"EFFECTIVENESS OF GASEOUS AND AQUEOUS 1-METHYLCYCLOPROPENE (1-MCP) ON HEATED AND UNHEATED MANGO FRUIT: UNDERSTANDING THE MODE OF ACTION"

FINAL REPORT

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SUMMARY

Gaseous 1-MCP delays ripening in some mango cultivars, but requires 12 hours of application in sealed containers. A new aqueous formulation applied as a postharvest dip for only 1 to 5 minutes has shown the same effectiveness as gaseous 1-MCP. This research was conducted to determine the effectiveness of aqueous 1-MCP on mango fruit with or without Quarantine Hot Water Treatment (QHWT); to determine the best step during the mango packing process to apply aqueous 1-MCP; and to determine the metabolic and physiological processes involved in the mechanism of action of 1-MCP applied to heated or unheated 'Kent' and 'Keitt' mango fruit. Eight activities were undertaken. The first was done in Mexico during the 2013 season and other seven in the Horticultural Sciences Department of the University of Florida during my Sabbatical from August 2013 to February 2014. Results were not as expected. Aqueous 1-MCP, although it showed some delay of ripening by maintaining pulp firmness longer and by slowing down pulp color development, had a negative interaction with QHWT. At the end of shipping simulation (3 weeks at 12 ± 1 °C; 90 ± 5 % RH) or at consumption stage, fruit treated with 1-MCP in combination with QHWT showed fair to bad external appearance. In contrast, for fruit treated with 1-MCP without QHWT the ripening process was delayed without affecting the external appearance. Thus, the new aqueous formulation of 1-MCP doesn't seem to be a good alternative for countries exporting mango to the USA where QHWT is mandatory. However, it could be useful for countries that don't demand mandatory QHWT.

To achieve the objective about determining the metabolic and physiological processes involved in the mechanism of action of 1-MCP applied to unheated or heated fruit, research focused on investigating the potential roles of 1-MCP diffusion and metabolism in modulating 1-MCP efficacy in 'Kent' and 'Keitt' mango fruit, as well as, in 'Solo' type papaya fruit. In mango, 'Kent' and 'Keitt' showed a different pattern related to 1-MCP sorption. However, 1-MCP sorption was similar between heated and unheated fruit. Moreover, sliced 'Keitt' fruit showed a 1-MCP sorption rate twice that of whole fruit. With respect to papaya, no significant differences in gaseous 1-MCP adsorption were detected between heated and unheated whole papaya fruit, but significance differences were found for sliced papaya from heated and unheated fruit. Also, significant differences were found for gaseous 1-MCP exposure time. The longer the exposure time, the greater the ingress of gaseous 1-MCP. Finally, with relation to the experiments done to measure the ingress of aqueous 1-MCP, no significant differences were found between heated and unheated fruit; no differences between 1 or 5 min dipping time; nor differences among sampling region (apical, middle, basal, or cavity). In relation to 1-MCP concentration, significant differences were detected between 1 mg $L^{-1}$and 3 mg L^{-1} in the experiment conducted in January, but not in the experiment conducted in December.

With respect to my sabbatical in the Department of Horticultural Sciences of the University of Florida, it was a great and exciting experience for me. I learn a lot from my Advisors, Dr. Brecht and Dr. Huber. I want to express my gratitude to both since they were very collaborative and let me use the entire infrastructure (labs and equipments) to develop my research. Also, I am very grateful because their Technicians (Kim Cordasco and James Lee), helped me when I had doubts about use of the GCs for respiration and ethylene, as well as for measuring 1-MCP content. I thank all the classmates with whom I shared seven months of my life. A special mention for Maricruz, Francisco, and Ferdous is necessary. Finally, I want to dedicate this memory to my wife, my children and my youngest brother for all the support given when I needed it.

