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Effect of Hot Water Immersion Treatment (HWT) on the Quality of 'Keitt' Mangoes in Ghana

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Currently, Ghana does not use Hot Water Treatment (HWT) as a phytosanitary control measure for mangoes. The effect of HW on the quality of 'Keitt' mangoes in Ghana was evaluated. Mangoes were washed with chlorinated water or hot water treated at 47^{o}C for 70 min and stored at 25^{o}C for 8 days. There was no treatment*Storage effect (P> 0.05) on the variables studied. Mangoes TA decreased (P<= 0.05) and pH increased with storage time. HWT had no impact on mango quality but had 50% reduction in decay during storage.

DEDICATION

This work is dedicated to Jesus Christ, the author and perfecter of my fate. Secondly to my family especially my parents Maame Nimo and Opanyin Sebe, my husband Victor Ashitey and my dear Jude who had to endure a whole year without me. To the departed soul of my uncle Wofa DD who sadly did not live to see this dream materialize, I know he is smiling at me from paradise, and finally all my siblings and Cousin Kofi DD as I choose to call him.

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CHAPTER I

INTRODUCTION

Mango (*Mangifera indica L.*) is a tropical fruit of the mango tree that belongs to the family Anacardiaceae. It originated from Southeast Asia, specifically Burma and Eastern India. Malaysia, eastern Asia and eastern Africa were the earliest places where mango was grown. The crop is believed to have been cultivated for at least 4,000 years (UNCTAD, 2012). Over the last thirty years, mango has grown to become a popular tropical fruit in the world with increased economic significance due to its excellent quality attributes including bright color, sweet taste, juicy flavor, nutritional value, vitamins, minerals, fiber, and other phytochemical compounds (Kim et al., 2007).

From 2008 to 2010, there was approximately 9% increase in the amount of mangoes produced in the world, from 35.5 million to 38.7 million metric tons. Developed countries are the main importers of this fruit; with the United States of America leading imports with 367,594 tons (UNCTAD, 2012).

India and China are the top two producers with 15,250,000 and 4,400,000 tons, respectively. The main African mango-producing countries are Nigeria with about 860,000 tons followed by Egypt with 450 000 tons (UNCTAD, FAO STATS, 2012). Ghana produced an estimated 87,500 tons of mangoes in 2012.

The mango export industry in Ghana has been severely affected by pest problems and this has resulted in loss of produce integrity on the international market. Ghana mangoes are not accepted in the United States because neither heat nor irradiation treatment, a phytosanitary (plant health with regards to pest and diseases) requirement for mango fruits destined for the USA market is done on the fruits in Ghana (USDA-APHIS). Lebanon, South Africa and the EU have at one point or the other had course to refuse entry or placed a total ban on mangoes from Ghana due to fruit fly infestation on shipments. Currently, mangoes from Ghana destined for export are washed in chlorinated water, dried and packaged for shipment.

The push for reduction in chemical usage in post harvest treatment to control insect pests, prevent fungal, rots etc. has given rise to the pursuit of heat treatment as either a substitute and/or as a compliment to phytosanitary control in mangoes. Heat treatment can be an alternative non-damaging physical treatment that is used in place of chemical treatment.

Hot water dips are believed to be the oldest and most widely used heat treatments for fresh fruits and vegetables. Hot Water Immersion Treatment (HWT), also called hydrothermal treatment is the commonest among the heat treatments mainly because it is relatively inexpensive and easy to operate (Sharp. 1994; Lurie, 1998). HWT is not done for mangoes exported from Ghana (Zakari, 2012).

Quality requirements of the mango fruits include size, shape, maturity, appearance and perishability of the produce and any post harvest treatment applied to the product should not adversely affect these qualities or the fruit would be unmarketable and rendered useless (Medina, 2002).

Kim et al., (2009) reported that the external qualities of 'Tommy Atkins' mango were not affected four days after they underwent HWT at 46.1ºC for 70 or 110 minutes.

Neither heat injury nor acceleration in skin color development was observed in mangoes after the study. The impact of prestorage hot water immersion treatment (HWT) on the prevention of rot development has been displayed in numerous temperate, sub-tropical and tropical fruit, vegetables and flowers (Fallik, 2004).

Extensive research has been done on HWT and the benefits and challenges it has on the phytosanitary (plant health with regards to pest and diseases) status and the quality attributes of the fruits have been well documented. However, not much work has been done on the impact of this treatment on mangoes grown in Ghana.

The objectives of this study were: 1. to determine the impact Hot Water Treatment (HWT) at 47^{o}C for 70 min will have on quality attributes of the 'Keitt' mango fruit from Ghana and, 2. to determine the impact of HWT on storage and decay of the aforementioned cultivar.

CHAPTER II

LITERATURE REVIEW

Mango (*Mangifera indica L.*) fruit is a compressed, fleshy drupe that greatly varies in characteristics such as size, shape, color, fiber, flavor, and taste. (Medina and Garcia, 2002).

Mango is a high-value tropical crop that has a significant market value in both domestic and international markets. Except for pineapples and bananas, mangoes are the most important tropical fruit with over a four-thousand-year history of cultivation. (Barth fruit; Van Melle and Buschmann, 2013).

