

# Fruit flies: disinfestation, techniques used, possible application to mango

Marie-Noëlle DUCAMP COLLIN<sup>a</sup>, Cécile ARNAUD<sup>b</sup>, Valérie KAGY<sup>c</sup>, Christian DIDIER<sup>a</sup>

<sup>a</sup> Cirad-Persyst, TA B-95 / 16,  
34398 Montpellier Cedex 5,  
France  
ducamp@cirad.fr,  
christian.didier@cirad.fr

<sup>b</sup> CNEARC, 1101 Av Agropolis,  
BP 5098, 34033 Montpellier  
Cedex 1, France

<sup>c</sup> Institut agronomique  
neo-calédonien, Centre de  
recherches fruitières de  
Pocquereux, La Foa,  
Nouvelle-Calédonie  
kagy@iac.nc

## Fruit flies: disinfestation, techniques used, possible application to mango.

**Abstract — Introduction.** The methods of fruit disinfestation against fruit flies use processes (physical methods) which differ according to the export country and fruit which must be disinfested. The term definitions are made clear and the various treatments are presented. **Heat treatments.** For mango, treatments usable for disinfestation can only utilize heat, because of the strong sensitivity of this fruit to cold temperatures. The heat treatments in general consist of using an immersion in hot water by a system of batches or an uninterrupted bath. These treatments are then followed or not by a fruit fast cooling which can be carried out by ventilation (cold air) or hydrocooling (water). Heat can also be obtained by use of forced hot air or hot vapor, because a higher temperature than 45 °C kills fly eggs and larvae. **Microwave treatments.** The use of microwaves is also a technique which makes it possible to increase the temperature in the fruit heart. **Irradiation.** The last possible solution is the use of irradiation, which uses a principle different from the preceding treatments. **Conclusion.** In comparison with the most current treatments (vapor heat treatment and forced hot-air treatment), the hot water treatment has many advantages: it is easy to implement, it is quick, it kills surface parasitic organisms, it makes it possible to clean the fruit surface and its cost only corresponds to approximately 10% of the cost of one vapor heat treatment. It would thus be recommended for mango disinfestation.

France / fruits / *Mangifera indica* / tephritidae / stored products' pest control / heat

## Mouche des fruits : désinfestation, techniques utilisées, application possible à la mangue.

**Résumé — Introduction.** Les méthodes de désinsectisation des fruits pour les infestations de mouches de fruits font appel à des procédés (méthodes physiques) qui diffèrent selon le pays d'exportation et selon le fruit qui doit être désinsectisé. Les définitions des termes sont reprises et les différents traitements sont présentés. **Traitements à la chaleur.** Pour la mangue, les traitements utilisables pour la désinsectisation ne peuvent faire intervenir que la chaleur en raison de la forte sensibilité de ce fruit au froid. Les traitements à la chaleur consistent en général à utiliser une immersion dans l'eau chaude par système de *batch* ou en continu. Ces traitements sont ensuite suivis ou non d'un refroidissement rapide des fruits qui peut être réalisé par ventilation (air froid) ou par *hydrocooling* (eau). La chaleur peut aussi être obtenue par utilisation d'air chaud forcé ou de vapeur chaude car une température supérieure à 45 °C tue les œufs et les larves des mouches. **Traitements aux micro-ondes.** L'emploi de micro-ondes est aussi une technique permettant d'augmenter la température à cœur des fruits. **Irradiation.** La dernière solution envisageable est l'utilisation de l'irradiation qui met en jeu un principe différent des précédents. **Conclusion.** En comparaison avec les traitements les plus courants (traitement à la vapeur d'eau chaude et traitement à l'air chaud forcé), le traitement par trempage en eau chaude a de nombreux avantages : il est facile à mettre en œuvre, il dure peu longtemps, il détruit des organismes parasites de surface, il permet de nettoyer la surface des fruits et son coût correspond à environ 10 %, seulement, du coût d'un traitement à la vapeur d'eau chaude. Il serait donc préconisé pour la désinfestation des mangues.

France / fruits / *Mangifera indica* / tephritidae / lutte antiparasite en entreposage / chaleur

\* Correspondence and reprints

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## 1. Introduction

The international transport of fruit, a potential host of fruit fly, has been the subject of a lot of research aiming at determining quarantine techniques intended to avoid the development of such insects in geographical areas which are free of them.

Applied in a precise and rigorous way, quarantine methods have reduced the development of fruit fly (Tephritidae). However, with the increase in transport and commercial exchange, quarantine barriers have become difficult to maintain and new flies are very often introduced; since 1980, a great number of them has been especially observed in the United States. The list of the flies thus listed is long: *Bactrocera invadens*, *Ceratitis capitata* (Mediterranean fruit fly), *Ceratitis rosa* (Natal fruit fly), *Bactrocera cucurbitae* (melon fruit fly), *Bactrocera dorsalis* (oriental fruit fly), *Bactrocera zonata* (peach fruit fly), *Anastrepha suspensa* and *Dacus bactrocera latifrons* (Malaysian fruit fly).

