CHAPTER 7

Mango quality after radio frequency dielectric heat on controlling fruit fly infested in Thai mango

Abstract

This experiment was to investigate the possibility of radio frequency (RF) combined with rotating container filled with water on controlling fruit fly infested in mango fruit compared with standard method according to USDA-APHIS-PPQ, 2002. The operation was proposed with an accuracy measurement, specific temperature for specific insect such as fruit fly. The experimental design was completely randomized (CRD) with 4 replications. The six treatments were untreated mango, RF heat treatment at 48°C for 4, 6 and 8 minutes compared with hot water temperature of 46°C for 90 minutes directly and containing mango in plastic box. At the end of these treatments, eggs and surviving larvae were observed as well as moisture and chemical qualities of treated mango were determined. The result found that RF 48°C for 8 min and hot water at 46°C for 90 min completely control egg and larvae as artificial infestation in mango fruit by showing 100% mortality. The thermal image of mango fruit treated with RF heating energy also performed the uniformity of heat distribution inside the fruit which similar to immersion the fruit in hot water at 46°C for 90 min. All heat treatments showed no significant effect on change of physiological mango property as weight loss, color and firmness. Moisture content of mango peel exposed to RF at 48°C for 8 min exhibited the highest moisture while dipping in hot water at 46°C for 90 min decreased to 80.99%. For chemical quality, Heat treatments showed significantly effect on pH, acid content in mango juice and ratio between soluble solids and mango juice acid content (TSS/TA) that reflected the taste of mango while it had no influence on total soluble solids as shown in brix. The mango treated at 48°C for 8 min showed no effect on acid content and TSS/TA similar with dipping at 46°C for 90 min which was not difference from untreated mango.

7.1 Introduction

The section of production development and pests control in fruits and vegetables for export, Department of Agriculture has reported about the conditions of international quarantine laws in the export of mango to prevent an outbreak of fruit fly through export markets. The present mango export markets from Thailandto Japan was required the steam process at a temperature of 47°C for 20 minutes and the air must be saturated with heat at the relative humidity over 95% (Chomchalow and Na Songkhla, 2008). Moreover, it must have been certified by the auditors from Japan to ensure the accuracy of steam. As well as exporting to the United States also set the conditions for control fruit fly pests in mango of which mango fruit must be soaked in hot water temperature of 46°C for 90 minutes (USDA-APHIS-PPQ, 2002). However, the insect pest infestation in rice and wheat is more resistant to heat than fresh fruit. The heat causes acceleration in fruit ripening process such as producing more ethylene, increase in breathing, color change and fruit injury (Lurie, 1998). Many researcher reported heat temperature treatment after harvest affected potential damages of mango and orange (Shellie *et al*., 1993; Shellie and Mangan, 1998; Obenland *et al*. 1999b). However the heat from radio frequency is an alternative treatment which needed short time process of heating energy which is clean and safe. Then, the RF is possible to be developed as a solution of the problems. While the operation was proposed with an accuracy measurement, specific temperature for each type of pest can be selected to control specific insect such as fruit fly.

7.2 Materials and methods

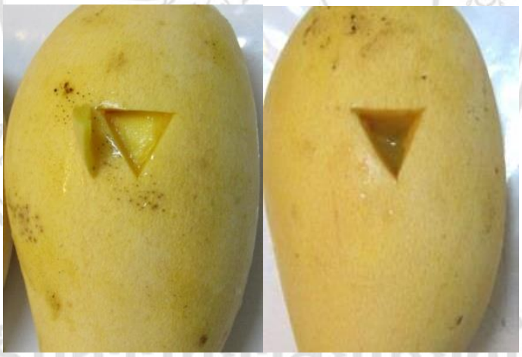
7.2.1 Mass rearing of fruit fly

In order to obtain egg, larvae, pupa and adult, insect cultures were set up before starting experiment. The oriental fruit fly, *Batrocera dorsalis* (Handel) (Tephrididae: Diptera) was originated from a stock rearing in the laboratory of Postharvest technology research institute, Chiang Mai University was introduced to net cage which is placed paper glass punched hole (size 1.5 mm) and inside was painted with high concentrate orange juice. The glass jars were placed up-side down on wide-rack filled with diluted orange jute with water (ration 1:1). Smell of vinegar helped to stimulate the adult females to lay eggs in the hole under the condition of light. The eggs were collected by small brush for 1 to 2 days to use in experiment

2.2.1. Some portions of egg were continued cultured in papaya until 2nd star larvae (4-6 days old) emerge and each stage was separated from mass rearing and used in experiment.