Often called the "King of Fruits", mango is known to be high in some food nutrients including vitamins A, C and D, minerals and fiber. It is also highly recommended as one of the remedies for beriberi, relieving, fatigue, nervousness and insomnia and as a laxative (Medina and García, 2002). Kim et al., (2009) stated that mangoes are a good source of many phytochemical compounds. These compounds also contribute some characteristic color and flavor to the fruit. Kim et al., (2007) also reported that mangoes contain different types of polyphenols, carotenoids, and ascorbic acid and possess many health benefits due to their antioxidant capacity.

Imports of fresh mangoes into the industrialized world such as United States of America (USA), Europe, and Japan have increased, largely due to increased consumer preference for mango products; both fresh and processed. There is a general increase in the trade of mango fruit both locally and internationally (Aveno and Orden; Kim el al., 2009).

Ghana's market share of fresh mango trade is relatively low, accounting for less than 3% of EU imports from ECOWAS as compared to the other countries in the West African sub-region (Zakari, 2012). However, fresh-cut mangoes from Ghana have made important inroads into the export market including the USA over the past few decades. Ghana produced an estimated 87,500 tons of mangoes in 2012, which as a calculated value of 17.32 million USD (FAOSTATS, 2012).

Fruit fly (Diptera: Tephritidae), classified as a "quarantine pest" is generally prevalent in areas where mangoes are grown. The presence of fruit fly larvae in a single fruit may be enough cause to quarantine interception and/or destruction of an entire consignment of mangoes (CTA, 2007). Van Melle, and Buschmann, (2013) reported that the largest share of mango production is traded and consumed fresh. This makes the likelihood of spreading fruit flies through international trade very high. As a result of this, it is mandatory to apply some form of phytosanitary measure or quarantine treatment to mango fruit before exported to certain destinations such as the United States and the European Union. Without either Irradiation or Heat Treatment, fresh mango fruits cannot be exported to the United States (Mitcham and Yahia, 2009).

In 2005, a non-native fruitfly, *Bactrocera invadens*, which originates from Asia was identified in Ghana. This species as well as native fruit fly species such as *Ceratitis cosyra*, have made mangoes from Ghana unacceptable in some export markets especially in the USA (USDA, 2001; Billah et. al, 2006).

An estimated 20 to 50% of mangoes are lost mainly due to the presence of the fruit fly, a host of disease among other factors (Zakari, 2012).

Non-chemical quarantine treatments of mangoes have gained prominence and the technology has been well documented. The increased interest in heat treatment as a means of controlling insect pests and preventing fungal rots is largely due to consumer demand for decrease use of postharvest chemicals for pest control (Lurie, 1998; Anwar and Malik, 2007).

Hot water treatment (HWT)

Fawcett (1922) first reported Hot water treatments in the control of decay on citrus fruit. HWT has now been extended to control insect pest infestation.

"Hot water immersion treatment (also called hydrothermal treatment) is the use of heated water to raise the temperature of the commodity to the required temperature for a specified period of time and it is used primarily for certain fruits that are hosts of fruit flies" (USDA-APHIS, 2012). The use of HWT has a number of advantages relative to other heat treatments; low cost of operation, ease of use, relatively accurate measurement of water and fruit temperature, and it has a lethal effect on surface-decay organisms (Jacobi et al., 2001; Fallik, 2004,).

HWT technology is widely used in Central and South America, HWT is however, not in use in Ghana (Jacobi et al., Zakari, 2012).

The required temperature range for hot water treatment is between 45°C and 47.8°C (113°F and 118°F) for control of fruit flies with the length of immersion depending on the general shape of the fruit and the fruit weight. Rounded mango fruits

(Tommy Atkins, Kent, Haden, Keitt) weighing less than 500g should be treated for 75 min; 501–700g should be treated for 90 min (USDA-APHIS, 2012; Brecht et al., 2014).

Fallik (2004) stated that physiological responses of cultivars of different fruit or flower species to heat treatments can depend on a number of factors including growing season and location.

The mango fruit on the markets in the United States is often believed to be of inferior quality. Many factors have been blamed for the loss in fruit quality; however, actors in the mango industry feel that the hot water treatment protocol is the main factor responsible for this condition. Hot water immersion can negatively affect mango fruit quality with small fruits being the most affected. (Yahia and Campos, 2000; Mitcham and Yahia, 2009).

Mango trees can be found across Ghana but commercial production is mainly found in two distinctive agro-ecological zones: Northern Ghana around Tamale and Southern Ghana (Greater Accra, Eastern and Volta Regions), with a harvest season running from March (early varieties) to June (late varieties). There are two harvest seasons in Southern Ghana (peak and minor season) (FAO, 2009; Van Melle and Buschmann, 2013).

'Keitt' mangoes originated from Homestead, Fl, USA Fruit large (20-26 oz.), it is ovate with slightly oblique apex, green, flesh rich, fiber only around the seed and one of the late maturing varieties. 'Keitt' is one of the main mango varieties that is commercially grown in Ghana (Medina and Garcia, 2002; Zakari, 2012).

Chemical and Physical Analysis

Ripeness in mangoes is characterized by compositional and physiological changes. These changes among others include; changes in flesh color, decrease in flesh firmness and increase juiciness, conversion of starch into sugars, with corresponding increase in sweetness, decrease in titratable acidity (TA) and associated sourness or tartness and increase in total soluble solids (TSS) content (combination of sugars, acids, soluble pectins, and other soluble constituents) and associated sweetness. These changes are also used as quality or maturity indices for mango fruit (Slaughter, 2009; Brecht et al., 2014).