The plant protection authorities of most of the importing countries accept various procedures using physical or chemical treatments, or a combination of both. However, the prohibition of ethylene dibromide, which began in the United States and which is currently spreading on an international scale, as well as the restriction of methyl bromide use as quarantine treatment by fumigation, involve the development and the application of substitute treatments for pollutant gases. Now, research efforts are relating to the application of physical treatments such as heat or cold, which are likely to be more expensive and more difficult to implement than the gas treatments.

An international consensus does not exist on the level of the necessary quarantine degree applicable to the products presenting contamination risks by fruit flies. Many imported and marketed tropical fruits do not have their own treatments of disinfection.

In this field, the most immediate prospect would relate to quarantine treatments or to systems making it possible to open or maintain the tropical fruit export and market through the quarantine barriers.

## 2. Terminology regarding fruit quarantine

Several terms describe the risk situation of fruit-bearing production with respect to its pests:

- A *quarantine host* corresponds to any tropical fruit, at one or more stages of its development, likely to be infested in the field and to become an insect or fungus development support.
- A *quarantine treatment* implies any action, or unit or multiple treatments, which can be applied for disinfecting tropical fruit hosts in order to ensure quarantine safety.
- A *quarantine system* is an approach system, which uses individual operational compounds, each one of them involving a reduction of the fruit infestation, or of the number of affected fruits, until quarantine completion.
- *Quarantine safety* implies a statistical degree of probability, which makes it possible to ensure that the quarantine treatments or systems are effective: after their action, the insects will not be able to be transported and to develop in the countries of arrival where they are not present.

The *quarantine treatments* are more difficult to develop if there are several developmental stages of the infesting organisms present on or in the fruits, because, as a preliminary, the most resistant stage to treatment has to be determined. For example, the “egg” and “chrysalis” stages can be more resistant to treatments by fumigation than the “larva” and “adult” stages because of their weaker metabolism and breathing. In addition, localization of the organism itself – whose developmental stages either are present on the fruit surface, or inside the fruit in the pulp, seed cavity or seed itself – affects the quarantine-treatment type and severity or the system chosen for disinfecting the fruits. Thus, the developmental stages of insects present only on the fruit-host surface are the most sensitive to the treatment because they are exposed to it; insects having stages developing inside the fruit host require more severe treatments because the products have to spread inside the fruit to cause their death.

Insecticides such as dimethoate and fenitrothion integrated into immersion baths or vaporizations are used as postharvest disinfestation treatment against the banana fly, but the technique does not have a broad action spectrum. Even the compounds presenting close spectra, such as methoprene, a growth regulator causing fly death, mixed with waxes and applied to the fruit, is not commercially used for disinfestation treatments.

Thus, the future of pesticides in this field appears very limited because it would be necessary to find efficient compounds, which are approved. Their already prohibitory cost is greatly increased by the tests which would be necessary to obtain their accreditation; their development and their use are slowed down by the legislation concerning the pesticide residual levels in food products and additives.

In fact, the technologies of the quarantine treatments used today are a palliative to fumigation by pollutant gases. They include the fruit-host temperature increase or reduction above or below the limits of thermal resistance of the insect concerned. They can also utilize irradiation to kill or sterilize the insect in question.

To be accepted by the quarantine authorities of certain countries, treatments must present a probability of significant effectiveness, proving that they kill more than 99.9968% of the insects present. Such a “probatory” value would mean that only three individuals among 100 000 individuals would be authorized to survive after a quarantine treatment.

Nevertheless, some other countries, including Japan, use a variation of this measurement, called “probit 9”, the concept of which does not authorize any insect survival in a population of 30 000 infesting individuals.

### 3. Heat treatments

Heat treatments, based on the fact that a temperature higher than 45 °C kills fly eggs and larvae, in general consist of treating fruit by forced hot air or hot vapor, or immersing them in warm water.

Relatively easy to apply, these treatments can be used against fungi or pests; they have the advantage of not leaving chemical residues. However, in certain cases, they have the disadvantage of causing damage to the fruits; this damage must be evaluated fruit by fruit.

### 3.1. Immersion in warm water

#### 3.1.1. Principle

Immersion in warm water, also called hydrothermal treatment, uses warm water to increase the internal temperature of the product to be treated during a given time. Warm water is a good vector, which makes it possible to raise the skin temperature, then that of the fruit pulp, in a uniform way.

The time-temperature couple is variable according to the fruit and the parasite to be eliminated; warm-water immersions of perishable goods, to be officially approved and satisfactory against fruit fly in particular, must allow a rise in temperature in the fruit heart varying between 43.0 °C and 46.7 °C, with durations ranging between 35 min and 90 min [1–12].

Treatment by warm-water immersion is successfully used to treat mangos infested by the Mediterranean fly and by other *Anastrepha* species before importation of fruit from Mexico, the Caribbean, Central America and South America (figure 1) into the United States.

