded positively compared to fruits harvested at 105 and 110 DAFI. In the first experiment, green peel color was kept until day 4 of storage which conjoins with a delay of the softening of the fruits. Similarly, this result coincides with the study of Hofman et al. [28] which reported that 1-MCP application retarded softening of mango.

Moreover, ethylene-treated fruits gave greater firmness loss especially on fruits harvested at 110 DAFI. Fruit softening is caused by the loss of tissues, particularly as they age, and is linked to changes in cell wall composition, as well as changes in the structure and composition of carbohydrates such pectin, hemicellulose, and cellulose [29]. As mentioned earlier, fruit softening on the three experiments is coupled with the changes in the chemical composition of the fruit as it ripens. In this experiment, 'Carabao' mango fruits harvested at 100 DAFI applied with 1-MCP turned into yellow before it softened which is similar with the research of Barry and Giovannoni [27] on their experiments using 1-MCP on tomatoes. While gas exposure method effectively held the green peel color of fruits, softening was also delayed. However, these fruits slowly changed its peel color from green and eventually develop uniform yellowing of the peel.

Cell wall disintegration, particularly pectin solubilization, is often implicated for softening during ripening in climacteric fruits. Increased activity of different cell wall hydrolases, whose activity is regulated by ethylene, could be one of these alterations [30]. Thus, as an ethylene blocker, 1-MCP slows down the softening process. Generally, the loss of fruit firmness during storage is a natural ripening process that occurs in almost all fleshy fruits as a result of biochemical changes in the cellular structure [31]. This could explain the observed decrease in firmness of mango fruits exposed to 1-MCP and ethylene induction during storage.

3.1.3. TSS, TTA, and pH

Evaluating the balance of sweetness and acidity determines the quality of taste which affects consumer acceptability. In this study, the TSS, TTA and pH of mango pulps were measured when fruits reached peel color index 6 (PCI 6). Based on the statistical results, TSS, TTA and pH of 'Carabao' mango fruits harvested at 100, 105 and 110 DAFI did not significantly affected by 1-MCP and ethephon treatments. Regardless of fruit age, TSS, TTA and pH levels of mango fruits were comparable with each other (Table 1). It is also notable that the 'Carabao' mango exhibited high TSS values since this variety has been known as one of the sweetest varieties in the world [6]. Although it was noteworthy that they were gathered on different days, the chemical properties seemed not significantly affected by the treatments.

Table 1. TSS, TTA, and pH of PCI 6 'Carabao' Mango Fruits Harvested at Three Stages of Fruit Maturity as Influenced By 1-MCP and Ethephon Application

Treatments	Chemical Properties ^{ns}								
	100 DAFI			**105 DAFI**			**110 DAFI**		
	TTS (%)	TTA (%)	pH	TTS (%)	TTA (%)	pH	TTS (%)	TTA (%)	pH
T1	21.20	1.22	4.80	22.00	1.24	5.34	23.80	1.11	5.64
T2	20.55	1.32	4.55	21.80	1.12	5.33	22.50	0.95	5.55
T3	20.31	1.40	4.50	21.50	1.20	5.10	23.40	1.11	5.40
T4	21.00	1.05	4.88	22.50	0.95	5.11	24.50	0.88	5.60
T5	23.60	1.10	4.82	25.20	0.86	5.20	25.40	0.64	5.64
T6	22.00	1.55	4.20	22.80	1.05	5.06	23.50	0.98	5.38

Note: ns denotes not significant

Total Titrable Acidity (TTA) was measured in the basis of percent citric and malic acids present, being the predominant acids in mango [32]. pH levels indicate a product's acidity and alkalinity, whereas tritratable acidity indicates the amount of acid present. Evaluating the pH levels and tritratable acidity of mango could indicate fruit maturity or ripeness. They are the indicator used to evaluate consumption quality and concealed attributes. Dadzie and Orchard [33] asserted that acids play a significant role in the fruit's postharvest quality because flavor is mostly a balance of acids and sugar levels.

Meanwhile, pH values of ripe mango ranges 4.4 – 5.5. In the study of Faasema et al., [34], the titratable acidity, pH and soluble solids of the three improved varieties of mango ('Peter', 'Brokin' and 'Julie') treated with 1-MCP seemed not affected significantly. Ascorbic acid content of 'Chokanan' mangoes applied with 1-MCP and stored at ambient condition were also not affected [35] l,k. Fresh-cut Philippine 'Carabao' mango (*Mangifera indica* L. cv. 'Carabao') fruits treated with 1-MCP post-cutting treatment had greater pH and total soluble solids, although total acidity was decreased [6].