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BACKGROUND

Mango is one of the favorite fruits in the US market, where consumption has doubled in the past 10 years. During the most recent 3 years for which data are available (2009-2011) an average of 71.7 million 10-pound boxes have been imported, mainly from Mexico (65.1 %), Peru (9.7 %), Ecuador (9.4 %), Brazil (7.4 %), Guatemala (4.6 %), and Haiti (2.5 %) [USDA-FAS, 2013]. However, the quality of mango fruit at the consumer level is often compromised, since exporter countries face several challenges in delivering high quality fruit (Brecht *et al.*, 2009). One of the major challenges to overcome in most countries exporting mangos to the USA, with the exception of Mexico, is that they require up to 4 weeks of refrigerated transport in sea containers, leading to over ripe fruit since refrigeration per se is not enough to delay the ripening process. In addition, the problem becomes worse because often packers attempt to address the above problem by harvesting immature fruit, leading to hot water and chilling injury, since immature mango fruit are more susceptible to both those disorders. Immature harvesting also prevents the fruit from realizing its full flavor potential.

There are several techniques other than early harvesting that may be used to delay ripening, extend shelf life, and maintain fruit quality. Recently a new tool, 1-methylcyclopropene (1-MCP) has been added to these techniques. 1-MCP is a potent ethylene inhibitor that binds to ethylene receptors, blocking its action (Sisler and Serek, 1997, 1999). Since the approval of 1-MCP for use in edible produce (EPA, 2002), extensive research has been performed. Blankenship and Dole (2003) described over 100 studies detailing 1-MCP action, its application, and effects on ethylene inhibition. They stated that 1-MCP prevents ethylene effects in several fruits, vegetables, and flowers; making it important not only for commercial purposes, but also in helping scientists to further understand the role of ethylene in plants. In fact, Huber (2008) found that 1-MCP is an effective tool for understanding the role of ethylene in senescence and ripening processes, especially for climacteric fruits like mango. Also, Watkins and Miller (2005) summarized the effects of 1-MCP on physiological processes or disorders in fruits, vegetables, and ornamental products, while Watkins (2006, 2008), pointed out that 1-MCP influences ripening and senescence of several fruits and vegetables by reducing ethylene production and respiration, affecting mainly softening and color changes.

The beneficial effect of 1-MCP in modulating ripening has been proven for several mango varieties including 'Zihua' (Jiang and Joyce, 2000), 'Kensington Pride' (Hofman *et al.*, 2001), 'Keitt' (Osuna-García and Beltran, 2002; Osuna-García, 2006), 'Rosa', 'Espada' and 'Jasmim' (Silva *et al.*, 2004), 'Kent' (Osuna and Beltran, 2004; Osuna-García and Muñoz-Ramírez, 2004; Osuna-García *et al.*, 2005; Osuna-García *et al.*, 2009), 'Tommy Atkins' (Alves *et al.*, 2004; Coelho de Lima *et al.*, 2006; Pereira-Bomfim *et al.*, 2011), 'Nam Dokmai' (Penchaiya *et al.*, 2006), and 'Namh-dawg-mai-sri-tong' (Chaiprasart and Hansawasdi, 2009). In most experiments, gaseous 1-MCP was applied in sealed chambers with doses ranging from 100 to 1200 ppb applied for 12 or 24 h at room temperature (22-25 °C) or while cooling the fruit at 12 °C. In general, results showed that 1-MCP delayed the climacteric peak and decreased ethylene production, maintained pulp firmness longer, and delayed ripening related color changes.

In spite of these encouraging results, the adoption of 1-MCP at the commercial level has been very limited, mainly due to the difficulty of its application. In addition, as suggested by research with other commodities, 1-MCP effectiveness could be affected by several factors such as the quarantine hot water treatment. Osuna-García *et al.* (2007) evaluated the effect of 1-MCP (0 and 300 ppb) applied after different hot water treatments (Control, 52 °C for 5 min and 46.1 °C for 110 min) on the physiology and quality of 'Keitt' mangos. They found the effectiveness of 1-MCP was greatly affected by the extent of hot water treatment. 1-MCP treated fruit without hot water treatment retained 80% of their initial pulp firmness at the end of shipping simulation (20 days at 13 ± 2 °C; 85 ± 10 % RH); those heat-treated at 52 °C for 5 min retained only 50% firmness, whereas those treated at 46 °C for 110 min (the insect quarantine treatment) had firmness levels that were almost the same as control fruit not treated with 1-MCP, since they retained only 10 % of their initial pulp firmness.

