

Abstract

In accordance with the APHIS regulations 7 CFR §319.56, movement of mangoes, *Mangifera indica* L., into the United States are allowed subject to satisfying specific entry requirements. Preceding shipment to the United States, mangoes from Mexico, certain Caribbean islands, and countries in South and Central America must be treated with an appropriate Probit 9-based T102-a hot-water immersion treatment to mitigate the infestations of several species of fruit flies. The T102-a quarantine treatment (<http://manuals.cphst.org/T1Index/index.cfm>) requires immersion of mangoes in hot-water bath with constant temperature of 46.1°C for a specified duration (minutes). Based solely on fruit weight, the T102-a has four published treatment schedules, which were proposed in late 2014 and are presently fully implemented. Prior to amending and harmonizing the T102-a treatment schedules, countries in South America had no USDA-approved hot-water immersion treatment for “over-sized” fruits (>650 grams); furthermore, the duration of treatment was dependent on the variety or shape of the fruit. The previously published T102-a quarantine treatment had 14 treatment schedules based on three variables: fruit weight, fruit variety or shape (“round,” “flat,” or elongated), and origin (country) of the fruit. Amendment and harmonization of T102-a from 14 to four treatment schedules were accomplished by removing restriction based on country of origin, eliminating restriction based on the variety or shape of the fruit, and harmonizing the treatment duration based on the weight of the fruit. Comprising the scientific evidence used in amending and harmonizing the T102-a treatment schedules are efficacy and validation data of T102-a hot-water immersion treatment to the following fruit flies in mangoes: Inga fruit fly, *Anastrepha distincta* (Greene); South American fruit fly, *Anastrepha fraterculus* (Wiedemann); Mexican fruit fly, *Anastrepha ludens* (Loew); West Indian fruit fly, *Anastrepha obliqua* (Macquart); sapote fruit fly, *Anastrepha serpentina* (Wiedemann); and Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann).

Objective

To review and summarize the supporting information and justification for the currently amended hot-water immersion treatment T102-a (http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf.) The amendment to the treatment schedule was necessary to allow importation into the United States of mangoes, *Mangifera indica* L., weighing more than 650g (also known as “over-sized” mangoes) from countries that had prohibition and to remove shape and country restrictions associated with the treatment.

Background

In accordance with the APHIS regulations 7 CFR §319.56, importation of mangoes from different countries are currently allowed subject to satisfying specific entry requirements. Mangoes from Mexico, certain Caribbean islands, and countries in South and Central America must be treated with an appropriate T102-a hot-water immersion treatment schedule, prior to importation into the United States, to mitigate infestations of several species of fruit flies. The T102-a hot-water immersion treatment has approved schedules for *Ceratitis capitata* (Mediterranean fruit fly) and *Anastrepha* spp., including *Anastrepha ludens* (Mexican fruit fly) for mango. Prior to the current amendment, the maximum allowable size (weight) of rounded mango varieties that can be treated with hot-water immersion and imported into the United States from Panama, countries in South America and the West Indies islands of Aruba, Bonaire, Curacao, Margarita, Tortuga, and Trinidad and Tobago was 650 grams (Figure 1). However, T102-a had treatment schedules allowing importation of rounded mango varieties weighing up to 900g from Mexico, Central America (north of and including Costa Rica), Puerto Rico, the U.S. Virgin Islands, and the West Indies excluding islands of Aruba, Bonaire, Curacao, Margarita, Tortuga, and Trinidad and Tobago.

Figure 1. The previously published (2014 and prior years) hot-water immersion treatment schedules for fruit flies in mangoes originating from different countries. The table numbers below are those used in the treatment manual.

Pests: *Ceratitis capitata* (Mediterranean fruit fly), *Anastrepha* spp.

