Alternatives to Hot Water Treatment

The Big Picture:
The tropical regions where mangos thrive are perfect for producing sweet, succulent fruit. But most mango growing regions are also home to pests – namely fruit flies – which means the fruit must be treated to kill the pests before it can be exported to the U.S.

While several quarantine treatments are available, hot water treatment (immersing the fruit in hot water) is by far the most popular in Latin America. However, members of the mango industry have expressed concern that hot water treatment is one reason that mango quality is often substandard. In an effort to address these concerns, the National Mango Board commissioned a research study to determine viable alternatives to hot water treatment for mangos.

In the study, led by Dr. Elizabeth Mitcham of the University of California-Davis, several alternatives to hot water treatment were evaluated. Forced hot-air treatment, forced hot-air with controlled atmosphere, and irradiation show the most promise for improvements to mango quality, Mitcham notes. While these methods could be implemented in a relatively short time frame, they are also costly.

For this reason, the NMB also explored how current hot water treatments could be improved to further enhance mango quality. Results show that there are a number of steps that can be taken with the current system to greatly improve mango quality. These include closely monitoring procedures at the packinghouses, updating facilities to allow for effective cooling of mangos after hot water treatment, and maintaining proper temperatures for storage and shipment of mangos.

Overall, the most cost-effective solution for improving mango quality with regard to phytosanitary measures involves focusing on the current system. However, the advantages of new technology, like irradiation and controlled atmosphere forced air treatment, are worth following as future options. Other potential solutions include a "systems approach" which would combine biological and operational methods to meet quarantine requirements.

Overall Findings:

HOT WATER IMMERSION TREATMENT

- **Improving the current hot water treatment process is key to maximizing mango quality. Hot water treatment remains effective, but shippers need to be proactive in following the proper cooling techniques after hot water immersion.** Poor cooling after hot water treatment is one of the primary reasons for poor mango quality. Researchers found that the hot water process could be improved by implementing the following steps:
    - Hydro-cool fruit immediately after hot water immersion, or after the 30 minute delay following treatment.
    - Set the hydro-cooler water bath temperature at 70-72˚F (21-22˚C).
    - Hydro-cool mangos long enough that the internal temperature reaches 80-85˚F (27-29˚C), generally about 30 minutes depending on the size of the fruit. Fruit that is not properly cooled will show increased signs of heat injury and will ripen more quickly.
    - Pack fruit immediately after cooling to minimize damage. Shippers that choose to hold the fruit for 12 hours after hot water immersion to check for heat injury should provide ventilation, such as overhead paddle fans, around the mangos

and allow at least 8 inches of space between the stacks of bins, researchers say.
    - Use forced-air cooling between the range of 48-50˚F (9-10˚C) to cool the mangos again after the fruit is packed and before they're placed in cold storage or a cold container. If fruit cannot be loaded for transport immediately, it should be placed in a cold room with temperatures from 50-60˚F (10-15˚C).
    - Ensure that transport containers are cooled before loading to a temperature no higher than 54˚F (12˚C).
    - Be sure that hydro-cooler water is properly sanitized with chlorine or other chemicals. Cool water can be pulled inside the warm fruit during hydro-cooling and potential pathogens in the water can contaminate the mangos.

- **Hot water immersion is not effective against the mango seed weevil.** At this time, most Central and South American countries are not hosts to the mango seed weevil, so this is not cause for immediate concern. If the U.S. considers importing mangos from other regions, like India for example, irradiation treatment at a higher dose – about 300 grays – could kill the mango seed weevil, Mitcham reports.

ALTERNATIVES TO HOT WATER TREATMENT

- **Forced hot air treatment remains effective for quarantine, but treatment facilities are relatively expensive. Forced hot air remains the second most common pest treatment method for mangos;** it's considered a better solution than vapor heat treatment – the oldest quarantine heat treatment.
    - Forced hot air treatment facilities can cost $120,000 for 8-ton capacity per load, researchers found. Hot water immersion equipment costs about one-third that of forced-air equipment to treat the same quantity of fruit.
    - Like all quarantine facilities, forced-hot air operations must be certified and thermal mapping of the treatment chamber is required. Mexican operators now must use 80 sensors for thermal mapping (a change implemented in 2008), up from 40 probes previously.
    - Each variety of mango must be evaluated separately for treatment because of differing shape and size.