Lobbit (2002), in a study done on peach fruit, stated the importance of acidity on the quality of the fruit. Acidity has an influence on the sweetness and sourness of fruit. Titratable acidity (TA) is one of the quality and maturity indices. The level of TA in a fruit is inversely proportional to the sugar content upon maturity; TA decreases as sugar content increases. This relationship results in the rising of the sugar-to-acid ratio (STA) (Pegg, 2014). Kumah and others, 2011) reported that there was a general downward trend in the titratable acidity (TA) values over a fourteen-day storage period in mangoes that were hot water treated at 52^{o}C/10min, 52^{o}C/5min, 50^{o}C/10min and 50^{o}C/5min. "Titratable acidity and pH are of different importance: pH represents the free hydrogen ion activity, while titratable acidity is the amount of total weakly bound and unbound hydrogen ions that can be released from the acids" (Lobbit. 2002).

Ripening of mango fruits result in a loss of firmness (Texture) caused by cell wall disintegration due to enzymatic activity (Bibi and Baloch, 2012). Texture of fruits is related to the structural, physiological, and biochemical characteristics of the living cells.

It can be altered by time and by exposure to high or low temperatures. Texture continuously changes, therefore, it is only significant during the evaluation period (Abbott and Harker).

Brix is a measure of total soluble solids content (TSS) in a fruit. Even though organic acids, amino acids, phenolic compounds, and soluble pectins also contribute to TSS, sugars are the major soluble solids in fruit juice; this makes TSS a good measure of sugar content. The TSS levels in mature green mangoes (minimum of 7 to 9% at harvest) increase with ripening to reach 14 to 20% in ripe fruit. (Brecht et al., 2014).

The changes of mango flesh color is a credible parameter in determining the level of fruit ripening (Kim et al., 2007). Organic acids and sugars have a great impact on the perception of mango flavor. The principal acid found in mangoes is citric acids whereas sucrose is the main sugar in the ripe fruit. Sugar-to-acid ratio is the number of parts of sugar to every one part of acid (Malundo, 2001; ACQS, 2011).

CHAPTER III

MATERIALS AND METHODS

A total of one-hundred and seventeen (117) ‘Keitt’ mangoes in the mature-green stage of uniform size and free from external defects were harvested from Fair Fax Farms, located at Somanya in the Yilo Krobo District of the Eastern Region of Ghana on January 31, 2015. The mangoes were packed in generic mango export cartons (13.4” x 11” x 4.3”) and kept in a packing-house for five days at room temperature (25^{o}C).

The mango samples were then transported in export cartons to the Ghana Atomic Energy Commission (GAEC) laboratory for analysis. The transport period was approximately two hours

Sample preparation

The mango samples were sorted out and those that did not meet the standard in terms of size and level of maturity were discarded. A total of one-hundred and eight (108) mangoes were finally chosen for the experiment.

The mangoes were randomly assigned to three replications per treatment (18 mangoes/replication/treatment). Each replication was subjected to the control treatment, (CTL) where mangoes were washed with chlorinated potable water at 20^{o}C in a washing tank or to the hot water treatment, (HWT). The latter were washed in chlorinated water at 20^{o}C and then submerged water in a water bath (Grant OLS200) and heated at a temperature of 47^{o}C for 70 min (USDA Treatment Manual, PPQ, 2014).   Two parts of water to one mangoes of hot water was used to treat 18 mangoes at each treatment period in order to ensure that the mangoes were completely submerged. They were then cooled very quickly in an air conditioned room at 18ºC. The cooled mangoes were then placed in fresh mango export cartons and kept at 25 ºC for the duration of the study.

Mangoes from each treatment-replication combination were then sampled every two days for 8 days. They were analyzed for decay (the number of rotten removed from the box at time of sampling), total soluble solids, pH, titratable acidity, firmness. The mangoes were in a very advanced state of maturity by day 10 and thus, the experiment was stopped by day 8.

Decay Incidence

Fruit was evaluated for decay as per the method of Angasu et al., (2014). The evaluated mangoes were kept at room temperature (25ºC) for rot studies (Decay Incidence). Decay is described as the sum of a number of defects in mangoes driven by many factors (Kader, 1997). Heat injury leads to skin scald, blotchy coloration and uneven ripening. Soft-nose, softening of tissue at apex as a result of calcium deficiency, over-ripe appearance of flesh and may discolor and become spongy. Anthracnose, caused by *Colletotrichum gloesporioides*, begins as latent disorder infections in unripe fruit and develops when the mangoes begin to ripen- lesions may remain limited to the skin or may invade and darken the flesh. Diplodia stem-end rot, caused by *Lasiodiplodia theobromae*, affects mechanically-injured areas on the stem or skin where the fungus grows from the pedicel into a circular black lesion around the pedic.

Decay was evaluated on 18 mangoes per treatment. Decay at each sampling time and accumulated (number of total fruit decay after each sampling time) were measured.

% Decay (Rots) = (Number of rotten fruits /Total number of fruits) x 100 (1)

Accumulated decay was calculated as the total number decayed fruit for each period by the total number of fruits.

% Accumulated decay= (Sum of rotten fruits/Total fruits) x 100 (2)

Firmness

The texture/firmness of the fruits was determined through flesh penetration force on both cheeks (with skin removed) using a penetrometer (Model GY-2, CAPACITY 4Kg/cm2 d= 0.02 CAPACITY 4x105 Pa, d=0.02 from Agriculture Solutions LLC, ME USA) (Brecht et al., 2014).