7.2.2 Mango sample preparation

Thai mango (*Mangifera indica*) was used in all of experiment. The egg and 2nd star larvae (4-6 days old) stages of oriental fruit fly were used to artificial infest on mango. The uniform in ripen of sample mango fruit were collected and then cut into 1 cm^2 and deep with 0.5 cm. The similar age of eggs of fruit fly under the microscope were placed on peeled mango into the hole and covered with the same piece of the same mango and sealed with a sicker (Figure 7.1). For another stage, the similar drilling of sample was also done and placed with 10 times of 2nd stage larvae (4-6 days old) instead. Both of mangos with artificial infestation were supposed to treat in the experiment.



A B

Figure 7.1 Preparation of mango fruit fly with artificial infestation eggs stage (A) and2nd star larvae stage (B)

7.2.3 Experiment

To compare the heat resistance, the egg and larva infested mango sample were supposed to RF heating energy. The RF applicator has been developed and built at the Institute of Agricultural Engineering, University of Goettingen, Germany. The unit has a variable power supply and operates at 27.12 MHz. The whole system consists of a RF-generator and applicator with plate applicators was used as the source of RF energy in this study. Fruit rotating chamber was combined with radio frequency application. Prior to RF treatment, all mango samples were immersed in hot water at 45°C for 50 min. A mango sample was put into the rotating container (seed detail on CHAPTER 6) and filled with the exact volume of water at temperature of 25°C. Then, the water was heated with the radio frequency generator and heat treatments are as followed:

Treatment 1 Untreated mango

Treatment 2 RF heat treatment at 48°C for 4 minutes

Treatment 3 RF heat treatment at 48°C for 6 minutes

Treatment 4 RF heat treatment at 48°C for 8 minutes

Treatment 5 Dipping in hot water at 46°C for 90 minutes

Treatment 6 Contain mango in seal plastic box before dipping in hot water at 46°C for 90 minutes

After treating, the mango was cut in half lengthwise and measured the thermal distribution image. Continuously, all treated mango sample were soaked into cold water (4°C) for 30 minute then, dried before testing for physical property and chemical analysis.

7.2.4 Data collection of insect mortality

At the end of these treatments, eggs and surviving larvae were observed in treated mango samples for additional 8 days, respectively. Mortality of pupae was evaluated by the level of adult immergence for 4 days (larvae) and 8 days (eggs) at 25°C. Mortality was calculated in percentage of dead insect relative to total treated insect in each treatment. Mean values and standard deviation were calculated for 10 replications for each treatment. Then, the collected data was corrected for control mortality using the Abbott (1925) formula.

7.2.5 Determination of physical property of mango

1) Measurement of the heat distribution of the fruits by using an infrared camera (Therma CAM^{TM} Researcher 2001, FLIR system, Portland, Oregon).

2) Measurement of weight and weight loss before and after treating by using two digit balance (Mettler Toledo, PB 3002-5, Switzerland) and weight in gram.

3) Measurement the color of mango skin by using a colorimeter (Color Quest XE, Hunter Associates Laboratory, Inc., New York, USA) with CIELAB (L *, a * and b *) (McGuire, 1992)

4) Measurement of mango firmness with Texture analyzer (TA-TX2) and expressed the data in unit of Newton

7.2.6 Determination of chemical quality

1) Determination of peel and flesh moisture of the mango by hot-air oven method. The 5 g of sample were dried at 105°C C for 72 hours in oven (Venticell 111, MMM med center Einrichtungen GmbH, Germany)

2) Determination of total soluble solids in mango juice using digital refractometer (ATAGO, PR-101, Japan) (Mitcham *et al*., 2003).