Table 1. Determine Dip Time Based on Origin of Fruit¹

If the origin of the fruit is:	And the shape of the fruit is:	And the weight is (grams):	Then dip
Puerto Rico, U.S. Virgin Islands, or West Indies (excluding Aruba, Bonaire, Curacao, Margarita, Tortuga or Trinidad and Tobago)	Flat, elongated varieties ²	Up to 400 grams	65 minutes
		401 to 570 grams	75 minutes
	Rounded varieties ³	Up to 500 grams	75 minutes
		501 to 700 grams	90 minutes
		701 to 900 grams	110 minutes

Table 2. Determine Dip Time Based on Origin of Fruit¹

If the origin of the fruit is:	And the shape of the fruit is:	And the weight is (grams):	Then dip
Mexico or Central America (north of and including Costa Rica)	Flat, elongated varieties ²	Up to 400 grams	65 minutes
		401 to 570 grams	75 minutes
	Rounded varieties ³	Up to 500 grams	75 minutes
		501 to 700 grams	90 minutes
		701 to 900 grams	110 minutes

Table 3. Determine Dip Time Based on Origin of Fruit¹

If the origin of the fruit is:	And the shape of the fruit is:	And the weight is (grams):	Then dip
Panama, South America or West Indies islands of Aruba, Bonaire, Curacao, Margarita, Tortuga, or Trinidad and Tobago	Flat, elongated varieties ²	Up to 375 grams	65 minutes
		376 to 570 grams	75 minutes
	Rounded varieties ³	Up to 425 grams	75 minutes
		426 to 650 grams	90 minutes

¹ Valid if the fruit is not hydrocooled within 30 minutes of removal from the hot-water immersion tank.
² Such as ‘Frances,’ ‘Carrot,’ ‘Zill,’ ‘Ataulfo,’ ‘Carabao,’ ‘Irwin,’ and ‘Manila.’
³ Such as ‘Tommy Atkins,’ ‘Kent,’ ‘Hayden,’ and ‘Keitt.’

Efficacy Data Supporting Amendment of T102-a Quarantine Treatment

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In collaboration with APHIS, Perú-Servicio Nacional de Sanidad Agraria (SENASA) conducted studies with the general objective to validate the efficacy of T102-a hot-water immersion quarantine treatment for oversized ‘Kent’ mangoes infested with eggs and larvae of Inga fruit fly, *Anastrepha distincta* (Greene); South American fruit fly, *Anastrepha fraterculus* (Wiedemann); West Indian fruit fly, *Anastrepha obliqua* (Macquart); sapote fruit fly, *Anastrepha serpentina* (Wiedemann); and, Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann).

SENASA conducted four studies required by and in collaboration with APHIS. All studies were conducted at the SENASA Fruit Fly Production and Sterilization Center (CPEMF) located on the campus of Piura National University, District of Miraflores-Castilla, Department of Piura. Experimental design and methods followed the “USDA Guidelines for Hot-Water Immersion Research to Control Fruit Fly Infestations in Peruvian Mangoes.”

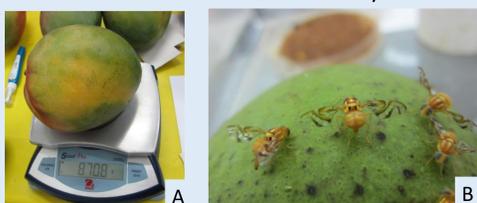


Figure 2. Over sized mango (>650 grams) being weighed (A). *Anastrepha fraterculus* ovipositing on mango (B).

Study 1. Fruit Fly Life History Parameters

Study 1 determined the mean and median developmental periods of eggs and larvae of *A. distincta*, *A. fraterculus*, *A. obliqua*, *A. serpentina* and *C. capitata* reared in ‘Kent’ mangoes. This study satisfies the USDA requirement that “Treatment should only commence when more than 50% of the test population is at the desired life stage.” Table 1 summarizes the number of days following egg deposition during which each life stage is reached by 50% of the population infesting ‘Kent’ mangoes.

Table 1. Mean and median developmental periods (days) of immature stages of select fruit flies.