Total Soluble Solids (TSS), pH, Titrable acidity (TA), and Sugar-to-acid ratio (STA)

Mangoes from each replication/treatment combination were randomly selected at each sampling time. They were then peeled, the flesh was chopped into pieces and the seeds were discarded. Mango juice was extracted by macerating the mango pulp using a domestic juice extractor. The blended juice was filtered using a steel sieve with an approximate diameter of 2 mm to remove fiber in order to obtain a clear juice. Total soluble solids (TSS) were determined using a hand held refractometer (Westover Model RHB-32ATC, Owatonna, MN, USA) and results were expressed in standard ^{o}Brix. The determination was repeated three times for each of the group and results recorded (Brecht et al, 2014).

The pH of mango juice was determined using a pH meter (Mettler Toledo Inlab Pro pH, Columbus OH, USA) (Dea, 2010; Brecht et al., 2014). Titratable acidity (TA) was determined by taking aliquots (6.00 g) of mango juice and diluting with 50mL distilled water. The TA titratable acidity determined by titration with 0.1 mol L−1 sodium hydroxide (NaOH). Titratable acidity was expressed as percent citric acid (0.064 meq) (Dea, 2010).

$$\% \text{ TA (citric acid g/100 mL)} = \frac{(mL\ NaOH\ used) \times (Normality\ of\ NaOH) \times (0.064)}{mL\ of\ sample} \times 100 \quad (3)$$

Sugar-to-acid ratio (STA) was calculated by dividing the TSS (^{o}Brix) by titratable acidity (TA) as shown in the equation below.

$$\text{STA} = \text{(Total Soluble Solids/Titratable Acidity)} \times 100 \quad (4)$$

Experimental Design and Statistical Analysis

Data was arranged in a 2 (treatments: CTL, HWT) by 4 (sampling days in storage) factorial arrangement in a completely randomized design (n=3). Two fruits (subsamples) were randomly drawn from each replicate during each experimental day to determine TA, TSS, pH, Texture. Data was analyzed using Analysis of Variance (ANOVA) and means separated using Tukey's Honesty Significant Difference (HSD) test.

CHAPTER IV

RESULTS AND DISCUSSION

There was no treatment*storage time ($P>0.05$) effect on mango decay (% mango rots) but treatment and storage time had an effect ($P\leq 0.05$) on mango decay (Table 1). Hot water treated (HWT) mangoes had lower overall incidence of rots (1.7 vs. 2.9) than control (CTL) mangoes, (Table 1) with the incidence increasing over time (Table 2). At the end of storage (8th day), the CTL (Table 2) and the HWT mangoes averaged 39% and 67% rots, respectively (Table 2). The rotten mangoes showed signs that appeared to be anthracnose (*Colletotrichum gloeosporioide*) and/or other fungal rots. The results obtained here are consistent with those reported by Jabbar et al., (2011). According to Spalding and Reeder (1986), anthracnose and stem-end-rot (*Diplodia natalensi*) are the main causes of rots in Florida mangoes.

HWT showed significant effect in controlling anthracnose incidence and other rots caused by fungi and bacteria in mangoes during storage (Kumah et al., 2011; Jabbar et al., 2011). Angasu et al. (2014) recorded no symptoms of anthracnose rot five days after hot water treatment of mangoes with untreated samples recording high incidences of rots.

There was no interaction or treatment effect ($P>0.05$) on firmness of mangoes, but storage time had an effect ($P\leq 0.05$). There was a steady decline in mango firmness from 485 kPa (4.9 kg/cm^2) on day 2 to (2.1 kg/cm^2) for both HWT and CTL samples (Table 2).

Ripening in mango (a climacteric fruit) is associated with softening of flesh/pulp. Pectin is a structural polysaccharide that contributes firmness to the fruit. However, during ripening, its (pectin) polymers become loosely bound within the cell walls of the fruit. This results in fruit softening (Abbot and Harker; Lurie, 1998; Rathore et al., 2007). Hazbavi et al (2013) did not find any changes in texture of palm fruit after HWT treatment, but they softened during storage. Kim et al (2007) reported that hot water immersion inhibited anthracnose incidence during ripening of mango. Dea et al., (2010) in a work done on 'Kent' mangoes in 2010 also recorded no HWT effect on firmness but storage time had an impact as high loss of firmness was recorded.

There was no interaction, treatment or storage time effect (P>0.05) on total soluble solids (TSS). Even though there was softening of mangoes over storage, regardless of treatment, this process maybe due to senescence and not to ripening, since TSS did not change significantly (Tables 1, 2). TSS in HWT mangoes changed from 16.9 ^{o}Brix on day 2 to 18.2 ^{o}Brix on day 4 and finally decreased to17.4 ^{o}Brix on day 8. The CTL mangoes recorded 16.2 on day 2 to 17.2 on day 8 (Table 2). The mangoes had reached their maturity stage prior to treatment. The TSS results obtained in this work were consistent with work done on some varieties of Thai mangoes by Vásquez-Caicedo et al., (2002), which gave TSS values with an average of 16.6^{o}Brix. Anwar and Malik (2007) reported that control samples had higher TSS value than the HWT mangoes. They attributed the higher TSS to the phenomenon of HWT being a hindrance to natural starch hydrolysis. Mango is a climacteric fruit and so there is a hydrolytic conversion of starch into sugars over the storage period and that in turn results in the increase in sugar concentration (Vásquez-Caicedo et al., 2002; Rathore et al., 2007; Wang et al., 2007).