Recently, a new aqueous 1-MCP formulation has been developed, allowing more flexibility for its application. Initially, the aqueous solution was intended for preharvest application, but when applied as a postharvest dip for only 1 to 5 min, it has shown the same effectiveness as a 9 to 12 h application of gaseous 1-MCP, delaying the ripening and softening process in mango, avocado, tomato, carambola, and pear fruits (Contreras-Martínez *et al.*, 2007; Choi *et al.*, 2008; Choi and Huber, 2008; Warren, 2009; Cheng *et al.*, 2012). This new formulation could be much more easily incorporated into the mango packinghouse processes than gaseous 1-MCP application, either right after washing the fruit or following the hot water treatment. If we test both scenarios, we can find out what is the most suitable step to apply aqueous 1-MCP successfully and provide the mango industry with a powerful tool to allow harvest of fully mature fruit and subsequently delay ripening, extend shelf life, and maintain fruit quality.

GENERAL OBJECTIVES

- To determine the effectiveness of aqueous 1-MCP on mango fruit with or without quarantine hot water treatment.
- To determine the best step during the mango packing process to apply aqueous 1-MCP.
- To evaluate the effect of aqueous 1-MCP on ripening processes, extension of shelf life, and keeping fruit quality of 'Kent' and 'Keitt' mango varieties.
- To determine the metabolic and physiological processes involved in the mechanism of action of 1-MCP applied to heated or unheated mango fruit.

METHODOLOGY

The following activities were done:

1. **Effectiveness of aqueous 1-MCP on mango fruit with and without QHWT (Mexico).**

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2. **Effectiveness of aqueous 1-MCP on 'Kent' and 'Keitt' mango with QHWT.**
3. **1-MCP sorption by 'Kent' and 'Keitt' fruit:**
    a. **Capacity of heated and unheated 'Kent' and 'Keitt' fruit to bind 1-MCP.**
    b. **Capacity of whole and sliced 'Keitt' fruit to bind 1-MCP.**
4. **Effect of water source on 1-MCP performance.**
5. **Comparison of two sources of 1-MCP (AFXRD-038) formulation.**
6. **Capacity of heated and unheated whole and sliced papaya fruit to bind 1-MCP.**
7. **Ingress of 1-MCP in heated and unheated papaya fruit.**
8. **Internal gaseous 1-MCP in heated and unheated papaya fruit treated with aqueous 1-MCP.**

Note: The first activity was done in Mexico during the 2013 mango season while the others were done during my Sabbatical in the Horticultural Sciences Department of the University of Florida from August 2013 to February 2014.

1. **Effectiveness of aqueous (1-MCP) on mango fruit with and without QHWT (Mexico).**

Particular Objectives

- To determine the effectiveness of aqueous 1-MCP on mango fruit with or without **QHWT**.
- To determine the best step during the mango packing process to apply aqueous 1-MCP.

Material and Methods

Aqueous 1-MCP at 625 µg L^{-1} was applied to 'Kent' and 'Keitt' mango fruit before or after QHWT (in a commercial facility). The fruit were harvested and treated at the optimum physiological ripeness stage. After that, the fruit were kept in refrigeration (12 ± 1 °C; 85 ± 5 % RH) for 3 weeks and then at market simulation (22 ± 2 °C; 75 ± 10 % RH) until full ripeness. Sampling was done at the beginning and at the end of refrigerated storage, and then at day 4 and 7 of market simulation. Variables recorded were: Weight loss, External Appearance, Pulp Firmness, Pulp Color, Total Soluble Solids (°Brix), and Tritatable Acidity. A Completely Random design with 20 single fruit replications for weight loss and 8 for other variables was used.