- **Controlled atmosphere in addition to forced hot-air heating allows for faster treatment time than forced-air heat alone. However, this treatment option is not yet approved for product imported into the U.S.**
    - By using reduced oxygen and/or elevated carbon dioxide gas levels along with hot air, treatment time with CA can be one half that of heat treatments alone, researchers found.
    - Approval from the USDA is probable (high-temperature CA treatments were approved for nectarines, sweet cherries and apples originating in the U.S. for export in 2008), but the time frame is not clear. It would likely take several years for forced hot-air CA treatment to be approved for imported fruits.
    - CA treatment involves more components to monitor – gas levels as well as temperature. A failure of just one component would mean retreating the entire load.
    - Each mango variety would need to be studied individually to determine the proper atmosphere in CA treatment to effectively control pests without damaging the fruit.
    - With regard to facilities, the industry would need to come up with quite a bit of capital, as there has not yet been a large investment in forced hot-air treatment facilities.

- It is not clear that the shorter treatment time or the improved fruit quality would be sufficient to warrant the extra expense, but this treatment option is worthy of further consideration, researchers said.

- **Irradition is a viable quarantine option because it poses less potential damage to the fruit. The key concerns with irradiation involve traceability throughout the treatment process and trust between vendors.** In this process, ionizing radiation is used to modify pests' DNA, making them sterile. Thus, this process requires not only new infrastructure but also a new mindset for those in the industry, as live pests may still be present in mangos after quarantine treatment. Mangos treated with radiation at low doses fare well and do not show damage. However, irradiating the fruit in larger batches is more economically feasible. But the higher the dose of radiation mangos receive, the greater the risk of potential damage to the fruit. The industry must weigh the tradeoffs between cost and potential fruit damage when considering this alternative treatment. Although the U.S. approved irradiation for imported fruit in 2002, irradiated product did not arrive in the U.S. until 2007. However, irradiation has been used since 2004 to disinfest mangos shipped from Australia to New Zealand of fruit flies, researchers noted.

  - **ADVANTAGES TO IRRADIATION**
    - The USDA APHIS has approved generic radiation dosages for treating various fruit fly species, regardless of the commodity. So, all varieties of mangos could be treated the same way without the need for researching how each individual cultivar responds to treatment.
    - The gamma rays used in treatment are easily able to deeply penetrate pallet loads of food, so irradiation can be used to treat large loads at once.
    - If the mango industry could share irradiation facilities with commodities with different harvest schedules, operational costs of the plants would be more economical because they could be used year-round.
    - While any quarantine treatment poses potential damage to mangos, partially ripe Haden mangos showed no change in the rate of ripening after irradiation, researchers found. Since most fruit is shipped partially ripe, this treatment may be easier on the fruit than some other methods.
    - Expense, radiation dosage, and potential fruit damage are indelibly linked. The larger the dose of radiation mangos receive, the less expensive it is because fruit can be treated in large batches. However, in order to get fruit in the center of the batch to the proper radiation levels, the fruit along the outside could receive two to six time higher dosages, which could cause damage. On the other hand, if pallets were to be disassembled and fruit was treated in boxes, the radiation dosage to the mango would be much smaller, but increased labor would make it much more expensive.
    - Some studies show that irradiation combined with a hot water dip can help to reduce postharvest diseases like anthracnose decay.
    - Mangos retained strong vitamin C content when exposed to low doses of radiation (lower than 750 Gy).
    - An international company with many irradiation facilities worldwide (Sterigenics) operates a plant in Hidalgo, Mexico, and has been approved by USDA-APHIS to irradiate mangos and guavas. The facility has the capacity to treat approximately 25,000 pounds of fruit per hour when the entire product is treated at the same settings, researchers say.