Research carried out on mangos, which are relatively resistant-to-heat fruits, shows that the warm-water treatment can be approved in quarantine for mangos infested by immature flies [5–10, 12, 13].

#### 3.1.2. Batch system, also called “jacuzzi”

Most of the systems used to treat fruit by immersion in warm water are of the *batch* type. During this process, fruit cases are loaded onto a platform which is itself plunged into an immersion tank, maintained at the desired temperature. After the processing time is completed, the cases are taken out. Identification by case marking makes it possible to follow up if there is a premature



**Figure 1.** Steps of mango packaging in Brazil, integrating a warm-water treatment step.

exit out of the tank. However, there can be an electronic or different witness which actuates itself if a load leaves the bath too early, and which stops or blocks the system as long as the treatment is not finished.

### 3.1.3. Uninterrupted system

In the system of continuous immersion in warm water, the products to be treated are placed in cases on a mechanical conveyor which slowly moves from one end to another of a warm-water bath.

The speed of the conveyor is controlled so that fruits remain immersed during the desired time; the system requires instrumentation to control the speed of the conveyor.

A speedometer placed in the system makes it possible to check the speed of the conveyor drive belt and, at the same time, the duration and the temperature of the treatment; it can indicate when the system is moving or when it was stopped in the process of treatment.

Small sized fruit require an adaptation of the technique; this is why the conveyor system, the belt speed and the processing times must be adjustable. Thus, if the speed of the conveyor is constant, it is then necessary to

be able to adapt the length of the immersed portion of the conveyor and the contact time determined for this specific category of fruits. In addition, it is necessary to avoid having a movement back and forth in the tank because of possible floating of the fruits.

Systems of this type, set up after the nineties, could have the disadvantage of causing mechanical damage to the fruits if they are not placed in baskets. In addition, the fruit-treatment uninterrupted system has the disadvantage of occupying a greater space on the ground compared with an installation of the *batch* type.

According to the fruits, there can be variations in the species and the larva developmental stages of the insect controlled by these treatments. When circulation in the warm-water bath is correctly carried out through the fruit cases and when the necessary setting temperature is fast and uniform, this treatment allows a heat transfer [14]. The technique has the advantage of being able to control postharvest problems such as anthracnose and stem-end rot [13, 14,]. However, times and temperatures of warm-water treatment can damage the treated fruits, as certain symptoms observed on mangos show (*table I*).

**Table I.**

Description of damage caused to mangos by quarantine treatments (warm water, hot air or vapor heat) [33].

Mango cultivar	Heat treatment	Heat injury	Reference
Carabao	VHT 46 °C for 10 min	Internal browning in inner mesocarp of ripe fruit; white, starchy, tough lesions; fermented odor	[39]
Haden, Irwin, Kensington, Strawberry, Tommy Atkins, Keitt	HWT (42 to 48) °C for 30–90 min	Skin scalding	[36]
	HWT 46 °C for 90 min or HWT 49 °C for 60 min	Darkened lenticels	[34]
	VHT 46 °C for (3 to 4) h or VHT 48 °C for 5 h	Internal cavities formed near the seed Surrounded by hard unripe tissue	[38]
Kensington	HWT 48 °C for (7.5 to 30) min	Skin scalding: uneven skin color development with ripening; starch retention in the form of layers and spots in ripe fruit; internal cavities	[35]
	HWT 47 °C for 25 min	Internal cavities; starchy regions retained in ripened mesocarp	[37]
Tommy Atkins	HWT 46 °C for 120 min or HWT 49 °C for 60 min	Darkened lenticels	[34]
	FHAT 51.5 °C for 125 min	Peel pitting	[23]

VHT: Vapor Heat Treatment, FHAT: Forced Hot-Air Treatment, HWT: Hot-Water Treatment.

We have to note that:

- in Central America, the treatment consists of a 46.1 °C steeping carried out either in a tank, or in an uninterrupted system, for (65 to 90) min;
- the protocol of disinfestation by warm water is approved for the admission into the United States for mangos from Mexico, Puerto Rico, Virgin Islands and the West Indies;
- generally, fruit of lengthened type of less than 375 g are treated at 46.1 °C for less than 65 min; for fruit weights ranging between (375 and 570) g, a temperature of 46.1 °C is maintained for 75 min;
- these treatments can cause rather significant damage on the fruit skin (*table I*).

According to the international standards, it would be necessary to treat fruits for 20 min, at 48 °C. However, tests carried out on five mango varieties showed that a more than 90-min treatment would prove to be necessary. A steeping longer than 30 min would cause 100% pest mortality.

Fruits maintained at 25 °C after treatment are analyzed according to acceptance criteria, which can be their weight loss within the limit of 10%, their marketable rate, which must be higher than 75% of the treated batch fruits, etc.

Fruits treated on the harvesting day often present damage on the surface. On the other hand, if they are treated (24 to 48) h after harvesting, these disadvantages are reduced.