Results

- For 'Kent', 1-MCP significantly affected most variables. It decreased water loss, maintained firmness longer, and delayed pulp color development, but negatively affected the external appearance when used in combination with QHWT. 1-MCP applied without QHWT didn't affect the external appearance.

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- For 'Keitt', 1-MCP without QHWT significantly decreased weight loss, maintained firmness longer, and delayed pulp color development without affecting external appearance. In contrast, 1-MCP in combination with QHWT showed a similar trend but it negatively affected the external appearance.
- It seems that 1-MCP is not a good alternative for mangos exported to the USA, but could be useful for countries that don't demand mandatory QHWT.

2. **Effectiveness of aqueous 1-MCP on 'Kent' and 'Keitt' mango with QHWT (UFL).**

Particular Objectives

- To determine the effectiveness of aqueous 1-MCP on mango fruit with or without QHWT.
- To determine the best step during the mango packing process to apply aqueous 1-MCP.
- To evaluate the effect of aqueous 1-MCP on ripening processes, extension of shelf life, and maintenance of fruit quality for 'Kent' and 'Keitt' varieties.

Material and Methods

1-MCP at 625 $\mu g\ L^{-1}$ a.i. in 50 L DiWater was applied between 20 and 45 min after preparation by dipping fruit for 5 min. The application was before and after QHWT. A completely random design was used with 10 single fruit reps for weight loss; 5 reps for other variables, except 3 reps for respiration and ethylene). The varieties used were as follows:

a. Kent (Lyons Farms, Homestead, FL). August-September, 2013.
b. Keitt (USDA-ARS, Miami, FL). August-September, 2013.
c. Keitt2 (Tropical Mangoes, Merrit Island, FL). September-October, 2013.

The QHWT (46.1 °C for 90 min) and hydrocooling (21-23 °C for 30 min) were applied to physiologically mature fruit according to the USDA APHIS protocol. Then, simulation of refrigerated shipment (3 weeks at 12 °C; 90 ± 5 % RH) then market simulation (20 °C; 90 ± 5 % RH) until the consumption stage was reached. Sampling was done initially, at the end of the refrigerated storage period, and at the consumption stage. The variables measured were: Weight loss, external appearance, firmness, pulp color, total soluble solids (°Brix), respiration, and ethylene.

Results

- In fruit of 'Kent' variety 1-MCP significantly affected most of the variables. When applied after the QHWT 1-MCP increased weight loss, maintained firmness longer, and delayed pulp color development, but negatively affected the external appearance of the fruit since 1-MCP caused lenticel blackening.

- When applied to 'Keitt' fruit, 1-MCP showed a similar trend as in 'Kent', except for weight loss, which was decreased. However, 1-MCP applied in combination with QHWT also negatively affected the external appearance of the fruit.
- The results found in the experiments conducted at the University of Florida showed the same trend as those in Mexico. 1-MCP delayed the ripening process by maintaining firmness longer and by delaying the pulp color development, but in combination with QHWT negatively affected the external appearance of the fruit.
- 1-MCP doesn't seem to be a good alternative for countries exporting mango the USA, where the QHWT is mandatory.

3. 1-MCP sorption by 'Kent' and 'Keitt' fruit:

Particular Objectives:

- To measure the capacity of mango fruit to bind 1-MCP.
- To find differences in combined binding and destruction of 1-MCP by heated and unheated fruit (by measuring 1-MCP depletion in a closed system containing mango fruit and 1-MCP).