Calderon-Lopez et al. [36] generalized that 1- MCP treatment on apple slices had little or no effect on TSS and TA, despite the results of numerous investigations being conflicting. Papaya [28] and apples [37] both showed similar results. 1-MCP treatments also reduced ethylene-induced acidity loss in carrots and delayed or inhibited TTA loss in tomatoes, according to Fan et al. [37].

3.1.4. Organoleptic attributes

The organoleptic or sensory attributes were assessed employing the 9-point hedonic scale to measure the pulp color, taste, aroma and overall acceptability of 'Carabao' mango fruits at peel color index 6 (PCI 6). Nine (9) was the excellent sensory scale while one (1) denoted poor sensory attribute. Based on the statistical analysis, the sensory attributes of mangoes harvested at 100 and 110 DAFI were not significantly influenced by 1-MCP and ethephon applications (Table 2). However, in experiment 2 (105 DAFI), it appeared that all fruits with ethephon application (T2, T4 and T5) have desirable taste compared to other treatments, while other sensory attributes have no significant differences. The result of this experiment elucidates that the balance of sugar and acidity content of 'Carabao' mango fruits affecting the taste of the fruit were enhanced by the ethephon application.

Table 2. Organoleptic Attributes of PCI 6 'Carabao' Mango Fruits Harvested at Three Stages of Fruit Maturity as Influenced by 1-MCP and Ethephon Application

Treatments	Organoleptic Attributes											
	100 DAFI ^{ns}				105 DAFI				110 DAFI ^{ns}			
	A	B	C	D	A^{ns}	B*	C^{ns}	D^{ns}	A	B	C	D
T1	7.04	7.08	7.00	7.16	7.98	7.13 $_{b}$	8.15	8.23	7.97	7.76	7.88	8.06
T2	6.86	7.19	6.95	7.27	8.07	7.75 $_{a}$	8.02	8.10	7.88	7.99	8.00	7.97
T3	6.89	7.10	7.00	7.18	7.87	6.99 $_{b}$	7.85	7.93	7.75	7.43	7.95	7.84
T4	6.93	7.06	7.09	7.14	7.90	7.56 $_{ab}$	7.95	8.03	7.97	7.87	8.05	8.06
T5	7.22	7.44	7.21	7.40	8.10	8.40 $_{a}$	8.23	8.31	8.00	8.22	8.11	8.09
T6	6.96	6.89	7.00	6.97	7.80	6.00 $_{c}$	7.85	7.93	7.88	7.89	8.00	7.97

*Note: A - Pulp Color; B - Taste; C - Aroma; D - Overall Acceptability. Ns = not significant; * = significant (p-value is less than 0.05). Same letter superscript means not significantly different from each other*

The taste and other sensory attributes of the fruits correlates with the chemical changes. While studies showed that 1-MCP have no significant effects on the chemical changes of the mango fruit as compared to control or untreated fruits [6, 34, 35], the sensory attributes were also not seemingly affected. 'Tommy Atkins' mangoes for instance were not influenced by 1-MCP as panelist did not noticed variations in aroma, color or firmness between the untreated and treated fruits at 0.1 µL/L of 1-MCP [38].

The pigmentation of the peel happens when chlorophyll is converted to simple sugars. Increased fruit sweetness as a result of higher soluble sugar concentration during ripening is regarded as a significant compositional alteration in relation to mango flavor. Starch concentration rises in chloroplasts throughout mango development and is entirely hydrolyzed to sugars during ripening [39]. As the ripening process delayed same in 1-MCP treated fruits, the transformation of sugar will be delayed.

3.2. Fruit Shelf-life

For this parameter, results revealed that fruits applied with 1-MCP alone (via gas exposure at 0.5 µL/L) held its shelf life for up to 15 for 100 DAFI, 12 days for 105 DAFI and 9 days for 110 DAFI compared to control with 12, 10 and 8 days respectively (Figure 6).