3) Measurement of pH of mango juice with a digital pH meter (pH-meter, SCHOTT GERATE, Consort C 831, Belgium) (Method No. 981.12; AOAC, 1995).

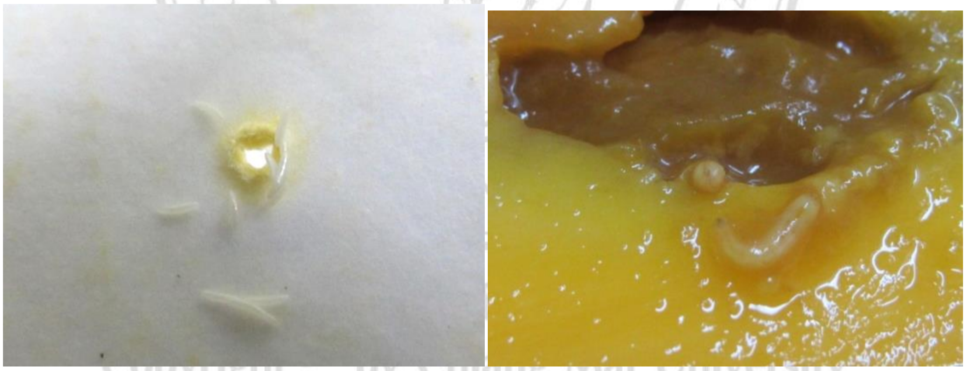
4) Determinations of titratable acidity in the tri-nitrate mango juice with 0.1 M sodium hydroxide (NaOH; AG, BDH Chemicals, Poole, England). The used volume of NaOH at the end point of pH 8.1 were collected and used to calculate to the amount of acid in. nitric or citric acid (g) per 100 ml of mango juice (Method No. 967.22; AOAC, 1990).

5) Determination the ratio of total soluble solids normalized by the tritatable acidity (TSS/TA), and indicator of fruit quality which the higher value, the more sweetness.

7.3. Results and Discussions

7.3.1 Mortality of egg and larvae artificial infested in mango fruit

Figure 7.2A showed the egg and 2nd star larvae (4-6 days old) stages (Figure 7.2B) of oriental fruit fly used in artificial infested on mango fruit before RF heat treatments. It was found that the mortality of fruit fly egg was significantly difference when compared with the control (Table 7.1). The egg mortality from treated mango by using RF heat at temperature of 46°C for 8 min was not different from immersion mango in hot water at 48°C for 90 min which showed completely control fruit fly egg (100%). This result of egg survival in mango contained in box immersed in hot water at 46°C 90 min confirmed that the fruit have to be directly soaked and contacted with hot water. No significant differences were found between using RF heat at 48°C for 4and 6 min. Then, to ensure of consistency of heat contributed in the fruit, time prolonging is also need to completely control fruit fly egg infestation.



A **B**

Figure 7.2 The egg (A) and 2nd star larvae (4-6 days old) stages (B) of oriental fruit fly

Table 7.1 Mortality of fruit fly at egg and larva stage infested in mango after heat treatments

Treatment	**Stage of insect infestation**	
	egg	**larva**
	Mortality (%)	
Control	10.00 ± 5.77c*	7.50 ± 4.79c
RF at 48°C for 4 min	82.50 ± 5.95ab	60.00 ± 7.91b
RF 48°C for 6 min	62.50 ± 8.29b	38.68 ±1 3.28b
RF 48°C for 8 min	95.00 ± 5.00a	100.00a
Hot water at 46°C for 90 min	100.00a	100.00a
Mango contained in box and hot water at 46°C 90 min	73.75 ± 9.44b	52.85 ± 16.42b

*Different letters within row indicate that means are significantly different (P≤0.05)

The same evident was also found in controlling larva infested in mango fruit which RF heat treatments were significantly difference when compared with the control (Table 1). Using RF heat method at 48°C for 8 min and immersion in hot water at 46°C for 90 min completely controlled fruit fly at larva stage (100% mortality) infested in mango fruit. While the heat distribution from heating of RF at 48°C for 4 and 6 min was not enough to raise lethal temperature the percent of mortality was 60 and 38.68, respectively. This result parallel with reports of Sharp (1990) who conducted the experiment by using hot water at temperature of 46.1±0.25°C to control larvae of *C. capitata*, *A. oblique*, *A. fraterculus* distinct infested in mango of which the mortality of larva was found 99.99 percent with the heating periods of 76.1, 113.4, 75.6 and 65.8 min, respectively.