Material and Methods

a. **Capacity of heated and unheated 'Kent' and 'Keitt' mango fruit to bind 1-MCP.**

The 1-MCP concentration used was 20 μL L^{-1} for 'Kent' and 'Keitt' varieties. The treatments were:

1. Control (1-MCP at 20 μL L^{-1} without fruit)
2. 1-MCP at 20 μL L^{-1} with unheated fruit
3. 1-MCP at 20 μL L^{-1} applied to heated fruit just after QHWT
4. 1-MCP at 20 μL L^{-1} applied to fruit with hydrocooling for 30 min after QHWT
5. 1-MCP at 20 μL L^{-1} applied to heated fruit 24 h after QHWT

The QHWT (46.1 °C for 90 min) and hydrocooling (21-23 °C for 30 min) were applied to physiologically mature fruit according to the USDA APHIS protocol. The average fruit size for 'Kent' was 853.3 g while for 'Keitt' it was 987.5 g. Plastic containers of a 6.7 L capacity sealed with parafilm were used. The 1-MCP depletion was measured using a Varian CP-3800 GC. The design was completely randomized with 5 single fruit reps.

b. **Capacity of whole and sliced 'Keitt' fruit to bind 1-MCP**

The 1-MCP concentration used was 20 μL L^{-1} for 'Keitt' variety (USDA-ARS, Miami, FL). 29 August, 2013.

The treatments were:

1. Control (1-MCP at 20 μL L^{-1} without fruit)

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2. 1-MCP at 20 μL L^{-1} applied to whole fruit
3. 1-MCP at 20 μL L^{-1} applied to sliced fruit

QHWT: No

Average fruit size: 500.4 g Plastic containers sealed with parafilm: 6.7 L.

Variables to measure: 1-MCP depletion by a Varian CP-3800 GC.

Design: Completely randomized with 5 reps.

Results

- 'Kent' and 'Keitt' fruit showed a different pattern related to 1-MCP sorption. Unheated and heated fruit were very similar in the 1-MCP sorption rate, which was lower than that of fruit with QHWT + hydrocooling and fruit with 24 h rest after QHWT.
- In contrast, 'Keitt' fruit that were unheated or with 24 h rest after QHWT showed similar but lower 1-MCP sorption rates than those fruit that were heated or heated + hydrocooling.
- In addition, it was observed that sliced 'Keitt' fruit showed a 1-MCP sorption rate twice that of whole fruit.

4. Effect of water source on 1-MCP performance.

Particular Objectives:

- To determine the effect of water source on the performance of aqueous 1-MCP.
- To find out if the water sources influence the efficacy of 1-MCP on mango ripening in terms of shelf life, quality characteristics, and physiological processes like respiration and ethylene production.

Material and Methods

The dose of 1-MCP was at 625 μg L^{-1} a.i. in 15 L water; applied 25 min after preparation by dipping fruit for 5 min. The application was before QHWT. The treatments were as follows:

1. DI water
2. Tap water
3. Chlorinated water (50 ppm)

The variety was 'Keitt' and the QHWT (46.1 °C for 90 min) and hydrocooling (21-23 °C for 30 min) were applied to physiologically mature fruit according to the USDA APHIS protocol. After treatment, the fruit were kept in simulated refrigerated shipment conditions (3 weeks at 12 °C; 90 ± 5 % RH) then market simulation (20 °C; 90 ± 5 % RH) until the consumption stage was reached. Sampling was done initially, at the end of the refrigerated period, and then at the consumption stage. The variables measured were: External appearance, firmness, pulp color, total soluble solids (°Brix), respiration, and ethylene. The design was completely random with 4 single fruit reps for all variables.

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Results

- The water source used for preparing the aqueous 1-MCP solution significantly affected pulp color, respiration, and ethylene production.
- With respect to pulp color, the treatment containing chlorinated water showed the highest pulp color intensity, indicating a quicker ripening process.
- In relation to respiration rate, the fruit treated with 1-MCP prepared in distilled water initially had the highest respiration rate, but at the end of shipping simulation it was the lowest.
- With respect to ethylene production, significant differences were detected only at the initial measurement, when fruit treated with 1-MCP dissolved in tap water showed the lowest rate.
- Results suggested that 1-MCP should be dissolved in distilled or tap water but not in chlorinated water because chlorine apparently disables 1-MCP function, likely through oxidative destruction.

5. Comparison of two sources of 1-MCP (AFXRD-038) formulation.

Particular Objectives:

- To compare the initial concentration of AFXRD-038 formulation used in Dr. Huber's lab versus the AFXRD-038 formulation used in Mexico.
- To compare the depletion rate of both formulations.
- To prove the AFXRD-038 formulation used in Mexico has at least the same performance as that used in UF lab.