There was no interaction or treatment effect ($P>0.05$) on titratable acidity (TA) of mangoes, but there was a storage time effect ($P\leq0.05$). Titratable acidity declined ($P\leq0.05$) from day 2 to day 4 from 19.0% for the CTL and 17.7% for HWT to 11.4% to 9.2% respectively (Table 2). It then declined steadily up to the day 8. There was no interaction or treatment effect ($P>0.05$) on pH of mangoes, but there was a storage time effect ($P\leq0.05$). pH increased steadily as TA decreased. At day 2, the pH averaged 3.7, increasing to 4.5 by day 8 (Table 2). Titratable acidity and pH changes are basically due to alterations in organic acids such as citric and malic acids. The organic acids level decrease during ripening and this results in a decline in TA and in turn increasing pH levels (Tefera et al., 2007; Angasu et al., 2014).

There was no interaction or treatment effect ($P> 0.05$) on Sugar-to-acid (STA) of mangoes. However, STA increased after 4 days of storage and remained constant thereafter. STA is one of the maturity indices that has an impact on flavor as TA level affects sour and biting tastes in mangoes (Malundo et al., 2001). Ripeness increases the levels of sugar-to-acid ratio and enhances flesh color development; the color change of mango is a reliable parameter to determine the extent of fruit. HWT enhances some characteristics in the fruit while inhibiting others (Lurie, 1998; Jabbar et al., 2011).

Table 1 Effect of Hot Water Treatment on Decay, Firmness and Chemical indices of 'Keitt' mangoes stored at 25^{o}C for 8 days

Treatment	Decay	Accumulated Decay	Firmness	Titrable Acidity	pH	Total Soluble Solids	Sugar-to-acid
	(#rot)	(%)	(kg/cm2)	(%Citric acid)		^{O}Brix	
CTL	2.9^{a}	34^{a}	3.1^{a}	11.4^{a}	4.2^{a}	17.0^{a}	18.3^{a}
HWT	1.7^{b}	22^{b}	2.9^{a}	10.8^{a}	4.2^{a}	17.3^{a}	18.4^{a}
EMS	0.83	116	0.51	5.6	0.04	2.2	23.5

(n=12)
Treatments: CTL-Control, HWT-Hot Water Treatment
(ab means columns not followed by the same letter differ ($P \leq 0.05$)
% Accumulated decay= (Sum of rotten fruits/Total fruits @ day 0) x 100

Table 2 Effect of Hot Water Treatment on Decay, Firmness and Chemical indices of 'Keitt' mangoes stored at 25oC for 8 days

Storage time at 25^{o}C	Decay	Accumulated Decay	Firmness	Titrable Acidity	Ph	Total Soluble Solids	Sugar-to-acid
(Days)	(#rot)	(%)	(kg/cm2)	(%Citric acid)		^{O}Brix	
2	3.2^{a}	4.6^{a}	4.9^{a}	18.4^{a}	3.7^{a}	16.5^{a}	9.0^{a}
4	2.8^{a}	17.6^{ab}	3.2^{b}	8.4^{b}	4.22^{b}	17.5^{a}	18.6^{a}
6	2.3 ^{ab}	33.3^{b}	2.1^{bc}	10.3^{b}	4.26^{bc}	17.4^{a}	21.4 ^{a}
8	0.8 ^{b}	57.4^{c}	1.9^{c}	7.4^{b}	4.59^{c}	17.3^{a}	24.2 ^{a}
EMS	0.83	116	0.51	5.6	0.04	2.2	23.5

(n=6)
(abc means columns not followed by the same letter differ ($P \leq 0.05$)
% Accumulated decay= (Sum of rotten fruits/Total fruits @ day 0) x 100

Figure 1 Untreated (CTL) ‘Keitt mangoes showing clear symptoms of decay (rot) on day 8

(Note: R=Replicate and H=Hot Water treated)

Figure 2 Hot water treated (HWT) ‘Keitt’ mangoes showing slight shrinkage and few symptoms of decay (rot) on day 8

(Note: R=Replicate and H=Hot Water treated)

CHAPTER V

SUMMARY AND CONCLUSIONS

This study showed that the application of hot water treatment, HWT to 'Keitt' mangoes is beneficial to their shelf life, and can also increase exports of Ghana mangoes to USA, EU and others since hot water treatment is a proven technology to kill those exotic pests like fruit fly and others. Applying HWT to Ghana 'Keitt' mangoes did not affect quality traits negatively and reduced decay by ~50%.

HWT has a profound impact on a number of metabolic processes, including oxidative processes, cell wall changes.

Further research on the organoleptic properties (sensory, color, etc) of Hot water treated Ghana mangoes needs to be conducted.