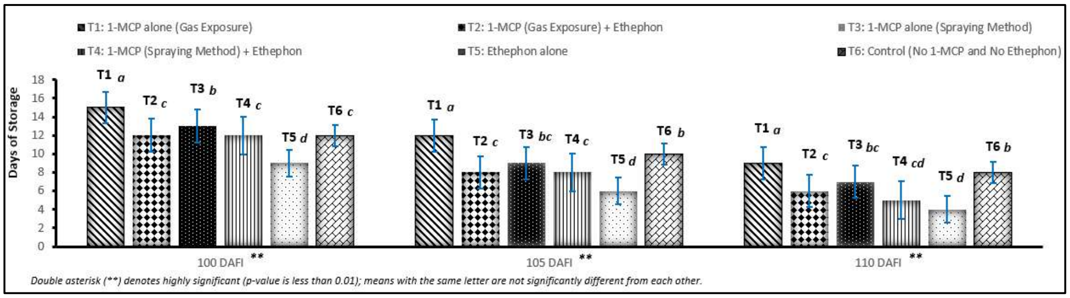

Figure 6. Shelf Life of Harvested 'Carabao' Mango Fruits as Affected by the Application of 1-MCP and Ethephon

The results indicated that 1-MCP treatment via gas exposure at 0.5 μL/L for 20 hours has immense ability for preserving the quality of 'Carabao' mango fruits. Similarly, in the study of Chaiprasart & Hansawasdi [24], 'Namh-dawg-mai-sri-tong' mango were also applied with 1-MCP during storage and found effective, however, the rate was way higher at 1000 ppb. Furthermore, because of the suppression of respiration and C_2H_4 evolution, the highest 1-MCP concentration retarded the changes in peel and pulp color, fruit firmness, and prolonged the shelf life for up to 15 days.

The shelf life of mango was greatly influenced by the temperature and harvest days of the collected produce. Baloch and Bibi [40] found that a storage temperature of 30°C gives the system enough energy to complete the ripening process effectively. They came to the conclusion that the harvest days and storage temperature had a significant impact on the shelf life, waste percentage, and fruit quality. The temperature also affects the fruits' metabolic activities. Sugars, acids, vitamins, calories, potassium, and carbs are just a few of the water-soluble substances found in mangos and other fruits. The soluble solid content of the fruits is made up of these soluble substances. Sugar is the primary component of soluble solids in most ripe fruits. The increased activity of enzymes responsible for the hydrolysis of starch to soluble sugars has been linked to fruit ripening. Mango is a climacteric fruit that increases soluble solid content until it reaches a maximum at full ripeness, then shows a modest decrease as it approaches senescence [41].

3.3. Visual Quality Rating (VQR)

Fruit visual quality is a key market requirement since it influences customer preference and restricts marketability. Presented in Figure 7 are the visual quality rating of 'Carabao' mango fruits as affected by the application of 1-MCP and ethephon. Fruits applied with ethephon alone (T5) in experiment 1 have lower VQR compared to other treatments as manifested in day 10 of storage. Conversely, T5 along with T2 (1-MCP gas exposure with ethephon) and T4 (1-MCP spraying with ethephon) have higher VQR in experiment 2. This scenario occurred at days 2 and 6 of storage. However, this did not sustain on day 8 and 10 of storage since fruits applied with 1-MCP alone via gas exposure (T1) obtained the highest VQR surpassing other treatments. On experiment 3, fruits with 1-MCP treatments but have no subsequent ethephon applications (T1 and T3) as well as treatment 6 (no 1-MCP and no ethephon) have higher VQR than other treatments as exhibited on day 8 of storage.

The aesthetic quality of the fruits applied with 1-MCP was also delayed because 1-MCP slows fruit ripening qualities such as peel color change and, as a result, reduced water loss. Mango's visual appearance, quality, and shelf life may suffer because of the water loss in the fruit [23]. However, as the fruits ripen, they lose water content, causing fruit shriveling, as seen by inferior visual quality as compared to fruits that were not treated with 1-MCP.

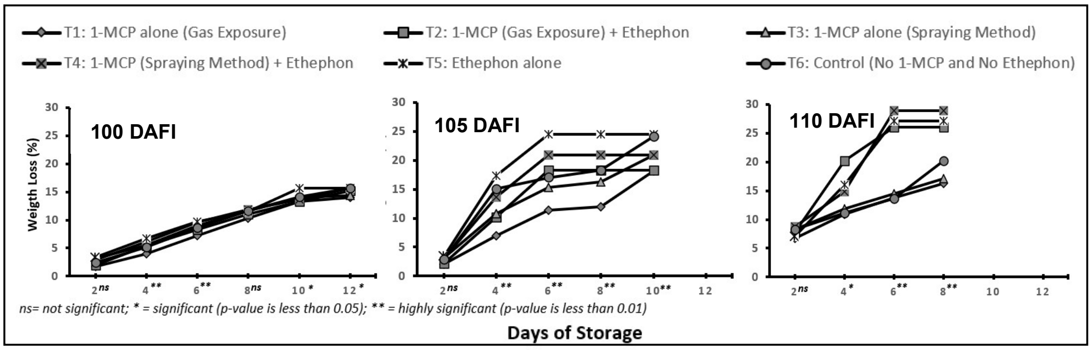

Figure 7. VQR of Harvested 'Carabao' Mango Fruits at Three Stages of Fruit Maturity as Influenced by 1-MCP and Ethephon Application