- **CHALLENGES OF IRRADIATION**
  - Irradiation is expensive, requiring a substantial initial investment of at least $4 million to build a facility to treat between 20 million to 40 million pounds annually. Making the facility fully operational would require an outlay of about $10 million total, experts say.
  - The effectiveness of irradiation treatment relies largely on ensuring that treatment is correctly carried out and proper documentation throughout the process occurs. This process requires meticulous records of everything from product origin to how product was stored and handled before irradiation to what specific dosages of radiation each section of the load received during treatment. Because pests will still be present after treatment, confidence in the plant and its operators is paramount.
  - Consumer acceptance of irradiated produce is questionable. While tolerance of the treatment is increasing, "serious social and public policy issues remain," according to researchers.
  - If a lower-cost irradiation method is chosen (irradiating large batches of fruit instead of treating individual boxes), fruit could be exposed to higher doses of radiation that could cause damage to the mangos.

- **Microwave or radio frequency (RF) treatment provides a high-temperature-short-time quarantine method. Mangos hold up well to RF treatment, but implementing this method for fresh fruits in large scale systems is difficult because of the potential for large temperature variations within the treated load.** Microwave treatment is attractive because it is fast, can penetrate deep and sometimes heats insects more than the fruit, researchers found.
  - A combination of RF followed by vapor heat treatment showed promise – the combo treatment killed fruit flies while minimizing internal damage to the mangos.
  - RF treatment requires immersion of fruit in a saline solution, which requires additional engineering solutions that have not yet been developed.
  - Researchers believe that the extra expense and engineering challenges do not make RF treatment as viable as other options like hot water and hot air treatments.

SYSTEMS APPROACH OPTIONS

- **In addition to quarantine treatment options, a "systems approach" should also be examined as a phytosanitary alternative to hot water treatment.** This approach combines biological, physical and operational factors in such a way that two or more methods overlap to provide protection. Some options that the mango industry could consider include the following:
  - ***Establishing certified pest-free locations and/or areas of low pest prevalence help to establish protection at the base level.*** Ways of implementing pest-free zones include using baited sprays to attract fruit flies to traps. In areas where fruit flies and other pests are seen in low densities, pest reporting and monitoring the population is key. Texas's Rio Grande Valley currently operates a fruit fly-free zone that was started in 1981. The program uses bait sprays and release of sterile fruit flies to eliminate the Mexican fruit fly. In Mexico, a campaign to control fruit flies is ongoing, researchers note. This program uses a variety of approaches to control the pest, including baits, sterile insect techniques, and cultural practices to destroy host fruits. Weather conditions and topography play a role in how successful these programs can be, Mitcham says.

- ***Combining a variety of cultural controls*** like pruning of dead and diseased branches, orchard sanitation, the application of pre-harvest pesticides and fruit bagging after harvest can prevent fruit fly infestation, researchers noted.
- ***Certified inspections add another layer of protection.*** Sampling fruit periodically (both before and after harvest) keeps potential infestation in check. Subjecting production areas to unannounced visits from certified officials further ensures that phytosanitary requirements are being achieved.
- ***Stringent postharvest and packinghouse procedures are essential for maintaining a pest-free environment.*** Researchers suggest that fruit be covered with tarps and efficiently moved from the field to the packinghouse, where the fruit should be mechanically brushed to remove exterior pests and immersed in a disinfecting bath. Obvious procedures like inspecting the fruit before it's packed and loading it onto refrigerated containers also help to maintain a phytosanitary environment.

Looking ahead:

It's clear there are many alternatives to hot water treatment for mangos, but several methods remain cost prohibitive. For the short term, improving the current hot water treatment process (with an emphasis on improving hydro-cooling techniques) seems to be the most cost-effective way to improve mango quality for export into the U.S. However, the technology of irradiation and/or controlled atmosphere forced air treatment also warrant further study. Improving the overall quality of mangos to be exported is clearly the goal; providing high-quality fruit at retail will boost sales and eventually increase demand for mangos.