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APPENDIX A

SUPPLEMENTAL TABLES AND FIGURES

Table 3 Type III Sum of Squares analysis for Variable Decay (# Rots) in mangoes as affected by hot water treatment and storage time

Source	DF	Sum of squares	Mean squares	F	Pr > F
Trt	1	9.375	9.375	11.250	0.004
Day	3	19.125	6.375	7.650	0.002
Trt*Day	3	1.125	0.375	0.450	0.721

Table 4 Type III Sum of Squares analysis for Variable Firmness (kg/cm2) as affected by hot water treatment and storage high

Source	DF	Sum of squares	Mean squares	F	Pr > F
Trt	1	0.398	0.398	0.785	0.389
Day	3	32.812	10.937	21.581	< 0.0001
Trt*Day	3	1.463	0.488	0.962	0.434

Table 5 Type III Sum of Squares analysis for Variable TSS (°Brix) as affected hot water by treatment and storage

Source	DF	Sum of squares	Mean squares	F	Pr > F
Trt	1	0.482	0.482	0.219	0.646
Day	3	3.293	1.098	0.500	0.688
Trt*Day	3	6.178	2.059	0.937	0.446

Table 6 Type III Sum of Squares analysis for Variable TA (ml) as affected by hot water treatment and storage

Source	DF	Sum of squares	Mean squares	F	Pr > F
Trt	1	2.622	2.622	0.465	0.505
Day	3	444.926	148.309	26.283	< 0.0001
Trt*Day	3	8.385	2.795	0.495	0.691

Table 7 Type III Sum of Squares analysis for Variable pH as affected by hot water treatment and storage

Source	DF	Sum of squares	Mean squares	F	Pr > F
Trt	1	0.004	0.004	0.107	0.748
Day	3	2.244	0.748	18.295	< 0.0001
Trt*Day	3	0.029	0.010	0.238	0.868

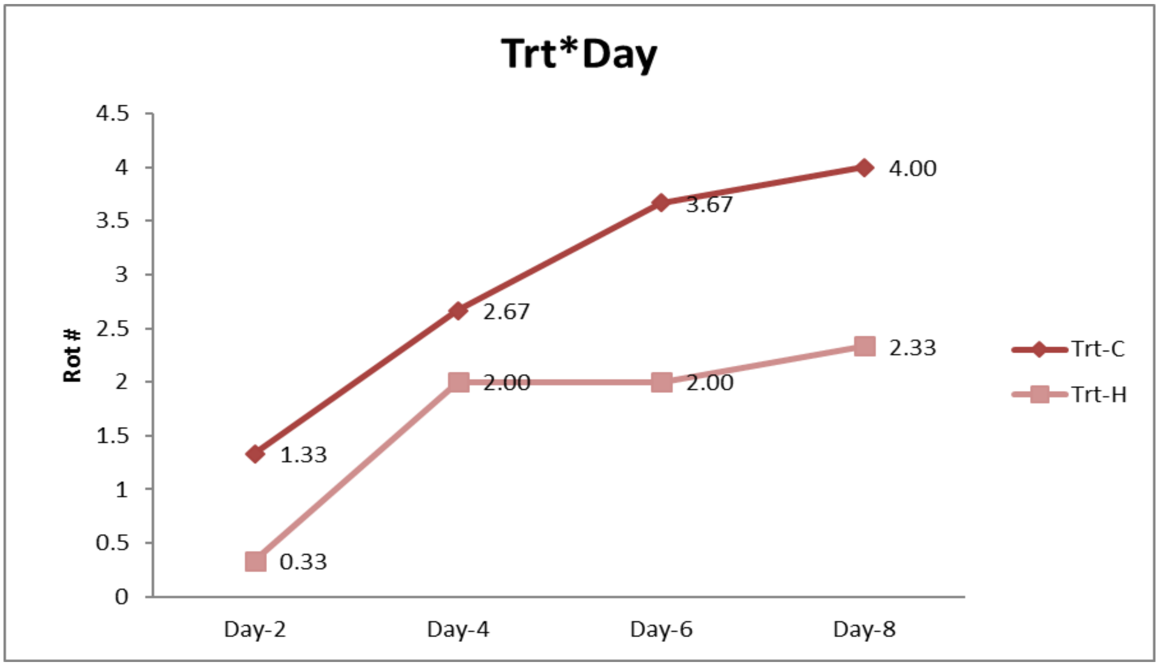

Figure 3 Number of decay (rotten) untreated (C) and hot water treated (H) 'Keitt' mangoes during storage at 25C for up to 8 days