#### **3.1.4. Fruit cooling after warm-water treatment**

Fruit cooling after the warm-water treatment is not an obligation required by the treatment technique registration authorities. However, many factories install a cooling system to treat fruits when they exit the warm water.

In order to improve the effectiveness of the warm-water treatment on larva mortality, the treated fruits should not be transferred into a cooled room during the 30 min which follow the treatment.

For mangos, the recommended cooling temperature is 12.8 °C with 85–90% of relative humidity. These parameters would make it possible to slow down the fruit softening and to increase its shelf life by 2 to 3 weeks.

The fruit cooling can be carried out by ventilators or hydrocooling:

- Ventilator use can be authorized for fruit sweeping after exiting the warm-water tanks; the ambient air temperature must be lower than 21.1 °C.

- Hydrocooling, by immersion or sprinkling, can be considered but, as previously explained, it must be carried out 30 min after the fruit heat treatment. Between these two periods of treatment, mangos, for example, must be stored in a room or a tunnel separate from the warm-water tanks. During the hydrocooling, the water temperature is not controlled; on the other hand, the temperature used must not be too cold because that could involve damage on the fruit surface.

According to the producer countries, destinations and fruits concerned, the treatment methods can differ (*figures 1–4*).

### **3.2. Hot-air treatment**

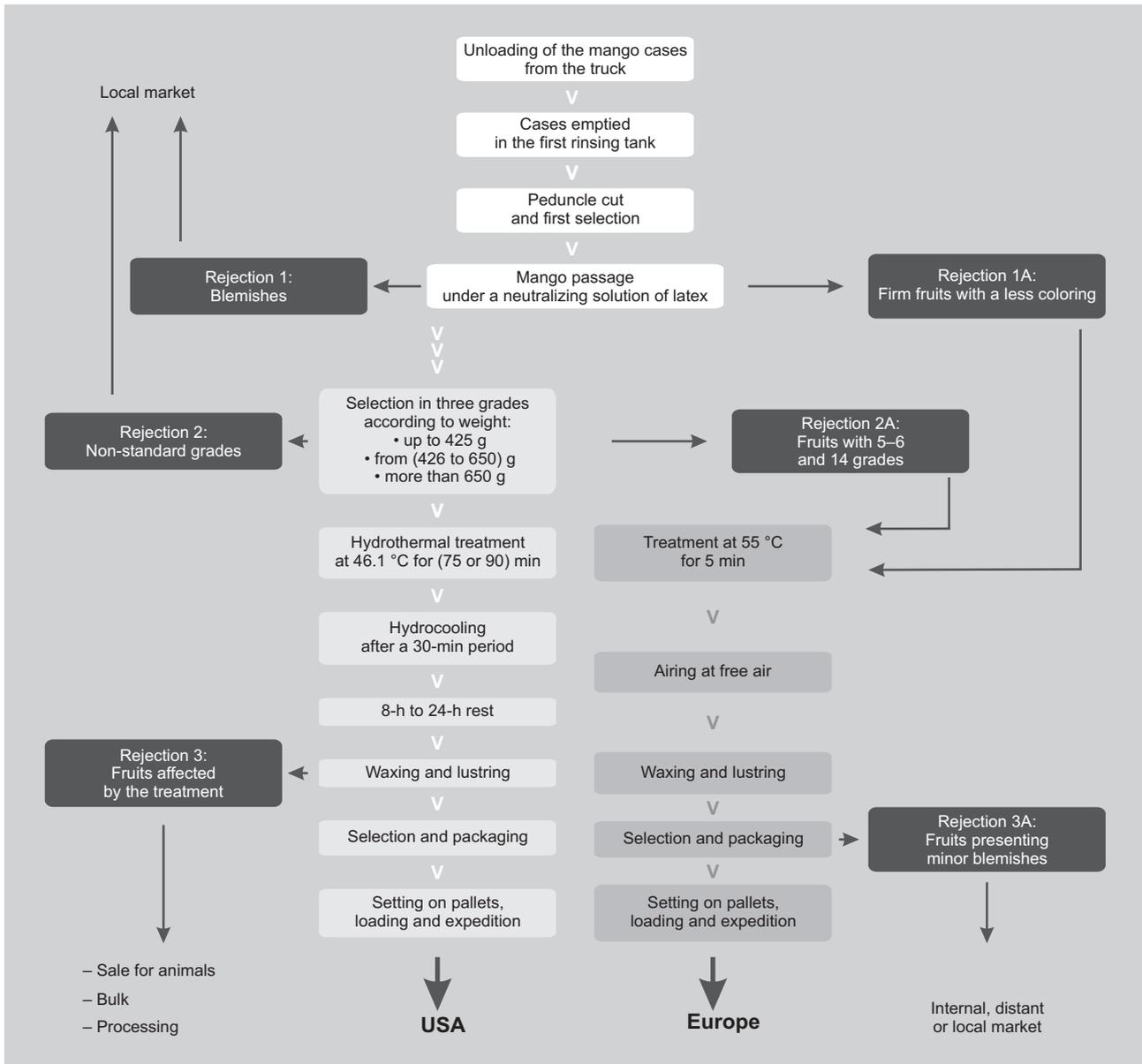
Vapor heat treatments and high-temperature forced air are virtually identical: nevertheless, in the vapor phase, water condenses on the fruit surface whereas, in high-temperature forced air, it remains dry.