1-MCP inhibited ethylene synthesis, reduced respiration rates, maintained firmness, and other quality characteristics in 'Carabao' mango fruits both during and 14 days after storage [13]. These assertions back up the findings of the first trial (at 100 DAFI), which found that 1- MCP-treated fruits had good visual quality in the first few days of storage. Nonetheless, as the fruits ripened, the water content decreased, causing shriveling of the fruit, as seen by poor visual quality, as opposed to fruits that had not been treated with 1-MCP.

Although 1-MCP decreased the daily visual quality rating at ambient storage, it can be significantly enhanced by storing at low temperatures, which has been successfully utilized to lengthen the shelf-life of fresh horticultural crops. When ripening mangoes, Paull and Chen [42] found that keeping the fruit between 20°C and 23°C provided the optimum look, palatability, and decay management.

3.4. Cumulative Weight Loss (%)

Water loss, also known as transpiration, causes weight loss. Fruits have a high-water content at harvest, which gives them a good appearance and strong texture. Figure 8 shows the cumulative weight loss (in percentage) of harvested 'Carabao' mango fruits under ambient storage conditions as impacted by 1-MCP and ethephon treatment.

On the first experiment (100 DAFI), fruits applied with 1-MCP alone via gas exposure (T1) consistently obtained the lowest weight loss percentage throughout its storage period. Although there were days where T1 was comparable to some treatments. For instance, on day 12, T1 was comparable to T3 (1-MCP spraying alone). Similarly, T1 also showed consistent significant result on weight loss as it obtained the lowest cumulative weight loss (%) on the second experiment. However, T1 was also comparable with T2 on days 2, 4 and 10 of storage. The scenario was also similar with the third experiment as T1 also consistently gained the lowest cumulative weight loss.

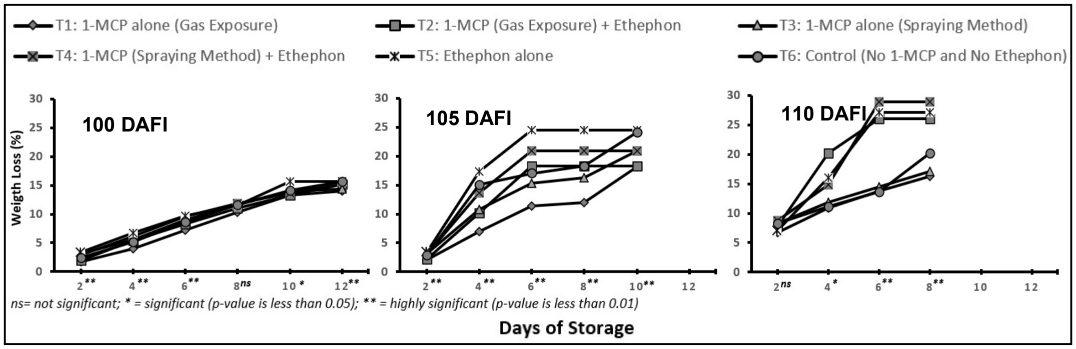

Figure 8. Cumulative Weight Loss of harvested 'Carabao' Mango Fruits at Three Stages of Fruit Maturity as Influenced by 1-MCP and Ethephon Application

In this result, 1-MCP treated mango fruits obtained lower weight loss percentage as the fruits delay the ripening process. This weight loss reduction is most likely due to 1-MCP's ability to block the ethylene action, which has a direct relationship with respiration and fruit ripening. The findings are consistent with those of Silva et al. [18], who found that mango fruits treated with 1-MCP lost less weight than non-treated controls in two mango cultivars, 'Kent' and 'Keitt.' The study's ambient storage conditions favored quick water loss from harvested fruits and accelerated the ripening process. According to Tirmazi and Wills [43], faster air movement around fruits could lead to more water loss.

3.5. Disease Incidence and Severity

Postharvest infections are economically significant because they have an impact on a variety of quality considerations, particularly in the market. Anthracnose, caused by *Colletotrichum gloeosporioides* (Penzig), and stem-end rot, caused by *Botryosphaeria spp.,* are the two most frequent postharvest diseases seen in mango [44]. In this study, anthracnose diseases of 'Carabao' mango fruits harvested on 100, 105 and 110 DAFI did not significantly influenced by 1-MCP and ethephon applications under ambient storage condition (Figure 9).