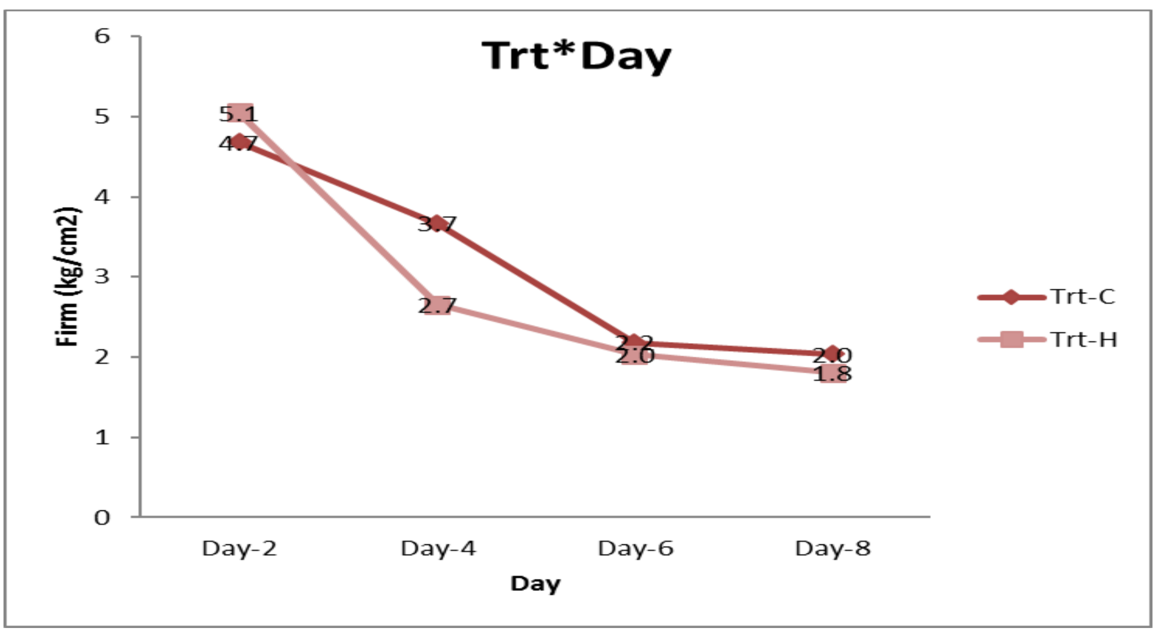

Figure 4 : Firmness (Kg/cm2) of untreated (C) and hot water treated (H) 'Keitt' mangoes during storage at 25C for up to 8 days

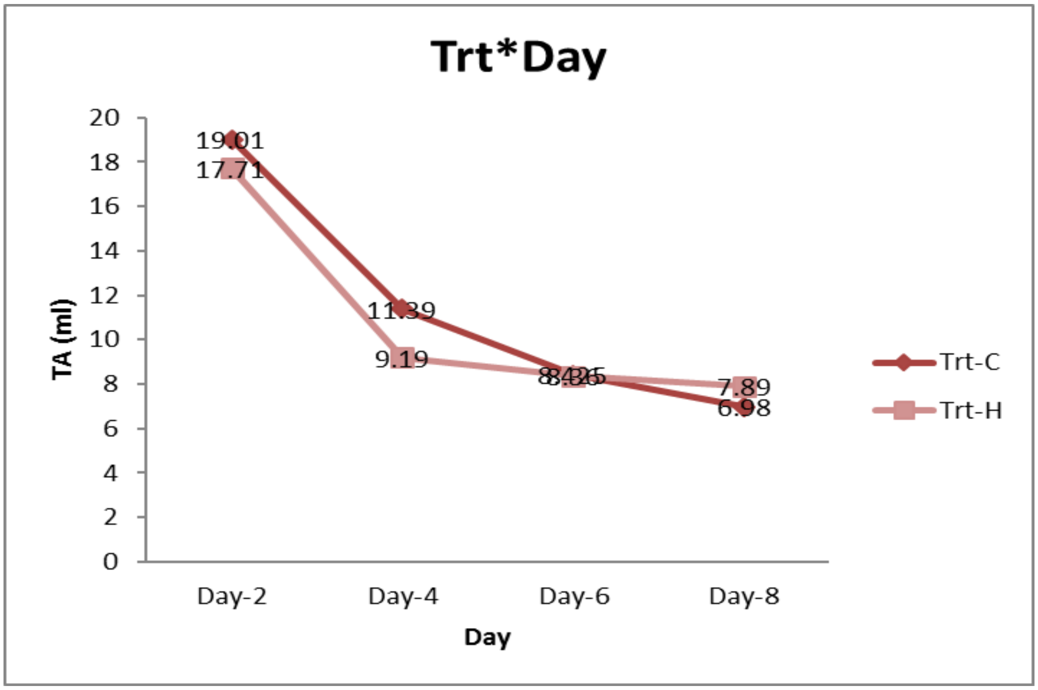

Figure 5 Titratable acidity, TA (ml%) of untreated (C) and hot water treated (H) 'Keitt' mangoes during storage at 25C for up to 8 days

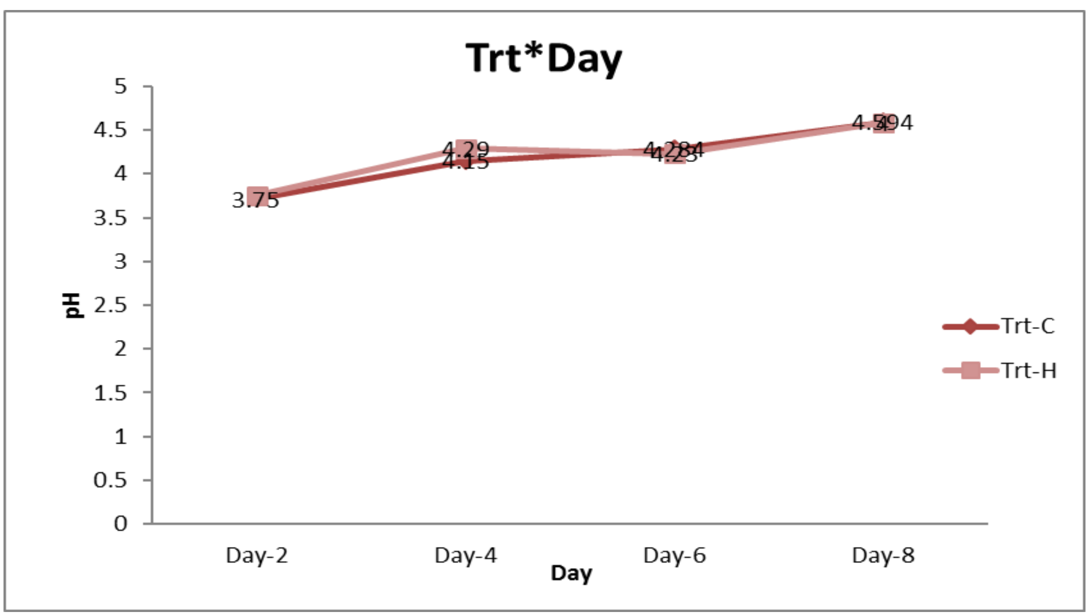

Figure 6 pH of untreated (C) and hot water treated (H) 'Keitt' mangoes during storage at 25C for up to 8 days