7.3.2 Thermal image of mango fruit treated with RF heating energy

Figure 7.3 showed temperature distribution which mango without heating or control showed the temperature of skin at 22°C and inside the fruit was 20°C while the core of fruit was lower (19°C) (Figure 7.3A). When the mango was heated with RF heat energy at 48°C for 4 and 6 minute (Fig 7.3B and C), the mean temperature of individual mango varied from 27.50 to 42.5°C while the non-uniform heating was observed at the core of fruit which temperature was 27.5 and 30°C, respectively. The consistent hot spot on the end of mango fruit was found when exposure time for 8 minutes and raised the temperature range from 37.5 to 42.5°C (Figure 7.3D). On the other hand, when dipped mango into hot water at 46°C for 90 min, relatively uniform heat distribution in mango fruit was performed (Figure 7.3E). The non-uniformity of heat on the closely edge of mango fruit was found when mango contained in seal plastic box before dipping in hot water at 46°C for 90 minutes (Figure 7.3F).

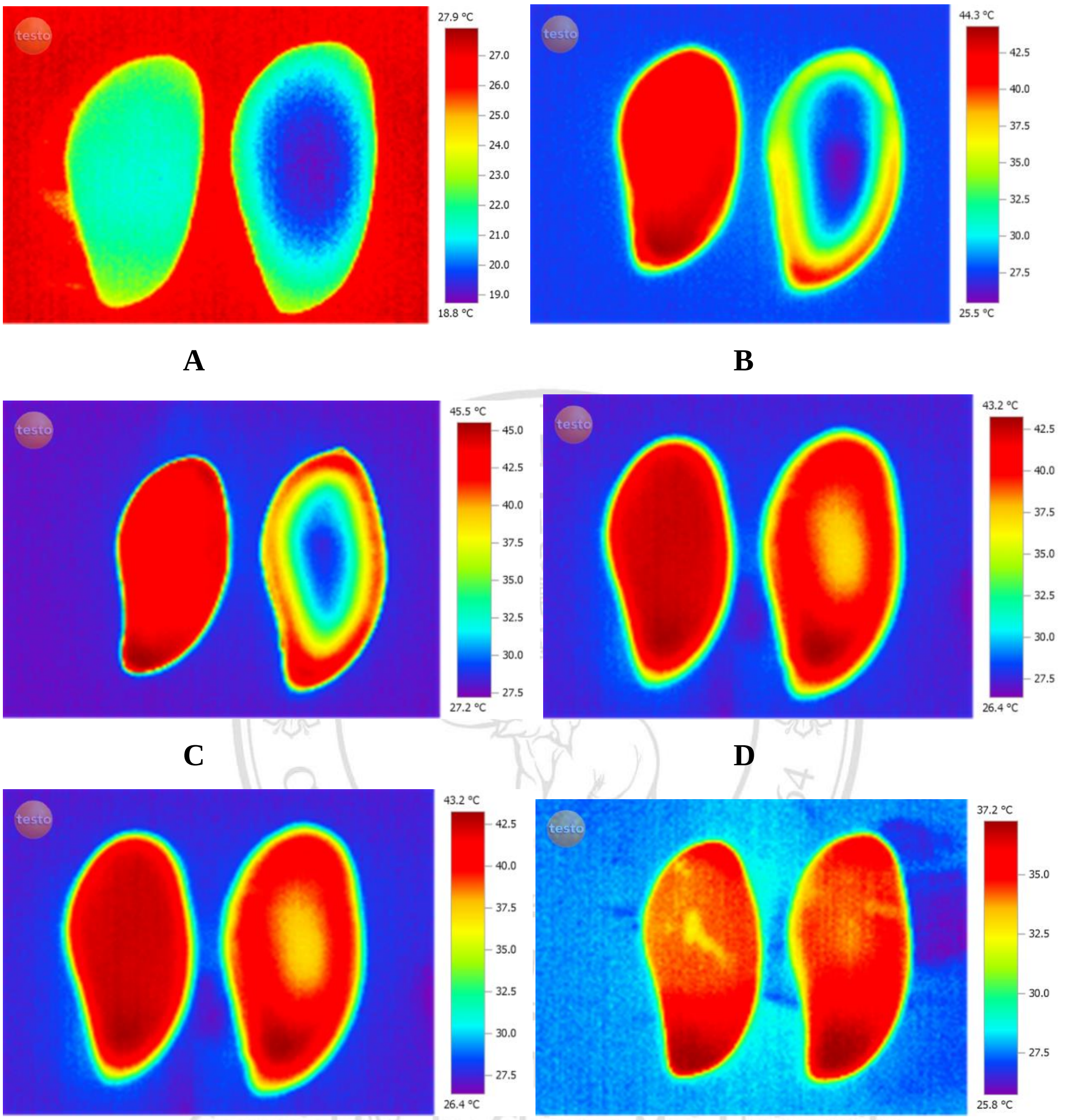


Figure 7.3 Thermal distribution and temperature legend in mango untreated mango (A) and after treatment: RF at 48°C for 4 min (B), 6 min (C), 8 min (D), immersion in hot water at46°C for 90 min (E) and mango in box at hot water at 46°C 90 min (F)

7.3.3 Physical qualities change in mango after heat treatment

Table 3.3 shows that weight loss of stored mango fruit for 3 days was not difference and decrease amount range from 2.4-2.64%. Measuring skin color showed the brightness of the color (L *) to red (a *) and yellow (b *) which showed that all treated mango showed no difference from control mango. In addition, the firmness of the mango flesh was not difference between untreated and treated mango. It can be implied that all heat treatments showed no significant effect on change of physiological mango property.

Table 7.2 Physical qualities change in mango after several heat treatments