It was noticed that the prevalence of postharvest disease in mango fruits did not differ considerably regardless on the age of the fruit and method of 1-MCP application. This demonstrates the efficacy of 1-MCP as an ethylene action inhibitor, since it was unable to prevent or postpone postharvest diseases in mango fruits specifically 'Carabao' variety. Anthracnose, insect damage, jelly seed, scab, scars, sunburn, malformed, and lenticels damage are some of the postharvest diseases of mango [44]. It's also worth noting that the fruits were treated with hot water, which could explain why there were fewer postharvest illnesses in this study.

It can also be noted that as the fruit ripens, ethylene was also produced. As ethylene enhances ripening, it also initiates senescence, hastens deterioration and attack to microorganisms.

Exogenous ethylene promotes spore germination of microorganisms which increase decay incidence of perishable crops such as mango [11].

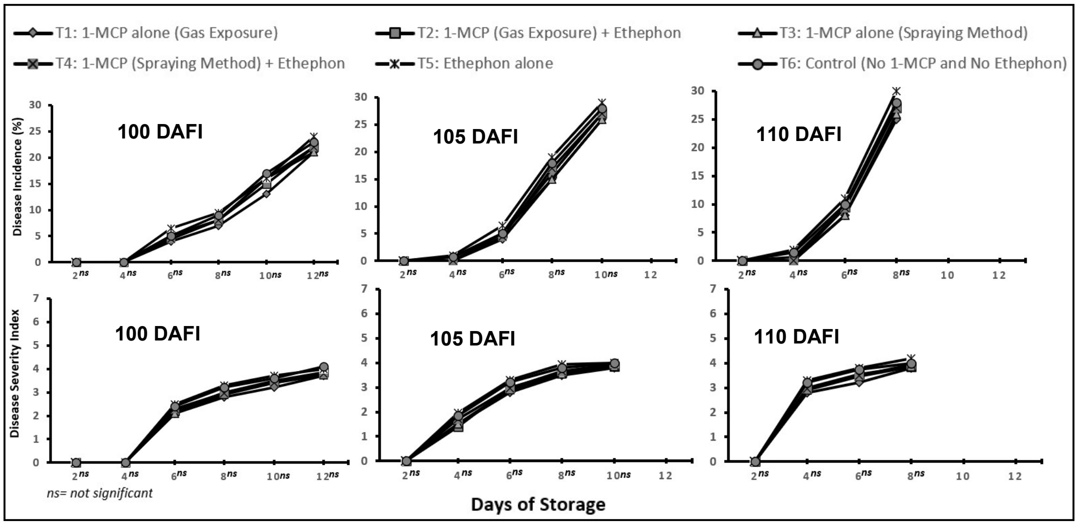

Figure 9. Incidence and severity of anthracnose disease exhibited by 'Carabao' mango fruits at three stages of fruit maturity as influenced by 1-MCP and ethephon application

The influence of 1-MCP on a variety of postharvest disorders and diseases is specific to a certain commodity and differs from species to species. 1-MCP treatment lessen disorders in some cases while others resulted otherwise in golden berries, it influences pathogen infection and development in ripening [45].

4. Conclusion and Recommendation

1-MCP has a considerable influence on delaying the ripening of 'Carabao' mango fruits. As to the best treatment for fruits harvested at 100, 105 and 110 DAFI, treatment of 1-MCP via gas exposure consistently showed favourable effect in delaying its shelf life for up to 15, 12 and 9 days, respectively. Ethephon on one hand enhances the ripening attributes of harvested 'Carabao' mango fruits. Moreover, this study also concluded that 1-MCP prolongs shelf life of 'Carabao' fruits but cannot control its anthracnose incidence. As expected, fruits harvested at later stage of maturity (110 DAFI) deteriorates sooner that fruits harvested earlier (105 and 100 DAFI). With the expedient and practical results of these experiments, the shelf life can be prolonged longer by 1-MCP through gas exposure and preserved its freshness when the treatment was coupled with disease control. This is precisely because 1-MCP can prolong shelf-life but cannot control anthracnose incidence which also causes deterioration to fruit. Experimental research on the application of 1-MCP coupled with appropriate control on postharvest diseases specifically on the use of beneficial microorganisms that are antagonistic to the disease-causing pathogens is highly recommended.

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