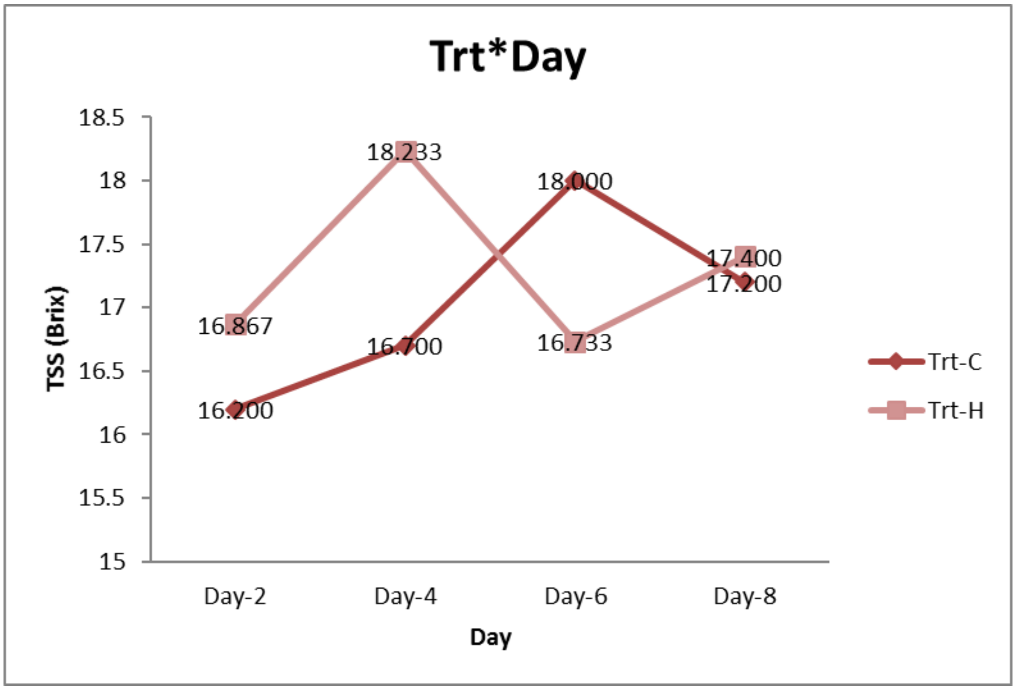

Figure 7 TSS (ºBrix) (C) and hot water treated (H) 'Keitt' mangoes during storage at 25C for up to 8 days

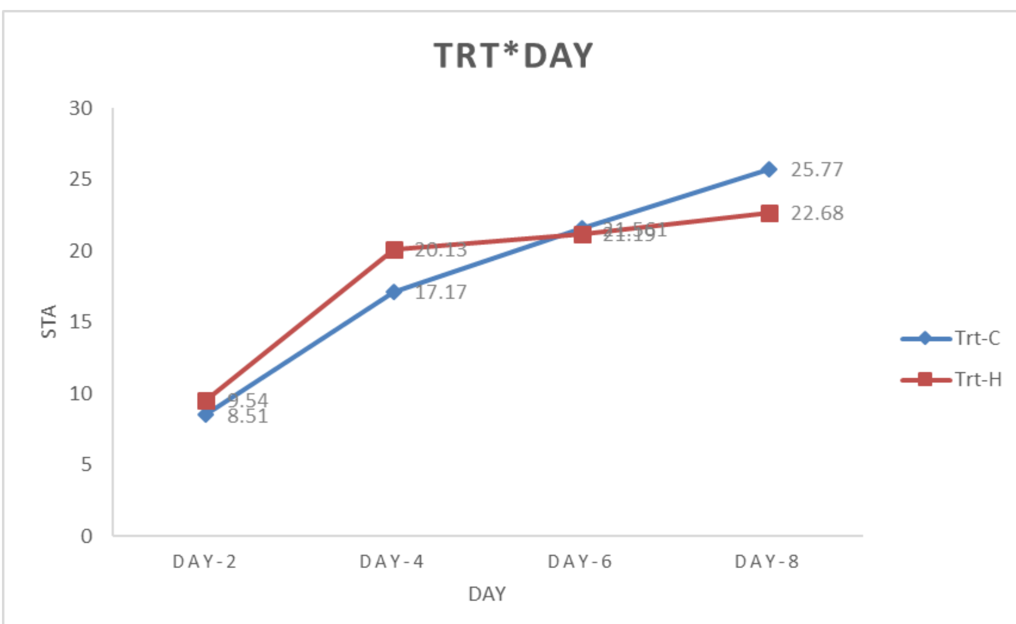

Figure 8 STA (C) and hot water treated (H) 'Keitt' mangoes during storage at 25C for up to 8 days