Material and Methods

The 1-MCP sources used for this assay were as follows:

a. AFXRD-038 formulation obtained from Rohm and Haas in October, 2011.
b. AFXRD-038 formulation obtained from Dow Chemical (formerly Rohm and Haas) in May, 2013.

Initial concentration was 30,156 ppm (1 g AFXRD-038 dissolved in 50 mL distilled water in a 500 mL side arm flask). The 1-MCP depletion was monitored every 2 h for up 8 h during the first day and then every 4 h during the second and third days. A Varian CP-3800 GC was used. Three aliquots of the same sample were taken.

Results

- No significant differences were found for either the initial concentrations or the depletion rates of both formulations.
- The AFXRD-038 formulation used in Mexico showed the same or better performance than that used in Dr. Huber's lab.

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6. Capacity of heated and unheated whole and sliced papaya fruit to bind 1-MCP.

Particular Objectives:

- To measure the capacity of heated and unheated intact papaya fruit to adsorb 1-MCP.
- To measure the capacity of heated and unheated sliced papaya fruit to adsorb 1-MCP.
- To determine if there are differences in combined sorption and degradation of 1-MCP by heated and unheated, whole and sliced papaya fruit.

Material and Methods

1-MCP concentration was at 20 μL L^{-1}. Treatments were the following:

1. Control (1-MCP at 20 μL L^{-1} without fruit)
2. 1-MCP at 20 μL L^{-1} applied to unheated whole fruit
3. 1-MCP at 20 μL L^{-1} applied to whole fruit treated with QHWT
4. 1-MCP at 20 μL L^{-1} applied to slices from unheated fruit
5. 1-MCP at 20 μL L^{-1} applied to slices from fruit treated with QHWT
6. 1-MCP at 20 μL L^{-1} applied to fruit slices heated in microwave oven

Papaya 'Solo' type fruit harvested in Florida were obtained from a commercial vendor at physiologically mature stages (¼ to half ripe). Fruit were washed with a tap water solution containing liquid soap detergent (1 mL L^{-1}) and wiped dry with paper towels. Fruit were separated into two groups: Unheated and heated fruit. Unheated fruit were not subjected to hot water treatment while those heated were subjected to QHWT according to the USDA APHIS protocol; at 48.0 °C for 75 min. Slices were prepared from heated and unheated fruit, while those slices that were heated in a microwave oven were subjected to 90 sec exposure. After that, fruit were put inside 7.6 L jars into which was injected 1-MCP to obtain a concentration of 20 μL L^{-1}. 1-MCP sorption was monitored every 1.5 h for up 6 h at 20 °C using a Varian CP-3800 GC. A completely randomized design with three replications per treatment was used. The experiment was conducted in December 2013 and January 2014.

Results

- No significant differences in gaseous 1-MCP adsorption were detected for heated or unheated whole papaya fruit.
- Significant differences in gaseous 1-MCP adsorption were found between unheated sliced and heated (HWT or Microwave) sliced papaya fruit.

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7. Ingress of 1-MCP into heated and unheated papaya fruit.

Particular Objectives:

- To measure the ingress of gaseous 1-MCP into heated and unheated intact papaya fruit.
- To find if there are differences in the ingress of 1-MCP according to the region of the fruit.

Material and Methods

1-MCP concentration applied was 20 μL L^{-1}. Factors and treatments were the following:

Factors:

1. Factor A (heated or unheated)
2. Factor B (1-MCP exposure time: 1, 3, 6, and 24 h)

Treatments:

1. Heated + 1-MCP for 1 h
2. Heated + 1-MCP for 3 h
3. Heated + 1-MCP for 6 h
4. Heated + 1-MCP for 24 h
5. Unheated + 1-MCP for 1 h
6. Unheated + 1-MCP for 3 h
7. Unheated + 1-MCP for 6 h
8. Unheated + 1-MCP for 24 h