Treatment	Weight loss (%)	Color			Firmness (Newton)
		L*	a*	b*	
Control	2.62	83.05	1.70	29.81	60.89
RF at 48°C for 4 min	2.38	83.97	1.62	27.44	70.78
RF 48°C for 6 min	2.45	81.54	1.81	28.63	79.17
RF 48°C for 8 min	2.40	77.48	2.25	27.86	70.43
Hot water 46°C 90 min	2.64	82.60	2.34	30.83	70.55
Mango in box and hot water 46°C 90 min	2.46	78.23	1.75	30.02	68.53
F-test	ns*	ns	ns	ns	ns
CV (%)	12.43	4.55	18.20	12.46	27.40

*ns=non significantly difference

7.3.4 Change of chemical quality of mango

1) Moisture content

Table 7.3 shows the measurement of moisture content in skin and flesh of mango fruit. The result found that moisture level in mango flesh was significantly different ($P \leq 0.05$). Mango exposed to RF heat energy at 48°C for 8min exhibited the highest moisture content in flesh of 83.93%followed by RF heat energy at 48°C for 6min which was not different from control. Immersion in hot water at 46°C for 90 min decreased the moisture content to be 80.99%. However, the moisture of mango peel in all treatments did not different.

Table 7.3 Moisture in flesh and peel of mango after several heat treatments

Treatment	Moisture content(%)	
	Flesh	**Peel or skin**
Control	83.57ab	74.67
RF at 48°C for 4 min	82.70b	72.69
RF 48°C for 6 min	83.33ab	72.69
RF 48°C for 8 min	83.93a	73.48
Hot water at 46°C for 90 min	80.99c	72.95
Mango in box and hot water 46°C 90 min	82.71b	72.02
F-test	*	ns
CV (%)	1.16	2.48

*Different letters within row indicate that means are significantly different (*P*≤0.05)

2) pH value

Table 7.4 shows the changes of the chemical properties of the juice of treated mango. The pH in each treatment was significantly different (P≤0.05). Heating by immersion the mango in hot water at 46°C for 90 min expressed the highest acid as pH 3.14) while mango heated with RF at temperature of 48°C for 6 and 8 min was not different from control mango that had the lowest pH at 2.63 followed by RF treating at 48°C for 4 min (pH 2.92).