#### **3.2.1. Vapor heat treatment**

Vapor heat treatment (VHT) is also called heating by air with high moisture.

To bring the fruits which must be treated to the desired temperature, during a determined period which is specific according to the insect to eliminate, the VHT uses vapor-saturated hot air. In this case, the increase in temperature is achieved thanks to the latent heat released during the vapor condensation on the skin, then on the fruit pulp.

In this type of process, just as for warm water, the time-temperature couple varies according to the treated fruit and to the pest



which has to be eliminated. Generally, the temperature of the fruit pulp is raised to 43,3 °C – 44,4 °C during a (6 to 8)-h period; it is then maintained at that temperature during an additional (6 to 8) h. Fruits are immediately cooled after treatment. Shorter times can be applied for cut flowers or foliage.

Vapor heat treatment is approved by the *United States Department of Agriculture* (USDA) for the importation, inter alia, of

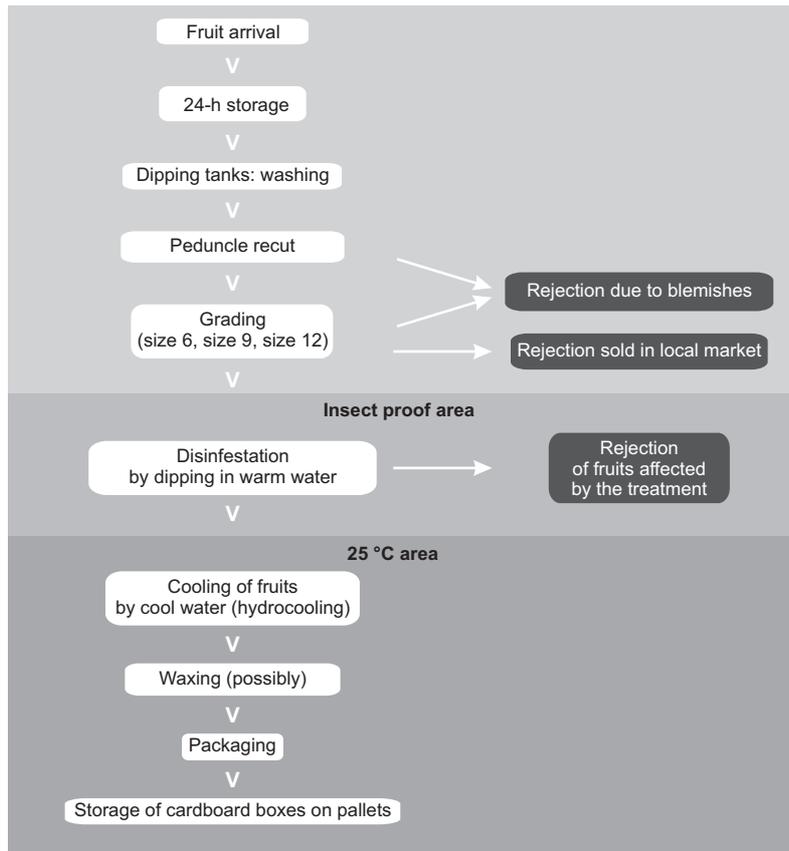
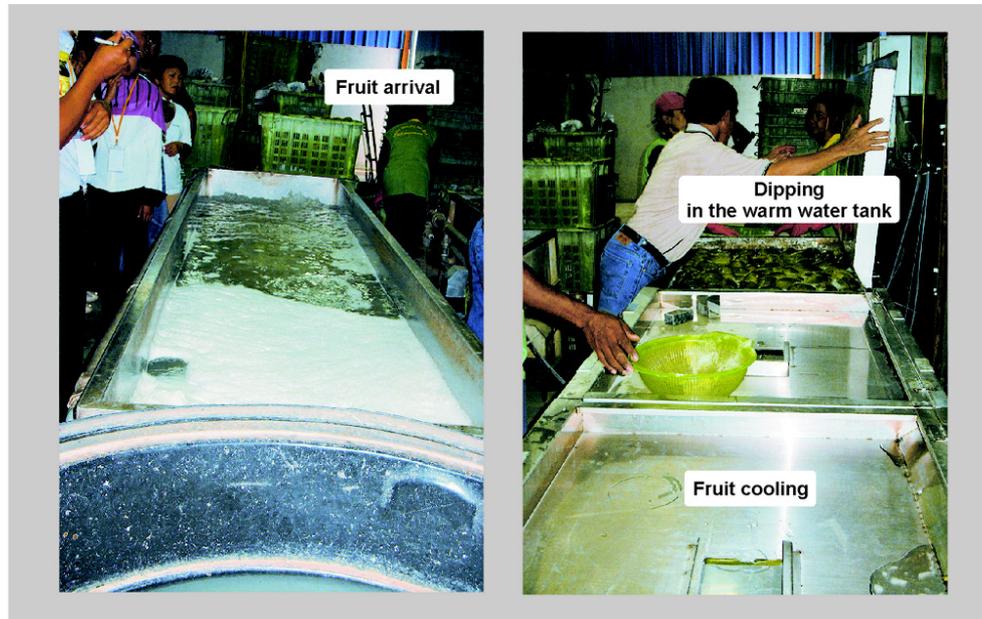
mangos from Mexico, as well as other products likely infested by the Eastern Mediterranean fly or by the melon fly.