	<i>A. distincta</i>	<i>A. fraterculus</i>	<i>A. obliqua</i>	<i>A. serpentina</i>	<i>C. capitata</i>
Eggs	1	1.5	1	2	1
First-Instar Larvae	3	3	3	5	3
Second-Instar Larvae	5	5	5	7	5
Third-Instar Larvae	8	9	10	10	7

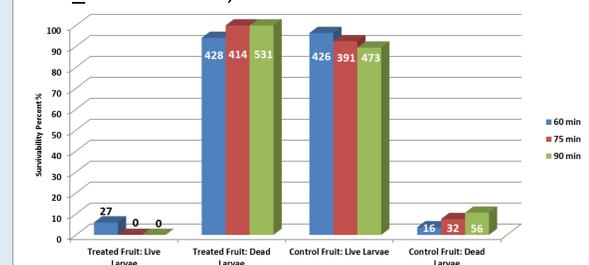


Figure 3. Mangoes with temperature sensors inserted in the mesocarp and taped to the surface in preparation for hot-water treatment (A). Hot-water immersion tank showing temperature sensors inserted in test mangoes during treatment (B). Dissected mango showing dead fruit fly eggs after hot-water treatment (C).

Study 2: Heat Tolerance of Developmental Stages by Diagnostic Bioassay Method

Study 2 determined the most heat tolerant species and stage of development among *A. distincta*, *A. fraterculus*, *A. obliqua*, *A. serpentina*, and *C. capitata* by immersing 800 ± 25 g, fruit-fly infested ‘Kent’ mangoes in 46.1°C hot-water bath for 60-, 75- and 90-minute durations. Eggs and first- to third-instar larvae of *A. distincta*, *A. fraterculus*, *A. obliqua*, *A. serpentina* and *C. capitata* had 100% mortality after fruit immersion in 46.1°C hot-water bath for 75 and 90 minutes. Based on these results, third-instar larvae of *C. capitata* appear to be the most heat tolerant and that the efficacy of the hot-water immersion quarantine treatment should be validated using third-instar larvae of *C. capitata* (Figure 4).

Figure 4. Mortality and survival results of *C. capitata* 3rd instars after hot-water tolerance treatments at 46.1 ± 0.25°C for 60, 75 and 90 minutes.



Study 3: Hot-water Immersion Quarantine Treatment Validation Test

A total of 112,178 third-instar larvae of *C. capitata* infesting ‘Kent’ mangoes were subjected to 110-minute immersion in 46.1°C hot-water bath; all (100%) third-instar larvae in treated fruits died (Figure 5).

Figure 5. Efficacy of hot-water immersion in large mangoes (800 ± 25 g) per 110 minutes using third instar *C. capitata* larvae.

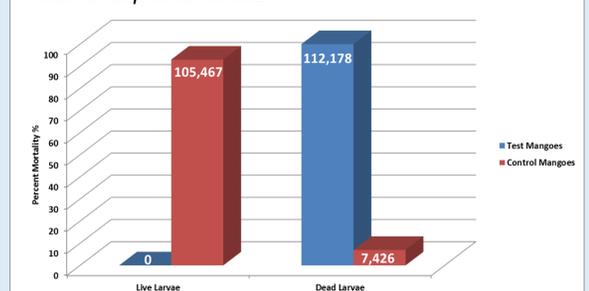


Figure 6. Research team dissecting mangoes to determine the rate of survival of fruit fly eggs and larvae after hot-water immersion treatment.

Study 4: Quality of Hot-Water Immersion Treated Fruit

Quality evaluation tests showed no difference in quality of treated and control fruits following hot-water immersion.

Conclusion and Regulatory Decision

The APHIS-PPQ-Center for Plant Health Science and Technology (CPHST) reviewed the research findings and agreed with the above conclusions. Therefore, CPHST recommended revising the hot-water immersion treatment T102-a by adding a fruit immersion duration of 110 minutes for all mango varieties weighing 651-900 grams and originating in any country where T102-a is currently required (Table 2). CPHST also recommended removing shape and country associations with the treatment and maintaining the option to delay hydro-cooling for 30 minutes following completion of the treatment duration or add 10 minutes to the treatment duration to allow hydro-cooling: The amendment allows importation of all varieties of mangoes weighing 651-900 grams from countries currently approved for entry into the U.S.

Table 2. T102-a Treatment schedules for fruit flies in mangoes

If the weight is (grams):	Then the dip time (minutes) is:
Up to 375	65
376 to 500	75
501-700	90
701 to 900	110