Papaya 'Solo' type fruit harvested in Florida were obtained from a commercial vendor at physiologically mature stages (¼ to half ripe). Fruit were washed with a tap water solution containing liquid soap detergent (1 mL L^{-1}) and wiped dry with paper towels. Fruit were separated in two groups: Unheated and heated fruit. Unheated fruit were not submitted to hot water treatment while those heated were subjected to QHWT according to the USDA APHIS protocol, at 48.0 °C for 75 min. Then, individual fruit were placed into 7.6 L jars, which were sealed, and 1-MCP injected to obtain a concentration of 20 μL L^{-1}. After the indicated exposure times, jars were opened and the fruit were immediately immersed in distilled water. Replicate jars of each treatment were opened at 2 min intervals. While a fruit was held underwater, three samples of internal atmosphere were removed from three locations at approximately 1 cm depth (one inch from the apical part, in the middle, one inch from the basal part) and from within the cavity using a 1 mL syringe with a 23-gauge, 2.5 cm needle. The 1 mL sample was immediately injected into 5 mL React vials fitted with Teflon-lined septa. A 1 mL sample was removed from the vial and analyzed for 1-MCP concentration at 20 °C using a Varian CP-3800 GC. A complete factorial design with three replications per treatment was used. The experiment was conducted in December 2013 and January 2014.

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Results

- No significant differences in gaseous 1-MCP ingress were detected between heated and unheated papaya fruit.
- Significant differences were found among the gaseous 1-MCP exposure times. The longer the exposure time, the greater the 1-MCP ingress.
- The results for internal 1-MCP were not consistent between the experiments conducted in December 2013 and January 2014. In the first experiment the apical region showed the highest 1-MCP concentration while in the second experiment the highest 1-MCP concentration was in the cavity of the fruit.

8. Internal gaseous 1-MCP in heated and unheated papaya fruit treated with aqueous 1-MCP.

Particular Objectives:

- To measure the ingress of aqueous 1-MCP into heated and unheated intact papaya fruit.
- To find if there are differences in the ingress of 1-MCP according to the region of the fruit.

Material and Methods

Factors and treatments were the following:

- **Factors:**
  a. Factor A (heated or unheated)
  b. Factor B (1-MCP concentration: 1 and 3 mg L^{-1})
  c. Factor C (Exposure time: 1 and 5 min)
- **Treatments:**
  a. Heated and dipped in 1 mg L^{-1} 1-MCP for 1 min
  b. Heated and dipped in 1 mg L^{-1} 1-MCP for 5 min
  c. Heated and dipped in 3 mg L^{-1} 1-MCP for 1 min
  d. Heated and dipped in 3 mg L^{-1} 1-MCP for 5 min
  e. Unheated and dipped in 1 mg L^{-1} 1-MCP for 1 min
  f. Unheated and dipped in 1 mg L^{-1} 1-MCP for 5 min
  g. Unheated and dipped in 3 mg L^{-1} 1-MCP for 1 min
  h. Unheated and dipped in 3 mg L^{-1} 1-MCP for 5 min

Design: Completely randomized with three replications. QHWT was applied according to the USDA APHIS protocol, at 48.0 °C for 75 min. The experiment was conducted in December 2013 and January 2014.

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Results

- Different results were found according to the date of the experiment. For the first experiment in December there were no differences in ingress of aqueous 1-MCP between heated and unheated fruit; and there were no differences between 1-MCP concentrations and dipping times. In addition, no significant differences were detected among the sampling regions of the papaya fruit.
- The results of the second experiment in January showed lower 1-MCP concentrations than found in the December experiment. A significant difference was observed only for the 1-MCP concentrations. The dose of 3 mg L^{-1} resulted in higher internal 1-MCP than 1 mg L^{-1}.
- These experiments showed the highest coefficient of variation because of the difficulty in taking the samples. Maybe the accuracy could be improved if the number of replications were to be increased as well.

PRODUCTS

- A final report
- At least the draft for one article to be published in a scientific journal

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