Quarantine treatments, carried out with vapor, are used for exports of Philippines', Thailand's, and Hawaii's mangos to Japan:

- Protocols required by the Japanese market include a 46 °C treatment in the fruit heart for 10 min for the Carabao mango of the Philippines; 46.5 °C for 30 min for the

**Figure 2.** Diagram of a packaging system including a warm-water treatment (Brazil, according to C. Arnaud, CIRAD).

**Figure 3.** Traditional system of warm-water treatment for papaws in Malaysia (according to C. Didier, CIRAD).



**Figure 4.** Chain including the disinsectization warm-water treatment for mangos in Brazil for export to the United States.

Irwin and Haden mangos from Thailand; 46.5 °C for 10 min for the Nang Klang Wun mango of Thailand; and 47 °C for 10 min for the Nam Doc Mai, Pimsen Dang and Rad mangos.

- The protocol accepted by Japan for the admission of the Australian Kensington variety fruits requires a temperature of 47 °C in the fruit heart for 15 min.
- In the USA, the Mexican Manila variety mango is authorized to enter only after a treatment at 43.3 °C for 6 h.

It is noted that each variety, each origin and each pest involves a modification of the treatment protocols.

### 3.2.2. Forced-air treatment

For this postharvest type of treatment, a heated and humidified air is forced to circulate through fruits in order to increase the temperature to a lethal level for the pests which must be killed. Use of air heated between (40 and 50) °C, in general by means of four increasing temperatures and for less than 8 h, has become a usual control for fruit fly of the tropical species [9, 15–22].

Accurate control of the temperature and relative humidity has many advantages because it prevents having condensation in the treatment areas and on the fruit surface,

which makes it possible to prevent fruit desiccation and scald [18].

Fruits which tolerate forced-air treatment are carambolas [22], mangos [19, 22, 23], navel oranges [24], papaws [16] and pomelos [9, 13, 21]. On the other hand, this treatment is not recommended for avocados, litchis or nectarines [20]. Forced-air treatment is approved by the USA for mangos, papaws and pomelos.

The flies concerned with forced-air treatment are:

- for mangos from Mexico City: the Mexican fly (*Anastrepha ludens*), the West-Indies fly (*Anastrepha obliqued*) and the black fly (*Rhagoletis ribicola*);
- for pomelos from Mexico City: the Mexican fly;
- for papaws from Hawaii: the Mediterranean fruit fly (*Ceratitidis capitata*), the oriental fruit fly (*Bactrocera dorsalis*) and the melon fruit fly (*Bactrocera cucurbita*) [1].

Forced-air treatments are used for the export of Hawaiian papaws to the USA and for papaws from the Cook Islands to New Zealand (figure 5).

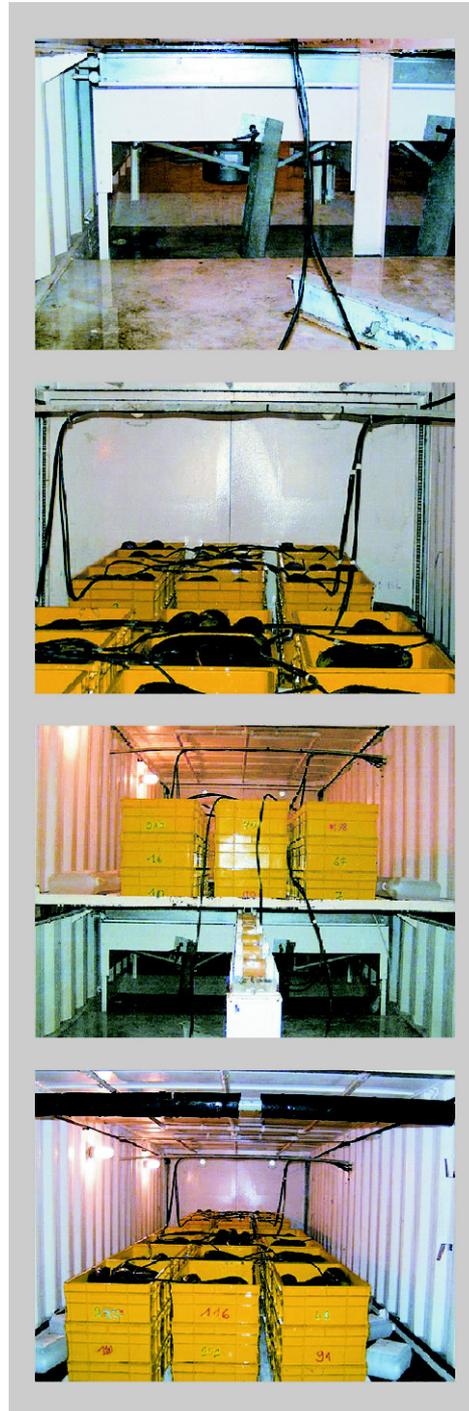
### 3.3. In short...