3) Acid titration

Measurement of acid titration amount (titratable acidity, TA) was to determine the acid content in mango juice as shown in Table 7.4. The result noted that heating process significantly affected on TA (P≤0.05). Heating mango contained in box in hot water at 46°C for 90 min has the highest acidity (1.05%), followed by the methods provided heating by RF 48°C for 6 min. Both of the treatments were different from using heat from RF process at 48°C for 4 and 8 minutes which showed low acid content and these were not different from control.

4) Total soluble solids

The amount of total soluble solids (TSS) was to determine solids amount, solute in mango juice. It was found that all of heat treatment showed no effect on TSS which soluble solids was 9.22 to 10.63 Brix (Table 7.4).

Table 7.4 Chemical quality in mango after heat treatment

Treatment	pH	TA (%)	TSS (Brix)	TSS/TA
Control	2.63d	0.64c	9.35	14.98ab
RF at 48°C for 4 min	2.92b	1.02ab	10.07	10.68bc
RF 48°C for 6 min	2.68cd	1.04ab	9.43	10.40bc
RF 48°C for 8 min	2.74cd	0.63c	9.77	15.88a
Hot water at46°C for 90 min	3.14a	0.77bc	10.63	15.07ab
Mango in box hot water at 46°C 90 min	2.79c	1.05a	9.22	9.05c
F-test	*	*	ns	*
CV (%)	3.57	26.98	12.39	32.46

*Different letters within row indicate that means are significantly different ($P \leq 0.05$)

5) TSS/TA ratio

The ratio between soluble solids and mango juice (TSS) acid content (TA) reflected the taste of mango as presented in Table 7.4. The result have showed that the TSS/TA of the mango of RF treated mango at 48°C for 8 minutes was very sweet and the ratio of TSS to TA were statistically different from the other treated mangos ((P≤0.05) and the sugar is 15.88, followed by heat treatment by immersion in hot water at 46°C for 90 minutes as well as it was not different from control. Heating process in the container filled with hot water at 46°C for 90 minutes contained a low sugar (9.05). Barkai-Golan *et al*. (1992) noted that damage mango caused by heat treatment due to the effect from heat accelerated the rate of respiration, and continuously increased yield loss increased. In addition, Esquerra *et al*. (1989) reported that when the mango was heated, the value of soluble solids (TSS) increased at a faster rate than the control. The same result was also found in this experiment, which titrated acidity (TA) decreased at a faster rate than the control. For the ratio of solids can be dissolved with acid titration (TSS/TA) also expressed higher rate than in the control due to heat treatment affected mangoes metabolic whereas the mango fruit has currently breath as climacteric fruit. Will *et al*. (1981) described that typically the organic acids found in fruit in the form of acid and acrylic acid in the string of acid and tar paint acrylic as oxalic acid and glycolic acid which was the major amount of acid. The maximum effect of heat decreased to be the acid used as a precursor of the battle's application cycle (Kreb's cycle) and the amount of sugar was increased due to the main result from the reaction.

7.4. Conclusion

The heat from radio frequency is an alternative energy when combined with rotating container filled with water as a supporting tissue to provide the heat to mango as similar to hot water treating. The heat distribution inside mango fruit was performed by the RF heat treatment at 45°C for 8 minutes and the uniformity of the heat is as well as dipped mango into hot water at 46°C for 90 min. Not only completely control the egg and larvae of fruit fly, but also the treatment also showed no adverse effect on the chemical qualities of treated mango. The result confirmed that the RF energy is more suited for potential postharvest disinfestations treatments of this fruit due to its rapidly process.