Warm-water and vapor heat treatments are usually used on mangos. They control pests well. However, certain problems can appear on the skin depending on the treated fruits, their maturity, their size and thermal conductivity; thus, special attention must be paid to these types of treatment, which, in addition, can accelerate the fruit maturation, in certain cases; this is strongly inadvisable for their transport (table II).

These heat treatment techniques, by immersion or vapor, and the ambient parameters must be very strictly controlled, which often poses problems for their implementation. The necessary installations, which are expensive, can, however, be offset by other uses.

## 4. Microwave treatments

Energy generated by the waves corresponding to radio frequencies is not initially heat;



**Figure 5.**

Blast hot-air treatment: interior of the hot-air treatment box set up at the Tontouta airport, Noumea, New Caledonia (according to V. Kagy, IAC, New Caledonia).

in fact, microwaves used in the electromagnetic energy spectrum of 10 kHz to 100 GHz are used to heat products by conversion of electromagnetic energy into calorific energy.

**Table II.**

Description of mango maturation acceleration by postharvest disinfestation quarantine treatments according to the studied variety [33].

Cultivar	Heat treatment	Ripening response	Reference
Carabao	VHT 46 °C for 10 min	Increased respiration rate, yellowing of skin	[39]
Keitt	HWT 46.1–46.7 °C for (20 to 60) min	Yellowing of skin, uniformity of color	[41]
Keitt, Palmer, Tommy Atkins	FHAT 46 °C for 3.25 h or FHAT 48 °C for 2.5 h or HWT 44 °C core for 25 min	Yellowing of skin, uniformity of color, fruit softening	[14]
Keitt, Tommy Atkins	HWT 46 °C for (60 to 120) min or HWT 49 °C for 60 min	Yellowing of skin	[34]
	FHAT 46 °C for (3 to 4) h or FHAT 48 °C for 5 h	Increased respiration rate	[38]
	Conditioning 38 °C for 48 h	Yellowing of skin	[40]
Kensington	VHT and HWT 47 °C for (7.5 to 30) min or VHT 46.5 °C for 10 min or VHT 47 °C for 15 min	Yellowing of skin, uniformity of color, fruit softening	[35, 42]
Tommy Atkins	FHAT 51.5 °C for 125 min	Fruit softening	[23]

VHT: Vapor Heat Treatment, FHAT: Forced Hot-Air Treatment, HWT: Hot-Water Treatment.

Conventional heating methods using air and water allow an increase in the temperature of the skin towards the product's heart, but they are slow compared with microwave techniques. The microwave energy on spherical products is focused towards the product's center and the maximum concentration is reached when the penetration thickness is approximately equal to 1.5 times the product diameter. The heating rate can be controlled; it depends on the type of material used and the treated product.

Studies using microwaves were done to try to destroy certain mango parasites (*Cryptorhynchus mangiferae*) [25]. They prove that fruits are damaged by the generated temperatures: a temperature of 63 °C involves a parasite mortality of 87%. With an intermittent treatment of (10 to 15) s instead of a continuous treatment longer than 60 s, damage is decreased, but not completely removed.

To try to improve the treatment effectiveness, probes were distributed in fruits of the Kent mature green mango: one of them was placed in the stone's center, another on the stone's surface and a third midway between the skin and the stone. Certain physical characteristics were measured; the results

were the following: fruit weight, ( $535.2 \pm 11.8$ ) g; distance between the skin's surface and the stone's center, ( $40.7 \pm 6.8$ ) mm; distance between the skin's surface and the stone, ( $30.7 \pm 5.2$ ) mm and half of the distance between the skin and the stone's surface, ( $15.3 \pm 3.6$ ) mm.

As the heating evolves from the fruit's surface towards its center, *Cryptorhynchus mangiferae* larvae, present in the mango stone, are difficult to control with the conventional systems previously described (hot air, vapor heat or dipping into warm water). Indeed, before reaching 48 °C in the stone's center, the fruit pulp can suffer severe damage because of its exposure to a too strong heat. On the other hand, microwave use makes it possible for the stone to reach this lethal temperature for the larvae, before the other fruit parts are deteriorated by too strong temperatures. Parasites present inside the stone are thus killed and the damage to the pulp is reduced. The microwave technique is also effective against *Bephratelloides cubensis*. Because this weevil is present in West Africa, research on the microwave treatment effectiveness would be particularly interesting in order to control this parasite, and for the setting up of the quarantine processes.

In spite of very optimistic beginnings in product disinfestation by the use of microwave heat, this process is still not commercially used because of its cost in energy, the nonhomogeneous heating of tissues and the damage generated to the products [26]. A better comprehension of the operating process of the heating system by microwaves could be useful to progress with the use of this technology in the quarantine systems.

Microwave use on fresh material currently presents application problems; studies should be undertaken to test different wavelengths, intermittent exposures and the concomitant use of microwaves with other techniques to perfect a quarantine treatment [25]. However, this system was patented for the disinfestation of dates [27]. The concomitant use of two treatment techniques has a synergy effect which involves a pest mortality higher than that observed with the addition of two individual treatments. In addition, tests were realized by using gamma irradiations coupled to microwaves [28].

## 5. Irradiation

Irradiations with X- and gamma rays are used in quarantine treatment against fruit fly (Tephritidae).

Research carried out in Hawaii showed that a (15 to 100) krad gamma irradiation made it possible to treat many fruits and vegetables infested by the Mediterranean fly [29].

Many countries accept foodstuff irradiations and, in particular, fruit irradiation. The Food and Drug Administration of the United States (US-FDA) accepts this quarantine treatment of fresh fruits provided that it does not exceed a rate of 1 kGy [30].

The majority of the installations allowing treatments by irradiation use radioactive isotope sources, such as cobalt or cesium. Other systems such as electron accelerators can be employed; the energy rate is identical to that of the cobalt or cesium sources, but this system covers a much broader photonic

energy band, which causes a more homogeneous irradiation of the products. Moreover, contrary to the radioactive sources, there are then no problems when the machine is stopped.

This kind of quarantine use remains subject to certain reserves:

- studies must be undertaken to check that the treatment does not degrade the fruit quality;
- the system profitability must be checked because it requires a very strict installation and maintenance;
- the purchase acceptance, by the consumer, of irradiated products must finally be tested.

If the answers to these various questions were positive, this quarantine treatment against fruit fly would be completely possible [31].

Currently, this technique is being commercially tested in the USA on papaws from Hawaii, litchis and other tropical fruits to see whether product irradiation can be developed in quarantine treatment.

It should be noted that there exists a very strict regulation for marking of products treated by irradiation, which must inform the consumer. The consumer could therefore strongly reject this type of treatment which, in addition, has an extremely high cost.

## 6. Conclusion

In comparison with the most usual treatments (vapor heat treatment and forced hot-air treatment), the treatment by warm-water immersion has many advantages:

- it is relatively easy to implement in the packaging stations;
- the treatment time is short; it can be connected and controlled by both the fruit level and the water temperature;
- it has the advantage of destroying surface parasitic organisms, generators of post-harvest losses;
- it makes it possible to clean the fruit surface (exudate suppression, for example);

– its cost only corresponds to approximately 10% of the cost of one vapor heat treatment [32].

Thus, treatment by warm-water steeping would be recommended for mango disinfection.

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### **Mosca de las frutas: desinfectación, técnicas empleadas, posible aplicación en el mango.**

**Resumen — Introducción.** Los métodos de desinfectación de las frutas para las infestaciones de moscas de frutas exigen procedimientos (métodos físicos) que difieren según el país de exportación y según el fruto que debe ser desinsectizado. A continuación se retoman las definiciones de los términos y se presentan los diferentes tratamientos. **Tratamientos mediante calor.** Para el mango, los tratamientos empleados para la desinsectación permiten únicamente que intervenga el calor, debido a la fuerte sensibilidad que posee este fruto al frío. Los tratamientos mediante calor consisten por lo general en utilizar una inmersión en agua caliente mediante sistema de cargas sucesivas o de cargas en continuo. Estos tratamientos pueden ser sucedidos o no por un rápido enfriamiento de los frutos, el cual se puede realizar mediante ventilación (aire frío), o mediante *hydrocooling* (agua). Puede obtenerse también el calor mediante el uso de aire caliente forzado o de vapor caliente, ya que una temperatura superior a 45 °C mata los huevos y las larvas de las moscas. **Tratamientos mediante micro-ondas.** El uso de micro-ondas representa asimismo una técnica que permite aumentar la temperatura desde el corazón del fruto. **Irradiación.** La última solución planteable es la utilización de la irradiación, que pone en juego un principio diferente al de los anteriores. **Conclusión.** En comparación con los tratamientos más corrientes (tratamiento mediante vapor de agua caliente y tratamiento mediante aire caliente forzado), el tratamiento mediante sumersión en agua caliente posee numerosas ventajas: es fácil de poner en obra, dura poco, destruye los organismos parásitos de superficie, permite limpiar la superficie de los frutos y su coste corresponde aproximadamente a tan sólo el 10% del coste de un tratamiento mediante vapor de agua caliente. Por ello se preconiza para la desinfestación de los mangos.

**Francia / frutas / *Mangifera indica* / tephritidae / control de plagas / calor**

